A FUZZY LOGIC APPROACH IN MODELLING AND SIMULATION OF A SCHEDULING SYSTEM FOR HOSPITAL ADMISSIONS USING ARENA SIMULATION SOFTWARE

NURUL ATIQAH BINTI MAT AYOB

ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITY TEKNOLOGI PETRONAS
JUNE 2010

A FUZZY LOGIC APPROACH IN MODELLING AND SIMULATION OF A SCHEDULING SYSTEM FOR HOSPITAL ADMISSIONS USING ARENA® SIMULATION SOFTWARE

by

NURUL ATIQAH MAT AYUS

DISSERTATION

Submitted to the Electrical & Electronics Engineering Program
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

A FUZZY LOGIC APPROACH IN MODELLING AND SIMULATION OF A SCHEDULING SYSTEM FOR HOSPITAL ADMISSIONS USING ARENA® SIMULATION SOFTWARE

by

Nurul Atiqah Mat Ayus

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

Approved:

(Assoc. Prof. Dr. Nordin Saad)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURUL ATIQAH MAT AYUS (8292)

ABSTRACT

This report basically discusses the research done and basic understanding of the chosen topic, which is on *A Fuzzy Logic Approach in Modeling and Simulation of a Scheduling System for Hospital Admissions Using ARENA® simulation software*. The aim of this project is to develop a simulation model of a scheduling system based on practical situation implemented on *ARENA® simulation software*. Besides, this project also seeks to incorporate Fuzzy Logic Control in decision making processes. This project mainly focuses to develop a model of a scheduling system for admission of hospital Emergency Department (ED) using *ARENA® simulation software*. It manipulates the sequence patient's flow for admissions to the hospital. The specific steps that need to be accomplished for demonstrating the technical feasibility of the model is to develop a hospital simulation model and integrate Fuzzy Logic admission control approach in *ARENA® simulation software*. The procedures include data gathering, model building, simulation, verification, and validation and performance analysis. Data and observation of the real process has been obtained through research at collaborated health care centre, Hospital Seri Manjung. The data is based on the backlog of patients' admission and patient flow pattern. The models depend on inputs from data collected and fitted to Visual Basic for Application (VBA) to for Fuzzy Logic Control. The output can be viewed by animation in *ARENA® simulation software*. The output of the simulation is generated in a form of report which summarizes all replications.

ACKNOWLEDGEMENT

First and foremost, praise Allah the Almighty who has helped and gave me courage and strength in completing the Final Year Project (FYP). Without His permission, this FYP will not be a success

I would like to take this opportunity to express my deepest gratitude to all parties involved in conducting this project ranging from UTP lecturers, technician and graduate assistant to external organizations who have put a large effort in making this project a success.

I am very grateful to my supervisor Dr. Nordin Saad who has guided me to handle this project. The compliment should also go to all Electrical and Electronics lecturers and technician for bundles of information and assistance in completing this project.

I would also like to give special thanks to my parents and classmates for giving continuous support and motivation throughout completing this project. Last but not least, many thanks to others that have one way or another contributed to accomplishment of this project.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of study

ARENA® simulation software is one the most effective and user friendly method in protecting business by predicting the impact of new ideas, rules, and strategies before actual implementation – offline, without causing disruptions in service. Poorly planned implementations can have disastrous effects, resulting in frustrated customers, lost business, and sinking profits.

In today's highly competitive healthcare market, hospitals management is experiencing a business-oriented challenge as they are now facing increasing competition for their services. Thus, they are being driven to both cut costs and provide quality healthcare. Hospitals worldwide have made different attempts to re-organize patient flow logistics in an effort to develop a patient-centered model, which is a more efficient and integrated system. These redesign efforts are intended to eliminate inefficiencies contributed by hospital services.

The need to simulate and revamp the scheduling process to allow hospital administration to explore various options and scenarios are crucial. An alternative scheduling system of hospital admission has a huge impact on hospital performance in general. The effectiveness and efficiency patient flow is indicated by high patient throughput, low patient waiting times, while maintaining adequate staff utilization rates. Here, adequate patient care and service guarantee can be ensured by applying a proper prioritization rule.

1.2 Problem statement

1.2.1 Problem identification

As for health care centre, every year cost continuous to increase to serve the best treatment for patients which keeps boosting daily. Thus, initiatives must be taken to improve the operational efficiency and cost effectiveness of the admission process. In most organization, all improvement and development made for the systems are usually implemented directly and simulation approach is rarely being applied. This is a manual analysis which actually consume a lot of time and cost plus it is highly exposed to the probability of the idea might not work out anyhow.

Compared with the human brain, computers are well suited to making rapid calculations and recalling large numbers of facts, permitting the creation of decision networks that support near limitless complexity [16]. Thus, an optimal way to overcome these situations is by opting animated ARENA® simulation software to represent patient flow based on flow pattern identified from sequence of patient admissions and discharges.

In order to achieve a competence patient flow of hospital admission, manipulating patients and staffs are very important. However, for some situations, the variable nature of human characteristics makes it difficult, even impossible, to decide exactly what should be done in some set of circumstances. We cannot really control of how many patients would turn up each day, total time taken to treat each patients, tor even the competency of staffs in handling a case. Thus, this would involve some intuitive decision making which is usually described as being poorly suited to computerization or simulation.

This can be overcome by applying the methods of Fuzzy Logic Control (FLC), suited to this kind of endeavour and can lead to algorithms since FLC capable to handle decision making which is complex and based on ambiguous decision.

With that, author has taken an action to develop a model of a scheduling system for hospital admission (specifically at Emergency Department (ED)) using ARENA® simulation software plus combining the Fuzzy Logic Control approach in some decision making situation. It is expected that the simulation model be able to simulate the scheduling system for ED admission to improve the efficiency of the system.

1.2.2 Significant of the project

The ARENA® simulation software product is the most ideal tool for predictive analysis applications that provides more alternatives without costing experimenting the real system [1]. For this project, the major value is the manual method of changes or improvement in system can be replaced by software which provides easiness and assist to increase the efficiency in simpler way in less time.

The problem focused on manipulating the staffing and prioritizing the patients' admission according to the seriousness of the case to achieve low patients' waiting time, high staff or resource utilization and low staffing cost. Here, ARENA® simulation software will be integrated with Visual Basic for Application (VBA) to implement the Fuzzy Logic Control for decision making situation.

1.3 Objective and scope of study

The main objective for this project is to overcome the problem faced by both patients and management of health care center, specifically Emergency Department. In order to fulfill the objective, a simulated system based on practical situation needs to be developed through ARENA® simulation software. Then, author manipulate the situation by varying the patients' flow and utilization of staff to come out with several alternatives that capable to improve the real practical situation of the scheduling system in the Emergency Department. The relevant performances measured from the simulation analysis results will be used to identify the best alternative that will be implemented to resort the problem faced in the admission system.

The general objectives for this project would be to:

a) Design model of scheduling system for hospital admission.
b) Simulate the model of scheduling system for hospital admission.
c) Analyze and suggest the most favorable modification in performance measures of scheduling system for hospital admission.
d) Incorporate Fuzzy Logic Control in decision making processes.

The scope of this research has been narrowed down to minimize delay on patients' waiting times, prioritizing cases according to the seriousness of the patient's condition, enhance staffs utilization and to minimize the staffing cost. The developed system is provided with ability to enable any possible changes to be made. As to make the simulation more realistic and practical, Fuzzy Logic Control is being integrated in decision making processes to perform a reliable, mathematical-based priority and multiple queue selection. Additional application used to realize the FLC is the Visual Basic for Application (VBA) software which is then will be used to Fuzzy Logic concept that involves fuzzification, inference, defuzzification and to apply Fuzzy Logic rules in table form.

1.4 The relevancy of the project

Discrete Event Simulation (DES) such as ARENA® is the world's leading simulation software that has been used successfully by organizations all over the world to advance the efficiency and productivity of their business. With ARENA®, changes can still be made repeatedly to model and 'test drive' it before the changes being implemented into the actual system. With Fuzzy Logic approach, it can also prove that the element of control can also be combined with an operation management. As matter of fact, this would boost the reliability of the operation since Fuzzy Logic provides a means for encapsulating the subjective decision making process in an algorithm suitable for computer implementation [16]. Even though, this simulation software is still not widely used in Malaysia, the best first attempt is to implement as much projects and researches so that organizations in Malaysia would be exposed to the benefits.

1.5 Feasibility of the project within the scope and time frame

This project should be completed within two semesters. For the first semester, author is focusing on research and data gathering, mastering the ARENA® simulation software and building base models. In the second semester, the author concerns more on incorporate Fuzzy Logic Control in decision making and analyzing result of simulation.

Being a pioneer of this simulation, the author is confronting with a lot of challenges as this project does consume a lot of time and not many people is skillful in handling this software. Nevertheless, author is exposed to a lot of features and a lot of ideas to be implemented.

Overall, it is hoped in Chapter 1 – Introduction, readers would successfully acquire the ideas of this project (*A Fuzzy Logic Approach in Modelling and Simulation of A Scheduling System for Hospital Admissions Using ARENA® simulation software*) through explanations from sections Background of Study, Problem Identification, Significant of the Project, Objective and Scope of Study, The Relevancy of the Project, Feasibility of the Project Within the Scope and Time Frame.

In the next chapter, Chapter 2 – Literature Review, the concepts involved in this project is explained in details along with description on the operation of Emergency Department at a selected local hospital – Hospital Seri Manjung, Perak.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to modelling and simulation software

In our daily life, there are simply lots of problems which are too complex to be solved via exact mathematical analysis. This might due to the system itself being too compound or perhaps the theory is not yet developed adequately. Besides, too many uncertainties are also almost impossible to handle and this includes weather, traffic jam, and aircraft flight. Nowadays, simulation with computer provides another alternative for laboratory experiments which are usually expensive and time consuming. The analysis process is cheaper and faster and more importantly, efficient [25].

In an increasingly competitive world, simulation has become a very powerful tool for the planning, design, and control of the systems [9]. Simulation is a tool for the evaluation and analysis of a new system design, modifications to existing systems and to propose changes to control systems and operating rules. Simulation itself is divided into about seven parts which are 'discrete distribution', 'continuous distribution', 'probability simulation', 'time dependent versus time independent simulation', 'simulation software', 'visual simulation' and 'object-oriented simulation'. Simulation model has been like a virtual world out of small components.

Modeling and simulation is one of the most powerful analysis tools available to those responsible for the design and operation of complex processes or systems. Instead of experimenting with an actual system, a scaled down model of the system itself is developed to change parts of the model to observe resulting behavior. The importance of simulation are as the following:

a) Planning: Simulation can be said as a proposal which would be handy in assisting new system by layout how, when and what needed to be done.

b) Decision making: Simulation can be used to provide options or alternatives to generate a new system or improving an existing system.

c) Prediction: Simulation can be used to predict the outcome of a decision and what is going to happen in the situation.

d) Communication: Animation shows a system in simulated operation so that the plan can be visualized.

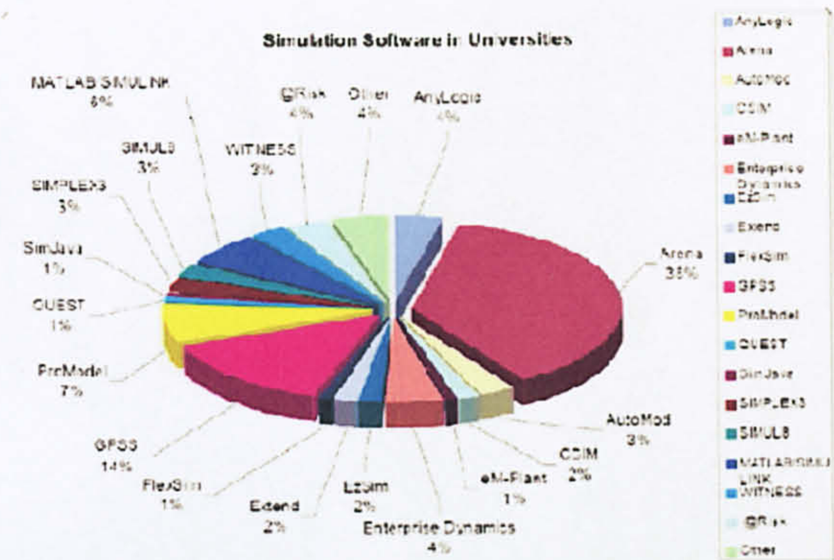


Figure 1: Simulation software in Universities – around the world [20].

With modelling and simulation, one organization can cut cost by building a model than to experiment with real system and may save time since model only have to run for a few minutes or even seconds to simulate the future behaviour of the system over many years. Besides, to model out a dangerous situation, such as a plan to move tsunami victims to safer area, simulation can be very useful. Even for real system which does not exist, simulation may still be used to investigate such systems.

2.2 Modelling and simulation with ARENA® simulation software

Stephen Kropp (2007) points out that inconsistency in development process need to be explored and modelled through Discrete Event Simulation (DES). The dynamic and uncertain nature of the software development process has made simulation a desirable tool for such a purpose. DES uses the object oriented archetype to make designs which helps system analysts make a model without writing a code.

Discrete event simulation software is also known as event based simulation that allows the system's transition to depend on distinct incidents known as events that are sent in one direction. In other words, a system's operation is represented as a sequential progression of events and each event takes place at an instant of time Other applications of discrete event simulation software include, modelling important functions of volunteer computing, for systems which are difficult to be modelled and also make changes in the systems that need to be processed.

As one of operations research technique, Discrete-event simulation (DES) allows the user to evaluate the effectiveness of existing health care delivery systems and to propose a new systems if improvement needed. Besides, DES can also be used to forecast the impact of changes in patient flow, to examine resource needs, and to investigate the complex relationships among the different model variables such as rate of arrivals [5]. With this information, operation managers will be able to select a few management alternatives that can be used to reconstitute the existing systems and thus improving system performance. Designing and planning a new system is also possible with DES without the need to alter the present system.

The proceedings of world's leading conference on discrete event simulation – Winter Simulation Conference (WSC) has verified that ARENA® simulation software is an unquestionable top choice among users of any organization process simulation especially in business. Rockwell ARENA is simulation and automation software acquired by Rockwell Automation and it uses the SIMAN processor and simulation language. SIMAN is an older version of text- orientated simulator. The base modules in ARENA® simulation software hierarchy represent SIMAN language. Despite this project use the drop-in blocks to build model, it is possible as well to use all SIMAN commands and show the graphical model in SIMAN-code.

ARENA® simulation software grows in time by the occurrence of events at possibly standard time intervals. This type of DES is proven to be practically in real-world applications. For instance, the virtual call center, batch process, banking transaction, flexible manufacturing, movie theatre analysis and last but not least healthcare system. Most of these systems can be modeled in terms of discrete events whose occurrence causes system to change from one state to another [21]. For this project, ARENA® simulation software model is built to model and evaluate alternative schedules to increase the operational efficiency and cost effectiveness of health care delivery process.

2.3 Problem analyzing via Animation

Animation is one of the features in ARENA® simulation software that gives it advantage compared to the other DES software. With animation, the correctness of the model can be determined as well as to make the model look like the real system before decision makers are allowed to view it. Here, the status of the resource can be seen during the run and parts can be tracked by looking at the resource. Other than that, statistic such as WIP, production output, resource utilization, entity movements and queue size can also be seen. To make the animation more interesting, image can be assigned to each part in Animation.

Figures below are some examples of the animation based on real-system system that can be built through ARENA® simulation software.

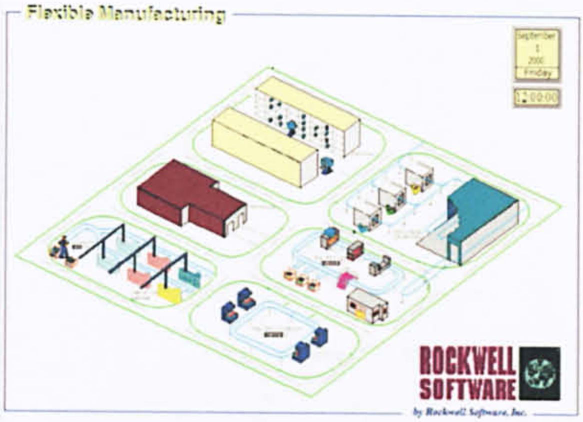


Figure 2: Example in ARENA® simulation software – Flexible Manufacturing.

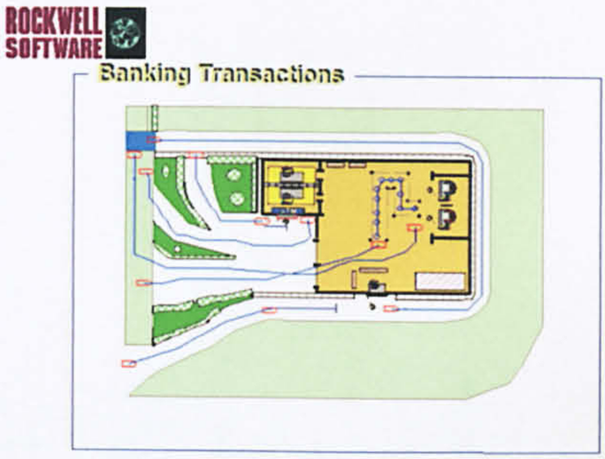


Figure 3: Example in ARENA® simulation software – Banking Transaction.

2.4 Description of Emergency Department (ED) at Hospital Seri Manjung

The healthcare provider in the Emergency Department is responsible to cater the various needs of these patients. ED in each hospital is renowned as the front door where a major number of patients' admissions take place. Here, the health provider plays an important role as a gatekeeper toward delivery of care and patient satisfaction [26].

Emergency Department is the most crucial department in hospital. Function of ED is to stabilize patient neither they need medical, emergency or surgical attention which is totally different from Intensive Care Unit (ICU). Once the patients have been stabilize, they will be warded for further check up before being released. If ED failed to stabilize patients, they will be transferred to Operation Theatre (OT). Patients' flow in ED of Hospital Seri Manjung is shown is Figure 4.

During office hours which are from 7am to 5pm, the situation at ED is under control. However, ED will be flooded with patients and beyond control especially from 5pm to 7am during weekdays and the whole day during weekends. This is because Outpatient Department (OPD) only operates during office hours. Thus, beyond that range of time, outpatient will refer to ED. This situation has increase patients waiting time. The fact that tremendous increase in the number of patients visiting ED has contributed to patient dissatisfaction and this drives the healthcare provider to compete against other organization in serving the best service for patients.

2.4.1 Triage station

Triage is a process of prioritizing patients based on severity of their condition. Medical Assistant (MA) will evaluate the patient's condition and determine the priority by giving them card which indicates the code. Only one MA is being positioned at the triage station for each of the three shifts. The job scopes of MA at triage station are:

1) Handle patient's registration
2) Do triage classification according to code red, yellow or green
3) Provide wheelchair or stretcher for serious patient
4) Call ambulance if patient needed to be transferred to other hospital

There are three codes altogether which is important to set the maximum patients have to wait. Table 1 describes the case that falls into each code.

1) Red code – Life threatening: treated immediately
2) Yellow code – semi critical: maximum 15 minutes
3) Green code – mild sickness: maximum 30 minutes to 1 hour.

Table 1: Code for Triage case.

<table>
<tr><td>RED CODE : Life threatening and unstable cases treated immediately</td><td rowspan="2">• Severe chest pain
• Severe asthma
• Unconscious
• Severe fire - burning
• Road accident
• Seizure
• Poisoning
• Fracture
• Eye – injury
• Severe bleeding
• Paralyzed patient
• Severe pain at any body part
• Confused patient
• Head – injury
• Snake – bite</td></tr>
<tr><td>YELLOW CODE : Serious but stable cases treatment after code red cases</td></tr>
<tr><td>GREEN CODE : Non emergency cases treatment after code red and yellow cases</td><td>• Moderate fever
• Cough and flu
• Minor injury and scratch
• Chronic rashes and allergic
• Chronic pain
• Chronic headache
• Moderate diarrhea
• Moderate vomit
• Moderate bug – bite
• Moderate fire - burning</td></tr>
</table>

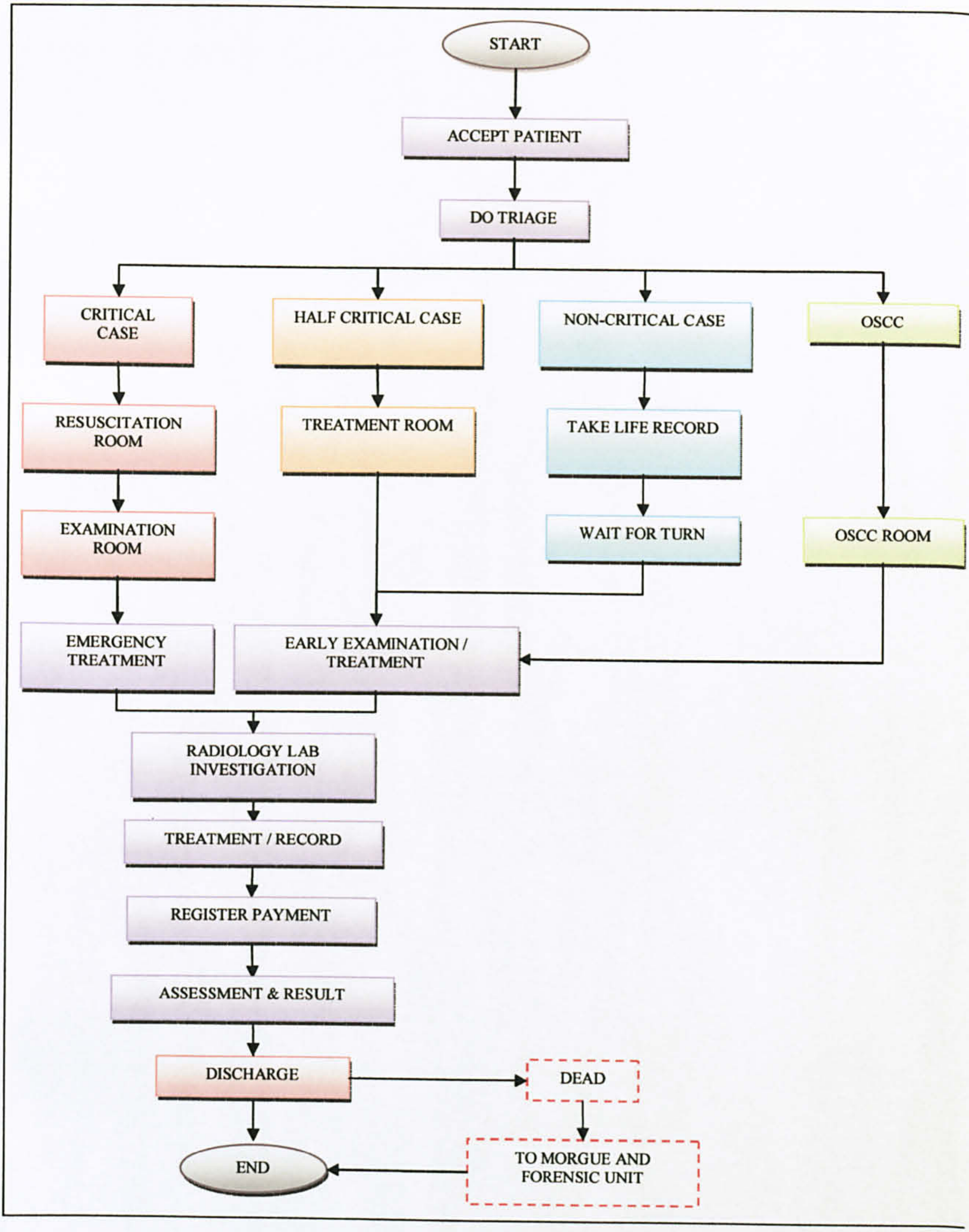
Courtesy of Hospital Seri Manjung, Perak (11th January 2010)

2.4.2 Treatment

At ED, when patients first arrive, an attempt to stabilize patient will be carried out by Trained Nurse and Medical Assistant (Medical Practitioner, Paramedical Staff). Doctors will only be called if patients can't be stabilized.

There are six beds altogether in ED. Supposedly, these beds are for red code's patient only. But due to space limitation, all patients have to share the bed section. If more beds needed, patient will be treated along the pathway.

Outside office hours, doctor from other clinics nearby will be imported to treat the green zone's patient. This would actually help to reduce patient's waiting time and overcome lack of staffs on duty. However, they only attend during peak hours which have been identified on weekends from 10am – 2pm and 6pm – 10pm.



Courtesy of Hospital Seri Manjung, Perak (11th January 2010)

Figure 4: Patient flow in Emergency Department of Hospital Seri Manjung.

2.5 Overview of problems on scheduling system of hospital admissions in Emergency Department (ED)

An efficient and effective timing of operation is very important in scheduling. The criteria of scheduling system are maximizing utilization of resources, minimize cost of staffing and minimize patients' waiting time. Some of scheduling decisions that needs to be considered by healthcare managers are the operating room used, outpatient treatments, maintenance of staff and patient admission which is the focus of this project.

Healthcare organizations must alert to the patients' needs, financially practicable and cost-effective. Today, the significant issue that are getting worse in all Emergency Department (ED) is getting crowded and the rising of healthcare costs. Thus, in order to counter the increment of incoming patients, hospital departments, including emergency rooms, have to re-evaluate their current facilities, procedures and practises from an operations management perspective. In a typical ED, it is important to minimise not only the patient's waiting time but also the staff idle time while maintaining the high utilisation rate of medical facilities and the staff themselves [19]. With that, the computer simulation such as ARENA® simulation software is recognised as a powerful tool, for medical management, to improve productivity and increase the service level to patients.

Once the simulation model is developed and validated for a given hospital, it can be used to design the scheduling system, which consists of various scheduling parameters and decision rules [3]. Decisions concerning resource allocation and redirecting the flow of patients within the hospital have direct influence on the outcome of the patients. A suitable plan and successful scheduling system are essential for the improvement of the total functioning of the hospital [6].

2.5.1 Resource utilization

Besides, an effective staffing plan is important to determine a feasible resource (nurse and doctor) schedule to minimize the average waiting time, while simultaneously reducing the staffing cost [8]. If the arrival of patient per day is low, the amount of resource on duty can be minimized. Meanwhile, if the rate reaches higher than expectation, more resources are needed to serve the purpose of minimizing the patient waiting time.

Resource utilization is important to determine number of patients served by the staff relative to their capacity. All resources need to be fully utilized to ensure tasks are equally distributed and achieved optimum amount of resource utilization. Here, the resource idle time needs to be considered. Idle time would means resource which is not being used, similar to resource utilization. If the resource is not fully utilized, value of the system will degrade by reducing the total throughput and the resource utilization itself.

2.6 Integration of Fuzzy Logic Control (FLC) in ARENA® simulation software

Classical computational models aim to describe numerical calculations and input-output relationship consists of exact rather than vague data [27]. As for systems in which the input-output relationship is defined with uncertainty, the control can only be resolved by human expertise. Human knowledge is important for systems where input determination is done with deliberation of multiple criteria. Today, a lot of healthcare centre that implement fuzzy logic theory have been anticipated by virtue of Fuzzy Logic Control due to their capability of the logic control to assemble human knowledge and expertise and by dealing with uncertainties and complexities.

In many real-time applications, FLC is the most suitable tool to handle admission problems which involve more complex and need to make decision based on multiple conditions. The tool is implemented as a "drop-in" model block that performs admission control. The block can be configured to perform simple or priority-based admission, as well as multiple queue selection (Qisheng Le and Gerald M. Knapp, 2003). The controller performs as a gate, to decide whether a new arrival will be allowed to enter a system or subsystem. This paper will assess the feasibility of using intelligent control techniques such as FLC to integrate information into the decision-making process in ARENA® simulation software.

In order to conduct this study, some decision making situation in the model is implemented based on hypothetical outcome which mimics the real environment of the Emergency Department. The framework is implemented on software which includes Visual Basic, Microsoft Excel and ARENA® simulation software. The generator model with output function and output sets is implemented in the ARENA® simulation software using the Visual Basic programming language and a Microsoft Excel [27]. The language with outputs is created in VBA and Excel using Fuzzy Table of Rule and the data are fed to the ARENA® simulation software package.

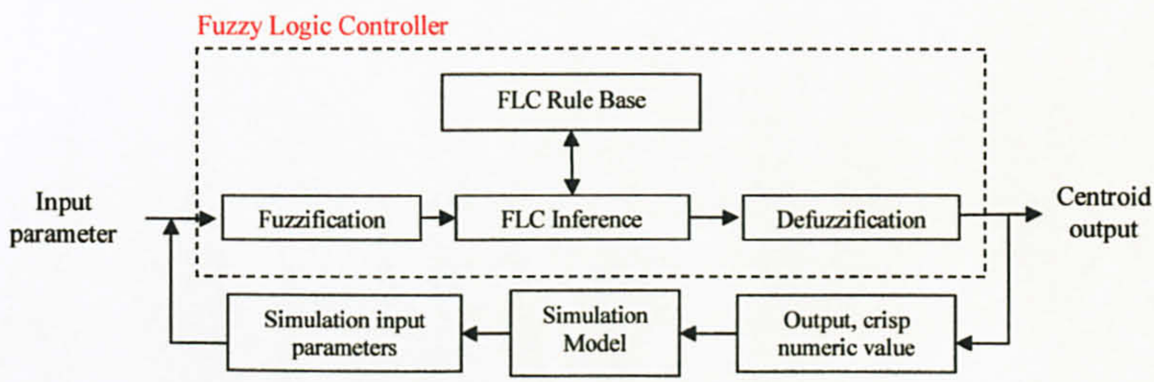


Figure 5: Block diagram of Fuzzy Logic Control

Figure 6 above best describe the flow of FLC. When input parameter such as entity enters the FLC block which is implemented using VBA block in the simulated system, it triggers the FLC decision process. The flow logic of the FLC is as the following:

a) FLC code querying the ARENA® simulation software for input parameters which are Patient Arrival and Type of Patient.

b) Fuzzification: Input parameters are "fuzzified" according to the specified fuzzy linguistic terms and membership functions are defined.

c) Inference: Refer to computational procedure to evaluate the fuzzy rules of form "*if-then*" statement.

d) Defuzzification: Fuzzy set is then "defuzzified" since a crisp control action is required. The FLC block makes a decision to assign the priority number based on result of *centroid computation*.

e) The entity them is routed to the appropriate branch out from Decision Block.

The first block inside the controller is fuzzification, which functions to converts input parameters, which come from entity attributes of ARENA® simulation software, to fuzzy linguistic value according to degrees of membership. The fuzzification block thus compares the input parameters with conditions of the rules to determine the relevance. There is a degree of membership for each linguistic term that applies to that input variable.

Fuzzy rule base is a set of linguistic inference rules that characterize control rules and policies for the system. These fuzzy rules are obtained either from domain experts or by observing the people who are currently doing the control [27]. Fuzzy rule base characterizes the control goals and control policy by means of a set of linguistic control rules. The controller then selects the most desired behaviour.

Basically a linguistic controller can be presented in different formats [12]. Some controller can contain rules in the *If - then* format, *Relational* format while some set of rules could be presented in a tabular linguistic format which is a more compact representation with input variables are laid out along the axes, and the output variable is inside the table [12]. As for this project, *Relational* format is being used and the table is implemented using MS- Excel. *If- then, and* and *or* statements are known as connectives. *If- then* is important is building the linguistic. Meanwhile *and* and *or* is implemented as *min* and *max* respectively in Inference Engine. '*min-max'* inference method is also used to define result of the rule which through output of membership functions that been assigned with the truth value (numerical).

The FLC inference processing is the central part of rule evaluation using Fuzzy Logic Rule, and is expressed by linguistic value. Rules are statements expressing a dependency relation among system inputs and system outputs. Rule evaluation takes the fuzzy inputs (degrees of membership) from fuzzification step and rules from knowledge base and calculates fuzzy outputs. This result in turn will be mapped into a membership function and truth value controlling the output variable.

Table 2: Fuzzy Logic Rule Base

		INPUT1						
		NB	NM	NS	ZE	PS	PM	PB
INPUT 2	N	NB	NB	NM	NS	ZE	PS	PM
	Z	NB	NM	NS	ZE	PS	PM	PB
	P	NM	NS	ZE	PS	PM	PB	PB

In this simulation study, desirability values are mapped to five different fuzzy sets: *large negative, small negative, zero, small positive and large positive.* After defining fuzzy sets of performance measures, fuzzy sets of desirability values are determined.

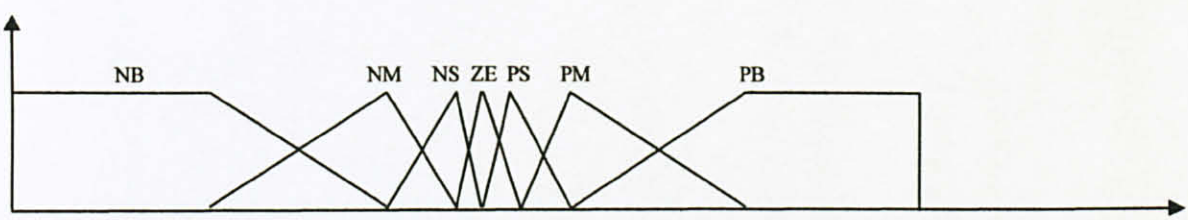


Figure 6: Input 1 Membership Function

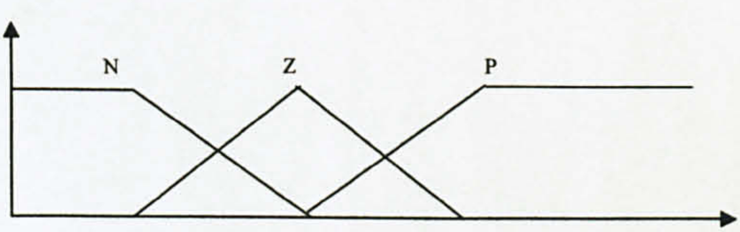


Figure 7: Input 2 Membership Function

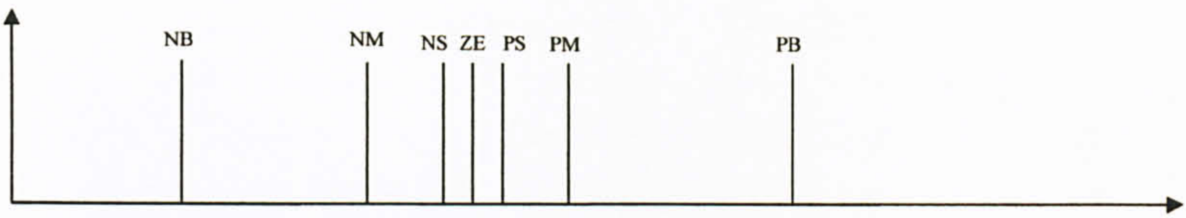


Figure 8: Output Membership Function

Membership function essentially embodies all fuzziness for a particular fuzzy set; its description is the essence of a fuzzy property or operation [11]. Some may use the membership function in defining the input parameter states. There are many ways to assign membership values or functions to fuzzy variables and this assignment process can be intuitive or it can be algorithmic or logical operation. Figure 7, 8 and 9 describe the *Intuition* method. The important character of these curves for purpose of use in fuzzy operation is the fact that they overlap [11].

Once fuzzy rule bases are defined for different scenarios, defuzzification technique takes place to obtain crisp values of the desirability values. This 'crisp' numeric value will used as control input to system in ARENA® simulation software. In this project, *fuzzy centroid* method is used to generate a single value from the fuzzy sets. This method can be formulated as:

$$centroid\ computation = \frac{\sum_{j=1}^{p} c_j m_b(c_j)}{\sum_{j=1}^{p} m_b(c_j)}$$

where c_j is the centroid of the *j*th fuzzy set, m_b are the weights of the fuzzy set *B*, and *p* is the total number of fuzzy set.

The numeric output value from FLC, which is result from *centroid computation*, is assign as variable named *Priority*. This variable will indicate the priority that should be assigned to each type of patient synch with total number of patients' arrival.

Model 1 and 2 are simulation models without a fuzzy rule base since the focus of these models are on verifying the reliability of opting ARENA simulation approach, by implement the real data into model. In Model 3, fuzzy control rules are first developed based on the selected performance measures. A fuzzy rule base is then created using these rules and integrated to the blocks. The effectiveness of fuzzy rule base is proven in *Chapter 4, Result and Discussion*.

Overall, in Chapter 2 – Literature Review, author has explained on the Theory of ARENA® simulation software, Scheduling System of Hospital Admission, Description of Operation for Emergency Department (ED) at Hospital Seri Manjung and Fuzzy Logic Control.

Next chapter, Methodology will explain the sequence of tasks and tools.

CHAPTER 3

METHODOLOGY

3.1 Procedure identification

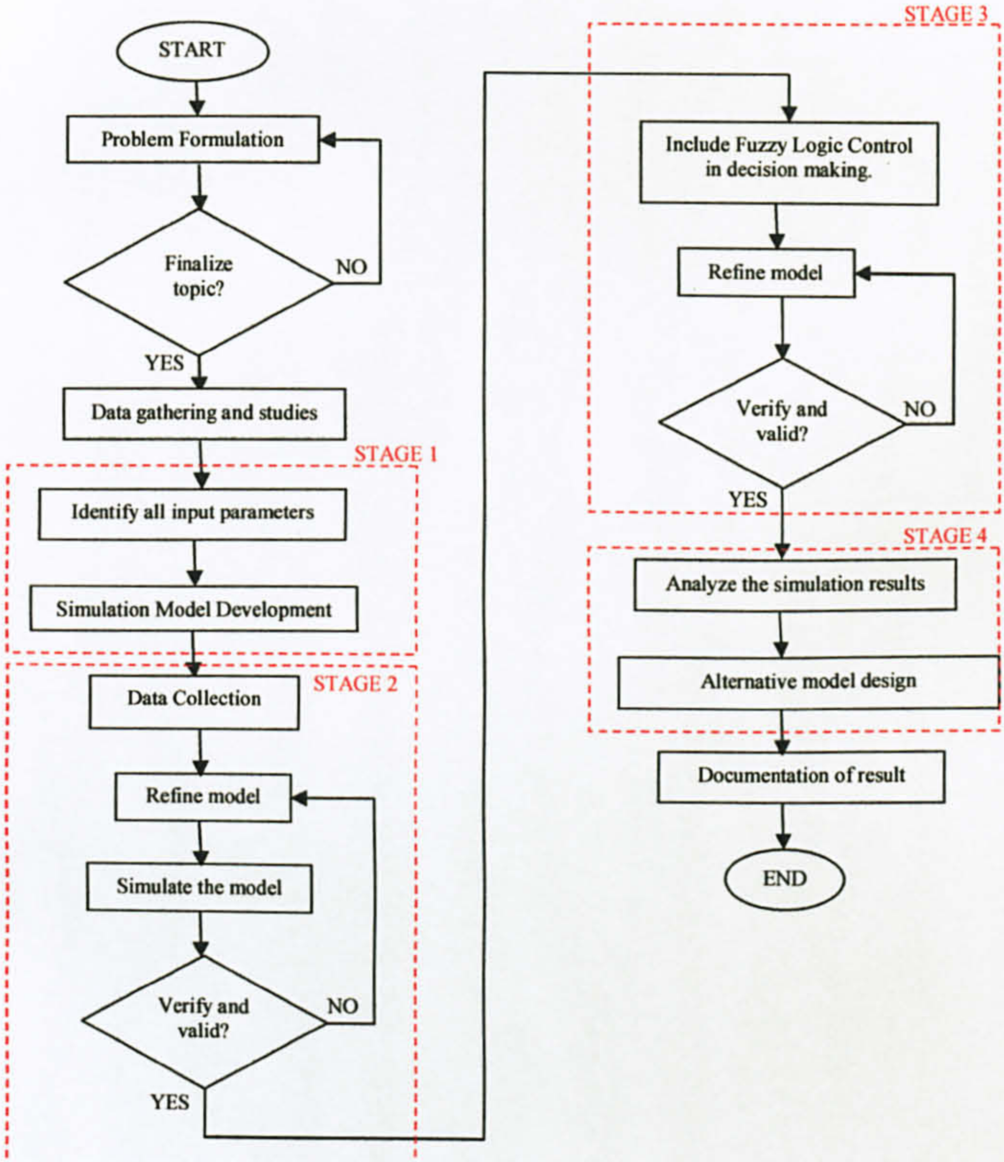


Figure 9: Project flow chart

Simulation of a model requires a sequence of methodology. The purpose is to understand the behavior of the system and to evaluate strategies for the operation. Figure 10 defines the flow chart of this project.

3.1.1 Problem formulation

Generally, problem formulation is the need to define measure of system performance and objective function. A preliminary model structure is developed to interrelate the inputs and measure of performance. Initially, author needs to identify a suitable hospital which capable to provide the scheduling system of the patients admission. This is important because some hospitals refuse to undertake this project due to two issues which are data security purpose and did not believe in simulation method. Finally, a general hospital, Hospital Seri Manjung, Perak, is chosen to be data provider and some research has been conducted there. In this project, only one department is focused, Emergency Department (ED), since trying to solve other departments along would only make the simulation more complicated and less reliable. For the early stage and based on interview carried out, some of the common problems occur in the scheduling system of ED admission are:

a) Patients often suffering from extremely long waiting time to be treated.

b) Some unserious patients such as outpatient and minor injury patient also refer to ED which would cause interruption in treating other more serious patients such as life threatening case.

c) There are also cases such as staffs on duty are not fully utilized. This would cause loss in profit since the organization is paying for those who did not perform their tasks.

In order to determine the feasible improvements to counter these problems, a list of possible improvements need to be identified first since it would be easier to relate when it comes to verification and validation procedure.

Some actions that need to be taken are:

a) Minimize the entities WIP – minimize patient's waiting time
b) Maximize resource utilization – maximize utilization of nurse, doctor, bed, administration officer and triage nurse
c) Minimize number of staff – minimize the hiring of nurse, doctor, administration officer and triage nurse

3.1.2 Simulation model development

As a beginner, it is important to create an understanding of the basic idea whether on the flow of process or the main chronology. Thus, before the simulated model is being constructed, a few basic models of scheduling system for hospital admission have to be designed. ARENA® simulation software is equipped with a few templates which are divided into three:

a) Basic Process Template
b) Advanced Process Template
c) Advanced Transfer Template

These templates are important to proceed with mapping process. Some of the modules in the templates correspond to the element modules, thus every characteristic of the system must be defined precisely to obtain a matching modules. Figure 11, Figure 12, and Figure 13 below shows the examples of templates in ARENA® simulation software.

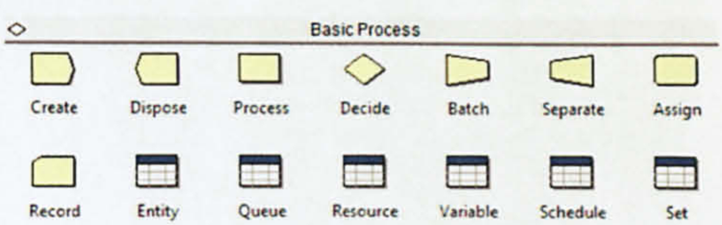


Figure 10: Basic Process Templates.

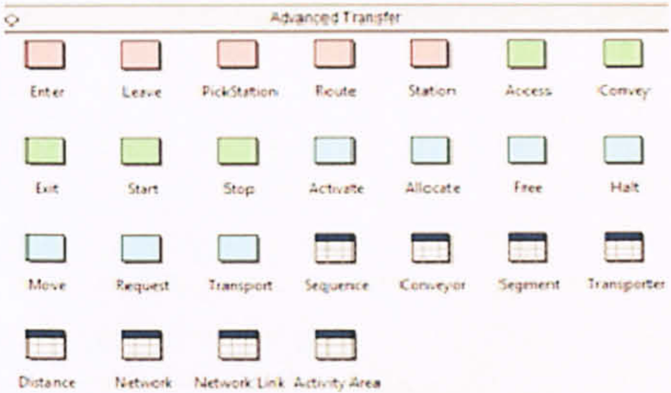


Figure 11: Advanced Transfer Templates.

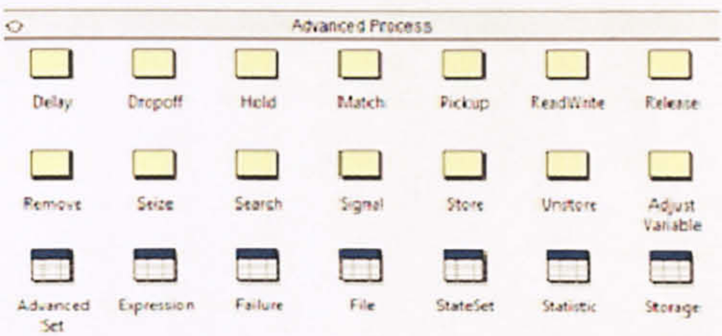


Figure 12: Advanced Process Templates.

In this project, author has divided the major stations of the scheduling system of Emergency Department admission using ARENA® simulation software into six areas which are

a) Entrance
b) Triage Station (consist of Triage Nurse)
c) Admission Station (consist of Admin Staff)
d) Bed Station (Consist of Bed, Nurse and Doctor)
e) Vehicle Out.

3.1.3 Data collection - Conduct research at Hospital Seri Manjung, Perak

Most of the data were extracted from documents such as backlog of patients' arrival, but some, for instance the common data is given verbally by staff of Emergency Department (ED) such as nurse, doctor and medical assistant. These data are necessary to perform analysis of existing scheduling system of ED admission. However due to confidentiality, the data is not presented in its original version. It is regenerated in order to conceal the confidential information.

During semester break for July 2009, author has conducted a research at Hospital Seri Manjung. The purpose of the research is to understand in depth and correctly the flow of patients in ER of a hospital. This visit has added quite a bit of time to the project because approvals need to be obtained from various organizations in order to preserve the confidentiality of the data. The copy of the approval letters are as attached in Appendix I, II and III.

On 5th January 2010, author visited Jabatan Kesihatan Negeri Perak (JKN) and had been referred to Timbalan Pengarah Kesihatan Negeri (Perubatan), Dr. Hj. Ahmad Nordin bin Mohd Jais. The purpose of this first visit is to obtain Approval Letter from JKN. During a visit at Jabatan Kesihatan Negeri Perak (JKN), Dr. Ahmad Nordin; Timbalan Pengarah Kesihatan Negeri (Perubatan), requested to have a discussion on the reliability of opting either human or computer in solving the patient waiting times issue. Dr. Ahmad Nordin gave two proposals for this project:

1) Focus on one department only, preferably Emergency Room (ER). This is because flow of work at all departments are different and it would be more complicated if I wish to combine them in one project.
2) State an assumption in this project that that all resources have same pattern of behaviour though the fact is that each human are individualistic and have different characteristic.

On 11th January 2010, an official research had been conducted at Hospital Seri Manjung specifically at Emergency Department (ED). One of the Medical Assistant (U36), Mr. Mohamad Zaki Shafie was assigned to guide author throughout research at ED. At Hospital Seri Manjung,

3.1.4 Model runs and output analysis

At this stage, simulation is expected to be able to carry the correct statistical analysis which would bring the accurate and precise statements. Analysis is implemented to track any missing data. Trial and error method is also done to figure out any error for any parts of process to be corrected.

3.1.5 Verification and validation

In general, verification means focusing on internal consistency of model. Verification will checks the implementation of the simulation program with the models built. Meanwhile validation concerns with the correspondence between the model and reality either the process simulated correctly with respect to real system.

In term of IEEE Standard Glossary of Software Engineering Terminology, verification is defined as "process of evaluating system or component to determine whether the products of a given development phase satisfy the conditions imposed at the start of the phase" [22]. Meanwhile validation is defined as "process of evaluating a system or component during or at the end of the development process to determine whether is satisfies specified requirements" [23].

When simulation is run and the model is successfully matched with real system, user can determine any problems via animation such as resource utilization and work-in-process (WIP). A sequence of summary report known as Crystal Report is generated by ARENA® simulation software based on common decision.

3.1.6 Alternative model design

Here, model is to be changed to get the most satisfied result. Three models are built and simulated with each represent different parameters characteristic.

a) Model 1 depicts the actual data obtained from research at Emergency Department of Hospital Seri Manjung such as the number of patients' arrival, number of staff on duty and approximate distribution time taken at each station. Here, type of patients is divided into three which are red, yellow and green.

b) Model 2 represents the improvement made based on Model 1 such as reducing the number of idle resource to cut down the cost and increase staff utilization. This model also divides the type of patients into five categories which are outpatient, stable patient, minimal injury patient, minimal accident patient, and life threatening patients.

c) Model 3 combines Model 2 with Fuzzy Logic Control (FLC) to improve the ambiguity of decision making involves in the modelling.

3.1.7 Documentation of result

Generating repots is a part of a communication medium between the simulated model and analyst. As for ARENA® simulation software, a recorded statistic in form of Crystal Report is automatically produced where is covers all statistic which summarizes all replications executed according to sections. The sections are key performance indicators, activity area, conveyor, entity, process, queue, resource, transporters, station and user specified. Mainly, the crystal report gives great insight on process performance and behavior. From it, analysts can make prediction and then improve on the weakness by spotting the inefficiencies of the system from the statistic generated by viewing at various sections or aspects [24].

3.2 Project Activities

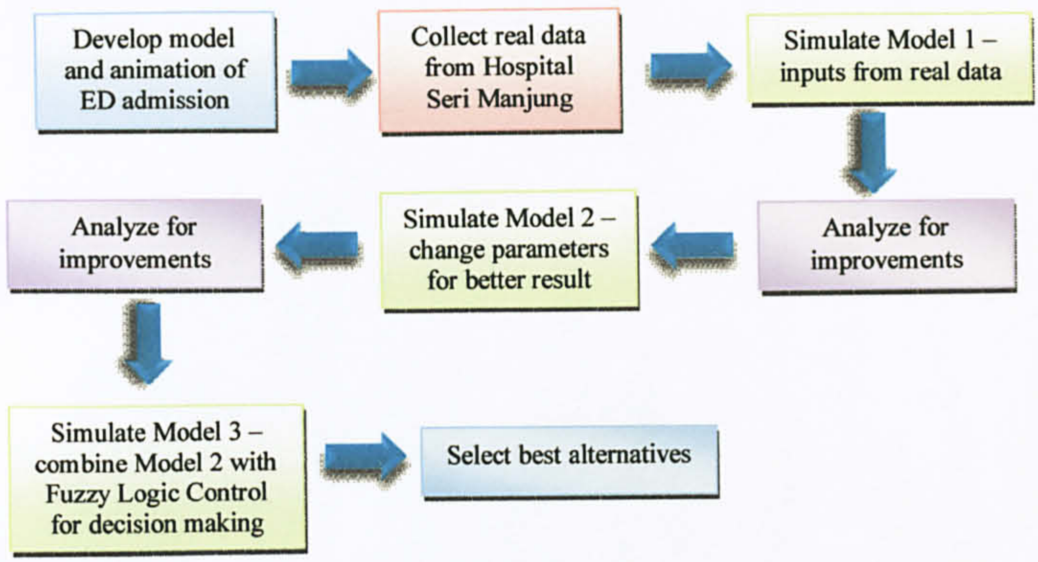


Figure 13: Project activities

This project has been divided into four stages. In Stage 1, a model along with animation of Emergency Department is built with some random data being inserted to ensure no error occurs during simulation of the model. While in Stage 2, a research has been conducted and well received by selected hospital which is Hospital Seri Manjung, Perak. Real data collected are implemented in the model previously built and known as Model 1. Result of the simulation of Model 1 is analyzed to make room for improvements in Model 2 by changing parameters at a few weak points of the system. As for Model 3, combination of Model 2 and Fuzzy Logic Control Approach in decision making blocks is expected to make the system more reliable and realistic.

The result of the Modelling and Simulation is discussed in *Chapter 4, Result and Discussion.*

3.3 Tools and equipments required

For a simulation research project, most tools required are consists of software elements as this is a computer-based project. All featured software that will be used is as in Figure 15.

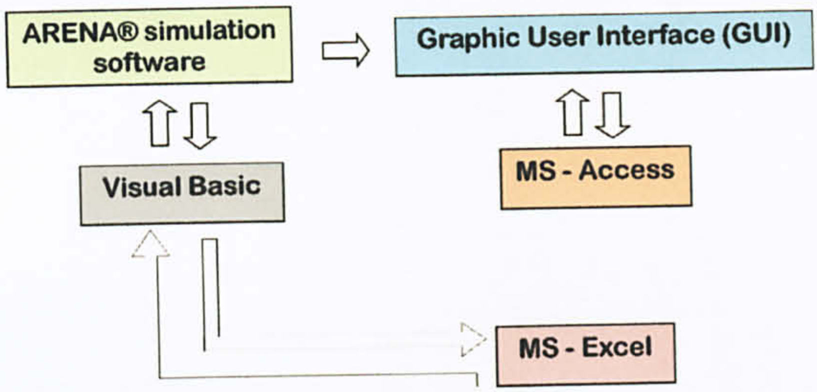


Figure 14: The system structure.

3.3.1 ARENA® simulation software

ARENA® simulation software provides alternative and interchangeable templates of graphical simulation modelling and analysis module that can be combined to build a fairly wide variety of simulation models (W. David Kelton, Randall P. Sadowski, David T. Sturrock, 2007). Besides, ARENA® simulation software also has element of dynamic animation which support graphics for statistical design and analysis.

3.3.1.1 Input Analyzer

Input Analyzer fits probability distributions to the observed real-world data for specifying model inputs (W. David Kelton, Randall P. Sadowski, David T. Sturrock, 2007). With that user may compare distribution functions or observe the effects of changing parameter.

3.3.1.2 Process Analyzer

Process Analyzer is another tool under ARENA® simulation software for performance plotting. It organizes the efficient way to make multiple simulation runs, which may represent different model configuration and keep track of the results (W. David Kelton, Randall P. Sadowski, David T. Sturrock, 2007). With that user be able to carry out suitable statistical analyses to select the best from several different model configurations

3.3.2 Visual Basic

MS-Visual Basic for Application (VBA) allows user to interact with the model, allow manipulation of variables or delay times, change the number of replications, and many other useful functions. VBA is for online editing where instant modification may be inserted in generated user form, thus producing faster result instead of defining the parameters as in Input Analyzer. The VBA block stores and retrieves information from MS-Access or MS-Excel (David Bregman, Dagan Gilat and Lion Levi). As in this project, VBA is used to as a Fuzzy Logic Control (FLC) Inference, to call Table of Fuzzy Rule from MS – Excel and to be exported to ARENA® simulation software model logic via a block known as 'ReadWrite' which is explained in *Chapter 4, Result and Discussion.*

3.3.4 MS-Excel

MS-Excel can be used to view any user specified result especially for users whom not familiar to ARENA® simulation software and for result of modifications. Chart of the result can be displayed in MS-Excel. As for this project, MS – Excel is used to store Table of Fuzzy Rule. This table is linked to ARENA® simulation software through VBA.

3.3.5 Dongle

Dongle is a device that looks like a USB drive which is needed for software activation. It is also called 'node-locked' where the activation is saved on computer's hard disk but locked to a particular hardware – *Dongle.*

Overall, Chapter 3 – Methodology has described the Procedure Identification, Project Activities, Data Collection by conducting research at hospital and Tools Involved.

In the Chapter 4, result of the modelling and simulation will be discussed.

CHAPTER 4
RESULT AND DISCUSSION

4.1 ARENA® software building and simulation model

In ARENA® software, experiment *models* is built by placing *modules* or *blocks* that represent processes or logic. Connector lines are used to join these blocks together and denote the flow of *entities*. List of entities and resources used in this project is explained in Table 3.

Table 3: List of resources and entities used

Type of Entities		Entities Pictures
	Outpatient	
	Stable patient	
	Minimal injury patient	
	Minimal accident patient	
	Life threatening patient	

Resources		Idle	Busy	Inactive / Failed
	Triage Nurse			
	Administrator			
	Nurse			
	Bed			
	Doctor			

While modules have specific actions relative to entities, flow, and timing, the precise representation of each module and entity relative to real-life objects is subject to the modeler. Statistical data, such as cycle time and WIP (work in process) levels, can be recorded in reports.

Starting with a simple model and building towards greater complexity is one of a good strategy when building simulation models. This simple base model helped determine some of the requirements and needs in developing the final model, such as recognizing the need for passing parameters to instantiate the number of objects at model execution

Starting with a simple model and building towards greater complexity is one of a good strategy when building simulation models. This simple base model helped determine some of the requirements and needs in developing the final model, such as recognizing the need for passing parameters to instantiate the number of objects at model execution. There are six basic models that have been built are shown as in Figure 16, 17, 18, 19, 20 and 21. These models are then been sub modelled or combined in an Animation that would create a functioning patients' flow in an Emergency Department of a hospital.

4.1.1 Model: Patient's Profile

The first model, as in Figure 16 , *Patient's Profile* functions to keep track of patients' arrival at station 'Doorway' according to their case either they are Typical, Mild Injury, Severe Injury or Extremely Critical patients. In this model, patient will be assigned with priority according to their level of seriousness where Extremely Critical patient always been given the first priority. This model also defines the entity's name for each type of patient and picture of vehicle they came with either car or ambulance.

4.1.2 Model: Triage Evaluation

The second model in Figure 17, *Triage Evaluation*, a resource named 'TriageNurse' has been assigned at 'Triage Counter' to do triage evaluation on patients. The Triage Nurse will decide either to send patient to 'BedStation' or to 'Admission Counter'. Here, patients have to wait till there is vacant room. Room will be given to patient according to first available room.

4.1.3 Model: Patients Admission

The third model as in Figure 18, *Patients Admission* functions to deal with patient's admission. A set of resource named Receptionist has been assigned at Admission Counter. The receptionists will entertain patient according to first available member of the set. Then, patients will be routed to next station which is 'Triage Counter'.

4.1.4 Model: Patient Treatment

The fourth model, as in Figure 19, *Patient Treatment* illustrates the patients' flow at 'Bedstation'. When patient first arrive, the entities have to wait in queue for resource (bed) to be available. Some delay will occur as of wait duration where cost and time will be calculated in preparing the bed. Next, entities have to wait in queue for resource (nurse) to be available. Again delay to be entertained by nurse will be calculated. Lastly, entities have to wait in queue for resource (doctor) to be available and calculated delay occurs when evaluated by doctor. Once done, all resources (bed, nurse and doctor) that have been seized will be released. Same goes for entities where they are disposed through block DISPOSE. Number of entities that have leave through this block is displayed as NumberOut.

4.1.5 Model: Patients Flow

The fifth model, as in Figure 20, *Patients Flow in Hospital* is important for animation. This model defines picture for each entities comprise of all four type of patients, car, and ambulance plus to animate the patients' flow starting from 'Doorway' up to 'ParkExit' station. Upon arrival, entities will be evaluated and Extremely Critical Patient will be routed to Operation Theatre (OT) directly. There is also an option to refer these entities (patients) to other hospital if the hospital cannot handle the case. Extremely Critical Patient will be transferred by Ambulance, while others will be taken by car.

4.1.6 Model: Parking Lot

The last model, as in Figure 21, *Parking Lot* functions to dispose the entity Car and Ambulance from station 'ParkExit' through block DISPOSE. Number of entities (Extremely Critical Patient) that has been referred to other hospital will be known.

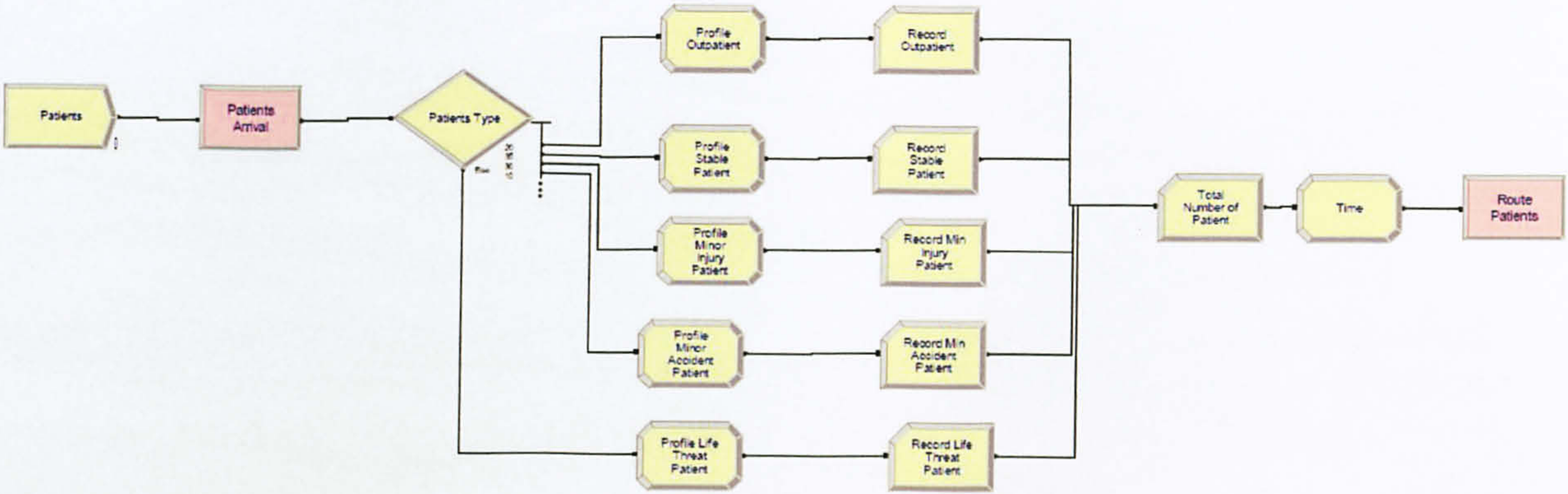


Figure 15: Patient's Profile

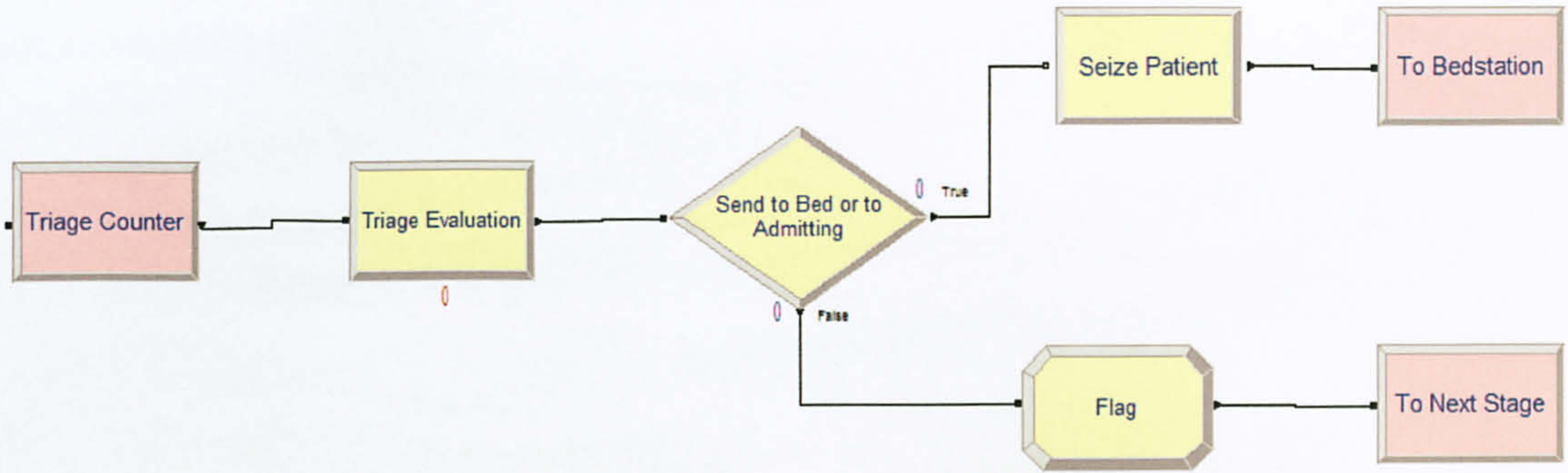


Figure 16: Triage Evaluation

Figure 17: Patients Admission

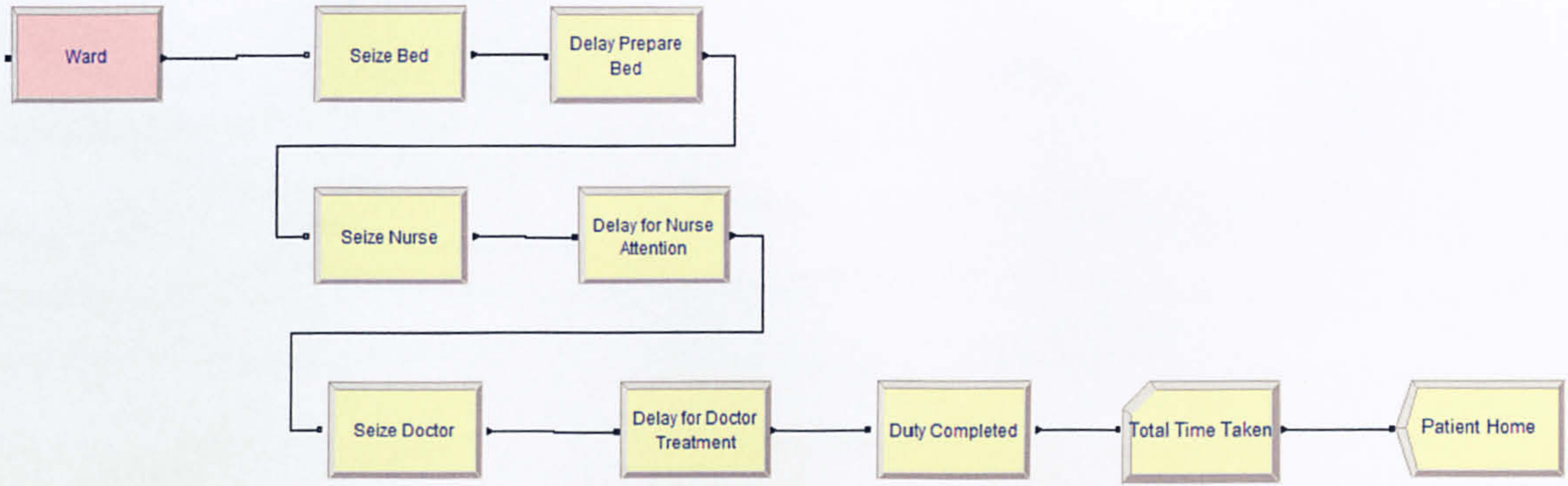


Figure 18: Patient Treatment

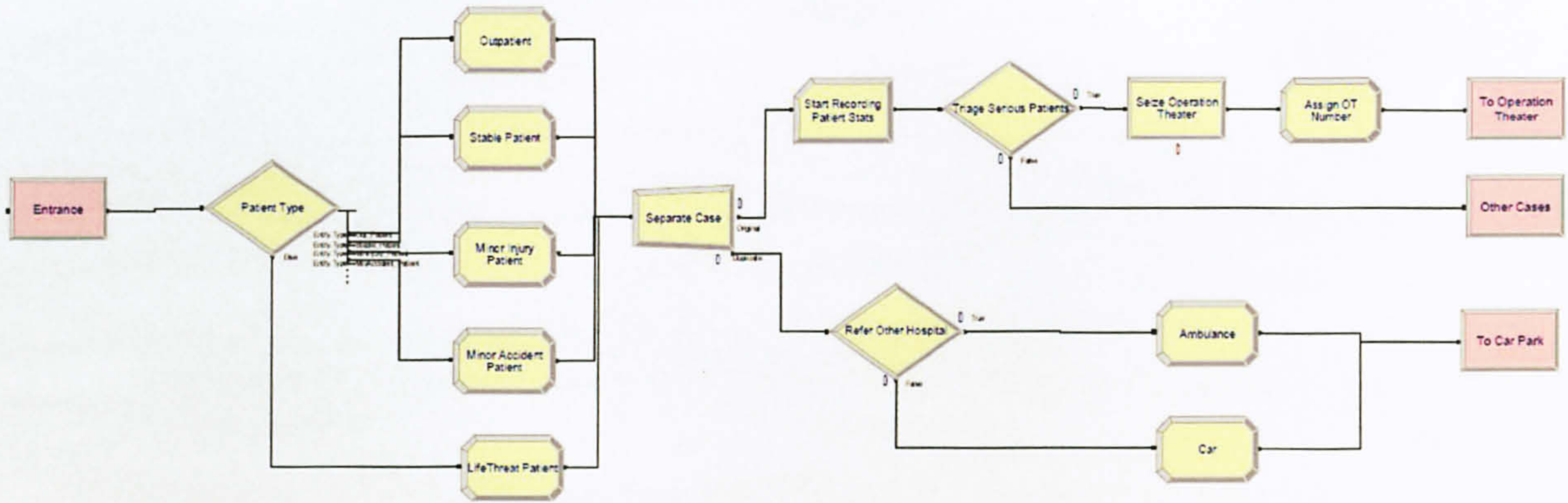


Figure 19: Patients Flow

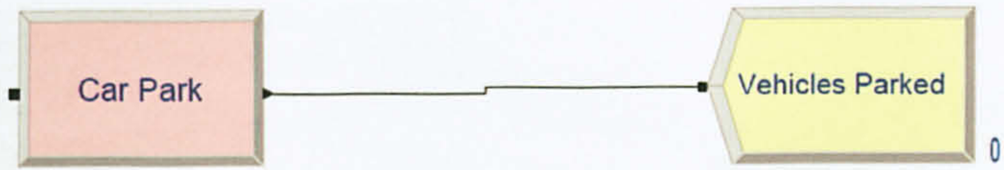


Figure 20: Parking Lot

The basic model creation is an important step as the blocks being dragged into model window would determine the flow of the system according to real situation. Another vital step is to add real data and refine model, along with creation of animation to make the simulation more realistic. The animation requires design skill that capable to visualize real situation of patients' admission in Emergency Department.

The Animation of flow in an ED is shown in Figure 22. Before patients arrive, they are all assumed to be from a station named 'Entrance' which means patients are on the way to hospital. Then, the first station that patients need to encounter is 'Doorway' which can illustrates the vehicle they came with either car or ambulance. Next station can be either 'Triage Counter' or 'Admission Counter'. There are patients who will to go to Triage Counter first then directly admitted to Bedstation or go to Admission Counter. And there are also patients who will encounter Admission Counter first followed by Triage Counter. The sequence would depend on type of entities (patients) that has been assigned by block SEQUENCE.

Table 4: Sequence of entities' flow in Emergency Department

Typical Patient	Doorway → Triage Counter → Admission Counter → Triage Counter → Bedstation
Mild Injury Patient	Doorway → Triage Counter → Admission Counter → Triage Counter → Bedstation
Severe Injury Patient	Doorway → Triage Counter → Admission Counter → Triage Counter → Bedstation
Extremely Critical Patient	Doorway → Bedstation

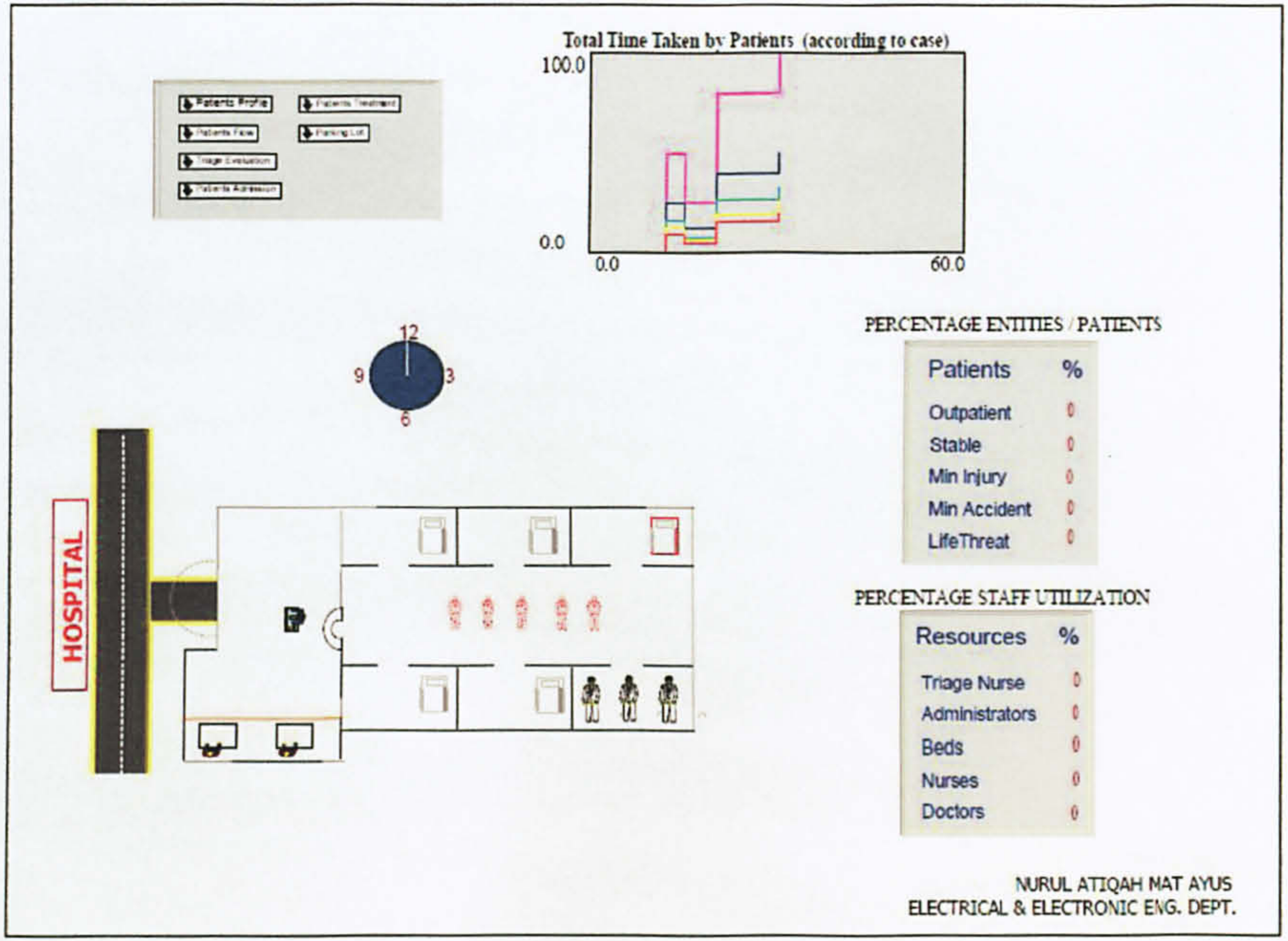


Figure 21: Animation of flow in an Emergency Department

4.2 Real data gathered from Hospital Seri Manjung

Several variables from real data obtained during visit at Hospital Seri Manjung were data on patients' waiting time, total time of treatment or work process, number of doctors on duty and number of staffs or medical assistant at the registration counter. Data is gathered through interview. In carrying out this research, some of the management staff and doctors were interviewed to obtain information on the working process in the hospital. During the visit, author manages to see the record of total number of patients' arrival for 7-days, from Monday to Sunday. However, due to confidentiality, they can only show and explain the records of patients' arrival and the approximate distribution time as outsider was not allowed to have a copy of the record. Thus, the data is represented in Table 5 as the mean total of patients' arrival for a week.

Table 5: Mean total patients' arrival 24 hours in 7-days for each code according to three zone

	Total patient in 24 hours			Total each day
Day	Green	Yellow	Red	
Monday	3	16	1	20
Tuesday	9	17	2	28
Wednesday	9	14	0	23
Thursday	4	13	2	19
Friday	7	12	3	22
Saturday	23	20	5	48
Sunday	21	23	7	51
TOTAL	76	115	20	**211**

Courtesy of Hospital Seri Manjung, Perak (11th January 2010)
Authorized by Mr. Mohamad Zaki Shafie,
Medical Assistant (U36)

Based on discussion with administration of the hospital, they suggested author to divide the type of patients to smaller scope. This is because dividing the type of patients into three types only, green, yellow and red may produce inaccuracy for the modelling and simulation and it is believed that smaller scope of patients would be a good future improvement for the Emergency Department as well. Thus, another observation is carried out to analyse and break down the type into five categories based on seriousness of the case. The analyzed data is as in Table 6.

Table 6: Mean total patients' arrival 24 hours in 7-days according to five types

Day	Total patient in 24 hours					Total each day
	Outpatient	Stable	Minimal Injury	Minimal Accident	Life Threatening	
Monday	5	9	8	4	0	26
Tuesday	7	13	11	3	1	35
Wednesday	6	8	4	6	2	26
Thursday	5	13	9	2	1	30
Friday	3	9	6	6	1	25
Saturday	10	7	12	2	2	33
Sunday	11	10	9	3	3	36
TOTAL	47	69	59	26	10	**211**

Courtesy of Hospital Seri Manjung, Perak (11th January 2010)
Authorized by Mr. Mohamad Zaki Shafie,
Medical Assistant (U36)

Based on interviews with some doctors, nurses and medical assistants, they concluded that it is hard to determine the exact time that would be allocated to treat each patient since each case is individualized and it depends on various aspects such as the seriousness of the case and the expertise of staffs. However, they may give estimation of the average time and staff allocation. These data are proven reliable since all are obtained from experience and certified medical assistants and admin officers. Table 7 and Table 8 show the distribution time taken at each station and distribution number of staffs on duty.

Table 7: Approximate distribution time taken at each station

Station		Distribution time taken at each station
Triage Counter		UNIFORM (2, 5) - minute
Admission Counter		UNIFORM (5, 10) - minute
Bed Station (according to zone)	Red	TRIA (0.5, 1, 1.5) - hour
	Yellow	TRIA (20, 10, 60) - minute
	Green	UNIFORM (10, 20) - minute

These data are used in the models in ARENA® software to ensure the all models built are able to represent the actual system. Model 1 will verify that modelling and simulation has the capability to represent real system, given all conditions, distribution time, number of resource are same as real data obtained.

Table 8: Distribution number of resources in Emergency Department

Station	Resources	Distribution number of resources
Admission Counter	MA - Admission	1 - 2
Triage Counter	MA - triage	1 - 2
Bed Station	Nurse	4 - 5
	Doctor	2 - 3
	Bed	5 - 6 beds including to be admitted to OT
	Room	5 - 6 rooms including OT

4.3 Model 1 - Verification and validation: Based on real data

Verification and validation of the simulation model were based on animation checking and by comparing total patients according to type obtained by the simulated model with total patients according to type based on the real system. The animation for Model 1 is same as in Figure 22. Before the modelled and simulated model is used to proceed with the improvement of models, Model 1 has to be validated first. The validation confirms that this model has successfully reflected the actual or real situation of Emergency Department with data from Hospital Seri Manjung as the benchmark.

To ensure we use same data as real data for simulation, total number of patient count for simulation is limited to 211 patients per day since the average of real data in 7-days is 211 patients.

Table 9: Validation Info total number of patient arrival

Type patient	Actual Data		Simulation	
	Patient Count	% Patients	Patient Count	% Patients
Outpatient	47	22	34	21
Stable	69	33	58	35
Minimal Injury	59	28	46	28
Minimal Accident	26	12	20	12
Life Threatening	10	5	6	4

Below is the calculation of percentage total number of patients in 24-hours and the percentage total number according to each type:

$$\frac{Patient\ Count}{Total\ Patient\ Count} \times 100$$

These four equations define the calculation used to calculated percentage total number of patients in 24-hours, according to type:

$$\text{Outpatient} = \frac{nc(Outpatient\_Count)}{mx\ (1,nc(TotalPatientCount))} \times 100$$

$$\text{Stable Patient} = \frac{nc(Stable\_Count)}{mx\ (1,nc(TotalPatientCount))} \times 100$$

$$\text{Minimal Injury Patient} = \frac{nc(MinInjury\_Count)}{mx\ (1,nc(TotalPatientCount))} \times 100$$

$$\text{Minimal Accident Patient} = \frac{nc(MinAccident\_Count)}{mx\ (1,nc(TotalPatientCount))} \times 100$$

$$\text{Life Threatening Patient} = \frac{nc(LifeThreat\_Count)}{mx\ (1,nc(TotalPatientCount))} \times 100$$

Model error is calculated as in Table 10 below to validate the model with minimum error.

$$Percentage\ of\ Model\ Error\ (\%) = \frac{|Simulation - Actual|}{Actual} \times 100$$

Table 10: Percentage of model error according to type of patients

Type patient	Actual % Patients	Simulated % Patients	% Error
Outpatient	22	21	4.55
Stable	33	35	6.00
Minimal Injury	28	28	0
Minimal Accident	12	12	0
Life Threatening	5	4	20

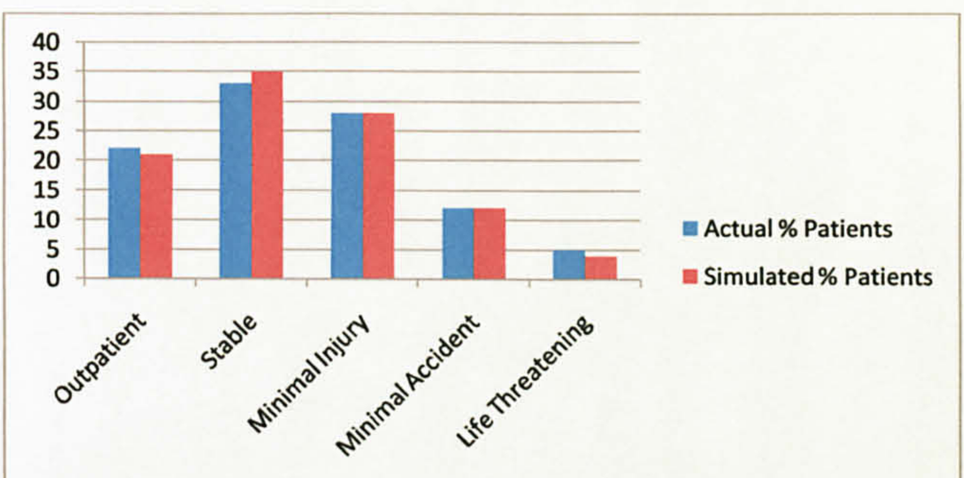


Figure 22: Comparison of total number of patient arrival for actual and simulated data

The acceptable error less than 5%, which is within the standard total differences is to be considered as acceptable and valid [27]. From Figure 23, it is seen most of the percentage is less than 5%. Only Stable and Life Threatening patient exceeded 5%. This error is identified due to the low admission recorded by Life Threatening patient. Meanwhile, though error of Stable patient is 6%, it is still acceptable since it is not far deviated from 5%. This proves that Model 1 is still considered valid and verified since both actual and simulated data seem closely correspond to one another.

4.4 Model 2 - Alternative model: Improvement by manipulating staffing

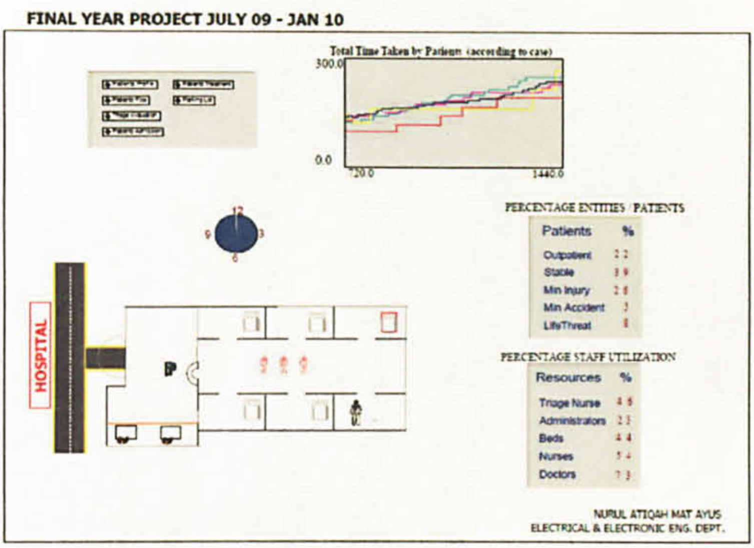


Figure 23: Animation for Model 2 with manipulated staffing

4.4.1 Resource utilization

The utilization of the resources is a key factor to keep production at low cost. Production cost will be low at high utilization of the resources otherwise production cost will be higher because it has to pay for the resources if used or not.

The comparison between the conventional scenario and intelligent scenario of resource utilization is depicted in Figure 11. It illustrates that the utilization of the intelligent model is better for most of the resources. Product mix affects the system performance because of the variation of operation sequence and processing time of different job systems. It should consider the utilization factor to make more realistic decisions.

Table 11 shows the percentage of utilization for Model 2 with number of staff being reduced one by one.

Table 11: Resource utilization result

Resource	Model 1 (%)	Model 2 (%)			
		-1 Doctor -1 Nurse	-1 Doctor -2 Nurse	-2 Doctor -1 Nurse	-2 Doctor -2 Nurse
Triage Nurse	72	75	79	81	85
Administrator	39	39	41	42	44
Beds	46	46	44	45	45
Nurses	34	34	47	46	56
Doctors	26	30	47	50	77

Triage Utilization = $DAVG\ (TriageNurse.Utilization) \times 100$

Admissions Utilization =

$$\frac{(DAVG\ (Receptionist1.Utilization) + (DAVG\ (Receptionist2.Utilization)}{2} \times 100$$

Beds Utilization = $TotalBedUtl \times 100$

Nurses Utilization = $\frac{TotalNurseUtl}{3} \times 100$

Doctors Utilization = $TotalDoctorUtl \times 100$

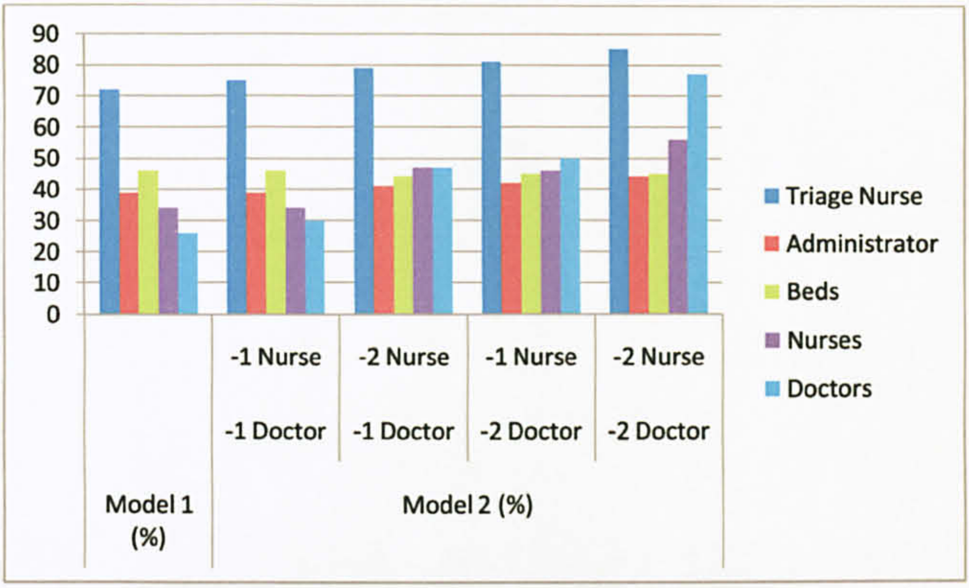


Figure 24: Comparison of resource utilization for actual and simulated data

Based from Figure 25 above, in Model 1, it is clearly shown that not all resources were performing at their optimum performance and not fully utilized. This is indicated by the low utilization percentage especially by doctors, nurses and administrator. Thus, Model 2 will modify the number of this resource by cut the number of doctor and nurses one by one on duty per day – 24 hours. As seen in Figure 25 utilization of doctors, nurses, beds and administrator has increased compared to utilization of Model 1. It is proved that manipulating staffing has successfully maximized the utilization percentage of the resources. In order to meet the expectation of health care centre along with logical improvement, it is propose that by cut out the number of nurse by two and one doctor, this idea can work out.

4.4.2 Process time improvement

Transfer Time is accumulated when the entity incurs a delay at a process whose allocation has been designated as transfer. Meanwhile, *Wait Time* is an accumulated time when unit incurs delay at a process whose allocation has been designated as wait. *Wait Time* also accumulates when unit resides in a queue until the entity exits the queue. *Total Time* on the other hand, is an overall time taken for the unit to be processed based on time it enters the system until statistics generated.

Table 12: Process time result for from Model 1 – real data

Type patient	Transfer Time / unit (sec)	Wait Time / unit (sec)	Total Time / unit (sec)
Outpatient	43.3158	70.0384	139.56
Stable	42.8526	78.0753	147.2
Minimal Injury	43.3158	78.6047	153.21
Minimal Accident	43.0000	73.1080	143.72
Life Threatening	34.7250	80.4712	135.24
TOTAL	207.2092	380.2976	718.93

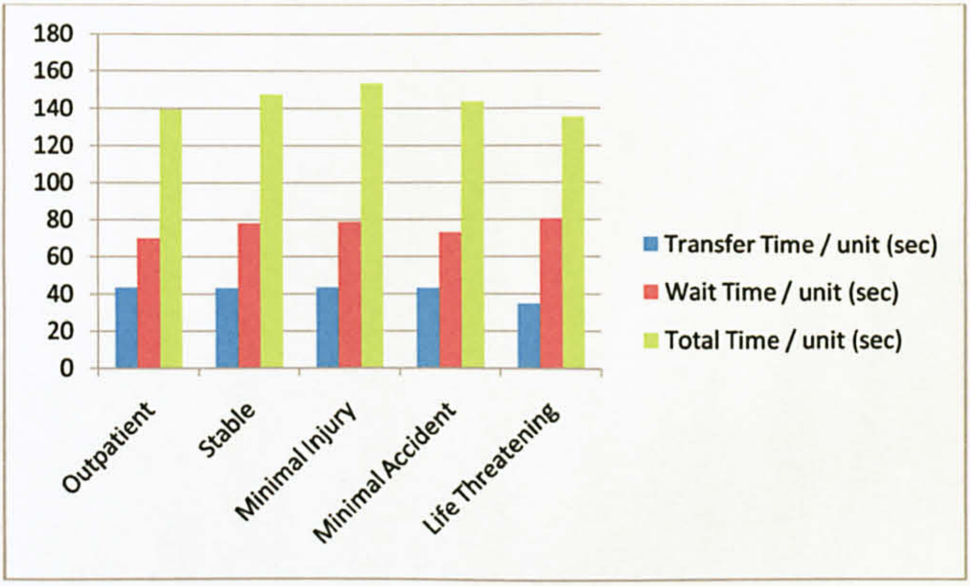


Figure 25: Process time result for from Model 1

Based on graph in Figure 26, the total time taken to treat a case is approximately same with other case regardless of the seriousness of the patients. This clearly shows that emergency case such as a life threatening patient is not given the particular priority compared to other patients.

Table 13: Process time result for from Model 2 – Total Time

Type patient	-1 Doctor -1 Nurse	-1 Doctor -2 Nurse	-2 Doctor -1 Nurse	-2 Doctor -2 Nurse
Outpatient	187.11	185.13	185.13	182.27
Stable	195.31	196.01	196.12	194.54
Minimal Injury	189.58	188.11	189.23	188.21
Minimal Accident	156.91	157.81	158.12	155.19
Life Threatening	180.93	182.00	183.13	180.95
TOTAL	909.84	909.06	911.73	901.16

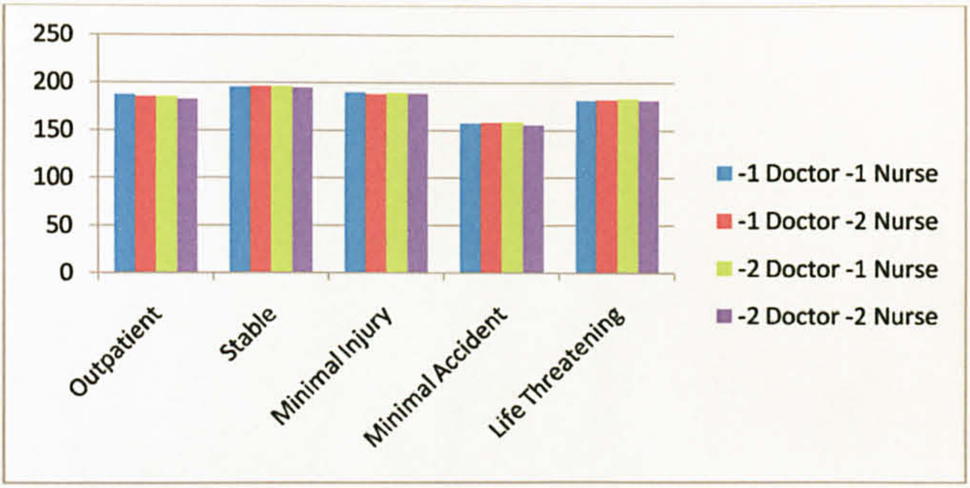


Figure 26: Process time result for from Model 2

As shown in Table 13, number of nurse and doctor is manipulated one by one and the effect of total time taken by each type of patient is recorded and being compared in Figure 27. Here we can see that, as we reduce the number of staff, total time taken will be affected. Though some does not very much, this proves that even with number of staffing reduced tremendously, we can still keep the waiting time as satisfying rate.

Since the value of time shown is both Table 12 and Table 13 are diverse, the total time taken for each type of patients in Model 1 and Model 2 will be compared in percentage. The percentage of total process time taken for each type of patient in Emergency Department is calculated based on following equation below and the result is as shown in Table 14.

$$Percentage\ of\ process\ time = \frac{total\ time\ for\ a\ type\ of\ patient}{total\ time\ for\ all\ type\ of\ patient} \times 100\%$$

Since cut the number of nurse and doctor by 2 produce least total time, this value of Model 2 will be compared to Model 1 as in Table 14.

Table 14: Percentage of total time taken for each type of patient

Type patient	Model 1 - Total Time / unit (%)	Model 2 - Total Time / unit (%)	Deviation (%)
Outpatient	19.41	20.23	+0.82
Stable	20.47	21.99	+1.52
Minimal Injury	21.31	20.89	-0.42
Minimal Accident	19.99	17.22	-2.77
Life Threatening	18.81	20.08	+1.27

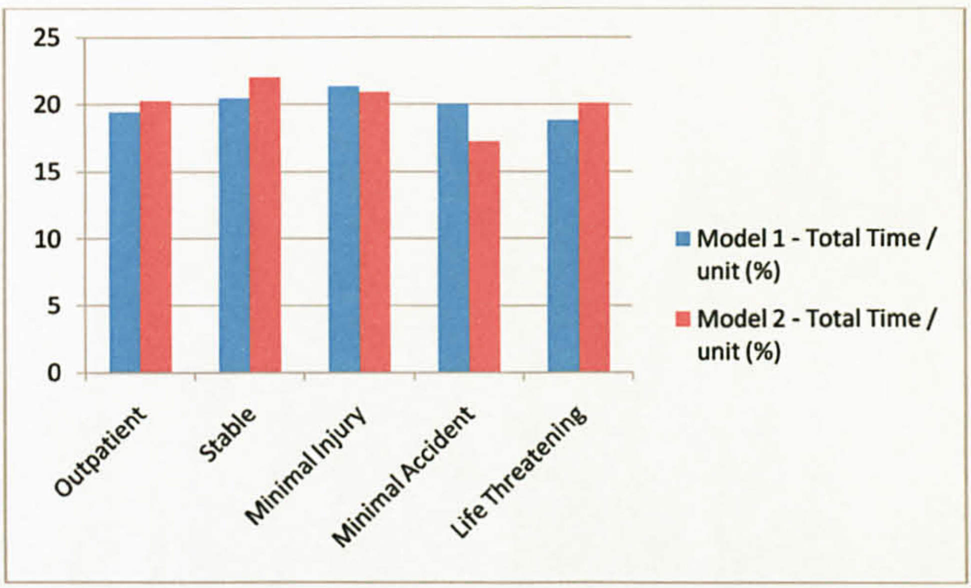


Figure 27: Percentage of total time taken for each type of patient

Figure 28 shows that Model 2 causes slight increment of total time taken to treat some type of patients over Model 1. However, this is not apparent since the deviation time between Model 1 and Model 2 does not affect the process time too much. Next section which is staffing cost minimization will prove that model 2 is applicable for health care which focuses to cut cost while maintain to provide satisfying service to patients.

4.4.3 *Staffing cost minimization*

There are a lot of factors that has been identified to contribute as system waste. For this project, only one major waste would be focused on which is *idle time*. Idle time means resource that is not being used to provide service to patients. It is similar to resource utilization. If resource is not fully utilized, obviously health care will be at loss since they still have to pay for monthly salary regardless the resource is contributing to the organization or not. Idle time may be due to actions of chatting with other resources or wandering around without doing works.

In order to the health care is paying the salary for the right people, idle cost for Model 1 and Model 2 is being compared. In Model 1, two (2) admin, three (3) doctors, five (5) nurses and one (1) triage nurse is set on duty meanwhile Model 2 has taken initiative to cut the number of staff to have only one (1) doctor and three (3) nurse. It is assume that doctor receive salary up to RM8000/month with about RM360/day while nurse receive RM3000/month with about RM136/day.

Table 15: Idle cost result for Model 1 and Model 2

Resource	Cost Model 1	Cost Model 2			
		-1Doctor -1 Nurse	-1Doctor -2 Nurse	-2Doctor -1 Nurse	-2Doctor -2 Nurse
Admin	441.61	446.98	400.10	460.00	400.25
Doctor	1783.00	1902.01	1855.13	1915.03	1964.52
Nurse	4294.31	4271.19	4224.31	4284.21	4348.10
Triage Nurse	133.56	128.87	81.99	141.89	70.68
TOTAL COST	6652.48	6749.05	6561.53	6801.13	6783.55

From Table 15, it is shown that by cutting number of nurse by two and one doctor, it will produce least cost. This proves that arrangement made in Model 2 is better than Model 1 as it assist health care centre to evaluate number of resources should be opt in order to minimize cost.

4.5 Model 3 - Alternative model: Integrating Fuzzy Logic Control in decision making block

In model 1 and 2, the priority of each type of patients is already set. Thus, in model 3, a new approach is applied by using Fuzzy Logic Control to balance the patient type and total number of patient arrival in order to assign a suitable priority that would reduce the waiting time much effective. The suitable code is generated to incorporate Visual Basic into ARENA® simulation software for FLC purpose. To import data from table of fuzzy rule to VBA, MS – Excel is used to store the table as database.

4.5.1 Building a fuzzy controller

The Fuzzy Logic table of rules that have been implemented in MS-Excel as in Table 12 and Table 13 below show two input parameters that will be fuzzified.

Table 16: Table of fuzzy rule – Patient Arrival

	Entity Type				
Output	LifeThreat	MinAccident	MinInjury	Stable	Outpatient
LP	-0.5	0	0.5	1	0.5
SP	0	0.5	1	0.5	0
ZE	-1	-0.5	0	0.5	1
SN	0.5	1	0.5	0	-0.5
LN	1	0.5	0	-0.5	-1

Table 17: Table of fuzzy rule – Entity Type

	Patient Arrival				
Output	0 - 44	45 - 88	133 - 176	177 - 220	89 - 132
LP	-0.5	0	0.5	1	0.5
SP	0	0.5	1	0.5	0
ZE	-1	-0.5	0	0.5	1
SN	0.5	1	0.5	0	-0.5
LN	1	0.5	0	-0.5	-1

There are two Fuzzy Table of Rule which correlates to produce an output. Thus output will determine the status that should be given to each and every entity that comes into the Model Logic. Linguistic rule base is then implemented using VBA which consist of logical combination of the two input parameters from ARENA® simulation software, PatientArrival and EntityType. Suppose this fuzzy system has the following rule base:

Rule 1 : *IF* PatientArrival = LP *AND* EntityType = LP *THEN* Output = ZE
Rule 2 : *IF* PatientArrival = LP *AND* EntityType = SP *THEN* Output = LP
Rule 3 : *IF* PatientArrival = LP *AND* EntityType = ZE *THEN* Output = SN
Rule 4 : *IF* PatientArrival = LP *AND* EntityType = SN *THEN* Output = LN
Rule 5 : *IF* PatientArrival = LP *AND* EntityType = LN *THEN* Output = LP
Rule 6 : *IF* PatientArrival = SP *AND* EntityType = LP *THEN* Output = ZE
Rule 7 : *IF* PatientArrival = SP *AND* EntityType = SP *THEN* Output = SP
Rule 8 : *IF* PatientArrival = SP *AND* EntityType = ZE *THEN* Output = SN
Rule 9 : *IF* PatientArrival = SP *AND* EntityType = SN *THEN* Output = LN
Rule 10 : *IF* PatientArrival = SP *AND* EntityType = LN *THEN* Output = ZE
Rule 11 : *IF* PatientArrival = ZE *AND* EntityType = LP *THEN* Output = SN
Rule 12 : *IF* PatientArrival = ZE *AND* EntityType = SP *THEN* Output = SP
Rule 13 : *IF* PatientArrival = ZE *AND* EntityType = ZE *THEN* Output = LP
Rule 14 : *IF* PatientArrival = ZE *AND* EntityType = SN *THEN* Output = LN
Rule 15 : *IF* PatientArrival = ZE *AND* EntityType = LN *THEN* Output = LP
Rule 16 : *IF* PatientArrival = SN *AND* EntityType = LP *THEN* Output = ZE
Rule 17 : *IF* PatientArrival = SN *AND* EntityType = SP *THEN* Output = SP
Rule 18 : *IF* PatientArrival = SN *AND* EntityType = ZE *THEN* Output = LP
Rule 19 : *IF* PatientArrival = SN *AND* EntityType = SN *THEN* Output = LN
Rule 20 : *IF* PatientArrival = SN *AND* EntityType = LN *THEN* Output = ZE
Rule 21 : *IF* PatientArrival = LN *AND* EntityType = LP *THEN* Output = SP
Rule 22 : *IF* PatientArrival = LN *AND* EntityType = SP *THEN* Output = ZE
Rule 23 : *IF* PatientArrival = LN *AND* EntityType = ZE *THEN* Output = LN
Rule 24 : *IF* PatientArrival = LN *AND* EntityType = SN *THEN* Output = SP
Rule 25 : *IF* PatientArrival = LN *AND* EntityType = LN *THEN* Output = SN

Where :

LP	=	1
SP	=	0.5
ZE	=	0
SN	=	-0.5
LN	=	-1

'*min-max'* inference then is used to define result of the rule which through output of membership functions that been assigned with the truth value. Since only connective *AND* is used in *if-then* statement, only '*min*' inference will be used. For instance, if the total number of patient arrival is 34 and entity type is minimal injury patient, thus:

Table 18: Example of '*min*' interference

	Patient Arrival	Entity Type
	45 -88	Stable
LP	0	1
SP	0.5	0.5
ZE	-0.5	0.5
SN	1	0
LN	0.5	-0.5

Next step should be done is calculating *min-max'* inference for each of the 25 rule base. As for a sample taken above:

Rule 1 : *IF* PatientArrival = LP *AND* EntityType = LP *THEN* Output = ZE

$m_{b1} = \min(0,1) = 0$

$c_1 = 0$ because the output for Rule 1 is set as ZERO.

Rule 12 : *IF* PatientArrival = ZE *AND* EntityType = SP *THEN* Output = SP

$m_{b12} = \min(-0.5, 0.5) = -0.5$

$c_{12} = 0.5$ because the output for Rule 12 is set as SP.

After *min-max'* inference is done for all 25 rule base, the *priority* is now can be determined based on centroid computation:

$$priority = \frac{\sum_{j=1}^{p} c_j m_{bj}(c_j)}{\sum_{j=1}^{p} m_{bj}(c_j)}$$

The rule base for control action is determined by the control objectives. In this project, as has been explain in *Chapter 1, Introduction*, the study aim to prioritizing emergency case and minimize patients' waiting time As for this model, to determine the priority of a case in an ED, which will be implemented in the VBA code, we assume and must always hold to below rules:

a) Always give first priority for Life Threatening Patient.

b) If total Patients' Arrival exceed (ie) 20 for min injury patient, 2nd priority will be given

c) If total Patients' Arrival exceed (ie) 50 for outpatient, 4nd priority will be given

By using Centroid Computation, result of defuzzification for both inputs has been recorded as in Table 15 below:

Table 19: Result calculation of Centroid Computation for 25-Base Rule

Entity Type	Patient Arrival	Centroid Computation
Life Threat	0 - 44	0.125
	43 - 88	0
	133 - 178	0.1875
	177 - 220	0
	89 - 132	0.35
Min Accident	0 - 44	0.1818
	43 - 88	-1.5
	133 - 178	0.2
	177 - 220	-0.5
	89 - 132	0
Min Injury	0 - 44	0.25
	43 - 88	-0.4
	133 - 178	0.25
	177 - 220	0.1
	89 - 132	0.0625

Stable	0 - 44	0.045
	43 - 88	2
	133 - 178	-0.1
	177 - 220	-0.5
	89 - 132	0.045
Outpatient	0 - 44	0
	43 - 88	0.33
	133 - 178	0.125
	177 - 220	0.136
	89 - 132	-0.1

Thus, author has come out with a range of priority that will determine the status prioritization that ought to be assigned to entities when they pass through the logic model. This range of values is result of calculation from centroid computation.

Table 20: Priorities assigned according to result of centroid computation

Category	Priority
'Life Threat'	1
-1.5 to 0.1	2
0.11 to 0.25	3
0.26 to 0.30	4
0.30 >	5

4.5.2 Modification on model – integrate VBA-Excel- ARENA® simulation software

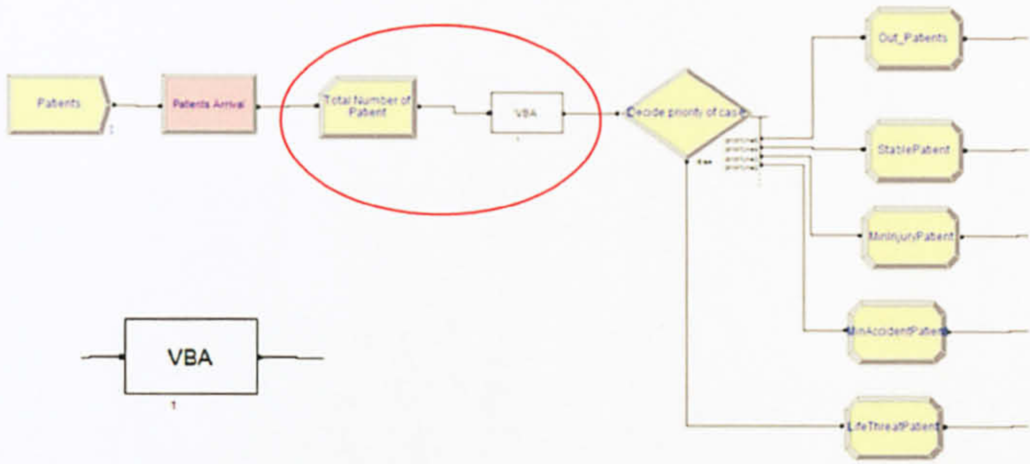


Figure 28: Modification on Model 3

The VBA block sends the entity to a user-coded Microsoft® Visual Basic for Applications procedure, which is added to the model via the Visual Basic Editor. When an entity arrives at the VBA block, control of the entity is passed to the VBA Sub procedure.

The VBA Cookie number specified in the VBA block is unique for each VBA block in the model. A corresponding Sub procedure is created in the Visual Basic Editor for each VBA block. For example, a VBA block with value of 1 will have a corresponding procedure in the Visual Basic Editor called VBA_Block_1_Fire (and an Object entry named VBA_Block_1 in the code editor).

```
Option Explicit

' Global variables
Dim oSIMAN As Arena.SIMAN

' Global Excel variables
Dim oExcelApp As Excel.Application, oTableFuzzyRule As Excel.Workbook,
Dim oEntityType As Excel.Worksheet, oPatientArrivalCount As Excel.Worksheet

Private Sub VBA_Block_1_Fire()
        ' Retrieve entity type and total patient arrival from SIMAN object data
        Dim dEntityType As String, dPatientArrivalCount As Integer
```

```
                dEntityType = oSIMAN.EntityType
                dPatientArrivalCount = oSIMAN.PatientArrivalCount

  ' Set numerical values to Fuzzy rule base
  With oWorkbook
            .Cells(1).value = LP
            .Cells(0.5).value = SP
            .Cells(0).value = ZE
            .Cells(-0.5).value = SN
            .Cells(-1).value = LN
  End With

  ' Read the values from the spreadsheet
  With oWorksheet. oEntityType
        .Cells("B3:B7").value = 'LifeThreat'
        .Cells("C3:C7").value = 'MinAccident'
        .Cells("D3:D7").value = 'MinInjury'
        .Cells("E3:E7").value = 'Stable'
        .Cells("F3:F7").value = 'Outpatient'
End With

With oWorksheet. oPatientArrivalCount
        .Cells("B3:B7").value = '0 – 44'
        .Cells("C3:C7").value = '45 – 88'
        .Cells("B3:B7").value = '133 – 176'
        .Cells("D3:D7").value = '177 – 220'
        .Cells("F3:F7").value = '89 – 132'
  End With

Private Sub ModelLogic_RunBeginSimulation()
  ' Set the global SIMAN variable
  Set oSIMAN = ThisDocument.Model.SIMAN

  If PatientArrivalCount == LP and EntityType == LP Then Output == ZE
     mb1 = min (EntityType, PatientArrivalTotal)
     c1 = output
  If PatientArrivalTotal == LP and EntityType == SP Then Output = LP
     mb2 = min (EntityType, PatientArrivalTotal)
     c2 = output
  If PatientArrivalTotal == LP and EntityType == ZE Then Output = SN
     mb3 = min (EntityType, PatientArrivalTotal)
     c3 = output
  If PatientArrivalTotal == LP and EntityType == SN Then Output = LN
     mb4 = min (EntityType, PatientArrivalTotal)
     c4 = output
  If PatientArrivalTotal == LP and EntityType == LN Then Output = LP
     mb5 = min (EntityType, PatientArrivalTotal)
     c5 = output
```

```
If PatientArrivalTotal == SP and EntityType == LP Then Output = ZE
    mb6 = min (EntityType, PatientArrivalTotal)
    c6 = output
If PatientArrivalTotal == SP and EntityType == SP Then Output = SP
    mb7 = min (EntityType, PatientArrivalTotal)
    c7 = output
If PatientArrivalTotal == SP and EntityType == ZE Then Output = SN
    mb8 = min (EntityType, PatientArrivalTotal)
    c8 = output
If PatientArrivalTotal == SP and EntityType == SN Then Output = LN
    mb9 = min (EntityType, PatientArrivalTotal)
    c9 = output
If PatientArrivalTotal == SP and EntityType == LN Then Output = ZE
    mb10 = min (EntityType, PatientArrivalTotal)
    c10 = output
If PatientArrivalTotal == ZE and EntityType == LP Then Output = SN
    mb11 = min (EntityType, PatientArrivalTotal)
    c11 = output
If PatientArrivalTotal == ZE and EntityType == SP Then Output = SP
    mb12= min (EntityType, PatientArrivalTotal)
    c12 = output
If PatientArrivalTotal == ZE and EntityType == ZE Then Output = LP
    mb13 = min (EntityType, PatientArrivalTotal)
    c13 = output
If PatientArrivalTotal == ZE and EntityType == SN Then Output = LN
    mb14 = min (EntityType, PatientArrivalTotal)
    c14 = output
If PatientArrivalTotal == ZE and EntityType == LN Then Output = LP
    mb15 = min (EntityType, PatientArrivalTotal)
    c15 = output
If PatientArrivalTotal == SN and EntityType == LP Then Output = ZE
    mb16 = min (EntityType, PatientArrivalTotal)
    c16 = output
If PatientArrivalTotal == SN and EntityType == SP Then Output = SP
    mb17 = min (EntityType, PatientArrivalTotal)
    c17 = output
If PatientArrivalTotal == SN and EntityType == ZE Then Output = LP
    mb18 = min (EntityType, PatientArrivalTotal)
    c18 = output
IF PatientArrivalTotal == SN and EntityType == SN Then Output = LN
    mb19 = min (EntityType, PatientArrivalTotal)
    c19 = output
If PatientArrivalTotal == SN and EntityType == LN Then Output = ZE
    mb20 = min (EntityType, PatientArrivalTotal)
    c20 = output
If PatientArrivalTotal == LN and EntityType == LP Then Output = SP
    mb21 = min (EntityType, PatientArrivalTotal)
    c21 = output
```

```
  If PatientArrivalTotal == LN and EntityType == SP Then Output = ZE
     mb22 = min (EntityType, PatientArrivalTotal)
     c22 = output
  If PatientArrivalTotal == LN and EntityType == ZE Then Output = LN
     mb23 = min (EntityType, PatientArrivalTotal)
     c23 = output
  If PatientArrivalTotal == LN and EntityType == SN Then Output = SP
     mb24 = min (EntityType, PatientArrivalTotal)
     c24 = output
  If PatientArrivalTotal == LN and EntityType == LN Then Output = SN
     mb25 = min (EntityType, PatientArrivalTotal)
     c25 = output

End Sub

Private Sub ModelLogic_RunBeginReplication()
  Dim nPriority As Long

'calculate centroid computation
        npriority = (((mb1*c1)+ (mb2*c2)+ (mb3*c3)+ (mb4*c4)+ (mb5*c5)+ (mb6*c6)+
        (mb7*c7)+ (mb8*c8)+ (mb9*c9)+ (mb10*c10)+ (mb11*c11)+ (mb12*c12)+
        (mb13*c13)+ (mb14*c14)+ (mb15*c15)+ (mb16*c16)+ (mb17*c17)+ (mb18*c18)+
        (mb19*c19)+ (mb20*c20)+ (mb21*c21)+ (mb22*c22)+ (mb23*c23)+ (mb24*c24)+
        (mb25*c25)) / ((mb1)+ (mb2)+ (mb3)+ (mb4)+ (mb5)+ (mb6)+ (mb7)+ (mb8)+
        (mb9)+ ((mb10)+ (mb11)+ (mb12)+ (mb13)+ (mb14)+ (mb15*c15)+ (mb16*c16)+
        (mb17)+ (mb18)+ (mb19)+ (mb20)+ (mb21)+ (mb22)+ (mb23)+ (mb24)+ (mb25)))
End Sub
```

However, this coding need fails to integrate with ARENA®. This is because of the complexity to interconnect ARENA® and VBA. It is hoped that this work will be continued in the future.

4.5.3 Other alternative - READWRITE block

Other than using VBA to read Fuzzy Table of Rule from MS - Excel, there is also other option to read from MS-Excel, which is by using READWRITE block. Here, ARENA® will directly call the cells from the table into the model. The READ block reads data from input files and assigns the values to the list of variables. The *File ID* operand represents the file *Number* or *Name* as specified in the first two operands of the FILES element. (Note: *File ID* is not the system-specific file name.) Defaulting *File ID* or specifying the keyword STDIN provides a convenient way of reading information from the standard input (usually the keyboard). If *File ID* is specified, then the READ logic varies according to the *Access Type* of the file specified in the FILES element.

The FILES element must be included whenever external files are accessed using the READ and WRITE blocks. It identifies the system file name and defines the access method, formatting, and operational characteristics of the files. Either the file *Number* or the file *Identifier* can be used in a READ or WRITE block.

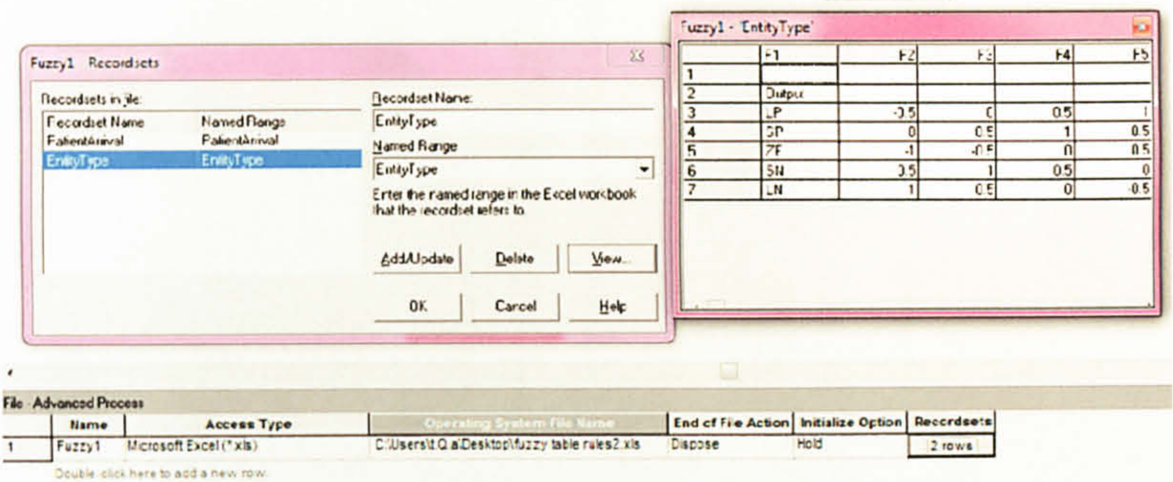


Figure 29: File Module

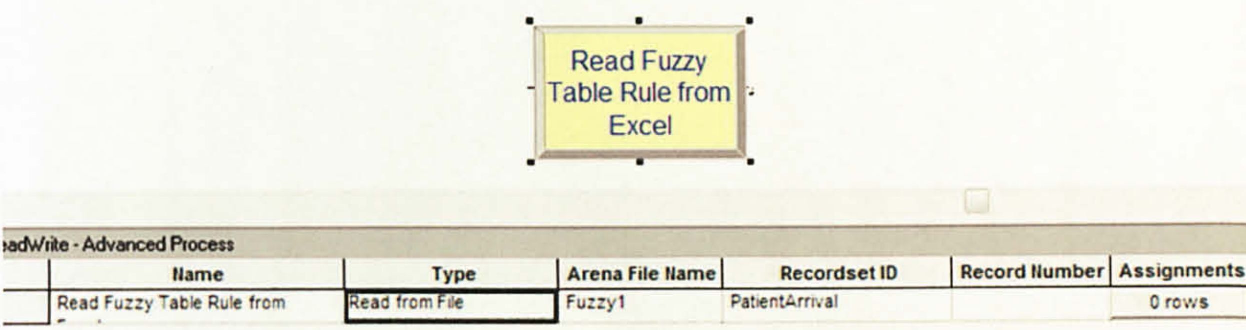


Figure 30: Read block from ReadWrite Block

Here, the study of integration between FLC – Visual Basic - ARENA® simulation software need to be enhanced since there are not many research that has been conducted on integrating these tree main concepts and software. This is based on author experience to struggle with coding in VBA to come out with fuzzy logic rule base and then to be integrated with ARENA® simulation software.

The literature on fuzzy logic applications in healthcare and any medicine remains modest. This is a largely untapped area that holds great promise for increasing the efficiency and reliability of health care delivery [16]. It is believe that greater effort should be applied to the exploration of ways to apply fuzzy logic in medical decision making.

Overall, this chapter has revealed the result of modelling and simulation of a scheduling system for a hospital admission. The Fuzzy Logic concept that has been incorporate used Visual Basic (VB) to create a statement that would link the concept to ARENA® simulation software.

Lastly, the conclusions and all recommendations made for this project will be discussed in the next chapter, Chapter 5 – Conclusion and Recommendation.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Realizing the advantages of simulation techniques to mimic a real-world system, this study incorporates the use of ARENA® simulation software to help Emergency Department develop a model for the analysis of different alternatives to enhance health case operational efficiency. The simulation process would be an effective approach compared to direct implementation of any adjustment to the real system. Besides, result can be achieved immediately which would be easier for analyst to analyze the actions ought to be taken. Besides, based on researches that had been conducted by many expertises, this system is proven to increase the profit or save cost and time as well.

Modelling and simulation requires a lot of practice and exposure since ARENA® simulation software offers a wide range of problem solving in most organizations. The simulink tools make it easier for analyst to manipulate and create model to represent the real system behavior. The user friendly features such as drag and drop of modules to build models that can be inputted with current or existing process data to accurately simulate processes makes Arena Simulation Software a simple yet effective simulation tool [11].

Even though simulation is most practical when dealing with objects which have same characteristics or traits, this approach can still be implemented on living things such as patients as for this project. The reliability can be boost through the incorporation of Fuzzy Logic Control which able to translate the problem to mathematical models and solve the decision making situation.In this paper, we advocate an application of fuzzy modeling, namely, as a tool that can assist healthcare person in the difficult task of transforming their observations into a mathematical model.

Generally, the simulation model developed in this project can be used as a decision making tool for the healthcare management to look into ways of shorting waiting time, maximize utilization, minimizing cost and the introduction of integration of FLC will enhance this decision making tool. Hopefully, the objectives of this research can contribute to enhance the productivity of hospitals in nationwide.

5.2 Recommendations

As for improvement of Final Year Project Program at UTP, first suggestion for future work is to organize a talk or seminar to expose students with Discrete Event Simulation (DES) by inviting simulation software-based company such as Rockwell. Students need to be exposed to the advantages of applying the simulation techniques so that they may bring the nation one step forward to be as successful as the international organizations.

Second suggestion is for FYP committee to have an official meeting with the chosen organization to clarify that the university will keep the data obtained from selected organization that collaborate in this project as private and confidential. This is proven by the author experience where the first idea for author's Final Year Project on "Analysis of Power Performance through OSI - Plant Information (PI-ProcessBook®)" was disapproved by a power plant though author has been working on that project during industrial internship training. This is all due to their huge concerns on data security.

Third suggestion is to have further work of incorporating other application with ARENA® simulation software. This project has introduced integration between Fuzzy Logic Control and ARENA® simulation software. It is believed there are a lot of other applications such as MATLAB that can be combined with

ARENA® simulation software. This would give a positive impact on the simulation itself as it will portray the ability to produce more reliable and realistic model.

The fourth suggestion is specifically for healthcare organizations to have electronic records of service activities with timestamps, which denote the date and time of the occurrence of certain events. Ideally, the system should record the arrival time at waiting queues, the service starting time, and the service completion time at each process, from which the distribution of waiting time and service time for each process can be accurately derived. This is useful for modelling and simulation where such information as patient arrival distribution, transition pattern within the system, and the service time distribution of each server is needed to prove the model can behave like the real system.

The final suggestion is to continue the research to focus in depth the VBA coding required to integrate Fuzzy Logic Control with ARENA® simulation software. This is because the complex integration that involves coding requires extensive research. Besides, this integration needs to be enhanced since not many researches have been conducted.

REFERENCES

[1] W. David Kelton, Randall P. Sadowski, David T. Sturrock, 2007 "Simulation with Arena", Mc Graw Hill, 4th Edition.

[2] Rockwell Automation, 2005, Arena User's Guide, Rockwell Software Inc.

[3] J.C. Lowery, 1996 "Design of hospital admissions scheduling system using simulation," wsc, pp.1199-1204, 1996 *Winter Simulation Conference (WSC'96)*

[4] Stephen Kropp, 2008, "Using Discrete Event Simulation (DES) to Model Software Development Process", Graduate Research - Q-Labs Business Process Modeling in Arena - Discrete Event Simulation.

[5] P.S. Welgama, R.G.J. Mills, 1995, "Use of simulation in the design of a JIT system", International Journal of Operations & Production Management, Volume: 15, Issue: 9 , pg. 245 – 260

[6] David Bregman, Dagan Gilat, Lion Levi, "The Use Of An Arena System In Developing And Implementing Readiness Of Hospital Management To Disastrous Situations", The College Of Management, Information Systems Dept., School Of Business Administration, Tel-Aviv, Israel.

[7] Ming Guo, M. Wagner, C. West, 2004, "Outpatient Clinic Scheduling - A Simulation Approach," wsc, vol. 2, pp.895-901, 2004 *Winter Simulation Conference (WSC'04) - Volume 2*

[8] Lisa Patvivatsi, Barbara M.P. Fraticelli and C. Patrick Koelling, 2003, "A Simulation-Based Approach for Optimal Nurse Scheduling in an Emergency Department"

[9] Jong (Brian) H. Jun, 1999, "A Visual Simulation Life-Cycle of the Question Physician Network", Faculty of the Virginia Polytechnic Institute and State University

[10] Qisheng Le And Gerald M. Knapp, 2003, "Incorporating Fuzzy Logic Admission Control In Simulation Models", The Industrial And Manufacturing Systems Engineering Department, The Louisiana State University, *Proceedings Of The 2003 Winter Simulation Conference.*

[11] Timothy J. Ross, 1997, "Fuzzy Logic with Engineering Application", McGraw-Hill International Edition.

[12] Jan Jantzen, 1998, "Design of Fuzzy Controllers", Department of Automation, Technical University of Denmark.

[13] W. David Kelton, Randall P. Sadowski, Deborah A. Sadowski, 1998. "Simulation with Arena", McGraw Hill, 4^{th} Edition.

[14] Dr. Hj. Ahmad Nordin bin Mohd Jais, Timbalan Pengarah Kesihatan Negeri (Perubatan), Jabatan Kesihatan Negeri Perak.

[15] Mr. Mohamad Zaki Shafie, Medical Assistant (U36), Hospital Seri Manjung, Perak.

[16] Jason H T Bates, Michael P Young, 2003, " Applying fuzzy logic to medical decision making in the intensive care unit ", American Journal of Respiratory and Critical Care Medicine, Volume: 167, Issue: 7, Pages: 948-952, PubMed ID: 12663335.

[17] Handout, Time Study and Line Balancing, 2006.

[18] Tom Zidel, 2006, "A Lean Guide to Transforming Healthcare – How to Implement Lean Proncples in Hospitals, Medical Offices, Clinic and Other Healthcare Organizations", American Society for Quality.

[19] Fabio Fruggiero, Alfredo Lambiase, Daithi Fallon , 2008, "Computer simulation and swarm intelligence organisation into an emergency department: a balancing approach across Ant Colony Optimisation", International Journal of Services Operations and Informatics 2008 - Vol. 3, No.2 pp. 142-161.

[20] Yuri Merkuryev, Jelena Pecherska, 2005, "Discrete Event Simulation: Methodology and Practice", Department of Modelling and Simulation, Riga Technical University.

[21] Ahad Ali, Xiaohui Chen, ZimingYang, JunNi, JayLee, 2008, "Optimized Maintenance Design for Manufacturing Performance Improvement Using Simulation", *Proceedings of the 2008 Winter Simulation Conference.*

[22] Eushiuan Tran , 1999, "Verification/Validation/Certification", Carnegie Mellon University , 18-849b Dependable Embedded Systems Spring.

[23] Nurul Faezah Mohhod, 2007, "Modelling and Simulation on Manufacturing System using ARENA", Universiti Teknologi Petronas.

[24] P.Y.K Chau, 1993, "Decision Support using Traditional Simulation and Visual Interactive Simulation", Inf. Decis. Technol, pg 63-76.

[25] Christof Weinhardt, Stefan Luckner, Jochen Stößer, 2009, "Designing E-Business Systems: Markets, Services, and Networks", Springer, 7th Workshop on E-Business, WEB 2008, Paris, France (December 13, 2008).

[26] Raper, J., Davis, B.A. & Scott, L, 1999, "Patient Satisfaction with Emergency department triage nursing care: Multicenter study", *Journal of Nursing Care Quality Assurance* 13(6): 11-24.

[27] Nebil Buyurgan, Can Saygin, 2005, "An integrated control framework for flexible manufacturing systems", Springer-Verlag London Limited 2005.

[27] Carson,]. S., 2002, "Model verification and validation", in Proceedings of the 2002 Winter Simulation Conference, (pp.52-58). New York: Association for Computing Machinery.

APPENDICES

APPENDIX I :

Request Letter to Conduct Research at Hospital Seri Manjung –

From Student to Hospital Seri Manjung

UNIVERSITI
TEKNOLOGI
PETRONAS

Nurul Atiqah Mat Ayus
Universiti Teknologi PETRONAS,
Bandar Sri Iskandar,
31750 Tronoh,
Perak, Malaysia

17th December 2009

Director,
Hospital Seri Manjung,
32040 Seri Manjung,
Perak, Malaysia

To whom it may concern,

REQUESTING TO CONDUCT AN INTERVIEW WITH HOSPITAL'S STAFF AND TO OBTAIN PATIENT'S ADMISSION INFORMATION

With regards to the above, I am a final year student of Universiti Teknologi PETRONAS (UTP) who is now conducting a Final Year Project (FYP) to complete a Bachelor's Degree Program. For your information my project is a research-based project entitled – A Fuzzy Logic Approach in Modeling and Simulation of a Scheduling System for Hospital Admissions Using Arena Software.

The main goal for this project is to overcome the problem faced by both patients and management of health care center, specifically hospital. Thus, in order to fulfill the objective, a simulated system based on practical situation needs to be developed through ARENA software.

For this project a model of a scheduling system for hospital admission is developed using ARENA using an engineering approach known as Fuzzy Logic. It is expected that the simulation model be able to simulate the hospital admission scheduling system to improve the efficiency of the system. This model will reflects the dynamic functioning of the hospital at times of patients' arrival till discharges. With this modeling and simulation approach, the alternative strategies produced can be compared and select the best based on simulation

The research has been narrowed down to remedy delay on patients' waiting times for appointment, eliminate delay in managing emergency cases, manipulating amount of staffs on duty to minimize patients' waiting times and the control of inpatient bed occupancy. Thus, I need to obtain some data from your management such as:

1. Detailed daily operations of patient arrivals
2. Level of urgency of the appointment, especially last minute request

3. Record of patient's arrival rate per day (walk-in and appointment)
4. Record of appointment made and approximate number of patients did not shown up per day and reschedule the appointment
5. Record of bed occupancy in two weeks
6. Record of resource / staff (doctor and nurse) on duty per day
7. Number of incoming request for appointment daily
8. Number of incoming emergency case daily
9. Number of beds to reserve for emergency admissions
10. Estimation the length of stay of patients prior to admissions

I would be grateful if you could allocate some time for the interview and allow me to obtain the data needed for my FYP research. I can assure you that the data will be kept as private and confidential by our institution.

Thank you for your consideration of this request.

Sincerely yours,

Nurul Atiqah Mat Ayus,
Electrical & Electronic Eng. Degree Program,
Universiti Teknologi PETRONAS.

Endorsed by,

Assoc. Prof. Dr. Nordin Saad,
FYP Supervisor,
Electrical & Electronic Eng. Department,
Universiti Teknologi PETRONAS.

APPENDIX II :

Request Letter to Conduct Research at Hospital Seri Manjung –

From FYP Coordinator to Hospital Seri Manjung

UNIVERSITI
TEKNOLOGI
PETRONAS

17th December 2009

To whom it may concern,

Dear Sir / Madam,

REQUESTING TO CONDUCT AN INTERVIEW WITH HOSPITAL'S STAFF AND TO OBTAIN PATIENT'S ADMISSION INFORMATION

The bearer of this letter is a student of Universiti Teknologi PETRONAS (UTP) who is now conducting a research for Final Year Project (FYP) on a scheduling system at your esteem establishment. The Final Year Project is a compulsory course in all engineering programs offered in UTP. For your information, FYP is a two-semester project which can be either on design or research – based. This course is an opportunity for students to use the tools and techniques of problem-solving to solve the problems they have encountered. Management concepts which provide students with skills required for managing a project are also incorporated. Thus, the students are expected to be well rounded by mastering various useful disciplines, which will enable them to participate and prepare for future employment.

The institution would be grateful if you could allocate some time for the interview and supply this student with the data needed for her FYP research. We can assure you that the data will be kept as private and confidential by our institution. Should you require a personal reference for this student, you may contact her project's supervisor, Assoc. Prof. Dr. Nordin Saad at 605-3687835 or e-mail: nordiss@petronas.com.my

Your contribution and support toward the success of UTP's program are highly appreciated.

Thank you.

Yours faithfully,

Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
Bandar Seri Iskandar 31750 Tronoh
Perak Darul Ridzuan
Tel: +605-368 7806 Fax: +605-365 7443
Website: http://www.utp.edu.my

Coordinator,
FYP Committee,
Electrical & Electronic Engineering Department,
Universiti Teknologi PETRONAS

APPENDIX III :

Approval Letter to Conduct Research at Hospital Seri Manjung –

From Jabatan Kesihatan Negeri Perak (JKN)

JABATAN KESIHATAN NEGERI,
PERAK DARUL RIDZUAN,
(PERAK STATE HEALTH DEPARTMENT),
JALAN PANGLIMA BUKIT GANTANG WAHAB,
30590 IPOH.

Telefon: 05-2084200
No. Fax: 05-2535660 (Pentadbiran)
05-2553136 (Sumb. Manusia)
05-2433420 (Kewangan)
05-2427564 (Kes. Awam)
05-2542916 (Perubatan)

Laman Web: jknperak.moh.gov.my
E-Mail: jknperak@prk.moh.gov.my

Ruj. Kami : Bil(67) dlm.JKN.PK 234/14 Jld.201
Tarikh : 29 Disember 2009

Cik Nur Atiqah Mat Ayus
Electrical & Electronic Engineer Degree Program
Universiti Teknologi Petronas

Puan,

PER : PERMOHONAN KELULUSAN UNTUK MENJALANKAN PROJEK PENYELIDIKAN DI HOSPITAL SERI MANJUNG

Dengan segala hormatnya perkara diatas adalah dirujuk.

2. Sukacita dimaklumkan bahawa, setelah menyemak objektif dan keperluan yang diperlukan, permohonan untuk menjalankan penyelidikan seperti permohonan yang telah dikemukakan melalui surat bertarikh 4hb Januari 2010 adalah diluluskan.

3. Walau bagaimanapun, perkara-perkara berikut perlulah dipatuhi:

3.1 Penyelidikan adalah semata-mata untuk keperluan pembelajaran / akademik yang diikuti.

3.2 Segala data, keputusan adalah untuk tujuan seperti dipohon, sebarang tujuan lain perlu mendapat kelulusan daripada Kementerian Kesihatan terlebih dahulu.

3.3 Sewaktu menjalani penyelidikan, tidak boleh dalam apa juga keadaan dan masa sekalipun menganggu tugas kakitangan dan proses rawatan/ perkhidmatan Hospital.

3.4 Presentasi dan penerbitan diluar tujuan yang disebutkan di dalam permohonan perlu mendapat kebenaran dari Ketua Pengarah Kesihatan terlebih dahulu.

3.5 Kelulusan hanya khusus untuk tempoh kajian ditetapkan dan perlu dipersetujui terlebih dahulu oleh Pengarah Hospital Seri Manjung.

3.6 Perlu mematuhi semua peraturan-peraturan yang ditetapkan oleh pihak Hospital Seri Manjung.

(SILA CATATKAN RUJUKAN JABATAN INI APABILA BERHUBUNG)

4. Keputusan ini boleh terbatal secara automatik sekiranya peraturan-peraturan yang ditetapkan tidak dipatuhi. Sebelum sebarang kajian dimulakan, perlulah melaporkan diri pada Pengarah Hospital Seri Manjung terlebih dahulu.

Sekian, terima kasih.

"PENYAYANG, KERJA BERPASUKAN DAN PROFESIONALISMA ADALAH BUDAYA KERJA KITA"

Saya yang menurut perintah,

(Dr. HJ. AHMAD NORDIN B. MOHD JAIS)
Timbalan Pengarah Kesihatan Negeri (Perubatan)
Jabatan Kesihatan Negeri
Perak Darul Ridzuan

s.k :
- Pengarah Hospital Seri Manjung
- Pn. Salina bt. Mohmad
  FYP Coordinator
  Electrical & Electronic Eng. Department
  Universiti Teknologi PETRONAS

APPENDIX IV :

CRYSTAL REPORT – MODEL 1

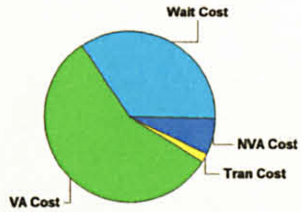
ency Room

tions: 1 Time Units: Minutes

Key Performance Indicators

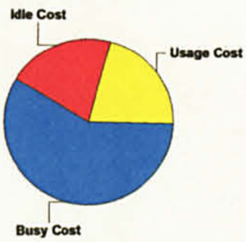
Entities

	Average
Non-Value Added Cost	1,775
Other Cost	0
Transfer Cost	420
Value Added Cost	14,591
Wait Cost	8,893
Total Cost	25,678



Resources

	Average
Busy Cost	18,878 *
Idle Cost	6,652
Usage Cost	6,800 *
Total Cost	32,330



* *these costs are included in Entity Costs above.*

stem

	Average
Total Cost	32,330
Number Out	272

rgency Room

cations: 1 Time Units: Minutes

y

e

ne	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	7.3943	(Insufficient)	0.00	26.5205
ident_Patient	9.8000	(Insufficient)	0.00	36.6234
ry_Patient	10.8222	(Insufficient)	0.00	34.4965
tient	8.0470	(Insufficient)	0.00	22.9018
Patient	8.8893	(Insufficient)	0.00	29.0257

ime	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	2.6488	(Insufficient)	0.00	9.7260
ident_Patient	5.9962	(Insufficient)	0.00	18.9560
ry_Patient	6.3196	(Insufficient)	0.00	18.3075
tient	6.0563	(Insufficient)	0.00	19.7448
Patient	5.7017	(Insufficient)	0.00	19.3253

ime	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	80.4712	(Insufficient)	0.00	287.39
ident_Patient	73.1080	(Insufficient)	0.00	391.31
ry_Patient	78.6047	(Insufficient)	0.00	395.67
tient	70.0384	(Insufficient)	0.00	388.51
Patient	78.0753	(Insufficient)	0.00	390.92

er Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	34.7250	(Insufficient)	30.0000	53.6565
ident_Patient	43.0000	(Insufficient)	30.0000	63.0000
ry_Patient	44.3846	(Insufficient)	30.0000	63.0000
tient	43.3158	(Insufficient)	30.0000	63.0000
Patient	42.8526	(Insufficient)	30.0000	63.0000

Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	0.00	(Insufficient)	0.00	0.00
ident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
tient	0.00	(Insufficient)	0.00	0.00
Patient	0.00	(Insufficient)	0.00	0.00

rgency Room

cations: 1 Time Units: Minutes

y

e

Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	135.24	(Insufficient)	30.0000	394.31
cident_Patient	143.72	(Insufficient)	30.0000	515.33
ry_Patient	153.21	(Insufficient)	30.0000	528.79
atient	139.56	(Insufficient)	30.0000	517.07
_Patient	147.20	(Insufficient)	30.0000	518.40

t

st	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	68.4705	(Insufficient)	0.00	251.60
cident_Patient	59.1853	(Insufficient)	0.00	271.45
ry_Patient	64.9610	(Insufficient)	0.00	226.90
atient	39.1670	(Insufficient)	0.00	121.66
_Patient	48.1440	(Insufficient)	0.00	187.40

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	6.6220	(Insufficient)	0.00	24.3151
cident_Patient	6.2590	(Insufficient)	0.00	18.6686
ry_Patient	6.7421	(Insufficient)	0.00	23.0276
atient	6.0549	(Insufficient)	0.00	23.3032
_Patient	5.6122	(Insufficient)	0.00	22.7675

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	22.3419	(Insufficient)	0.00	154.90
cident_Patient	26.6802	(Insufficient)	0.00	159.50
ry_Patient	40.1870	(Insufficient)	0.00	198.64
atient	33.0672	(Insufficient)	0.00	214.16
_Patient	26.1185	(Insufficient)	0.00	188.42

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	0.00	(Insufficient)	0.00	0.00
cident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
atient	0.00	(Insufficient)	0.00	0.00
_Patient	0.00	(Insufficient)	0.00	0.00

rgency Room

cations: 1 Time Units: Minutes

y

t

fer Cost

	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	46.6667	(Insufficient)	0.00	140.00
cident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
tient	0.00	(Insufficient)	0.00	0.00
Patient	0.00	(Insufficient)	0.00	0.00

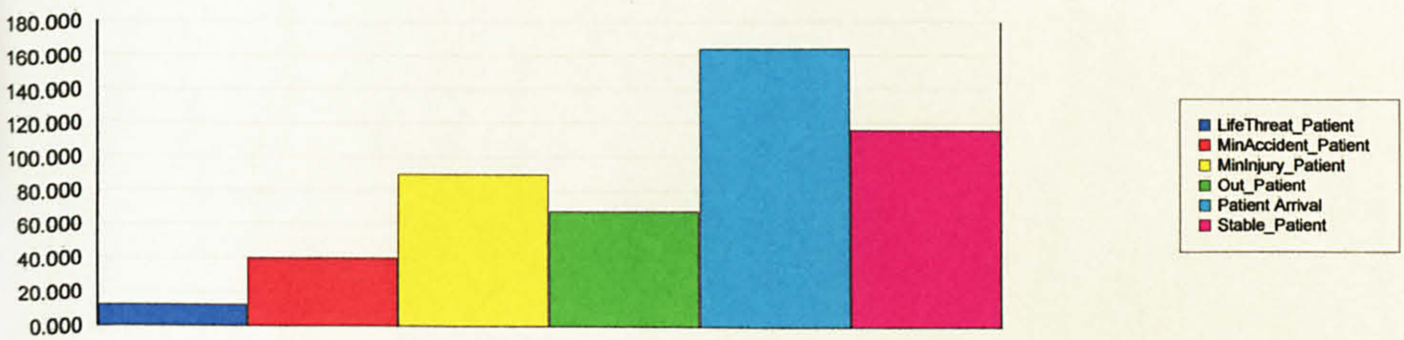
Cost

	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	144.10	(Insufficient)	0.00	563.17
cident_Patient	92.1245	(Insufficient)	0.00	446.08
ry_Patient	111.89	(Insufficient)	0.00	390.30
tient	78.2892	(Insufficient)	0.00	336.45
Patient	79.8747	(Insufficient)	0.00	398.59

er

er In

	Value
eat_Patient	12.0000
cident_Patient	40.0000
ry_Patient	90.0000
tient	68.0000
Arrival	164.00
Patient	116.00



rgency Room

cations: 1 Time Units: Minutes

y

er

ber Out

	Value
eat_Patient	9.0000
cident_Patient	33.0000
ury_Patient	78.0000
atient	57.0000
Arrival	164.00
_Patient	95.0000

	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	1.1597	(Insufficient)	0.00	4.0000
cident_Patient	3.9869	(Insufficient)	0.00	10.0000
ury_Patient	9.4786	(Insufficient)	0.00	16.0000
atient	6.6505	(Insufficient)	0.00	12.0000
Arrival	0.00	(Insufficient)	0.00	1.0000
_Patient	12.0511	(Insufficient)	0.00	23.0000

rgency Room

cations: 1 Time Units: Minutes

ess

e per Entity

me Per Entity	Average	Half Width	Minimum Value	Maximum Value
Evaluation	3.4410	(Insufficient)	2.0042	4.9960

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	7.3446	(Insufficient)	5.0157	9.9868

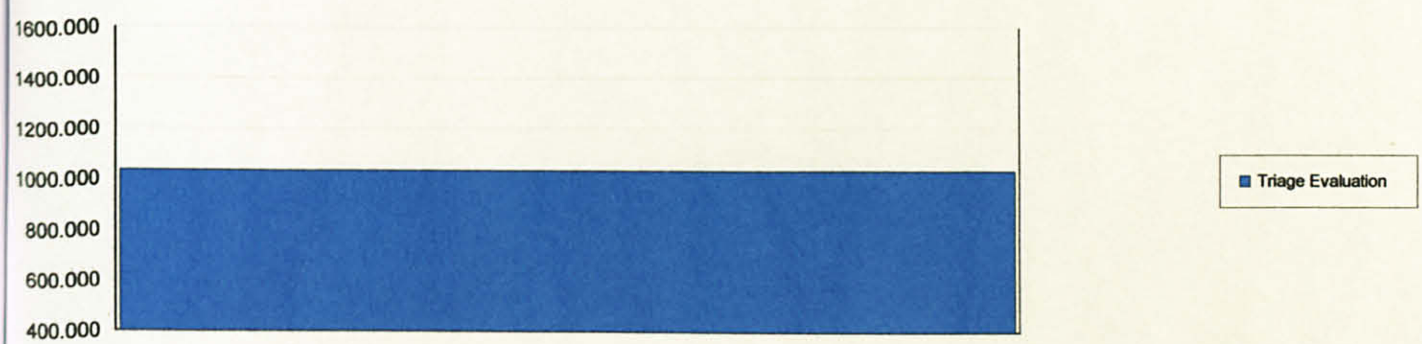
fer Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
Operation Theater	43.6751	(Insufficient)	32.2330	53.1565

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	0.05247553	(Insufficient)	0.00	1.6937
Operation Theater	226.99	(Insufficient)	172.57	277.70
Evaluation	3.0200	(Insufficient)	0.00	17.1143

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	7.3971	(Insufficient)	5.0157	11.3593
Operation Theater	270.66	(Insufficient)	225.73	323.34
Evaluation	6.4610	(Insufficient)	2.0229	21.9837

umulated Time

n VA Time	Value
Evaluation	1035.74



rgency Room

cations: 1 Time Units: Minutes

ess

umulated Time

n NVA Time

	Value
Admission	1109.04

n Transfer Time

	Value
Operation Theater	131.03

rgency Room

cations: 1 Time Units: Minutes

ess

umulated Time

n Wait Time

	Value
Admission	7.9238
Operation Theater	680.96
Evaluation	909.01

Accum Time

	Value
Admission	1116.96
Operation Theater	811.99
Evaluation	1944.75

t per Entity

ost Per Entity

	Average	Half Width	Minimum Value	Maximum Value
Evaluation	1.1470	(Insufficient)	0.6681	1.6653

rgency Room

cations: 1 Time Units: Minutes

ess

t per Entity

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	1.8362	(Insufficient)	1.2539	2.4967

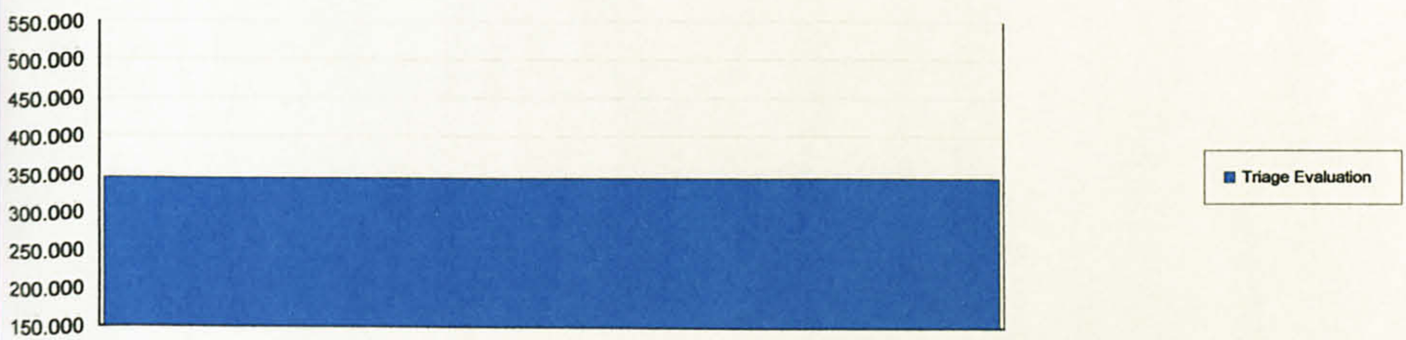
er Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
Operation Theater	140.00	(Insufficient)	140.00	140.00

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	0.00	(Insufficient)	0.00	0.00
Operation Theater	0.00	(Insufficient)	0.00	0.00
Evaluation	0.00	(Insufficient)	0.00	0.00

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
Admission	1.8362	(Insufficient)	1.2539	2.4967
Operation Theater	140.00	(Insufficient)	140.00	140.00
Evaluation	1.1470	(Insufficient)	0.6681	1.6653

umulated Cost

n VA Cost	Value
Evaluation	345.25



rgency Room

cations: 1 Time Units: Minutes

ess

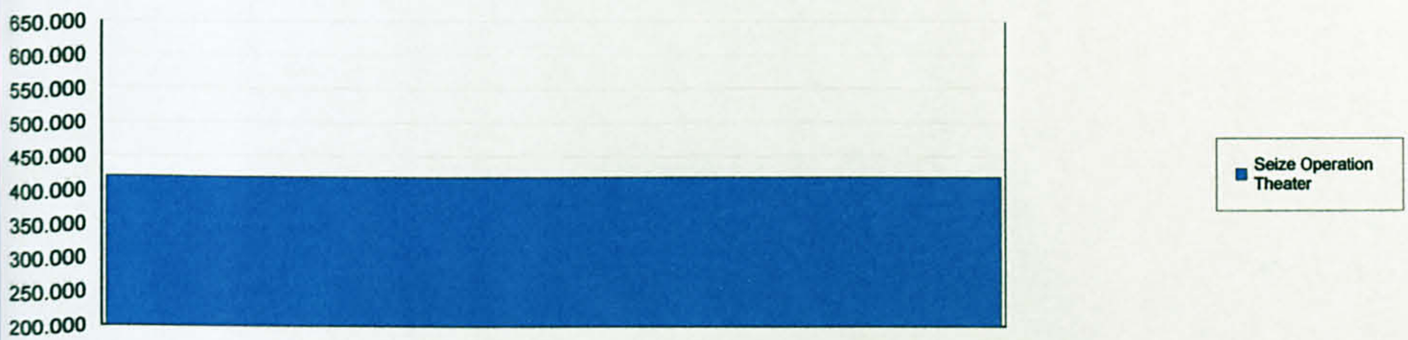
umulated Cost

n NVA Cost

	Value
Admission	277.26

n Transfer Cost

	Value
)peration Theater	420.00



n Wait Cost

	Value
Admission	0.00
)peration Theater	0.00
Evaluation	0.00

rgency Room

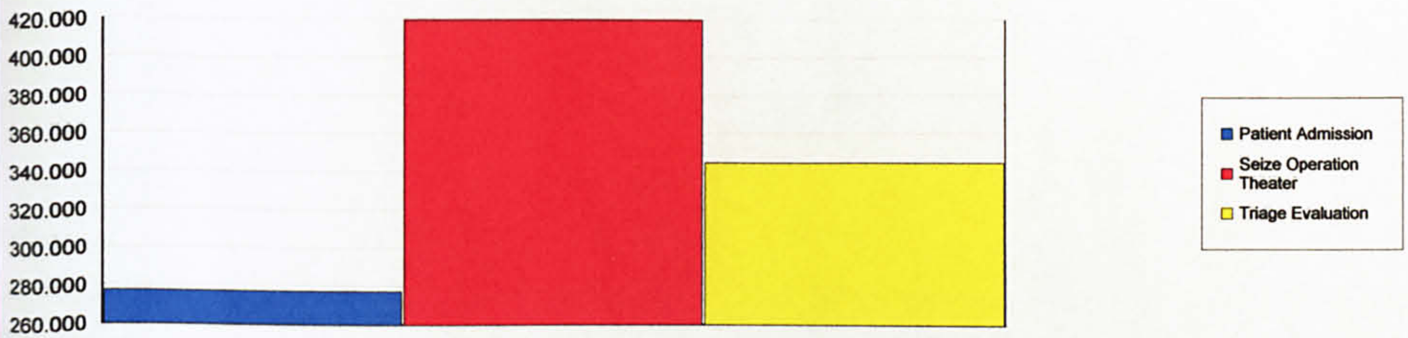
cations: 1 Time Units: Minutes

ess

umulated Cost

Accum Cost

	Value
Admission	277.26
Operation Theater	420.00
Evaluation	345.25



er

er In

	Value
Admission	152.00
Operation Theater	6.0000
Evaluation	305.00

er Out

	Value
Admission	151.00
Operation Theater	3.0000
Evaluation	301.00

rgency Room

cations: 1 Time Units: Minutes

ue

e

g Time	Average	Half Width	Minimum Value	Maximum Value
Admission.Queue	0.05213030	(Insufficient)	0.00	1.6937
Room	183.54	(Insufficient)	0.00	397.17
ed.Queue	0.00	(Insufficient)	0.00	0.00
octor.Queue	5.4094	(Insufficient)	0.00	40.1538
urse.Queue	0.2711	(Insufficient)	0.00	9.7326
peration Theater.Queue	226.99	(Insufficient)	172.57	277.70
Evaluation.Queue	3.0100	(Insufficient)	0.00	17.1143

t

g Cost	Average	Half Width	Minimum Value	Maximum Value
Admission.Queue	0.00	(Insufficient)	0.00	0.00
Room	0.00	(Insufficient)	0.00	0.00
ed.Queue	0.00	(Insufficient)	0.00	0.00
octor.Queue	22.1629	(Insufficient)	0.00	157.94
urse.Queue	0.4688	(Insufficient)	0.00	16.2210
peration Theater.Queue	0.00	(Insufficient)	0.00	0.00
Evaluation.Queue	0.00	(Insufficient)	0.00	0.00

er

er Waiting	Average	Half Width	Minimum Value	Maximum Value
Admission.Queue	0.00550264	(Insufficient)	0.00	1.0000
Room	18.5891	(Insufficient)	0.00	37.0000
ed.Queue	0.00	(Insufficient)	0.00	0.00
octor.Queue	0.4215	(Insufficient)	0.00	2.0000
urse.Queue	0.02108177	(Insufficient)	0.00	1.0000
peration Theater.Queue	0.8416	(Insufficient)	0.00	3.0000
Evaluation.Queue	0.6327	(Correlated)	0.00	5.0000

rgency Room

cations: 1 Time Units: Minutes

urce

ge

taneous Utilization	Average	Half Width	Minimum Value	Maximum Value
	0.4955	0.071072778	0.00	1.0000
	0.2778	0.060413522	0.00	1.0000
	0.4599	(Correlated)	0.00	1.0000
	0.4618	(Correlated)	0.00	1.0000
	0.4543	(Insufficient)	0.00	1.0000
	0.4516	0.082866715	0.00	1.0000
	0.7936	(Correlated)	0.00	1.0000
	0.00	0.000000000	0.00	0.00
	0.00	0.000000000	0.00	0.00
	0.5652	0.093581875	0.00	1.0000
	0.5629	0.095604865	0.00	1.0000
	0.5563	(Correlated)	0.00	1.0000
	0.00	0.000000000	0.00	0.00
	0.00	0.000000000	0.00	0.00
	0.9272	(Insufficient)	0.00	1.0000
	0.4502	0.094575306	0.00	1.0000
	0.9447	(Insufficient)	0.00	1.0000
	0.9410	(Insufficient)	0.00	1.0000
	0.9335	(Insufficient)	0.00	1.0000
	0.9295	(Insufficient)	0.00	1.0000
urse	0.7217	0.087397809	0.00	1.0000

rgency Room

cations: 1 Time Units: Minutes

urce

ge

er Busy

	Average	Half Width	Minimum Value	Maximum Value
	0.4955	(Insufficient)	0.00	1.0000
	0.2778	(Insufficient)	0.00	1.0000
	0.4599	(Insufficient)	0.00	1.0000
	0.4618	(Insufficient)	0.00	1.0000
	0.4543	(Insufficient)	0.00	1.0000
	0.4516	(Insufficient)	0.00	1.0000
	0.7936	(Insufficient)	0.00	1.0000
	0.00	(Insufficient)	0.00	0.00
	0.00	(Insufficient)	0.00	0.00
	0.5652	(Insufficient)	0.00	1.0000
	0.5629	(Insufficient)	0.00	1.0000
	0.5563	(Insufficient)	0.00	1.0000
	0.00	(Insufficient)	0.00	0.00
	0.00	(Insufficient)	0.00	0.00
	0.9272	(Insufficient)	0.00	1.0000
	0.4502	(Insufficient)	0.00	1.0000
	0.9447	(Insufficient)	0.00	1.0000
	0.9410	(Insufficient)	0.00	1.0000
	0.9335	(Insufficient)	0.00	1.0000
	0.9295	(Insufficient)	0.00	1.0000
urse	0.7217	0.087397809	0.00	1.0000

rgency Room

cations: 1 Time Units: Minutes

urce

ge

ter Scheduled

	Average	Half Width	Minimum Value	Maximum Value
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
1	1.0000	(Insufficient)	1.0000	1.0000
2	0.00	(Insufficient)	0.00	0.00
3	0.00	(Insufficient)	0.00	0.00
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
3	1.0000	(Insufficient)	1.0000	1.0000
4	0.00	(Insufficient)	0.00	0.00
5	0.00	(Insufficient)	0.00	0.00
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
3	1.0000	(Insufficient)	1.0000	1.0000
4	1.0000	(Insufficient)	1.0000	1.0000
urse	1.0000	(Insufficient)	1.0000	1.0000

rgency Room

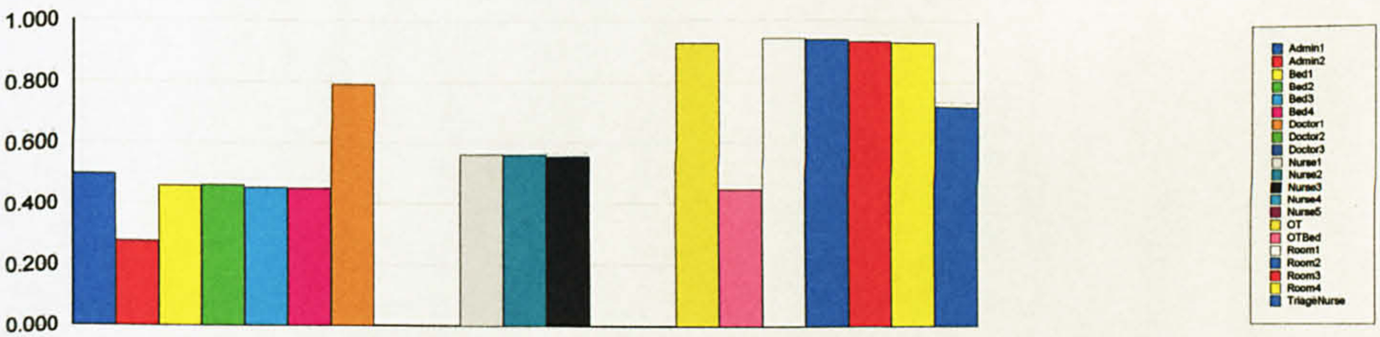
cations: 1 Time Units: Minutes

urce

ge

uled Utilization

	Value
	0.4955
	0.2778
	0.4599
	0.4618
	0.4543
	0.4516
	0.7936
	0.00
	0.00
	0.5652
	0.5629
	0.5563
	0.00
	0.00
	0.9272
	0.4502
	0.9447
	0.9410
	0.9335
	0.9295
urse	0.7217



rgency Room

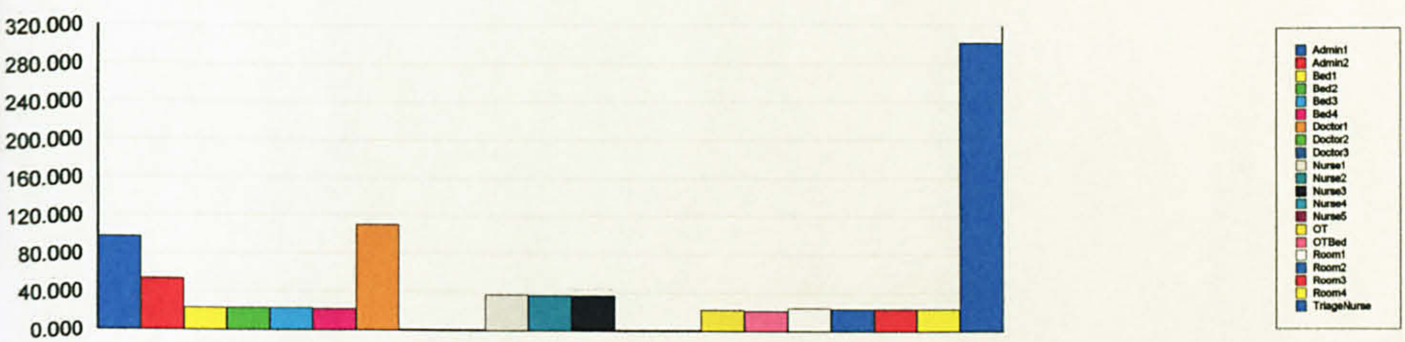
cations: 1 Time Units: Minutes

urce

ge

Number Seized

	Value
	98.0000
	54.0000
	23.0000
	23.0000
	23.0000
	22.0000
	111.00
	0.00
	0.00
	38.0000
	37.0000
	37.0000
	0.00
	0.00
	22.0000
	21.0000
	24.0000
	23.0000
	23.0000
	23.0000
urse	302.00



t

rgency Room

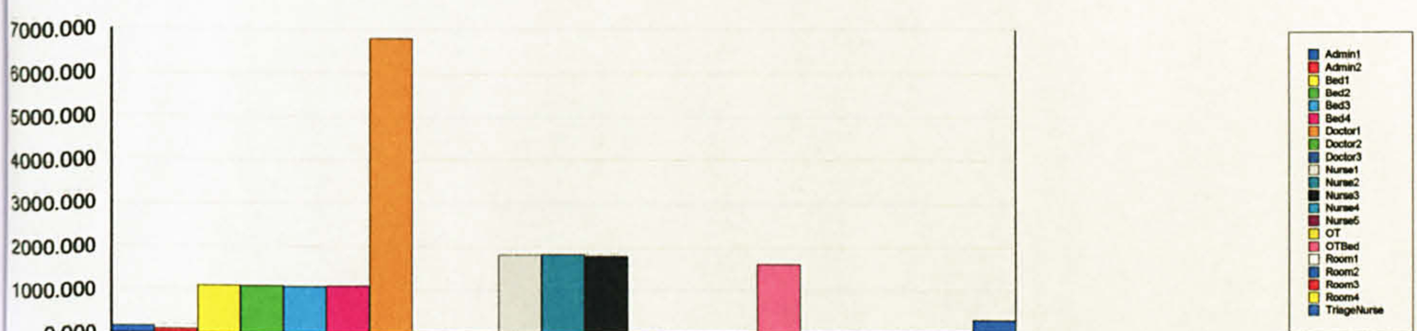
cations: 1 Time Units: Minutes

urce

t

Cost

	Value
	177.25
	100.01
	1103.78
	1094.80
	1079.50
	1083.86
	6808.37
	0.00
	0.00
	1829.90
	1837.21
	1797.34
	0.00
	0.00
	0.00
	1620.60
	0.00
	0.00
	0.00
	0.00
urse	345.25



rgency Room

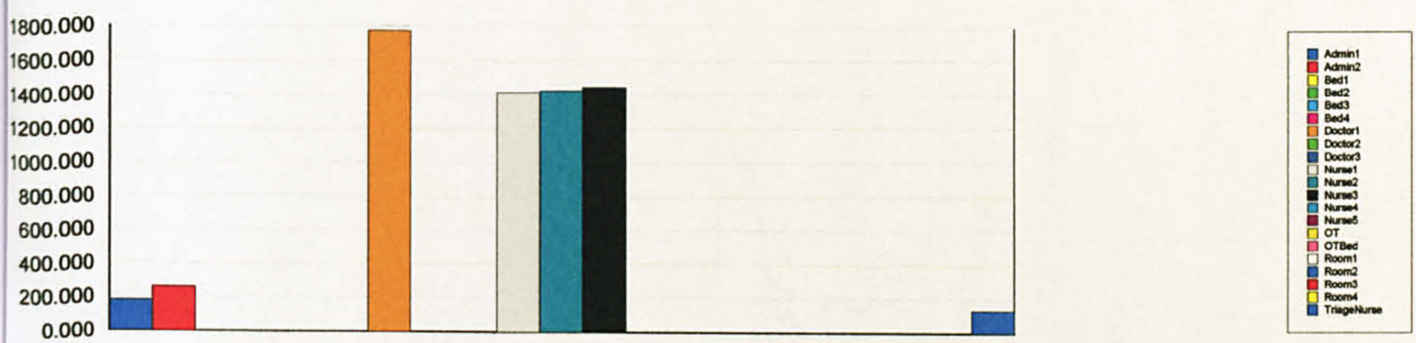
cations: 1 Time Units: Minutes

urce

t

ost

	Value
	181.62
	259.99
	0.00
	0.00
	0.00
	0.00
	1783.00
	0.00
	0.00
	1419.23
	1426.79
	1448.29
	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
urse	133.56



rgency Room

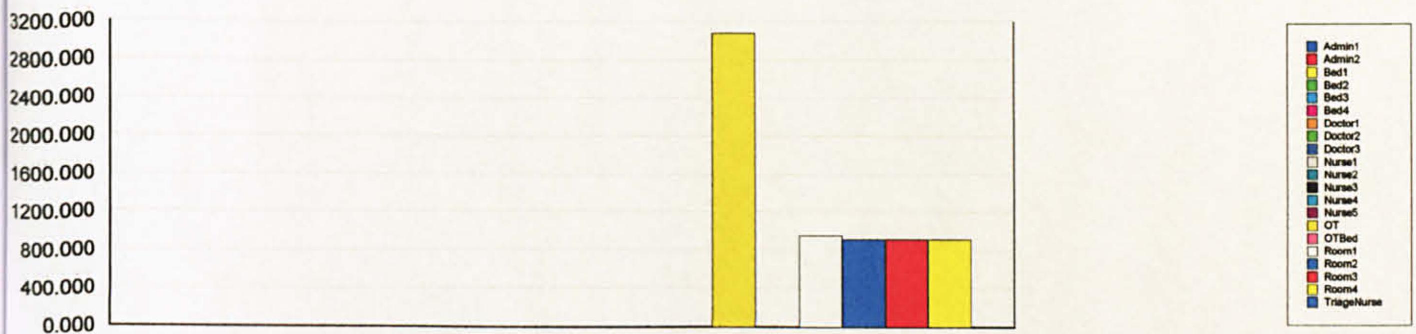
ications: 1 Time Units: Minutes

urce

t

e Cost

	Value
1	0.00
2	0.00
	0.00
	0.00
	0.00
	0.00
1	0.00
2	0.00
3	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
	3080.00
	0.00
	960.00
	920.00
	920.00
	920.00
urse	0.00



rgency Room

cations: 1 Time Units: Minutes

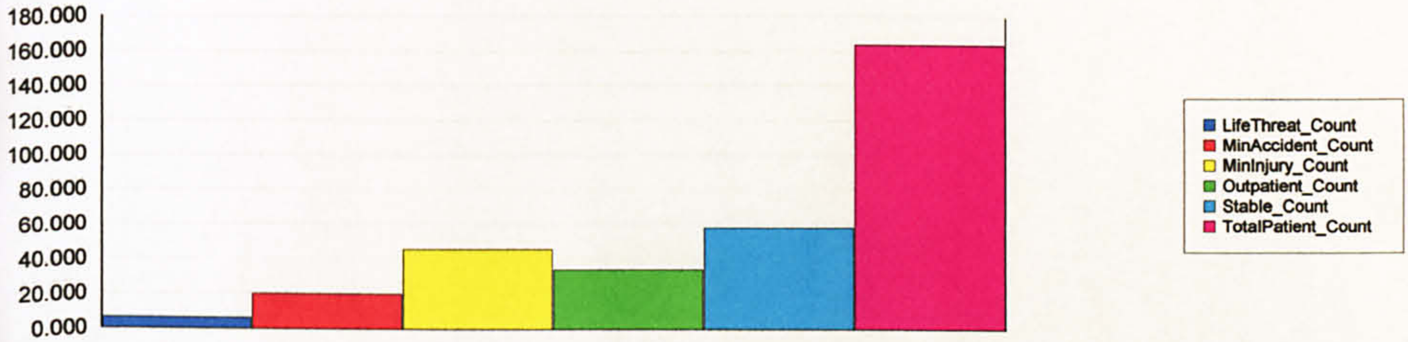
Specified

y

al	Average	Half Width	Minimum Value	Maximum Value
_Time_Interval	318.09	(Insufficient)	128.19	528.79

nter

	Value
eat_Count	6.0000
cident_Count	20.0000
ry_Count	46.0000
ent_Count	34.0000
Count	58.0000
atient_Count	164.00



Persistent

Persistent	Average	Half Width	Minimum Value	Maximum Value
NurseBusy	0.7217	(Insufficient)	0.00	1.0000

APPENDIX V :

CRYSTAL REPORT – MODEL 2

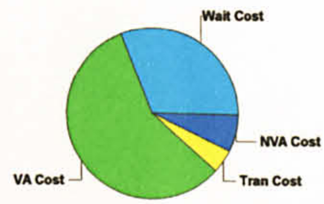
rgency Room

cations: 1 Time Units: Minutes

Key Performance Indicators

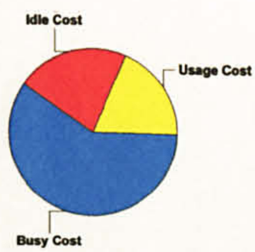
ll Entities

	Average
Non-Value Added Cost	1,696
Other Cost	0
Transfer Cost	1,120
Value Added Cost	13,999
Wait Cost	7,621
Total Cost	24,436



ll Resources

	Average
Busy Cost	18,536 *
Idle Cost	6,784
Usage Cost	5,900 *
Total Cost	31,220



* *these costs are included in Entity Costs above.*

ystem

	Average
Total Cost	31,220
Number Out	290

rgency Room

cations: 1 Time Units: Minutes

y

e

ne	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	9.6049	(Insufficient)	0.00	29.9607
ident_Patient	6.9188	(Insufficient)	0.00	36.6384
ry_Patient	8.1078	(Insufficient)	0.00	33.9309
tient	7.1238	(Insufficient)	0.00	23.8060
Patient	8.7482	(Insufficient)	0.00	28.1568

ime	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	3.2766	(Insufficient)	0.00	9.3994
ident_Patient	3.4048	(Insufficient)	0.00	15.7569
ry_Patient	4.7305	(Insufficient)	0.00	18.9330
tient	5.3486	(Insufficient)	0.00	18.8342
Patient	5.3964	(Insufficient)	0.00	18.2694

ime	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	111.69	(Insufficient)	0.00	483.77
ident_Patient	70.5478	(Insufficient)	0.00	565.43
ry_Patient	94.8930	(Insufficient)	0.00	516.59
tient	88.1436	(Insufficient)	0.00	579.04
Patient	97.2153	(Insufficient)	0.00	555.91

er Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	43.0486	(Insufficient)	30.0000	70.5052
ident_Patient	60.6818	(Insufficient)	60.0000	63.0000
ry_Patient	60.9750	(Insufficient)	60.0000	63.0000
tient	61.0313	(Insufficient)	60.0000	63.0000
Patient	61.1038	(Insufficient)	60.0000	63.0000

Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	0.00	(Insufficient)	0.00	0.00
ident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
tient	0.00	(Insufficient)	0.00	0.00
Patient	0.00	(Insufficient)	0.00	0.00

rgency Room

ications: 1 Time Units: Minutes

y

e

Time	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	180.95	(Insufficient)	30.0000	619.94
cident_Patient	155.19	(Insufficient)	60.0000	730.80
ry_Patient	188.21	(Insufficient)	60.0000	673.77
atient	182.27	(Insufficient)	60.0000	742.06
Patient	194.54	(Insufficient)	60.0000	721.38

t

ost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	88.1285	(Insufficient)	0.00	285.08
cident_Patient	45.0901	(Insufficient)	0.00	266.46
ry_Patient	47.5786	(Insufficient)	0.00	235.80
atient	34.6255	(Insufficient)	0.00	126.27
Patient	48.6602	(Insufficient)	0.00	188.63

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	8.1914	(Insufficient)	0.00	23.4984
cident_Patient	3.5031	(Insufficient)	0.00	17.8619
ry_Patient	4.7605	(Insufficient)	0.00	26.3058
atient	5.1412	(Insufficient)	0.00	18.1084
Patient	5.5059	(Insufficient)	0.00	24.7573

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	15.8548	(Insufficient)	0.00	91.8858
cident_Patient	10.4071	(Insufficient)	0.00	55.9211
ry_Patient	22.8332	(Insufficient)	0.00	163.35
atient	24.4819	(Insufficient)	0.00	136.21
Patient	32.0243	(Insufficient)	0.00	194.91

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	0.00	(Insufficient)	0.00	0.00
cident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
atient	0.00	(Insufficient)	0.00	0.00
Patient	0.00	(Insufficient)	0.00	0.00

rgency Room

ications: 1 Time Units: Minutes

y

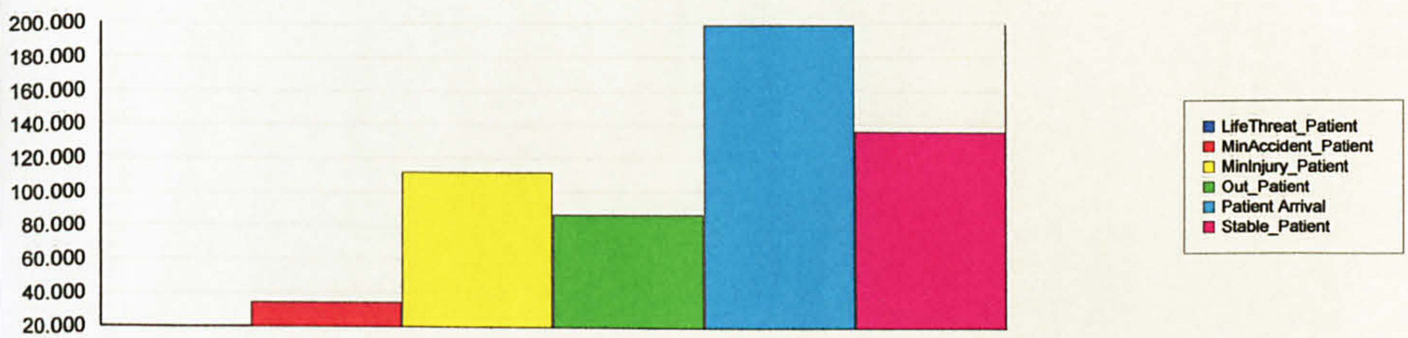
t

fer Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	62.2222	(Insufficient)	0.00	140.00
ident_Patient	0.00	(Insufficient)	0.00	0.00
ry_Patient	0.00	(Insufficient)	0.00	0.00
tient	0.00	(Insufficient)	0.00	0.00
Patient	0.00	(Insufficient)	0.00	0.00

Cost	Average	Half Width	Minimum Value	Maximum Value
eat_Patient	174.40	(Insufficient)	0.00	500.39
ident_Patient	59.0003	(Insufficient)	0.00	334.55
ry_Patient	75.1723	(Insufficient)	0.00	410.80
tient	64.2486	(Insufficient)	0.00	257.28
Patient	86.1904	(Insufficient)	0.00	408.30

er

er In	Value
eat_Patient	20.0000
ident_Patient	34.0000
ry_Patient	112.00
tient	87.0000
Arrival	199.00
Patient	136.00



rgency Room

lications: 1 Time Units: Minutes

ty

er

ber Out

	Value
reat_Patient	18.0000
cident_Patient	22.0000
ry_Patient	79.0000
atient	64.0000
Arrival	199.00
_Patient	106.00

	Average	Half Width	Minimum Value	Maximum Value
reat_Patient	2.5598	(Insufficient)	0.00	5.0000
cident_Patient	5.8202	(Insufficient)	0.00	15.0000
ry_Patient	16.5927	(Insufficient)	0.00	33.0000
atient	12.1251	(Insufficient)	0.00	24.0000
Arrival	0.00	(Insufficient)	0.00	1.0000
_Patient	19.3474	(Insufficient)	0.00	32.0000

ergency Room

lications: 1 Time Units: Minutes

cess

e per Entity

ime Per Entity	Average	Half Width	Minimum Value	Maximum Value
Evaluation	3.5134	0.105859509	2.0042	4.9933

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	7.3001	(Insufficient)	5.0139	9.8701

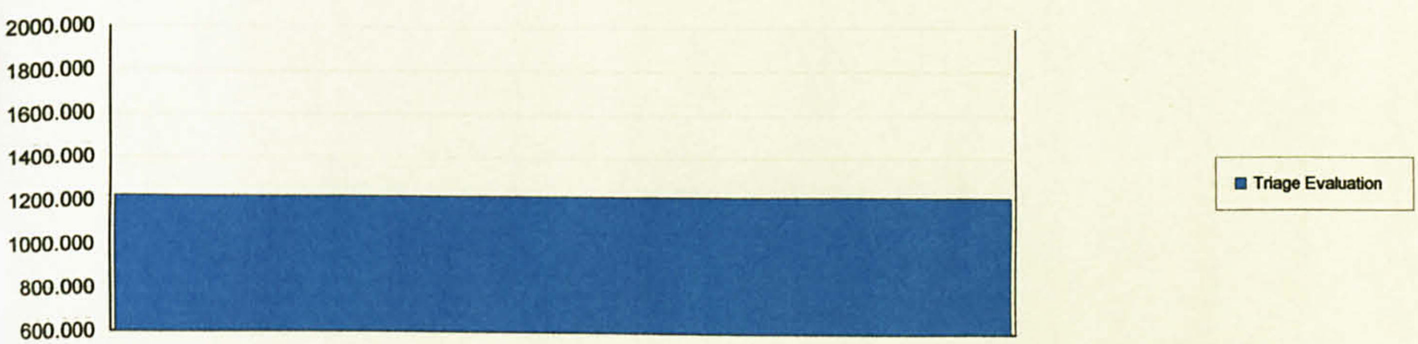
sfer Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
Operation Theater	58.8595	(Insufficient)	44.5787	70.0052

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	0.2147	(Insufficient)	0.00	3.8567
Operation Theater	243.53	(Insufficient)	15.6073	469.86
Evaluation	12.9687	(Correlated)	0.00	44.3323

Time Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	7.5148	(Insufficient)	5.0139	13.3368
Operation Theater	302.39	(Insufficient)	74.9176	537.29
Evaluation	16.4821	(Correlated)	2.0538	49.2105

umulated Time

m VA Time	Value
Evaluation	1226.16



ergency Room

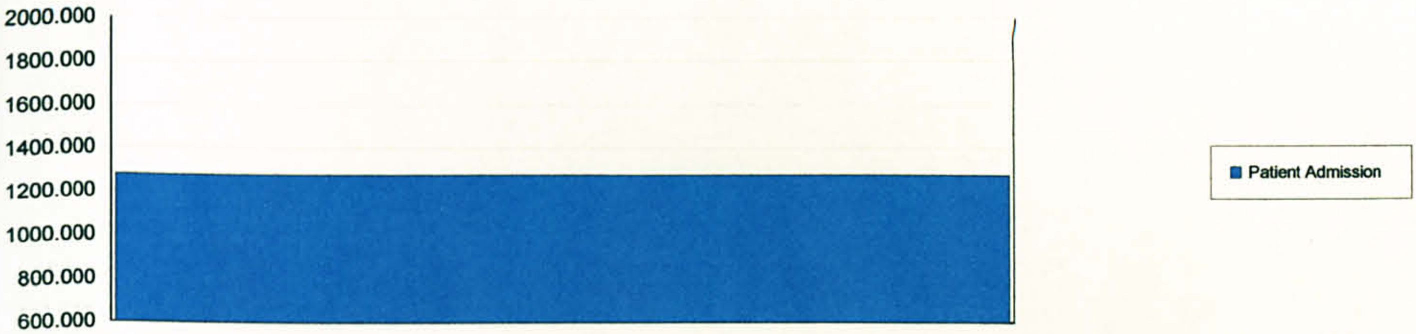
lications: 1 Time Units: Minutes

ess

umulated Time

m NVA Time

	Value
t Admission	1277.51



m Transfer Time

	Value
Operation Theater	470.88

rgency Room

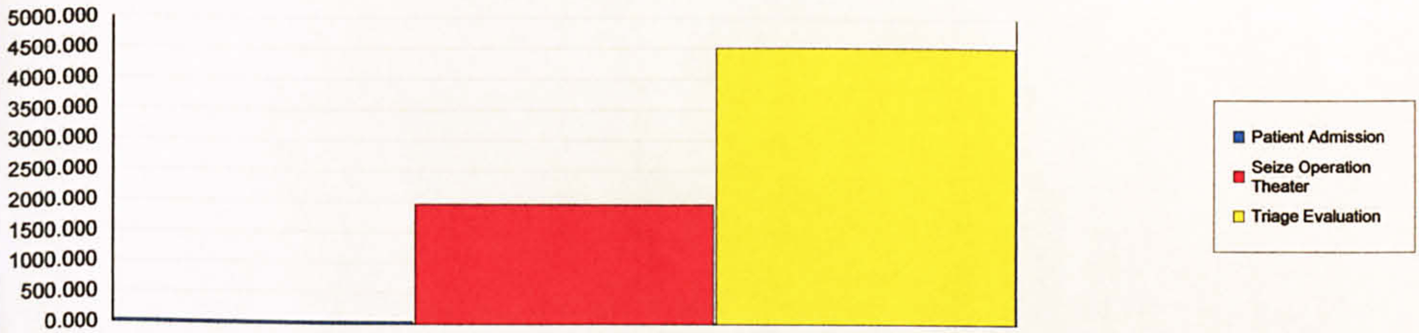
lications: 1 Time Units: Minutes

ess

umulated Time

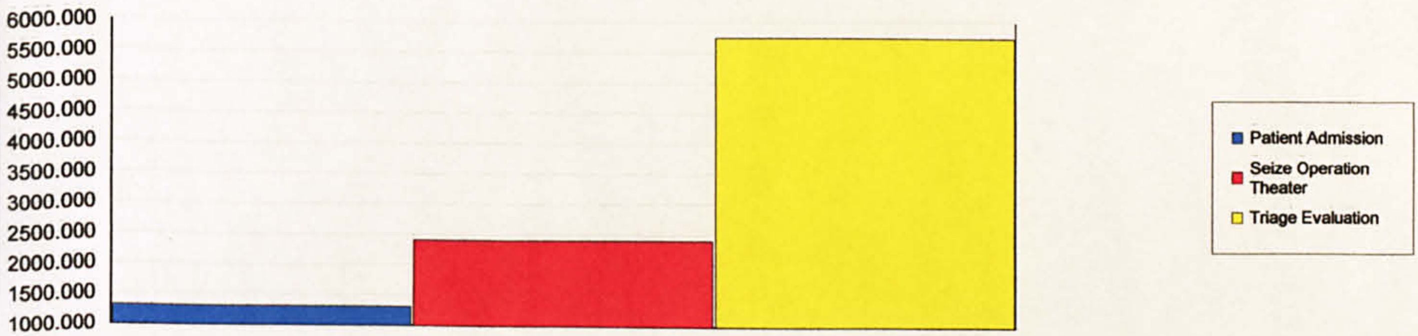
m Wait Time

	Value
t Admission	37.5728
Operation Theater	1948.25
Evaluation	4526.08



Accum Time

	Value
t Admission	1315.09
Operation Theater	2419.13
Evaluation	5752.24



t per Entity

ost Per Entity

	Average	Half Width	Minimum Value	Maximum Value
Evaluation	1.1711	0.035286503	0.6681	1.6644

rgency Room

lications: 1 Time Units: Minutes

ess

t per Entity

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	1.8250	(Insufficient)	1.2535	2.4675

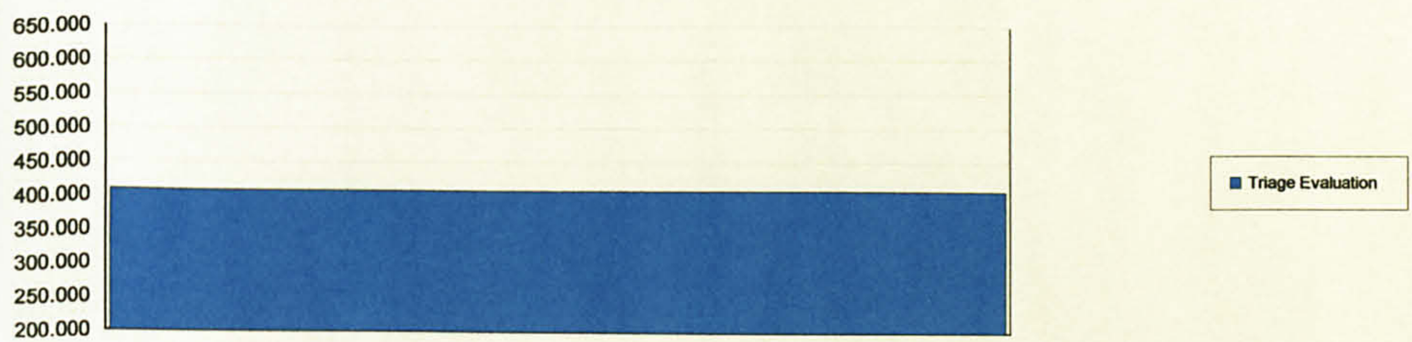
sfer Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
Operation Theater	140.00	(Insufficient)	140.00	140.00

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	0.00	(Insufficient)	0.00	0.00
Operation Theater	0.00	(Insufficient)	0.00	0.00
Evaluation	0.00	0.000000000	0.00	0.00

Cost Per Entity	Average	Half Width	Minimum Value	Maximum Value
t Admission	1.8250	(Insufficient)	1.2535	2.4675
Operation Theater	140.00	(Insufficient)	140.00	140.00
Evaluation	1.1711	0.035286503	0.6681	1.6644

umulated Cost

m VA Cost	Value
Evaluation	408.72



rgency Room

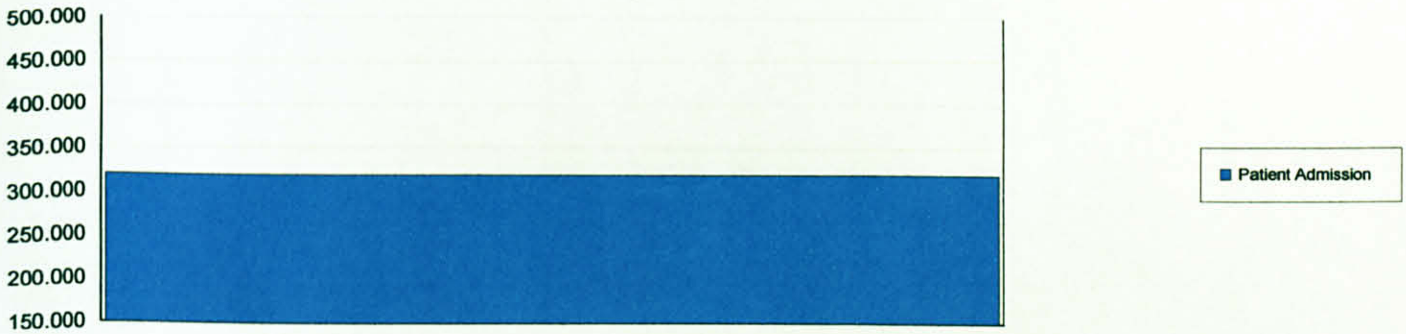
ications: 1 Time Units: Minutes

ess

umulated Cost

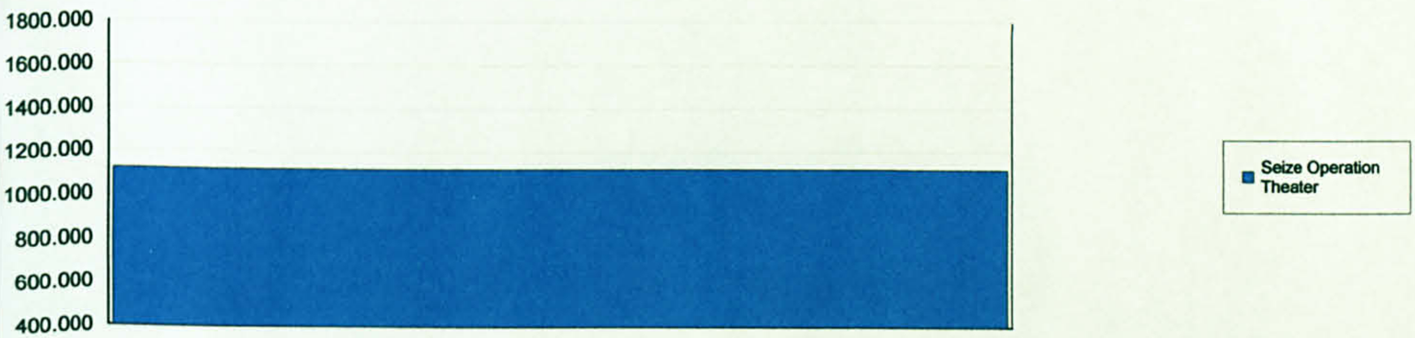
m NVA Cost

	Value
t Admission	319.38



m Transfer Cost

	Value
Operation Theater	1120.00



m Wait Cost

	Value
t Admission	0.00
Operation Theater	0.00
Evaluation	0.00

ergency Room

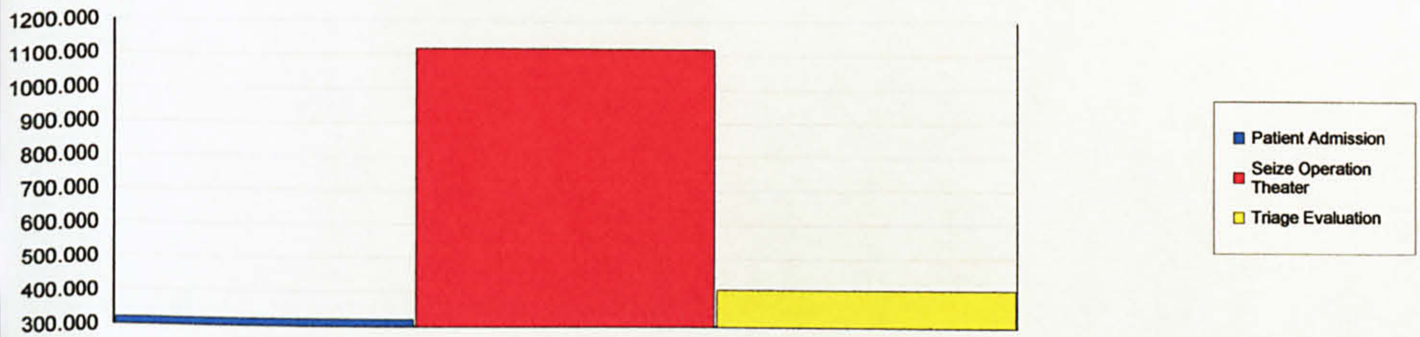
lications: 1 Time Units: Minutes

ess

cumulated Cost

Accum Cost

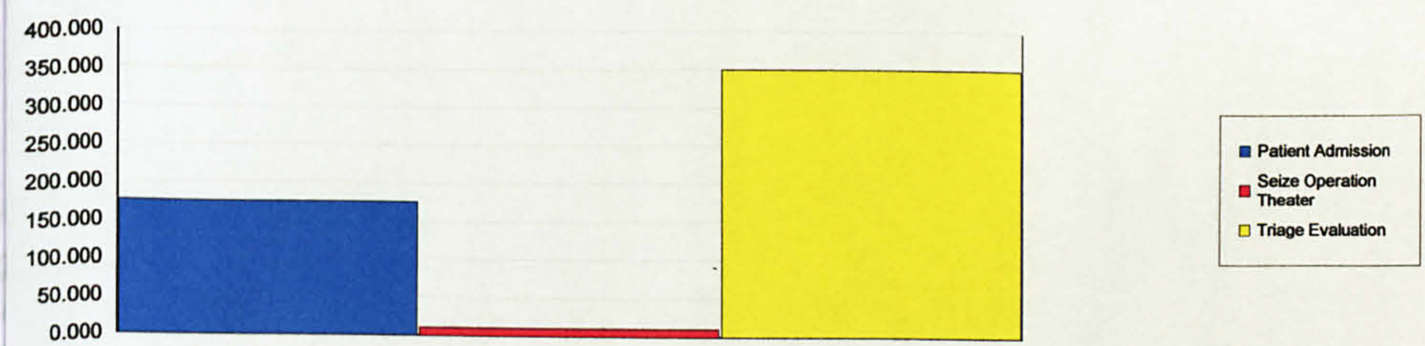
	Value
t Admission	319.38
Operation Theater	1120.00
Evaluation	408.72



er

ber In

	Value
t Admission	176.00
Operation Theater	10.0000
Evaluation	351.00



ber Out

	Value
t Admission	175.00
Operation Theater	8.0000
Evaluation	349.00

rgency Room

lications: 1 Time Units: Minutes

ue

e

ng Time	Average	Half Width	Minimum Value	Maximum Value
t Admission.Queue	0.2135	(Insufficient)	0.00	3.8567
e Room	263.95	(Insufficient)	0.00	538.26
Bed.Queue	0.00	(Insufficient)	0.00	0.00
Doctor.Queue	6.6983	(Insufficient)	0.00	25.1982
Nurse.Queue	0.5881	(Insufficient)	0.00	12.6120
Operation Theater.Queue	243.53	(Insufficient)	15.6073	469.86
Evaluation.Queue	12.9317	(Correlated)	0.00	44.3323

t

ng Cost	Average	Half Width	Minimum Value	Maximum Value
t Admission.Queue	0.00	(Insufficient)	0.00	0.00
e Room	0.00	(Insufficient)	0.00	0.00
Bed.Queue	0.00	(Insufficient)	0.00	0.00
Doctor.Queue	27.1028	(Insufficient)	0.00	99.11
Nurse.Queue	1.0184	(Insufficient)	0.00	21.0201
Operation Theater.Queue	0.00	(Insufficient)	0.00	0.00
Evaluation.Queue	0.00	0.000000000	0.00	0.00

er

ber Waiting	Average	Half Width	Minimum Value	Maximum Value
t Admission.Queue	0.02609221	(Insufficient)	0.00	2.0000
e Room	32.9398	(Insufficient)	0.00	73.0000
Bed.Queue	0.00	(Insufficient)	0.00	0.00
Doctor.Queue	0.4737	(Insufficient)	0.00	2.0000
Nurse.Queue	0.04165463	(Insufficient)	0.00	1.0000
Operation Theater.Queue	1.8037	(Insufficient)	0.00	4.0000
Evaluation.Queue	3.1443	(Correlated)	0.00	14.0000

ergency Room

lications: 1 Time Units: Minutes

ource

age

ntaneous Utilization

	Average	Half Width	Minimum Value	Maximum Value
1	0.5618	0.084005618	0.00	1.0000
2	0.3264	0.071435551	0.00	1.0000
	0.4628	(Correlated)	0.00	1.0000
	0.4607	(Correlated)	0.00	1.0000
	0.4649	(Insufficient)	0.00	1.0000
	0.4679	(Correlated)	0.00	1.0000
r1	0.7726	(Correlated)	0.00	1.0000
1	0.5357	(Correlated)	0.00	1.0000
2	0.5831	(Correlated)	0.00	1.0000
3	0.5491	0.106628921	0.00	1.0000
	0.9043	(Insufficient)	0.00	1.0000
d	0.3870	0.098926848	0.00	1.0000
1	0.9211	(Insufficient)	0.00	1.0000
2	0.9191	(Insufficient)	0.00	1.0000
3	0.9165	(Insufficient)	0.00	1.0000
4	0.9136	(Insufficient)	0.00	1.0000
eNurse	0.8528	(Correlated)	0.00	1.0000

ber Busy

	Average	Half Width	Minimum Value	Maximum Value
1	0.5618	(Insufficient)	0.00	1.0000
2	0.3264	(Insufficient)	0.00	1.0000
	0.4628	(Insufficient)	0.00	1.0000
	0.4607	(Insufficient)	0.00	1.0000
	0.4649	(Insufficient)	0.00	1.0000
	0.4679	(Insufficient)	0.00	1.0000
r1	0.7726	(Insufficient)	0.00	1.0000
1	0.5357	(Insufficient)	0.00	1.0000
2	0.5831	(Insufficient)	0.00	1.0000
3	0.5491	(Insufficient)	0.00	1.0000
	0.9043	(Insufficient)	0.00	1.0000
d	0.3870	(Insufficient)	0.00	1.0000
h1	0.9211	(Insufficient)	0.00	1.0000
h2	0.9191	(Insufficient)	0.00	1.0000
h3	0.9165	(Insufficient)	0.00	1.0000
h4	0.9136	(Insufficient)	0.00	1.0000
eNurse	0.8528	(Correlated)	0.00	1.0000

rgency Room

lications: 1 Time Units: Minutes

ource

age

ber Scheduled	Average	Half Width	Minimum Value	Maximum Value
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
r1	1.0000	(Insufficient)	1.0000	1.0000
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
3	1.0000	(Insufficient)	1.0000	1.0000
	1.0000	(Insufficient)	1.0000	1.0000
d	1.0000	(Insufficient)	1.0000	1.0000
1	1.0000	(Insufficient)	1.0000	1.0000
2	1.0000	(Insufficient)	1.0000	1.0000
3	1.0000	(Insufficient)	1.0000	1.0000
4	1.0000	(Insufficient)	1.0000	1.0000
Nurse	1.0000	(Insufficient)	1.0000	1.0000

rgency Room

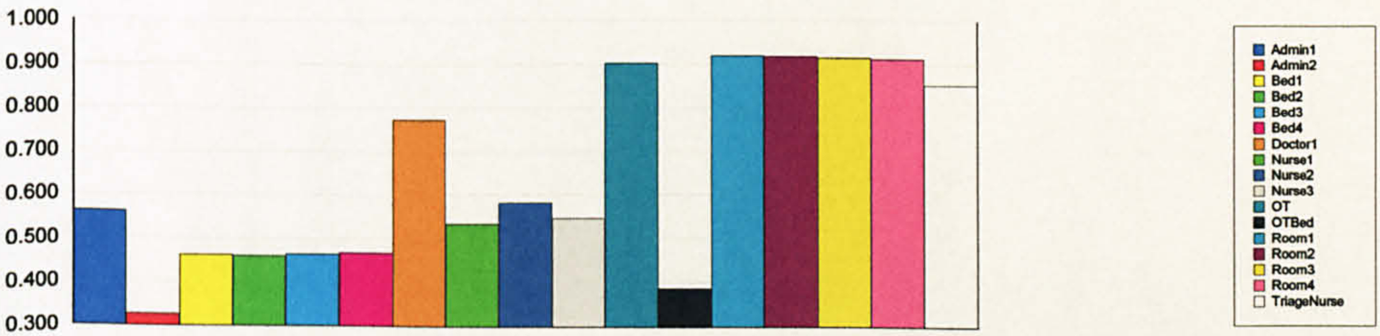
lications: 1 Time Units: Minutes

ource

ge

duled Utilization

	Value
1	0.5618
2	0.3264
	0.4628
	0.4607
	0.4649
	0.4679
1	0.7726
1	0.5357
2	0.5831
3	0.5491
	0.9043
d	0.3870
1	0.9211
2	0.9191
3	0.9165
4	0.9136
Nurse	0.8528



rgency Room

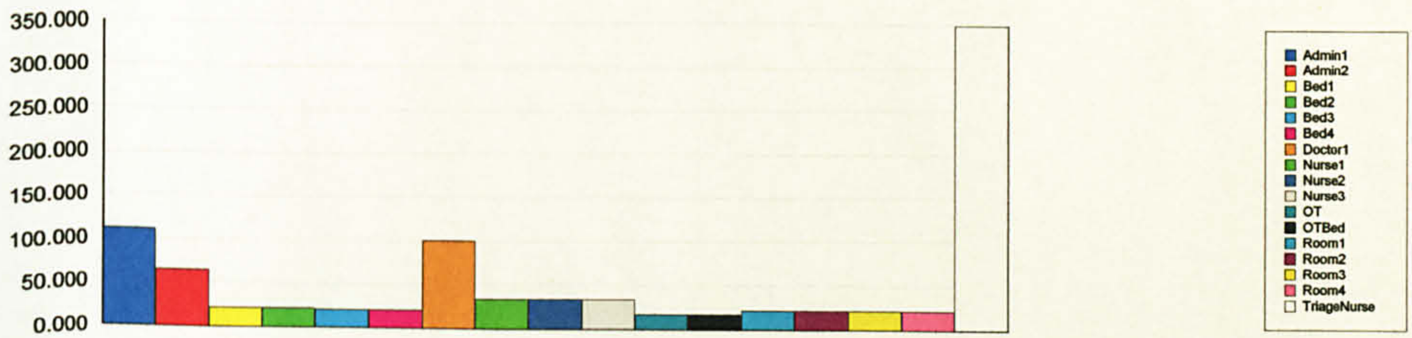
ications: 1 Time Units: Minutes

ource

ge

Number Seized

	Value
1	111.00
2	65.0000
	22.0000
	22.0000
	21.0000
	21.0000
1	101.00
1	34.0000
2	34.0000
3	34.0000
	17.0000
d	17.0000
1	22.0000
2	22.0000
3	22.0000
4	22.0000
Nurse	350.00



t

rgency Room

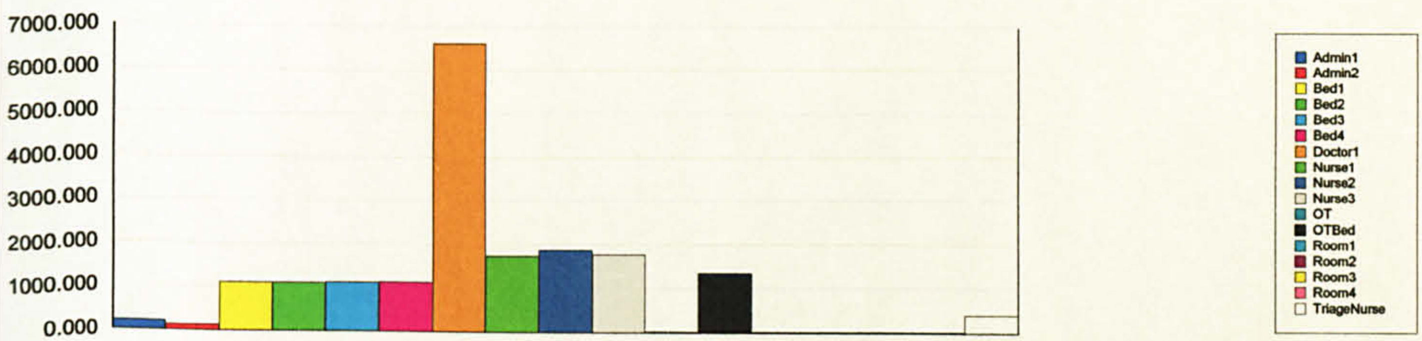
ications: 1 Time Units: Minutes

ource

st

Cost

	Value
1	201.86
2	117.51
	1101.24
	1097.06
	1115.70
	1122.85
1	6603.96
1	1748.44
2	1876.28
3	1779.36
	0.00
d	1363.48
1	0.00
2	0.00
3	0.00
4	0.00
Nurse	408.72



rgency Room

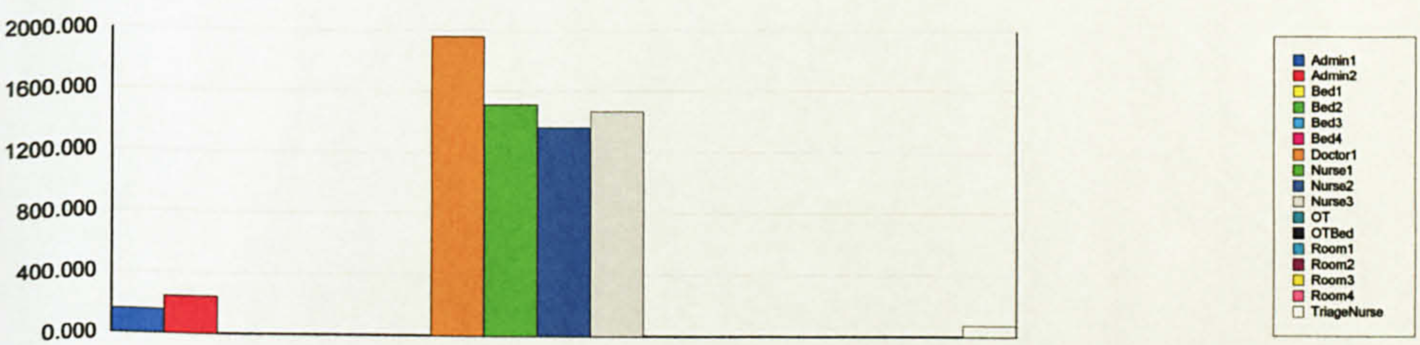
ications: 1 Time Units: Minutes

ource

t

Cost

	Value
1	157.76
2	242.49
	0.00
	0.00
	0.00
	0.00
1	1964.52
1	1515.56
2	1360.70
3	1471.84
	0.00
d	0.00
1	0.00
2	0.00
3	0.00
4	0.00
Nurse	70.6771



rgency Room

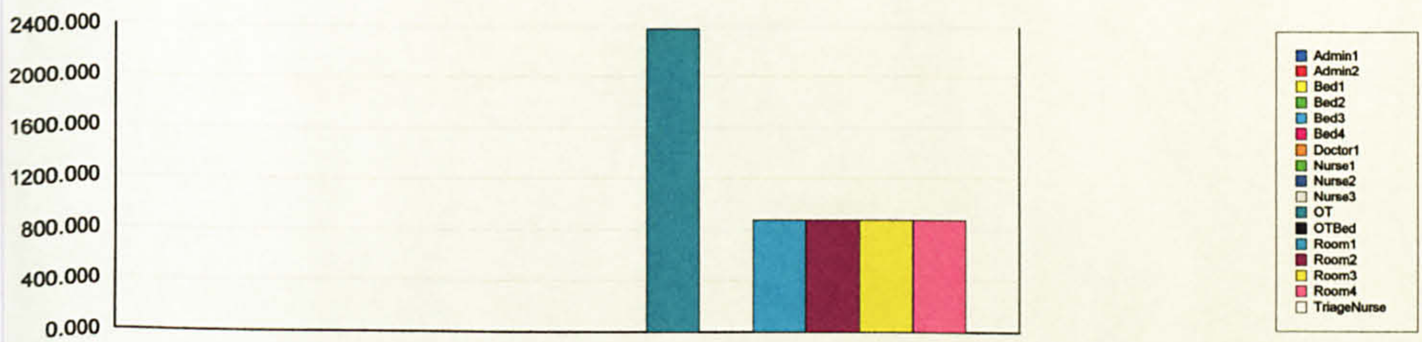
ications: 1 Time Units: Minutes

urce

t

e Cost

	Value
1	0.00
2	0.00
	0.00
	0.00
	0.00
	0.00
1	0.00
1	0.00
2	0.00
3	0.00
	2380.00
d	0.00
1	880.00
2	880.00
3	880.00
4	880.00
Nurse	0.00



ergency Room

plications: 1 Time Units: Minutes

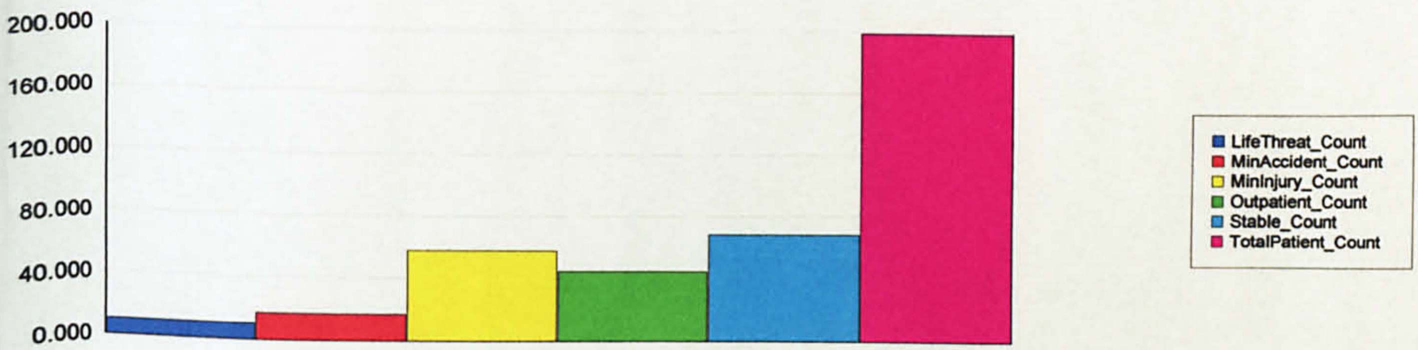
r Specified

ly

val	Average	Half Width	Minimum Value	Maximum Value
nt_Time_Interval	429.14	(Insufficient)	145.89	742.06

unter

nt	Value
reat_Count	10.0000
ccident_Count	17.0000
ury_Count	58.0000
tient_Count	45.0000
_Count	69.0000
Patient_Count	199.00



e Persistent

Persistent	Average	Half Width	Minimum Value	Maximum Value
NurseBusy	0.8528	(Insufficient)	0.00	1.0000