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SIMULATION MODEL FRAMEWORK FOR HOSPITAL EMERGENCY DEPARTMENT PATIENT FLOW

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ABSTRACT

A hospital's emergency department (ED) is responsible to treat patients in an immediate and fastest response as possible. However, the ED management faces greater challenge with patients overcrowd caused by long waiting time for each patient to receive treatment and eventually increased each patient's length of stay in the ED area. Any wrong decision made to overcome this problem may lead to a more serious problem in the future. This study presents a proposed simulation model framework to analyse the actual operation in an ED of a public hospital in Malaysia. The model is able to help the ED management to better understand daily operations of the department and how it affected by the level of resource capacity.

Key words: Emergency Department, Waiting Time, Length of Stay, Simulation Modelling, Discrete Event Simulation.

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1. INTRODUCTION

The effectiveness level (waiting time to get treated) of a public healthcare is far below patients expectation and improvements in any parts of the operation to reduce the problem are highly needed. ED is one of the most critical departments in a hospital to serve patients in need 24 hours daily. It is a getaway to hospital's admission and treats any kind of injuries and diseases. However, long waiting time to wait for a treatment especially hospitals located in an urban area may have lead to dissatisfaction among patients and staffs on duty. This common problem faced by ED around the globe.

Previous studies stated that the problem occurs due to limited resources available, which proper planning & reallocation are required (Kolb et al., 2007; Gunal and Pidd, 2006). To improve the operation's efficiency may require additional resources implementation, for example hiring more staff or deploying new equipments, which will increase the operations costs. Due to economics limitations, increasing operational costs is not an option. The improvement can be done by analyzing related processes, effectively reallocating available resources and using technological solutions.

New recommendations to solve the problem are possible, but the essence is to seek for the optimal solutions that can validate its effects towards the whole operations. Adding and reallocating resources such as staffs and some equipment are the most common ED management decision to overcome the problem, where mostly are done manually and by trial and error basis. The outcomes of such decision will be evaluated and in some cases may lead to even catastrophic situation. Any decisions with uncertain implications will risk the whole operation of ED, thus the management need to study every detail in the operation before the final decision implemented.

Simulation is one of the tools that can be used to analyze the problem. It has been used in many operations, such as manufacturing, transportation and logistics to examine the processes involved and product flows. Numerous studies have applied operational research methods to find solutions towards problems in healthcare domains (Garg et al., 2008) but simulation is among the most popular approach (Davies and Davies, 1994). Some rational reason for choosing simulation method is it can deal with a complex system where there many uncertainties and variability involved in the system (Brailsford, 2007). Therefore, this study attempts to propose a simulation model framework to model ED using discrete event simulation (DES) approach in order to provide ideas and directions towards better decisions.

The paper starts with the problem background of the system understudy. Then, it is followed by the review of previous literature of simulation approach in healthcare industry and the proposed simulation methodology for the problem. Finally, the conclusions are presented in the last section.

2. PROBLEM BACKGROUND

ED operations are uncertain and unpredictable. Number of visiting patients may vary from time to time, thus resource planning must be done accordingly to avoid or reduce operational problems. Lack of medical staff in Malaysia has lead to poor ED response time (News Strait Times, 2008). Medical doctor shortages are expected to continue and to become more serious in public hospitals (Mohamed, 2003). Due to this issue, it has become harder for the hospital to meet efficiency standards as portrayed by private hospitals (Pillay, 2009).

The real pressure faced by ED management at the hospital understudy is to increase the quality of the services with limited resources (nurses, doctors, beds etc.) available as they need to serve the patient within expected timeline. The shortage of resources will contribute to overcrowding situation where patient have to wait until the required services becomes available. If additional resources added to the system to solve the problem, it will automatically increase the operating cost as well, thus such decision have to be avoided. The ED management is concerned to reduce the patients' waiting time and length of stay in the ED in order to evade overcrowding because they served more than 9000 patients per month but the question is, does adding more resources really can solve the problems? Therefore, studying and analyzing the ED operation in detailed is very important before making final decision.

The ED management needs to find a better approach that can be used to test number of alternative solutions for the possible improvements to meet their target Key Performance Indicators (KPIs). This study aims to modelling ED existing system by using Discrete Event Simulation (DES) approach. This is to aid the management's to understand the flow of patient through the system as well as identifying the bottlenecks to the system operations. The alternatives changes can also be tested using this simulation model without affecting the existing system. The ED management can evaluate the effect of those changes to the system performance.

3. A REVIEW OF LITERATURE

As the number of EDs' patients increased from year to year, the ED management faces an immense challenge to improve their quality of services. ED crowding has contribute to the negative effects such as long patients' waiting time, length of stay, medical errors, human errors, patient and staff dissatisfaction, patient safety and high utilization rate of ED staffs (Cowan and Trzeciak, 2005 & Chawalit, 2013). Cote (2000) stated in his article entitled "Understanding Patient Flow", it is necessary to understand the flow of the patients through the system facility to support the system operations. Patient flow represents the movement of patients from one process to another process in sequential order as part of their pathway of care.

Patient flow is considered to be a key component in analyzing hospital performance (Anon, 2005). Van Sambeek et al. (2010) stated that the most effective and efficient way to improve the patient flow through the system operation is by targeting or identifying the bottlenecks processess (processes that caused congestion in the system). The operations of ED is more complicated and complex because the flow of patient is unpredictable. Data collection is also slightly different and challenging in the healthcare environment. Therefore, finding the right methods or techniques to solve the problem is essential.

Over the last decade, there have been fruitful efforts to solve the problems faced by the ED worlwide. Many approaches and methods have been applied in healthcare industry from the queuing theory to simulation modelling in order to solve the problems. Recently, simulation becomes an important tool for solving a more complex system with many elements and variablility (Babin & Greenwood, 2011). It is quite impossible to test various proposed solution

directly to the real complex system because it might contibute to more seriuos problem. Therefore, according to Maria (1997), simulation is used before a current system is modify or a new system is build (to reduce the chances of failure to meet specifications). It is also used to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources and to optimize system performance.

Simulation modelling have been successfully applied to many areas of study such as manufacturing industry, public service system, military system, transportation system, construction system and banking industry (Law and Kelton, 1991; Seila, 1995; Banks, 1998; Brenner et al., 2010). The objectives of most research are to minimize patients' waiting time, minimize patients' length of stay, maximize patient throughput, improving utilization rate and also to optimize the resources allocations (Eskandari et al., 2011). Saunders et al. (1989) performed a simulation model to observe the effects of resource allocation on the throughput time of patients, size of queue and resource utilization rate. Samaha and Armel (2003) also developed a simulation model that can reduce the length of stay of patient in the emergency department at Cooper Health System. Khare et al. (2009) used simulation modelling in order to investigate the impacts of number of beds towards the length of stay of patient. Kuo et al. (2012) also used simulation model to analyze how the allocation of resources give an impacts to patients' experience in ED.

Komashie and Mousavi (2005) developed a simulation model using DES approach to determine the impact of beds, doctors and nurses on queuing time and length of stay. DES is one of the approaches in simulation modeling that highly applied by previous researchers because it is proven to be useful for decision makers in studying, analyzing and evaluating any situations from a simple to complex operations (Kelton et al., 2015). DES is less detailed than continuous simulation but it is much simpler to implement and is widely used in variety situations because it supports animation and graphic visualization to ease the undertanding (Maria, 1997).

4. A PROPOSED METHODOLOGY

As discussed in previous section, simulation modeling is widely used around the world but fewer researches found in Malaysia. There is growing concern on applying those simulation methods because those models represents hospitals outside of Malaysia and it might not suitable to our local ED. Different structures and policies of the ED might be a reason why those methods not applicable to be used here. Therefore, there is a need to find a general simulation model that can represent our local ED.

The proposed methodology in this paper will be carried out based on DES approach. There are many stages involved in simulation modelling as discussed by previous research but generally they are the same. In this study, simulation modelling by [researchers] is modified and will be applied. Figure 1 shows the flowchart of the modelling phases. The modelling process can be divided into four phases as follows:

- Preliminary Investigation
- Model Development
- Alternatives Design
- Model Improvement

Preliminary investigation phase involved a few steps which are problem definition, setting project objectives, designing model conceptualization and data collection process. A few interviews have been conducted with the ED management to obtain a clear view of ED current

operations including the flow of patient from the arrival until discharged and also the processes involved in getting treatment. Besides, this process also helps to identify the problem in ED operations faced by the ED management. Then, the objectives of the study are define according to the requirements of the ED management. Based on the objectives, the system's current environment is then converted into conceptual model. This model represents the flow of patient in receiving treatment through the ED system. It is very important to clearly identify the flow of patient because the process varies between patients. Once the flow of model is as intended, the next process is data collection. This process involved determining what kind of data needed to act as an input to develop the simulation model (for example; inter-arrival time between patients, service time for each processes, number of resources available etc.). Data collection process involved on site observation (personally observed the current operation), review of database and manual records and if necessary an interview with ED management and staffs will be conducted to ensure sufficient data collected. An analyzed gathered data is then converted into distribution functions (probability distribution) and can be used in the next phase.

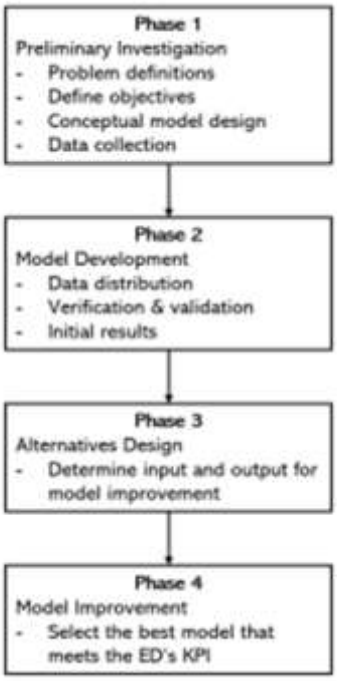

Figure 1 Flowchart of simulation modeling methodology

Once the preliminary investigation phase is completed, the constructed conceptual model will be translated into simulation model form. Then the process of verification and validation is executed. Verification is a process where the ED management will confirm either the simulation model is working as intended or not. Here, the flow of patient through the system being observed to ensure the flow is correct. Meanwhile, the validation process involved comparing the outputs of simulation model with the output of the existing system (historical data)(Ibrahim et al. 2015) and the model will be examined by the ED management. Validation process is allowed for model improvement where all the mistakes in the model can be adjusted and corrected until the model fits the existing system (Ghanes et al., 2014). This process is to ensure the simulation model developed is correct, consistent and valid to be used for decision making process.

The simulation model is then executed for several replications to obtain the accurate results. Expected results for performance indicators are patients' waiting time in the system and for each processes, patient's length of stay in the system, staffs and doctors' utilization rate and other physical resource utilization rate (utilization rate is the percentage of how much the staff is fully utilized in doing their works). The next process under this phase is to identify the performance bottlenecks to the current system (for example; identify which processes contribute to the highest patients' waiting time). Those bottlenecks will be presented to the ED management in order to design for an alternatives solutions.

The design of alternatives solution is based on the outputs from the simulation run and the discussion with the ED management. Generally, ED management have their on Key Performance Indicators (KPIs) to achieve thus they will proposed an alternative solutions to be tested in 'what-if' analysis process (for example; what happened to the patients' waiting time if two consultation rooms are added?). The list of alternatives solution is inserted into simulation model and runs independently. The results of each improvement models are then compared based on the performance measure indicators such as average waiting time of patients or average length of stay of patients in the system. Different alternative solutions can be constructed and tested in the simulation model to foresee the implications of such alternatives. This can help the management to better understand their system behaviors and to assist them in making decision.

5. CONCLUSION

In this paper, a simulation modelling using DES approach is proposed to enhance the performance of one of the public ED in Malaysia. Simulation is a valuable tool for ED management where it helps them understand their system in details (on how the current system operates and what factors contribute to the problems in the system). It also helps them to examine their proposed alternatives solutions by applying 'what-if' analysis scenarios efficiently. However, ED is a very complex system to model because it involves many factors, internal and external, that affects the flow of patient through the system. Those factors must be considered into the development of simulation model in order to ensure more accurate and valid model that best represents the real current system. Finding the right method is very important to ensure that the solution is able to give some impacts not only to the ED management but also to the patient itself. The expected outcome from this research is hoped able to assist the ED management in making decision effectively.

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