DOI: 10.7763/IPEDR. 2013. V63. 16

Simulating the Impact of an Increase in Patient Volume on a Government Emergency Department in Malaysia

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Abstract. This paper explores the potential of computer simulation model to assess the effect of patient increase to emergency department performance and the patient flow. A simulation model of emergency department is developed based on discrete event simulation and system dynamics modeling approach to capture the behavior of an integrated system. Several scenarios are conducted to help management determine the required resources due to patient volume increase that will not breach the national target time for patient to be attended to in emergency department. Results from the scenarios show that a 7% increase of patients affects most of the performance measures. In addition, medical assistants are the important resources in emergency department operations.

Keywords: Emergency Department, Hybrid Simulation, Discrete-Event Simulation, System Dynamics

1. Introduction

The impact of patient volume increase to emergency department (ED) performance is a global problem encountered by most hospital located in major cities [1]. Normally, the main performance indicator of ED is patients' waiting times. Increased number of patients usually increases waiting time by decreasing the resource capacity level, which may lead to ED congestion. To deal with this problem, hospitals try various ways [2]. Some ways worked while some failed. As healthcare environment is highly intolerant to failure, ED management requires a tool that can help them foresee the consequences of their decisions prior to implementation. In the case study ED of a general hospital in the northern part of Peninsular Malaysia, the management is concerned if the department will be able to handle the increasing patient volume with current resource capacity level. If the ED is not capable, then they would like to know how many additional resources are required to ensure that the ED does not breach the target time set by the Ministry of Health in Malaysia.

One possible way to study the process of ED operations, identifying the sources of bottlenecks and testing alternative decisions without directly affecting patient care is by using computer simulation modeling. Many ED simulation models have been developed to evaluate the performance of the system using discrete-event simulation (DES) [3-5]. The DES modeling tends to look at the variables individually, such as the time waiting to see a doctor and the queue length waiting for a treatment. However, ED is not a standalone system, but also depends on other units in the hospital. This aspect is actually important in ED modeling since some of the capacities required for emergency patients are shared by other patients in the hospital. Due to this fact, the management wants to evaluate the consequences of 7% increase in patient volume to ED's own resources and shared resources. The percentage reflects the annual increment in patient volume to the ED.

Nevertheless, what is lacking in the literature is a whole system approach that is able to capture the relationships of ED with other units such as wards, labs and ambulance. Thus, the need to simulate the whole system that involves ED services has challenged DES model, which was insufficient to represent the behavior of the whole system as it requires vast data.

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System dynamics (SD) on the other hand, requires less data than DES, as concern is put on aggregate values to represent the higher level of a system. With its focus on feedback and nonlinear relationship, SD is ideal to comprehend dynamic complexity [6].

This paper presents a hybrid simulation model of an ED based on the integration between DES and SD. Integration between both approaches will comprehend the detailed and dynamic complexity of a health care system [6]. With this model, the effects on ED operations due to the increased patient volume are evaluated through several scenarios. It is important to understand whether an increase in patient volume will affect ED performance in providing effective and timely medical care.

2. Material and Method

2.1. System Model Description

The case study ED is a non-terminating system, which is open 24 hours a day serving a catchment area of approximately 0.7 million inhabitants. Arriving patients are classified using a three-color triage zone. Yellow and Red medical triage cards (MTC) are given to patients with semi-critical to critical illnesses, while MTC Green is assigned to non-critical patients. Due to demographical changes and aging population, demand for emergency department services has increased. This situation is made tougher with the introduction of a new target time for patient to be attended to in ED by the Ministry of Health (MOH) in 2009 (Table 1). The new target time has put more pressure on ED staff as it must be achieved without additional resources. There are partially shared resources in the ED, which serve all patients at certain point of the process. For instance, medical assistants not only provide services for patients in ED and but also act as crews of ambulance service.

Table 1: MOH's New Target Time

Triage Zone	Time to be attended to
Red	100% immediately
Yellow	100% within 15 minutes
Green	75% within 60 minutes

2.2. Study Design

A hybrid simulation model of ED has been developed using AnyLogic simulation software. We modeled the system based on general process flow a patient may experience in ED. We used patient arrival data for April 2010 as the base case, which included 6225 total patients and a mean of 208 patients per day. After the model is validated, as described in Section 2.5, an increase of 7% patient volume is applied to see the impact on ED performance. Several scenarios were tested by varying the number of resources in the case study ED.

2.3. Model Outline

The summary of ED model is shown in Fig.1. The model starts with patient arrival. Arriving patients either walk-ins or by ambulance stop at the registration counter for registration. At the same time there will be a medical assistant triaging the patients. After triage, patients have to follow different path according to the triage zones. However, critical patients will be sent directly to the Red Zone and registration is performed at a later time by a registrar. After receiving treatment, patients will be discharged. Discharged patients can either be released to go home or sent to wards for further treatment.

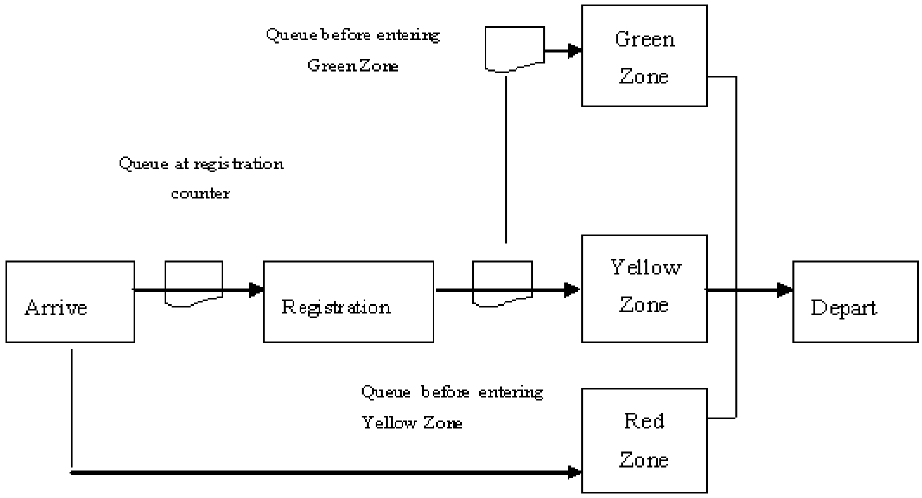

Fig. 1: The summary diagram of ED model

The detailed process flow in ED is captured in DES model while the interdependency between ED and other subunits such as ambulance, wards and labs are captured using SD model. Both types of models are run in parallel using AnyLogic simulation software. In parallel interaction, input data from DES model are passed to SD model during simulation running process.

The SD model consists of five sectors that show interrelationships between ED operations and other units such as ambulance, wards, labs and human resource. For each of the sector, we developed a causal loops diagram that acts as the dynamic hypothesis for computer model construction. Causal loops diagrams are capable of capturing the dynamic processes of a system by demonstrating the cause and effect relations between variables. Fig. 2 shows a diagram that depicts the dynamic hypothesis for wards sector at the case study ED.

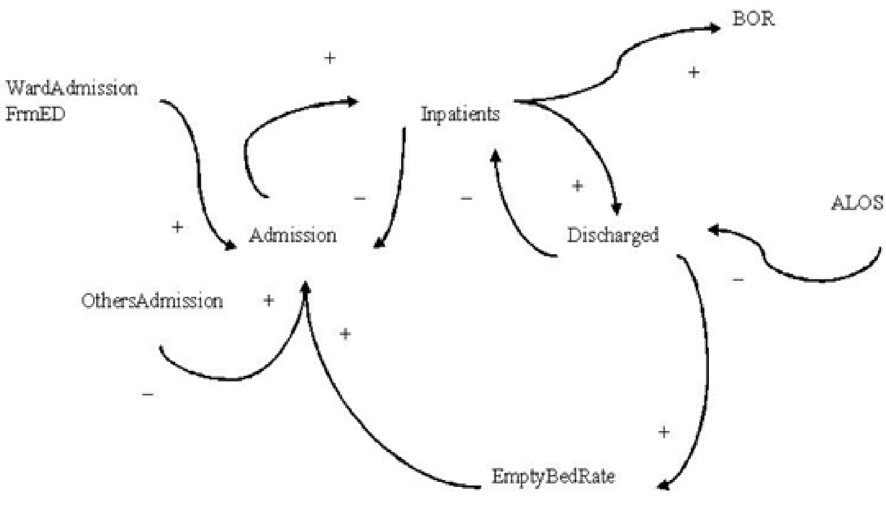

Fig.2: The dynamic effect of wards sector

The dynamic hypotheses for ward sector in Fig. 2 assume that an increase in admission increases the number of patients in wards and thus increases the bed occupancy rate (BOR). Here, admissions can either be from ED admissions or non-ED admissions. The number of patients in wards decreases as the number of patients discharged increases.

2.4. Data Collection

The data collected in this research came from both the primary and secondary data sources. Not all data was possible to obtain electronically. Most of the important data such as arriving time and departing time are manually recorded in log books. Other data like doctor-patient contact time, X-ray turnaround times and triage times were not available and therefore manual data gathering was conducted. Interviews with the staffs were also carried out to fully understand ED processes and identify the critical aspects in the ED that are needed to be included in our model.

Arena Input Analyzer was used to fit the appropriate distribution to the actual and empirical data obtained. Inter-arrival time and time spent at the registration counter follow a Weibull distribution [7]. Delay time for doctor-patient contact and lab results are independently and identically distributed as a Triangular distribution [8].

2.5. Model Verification and Validation

The ED model is a representation of a non-terminating system. Thus, only single replication is needed but with a period that is long enough to obtain a steady state and observations to compute confidence intervals [9]. In this research, warm up period is identified approximately as one and a half day or at $t = 2160$ by inspection from graph (Fig. 3). The model was run for 10080 minutes (one week), with the first 2160 minutes of the data eliminated.

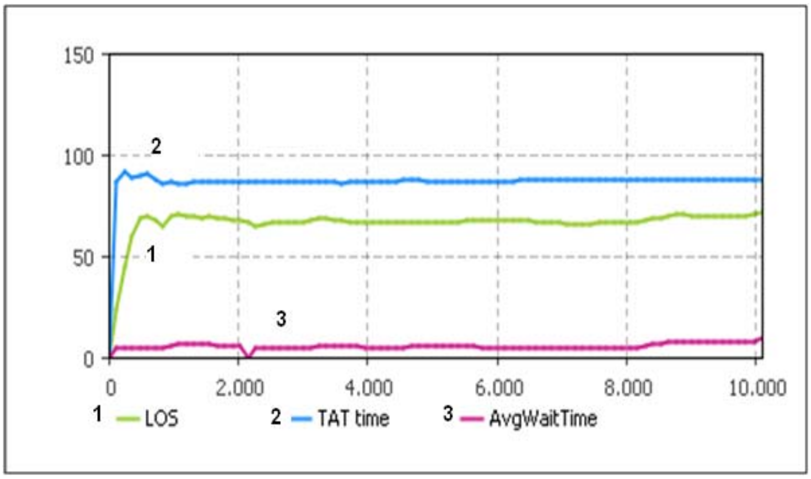

Fig. 3: The stabilization of the statistics of interest

The model logic was shown and checked by the head of the ED to verify that the model represents correct activities and flows in the department. In addition, the model was run and compared to ensure that the generated results from the model matched the empirical data collected from the ED. We focused on performance indicators that were obtained by Green triaged and Yellow triaged patients in the model; these were waiting times and length of stay (LOS). The reason to do so is because the two groups are claimed to be greatly affected when a sudden increase in demand strike the ED.

3. Result and Conclusion

For experimentations, patient volume is increased by 7%. Scenario A is tested by maintaining the current resources while Scenario B to Scenario D with varying staffing numbers and treatment beds. All results are shown in Table 2. The scenarios were chosen based on management recommendations and considering the high utilization rate obtained by medical assistants in the base case model. We notice that with the increased patient volume, number of patients in the waiting area increases considerably as does the waiting time. In addition, we observe that the capacity of medical assistant is vital in ED operations. We also observe that adding bed capacity is necessary when increasing the medical assistant capacity. In contrast, adding nurse capacity seems not important for the ED. Given that patient volume increase, the best scenario that yields an acceptable patients' waiting time and length of stay is Scenario B. Increasing the medical assistant capacity from an average of 14 to 15 and increasing the number of beds from 16 to 18 will meet the requirements of handling the increased patient volume without breaching the target time and maintaining the lower rates of staff utilization. In addition, the SD model shows that patients' length of stay is also influenced by labs turn-around time, bed occupancy rates in wards and ward admission rate. Therefore in future, the ED management should also focus on inter-departmental relationships while evaluating ED performance.

Table 2: Results

	Base Case	Scenario A	Scenario B	Scenario C	Scenario D
Critical resources Medical assistant Nurse Bed	 14 14 16	 14 14 16	 15 14 18	 14 15 18	 15 15 16
Time (minute) LOS (Green) LOS (Yellow) Wait time (Green) Wait time (Yellow)	 60 190 17 11	 92 197 48 13	 60 192 17 11	 70 193 27 13	 83 191 40 13
% wait time within target Green Yellow	 94.57 99.13	 78.86 98.81	 95.35 99.63	 90.56 99.39	 82.14 99.42

4. Acknowledgements

We are grateful to the head of department and staff at the case study ED for providing us with information and data required for this study. We also thanks the Ministry of Health, Malaysia for granting permission to collect data from the case study hospital, and to Universiti Sains Malaysia and Universiti Utara Malaysia for the financial support in conducting the study.

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