IMPROVING AN EMERGENCY DEPARTMENT FLOWS THROUGH MODELING AND SIMULATION

MENAMBAHBAIK ALIR JABATAN KECEMASAN MENERUSI MODEL DAN SIMULASI

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ABSTRACT

This study presents the simulation model to evaluate the treatment process of emergency department (ED). The three objectives are mainly considered, which are by identifying various procedures in ED of a general hospital, to model and evaluate resource utilization that may lead to the bottleneck as well as to propose a better configuration to the ED. ED is known as the frontline of service provider that opens 24 hours per day to serve patients that comes to their door. Regardless, with the increasing of patient's number, hospital was keen to meet the demands in ED where the demand of services provided exceeds their ability to serve patients in an appropriate time frame. The use of Discrete Event Simulation (DES) model allows hospital administrator to understand the treatment process and detected the bottlenecks area in the process. Theory of Constraints (TOC) is also used to identify the constraints in the areas examined in ED. The results from the scenarios experimentation showed that comparison with 20% increase of patients to triage zones affects the different treatment time procedures in both green and yellow zone.

Keywords: Waiting time; Bottlenecks; Simulation; Emergency Department; Patient Flow

ABSTRAK

Kajian ini membentangkan model simulasi untuk menilai proses rawatan jabatan kecemasan (ED). Ketiga-tiga objektif dipertimbangkan terutamanya dengan mengenal pasti pelbagai prosedur dalam ED hospital umum, memodelkan dan menilai penggunaan sumber yang boleh membawa kepada kesesakan serta mencadangkan konfigurasi yang lebih baik kepada ED. ED dikenali sebagai barisan hadapan penyedia perkhidmatan yang dibuka 24 jam sehari untuk melayan pesakit yang datang ke jabatan mereka. Dengan peningkatan jumlah pesakit, hospital harus memenuhi tuntutan pesakit di ED di mana permintaan perkhidmatan yang diberikan melebihi kemampuan mereka untuk melayani pesakit dalam jangka waktu yang sepatutnya. Penggunaan model Simulasi Acara Diskret (DES) membolehkan pentadbir hospital memahami proses rawatan dan mengesan kawasan kesesakan dalam proses. Teori Kekangan (TOC) juga digunakan untuk mengenal pasti kekangan dalam bidang yang diperiksa dalam ED. Hasil daripada eksperimen senario menunjukkan bahawa perbandingan dengan peningkatan 20% pesakit untuk zon triage mempengaruhi prosedur masa rawatan yang berbeza.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter discussed on the background of study of the overcrowding in emergency department (ED) and the consequences. The objectives were set related to understanding how overcrowding in an ED affects the patients' flow process. The performance of ED is measured started from the patient's average waiting time until being discharged from emergency room. The basic entire processes in the ED were simulated.

In addition, in this chapter, the system overview was discussed and the development of the simulation model was explained further. In this research, discrete-event simulation (DES) was used in healthcare industry to improve the performance in delivering services by emergency department staffs.

1.2 BACKGROUND OF STUDY

The Healthcare Department systems are interdependent and complex systems in which different departments interact with one another to provide health care services to the arriving patients. The Accident and Emergency (A&E) department often is the focus center in the hospital and the place where most inpatient admissions occur. The A&E department, which is the focus of this study, is the most complex, critical and busy hospital unit, where medical care is provided to patients without an appointment. If the A&E department is efficient, it reflects the entire performance and drives patient satisfaction for the hospital stay.

According to Nik Azlan, (2013) Emergency Department Overcrowding (EDOC) is a problem that has been discussed for a long time. It is defined as a situation where demand for emergency services exceeds the ability of the A&E department to provide quality care in

a timely manner and the inability foe the A7E to provide an optimum quality service care. The A&E department waiting room is a high risk, high liability areas for hospitals. Patients arriving and enrolling in non-clinical or non-placement areas in existing beds will increase wait times and prevent patients from receiving treatment and access to timely care. Depression in the A&E department is a global issue and has been identified as a national crisis in some countries. Rather, it is defined as a situation where the functioning of the A&E department is affected primarily by the excessive number of patients waiting to be seen, undergoing evaluation and treatment, or waiting to depart compared to the physical or personnel capabilities of the A&E Department. Patient safety and privacy, timely service and frustration among the staff of the A&E department in providing services should be given attention in the context of overcrowding in the A&E department.

Under the Malaysian Budget 2019, the government has allocated an amount of RM29 billion for the Ministry of Health, an increase of 7.8% compared to the previous year. In Healthcare National Key Economics Areas (NKEA) under the 10th Malaysia Plan (2011-2015) report, healthcare industry has spent higher than majority of peers, which was about 4.8 percent of Gross Domestic Products (GDP). Private health care sector in Malaysia has experienced continuous growth since the early 90s, while the public health care has been around since the 1950s. As in other countries in Asia, ensuring access to quality and affordable medicine is an important as stated in Malaysia's National Medicines Policy.

According to the National Healthcare Establishment and Workforce Statistics Hospital (NHEWS) as reported in The National Healthcare Statistics Initiative (NHSI) 2013 Bulletin, there were about 345 acute curative hospitals (51,457 beds) in Malaysia in 2012. They were which 139 public hospitals (37,857 beds), and 206 were private hospitals (13,600 beds). In 2013, the total number of acute curative hospitals in Malaysia increased to 351 hospitals (52,436 beds). Out of these, 141 are public hospitals (38,641 beds), and 210 are private hospitals (13,795 beds). However, for both years, proportion of total inpatient bed capacity was higher in the public hospitals (74%) compared with the private hospitals (26%). This proved that healthcare industry has become widely developed as the changing demography and lifestyles.

In the meantime, healthcare units in many hospitals face challenges of the increased operation cost, shortage of qualified medical staffs, and limited hospital facilities (Barrick, 2009). According to (Hamad and Arisha, 2013), the imbalance between limited resources and high demand is a major driver that will affect many units in hospitals. In Malaysia, overcrowding Emergency Department (ED) has become a public health problem that became more apparent when ED represents one unit in the hospital.

Over the past decades, worldwide Emergency Departments (EDs) are facing crisis from overcrowding (Hoot and Aronsky, 2008). In Malaysia, ED in public hospital is known as the main focus for patients looking for immediate health assistance at any time. Patients normally expect to being treated in a very minimum and less delays. Report of National Healthcare Establishment and Workforce Statistics (2010) stated that the total number of patients visited ED in Malaysia was about 8,105,520 and corresponds to 2860.69 visits per 10,000 populations. Data showed an increment of 2,524 visits per 10,000 populations for the year of 2009. This reflects to high demand for better services care provided and high usage facilities of Emergency Medicine and Trauma Departments (EMTS).

On top of that, being a critical entry to hospitals, ED may receive emergency patients at any time unexpectedly which patients must be treated with minimum delay. Failure to perform so, prolonged delay will contribute to the ED overcrowding, and this situation was defined by Canadian Association of Emergency Medicine as:

> "ED overcrowding is defined as a situation in which demand for services exceeds the ability to provide care within a reasonable time, causing physicians and nurses to be unable to provide quality of care".

From the definition, it summarizes all the different waiting times in ED, which may be waiting for doctor to treat, time to be seen by a consultant or the time waiting to get inpatient beds. In addition, it can be said that if any of these wait-times are longer than their key performance indicator (KPI) provided by Ministry of Health (MOH), it is considered as overcrowded and known as inefficient. Besides that, shortage of resources such as beds, medical assistant and nurse will also contribute to delay of care quality and might increase the potential of medical errors and long waiting time.

In addition, ED consists of three main components, which are people, processes and equipment (Norazura et al., 2012). ED system able to imitate the integration of all components, such that, the model is reasonably close to reality and can be used to evaluate the performance of ED in delivering their services. A significant amount of studies was conducted in EDs (Pillay et al., 2011). Among those studies, simulation has outnumbered as the approach for modeling of EDs (Ruohoen, Neittamanmaki, & Teittinen, 2006). In a nutshell, simulation is chosen to evaluate the performance of ED based on the reason that healthcare system has many variability and uncertainties that involved in the system itself. Hence it requires a stochastic approach that can deal with any difficult and complex system.

Simulation on the other hand, which was used in this study, is one of the tools that is used to evaluate the performance of an operational process. Simulation does not only emphasize on production performance in the manufacturing industries but also have widely used in measuring other types of performance. According to Gaba (2004), simulation is a technique rather than a technology used to replace or reinforce real-life experiences with guided experiences that evoke or imitate the larger aspects of the real world.

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1.3 PROBLEM BACKGROUND

There are several reasons why this study should be conducted. Emergency Medical and Trauma Service called frontline medical providers in the Ministry of Health, Malaysia. They provide 24-hour service daily and welcome patients at any unexpected time. The increasing number of patients and the number of patients who are waiting for transfer to the patient's bed are causing major depressions in ED performance in providing care. In depth, in ED overcrowding is a nationwide problem affecting the safety and availability of the health care system.

Up to 2015, the number of ICU beds in 49 MOH is 660 beds, an increase of 3.6% (23 beds) compared to the previous year. Also, the number of cases analyzed was 39,595, an increase of 4% compared to the previous year (Malaysian Registry of Intensive Care Report, 2015).

Hospitals are an integral part of the health care system and emergency departments in this hospital play a very important role, as they are interrelated between hospitals (e.g. Emergency Medical Services) and hospital resources (for example, Emergency Departments, Operating Rooms, Nursing Bed and so on) (J. Lee Jenkins et al., 2006). Many hospital EDs face a significant surge in daily demand due to their commitment to providing unplanned and unplanned healthcare services to all patients arriving in the ED. In addition, there is an increase in the demand and expectations of people for quality health services in the ED. For example, from 2011 to 2013, the number of visits to ED in Selangor increased from 121270 to 150865 as shown in Figure 1.1.

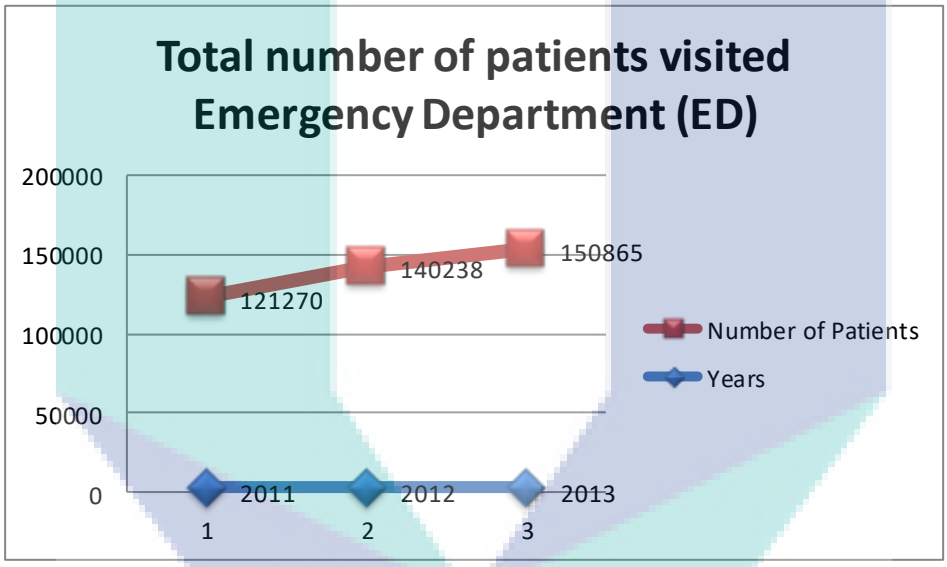

Figure 1.1: Number of patients arrival to an ED from 2011-2013

Source: Annual report of Health Informatics Department of Selangor (2013)

Figure 1.1 represents an overall increase of population in Selangor. This situation was crucial for ED to operate in a time frame. As a result, ED has been positioned in a pressure situation in delivering their care. As the number of patients increased and shortage of resources to treat them, ED is considered as overcrowded. If this situation is prolonged in a long term, what will happen to the ED operation? It might bring negative effects and perception toward their operation.

The Emergency and Trauma Services (ETD) shall be contained in a well-designated area and equipped with facilities that allow the delivery of care in appropriate emergency area. The main care areas shall conform and reflect the triage categories of EMTS including Critical, Semi-critical and Non-critical. The triage system in Malaysia shall use dedicated color convention that has been categorizes as Red (Critical), Yellow (Semi-critical) and Green (Non-critical). The surge in demand for emergency care associated with continually changing demand case mixes and makes ED operated in ever-changing system, making them more complex. This situation has become more complicated with the introduction of the key performance indicator (KPI) by Ministry of Health (MOH) in terms of targeted time for patients to be attended by doctors, as shown in Table 1.3. The KPI was use by the MOH to evaluate the performance of ED operation (EMTS, 2012).

Table 1.1: KPI for the triage zone

Triage Zone	Time to be attended by doctor	
	Prior	New
Red (Critical)	100% immediately	100% immediately
Yellow(Semi-critical)	100% within 30 minutes	100% within 15-20 minutes
Green(Non-critical)	75% within 90 minutes	75% within 60 minutes

Source: EMTS (2012)

As represented by Table 1.1, the new target time only affects the Yellow and Green zone cases. As the result of the new target time enforcement, it divides the ED staffs into two serving groups that will cover almost the total number of ED patients arrival. The new target time must be achieved because it represents the ED performance monitored by MOH. The KPI has positioned ED in a pressured situation in order to achieve the target time and delivering care without additional resources. Furthermore, many researchers have report treatment delays for patients with serious illness (Schull et al., 2004), patient and staff dissatisfaction (Rowe et al., 2006), rising left without being seen rates, inadequate management of severe pain, and increased patient mortality (Pines JM and Hollander JE, 2008).

Thus in this research, simulation technique is used as a mean to model the ED operations, incorporating efficient experimental designs and to identify the ideal operating conditions. Apart from that, the use of simulation modeling is expected to minimize the waiting time of patient. Thus, the simulation a tool used in the study to evaluate the performance of the operation.

1.4 PROBLEM STATEMENT

This research focused on the growing healthcare crisis, and how simulation can be used for process improvement. In Malaysia, hospital emergency departments (EDs) experienced both an increased in patient volumes and decreased in available resources. Due to these trends, patients experienced longer waiting times, and some of the patients left the department without being treated. The treated patients will either be in the ED where they stay in the treatment room or wait in the room provided until the bed is available. The target time released by Ministry of Health is a tool to measure emergency department efficiency as well as ambulance diversion to other hospitals reflects the occupied of the department no additional patients is to be handled based on the current resources (Nik, Ismail and Azizol, 2013).

1.5 RESEARCH OBJECTIVES

This research discussed on the application of simulation modeling on the ED overcrowding towards the performance of the ED operation. The aim of the study is to develop the simulation model to represent an emergency room. The following objectives were identified and pursued in order to achieve the aim of this study:

1.5.1 To identify patients' process flow in Emergency Department that leads to overcrowding of ED.

1.5.2 To develop the model of Emergency Department.

1.5.3 To propose for better configuration in improving Emergency Department patients' process flow.

1.6 SCOPE OF THE STUDY

The scope of this research concerned on the quality of the healthcare services provided by emergency department (ED) in general hospital in Malaysia. Emergency department (ED) is a unit in hospital that provides treatment for acutely ill and injured patients 24 hours daily. Unfortunately, according to Cowan and Trzeciak, (2005), many EDs around the world are crowded on a daily basis and sometimes an ED stays can last up to eight hours due to the overcrowding. As for that, simulations models were developed to evaluate the performance measure of quality services provided by ED of a general hospital in Selangor.

For the purpose of this research, the general hospital in Selangor is selected. Three areas which give impact the patient flow in an ED includes input, process and output. The process flows begin with input process which is arrival of patients. Next, the medical assistant will triage the patient and upon completion; the patient will move to the treatment area and they will have to wait to be treated. If any of the physician is available, patients will move to treatment area to see the doctor. The meeting rate of speed between a doctor and a patient depends on the level of the patient's health at that time. There are times when patients require further treatment and are not allowed to leave the ER but at the same time patients have to wait for bed availability. This is because the occupancy rate for beds in the ER is high. So the scope of the study is to identify the throughput capacity at the certain time. The crucial part of the study is to identify the potential bottleneck during the patient flow process. The occurrence of potential bottleneck will lead to the long waiting time for patient to be treated by the doctor. In this study, emphasis focus was given to the green zone since this zone is the most crucial part.

At the same time, the model that mimic the real system is develop and "what if" scenarios were designed to answer the possibilities generated from the models. The model can be changed accordingly to the "what if" simulation.

1.7 SIGNIFICANCE OF STUDY

This research can help those ED overcrowding researchers to deliver the information or message to the hospital organization where the lacking or error happened in the ED operations. Furthermore, they can also propose the idea to make some changes to the operational of ED based on the output generated from the simulation modeling. The result from the simulation modeling will come out with explanation on what action should the hospital take and how to maximize the quality performance provided by staffs in a constrained condition.

On the other hand, this research can also deal with a potential solution for overcrowding in Emergency Department (ED). Moreover, Emergency Department (ED) operation is very complex, which consisted of many dynamic variables and random features. Thus the hospital administration needs a tool to allow them to study the operation of the ED itself, which would also work as decision support tool.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers the exploration of all information that involved for a better understanding on research area. The information was extracted from the journals, reference books and previous study done by others. There is a structure of this chapter which shown in Figure 2.1. These sections are mainly concern on certain knowledge which relates to the research on Emergency Department Overcrowding (EDOC) that will give impacts towards their performance will assess by using computer simulation. This area is being discussed in order to understand the purpose of this research clearly. Few other sections under this chapter captured on the overview of simulation, the application and advantages as well as focus on the ED and research that has been conducted related to it.

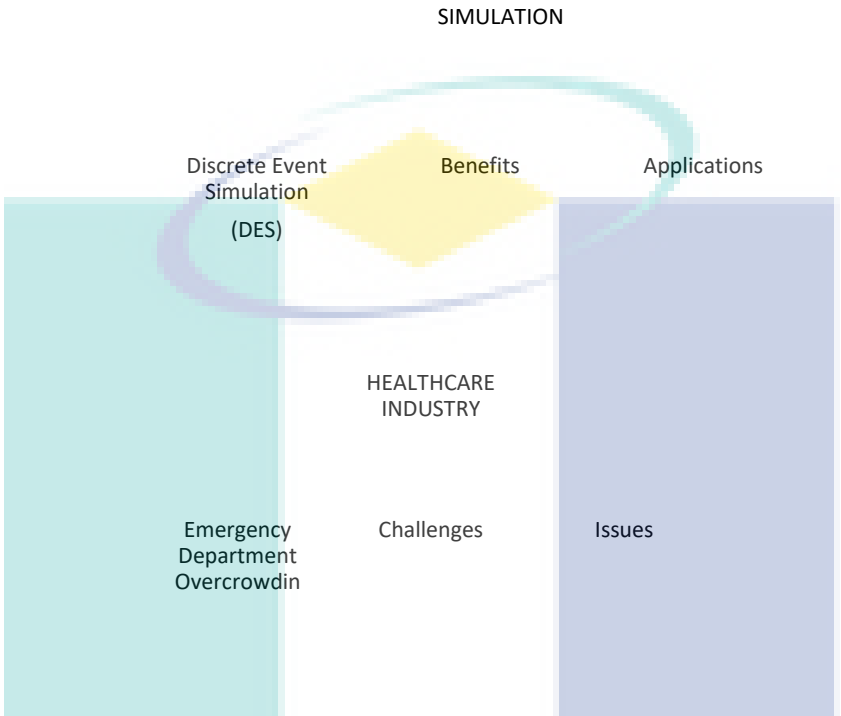

Figure 2.1: Literature review structure

2.2 INTRODUCTION TO SIMULATION

In Oxford Advance Learner's Dictionary, simulation is defined as a particular set of a condition which is created artificially in order to study or experience something that could exist in reality. In Arena, a software where manage to build simulation models, simulation is defined as a tool to create model of a real or proposed system for the purpose of evaluating the system's behavior for various conditions.

Different source will have different definition on simulation, but the concept of the simulation is still there. Simulation is an indispensable problem-solving methodology for the solution of many real-world problems (Banks, 1999). Simulation is used to analyze and describe the behavior of a system by asking "what-if" questions about the real system. This will aid in the redesign or reorganization of the real current system. Further, the ancient study of Maria in

(1997), she divided the study of simulation into 2 sides, one is the Real World and another one is the Simulation Study. In the real world, the system under study and the altered system are reversible which means that the cycle is keep repeating. On the other hand, the decision making to alter the under-study system is requiring the 4 stages. It starts from the developing of simulation model, designing the simulation experiment, analyzing the output until the formulating of conclusion. In simulation study, the decision can be made without any intervention to the real system by using the powerful simulation software. Experienced problems formulators and simulation modelers and analysts are necessary for a successful simulation study (Maria, 1997).

There are two types of system in simulation, discrete and continuous. Discrete system is a state variable that changed immediately at the point separated at the time. For example, the bank model, changes in circumstances occur only when the customer arrives or departs. Continuous System is a state variable that changes continuously as a function of time. For example, the flight of the aircraft, state variables such as position and velocity changes continuously. In addition, there is also a classification model simulations and the models are as follows:

- Static vs. dynamic
- Deterministic vs. stochastic
- Continuous vs. discrete

Simulation is the dynamic view or representation of an actual system by a computer model that behave the same manner as the system itself. Simulation brings out a lot of advantages and act as the tools to facilitate the problem solving process. In fact, by using simulation it allows the modeler to diagnose and identified the problem, take preventive measure, generate and come out with the ideas and then come out with the best solution that will improve the system and productivity.

Basically most often system is studied by the experimental with the real model or experiment with a model of the real system. In this chapter we will be focuses the areas of applications, simulation in healthcare and its application as well as the Emergency

Department issues that arise related with the simulation.

2.2.1 Areas of Application

In ancient study, the applications of simulation are vast (Banks, 1999). Basically simulation can be divided into three parts which are the manufacturing, service system and public system.

- Manufacturing and material handling application. In manufacturing and material handling application it included the evaluation of AGV routing strategies, material flow analysis of automotive assembly plants, analysis of the effects of work-in-process levels on customer satisfaction and other.
- Public system application. This included the health care system, military system, natural resources and public service.
- Service system application. In the service system application, it included the transportation, computer system performance, air transportation, and communication system.

With the various applications, it shows that simulations are the excellent vehicle for communication among various user groups in the company. Simulation also provides a logical and often a graphical description of the system under investigation. This lead to present of the ideas to the design team and managers went well and more effective (Sun and Ming, 1996).

2.2.2 Advantages of Simulation

In most of the companies, the benefits of using simulation are beyond just a forecast of the future. In the study of Jerry Banks, 1999, the benefits gained beyond the expectation have been mentioned by many authors (Law and Kelton 1991; Schriber 1991; Pegden, Shannon and Sadowski 1995; and Banks, Carson and Nelson 1996) and they are included below:

- *Choose Correctly*, which allow to test every aspect of desired change or addition without committing resources to acquisition.

- *Time Compression and Expansion*, which allow to speed up or slow down the phenomena for thoroughly investigation by compressing or expanding the time of simulation.
- *Diagnose Problems*, which allow to have better understanding the interactions taking place in one given moment. Simple saying, it is more likely to increase the understanding of the variables in affecting the performance of the overall system.
- *Explore Possibilities*, which allow you to explore a new set of policies, operating processes, or methods without disruption and costly in experimenting to the real system.
- *Understand "Why?"* which allow determining the answer to "why" questions by modifying the mimic scene in software and examine the system to find out why such thing happened.

2.3 EMERGENCY DEPARTMENT PATIENTS FLOW

2.3.1 Emergency Overcrowding

Emergency Department (ED) has always been the frontline provider of urgent care for people. However, recent trends including an increase in patient volume and decrease in ED resources has contributed a crowding problem in many of the nation's emergency departments. According to Nik, Ismail and Azizol (2013), the authors pointed out the main causes were found to be the increasing of patient acuity, shortage of hospital beds, increasing in patient volume and also delays from laboratory. Further, those authors also claimed that crowding has been a developing and longstanding problem that has gotten worse within recent years. In addition, previous research by Kolb et al. (2008) have defined crowding as patients waiting more than hour to see a doctor or physician, patients placed in the waiting room or hallway more than 6 hours per day, or ED beds being filled more than 6 hours per day. This research also been supported by Derlet, Richard and Kravitz (2001) that stated that crowding commonly perceived as a situation in which there are more patients than staffed treatments beds and waiting time exceed reasonable periods. Thus from the studies, this situation of crowding can be seen through performance measure including extended waiting times, patient length of stay before being seen by doctors and also on their resource utilization.

According to Noreen et al. (2014), authors pointed out that prolong from the crowding

crisis can reduce the quality of care administered in the emergency department, as medical providers are forced to handle more patients with fewer resources. Overworked medical providers are more likely to make errors and overlook serious condition, which lead to an increase in patient pain and suffering. In Malaysia, ED crowding is major problem that affects both rural and urban areas alike. This proved by reports from News Straits Times (2008) that reported news on lack of medical staff has led to poor response time at most EDs around the national. This news supported by surveyed from Health Informatics Centre (2009) that stated the doctor-patient ratio in the country is recorded as 1: 1,105, which is lagged behind developed countries and this becomes more serious in public hospitals. As a result, Pillay (2009) claimed that public hospitals are not achieving their standard of efficiency of key performance indicator released by Ministry of Health in Malaysia. Thus, public hospitals are still far behind the private hospitals.

2.4 SIMULATION IN HEALTHCARE

Simulation is widely used for modeling health care systems. The ancient study by England and Roberts (1978) showed that simulation in health care was performed for more than 30 years and the number of publications and literature reviews increases steadily. According to Gunal and Pidd (2010) the authors pointed out that the majority of simulation models approach only modeling discrete parts of hospitals, e.g. emergency rooms, outpatient clinics or operating theaters, as simulating a whole hospital is very complex. The main aim of these studies is to support decision making and operational planning in healthcare. In another review done by Pillay, Ghazali, Abd Manaf, Abdullah, Abu Bakar, Salikin, Umapathy, Ali, Bidin and Wan Ismail (2011) stated that this lack of simulation studies dealing with whole hospitals results from complexity of the systems and the large data requirements for modeling the systems. In addition, monetary and time resources are among the factors that may also lead to less research in this field.

In addition, the main focus of research dealing with simulation in EDs lies in the analysis of wait times and resource utilization. Gunal and Pidd (2010) emphasize that a variety of observable processes can be an important reason for the high activity in this field of research and thus lead to many such simulation studies. In addition, a large number of research in healthcare

has been done in the EDs area (June, Jacobson and Swisher, 1999). In most of these studies, simulations have surpassed the number of other operational research methods to model EDs (Ruohonen, Neittaanmaki and Teittinen, 2006). This trend might be related to many of the problems encountered in this unit. Long waiting time is one of the most common problems faced by EDs around the world. Some studies showed that this problem is related to limited resources, which requires proper planning and provision (Kolb et al. 2007 and Gunal and Pidd, 2006).

Therefore, ED system modeling needs an approach that able to imitate the integration of relationship between the components. Therefore it can be said that the simulation is selected for at least three reasons: First, the health care system requires stochastic approach because there is a lot of uncertainty and variability involved in the system. Second, the complex nature of the healthcare system requires a modeling approach that addresses complexity. Finally, the human involvement in the health care system requires the right approach to interaction and communication between the modeler and user (Brailsford, 2007).

2.4.1 Using DES for ED Improvement

DES is an approach where models developed enables final users such as health administrators to assess competencies and test the related scenarios for both current and future state. DES is a modeling system that can represent series of events at discrete time intervals. DES enables the modeler to create entities with the necessary human characteristics such as age, gender, marital status and manner of arrival. This feature is commonly seen in patients seeking various hospital treatments. Some researchers have successfully solved ED problems related to resource allocation, improved patient flow and reduced patient waiting time by using simulations (Komashie and Mousavi, 2005; Ruohonen et al., 2006; Gunal and Pidd, 2007; Powell, Khare and Reinhardt, 2007, Medeiros, Swenson and DeFlitch, 2008; Ahmad and Alkhamis, 2008; Brenner et al., 2010; Peck and Kim, 2010). Other researchers have taken advantage of the flexibility of the simulation approach by integrating simulations with other techniques such as integer linear programming (Centeno, Giachetti, Linn and Ismail, 2003) and optimization algorithms (Ahmad and Alhammer, 2008). This approach mainly uses discrete event simulations (DES) that can model the complexity of patient flows and provide detailed surgical features of the ED.

In addition, DES is also able to detect the status of individual entities in the system and assess the performance associated with the entity. Tracking is done by focusing on the time at which various events occur. DES emphasizes the effect of random variation. Stochastic effects are not considered in the analytical model but are less important in the construction of system dynamic models. Although many ED models are built, they represent hospitals in the United States and Europe (Brailsford, Harper, Patel and Pitt, 2009). Different factors and structures used in these countries however do not occur in Malaysia. For example, there is no transfer of patients in this country because the government hospital policy is to serve every patient who arrives at the hospital. Therefore, increasing the number of patients to the ED is inevitable and can increase the workload among staff. In addition, unlike developed countries with separate ambulance providers, ambulances are part of ED services overseen by ED staff who work as emergency personnel and ambulance crews in parallel.

2.5 EMERGENCY DEPARTMENT ISSUES ADDRESSED BY SIMULATION

Simulation is a technique and not a technology to replace or amplify real experiences with guided experiences that replicate substantial aspects of the real world in a fully interactive manner. The efforts to develop computer simulation of ED have been advancing since the late 1980s (Saunders et al, 1985). Since that time, DES models and other simulation techniques have been used to study a wide range of factors such as the effect of staffing levels and variables influencing patient throughput.

Eldabi and Paul (2001) state that the key issue in the success of health care simulation studies is the careful formulation of problematic statements, and the needs of all stakeholders. In manufacturing simulation studies, modeling errors and data can result in unexpected costs and have a poor performance impact. However, in health care simulation studies, such errors will eventually lead to lost lives and liabilities associated with the event. Therefore, the acceptable margin for error in the design and use of health care simulation models is much more limited. These restrictions provide barriers and barriers that can only be overcome through the highest attention to detail, as well as monitoring between all stakeholders.

Simulation models can only be implemented based on data entry, but data collection is a major challenge in healthcare. In healthcare, often simulation developers do not have sufficient

data entry for their simulation model which then results in inaccurate results. Data collection is a major challenge: historical data may not be available in useful formats; data collection should take place over a long period of time; Talking to healthcare professionals for data collection and verification purposes is also a difficult task because of their hectic schedule.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter begins with the focus of this research. Then, data collection method of research, research approaches and model of simulation for the study has been provided. Besides, this chapter also discussed about the suitable data collection method in this research. At the end of the chapter, the validity and reliability of the data collection will testing and analyze to ensure the correct process have been developed properly.

In addition, this chapter will also deal with the actual simulation model. A generic ED will be modeled to capture main processes found in any ED. The model will not represent a specific ED, since main processes such as reception, registration, triage, and treatment processes are inherent to all EDs. Besides, the model will capture the arrival of patients to the ED until the moment the patients exit. This description is in order to provide a clearer view of where is actually this study is about and what is actually happening in the ED. From Harrel and Tumay, (1995) claimed that the ultimate reward from developing a model is to gain information that can be used to improve decision making by study the system.

3.2 FOCUS OF THE STUDY

The research focuses on the Emergency Department (ED) at general hospital in Selangor, Malaysia. To limit the scope of Emergency Department operation, a general hospital that located in Selangor has been selected to take part in the process to collect the data. In addition, this research only focused on the patients flow process and impact from fewer resources such as bed occupancy. This is because the fewer resources will give a big impact towards delivering care services and will lengthen waiting time of patient. Thus, the result of data collected will become more validity and reliability.

3.3 DATA COLLECTION METHOD

Data collection is the process of preparing and collecting the data for further analyzing of study. The purpose of it is to get enough information on record, to decide on important issues and to spread the information to others as well. There are two types of data were used in collecting the data, which are primary data and secondary data. Primary data which is the data in gathered first time by researcher. In order to collect all the information regarding this research, primary data is gathered through interviewed and observation. Then, the results from the issues were discussed again with Head of Department (HOD) of ED for approval to release the data.

Besides, the secondary data is taken through secondary sources. In order to get those data several method and procedure were applied in this research in collecting data. These include the patient's medical record, system observations, interviews, and a variety of published papers in different journals. The observation on the patient's process flow and ED operation will conduct at the Emergency Room. The observation and interviews with the person in charge provided layout for the objective of the research.

3.4 RESEARCH APPROACH

In this section, the type of research approaches will be discussed. For instant, basically there have two types of research approaches, namely quantitative research and qualitative research. However, quantitative research will apply in this research. The focus of quantitative research is based on the quantitative and aims to test the hypothetical chain model that has been proposed. In addition, Hancock (2002) explains further that quantitative research is more concerned with the developing explanations of the social phenomena. He also explains that the quantitative approach is most suitable to test and analyze the data result that has the relationship between two data which is the real process and the imitate one.

3.5 SIMULATION MODEL

Simulation is the process of developing a model of an entity that can then be altered and analyzed to determine the impact of changes in key variables. Simulation also can be used for process improvement, scenario planning, and resource utilization. It is one of the most powerful tools available for analyzing new system design, retrofits to existing systems, redesign of system components, and proposed changes to operational processes. Simulation models enable the user to visualize how an entire system can be altered by changing an individual piece of the system. The simulation model of the system was proposed by Centeno and Carillo (2001), with the following steps which are formulation and problem analysis; project planning; formulation of the conceptual model; macro information and data collection; translation of the model; verification and validation; experimental project; experimentation; interpretation and statistical analysis of the results; comparison and identification of the best solutions; recommendation and implementation.

The conceptual model of the system was translated into software Arena for carrying out computer simulations (Kelton, Sadowski, and Sturrock, 2007). Sargent (2007) was proposed the methodological. Additionally, it was followed during the verification and validation of the model, highlighting the application of tests of continuity with historical field data for typical days of operation on the values concerning the patient's waiting time, backlog, as well as consultations with experts of the EDs. The simulation was initiated only after the model has been completely verified and validated and ensured that the assumptions and simplifications adopted from the real system were properly implemented. Figure 3.1 show the steps and flow of the modeling the simulation.

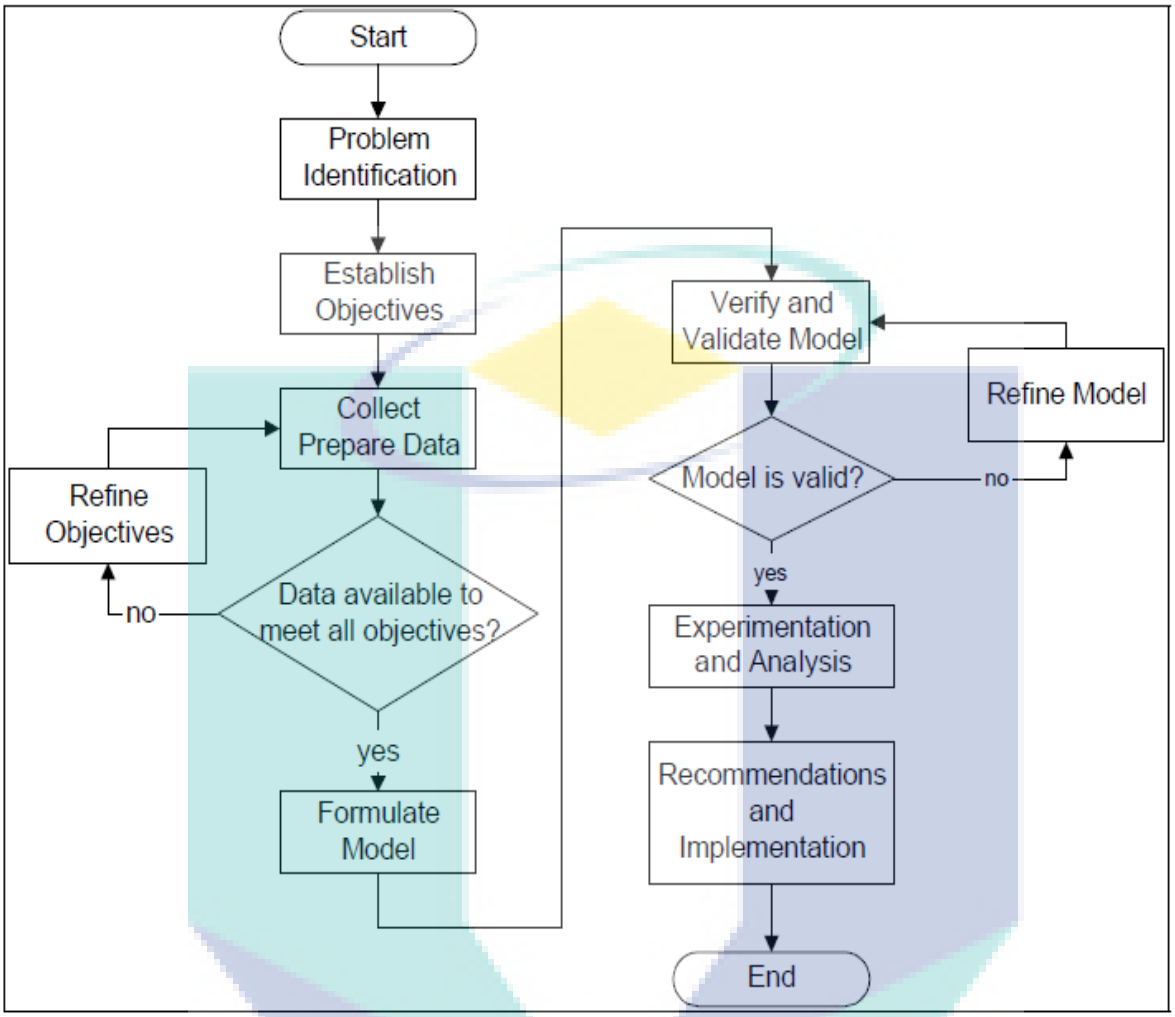

Figure 3.1: Steps and decisions for simulation modeling process

Source : Centeno and Carrillo (2001)

Hopkins (2004) claimed that modeling enables the mimicking of reality. A model must be certified as an accurate representation of such reality. Without the certification, the results of any and all experimentation with the model may be questionable. There are two aspects to obtaining such certification: verification and validation. From both of them, verification is the easiest one. It is simpler and only requires checking out that the model has been built as one intended it to build. Meanwhile, validation is the process of insuring that the model truly

represents the real world (Hopkins,2004). Based on the model from Centeno and Carillo (2001) there are several steps in a simulation project which are;

1. Problem formulation and setting of objectives.

In every research or experiment should begin with the statement of problem. The accurate definition of problem will be able to determine the question that must be answered and ensure the special care must be taken to the problem. Understanding the problem clearly and precisely is really needed. In this research, at the initial stage of research there were arranged few appointments with the Clinical Research Centre (CRC) people and also Head of Emergency Department to conduct an interview session. Then, some of observations to identify the various procedures in ED have been done for better understanding.

2. Model development.

The model development is the most visible part of computer simulation. The model developed represented the goals and objectives of research. The model will first capture the basic logic model of the system and also for the logic flow. The model is designed around the objectives and questions that need to be answered rather than try to mimic real system exactly. In this research, the emergency room logic model has been develop based on the real system and approved by Head of Emergency Department for the verification and validation process.

3. Data collection and input modelling.

The data collection is the stages where collection of the appropriate input data took place. As the model has been constructed, it will become clear that specific data is needed. In this research, Department of Medical Record and Department of Technology provided the statistics data such as the total number patients arrival and bed occupancy over a period of time. Besides, the data also must be either estimated or determined using pre-existing data. Object attributes must be instantiated with realistic data.

4. Model programming.

The model is programmed on a computer using which is known as Arena, or a simulation language/package. The choice of software used to develop the simulation model gives a crucial contribution to the research. After develop an initial process map and historical data is generated, the next stage is to code the simulation model. First, the suitable module must choose in order to construct the model. The simulation language can be used to solve almost any discrete simulation problem. However, for this study no program coding is involved as the software used is comprehensive to use the drag and drop modules.

5. Verification.

As the development of model functional completely, the model need to be ensure represents the actual operation of ED and does it work correctly. Therefore, the verification is used to determine if the model has been programmed correctly that includes module and integration testing. The verification seeks to show that the computer programs perform as expected and using the right data at the right time.

6. Validation.

On the other hand, validation process is to ensure that the model behavior validly represents the actual system that being simulated. The model needs to be tested if it represents accurate system. The differences value between simulation output and actual system must be around 10% or less in order to satisfy the validity level of construct model to the actual system.

7. Experimental design.

This stage represents the actual running of the experimental and analysis of the model. Further, it is known as a set of experiments whose results will help start the process of answering some of the questions set forth during the objective-setting phase. The simulation will be executed on the computer and outputs of model will be record.

8. Test runs and analysis.

Model run and output analysis is used to estimate measure of performance for the scenarios that are being simulated and results will be compared. For the accurate and stable results, the simulation needs to be run with many replications whereby replication is defined as executing the same model at numbers of time, but with different random number in each runs.

9. Final recommendation.

If the analysis form the experiments yield the best performance for ED operations, it will be proposed to head of department of ED as one of the improvement plan that they can follow. Nevertheless, the model should be documented first as references for non-experts to understand the functionality of the system.

CHAPTER 4

MODEL CONSTRUCTION

4.1 Introduction

This chapter will embrace more detailed on description of patients' flow in emergency department (ED). The area of this study covers only at semi-critical and non-critical units of emergency department. This description is in order to provide a clearer view on what is actually happening in the emergency department and how to go about.

4.2 Process Description

4.2.1Emergency Department Components

EDs around the world were primarily established to provide specialty clinical care and treated most critically needed patients who required instant care, 24 hours a day, 7 days a week. In practice, however, EDs will still have to deliver an appropriate time for all patients no matter on what health reasons they are seeking for treatments (Emergency Trauma and Services, 2012). In addition, patient process flow is different in every ED in this country. However, in most cases, the following procedures are the standard assessment and treatment procedures of ED patients. Figure 4.1 illustrates the main stage of the ED process:

Patient Arrivals: Basically, ED patient flows in a general hospital consists of three procedures of operations which are acuity level identification (triage), waiting to be seen (distribution location), receiving treatment. Patients that visit ED consist of ambulance patients and walk-in patients. The process begins when patients reach the ED either by walk-in or by the ambulance. Patients' arrival is unpredicted and was not planned or pre-booked. Immediate assessment and treatment should be instantly executed due to the patient's condition (Emergency Medicine and Trauma Services, 2012).

Triage: Walk-in patients will go through a procedure of being triaged by a nurse or medical assistants, where they are prioritized to care according to their MATC

(Malaysian Triage Category) level and their sequence of arrival within each level. Patients can be under-triaged when they are assigned at triage level lower than the patient's actual acuity which might compromise with patient safety. Meanwhile, for over-triaged patients, when they assigned at triage level higher than the patient's actual acuity might result in denying access of other patients to timely care. In Malaysia, triage was categorized into three color triage zone, namely Red, Yellow and Green. Red will represents critical cases, Yellow for semi-critical cases and Green represents the least severe cases (Emergency Medicine and Trauma Services, 2012). After being triaged, patients are registered before being admitted to a medical assistant in an examination room. If the patient arrives by ambulance, the triage and registration steps are different but an assessment is still being done in the ED.

Waiting Area: There must be at least one waiting area in EDs, sometimes two waiting area might have in EDs if the ED is designed for a fast track model that places critical cases patients in a separate waiting room and treats them with separate processes. While waiting for a bed or being seen by a doctor for treatment, some patients may optional to leave without being seen by a doctor.

Main ED: The main ED consists of beds, medical assistants, nurses, doctors and a hallway area consisting of boarding spaces. Once a patient occupies a main ED bed, the succeeding process is categorized into three steps. First, the patient spends time with a doctor for an initial assessment and may have to wait if all doctors are occupied with other patients. When MTAC I and II patients spend times with doctors, MTAC III and V patients spend times without doctors, during which time treatment and diagnostic tests are conducted. Finally, the patients spend more times waiting before being seen by doctors before being admitted or discharged.

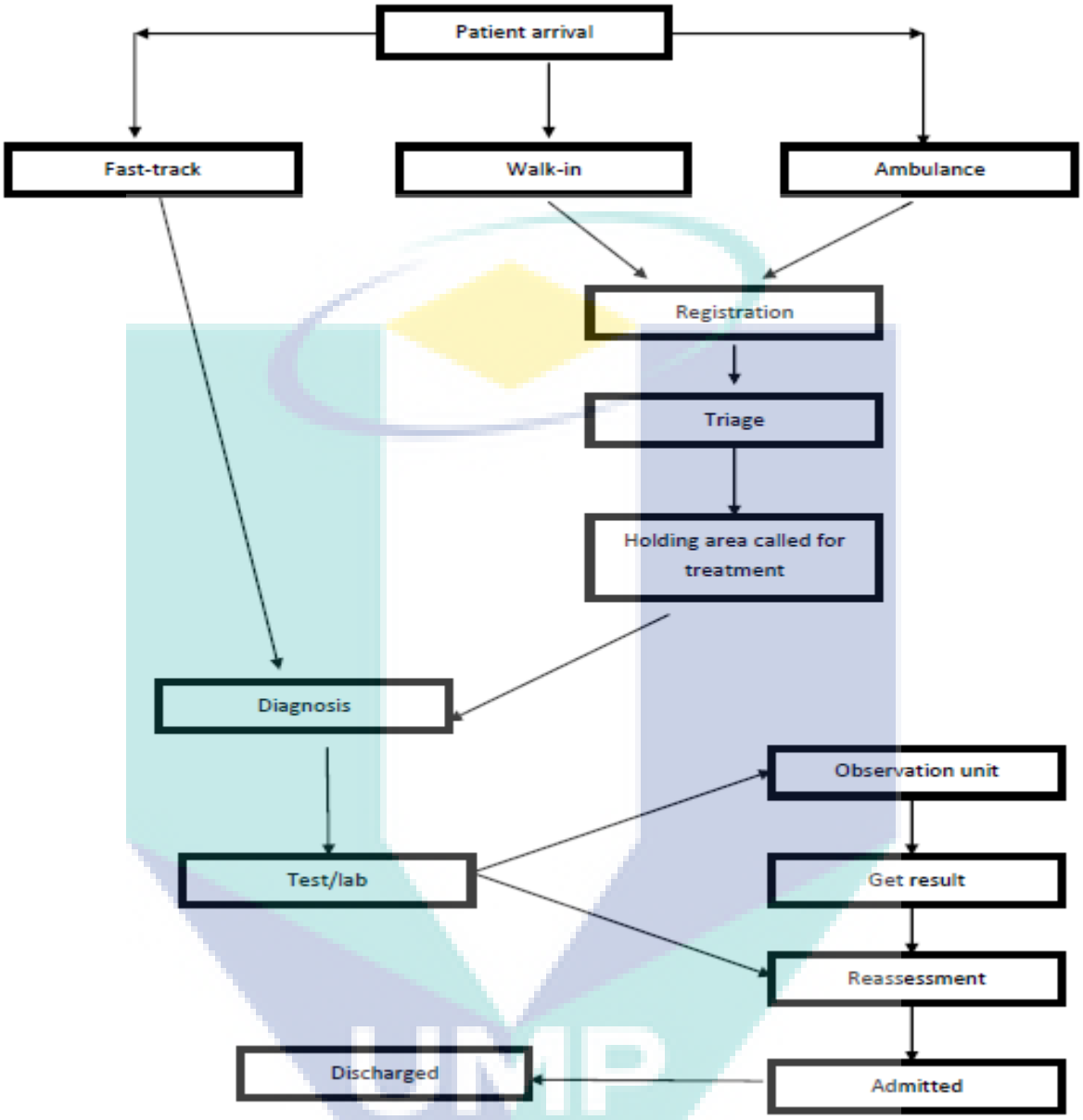

Figure 4.1: The generic process stage of main ED that patients go through for examination and treatment.

4.2.2 Model development

The ED is simulated by a discrete event model (DES) to describe the patients flow process in ED. The process flow begins with the arrival of patients either by walk-in or ambulance. The arriving of patients will stop at counter for process of registration and a medical assistant will start the triage procedure for the patient. Critical patients will be transferred

directly for fast track to the critical area and bedside registration.

Once triaged, the patient moves to the waiting area to be called for treatment. If there is availability of the doctors, the patient moves from treatment area and see the doctor. Delay of doctor to patient depending on illnesses severity. Then, doctor will decide if the patient needs further tests. Some patients will be temporarily monitored in the ED observation ward before discharge. The discharged patient is either sends to hospital wards or released to go home. Figure 4.2 shows model logic of the computerized model:

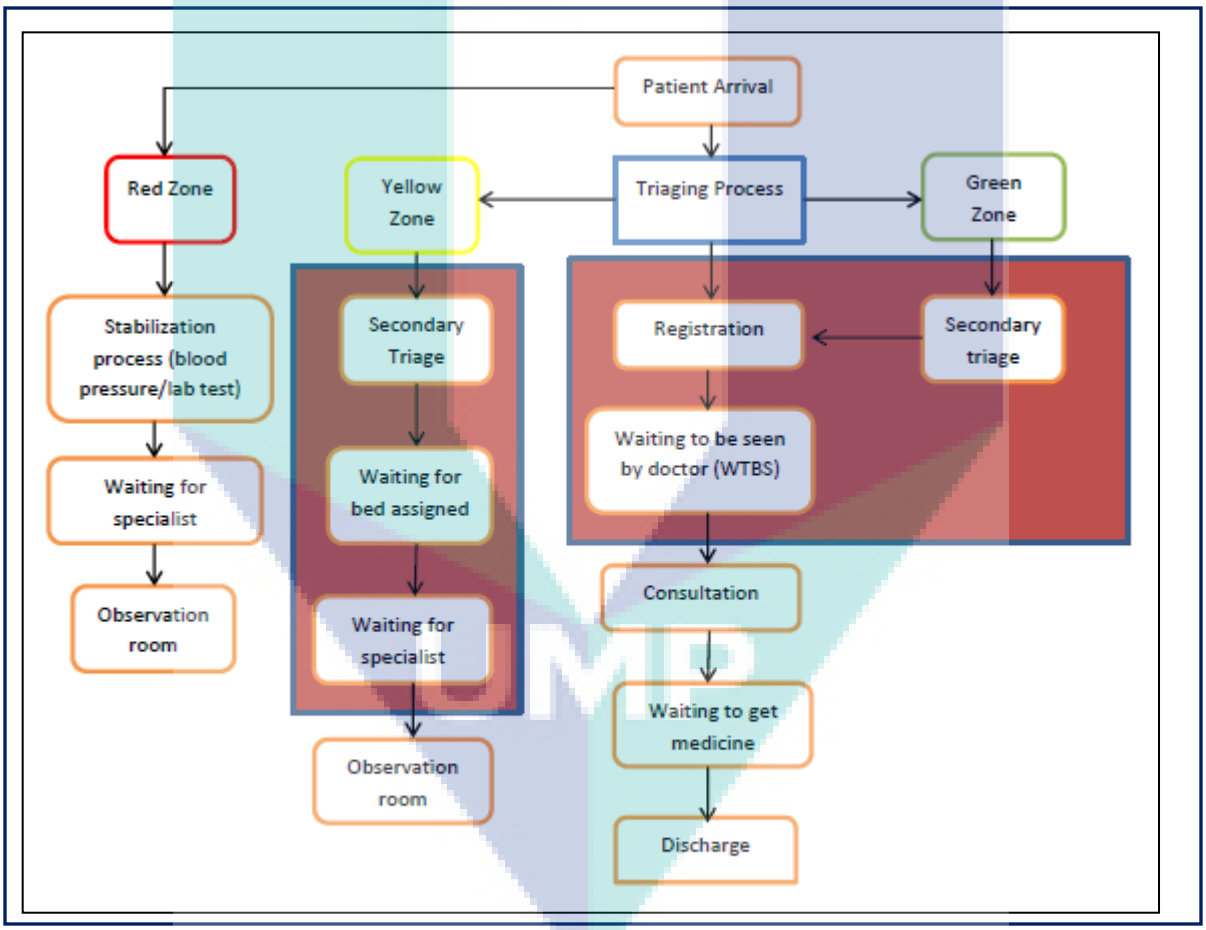

Figure 4.2: ED model that represents procedure in emergency room

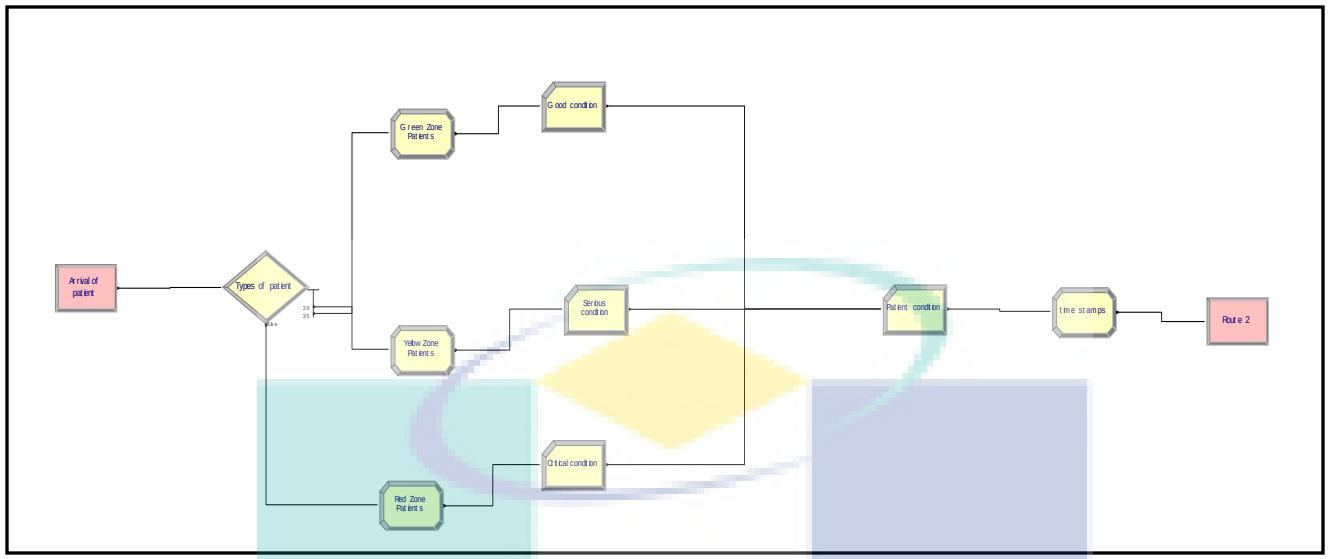

Figure 4.3: Arrival model of emergency departments

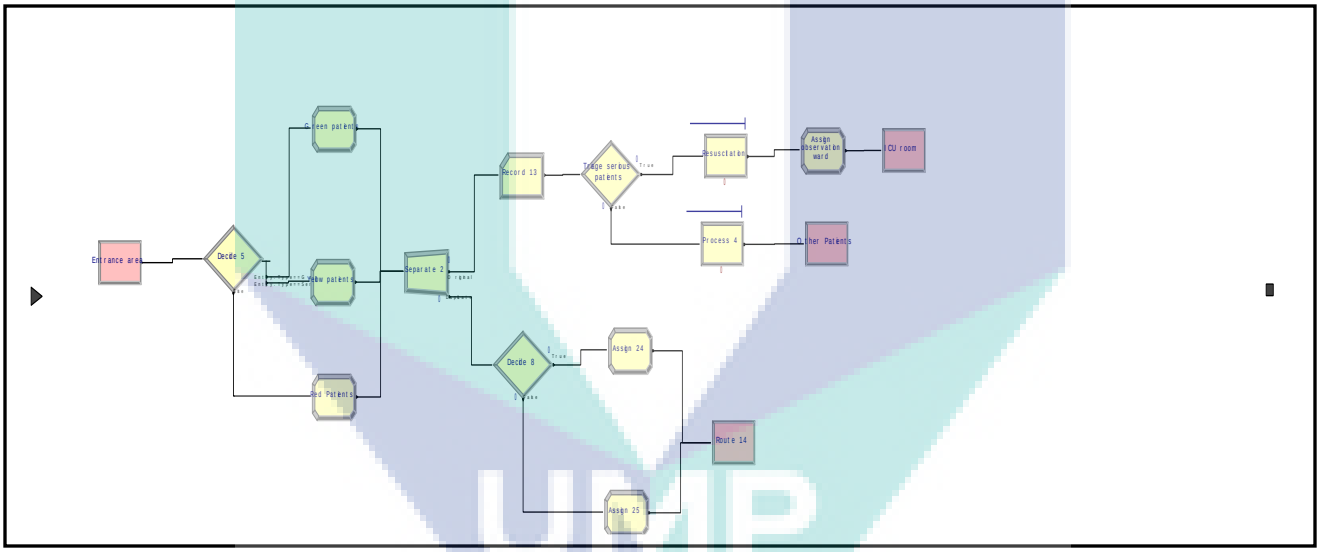

Figure 4.4: Waiting area model

4.3 Data Collection

After the process has been flow-charted and organized, pertinent information about the procedures and is collected. Operational assumptions are also established for system elements when actual data are in short supply or non-existent. System elements are assumed to operate in a certain manner for the purposes of the simulation model. The assumptions need to be documented and modeled correctly.

Data collection is very important and crucial because it contributes a lot to the simulation modeling verify process. There are several methods and procedures adopted in this study for data collection. These include medical records, system observations, interviews and measurements.

4.3.1 Medical Records

The main data collected for this study was from from the medical record for Emergency Department. It will include patient arrival and departure times. The patient data consist of emergency room patients and urgent care patients. When performing analysis on the data, the data set for urgent patients is eliminated. The data was parsed, identifying the patient arrival rates that vary from month to month, and day to day. The weekly patient arrival distribution was also identified. The data contained information regarding arrival time, arrival method, acuity level, whether the patient was admitted or not, any tests the patient received, and patient departure time. The time a patient left the emergency department was only recorded for admitted patients, which limited length of stay calculations. In this research, the details of process will not be touch.

4.3.2 Interviews

After gaining a general understanding of patient arrival distribution in the Emergency Department, the interviews were conducted to emergency department staff, including doctors, and nurses. There were three chief goals that need to accomplish throughout the interview process:

1. A general understanding of ED operations that cover Green Zone and Fever Centre.
2. Identification of issues faced by the emergency department.

To understand the various procedures, the in-person and open-ended interviews were conducted. Role-specific questions to all interviewees were asked to understand each step a patient takes within the emergency department and to ensure the interviewees were confident in the answers they provided. The questions were open-ended as to avoid limiting responses. Interviewees were encouraged to clarify answers when needed, but the interviews were conducted in a ―question and answer type of session. The questions were designed with simplicity in mind, to reduce the deviation of the interviewees' interpretation. In compliance with the Institutional Review Board (IRB) agreement, interviewees completed consent forms, as shown in Appendix.

4.3.3 System Observations

For the other method, data were collected through observations. The observations were implemented on the three main procedures (acuity level identification, distribution location and receiving treatment). At the triaging area, the station had been observed for three months. These multiple observations were done as back up in a case of missing or inaccurate data occurred.

At the beginning, observation was carried out at triaging area, so as to have better understanding of the various procedures in emergency department (ED). Other than that, observation was also implemented on asthma bay and trauma lane.

4.3.4 Other Information Resources

The next method for collecting data was from reports that were published by the hospital and Ministry of Health (MOH). The reports contained information such as workforce statistics, hospital statistics and hospital facilities. Other sources of data gathering include information from the newspapers, journals and books as well as the Internet. Among the

information obtained from those resources are articles on waiting times in hospital, browsing the website of hospital and government policies on healthcare industry.

CHAPTER 5

RESULT AND ANALYSIS

5.1 INTRODUCTION

The result on the first part which is validation was done using Mean Average Percentage Error (MAPE). Also the face validity and historical data comparison was made to ensure the model accuracy. The primary objective of this study to model and propose a better configuration for better ED operation.

5.2 VALIDATION AND VERIFICATION

According to Djamali (2018) Validation in dynamic system modelling can be done by some ways namely direct structure test. The validation in this modelling system is carried out by comparing the behaviour of modelling (data simulation) and real system (actual data) such as test of Mean Absolute Percentage Error (MAPE). This test can be used to know the suitability between estimation result and actual data. Of course, models cannot exactly reflect the real system; at best they are a good approximation of it. The formula to validate the model is as below:

$$\text{MAPE} = \sum \frac{|\text{Xm} - \text{Xd}|}{\text{Xd}} \text{x } 100\%$$

$$\text{Xm} = \text{data of simulation result}$$

$$\text{Xd} = \text{actual data}$$

Table 5.1 MAPE Percentage and Analysis

MAPE Percentage	Analysis
MAPE<5%	Very accurate
5<MAPE<10%	Accurate
MAPE>10%	Not accurate

Source: R. Abdoel Djamali (2018)

5.3 FINDINGS

The data-driven from simulation tool developed from managerial and operational concerns. In particular, ED administrators was interested to know how many staffs should be dedicated to different treatment areas, and how ED system would perform with arising in patient volumes using current resources. As a benchmark, base scenario was simulated in which resources and patient volumes were set at current levels. Human resource were subject to schedules which varied by the time of day. Results from the DES model reveal that average of 3230 patients visit the ED per week, which is indication of high variability patient volume to ED. Theory of Constraints (TOC) was first used to identify the constraints in the ED treatments and process. Prior to the output results from simulation, we first compare the base case, using 2016 data, against performance metrics within the emergency department for the same period. The results of this comparison are found in Table 5.2.

	Base model	Scenario 1 (increase triaged Green Zone by 20%)		Scenario 2 (increase triaged Yellow Zone by 20%)		Scenario 3 (increase triaged Red Zone by 20%)	
		Mean	CI	Mean	CI	Mean	CI
Mean wait time for primary triaged Green (minute)	2.5	3.30	[3.07-3.93]	3.72	[3.54-.20]	4.13	[3.82-4.95]
Mean wait time for secondary triaged Green (minute)	20.20	34.92	[24.76-45.62]	41.05	[30.54-50.65]	47.14	[40.64-54.92]
Mean treatment time for triaged Green (minute)	58.16	70.91	[65.07-73.87]	71.12	[68.45-80.34]	71.64.	[60.86-81.12]
Average length of stay in Green Zone (minute)	110.59	116.65	[112.13-124.11]	133.24	[113.52-150.76]	155.48	[126.28-184.56]
Mean wait time for triaged Yellow (minute)	4.5	5.45	[4.25-6.75]	8.76	[4.84-15.45]	9.28	[5.64-15.86]
Mean treatment time for triaged Yellow (minute)	113.26	132.12	[113.51-150.73]	110.78	[98.78-128.36]	136.78	[112.51-148.37]
Average length of stay in Yellow Zone (minute)	136.33	158.38	[126.43-183.65]	138.25	[126.38-154.44]	154.46	[122.89-184.96]

Table 5.2 Comparison of waiting times, treatment times and length of stay

From the discussion with ED administrators, this study used what-if analysis to test three scenarios by increased 20% the patients' attendances to the ED. The average waiting time to be seen by the doctors is presented as average treatment time for both Green Zone and Yellow Zone and also considered the up-triage process. As expected, for Scenario 1, by increase number of attendances to ED to 20%, average treatment time and average length of stay for non-critical (Green zone) patients is increase more than 50%. From the scenario, it also shows that average waiting time for secondary triage that give impact to the average waiting time to be seen also has increased.

In Scenario 2, due to the number of attendance increase by 20%, there is an obvious difference compare to the Green Zone patients. Both of the average waiting time for triage (bedside registration) and average waiting time for treatment increase along with the average length of stay in Yellow Zone. From both Scenario 1 and Scenario 2, it shows the higher comparison values compared to the base model.

For Scenario 3, with the increase of 20% number of patients, it clearly shows that when the numbers of patients in Red Zone increase, the average waiting time for both Green Zone and Yellow Zone is increase along with their average length of stay in ED by more than 130%. This happened due to the factors that the doctors and others staffs need to treat severe zone and do resuscitation process that took about more than half an hour per session.

With regards to output results, Table 5.3 represents for resource utilization, medical assistance score the highest utilization exceeds of 70%. The higher in utilization proved the administration's claim that they do not have sufficient medical assistant and they usually the busiest resources to assist the doctors in treatment process and also for others ED operation. Meanwhile, for the secondary triage phase, the waiting area becomes busier which was 70% from the normal time when the number of Green Zone triage and up-triage to Yellow Zone is increased.

Table 5.3. Resource Utilization in ED

	Original simulation output	Scenario 1 (increase triaged Green Zone by 20%)	Scenario 2 (increase triaged Yellow Zone by 20%)	Scenario 3 (increase triaged Red Zone by 20%)
Doctor	56%	62%	66%	68%
Medical Assistant	71%	73%	77%	75%
Nurse	45%	48%	51%	53%
Secondary Triage waiting area	70%	78%	76%	77%

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 Introduction

This chapter concludes on a summary of the research by presenting the work and how the three objectives have been achieved. This chapter also presents the contribution of this research especially to the ED in Malaysia general hospital. The study also highlighted on the future recommendations to further enrich the analysis as well the strengthen the findings for more comprehensive suggestion.

6.2 Summary

This study discussed on simulation study of an emergency department in general hospital. The developed model enhances administration understanding of treatment process that leads to EDOC by imbalance limited resources to the demands for healthcare services. The model is used to identify the bottleneck in the ED system by maintaining the existing resource capacity. The bottleneck detection of ED operations provides a direction for improvement of healthcare system. Using the proposed simulation model, ED administrators can have better understanding on the patient experience, process performances and also the staffing functions and relationships. The result shows that, by increase the number of patients to ED, the treatment process time and the staff utilization will also increase. The increment in the staff utilization leads to the heavy workload and became as the major influence on patient waiting time and also interrupts the treatment process in ED.

6.3 Discussion on findings

The analysis started up with the development of the ED model before the validation and verification process by using ARENA software in order to respond to the first objective. The model was then tested using the what if analysis. Three scenarios were tested to see the effect and impact for each decision proposed. As a result, it was found that by an increment of 20% patients at a time, the average treatment time and the length 0f stay for each patient in both green and yellow zone increased up to 50% - 130%. In fact, the scenarios tested proved the indications that there should be an increased numbers of resources in ED. The highest utilization of resources for the scenarios tested came from the medical assistance which represent more than 70% utilization. High utilization of resources may lead to inefficiency and this should not happen as it will affect the work performance. As people in the hospital deals with human lives, error should be avoided, therefore focus should be more and all patients should be carefully attentive.

Also, the increased numbers of patients led to not increased of waiting and treatment time in the green zone but also the yellow zone where this zone is a semi-critical zone and needs a fast response action from the ED staff. With the current resources, it is impossible to improve their service performance and therefore resources and facilities provided in the ED should be improved.

6.4 Contributions of study

Indeed, there have been many studies involving the ED using simulation but, their study focused only on some part of the zone. Although this study is hindered by the limited amount of data, but the impact of this is huge because it involves both analysis on the waiting time as well as the resource utilization focusing on 2 main zones. In addition, the contribution of this study also involves bridging the gap in the literature, if the previous studies only focus on certain zone/part, but this study demonstrated the ability to analysis both zones and strengthen the analysis

6.5 Recommendation on future work

As some elements and data could not be captured throughout this study, therefore, as future work, more additions will be made in this A&E department; where the use of resources will be considered and always maintained the same level of care can also be taken into account. In addition, more units should be introduced and simulated in the proposed model in the future. In addition, integration with the optimization tool, OptQuest, should be done to achieve the optimal solution.

In addition, more comprehensive and robust models and analysis must be carried out for future work taking into account other relevant data such as computer systems and facility maintenance into the model. Moreover, by adding more parameters, firm model and holistic analysis can be implemented to provide better recommendations based on what is test or scenario analysis.

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