Using Simulation to Examine the Respond Time Taken by Medical Responder during Radiological and Nuclear Emergency

Azurah A. Samah, Hairudin Abdul Majid and Lau Kee Wah
Faculty of Computing
University of Technology Malaysia
Johor, Malaysia

Abstract

This paper describes on the development and application of Discrete Event Simulation (DES) model to examine the medical response procedures to Radiation and Nuclear Event (RN). In this paper, a graphical simulation model based on discrete event simulation modeling is developed using AnyLogic software to visualize the detection procedures and the decontamination processes. Structural and operational elements of the simulation model were described in this paper to assist the understanding of the simulation model. This study followed by input modeling of the simulation model. System performances of the simulation model in terms of waiting time and capacity planning is included in the paper. The purpose of this research is to contribute the management of radiation and nuclear emergency by simulating and analyzing the detection and treatment for contaminated patients in achieving a secured nuclear safety environment in Malaysia.

Keywords
Discrete event simulation, nuclear emergency response, hospital emergency department, medical flow, waiting time.

1. Introduction
Malaysia is looking forward to develop nuclear energy. Thus, there are some risk perception issues including the safety guarantee and assurance and sufficiency of safety policy aspect. In the development of nuclear energy, the safety issue is a very important element. Therefore, when radiation and nuclear event happened, the initial diagnosis time for medical treatment unit become very important to ensure patients to have their treatment as soon as possible(Amy Hamijah binti AB. Hamid 2011, Amy Hamijah binti Ab Hamid 2011, Michael E Rea 2010). Therefore, there is a need to develop a simulation model to help medical management in the capacity planning. This paper describes the development of a simulation mode by using Discrete Event System (DES). Description of the entity, logic flow, layout of the model, nodes in the model, input analysis and preliminary result are presented in this paper

2. Literature Review
Simulation is a tool that can be used to experiment behavior of a system(Jerry Banks 2010, Razana Alwee 2007). A simulation model assists people to have a better understanding about a system. In order to handle the radiation treatment screening system, different approach can be applied into a model to compare the values and find a better solution.

Decision support systems (DSS) are rapidly gaining recognition and appreciation in service industries. Long an integral component efficient manufacturing systems, practitioners and researchers have only in recent years seriously applied their craft to service settings. And only in recent years, have some service industries been receptive to the potential efficiencies that decision support system provided. One service industry that has led others in recognizing the benefits offered by DSS is the health care industry. For over 20 years, decision support systems have played an important role in creating patient satisfaction, insuring a quality service encounter and optimizing operational practices. This has been accomplished by streamlining facility processes; creating more efficient flows of people, materials, equipment and information; and improving productivity metrics in the health care delivery system. Applied simulation efforts have focused attention on the operational process flow of specific health care delivery units. These studies include work on emergency rooms (Blake 1996, Dawson 1994, Draeger 1992, Gracia 1995, Kraitsik 1992, McGuire 1997, Ritondo 1993), outpatient services (Huebner 1996, Iskandar 1991, Kalton 1997, Levy 1989), and capacity modeling(Cohen 1980, Hendershott 1995).

3. Model Development

3.1 Entity

In this simulation model, the entities are object that were observed and studied in the system. In this research the entity is the casualties. The arrived casualties proceed to different services (stations) based on the probability of different injuries type. Previous study found that, patient with higher severity (life threatening) of an accident was around 5% and patient with injures was 20%(Joshi 2008). In this model, the traumatic type injuries combine with the radiological affection. The model was based on the life threatening condition and non-life threatening condition attached with the contaminated status. Table 1 shows the injuries type involved in an accident and table 2 shows the probability of injuries.

Table 1: Injuries Type

Condition	**Radiological affection**	**Contaminated type**
Life threatening	Contaminated	Internal
Life Threatening	Contaminated	External
Life Threatening	Not contaminated	-
Injuries	Contaminated	Internal
Injuries	Contaminated	External
Injuries	Not Contaminated	-
No Injuries	Contaminated	Internal
No Injuries	Contaminated	External
No Injuries	Not Contaminated	-

Table 2: Injuries Type Distribution

Injuries	**Distribution**
Life threatening	5%
Injuries	20%
Contaminated	1% (50% is internal contamination and 50% is external contamination)

3.2 Medical Handling Flow

The medical handling flow of this simulation model is based on flows outlined in the “Hospital Kuala Lumpur Emergency Plan” and “Triage, Monitoring and Treatment Handbook”. A medical respond will establish an onsite medical treatment respond area which includes a normal treatment area and a radiological treatment area(Carlos Rojas-Palma 2009, Dr. Hjh. Zaininah bt Mohd Zain 2011). Normal treatment area receive patient who is not contaminated. Patient who involved with external exposure and injuries are treated in the normal treatment area. In contrast contaminated patient or suspected contaminated patient cannot be treated in normal treatment area because the contamination might spread in the normal treatment area. In order to avoid the spread of hazard, a special care treatment area needed to be established. Therefore, contaminated patient needed to be treated in radiological treatment area.

When a patient arrived, medical personnel will identify the injuries level of the patient. If the patient involved with life-threatening issue, he will be given treatment immediately to stabilize the patient. Because of the patient does not proceed with radiological screening and have not determined whether he is contaminated or not, so in this stage, medical personnel must consider the patient was contaminated. Radiation safety procedure should be applied in this stage and screening is given during the treatment. After that, patient must transfer to hospital by ambulance. When arrive at hospital, the patient must inform the medical personnel in hospital and take suitable safety procedure especially for detected contaminated patient. Decontamination is given to patient in hospital after his life was stable.

For non-life-threatening case, patient will first proceed to a radiological screening. Uncontaminated patient will be treated at normal treatment area and contaminated patient will be treated in radiological treatment area. Patient with injuries will receive triage treatment at radiological before receive the decontamination process. Patient who does not have any injuries will directly receive decontamination. A final monitoring will be given to patient after contamination, for who cannot be decontaminated will consider as internal contamination. Patient who suspected internal contaminated will transfer to hospital and receive inpatient treatment care. The medical handling flow of the simulation as describe above is visualized in Figure 1.

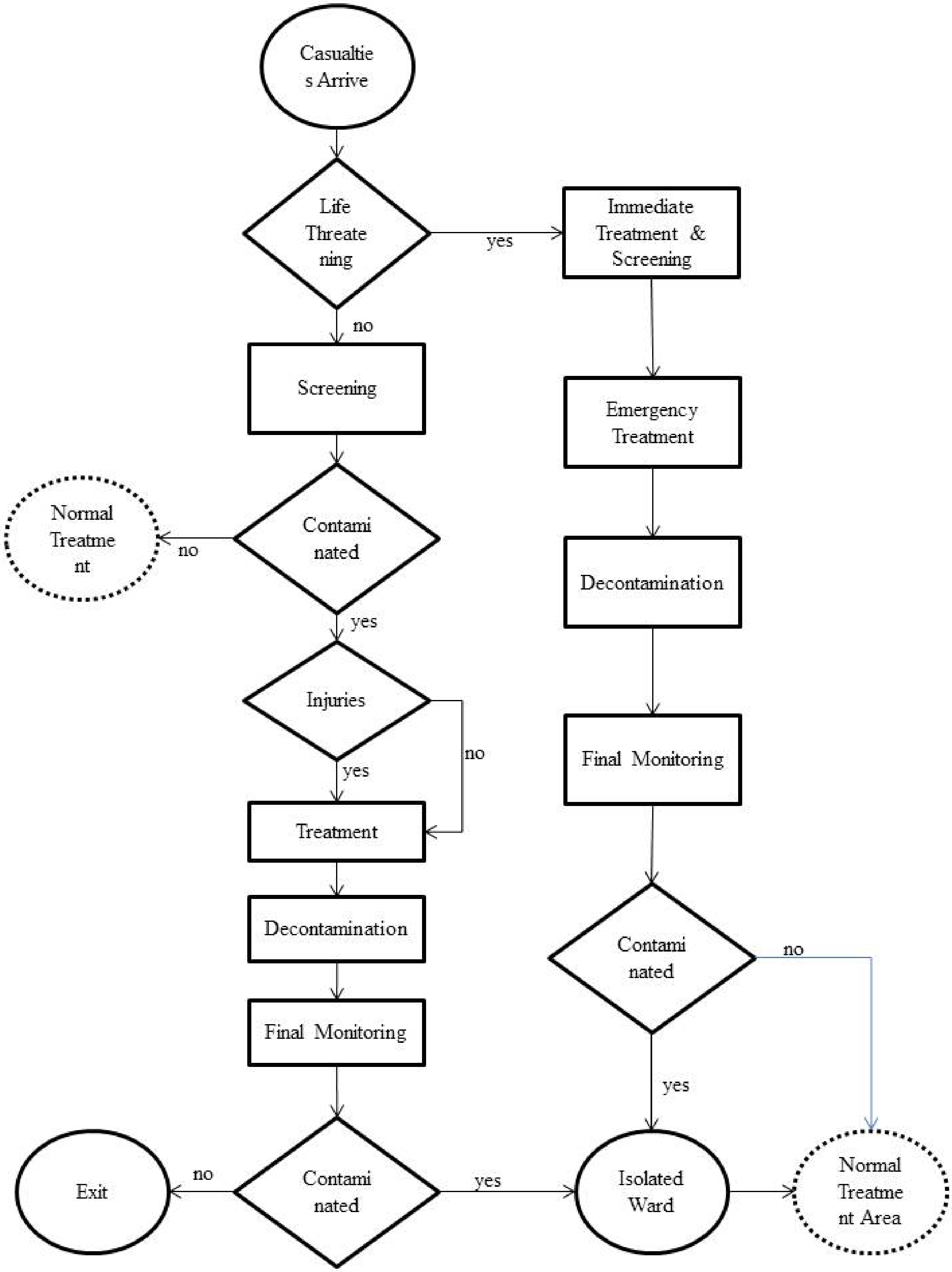

Figure 1: Medical Response Process

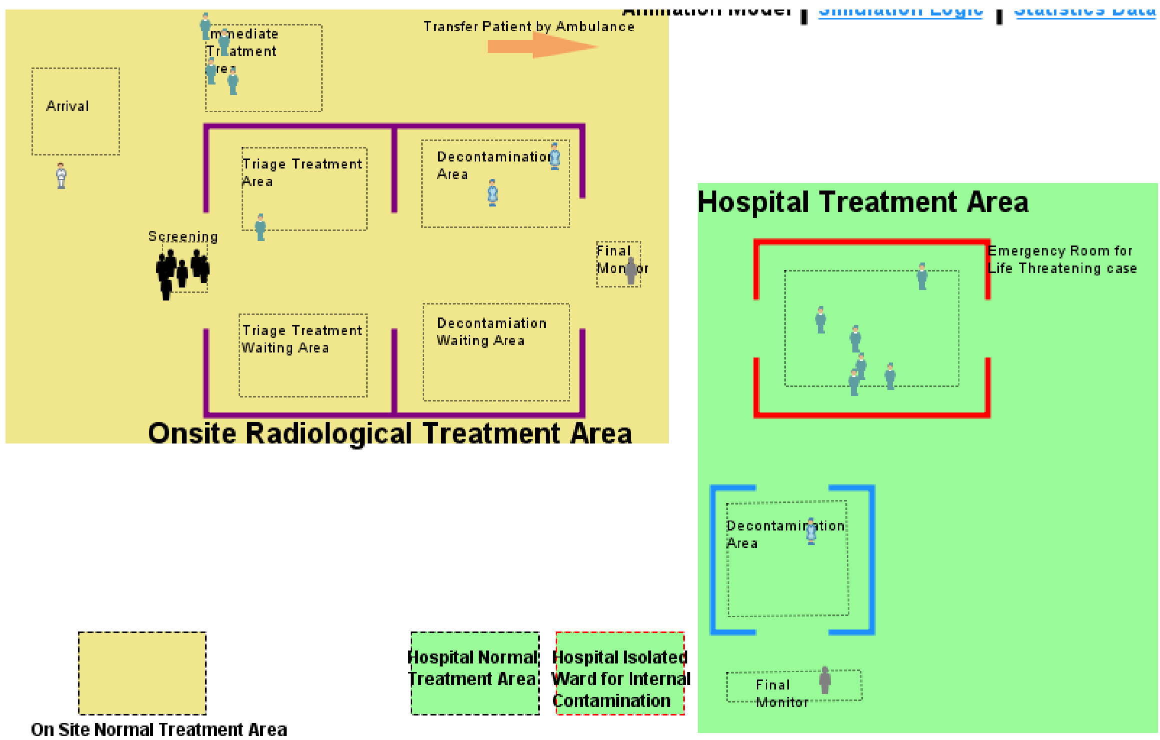

Figure 2: Simulation Model Layout

3.3 Treatment stations in the simulation Model

In this simulation model, the medical respond processes are separated in 2 areas, onsite and offsite. Each service's capacity was assume to have enough man power and resources to handle. For the onsite area, the first process involved is the Radiological Screening. It is the first service to handle the arrived casualties. Radiological Screening will proceeds the screening and identify whether the casualties was contaminated or uncontaminated. The second service is the Trauma Triage. It provides the initial treatment or medium and low severity physical injuries. After Trauma Injuries, contaminated patients will go to Decontamination service to precede the decontamination process. Finally, casualties will pass through the final monitoring service. Life threatening casualties will receive Immediate Treatment service near the Ambulance without proceed to the Screening service. Screening can be done during the immediate treatment. After that, the casualty will be sent to isolated emergency room in hospital, which is the offsite area. The offsite area is an isolated emergency area to avoid the contamination harming the normal treatment's environment. After the casualty receives the emergency treatment, they will proceed to offsite decontamination process. Finally the casualty will receive the final monitoring service. Table 3 shows the estimated service time for each node and its maximum waiting time.

Screening is the first station to determine contamination of patient. Screening process require survey meters. Basically, before doing the screening of patient, the personnel need to get the background reading. Patients who receive more than 3 times count was considered as contaminated. Then the personnel will label the contaminated area to prevent the contamination spread. The contaminated patients will then move into the isolated decontamination treatment area. The time that used to perform screening was 1 second for each 1 cm^2. Therefore, to estimate the screening time, the collected data from MANS about the average Malaysian population's height and weight(Mirnaline K 2008) was used to calculated the average surface of Malaysian body. By implement with the Mosteller formula(Johan Verbraecken 2006), the average body surface was calculated based on Body Surface Area (BSA) in m^2 = [(height(cm) x weight(kg)) / 3600]$^{0.5}$. Result shows as below:

Table 3 Average Malaysia height and weight

Height	Weight	Surface
159.6cm	58.3kg	160.76cm^2

$$BSA\ (cm^2) = 100\ X \sqrt{\frac{(159.6\ X\ 58.3)}{3600}} = 160.76\,cm^2 \quad (1)$$

$$Decontamintation\ time\ (minute) = \frac{160.76\ X\ 1}{60} = 2.67\ minutes$$

Hence, the estimate minimum time for screening a patient is 2.67 minutes. In order to consider there are few situations might require patient to remove their cloth for screening and label contamination area, the maximum time of the screening was estimated at 5 minutes per patient. The service time of screening was set to triangular distribution at value 2.67 for minimum and 5 for maximum. The procedure of final monitoring service is the same with the screening procedure, so the time of final monitoring was set to equivalent with screening service. The Decontamination was set to triangular (15, 30). Based on previous study, the emergency room mostly require 15 to 120 minutes(Joshi 2008) to stabilize a patient, with a mean of 60 minutes. The travel time is set based on assumption where the travel time from onsite to hospital is around 25 to 40 minutes. The travel time was established as input parameter to allow the changes. Each service in the model was indicated to a waiting time number as constraint. This constraint is able to determine the appropriate amount of capacities of each service maximum waiting for each station was constructed based on data collected and discussion with expertise in radiological and nuclear handling team. The service time and waiting time are shown in Table 4.

Table 4: Approximated services time and maximum waiting time

Nodes	Estimated time	Maximum Waiting time
Onsite Screening	Triangular (2.67, 5)	2 minutes
Trauma Triage	Triangular (15, 30, 60)	5 minutes
Onsite Decontamination	Triangular (15, 60)	10 minutes
Onsite Final monitoring	Triangular (2.67, 5)	2 minutes
Immediate treatment	Triangular (15, 30)	5 minutes
Ambulance	Triangular (25, 40)	10 minutes
Emergency Treatment	Triangular (15, 60, 120)	10 minutes
Offsite Decontamination	Triangular (15, 30)	10 minutes
Offsite Final monitoring	Triangular (2.67, 5)	2 minutes

The medical treatment process flow was translated into AnyLogic software. Each Node was assigned with its services time distribution as mentioned in Table 3.

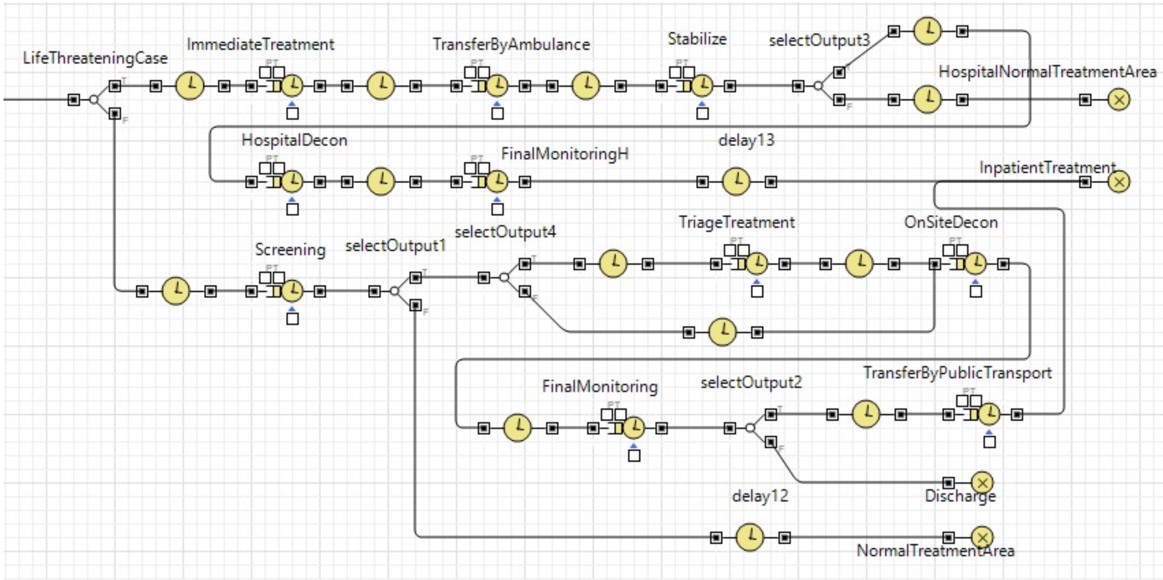

Figure 3: Modeling Logic Flow

4. Arrival Pattern

The simulation model assumes that arrival of patient is one at a time. In a disaster, patient arrivals are highly dynamic, and the arrival rate of patient's changes continuously from time to time. In this simulation model, the arrival rate with gamma distribution (2, 1) was randomly chosen to represent the arrival pattern of the initial model.

5. Verification and Validation of the Simulation Model

The objective of verification is to ensure the concept of the established simulation model can represent the actual situation. The verification has been made once the model was established. The verification was conducted based on the layout of the model, the location of each services, time and distance between onsite and offsite, the animation of the model and the service time of each service in the model. The simulation model was verified and validated by expertise from Nuclear Agency Malaysia

Table 5: Preliminary Results

	Onsite Screening	**Trauma Triage**	**Onsite Decontamination**	**Onsite Final Monitor**	**Immediate Treatment**	**Ambulance**	**Emergency Treatment**	**Offsite Decontamination**	**Offsite Final Monitor**
Capacity (units)	6	1	2	1	4	4	6	1	1
Maximum Waiting Time (minutes)	2	5	10	2	5	10	10	10	2
Z Test	-0.24	-7.07	-804.89	-138.88	-9.85	-0.31	1.52	0	0
Accept?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

During a mass accident, many patients needed to be screened. Therefore, the screening capacity plays an important role. From the experiment, we found that to handle 1,000 patients require 6 screening capacity to minimize the screening waiting time that meet the waiting time limitation. In mass casualties' accident, screening service is the bottleneck service for overall medical care process. The waiting time of screening service affected the time patient receive treatment, therefore, the screening service must able to give provide enough capacity to handle arrived patients. These suggestions of capacities contribute to similar emergency level. To ensure the nuclear and radiological safety, the emergency level contains the possibility of the contamination should be study in future to identify the appropriate contamination level with its emergency level. Also, these results help in the model validation and provide the initial guideline for future development of the model.

6. Conclusion

Simulation is an excellent tool to model different types of environments. Simulation proves to be powerful and effective to for emergency preparedness and disaster planning. Traditionally, planning for mass casualty is typically based upon the lessons learnt from previous disasters' experience and drill. However, not until the disaster strikes the capability of the plans developed from this exercise is realized. Computer simulation allows the response plan to be run under different scenarios and is a useful tool in planning the allocation and utilization of the resources. It allowed the planners to analyze a wide variety of different scenarios without involving much of time and money. The arrival rate was a very important factor to determine the resources of the medical respond in an accident. Unfortunately, the arrival rate for a radiological and nuclear accident did not exist and it is a dynamic factor that hard to predict accurately. This alternative simulation shows the screening service and immediate treatment were the bottleneck service in the model, hence, it capacity should highly concern during an accident to respond to the arrival rate. This is because the screening service is the first service provided during the medical respond process. It directly affected by the arrival rate in the simulation.

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Biography

Azurah A Samah is a senior lecturer in Faculty of Computing, University of Technology Malaysia. She received Dip and B.Sc. degree in Computer Science from University of Technology Malaysia in 1991and 1993 respectively. In 1996, she obtained her M.Sc. in Operational Research from the University of Southampton, UK and recently in 2010, she received her PhD in Operations Management from Salford University, UK. Dr Azurah has involved in various simulation project with Vehicle Inspection Company of Malaysia, Malaysian Institute for Nuclear Technology Research (MINT) and Ministry of Health Malaysia. Her research interests encompass Operational and Simulation Modelling, Soft computing Techniques and Scheduling

Hairudin Abdul Majid is a lecturer in Faculty of Computing, University of Technology Malaysia. He received Dip and B.Sc. degree in Computer Science from University of Technology Malaysia in 1993 and 1995 respectively. In 1998, he obtained his M.Sc. in Operational Research from the University of Salford, UK. He has involved in many projects with Malaysia Truck and Buses (MTB) Bhd , Vehicle Inspection Company of Malaysia, Malaysia Institute for Nuclear Technology Research (MINT) and Ministry of Health Malaysia. His research interests focused on Operations Management, Warranty and Maintenance and Soft Computing Methods.

LAU KEE WAH is currently furthering his studies in M.Sc in Computer Science specialising in Operational Business Intelligence, Universiti Teknologi Malaysia. Recently, he is interested in the research field of simulation programming and development in healthcare.