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Conference Paper · October 2016

DOI: 10.1063/1.4966085

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Citation: AIP Conference Proceedings **1782**, 040018 (2016); doi: 10.1063/1.4966085
View online: http://dx.doi.org/10.1063/1.4966085
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1782?ver=pdfcov
Published by the AIP Publishing

Modelling an Outpatient Unit in a Clinical Health Centre Using Discrete Event Simulation

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Abstract. This paper describes a project paper of a simulation modelling course. It presents the potential of computer simulation in modelling the current performance of an outpatient department of a clinical health centre in a rural area. The model was run using Arena student version 14.5. From the 60 replication length run, the obtained result shows that the patient's waiting time is 26.4 minutes, which is lesser than the established standard waiting time of 30 minutes.

INTRODUCTION

Waiting time is one of main indicator of quality assurance in health care industry. Patients always hope that they do not have to wait long and get a faster treatment when they reach a hospital or clinic. In the National Health Service (NHS) of the United Kingdom, waiting time has become the main concern among the public [1]. While in Malaysia, the government had organized The Tenth Malaysian Plan where one out of four initiatives to be addressed is on improving the quality, capacity and coverage in health system. Under this policy, the Ministry of Health (MOH) had started practising Lean Health Care system, which is a structured way of continuously exposing and solving problems to eliminate waste in systems that deliver value to customers. MOH also had released the Guidelines for the Management of Time Monitoring Waiting at Hospital Outpatient Department and Clinics Health in 2013. Throughout the guidelines, waiting time is defined from the time customers get a queue number to the time they entered the consulting room for examination. In order to monitor the waiting time, a web-form application has been introduced by the Division Information Technology, MOH to enable data collection run efficiently.

The web-form application allows constant monitoring and performance evaluation of hospitals and clinics in the country. Although, there is a statistical weekly report extracted from the web-form application to monitor the achievement, there is still a need to evaluate the outcome and impact of this new implementation by looking at the system as a whole. A question arises that either this new implemented system can achieve the established standard waiting time and compliment with the system itself. To evaluate the performance of the system directly during operations is quite difficult because it may affect patient care and create other problems with the system. Therefore, an effective tool that is able to capture the real environment of the health care processes is required. A possible tool to

The 4th International Conference on Quantitative Sciences and Its Applications (ICOQSIA 2016)
AIP Conf. Proc. 1782, 040018-1–040018-8; doi: 10.1063/1.4966085
Published by AIP Publishing. 978-0-7354-1444-0/$30.00

study the operational processes involved in a health care system and experimenting alternative decisions without directly affecting patient care is by using simulation modelling [2]. In order to determine the current performance of the system, a simulation model of a case study outpatient unit in a clinical centre is developed.

The remaining sections in this paper are structured as follows. The next section provides reviews of the related works. This is then followed by a brief explanation on the proposed model, which includes system description, data collection, model conceptualization and model development. Next, the analysis and some brief discussion on the obtained results are presented. Finally the conclusion discusses the achievement and limitations of the study as well as some suggestions for possible future work.

RELATED WORKS

The increased demand for health care and outpatient clinics has inspired many researchers to investigate the enhancement of health care services [3]. Many Operations Research (OR) techniques have been developed to better understand the underlying problems since 50 years ago to resolve outpatient clinic dissatisfaction [4]. These techniques include the queuing theory, mathematical programming, modelling and simulation. Taking into consideration of the advantages of simulation, many researchers have been using OR methods to solve problems in healthcare domains. There are many studies conducted using simulation approaches to improve the efficiency of health services in many areas including clinical simulation, operational simulation, managerial simulation and educational simulation which can be applied in primary care, hospitals, and chronic care [5]. In health care simulation modelling, managerial and operational directions are closely interrelated as they are the core components of healthcare process management. Therefore, numerous studies had been done regarding these two areas with waiting time become one of the topics being focused by the researchers and health care management [5].

Basically, there are three most common factors leading to long waiting time observed such as high patient load, few doctors and record clerks in clinic [6]. For instance, at General Outpatient Department of a Tertiary Health Institution in North Western Nigeria, more than half of the patients waited for more than 1 hours, with high patient load coupled with few doctors and nurses being the main causes of this long waiting time. Therefore, waiting and treatment time are usually regarded as important determinants of patient satisfaction and service quality. Waiting times for elective care have been considered as a serious problem in many healthcare systems since it acts as a barrier to efficient patient flows [7].

Similar observations were made in Malaysia where four major elements were found to cause long waiting time, namely human resources, availability of equipment, registration process and too many patients [8, 9]. In simulation and modelling, the queuing theory is used to understand and improve operations such as waiting time or queuing [4]. Frequently, many patients had chosen private health care providers because of the high quality of services provided. In addition, most of them want to avoid congestion and long waiting times which occurred in most public health care [10]. Thus, health care providers need training on the various ways by which waiting time can be reduced such as the application of computer simulation models to assist in allotting appointment time to patients and distribution system to sort out patients with urgent need of attention. Besides, reducing outpatients waiting time is not only valuable for patients, but also helpful to decrease the hospital workload.

[11] conducted a case study in the Jitra Health Centre and proposed a simulation model of the out-patient flow during one week's observation. The study focuses on determining the bottleneck factor of outpatient at the Health Centre, and the effect of numbers of doctors and patient's arrival pattern on the waiting time. While in 2014, [12] proposed a discrete-event simulation model to improve the service time in Gambang clinic whereby she focused on reducing the waiting and service time by handling the number of staff in the clinic. In addition, [3] develop a simulation-based decision support system conducted for the evaluation and optimization of scheduling rules in the Obstetrics and Gynecology Department at King Abdulaziz University Hospital, Jeddah, Saudi Arabia. In order to construct the simulation-based decision support system, three appointment scenarios had been proposed and examined in comparison with the current situation to determine suitable prioritization rules. From the literature review, it has been shown that simulation has been progressively applied in health care domains and therefore in our study, we developed a DES model to determine the current performance of a case study outpatient unit in a rural clinical centre.

THE PROPOSED MODEL

System description

The clinic under study is operating five days a week from Sunday to Thursday. It provides a range of specialties and subspecialties, healthcare services and treatment for the outpatient. All treatment services provided at this clinic start at 8.00 a.m. until 5.00 p.m. with an hour break at 1.00 p.m. till 2.00 p.m. During the break, the clinic is still operating, where the staffs such as doctors will alternately take turns to have a rest. However, the registration counter is closed for one hour on the break and if new patients arrive, they need to wait for the registration counter to re-open. Instead, if there is an emergency case, it will be sent directly to the emergency department.

The process flow in the clinic begins with patient arrival. All arriving patients need to be registered at the registration counter. Here the patients are identified according to their zone of residence laid down by the clinic management and the queue number is given based on their zone. The clinic management has divided the patient population into three zones. The zoning system was introduced in February 2016 as a continuously planned towards introducing "family doctor" system in the primary health care sector. A "family doctor" system means that patients in each zone are treated by fixed doctors, who are able to treat either new or old patients and discover health issues by zone. After registration, patients wait to be called for treatment in the waiting area. Zone A and B, each have a greater number of population and thus is allocated with three rooms for consultation and treatment. On the other hand, Zone C with less population is allocated with only two rooms (Table 1). Fixed doctors will carry out the treatment and decide whether a patient needs a follow-up treatment or allowed to go home without further treatment. If the doctor issues an appropriate list of prescriptions, patients may obtain the medicine from the pharmacist unit before leaving.

TABLE 1. Allocated room for each zone

Zones	Rooms
Zone A	Room 1
	Room 2
Zone B	Room 5
	Room 6
	Room 7
Zone C	Room 8
	Room 9
	Room 10

Data collection

In this study, the data was collected over a period of one week; five days of the working day. The data mainly consists of patient arrival times, patient registration times, calling for treatment times, initial and end of treatment times, drug prescription times and patient discharge times. Table 2 shows the number of observations for each of the five days.

TABLE 2. Number of observations collected for each processing time

Day	Number of observations
Sunday	250
Monday	258
Tuesday	114
Wednesday	256
Thursday	121
Total observations	999

Arena input analyser was used to fit the appropriate distribution to the collected data. The distribution summary of interarrival times for registration, treatment rooms, pharmacy and waiting time for pharmacy is presented in Table 3.

TABLE 3. Distribution summary of Arena input analyser

Data set input interarrival	Distribution	Expression
Arrival analysis input analyzer	Exponential	EXPO(0.303)
Registration input analyzer	Weibull	WEIB(1.17, 0.398)
zone A_room 1 input analyzer	Lognormal	LOGN(80, 848)
zone A_room 2 input analyzer	Beta	BETA(0.45, 2.38)
zone B_room 5 input analyzer	Weibull	WEIB(14.2, 0.811)
zone B_room 6 input analyzer	Weibull	WEIB(6.9, 0.414)
zone B_room 7 input analyzer	Weibull	WEIB(20.4, 0.679)
zone C_room 8 input analyzer	Weibull	WEIB(7.37, 0.403)
zone C_room 9 input analyzer	Beta	BETA(0.368, 1.38)
zone C_room 10 input analyzer	Beta	BETA(0.366, 2.11)
pharmacy waiting time input analyzer	Lognormal	LOGN(18.7, 62.3)
pharmacy input analyzer	Weibull	WEIB(1.34, 0.339)

Model conceptualization

In order to develop the simulation model, it is important to begin with the model conceptualization. The conceptual model in this study is based on the patient process flow as depicted in Figure 1. The same process shall be replicated and conceived using ARENA later in the model development, which included three important decision points namely zone allocation, room decision and pharmacy drug prescription.

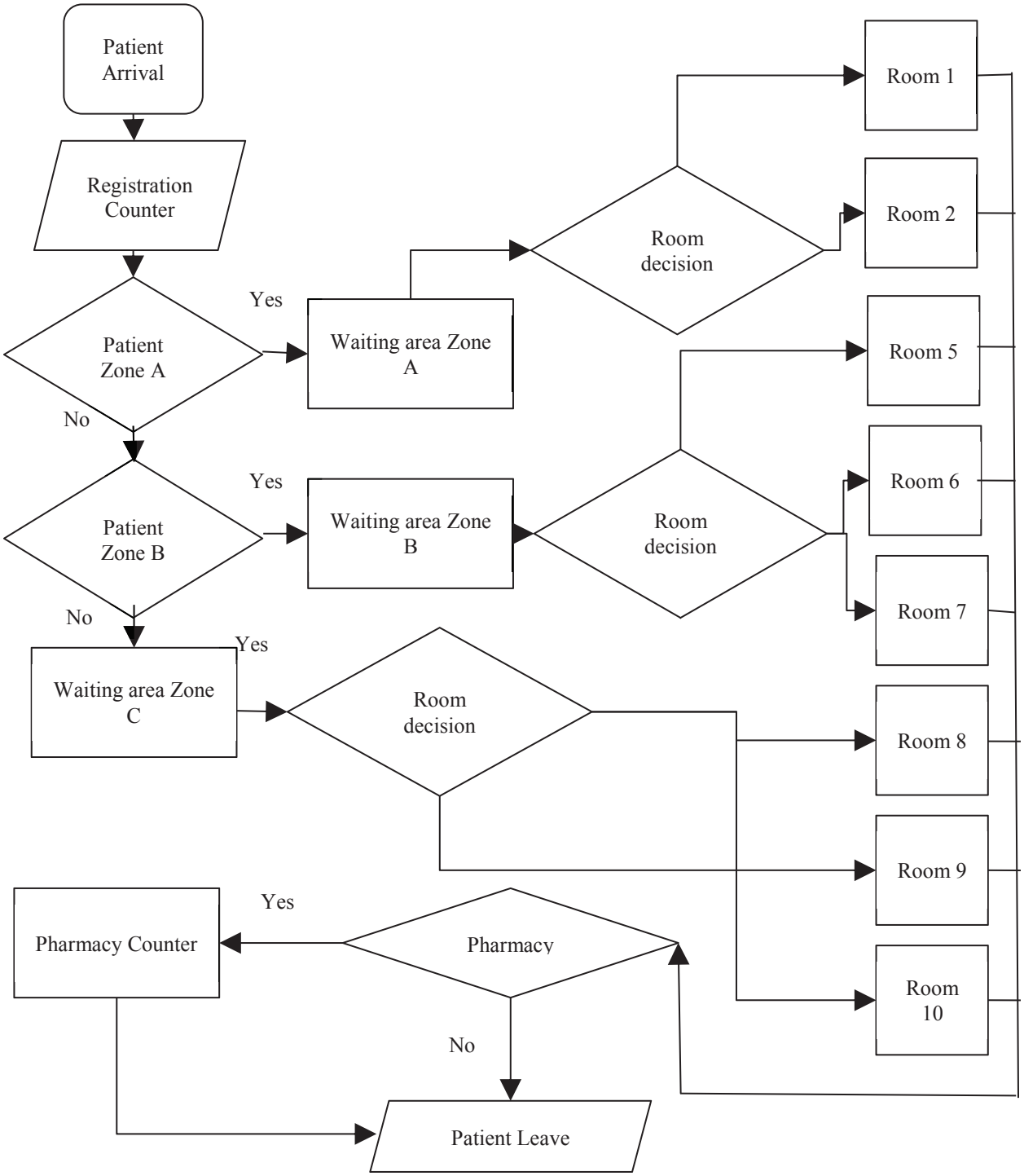

FIGURE 1. The process flow

Model development

There are a few structured approaches in simulation modelling, proposed by previous modellers, which in general have common elements [13-15]. A similar approach has been applied in this simulation study, which involves the following steps:

1. Problem Formulation
2. Model Conceptualization
3. Data Collection and Input Analysis
4. Model Development
5. Verification and Validation
6. Output Analysis

The clinic model in this study is developed using Arena Simulation Software version 14.5. Six models and three sub-models have been developed to represent the actual system. Figure 2 and Figure 3 display the model representation and logic build of a models and its sub-model. The structural components of the discrete event simulation model of the clinic service system include:

i. Model entities: Patients
ii. Model activities: A serial of activities for patients treatment
iii. Model resources: Service providers such as nurses and doctor
iv. Model layout: Service departments, locations and areas.

Several assumptions have also been made in building the model:

i. The model is only considered to be run started from 0800 until 1700 five times a week. Patients that arrived out of the operation hours are excluded.
ii. The model utilized all the treatment rooms available in the clinic throughout the operation hours.

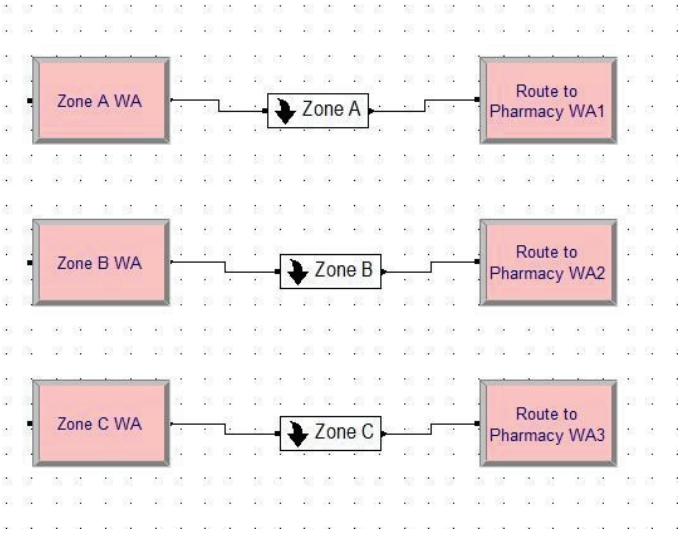

FIGURE 2. The waiting area model

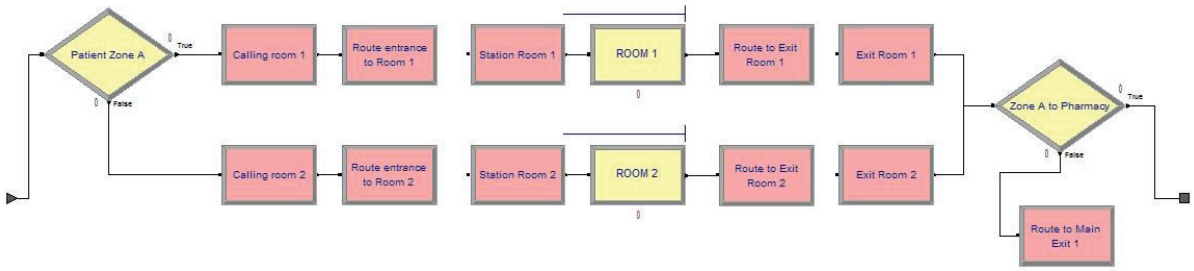

FIGURE 3. A sub-model of Zone A

RESULTS AND DISCUSSION

The pattern of patients flow from the system can be observed through the distribution of the data set itself, where the output of Arena Input Analyzer had indicated that most of the data set of interarrival time were best fitted as a Weibull type of distribution. The distribution of the data set shown that most of patients' arrival at the clinic was during the morning session and decreasing in the evening. The simulation model was analysed using 1, 60 and 540 minutes replication length. Due to the software limitation as this model was not created using a commercial license of Arena, the simulation model was unable to give an output for the run setup because the model had exceeded the entity's limit. There is a runtime error detected at time 66.6 minutes. Therefore, we can only use result that is based on the 60 replication length run set up. The result shows that the waiting time obtained is 26.4 minutes, which is lesser than the guideline stated by the ministry of 30 minutes (Table 4).

TABLE 4. Output summary of the simulation model

Replication length (in minute)	Number of Patient arrival	Number of Finished Patient	Total Processing Time (in minute)
1	4	1	4
60	178	42	56.9
540	No output	No output	No output

CONCLUSION

This study is currently in a preliminary stage and thus much more works are needed to construct the complete outpatient simulation model. Further development of the model should include the entire flow from end to end so that the model will represent the whole system of outpatient unit in the clinic. For instance, in this case study the model should include the patient decision of either to go or not to go to the appointment counter. The model should also include the utilization of the resources. Though it is going to be very complicated, but the reward will definitely be worth it. In order to do so, instead of using Arena student version, the developed model needs to be run using a licensing Arena simulation software license to allow real scale representation of the system with large number of entities and real operation time. Due to the limitation of the software used in this study, the analysis of result lacks of all impacts from the uncertainties and variables of the system performance.

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