Analysis of Patient Flows Using Discrete-Event Simulation (Case Study: Emergency Department of Hospital X)

Rahmad Inca Liperda [a,1*]

[a] Department of Logistics Engineering, Universitas pertamina, South Jakarta, Indonesia
[1] inca.liferda@universitaspertamina.ac.id*;
* corresponding author

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ABSTRACT

This research is intended to analyze the patient flows through a number of processes in the Emergency Department (ED) using Discrete Event Simulation (DES) approach. In this paper, the time that a patient spends in the ED as well as the total number of patients served by the ED in a day were investigated and compared with the standard of the medical service time set by the hospital. A case study of Hospital X's ED in Jakarta, Indonesia was modeled using ProModel software. In addition, this research also proposes a number of considerable scenarios for defining the suitable number of beds and nurses. The results signify that the average time spent in the ED and the number of patients served can be optimized by adding 1 nurse and 2 beds. This finding signifies that the DES modeling approach may assist the hospital managers with the decent decision for improving the efficiency of the patient flows in the ED.

INTRODUCTION

Hospital is one of the most fundamental healthcare facility that provides integrated health services to patients. Hospital plays an important role in the maintenance of the available resources such as healthcare workers, equipment, medicines, as well as related information to maximize the quality and safety of medical care. Along with the increasing cost of the health services [1], faster services with better quality are fast becoming the key instruments to adequately satisfy the patients' needs. The emerging challenges often faced by the hospital managers are the lack of receiving and treatment capacities in assisting prompt medical care. Enhancing hospital's performance is a continuing concern within the healthcare providers to ultimately increase the healthcare services' productivities.

Hospital operations consist of numerous interrelated activities that require interaction and synchronization aimed at ensuring the right delivery of care. The efficacy and efficiency of the hospital operations can be represented by the flow of patients from their arrival at hospital to their discharge, depending on their clinical demands and operational supply [2]. The patient flows through the various hospital's units are characterized by multiphase processes where each process comprises arrival, queue, treatment, and exit [2]. Optimizing the management of patient flows has received considerable critical attention among the healthcare providers to make hospitals more patient-centered. However, there are several major issues related to the failure of managing the patient flows: (i) queues and delays, (ii) inadequate capacity utilization, (iii) the level of workload and stress for hospital personnel, (iv) errors, and (v) inappropriate placement of patients [3]. These signify the needs for sufficient approach to portray complex flows of patients in hospitals.

Modeling and analyzing the complicated network of patient flows are vital to assist the hospital managers with operative decision-making. Simulation is known for its capability to mimic the behavior of complex systems as well as to evaluate the performance of the existing system under various scenarios [2]. Several attempts have been made to simulate the patient flow throughout the healthcare chain. The Discrete-Event Simulation (DES) has contributed a large part of the most utilized tools in assessing the system's efficiency. Rado et al. [4] implemented DES approach for analyzing patient flows in hospital emergency department. They used different scenarios to evaluate the impact resulted from possible changes made to the system. McKinley et al. [5] evaluated the impact of a quality improvement planning on patient flow by using a Discrete-Event Simulation approach. A case study of pediatric emergency

department was used to validate their developed model. Shenoy et al. [6] simulated the patient flow through an acute care hospital using DES model. In their work, the patients are classified based on acuity, service, gender, and specific type of disease. Williams et al. [7] attempted to utilize the DES modeling to anticipate the increased demand on critical care beds. Their model proposed the optimal number of the required critical care beds by simulating different "what-if" scenarios. The DES model proposed by [8] generated the operative decisions regarding the patient flow optimization in a healthcare system. Their research claimed that non-served patients can be decreased by adding some resources while eliminating few others. Basaglia et al. [2] developed the DES model of patient flow through hospital operations by taking into account the tremendous surge of patients following a major earthquake. In their model, patients' specific demand such as worsening conditions and type of injuries is considered.

This research is intended to analyze the patient flows by developing a Discrete Event Simulation (DES) model. In this research, a case study of Emergency Department (ED) in Hospital X was chosen. With regard to its close connection with human life and death [1], increasing the quality of care in ED is recognized as a serious concern. Thus, this research attempts to investigate patient's length of stay in the ED considering their flow through the hospital's ED. The patients' flows include their arrival, registration, triage, medical treatment, and patients' departure. In addition, this study also takes into consideration the number of patients served in a day. This work initially generates the abstraction of the simulation model as a conceptual model. Afterwards, the DES model of the case study is proposed using ProModel software. Finally, the decisions on the available beds and nurses to promptly treat the incoming patients are obtained by posing "what-if" scenarios.

The remainder of this paper is structured as follows. Section 2 presents the proposed DES model. Section 3 provides the results and discussions. Section 5 presents the conclusions obtained from this research.

THE PROPOSED DES MODEL

This section presents the case study of the Hospital X's ED, a general hospital in Jakarta, Indonesia. The hospital has already defined the standard of medical service to be 2 hours. Recently, the ED has 5 beds allocated for treating the patients. In the meantime, there are 3 ED nurses assigned at each shift to adequately provide the medical assistance. In order to comprehensively model the DES approach, this work utilizes ProModel 10.5 with computer specification CPU Core i5 with 4 GB of RAM.

In order to properly simulate the patient flows through a number of processes in the Hospital X's ED, this research has identified the elements incurred in the system. **Table 1** presents the classified elements including entity, resource, and location. Entity refers to the objects processed through the system [10]. In this case study, patient is appointed as entity. Resources, on the other hand, are persons, equipment, devices, etc. utilized to perform the activities in a system [11]. Nurses are categorized as resources employed to provide medical assistance to the patients. Subsequently, the waiting room, registration area, beds, and discharge point are set as location (the places where processing occur). To describe the flow of patients in Hospital X's ED, we present the layout of the current system in **Fig. 2**.

Table 1. System Elements

Element	Type
Patient	Entity
Nurse	Resource
Waiting Room	Location
Registration Area	Location
Bed	Location
Discharge Point	Location

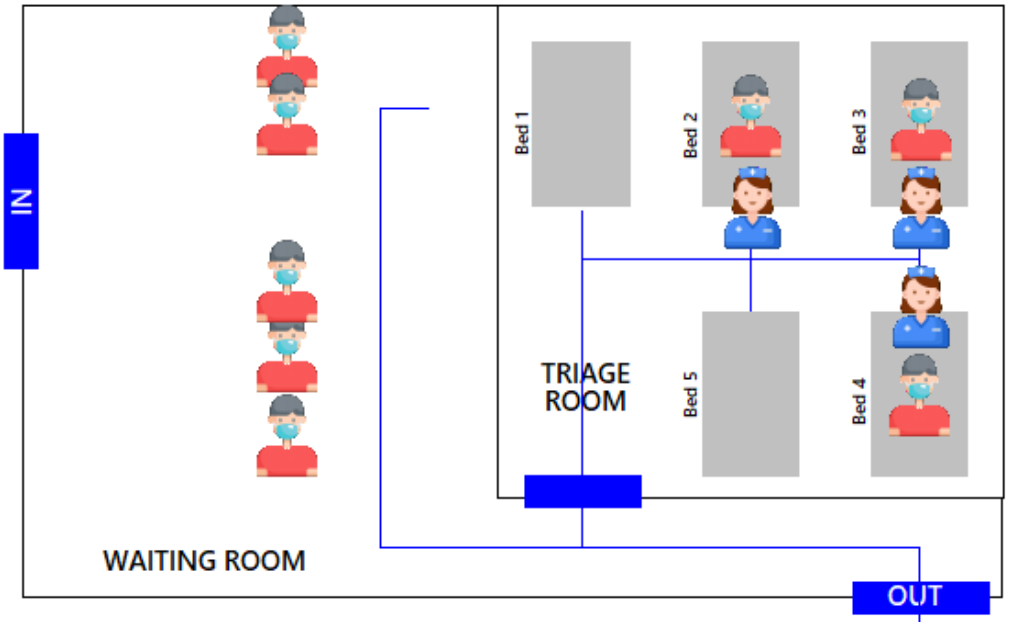

Fig. 1 Model Layout

As the patient arrives at the ED, the available nurse will be responsible for serving the patients, initiated from the registration process. When the bed is available, the ED nurse in charge will transfer patient to the bed and will demonstrate the triage process. After triaged, patients will receive medical treatment based on their severity conditions. Finally, the patients will leave the ED. The conceptual model of this research is deliberated in **Fig. 1**.

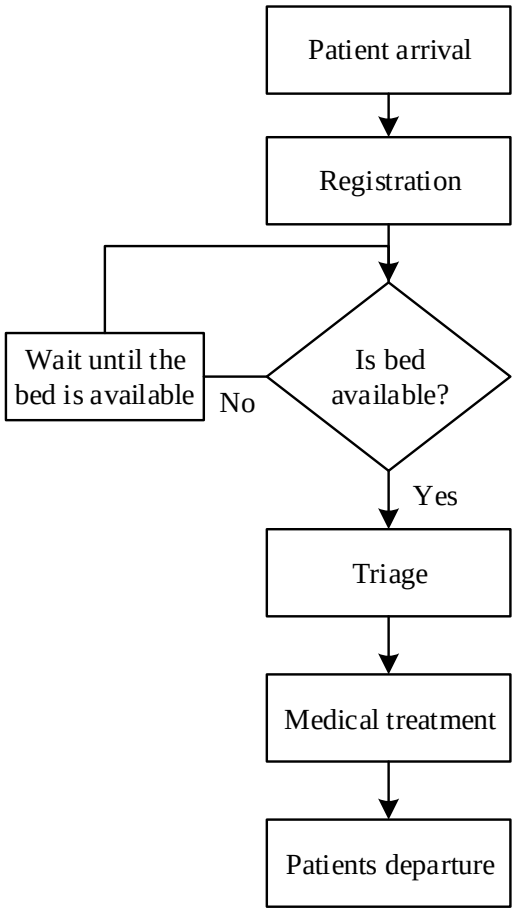

Fig. 2 Conceptual Model

1. *Patients' Arrival*

   The data collected on the patients' arrival include the number of the incoming patients in each day, the quantity of patients for each arrival, and the inter-arrival time between each patient. The fitted distribution for the number of arrival per day (person), quantity of each arrival (person), and inter-arrival time (minute) are Poisson (47.4), Poisson (2.1), and Geometric (0.0116), respectively.
2. *Registration*

   Registration process is aimed to gather patients' information regarding their demographics, medical history, laboratory results, etc. to be later renewed by the recent medical treatment. The data on the duration of the registration process (in minute) is distributed as Discrete Uniform (5, 30).
3. *Triage*

   The triage process is defined as the process of decision-making to prioritize the patients' needs according to their medical urgency [9]. The process time (in minute) for triage is fitted as Binomial Distribution (255, 0.057).
4. *Medical Treatment*

   The medical treatment immensely depends on the triage result. The time required for treating the patient may vary from one person to another. The collected data on the time needed for medical treatment (in minute) is Geometric (0.00987).
5. *Patients' departure*

   After receiving medical treatment, patient can be transported by nurse to Intensive Care Unit (ICU), medical ward, or to discharge from the hospital, according to patient's clinical demand. However, this research focuses only on the flow of patients in the ED in developing the DES model.

RESULTS AND DISCUSSIONS

The developed DES model sought to analyze the flow of patients by deliberating the length of time that the patient spends through the Hospital X's ED as well as the number of patients served by the ED in each day. To produce statistically significant results, the DES model is run for 30 replications. **Table 2** shows the simulation results of the existing condition. Based on **Table 2**, it is known that the average time that a patient spends in the ED is 2.90 hours with the average of patients served is 31.47 persons in a day. According to standard service time set by the hospital, the improvement of the current condition is necessary for reducing the medical service time as well as maximizing the number of patients served.

Table 2. Simulation Results for The Existing Condition

Replication	Total Exit (Person)	Average Time in System (Hour)	Replication	Total Exit (Person)	Average Time in System (Hour)
1	47	2.98	16	43	4.26
2	34	2.38	17	25	2.76
3	37	2.29	18	32	2.78
4	23	2.39	19	25	2.19
5	38	2.28	20	31	2.25
6	25	1.93	21	12	1.95
7	34	3.22	22	22	2.23
8	36	2.67	23	18	2.33
9	50	4.90	24	30	4.00

10	40	2.68	25	34	2.64
11	38	3.28	26	20	2.18
12	33	4.54	27	12	1.86
13	34	2.31	28	28	3.96
14	32	3.27	29	45	3.63
15	41	3.11	30	25	3.68
Average number of patients served (person)					31.47
Average number of time that a patient spend in system (hour)					2.90

This study develops a number of considerable scenarios intended to reduce the emergency medical service time at the Hospital X's ED. **Table 3** presents 5 proposed scenarios, consisting of bed and nurse additions. As can be seen from the results in **Table 3**, there are 4 possible decisions that can be implemented, namely scenario 1, scenario 2, scenario 4, and scenario 5. Those scenarios result in the desired medical service time that has been appointed by the hospital. With regard to the total number of patients served in a day, scenario 4 seems to be the most suitable decisions. By adding 1 nurse and 2 beds, scenario 4 generates the highest total exit compared to other possible scenarios. Hence, the application of this result may assist the hospital managers with the decent decision for improving the efficiency of the patient flows in the ED.

Table 3. Developed Scenarios

Scenarios	Nurse	Bed	Total Exit (Person)	Average Time in System (Hour)
Baseline	3	5	31.47	2.90
1	3	6	29.33	2.36
2	3	7	30.80	2.50
3	4	6	33.87	2.62
4	4	7	32.50	2.48
5	5	8	32.37	2.15

CONCLUSION

This research set out to analyze the flow of patients through the Emergency Department (ED) by developing Discrete-Event Simulation (DES) model. The flow of patients starts from the arrival, registration process, triage, medical treatment, and departure. The performance measures of the patient flows in the ED include the time that a patient spends in the ED as well as the total number of patients served by the ED. The DES model is run for 30 replications to produce statistically significant results. Based on the simulation results, it is found that the average time of a patient spend in the system as well as the number of patients served in a day were 2.90 hours and 31.47 persons, respectively. By developing a number of scenarios, the average time spent in the system and the total patients served can be optimized. This paper proposes adding 2 nurses and 2 beds to meet the established standard on the emergency medical care. Ultimately, this work has shown that the developed simulation model has significant implications to be applied in the case study.

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