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Simulation Modeling: Improving Patient Waiting Time in Emergency Department

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Abstract

The emergency department is the patients' main entrance to the hospital, which operates 24 hours a week to treat various types of illnesses categorized as emergencies. Therefore, many patients tend to seek treatment in this department, especially after office hours. The main function of the emergency department is to treat critical or semi critical cases. Nevertheless, this department has also become a place to treat patients with non-critical cases. The presence of a high number of patients every day has caused the emergency department to often face overcrowding. Realizing this fact, the management needs to curb this issue as soon as possible. Therefore, this paper discusses the application of the Discrete Event Simulation approach in modeling the daily operation of the Green Zone of the emergency department under study. The simulation model was developed using Arena simulation software to understand the behaviors of the system operation. Besides, from the simulation model, the management can identify the bottlenecks of the system which contribute to the high patients' waiting time and length of stay as well as the utilization rate of the resources. The simulation outputs show that waiting for available resources is the main issue that creates overcrowding in the waiting area of the Green Zone. A few alternative solutions were designed and discussed with the management of the emergency department for possible improvements. The results from the improvement model show a significant reduction in a patient's waiting time as well as a patient's length of stay. This improvement model also stabilized the utilization rate of the involved resources.

Keywords: Simulation Modeling, Arena, Utilization Rate, Waiting Time, Length of Stay

Introduction

The healthcare system is a large, complex, and dynamic environment, especially the emergency department. The emergency department is the main heart of a hospital and is the

main entrance to the hospital that provides initial treatment to patients before the patient is warded or discharged to go back home. The increase in the number of patients from day to day visiting the department has impacted on the management of the department. Previously, the department was only a unit that treated cases of severe or critical injuries, which are categorized as emergencies. However, this has changed due to the high demand for treatment, especially the non-emergency patients.

The cheap charges imposed by the government hospitals are also among the contributing factors that encourage not only citizens but also foreigners to seek treatment here. As a matter of fact, this department, which operates with a limited number of employees and resources, has been facing problems maintaining the quality of the service to the patients who came. In addition, this department had to deal with the problem of high patient congestion at one time and this, to some extent, has interfered with the operation of the department.

Based on media reports in the press, almost 80% of patients who came to this department are not due to an emergency case but only suffer from minor illnesses such as flu, cough, fever, normal skin itching and so forth, which are categorized as non-emergency cases (Latif 2017). Most of these patients do not understand the true function of this department and assume that it is easier to get specialist treatment in this department than in the available health clinics (Anon, 2019).

According to the National Audit Report in 2018, the number of patient arrivals exceeded the Level of Care set at between 5.7% to 95.6% and this has caused patients overcrowding. Apart from that, only 58.7% to 74.5% of patients can be treated in less than 4 to 6 hours, which means 25.5% to 41.3% of patients must wait for 4 to 6 hours before getting their treatment in the emergency department, based on the four audited hospitals. There were also 917 cases of patients who could not be transferred to the medical ward due to a lack of facilities. This department also had to provide 8 to 50 additional beds or 2 to 5 times the number of additional beds in Red Zone (RZ), Yellow Zone (YZ) and Observation Ward treatment because they could not accommodate the growing number of patients.

However, the increase in the number of patients is not the only contributing factor to congestion in this department, there were various other factors or constraints that contribute to the congestion problem. Among the constraints are the aspect of high workload, lack of medical equipment and limited treatment space, that were also affecting the department's services. According to the audit report, the emergency and trauma department also experiencing staffing shortages ranging from 11.6% to 53.1%, as compared to the number of staffing required based on the calculation of Workload Indicators of Staffing Need (WISN) 2010. The report also stated that the staffing shortage for emergency specialists was between 75.6 % to 79.5%, medical officers from 41.2% to 64.6%, assistant medical officers from 2.6% to 33.9% and trained nurses from 17.4% to 67.1%.

The overcrowding issue does not only occur in Malaysia, but in emergency departments around the world (Bittecourt et al. 2020; McKenna et al. 2019; Boyle et al. 2012; Hoot & Aronsky 2008). Overcrowding in the emergency and trauma department can be defined as the department's inability to provide quality emergency services within a reasonable period to meet the extremely high patient demand (Azlan et al., 2013). Some researchers describe

the congestion as the failure of the management to provide treatment in the specified time, causing the next patient to have to wait longer to get treatment (Salway et al., 2017; Erenler et al., 2016; Salvatore et al., 2014; Chen & Wang, 2015; Yarmohammadian et al., 2013; Morley et al., 2018; Savioli et al., 2022).

The congestion has a lot of negative impacts on the management of the hospital and the department itself and shows the inefficiency of the operations in the department. This, to some extent, puts pressure on the management to maintain the quality-of-service efficiency and if not resolved quickly will cause various other negative impacts. Among the negative impacts that often occur are, patient dissatisfaction, long waiting times to get treatment, the process of being in the system for a long time (length of stay), delays in providing treatment, errors in providing treatment by medical officers or staff due to high workload and increased in mortality (Darraj et al., 2023; Bittecourt et al., 2020; Salway et al., 2017). Obviously, the hospital management needs to take immediate steps to deal with the problems to accommodate the increasing number of patients every year.

Emergency Department Overview

The emergency department understudy operates 24 hours a day and receives 250 to 350 patients daily. It is one of the busiest emergency departments in Klang Valley area. Based on Malaysian Triage Category, this department divided patients into three triage categories namely Red Zone (RZ), Yellow Zone (YZ) and Green Zone (GZ) (Medical Development Division, 2012). RZ is a critical zone that works to provide treatment to critical and serious patients who may be in a life-threatening condition. YZ is a semi-critical zone that handles life-threatening cases but does not require immediate treatment like RZ. While GZ is a non-critical zone that works to handle emergency cases that are stable and non-life-threatening.

Generally, the Ministry of Health (MOH) stipulates that all patients defined as red cases must be treated by medical officers immediately (which means the waiting time is 0 minutes). Besides, MOH also stipulates that 90% of patients are seen by the medical officer within a period of 90 minutes (Ministry of Health portal, 2023). However, the target time for getting this treatment is also subject to the management of the hospital which has different target time for getting treatment for each zone based on the Key Performance Index (KPI) of the department. The target time for this treatment is the length of time the patient waits to receive treatment for the first time by a medical officer after the patient's arrival at the department (Aminuddin, 2018). Table 1 shows the target time set by MOH in 2009.

Table 1
Ministry of Health's target time

Triage Category	Time to be attended	
	Prior	New
Red	Immediately	Immediately
Yellow	30 minutes	15 minutes
Green	2 hours	90 minutes

A total of 80% of patients who attend the emergency department are patients from GZ. With the high number of patients, the waiting area becomes overcrowded especially after office hours and weekends. This department also has a policy to accept all types of patients and

they must provide proper treatment and patients cannot be transferred to another hospital. As a result, this situation contributes to the high volume of patients in this department and patients must wait a long time before seeking treatment. Based on an interview with the department management, they understand that the increase in waiting time and length of time occurs due to the inequality between the number of patients and the resources provided. They believe they need to increase the number of existing resources to meet the needs and overcome the problems faced. However, before an action to increase resources is carried out, the management needs to know if the addition can help reduce the congestion.

Improvements to departmental operations are usually done manually based on management experience and this is very risky, because the operational system of the emergency department is complex, and every constraint factor needs to be considered. Changing directly may cause higher congestion and potentially disrupt daily operations as well as increasing costs of operations if it does not turn out as expected. Therefore, the management needs to study in detail the operating system and all the possibilities available before any changes are made to the department's operations. To help the management in making decisions and achieving their GZ KPI for waiting time and length of stay, this study aims to build a simulation model that can help them to understand the GZ operating system as well as identify the bottlenecks (what caused the overcrowding) before the real improvements can be made. Simulation can be used to reduce chances of failure before an existing system is changed or a new system is built. The purpose is to meet system's specification by eliminating unforeseen bottlenecks, preventing under or over utilization of resources and optimizing system performance (Kozan & Diefenbach, 2008; Farahi & Salimifard, 2021; Nahhas et al., 2016)

The next section briefly explains research methodology involves in constructing the simulation model including verification and validation process. Then, simulation and improvement model results section discuss the results of the simulation and improvement model. The conclusions and future work are discussed at the end of the article.

Research Methodology

System Background

Usually, patients who come to the GZ have gone through the primary triage process at the front counter. Primary triage determines patient categories according to severity and priority. Before the patient proceeds to the secondary triage, the patient is required to register their information at the registration counter. Secondary triage assesses the patient's vital signs comprehensively. If the medical staff found that the patient's condition suddenly changes critically or semi-critically, the patient can be moved to the yellow or red zone category. The patient will wait at the waiting area until being called for the consultation. Each patient encounters a different waiting time depending on the availability of the consultation room. Currently there are 5 consultations rooms in this area with 5 Medical Officer (MO) per schedule.

After the consultation process with the MO is completed, the patient will be instructed to undergo several tests (if necessary) such as blood tests, urine tests, x-ray tests and so on. The results of the test will be evaluated by a medical officer to determine whether the patient needs other tests or not. If no further tests are required, the patient will be allowed a chance with the medicine supplied. Based on information from the management, 80% of the patients will be discharged. Only 20% of patients will be temporarily monitored in the YZ or GZ before

being discharged or admitted to the ward (if necessary). This process is excluded from the simulation model. Currently, the GZ operates with 5 MOs, 1 Primary Team Medical Officer (PTMO) and 11 staff (nurses, admin's staff, and medical assistants (MA)) as shown in Table 2.

Table 2
GZ's resources

Resources	Number of Resources
MA at Primary Triage	1
Staff at Registration Counter	2
MA at Secondary Triage 1 (Male)	1
Nurse at Secondary Triage 2 (Female)	2
Staff at Pharmacy	2
MA at X-Ray Room	1
MO at Consultation Room	5
MA at Laboratory	2
PTMO	1

Simulation Model Construction

To ensure that the simulation model developed for this study is reliable and can represent the real system, a series of interviews were held with the department's management to understand the operating system and the actual situation in the department. Followed by checking documents in the department's database and conducting field observations. Some of the unavailable data needs to be collected manually. Data collection team is allocated at each section to collect the processing time such as time taken for consultation or time taken to do the X-Ray. The data is collected for 24 hours in a month period. This data is then converted into the form of distribution function that will be inserted later in the simulation model.

GZ simulation model was developed using Discrete Event Simulation (DES) approach. DES is recognized as an important research technique to support decision making due to its versatility, flexibility, and analysis potential. DES modelling has been successfully applied in emergency department area by many researchers to determine the impact of critical resources (such as beds, doctors, and nurses) on key performances (WT and LOS). DES support animations and graphics visualization which makes the DES is a right approach to easily communicate with healthcare management. There are a few steps involved in developing the model as recommended by previous research (Shannon, 1998; Carson II, 2005) and the similar steps used in the research by Ibrahim et al. in 2017 are applied in this study as shown in Figure 1.

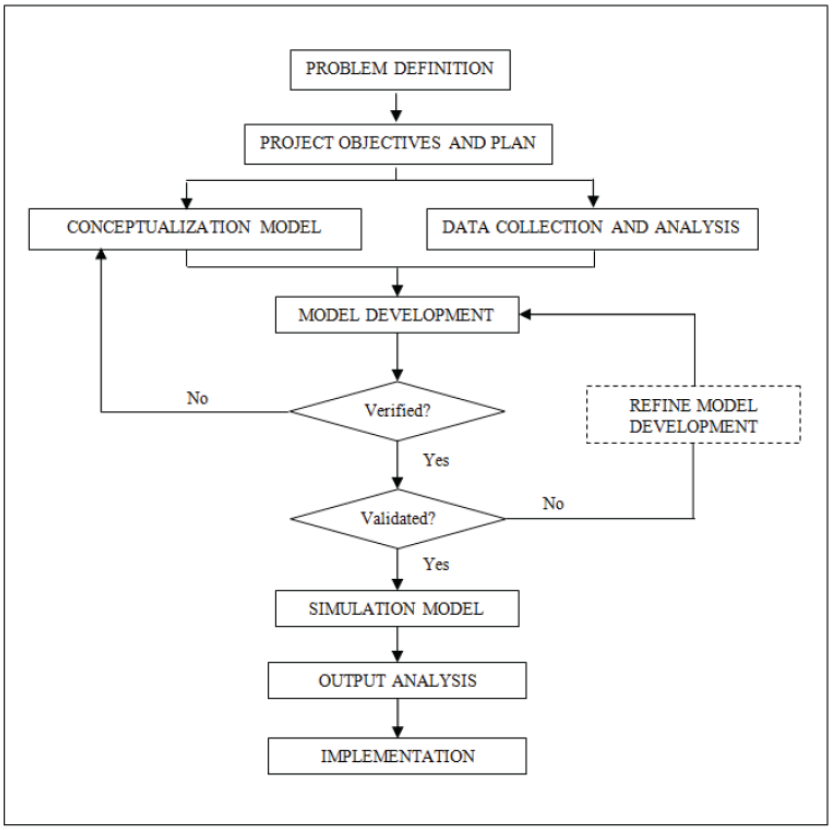

Figure 1. Simulation modeling phase

Simulation model development starts with investigating the system, which includes observations of the ED layout, patient flows, relationship for each activity and available resources. The early investigations helped us to understand the YZ system and its day-to-day operations. It involved identifying what processes are required and the constraints. A few assumptions were defined together with the ED management to limit the complexity of the flow because some of the assumptions do not affect the system. The GZ's patient flow (conceptual model) is translated into simulation model using the Arena software. All processes involved were designed into modules and then they are connected based on the conceptual model.

Completed simulation model is verified by the ED experts to ensure the model replicates the current YZ system operations. The model is executed and reviewed by the experts to inspect for any occurrence of errors in the flow, and improvement will be made until the experts agreed with the implemented flow. Next, the simulation model is executed for a few iterations and the outputs such as number of patients for each activity are used for the validation process. Validation is a process of confirming the simulation model represents the actual operating environment (Kelton et al., 2015).

Law and McComas (2001) stated that if the model is not a close approximation to the current system, any conclusions drawn from the model are likely to be erroneous. Therefore, to ensure the validity of the model, two validation steps are used for this study: the expert judgments and calculation of validation's accuracy. The results of the model are presented to the ED experts, and the validity of the results are confirmed based on their experiences. The results are compared to the original data collected using the formula in (1):

$$Difference(\%) = \frac{\left| Simulation\,output - Actual\,data \right|}{Actual\,data} \times 100\% \quad (1)$$

Based on the formula, the calculated difference must be no more than 10% for the simulation model to be considered valid and achieved its accuracy level (Carson and John, 2002). The simulation model was executed for 12 replications length to achieve accurate results. The simulation model outputs are shown in Table 3. The validation percentage between simulation model output and the actual data for the number of patients at laboratory is 0.5% which is within the acceptable level of accuracy. Meanwhile, the validation percentage for the total number of patients at pharmacy is also in the acceptable range, that is 1.29%. Therefore, the simulation model is concluded as valid and acceptable to be used for decision making process.

Table 3
Validation results (Simulation outputs and Actual data)

Item	Simulation Output	Actual Data	Validity %
Number of patients at Laboratory	1794	1785	0.50
Number of patients at pharmacy	1875	1851	1.29

Simulation and Improvement Model Results

There are three outputs monitored for performance measures as well as improvement model design: the average patient's waiting time for each treatment process, the average patient's length of stay (from arrival until being discharged) and the utilization rate of the resources. Based on the simulation results, the bottlenecks to the system are identified and several modifications to the GZ simulation model were presented and discussed with the ED management to improve the model. This is because only the ED management know their current available resources and the physical layout of GZ. The improvement model is designed by adding resources to the current system where necessary as shown in Table 4.

Table 4
Number of resources for original and improvement model

Resources	Number of Resources	
	Original Model	Improvement Model
MA at Primary Triage	1	1
Staff at Registration Counter	2	2
MA at Secondary Triage 1 (Male)	1	1
Nurse at Secondary Triage 2 (Female)	2	2
Staff at Pharmacy	2	2
MA at X-Ray Room	1	2
MO at Consultation Room	5	8
MA at Laboratory	2	3
PTMO	1	2

Table 5
Simulation (original model) and Improvement Model results

Activities	Average Waiting Time (minute) (Original Model)	Average Waiting Time (minute) (Improvement Model)	Resource Utilization Rate (%)	
			Original Model	Improvement Model
Primary Triage	2.48	-	72	-
Registration Counter	4.92	-	77	-
Secondary Triage 1	2.20	-	75	-
Secondary Triage 2	2.46	-	74	-
Pharmacy	6.76	-	77	-
X-Ray Room	44.16	33.18	94	65
Consultation Room (MO)	126.36	48.14	92	76
Laboratory (MA)	43.01	15.22	89	78
PTMO	109.32	45.16	97	77

Table 5 presents the comparison of results from simulation model and improvement model. The early results of the simulation model shows that the bottlenecks to the system are inadequate number of resources at the X-Ray room, consultation rooms, laboratory and PTMO. Based on such situations, the improvement scenarios were designed and proposed to the ED management. The total average patients' waiting times at X-Ray room, consultation rooms, laboratory and PTMO as well as utilization rates of the resources have been reduced significantly as shown in Table 5. Besides, the average patient's length of stay also significantly reduced by 36.48% from 361.92 minutes (6.03 hours) to 229.90 minutes (3.83 hours). The simulation improvement model has shown that human resources are critical resources that highly impacted the performance of the GZ.

Conclusion and Future Works

The simulation model developed in this study has allowed the ED management to perform risk-free what-if analysis that can be used to reduce the total average patient's waiting time as well as patient's length of stay. At the same time, balanced the resource's utilization rate. The simulation model identified four processes that contribute to the lengthy waiting period in the GZ which are at the consultation room, X-Ray room, laboratory and PTMO. Based on the simulation results, possible improvement is presented to the emergency department's management. Number of resources added to the identified processes and performance is measured. The results show significant improvement in average patient's waiting time, and length of stay as well as resource's utilization rate.

Even though the results have improved the system performance, there are still many limitations encountered due to the constraints involved. Many assumptions had to be made

to reduce the complexity of the model development. Those will be included in the next phase of the study.

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