ADDIS ABABA UNIVERSTITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

School of Mechanical and Industrial Engineering

Modeling & Optimization of Emergency Department(ED):

A Case in Tikur Anbessa Specialized Hospital (TASH)

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By: Fitsum Abebe

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Last but not least my precious wife W/ro Heaven Jada, this is all yours.

DECLARATION

I hereby declare that the work which is being presented in this thesis entitled, "**Modeling & Optimization of Emergency Department(ED) A Case in Tikur Anbessa Specialized Hospital (TASH)**" is original work of my own, has not been presented for a degree at any other university and all the resource materials used for this thesis have been properly acknowledged.

______________________ ________________________

Fitsum Abebe Date

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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Dr. Ir. Kassahun Yimer (Advisor) Date

Abstract

Healthcare Emergency Department modeling and optimization analysis is one of the tools that have been applied to model and analyze the resource scheduling and performance of a healthcare system. The modeling can be done either by analytical or simulation methods. The major problems of Tikur Anbessa Specialized Hospital, Emergency Department is overcrowding related with high length of stay, low throughput, high waiting time, low resource utilization, etc. Therefore, the principal objectives of this thesis are to identify the scheduling parameters (key constraints) that affect the allocation and scheduling of activities; to identify the critical sub activities contributing to lag overall process and to make a flexible and optimal resource scheduling through modeling. Some papers done in relation to health care and manufacturing system modeling has been reviewed for this thesis. Patient records, processing time, etc. primary and secondary data have been collected from the case company, through direct observation of the process and using stopwatch. Then, the data was analyzed and an appropriate model was selected from the available fit of probabilistic distribution. Modeling of the ED process was made with the help of (i.e. Arena™ student version) simulation and modeling software. The model was verified and validated in order to ensure that it behaves the same as the real system and finally analysis of the simulation model was conducted. Based on the analysis the optimized model has been proposed for implementation. In this thesis, waiting time, length of stay, resource scheduling optimization and flexibility, was used as a measure of the performance of the production line. After analyzing the ED process model, a number of problems were identified including; longer queuing time, absence of flexible flow lines and lower utilization of resources. Finally, a new model was proposed where the length of stay has decreased by 25.6%, 16.23%, and 27.55% in first triage, front assessment and red/resuscitation processes respectively. This reduction in length of stay increased the throughput and reduced the overcrowding of the ED by more than ten percent. The achieved results in the proposed model can be easily adapted after similar studies and the EDs can be improved significantly.

Keywords: Arena™, simulation, patient, length of stay, modeling, Emergency Department, resource

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Chapter One

1. Introduction and Background

1.1. Introduction

The processes used to deliver care in hospital emergency departments (EDs) are very complex, but are of central importance. Such systems are typically comprised of a group of activities, each of whose executions requires different entities that may be humans (e.g. doctors, nurses, etc.), equipment (e.g. Monitor, Beds, MRI devices, X-ray, CT-scan, etc.), or software (e.g. excel electronic patient records). This thesis refers such entities that are needed in order to enable the performance of an activity as the activity's resources. Because resource availability is usually limited, resource contention problems often arise during process execution, leading to delays and congestions. Careful resource assignment and scheduling/management can help to mitigate the negative effects of such inevitable contention, and can reduce delays, inefficiencies, and patient length of stay.

In Tikur Anbessa Specialized Hospital (TASH) Emergency Department (ED) resource scheduling is done simply intuitively from past experience and practices, and there is considerable evidence that it is often done very poorly resulting in inefficiencies and delays that can cause suffering and/or needless cost. Accordingly there are interests in exploiting resource scheduling/management research that has been applied in other domains. This work has focused on determining optimal schedules of assignment of resources to activities.

The research addresses the resource allocation and scheduling problems by using empirical data analysis and discrete-event simulations based on detailed models of system processes, and detailed models of resource characteristics and constraints. In this thesis, the researcher presents the results of developing these detailed models and running simulations to study the effects of various approaches to resource allocation and scheduling problems on such measures of emergency department key performance indicators. The simulations provided insights and perspectives that domain experts have found to be provocative.

1.2. Background of the Problem

Tikur Anbessa Specialized Hospital (TASH) has three emergency departments. The first one is Adults ED which serves those patients starting from the age of 16. The second one is Pediatrics ED for infant children and those up to 16 years age youths. And the third one is Gynecology Case ED for woman patients related to gynecology. Out of these three EDs Adults ED; (also called as simply ED) covers more than 70% of the overall ED patients flow of the TASH[i]. This study focuses on Adults' ED. The TASH adults' ED has mainly 3 main activity areas: Triage room, Front Examination room and Treatment zones (Orange, Yellow-Green, Ortho and Red/Resuscitation).

Currently the TASH ED receives annually 20,000 patients and 55 patients per day in an average out of which 75% of them are transferred to Front Examination room. Out of which 33.3% are admitted to Treatment zones every day having a minimum of three fold of patients being treated on the available beds and corridors simply lying on the floor. Hence, the treatment area is always congested with too much patients occupying the spaces between parallel beds and aisles. Congestion in emergency departments leads to negative effects such as decreased physician productivity, miscommunication between working staff, and dissatisfaction of patients who may sometimes leave without treatment (Jennifer L. Wiler, 2010) (Nana Serwaa A. Quao, 2017) (Erhan Kozan, 2008).

The researcher tried to make a brief root-cause analysis by interviewing and observation as shown on Figure: 1. and has found that one of the major root causes is related to resource management (i.e., doctors, nurses, beds and other medical equipment, etc.)

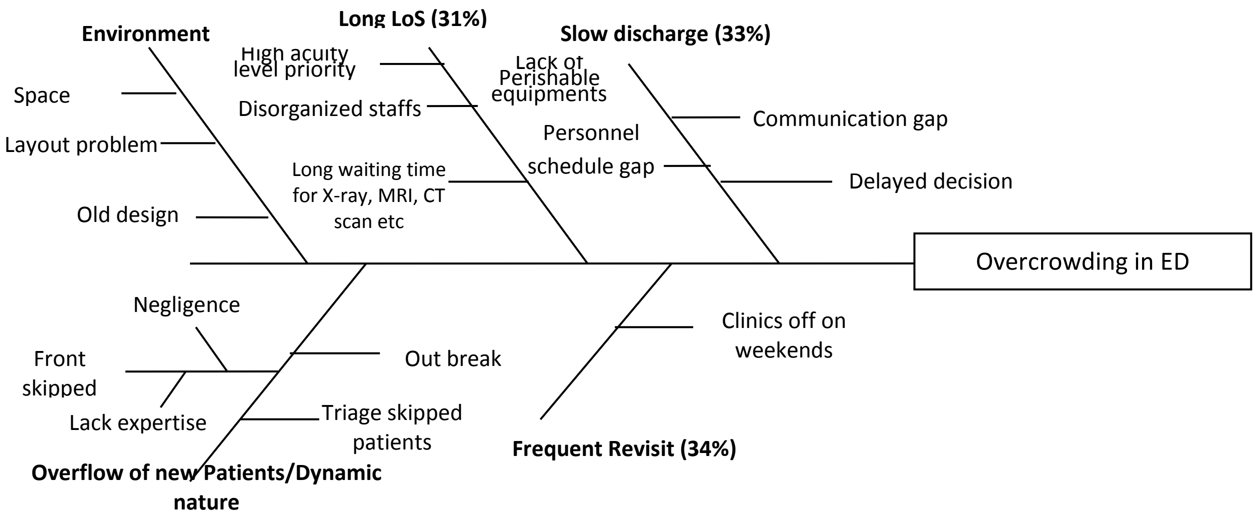

Figure1.2.1.1: Root cause analysis of Over-crowding

In order to discover the sources of overcrowding a research made by (Abicho, 2017) et al. Indicated that patients from follow-up clinics (34%), slow discharges which are related to poor resource management and scheduling (33%), high length of stay which is still mainly related to recourse scheduling (31%) and others collectively scored (2%).

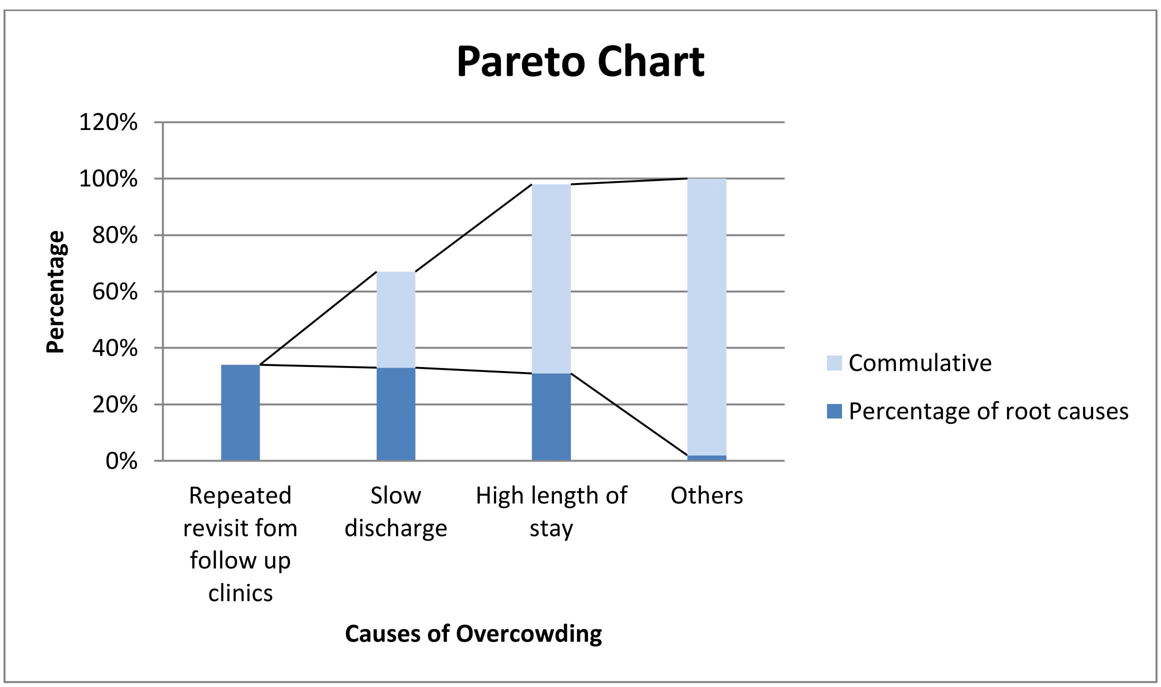

Figure 1.2.2: Pareto chart of cause of overcrowding

Therefore the cumulative effect 64 % of overcrowding is due to the cumulative effect of slow discharge and length of stay which is directly related to resource management. This problem is the motivation factor for the researcher to do this Thesis to work on resources scheduling and to minimize the total length of stay (LoS) so that eventually the overcrowding can be minimized.

1.3. Problem Statement

Scheduling plays an important role in achieving timely and cost effective production, which is becoming increasingly important in today's highly uncertain environments. In ED setting, scheduling systems usually operate in highly dynamic and uncertain environments in which several interruptions (mostly random in nature) prevent the execution of activity schedules exactly as they are developed. Examples of such disruptions are mass arrival in triage, scarcity of beds and other perishable and non-perishable resources, delayed decision, acuity level priority, etc. Even though real problems are dynamic and stochastic in nature, most of the solutions in the literature use static and deterministic models. In theory, most scheduling problems, even those with deterministic and static assumptions are NP-hard or mathematically intractable. (Ihsan Sabuncuoglu, 2010) . Also in practical, TASH's 64 % of overcrowding is due to resource scheduling problem.

For this reason, heuristic procedures are generally recommended for practical applications. Hence, the focus of this research is on the scheduling of resources as it is approached by the following research questions;

- What are the scheduling decision parameters (key constraints) that affect the allocation and scheduling of the activities?
- What are the critical sub activities contributing to lag the overall process?
- How do sub-activities be scheduled to enable flexibility and optimize resource usage?

1.4. Objective

1.4.1. General Objective

The main objective of this thesis is to optimize the resource scheduling process of ED through a dynamic resource scheduling approach in order to minimize the overcrowding.

1.4.2. Specific Objectives

- To identify the scheduling parameters (key constraints) that affect the allocation and scheduling of activities.
- To identify the critical sub activities contributing to lag overall process.
- To make a flexible and optimal resource scheduling.

1.5. Scope and Limitation

The scope of this thesis primarily is to deal with resource scheduling problems mainly focusing in human intensive systems. As a case Tikur Anbessa Specialized Hospital (TASH) Emergency Department is considered. The reason is TASH is the leading hospital in its capacity area and its reputation. And it could represent other similar hospitals. In addition, since TASH is the country's leading referral hospital focusing first on TASH could solve the other public hospitals problem.

1.6. Significance of the Study

Similar studies that are made are in the developed world in the hospitals with state of the art facility compared to ours'. Therefore this study proposed has given different perspective even for the researches in the future.

1.7. Organization of the thesis

This thesis is structured as follows: In Chapter 1: under Introduction and Background: 1.1 introduction; 1.2 background of the problem; 1.3 problems statements and research questions are discussed; 1.4 both general and specific objectives are briefly presented; 1.5 scope and limitations of the thesis are described; 1.6 designed research methodologies are described; 1.7Significance of the thesis and 1.8 Organization of the thesis are briefly discussed.

In Chapter 2: Literature review: 2.1 overview of resource scheduling in relation to healthcare activities is presented; 2.2 when and how to schedule scenarios from literature are discussed; 2.3 literatures perspectives in ED resource scheduling are reviewed. In Chapter 3: the data collection and analysis are discussed. Finally in Chapter 4: under Simulation Model Development; 4.1 Problem formulation and plan of study; 4.2 Fitting Input Distribution through the input analyzer;

4.3 As Is Model formulation and construction; 4.4. Model verification and validation and 4.5 Experimentation and analysis are presented.

In Chapter 5: Proposed Model Development has been discussed and finally in Chapter 6: Conclusions and Recommendations has been discussed.

Chapter Two

2. Literature Review

2.1. Resource Scheduling

Resource scheduling is a collection of techniques used to calculate the resources required to deliver the work required. There are two broad categories of resources consumable (perishable) and Reusable (non-perishable). Scheduling these resources ensures efficient and effective utilization; confidence that the schedule is realistic; and early identification of resource capacity bottlenecks and conflicts.

The resource scheduling activity has three steps the first one is allocation and then aggregation finally scheduling. Allocation involves identifying what resources are needed to complete the work. In the case of consumable resources it is total effort required and the number of individual resources. Once time scheduling and resource allocation are complete, the resources can be aggregated on a daily, weekly or monthly basis as appropriate. The aggregated data is usually presented a histogram that illustrates the functionality use of resources against time. In the case of consumable resources a cumulative curve (which usually takes the form of an 'S') is also used to show the total amount consumed at any time

Resources smoothing is used when the time constraint takes priority. The objective is to complete the work by the required date while avoiding peaks and toughs of resource demand. A smoothed resource profile can be achieved by delaying some work. This removes some flexibility from the schedule and its ability to deal with un-avoidable delays, but the advantage is usually a more efficient and cost effective use of resources.

All Reusable resources are limited, so the time schedule has to be adjusted to take accounts the limited availability of resource over time. There are two approaches to reconciling resource limits and time constraints; the first one is resource smoothing (or time limited resource scheduling) and the second one is resource leveling (or resource limited scheduling). Resource leveling is used when the limits on the availability of resources paramount. It simply answers the question with the resources available when the work can be finished. In many situations a mixture of leveling and smoothing may be required.

2.2. When and How to Schedule

Concerning the timing, Scheduling can be proactive or reactive or mixed. (Ihsan Sabuncuoglu, 2010) argues that even in proactive scheduling it could not last forever at some point it should be revised therefore the question is when to revise? And how to revise it? In the case of reactive scheduling as the frequency of rescheduling increases the systems' responsiveness increases. However, it is not feasible to reschedule as frequently as possible. Therefore, there are several alternative ways to decide on timing. Periodic scheduling: Period length can be constant or variable. In constant case revisions are made at the beginning of each time interval and it is the most common. However, in variable case, scheduling decisions are made after a certain amount of schedule is realized or after a certain number of random events (continuous scheduling policy). Adaptive scheduling (controlled response policy): A scheduling decision is made after a pre-determined amount of deviation from the original schedule (threshold).

Even though the 'when to schedule' decisions are analyzed to some extents by different researchers in manufacturing and project management sectors, the subject needs further research to know the condition under which policy is better than the other (especially considering the specific case(ED)).

'How to schedule' determines the ways in which schedule are generated and updated. There are four issues related that should be considered. These are, scheduling scheme; the amount of data used; type of response and performance metrics. As (Jennifer L. Wiler, 2010) stated, scheduling scheme: there are off-line, online or a combination of (hybrid) scheduling approaches. Offline scheduling refers to scheduling all operation before execution whereas online scheduling decisions are made one at a time during execution. On-line approach accommodates considerable flexibility to compensate for unforeseen system disturbances but lacks the global perspective provided by an offline approach. The issue is the amount of data used during scheduling generation. (Ihsan Sabuncuoglu, 2010) defined as the forecasting horizon (FH) it represents the maximum time period for which schedulers have enough information to generate a schedule. Look- ahead window (LW) is defined as the time span of job release date. Is defined as a portion of FH for which a new schedule is generated or a revision is made. If LW < FH: only a part of the available information is used. This is generally due to low confidence about the accuracy of the far-future information (Partial scheduling). If LW=FH all available information is used and this is called full scheduling. If full scheduling is employed in periodic review and if FH is equal to the period length, this policy corresponds to doing nothing. (I.e. leaving the system alone and setting it to recover from disruption).The third issue is type of Response/Nature of revision. Rescheduling the operation of all the remaining jobs from scratch; the three main responses are tracing no corrective action and letting the system recover itself from the negative of disruption and between two extremes, it is also possible to repair. The forth and the most important issue is performance metrics. The schedule should decide on which performance metrics to use. The classical performance metrics are – make span, flow time, earliness, and tardiness. And the recently focused issue - robustness, and stability; these are used particularly in the environment is a major issue. Robustness and stability are related with this difference. A schedule whose performance does not deteriorate much in the face of disruption is called robust. Robustness is concerned with the difference in terms of objectives function value. It refers to the insensitivity of scheduling performance to the disruption. Whereas, stability is concerned with the difference between initial and realized schedule themselves rather than between their performance.

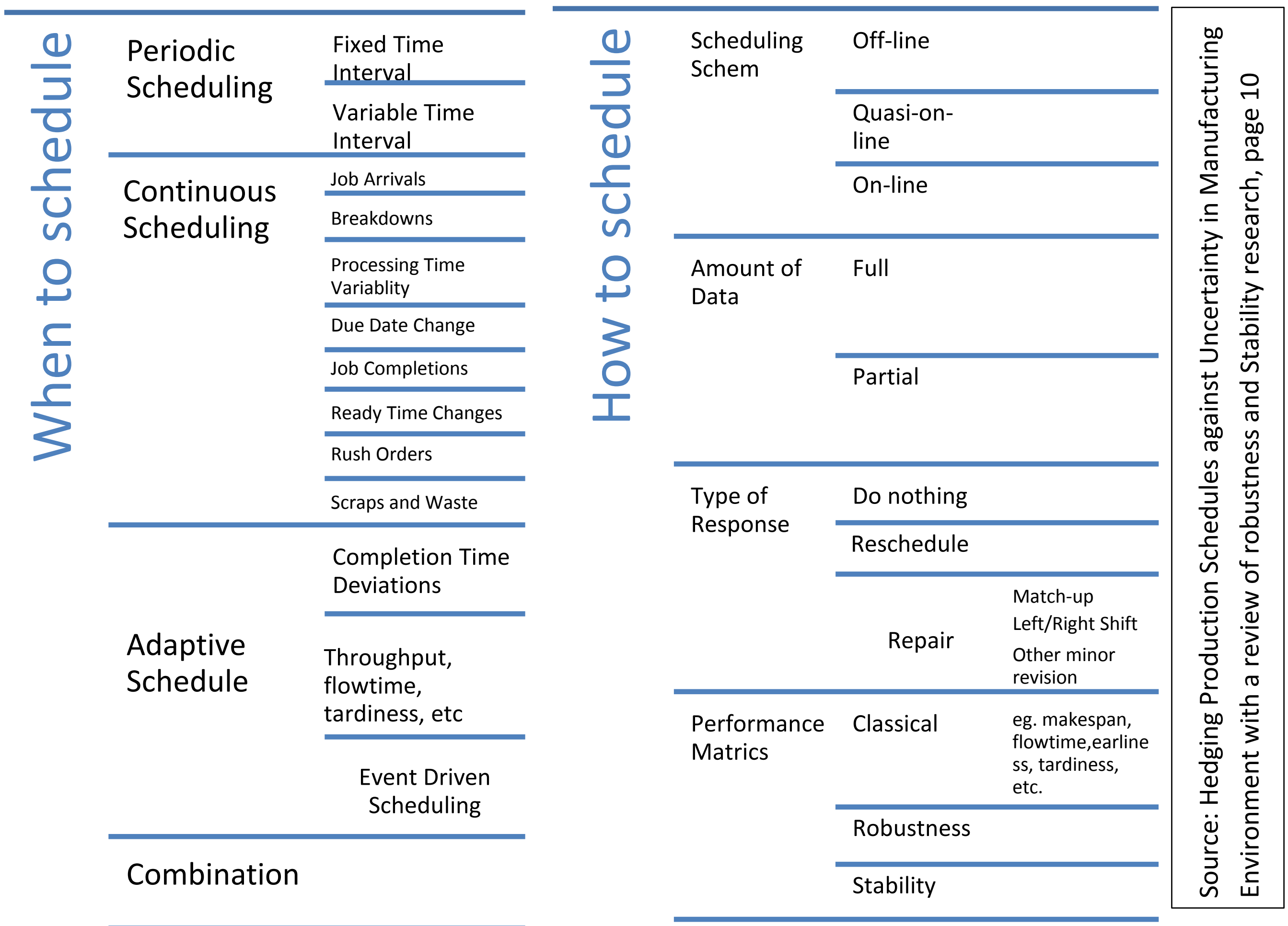

Figure 2.2.1 When and How to schedule summery

2.3. Scheduling in ED

Scheduling in Emergency Department of hospitals is presented in different approaches on literatures. The three main scheduling approaches are activity/process scheduling; human resource scheduling and non-human (perishable/re-usable) resources scheduling. Bair [2] discussed, the EDSIM model was used to compare the fast-track triage approach with an alternative acuity ratio triage (ART) approach whereby patients were assigned to staff on an acuity ratio basis. Acar [3] indicated four stages of human scheduling special attention given to nurses. The first one is nurse budgeting; which is high level planning made administrators. The author argues that this take 50% of the overall ED administration budget. The second one is nurse scheduling; the nurse manager forecasts the number of patients that enter to the given planning period (2-4 weeks) to determine the number of each skill type needed. The third one is nurse staffing (re-scheduling); set of nurse assignments are revised, indeed. The final stage is nurse assignment; each patient is assigned to a nurse at the beginning of each shift based on the work load. In the contrary, Diefenbach [4] discussed that analytical simulation model is used to investigate potential impacts by changing the following aspects of ED (physical layouts; number of beds; number and rate of patient arrivals; acuity of illness or injury of patients; access to radiology and pathology services; hospital staffing arrangements; and access to inpatient beds).

S.N	Author	Objectives/Problems	Method/Approach	Finding/Conclusion/Result	Remark/Gap
1	Willy Herroelen	Develop pre-schedule that can be observe distributions	Through mathematical programming model	Minimize expected weighted deviation in start time.	Considered deterministic activities.
2	Jannach et al.	Minimize unforeseen disruption during the execution of pre-schedule	Appling AOR (affected operation rescheduling)	Generalized AOR yields significant performance improvement.	Specific to resource constrained project scheduling problem(RCPSP) and deterministic
3	Sotskov et al.	Minimize total weighted job flow time.	Develop precedence dominance relationship among n jobs	Reduced total weighted flow time	Lacks flexibility (only for two machines flow shop problem)
4	Deepu Philip	Minimize max completion time	Comparing schedule deviations	Slacks to heavily utilized machine results a good robust schedule	Focused mainly on classical job shop problems
5	Oliver Lambrechs	Minimizing schedule instability		Predicted baseline schedule and yields significant performance gains	Deterministic schedule
6	Ilgin Acar	Unbalanced work load on nurse-to-patient	Analytical herarchial process	Reduced total work load	- Activity centric - Disregarded other

		assignment and its impact on the quality of care.	(AHP) analysis		resources
7	Subhamoy Ganguly	Scheduling problem	Mixed integer linear programing	Develops heuristic technique for particular type of jobs	Only two type of jobs sequencing
8	Nazanin Zinouri	Finding Best assignment of nurses to working shifts	SARIMA	Increased by 46% of performance.	Focused only on staffing
9	Seung et al.	Optimize staff scheduling to increase quality of care efficiency resources	Integer linear programming based simulation	Staffing policy that allows different shifts and overlapping	

Table 2.3.1 Summary of literature

Since scheduling is confined with too many uncertainties on the future disruptions. We need to be careful on making pre-schedule. Having new designed pre-schedule is one thing. However, there could still be unforeseen disturbances during execution of plans (preschedule). We need to repair using different techniques. [Iannach, 2006] suggests generalized affected operation rescheduling can yield significant performance improvement in comparison to the strategy of rescheduling all future activities. Considering the main objective which is to minimize the total length of stay (TLS), [Philip, 2008] suggests that it can be evaluated by comparing the simulation output of the average, minimum and maximum schedule deviations across all policies.

Therefore this research presents rescheduling approach into four aspects; first identify rescheduling factors then select rescheduling strategy/policy and then design rescheduling methods finally evaluate the rescheduling performance in terms of robustness and stability.

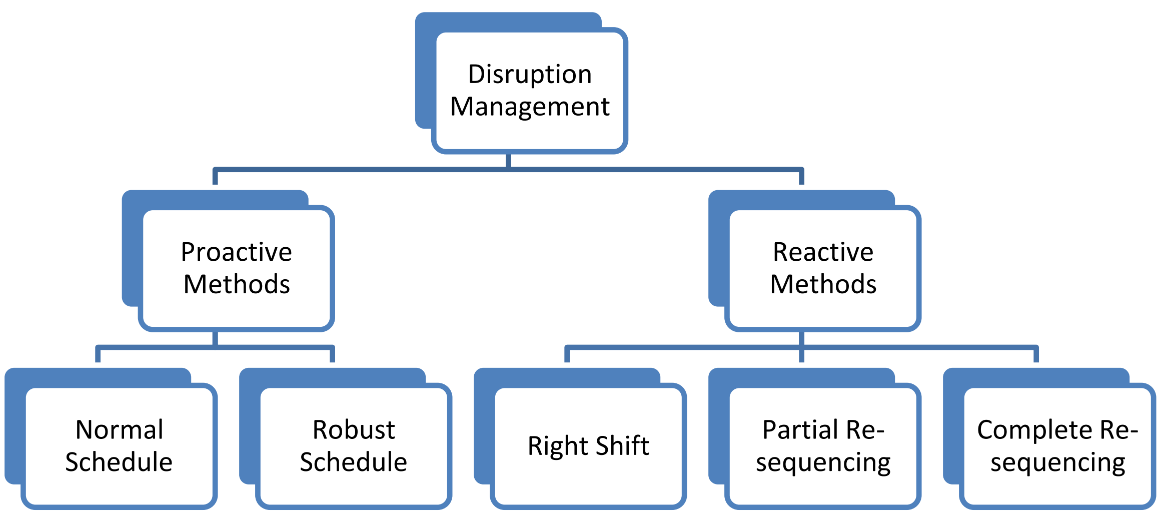

Figure 2.3.1 Disruption Management

One approach is static/deterministic resource assignment and scheduling, in which a complete schedule of resource assignment is computed in advance based on advance knowledge of the sequence of activities to be performed and the size and duration of all these activities (Cowling P., 2002) (Fowler J.W, 2006) which is actually being practiced in TASH also. However, a hospital emergency department is a dynamic environment, with great uncertainty about the future course of the execution of any realistic process. Uncertainties such as the sudden arrival of new patients, unexpectedly slow task performance, and unplanned lack of resources all change the execution environment creating the potential for consequent schedule disruptions.

Because of the inevitability of such uncertainties in the emergency department, different kinds of dynamic resource scheduling approaches, such as reactive scheduling, and proactive scheduling need to be considered. These methods seek to schedule only activities that are within a restricted part or phase of system execution. They address only a reduced set of activities using extensive or exhaustive searching approaches to compute optimal or near-optimal schedules. But the scale of the scheduling effort can still be quite large if the schedule covers an extensive part of the system's activities. In addition, disruptive events may still invalidate the assumptions of the scheduling effort, necessitating further rescheduling (this is especially problematic as the part of the system being scheduled becomes large).

These issues are particularly troublesome in ED of a healthcare, where patient care systems must continually adapt in response, for example, to new patient arrivals and medical emergencies. This indicates the need to find new ways to mitigate the problems inherent in incremental rescheduling. This thesis's approach exploits detailed specifications of emergency department activities, their needs for resources, and the characteristics of the resources themselves to achieve better resource scheduling. This research decomposed the overall resource scheduling problem into a series of dynamic rescheduling at selected times, covering sets of activities for which access to detailed information could be the basis for more effective resource schedules. To pursue this; the research explores:

1. Information about emergency department process activities and resources. This enables scheduling schemes to produce relatively high quality results that should remain accurate over most or all of the activities for which resources that is going to be scheduled.
2. Keeping the activity set for which resources are to be scheduled relatively small thereby keeping analysis time relatively modest and enabling relatively quick response to changing emergency department environment conditions.
3. Enabling dynamic changes in successive rescheduling. Earlier resource allocation decisions and unexpected events can alter the choice and importance of later activities,

affecting how resources might be allocated to them. Thus the researcher used scheduling parameters (e.g. constraint sets) that may vary to make it easier to compensate for the effects that previous activities have on resource allocation for upcoming activities.

Chapter Three

3.1. Research Methodology

3.1.1. Introduction

To do this study, the following methodologies were followed. The problem was identified and then supported by making preliminary reviews through different literatures like Books, theses, and other related researches etc. are reviewed. Then research questions were formulated. Based on the research questions both primary and secondary data were collected. And then preliminary data analysis has been performed and organized input data for the selected sub activities simulation. Then based on the data collected the AS-IS system simulation model is developed. And finally developed an optimal resource scheduling model based experiment and analysis performed on the AS-IS model.

3.1.2. Problem Formulation and Data collection

Gaining a better understanding of the healthcare process is essential for making correct justifiable decisions and providing effective solutions. Therefore, it is necessary to formulate the underlined problem from the point of view of briefly described methodologies.

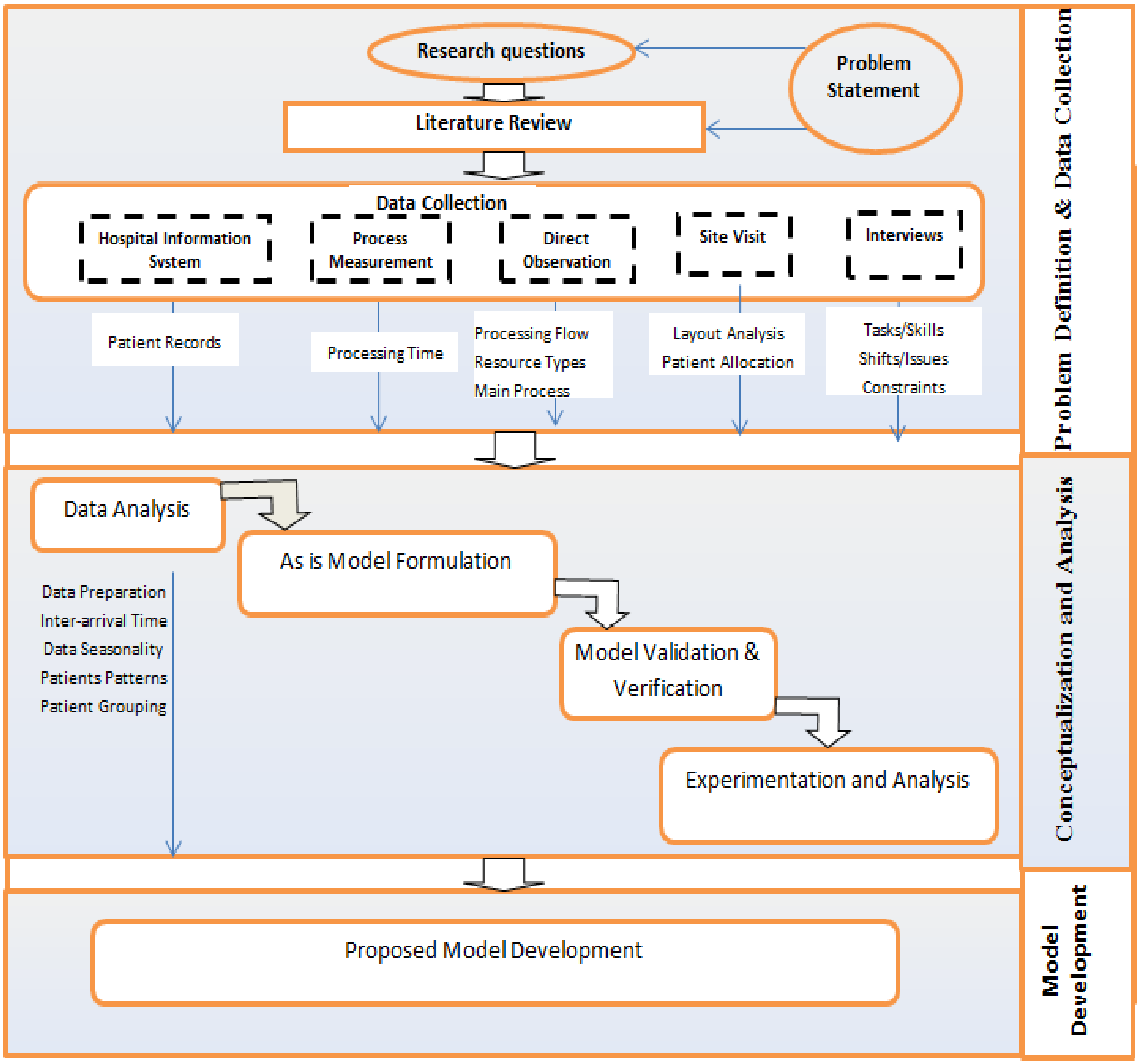

Figure 3.1.1 Research methodology framework

Accordingly, the data collection phase proceeds to gather primary and secondary information of the underlying processes. Which are the hospital ED quality information system data collected and reported, process flow associated resource requirements, direct observation and interviews. This phase focuses on the retrieval of the data and also on the construction of an existing model. The quantitative data is stored in excel and recorded on hard disk storage medium where the qualitative data obtained via direct observation of the system and interviews from the experts those who work in the hospital such as doctors, nurses, consultants, administrators and managers.

3.1.3. Conceptualizations and Analysis

The underlined ED healthcare processes are then mapped into the as is process activities model. The control flow definition is created by identifying the entities that flow through the system (e.g., patients, staff, and medical resources) and describing the connectors that link the different parts of the process. Finally, the resources are identified and assigned to the activities where necessary. The as is model is used in the simulation model for two purposes: first it is guidance for the actual simulation model, which contains and considers a higher degree of details, and second it is used as a communication platform in order to validate the model. Once the as-is model is completed, it is essential to validate it with the counterpart real data registered on excel. This is an essential step for the credibility of the simulation model and hence its output.

Once the as is model is validated, the model translation phase begins, which combines the validated as is model and the results of the patients' records analysis. Verification during the modeling phase ensures that the model logic reflects the underlying business process. The difference between verification and validation within the context of simulation modeling is that verification ensures that the transformation of the conceptual model has been applied correctly, where validation considers the representation of the model towards the system under investigation (Balci, 1997).

After the model verification and validation, the decision makers can use the model to investigate the impact of decisions and alternatives (i.e., what-if scenarios) to foresee the consequences of these decisions. The results can then be evaluated and interpreted by experts and decision makers, which provide guidance on the implementation of suggested alternatives and plans, as well as set benchmarks of the maximum performance that can be achieved using the available resources and staffing levels. Hence, more practical solutions and plans are recommended and tested using the simulation model.

3.1.4. Proposed Model Development

Finally based on the analysis and experimentation new proposed model has been proposed. Then by implementing the simulation the result of the newly developed model has been presented.

Chapter Four

4. Data Collection and Analysis

At this stage first the basic sub-process, which their process is going to be modeled is selected. The processes selected are triage activities, front assessment and major examination rooms processes. These processes are selected based on their criticality impact in the emergency department throughput. And due to this it is assumed that good conclusion about the ED process can be deduced from the output of their performance. After the basic sub processes are selected, the following data are gathered for each process:

- ED layout analyzed
- Type and number of resources required for each sub process,
- The sequences of activities required are identified.
- Arrival times of patients are collected
- Inter arrival time calculated
- Category of patients are identified
- Length of stay calculated

After the above data are collected, measurements of the following times are done using stop watch:

- Each process time
- Transfer times of patients between each sub process

Form the research questions raised the researcher identified what kind of data required and the way of acquiring it. The first one is to analyze the existing conditions of the ED. And to identify the key performance indicator that can answer the main objective question. Then made further analysis of resource scheduling to optimize the overcrowding.

4.1. ED Layout

The department has 8 major activity areas or rooms namely card/registration room for registration and keeping of patient identification no. and demographic information; waiting area, triage room for first screening of patients of health conditions, front is the major assessment area which has mainly medical and surgical sub sections with data encoding and supporting nurses' station, the other major activity areas are treatment zone (orange, yellow/green, orthopedics, red/resuscitation), lab, X-Ray and CT scan area, pharmacy, dressing room and stores (for perishable and non-perishable resources for day to day activities and just beside the main gate there is more than 12 trollies reserved for major trauma and critical care patients. Besides, the ED has an ambulatory car area. Patients that arrive by ambulance who are in critical conditions are routed directly to the resuscitation area, while ill patients who require their conditions to be monitored stay in the major assessment area.

4.2. ED Staff and other Resources

As a 24hr department, the ED has fifteen nurses during the day and the same amount of nurses at night which collectively are divided into six types of nurses; Advanced Nurse Practitioner (ANP), triage nurse, resuscitation nurse, respiratory nurse, majors/minors nurse, and healthcare assistant. Physicians (excluding the 2 Consultants who provide shop floor cover between 9am-5pm or 8am-8am with 24/7 on-call provision), referred to as non-consultant hospital doctors (NCHD), are divided into three types: registrar/specialist registrar (i.e., receiving advanced training in a specialist field of medicine in order eventually to become a consultant), Senior House Officer (SHO) (i.e., a junior doctor undergoing training within a certain specialty), and intern that are distributed as follows when the roster allows: three registrars per day with a 10hr shift starting at 8am, 12pm, and 5pm; two interns with a one shift per day from 8am to 5pm Monday to Friday; and overlapping shifts of SHOs during the day to make it possible to have more than one SHO at specific time (i.e. from 2 to 6 SHOs during the day).

4.3. Key performance Indicator Selection

Key Performance Indicators Selection Following repeated visits to the ED and interviewing the senior management team, the ED manager has identified two main key performance areas: patient throughput and ED efficiency. The performance measures for patient throughput are the average waiting time and average length of stay (LOS), while for ED efficiency they are; ED productivity, resource utilization and layout efficiency.

Figure 3 shows the breakdown of the key performance indicators (KPIs) according to the ED senior managers.

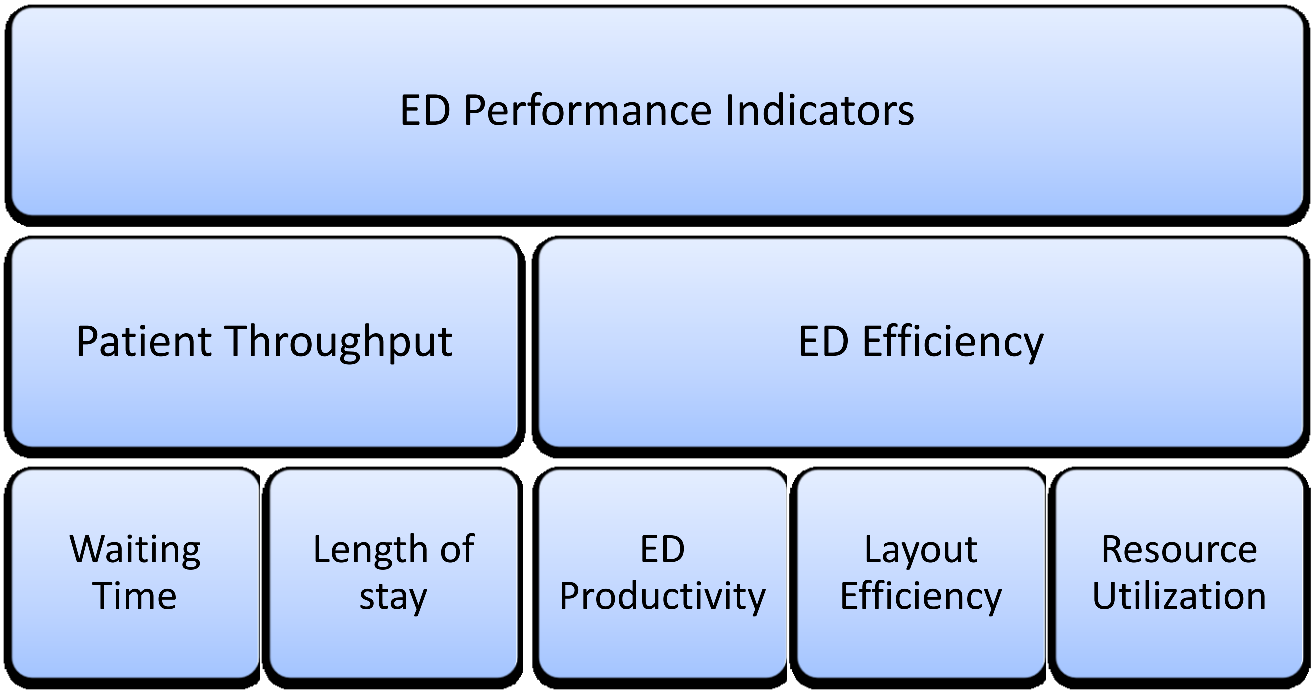

Figure 4.3.1 When and How to schedule summery

Waiting time is the time taken by patients while waiting for any activity or service in ED. whereas length of stay is the total time taken by patient starting from the arriving time until admitted to impatient ward for further non-emergency follow-up or discharged to home. In ED productivity is measured in terms of patient to nurse and patient to doctor effective interaction to maximize the total percentage of treated patients. In resource utilization; staffs and capacity utilizations are the main issues. Layout efficiency is also thought to affect the ED performance.

In the process of using the above selected key performance indicators it is important to analyze the effect each key performance indicator to one other. So that not to waste time and cost can be minimized by minimizing duplication of each KPIs usage effort. The researcher used a correlation matrix as shown in figure 6 below. As it observed from the matrix all KPIs are strongly correlated one another. Therefore, analyzing the patient flow in emergency departments to minimize length of stay, improve efficiency, and reduce overcrowding has become a crucial requirement for this thesis objective.

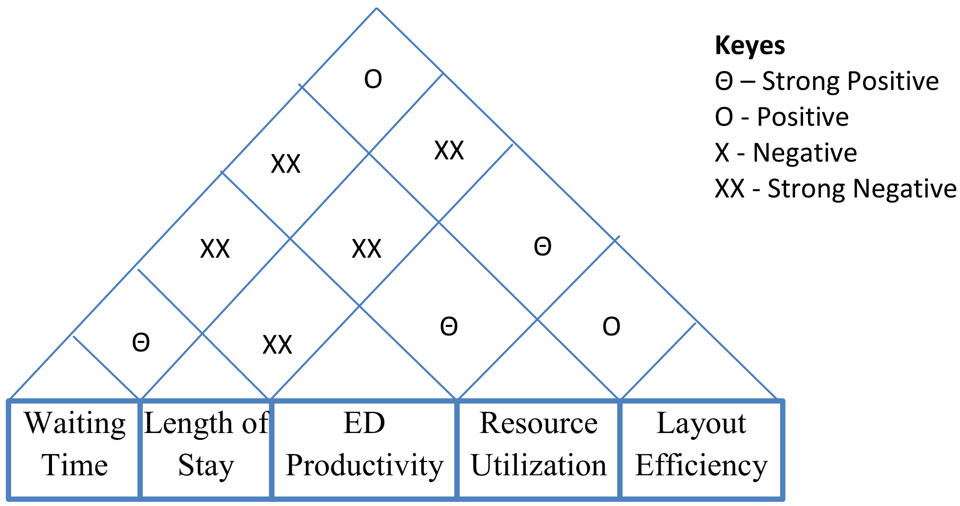

Figure 4.3.2 Key Performance Indicators Correlation Matrix.

4.4. Selection of Critical Sub activity

The next important question is to identify the most critical activity that hinders the overall length of stay in relation to resource scheduling. To identify this; first the overall process should be subdivided into major sub-activities. From the data found by interviewing and observations the ED main activity is subdivided into six (6) sub activities as it is shown below in table 2. These sub-activities are interrelated and mostly sequential. First Triage then Front then the patient are admitted to any of the next 4 activities depending on the decision made by Front/Major assessment area. Actually there is also fifth option which is discharge. This is out of the scope of this thesis.

Activity Area	Activity	Capacity to serve Patients	Resources

1	Registration & Triage	Register the incoming patient and Identify patients' acuity level for further examination and treatment.	1 at a time	2 Nurses, 1 supporting staff, 1 Bed, 1 Monitoring m/c, Oxygen and other supporting medical equipment
2	Front/Assessment Area	First examination of patients according to triage report and decide whether further follow-up and bed required or not.	4 at a time	2 Surgical intern/SHO Doctors, 2 intern/SHO Medical Doctors, 2 nurses, Oxygen and supporting medical equipment
3	Green/Yellow	Relatively mild risk stage patients are treated	42	More than 7 nurses, 10 beds and trolley spaces
4	Orange	Higher risk patients are treated	9	2 nurses, 9 beds and trolley spaces
5	Ortho	Those patients related to orthopedics are treated	12	2 nurses and 12 beds
6	Red/ Resuscitation	Those patients with life threatening conditions and immediate support requiring patients are treated.	7	2 nurses, 1 SHO doctor, 5 beds for Red and 2 beds for Resuscitation

Table 4.4.1 List of sub-activities

4.4.1. Patient Flow Analysis

Upon arrival at the ED and registration, walk-in patients (self-referral or GP referral) remain in the waiting area to be triaged

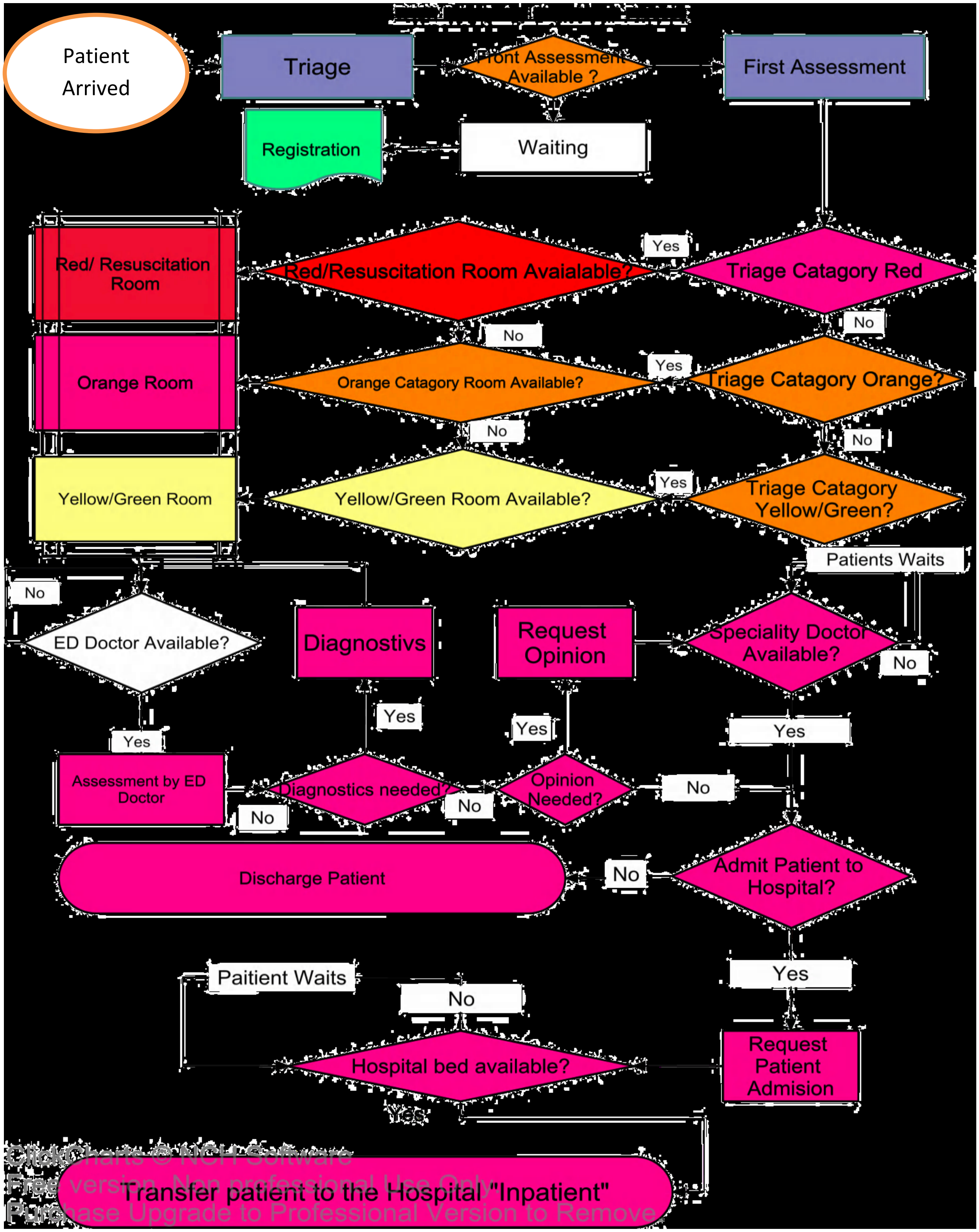

Table 4.4.1.1 Detailed flowchart for the patient flow in the ED

When a patients name is called, depending on triage staff availability, the patient is assessed by a triage nurse. Based on patient condition and triage assessment, each patient is assigned a clinical priority (triage category) according to the Manchester Triage System (MTS). The MTS uses five level scales for classifying patients according to their care requirements, immediate, very urgent, urgent, standard and non-urgent. Once triage category is assigned, the patient may be sent back to the waiting room until a bed or trolley is appropriate treatment area, based on the type and intensity of their care requirements. The patient waiting time depends on the triage category of patient and availability of both medical staff and empty trolleys, which are prerequisite for complete and accurate assessment. Following the patient's assessment by an ED clinician, a decision is made, either the patient is to be discharged or admitted to the hospital. These are the primary care stage which are relevant for all patients, whether they are discharged from or admitted to hospital, Secondary patient stages are those steps involved in the care of some but not all patients such as diagnostics (e.g. X-Ray and blood test), and second assessment by ED doctor. Opinion may be requested by ED staff from a medical/surgical specialist doctor to confirm that a patient should be admitted or to obtain advice on the best possible treatment for the patient who is to be discharged.

4.4.2. ED Process Mapping

Based on the analysis of patient flow through the ED, a detail flow chart is built which highlights the common process and decision points through the ED. ED process is then broken down into similar sub-functions with key resources (e.g. staff and medical equipment) at each care stage are identified and detailed using Arena™.

4.4.3. Empirical Data Analysis

The analysis of empirical data is essential in developing a robust simulation model that considers the time features of the intended system in terms of demand volume and patterns. A thorough analysis of data enables the discovery of different type of patterns that are essential to reduce complexity of the simulated system in terms of patient groupings and patient allocation and routing analysis. This valuable information is needed to build a comprehensive and representative dynamic model for the underpinned healthcare system. Historical patients' records have been gathered for the ED information system during ten months period provided by hospital patient data administrator 9,664 anonymous patient records. Each patient record is described by the following patient –level variables: (1) triage category assigned to patient, (2) mode of patient arrival, (3) patient attend date/time, (4) patient triage date/time, (5) date/time patient seen by doctor, and (6) whether the patient left without seen, discharged or admitted to the hospital. I analyzed patients' records to extract qualitative information about patients' arrival pattern, patient grouping and allocation, and routing information. Patients were grouped based on their stage category. Urgent patients (triage category red, orange) represent the largest group of new attendees to the ED annually (58% average) who are presented to the ED with a wide range of medical complains and aging conditions. Patient placement for each patient group through ED treatment areas along with the arrival mode is summarized in (Table 3)

Triage Category	% of Patient	Mode of Arrival	
		Walk-in	Ambulance
Red	33.1	16%	54%
Orange	25.1	18%	33%
Yellow	23.5	22%	4%
Green	18.2	44%	0%
Black	0.1	0%	8%

Table 4.4.3.1 detailed flowcharts for the patient flow in the ED

For each patient group, an estimation of patient arrival distribution is used to replicate the arrival pattern in the simulation model. From the simulation perspective, the inter-arrival data is required, not the arrival time, which describe the time delay between two consecutive patient arrivals. To do so, the difference between the arrival times of patient was obtained for each group. These inter-arrival times were then grouped into time slots where the relative frequency (i.e., percentage) of each time slot was accumulated and represented in a histogram (see Figure 4.4.3. (2-5)).

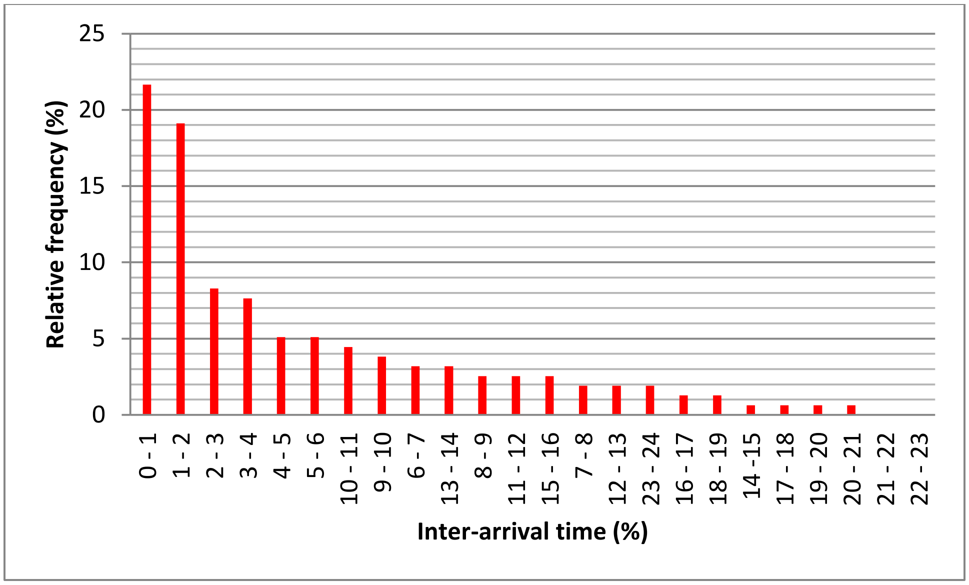

Table 4.4.3.2 Relative frequency diagram – Red Category patients

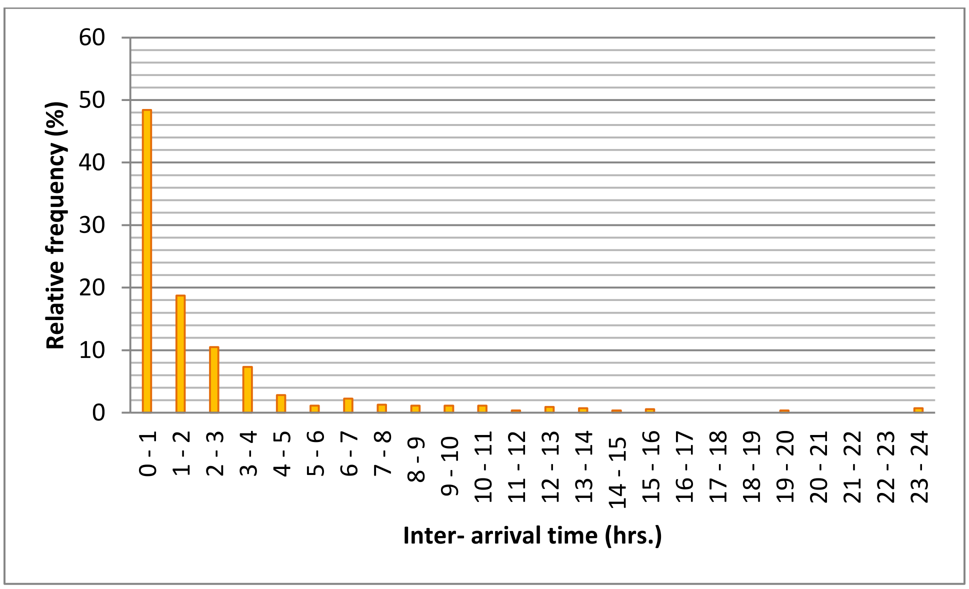

Table 4.4.3.3 Relative frequency diagram – Orange category patients

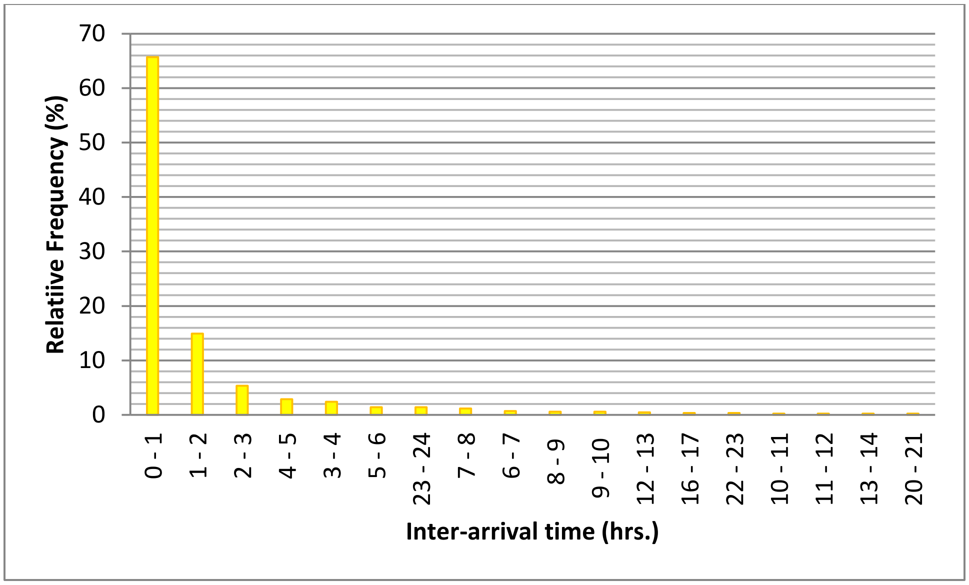

Table 4.4.3.4 Relative frequency diagram – Yellow category patients

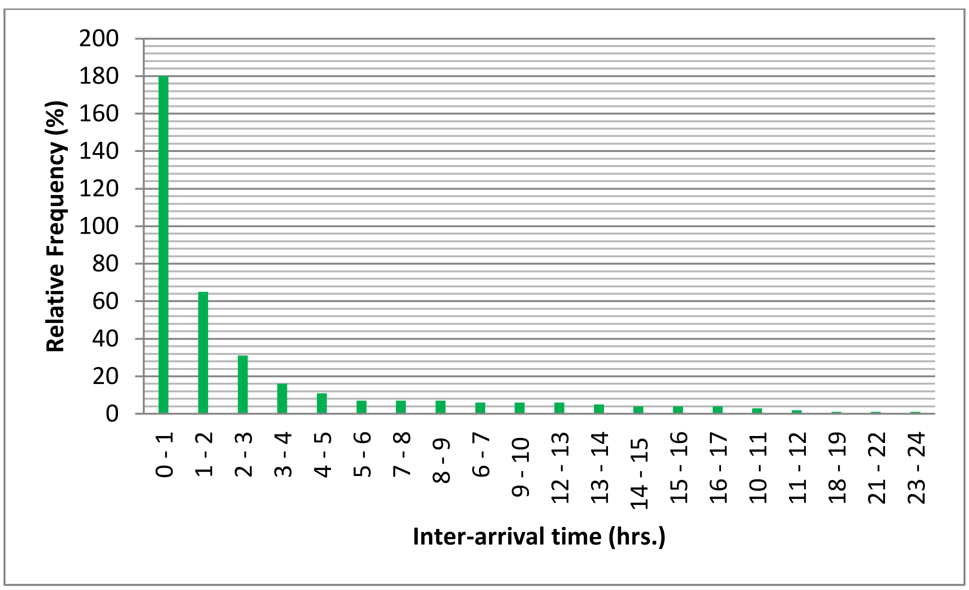

Table 4.4.3.5 Relative frequency diagram – Green category patients

Regarding patient allocation data, **Table 2** above shows the analysis of patients within the ED. Based on that analysis, the ED staff failed to fully implement the recommendations of the triage category concerning the disposition of patients, which is due to the overcrowding of the ED. For example, 88 % of immediate patients are seen in the majors' cubicles and 9% in the resuscitation room, while only 40% of very urgent patient are seen in inappropriate assessment areas.

Moreover, due to the overcrowding status of the ED, the majority of standard and non-urgent patient are assessed and treated in inappropriate areas (e.g., chairs) or in waiting areas.

From the analysis, it is easily understood that out of the 40% patients seen in an appropriate location are those patients categorized as red. The overcrowding occurred in orange and yellow/green area is due to 55% contribution of the red category patients' miss-location. Hence, from the data analysis it is identified that the scheduling optimization needs to be determined in the identified areas above.

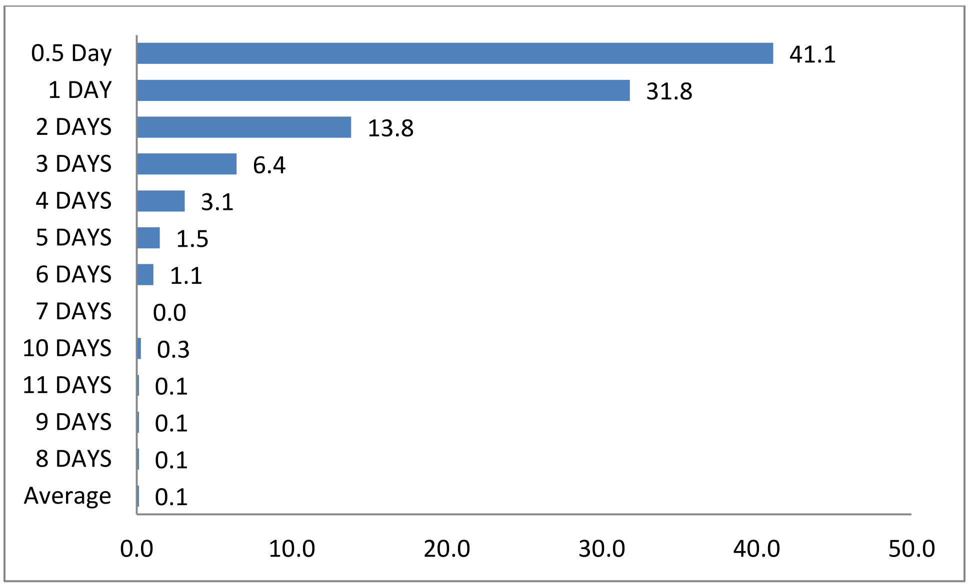

Table 4.4.3.6 Total Length of Stay

Chapter Five

5. Simulation Model Development

Based on the ED business process model, the designed KPI, and the empirical data analysis, a comprehensive simulation model for the ED has constructed. Modules of the simulation model are connected to resemble the ED business process model, where blocks are connected similar to the conceptual flow chart, which eases the model construction phase. Accordingly, the top-level of simulation model defines the overall model structure, where sub-level blocks containing additional modules with more details. A data base is used as to save the measured KPIs after each simulation run, followed by exporting for future analysis and validation.

Modeling of healthcare system using arena ™ can be done by taking each sub-activity that TASH ED has and modeling the whole process. However, this is quite difficult because of the large type and number of sub-activities being carried out in TASH ED. Therefore, to eradicate this problem; modeling of only the resuscitation, orange and yellow/green areas starting from triage and front examination activities. Then overall performance of the ED is analyzed using the output of those models.

Any simulation study has steps to follow. In this thesis, the modeling approach includes the following basic steps: problem formulation and plan of study, data collection and model definition, model formulation and construction, model verification and validation, and experimentation and analysis.

5.1. Problem Formulation and Plan of Study

The overall objective of the study is to model the ED process and analyze its performance using optimal resource scheduling simulation. Then finally, a proposed model is prepared with an improved congestion of the area. Specific question to be answered by this simulation is how sub-activities be schedule to enable flexibility and optimize resource usage.

The performance indicators that are used to evaluate the efficiency of different system configuration are patients' throughput time and ED efficiency which is related to:

- Waiting Time
- Length of stay
- ED Productivity
- Layout Efficiency
- Resource Utilization

Software used

There are different software's that can be used for simulation of any system whether it is a factory, bank, etc. They differ based on what they require, their flexibility, ease of use etc. AnyLogic, simul8, NetLogo; Arena, etc. are among some of the software's used to simulate any system. All software's have different version that is updated every time. In this thesis, Arena 10 version of simulation software is used to simulate the ED process. The researcher selected this software due to its availability, flexibility, ease of use etc.

5.2.Fitting Input Distribution through the Input analyzer

After the above data are collected, it has to be tested for their independence. Scatter plot method is employed for the data collected on each category. Before input distribution is fitted into the data, an ordinary ASCII text file containing the data in free format is prepared using notepad. The individual data values are separated by tabs. Then based on this data files, distribution is fitted to it. When input analyzer fits a distribution to the data, it estimates the distribution's parameter (including any shifts or offset that's required to formulate a valid expressions) and calculates a number of measures of how good the distributions fits the data.

There are theoretical and empirical distributions and each type of distribution is further broken down into continuous and discrete types. To select which type of distribution to use, the researcher has compared the square error of each distribution. The larger the square error value, the further away the fitted distribution is from the actual data (and thus the poorer the fit).

Therefore the following fit all summary orders the distribution from smallest to largest square error.

Similar procedure has been followed to determine the distribution of the rest of the ED process.

No.	Process	Distribution
1	Patient arrival	-0.001 + WEIB(0, 0)
2	Triage	4.5 + 29 * BETA(0, 0)
3	Waiting	TRIA(0, 0, 0)
4	Front assessment	1.5 + 11 * BETA(0, 0)
5	Arrival pattern to resuscitation	-0.001 + 1.44e+003 * BETA(0, 0)
6	Red/Resuscitation treatment	30 + WEIB(0, 0)
7	Arrival pattern to orange	-0.001 + WEIB(0, 0)
8	Orange patient treatment	180 + 9.9e+003 * BETA(0, 0)
9	Yellow/Green patients arrival pattern	-0.001 + WEIB(0, 0)
10	Yellow/Green patient treatment	-0.001 + 4.32e+003 * BETA(0, 0)

Table 5.2.1 Sub-activities process time and Inter-arrival

5.3. As Is Model Formulation and Construction

Before any simulation is begun, the basic thing to do is to formulate the model design. Some of the things that must be considered here are data structure or constraints, the type of analysis to be performed, the type of animation required etc. Different assumptions must be made on the entity and run-setup.

In TASH ED, different processes are carried out at a time. Most of the patients coming to the ED are referred from different health centers nearby and all-over the country there is option to refer back to anywhere else. However, as it is identified in 3.Data Collection and Analysis the most critical process that should be focused on are Red/Resuscitation and the hugely affected Orange and Yellow/Green treatment zones. The modeling of the existing process mentioned above is important to make the result more reliable and to increase the adaptability of the proposed model.

The simulation software used in this thesis is arena 10. The basic building blocks for Arena are called modules. These modules form the flow chart and data objects that define the process to be simulated and are chosen from panels in the project bar. Flowchart modules describe the dynamic process in the model. They are defined as nodes or places through which entities flow, or where entities originate or leave the model. Data modules are the set of objects in the spreadsheet view of the model that define the characteristics of various process elements, such as resources and queues.

5.3.1. Red/Resuscitation Process Model

In TASH ED, currently there is a triage process and front assessment process are carried out first; before main categories, which are red/resuscitation, orange and yellow/green patients are classified. Each process has their own nurses, doctors and clinical equipment having their own inputs and outputs. Therefore, the model for each process is modeled and analyzed separately. Finally, model integration is done to see the overall throughput. In this study, a generic model for the main process is selected. Therefore, not each process is considered as separate entity.

Arena Modules Required

In these model different Arena modules has been used. In this thesis, the process modules used are create, process, decide, record, delay, dispose, etc. and the data modules used are entity, queue, resource, schedule, failure, static, etc.

Triage Process Model

In this process, the basic operations performed are receiving newly arrived patients, and then based on level of seriousness of the illness(like chest pain, bleeding, comma, etc.) of the patient may go to directly to resuscitation or to regular triage room. Then in triage room with the available one nurse and two supporting staffs and available basic clinical devices basic physical conditions are evaluated and identification of the type and level of sickness is performed. Then based on primary triage procedure for further assessment the patient moves to the front assessment room with two doctors and two nurses to validate the triage identification and to diagnose patients with mild (mostly Green) cases. If the identified triage level need further diagnostic and treatment then the patient moves to red or orange or yellow green or ortho areas based on the triage category. The following figure shows the process described above.

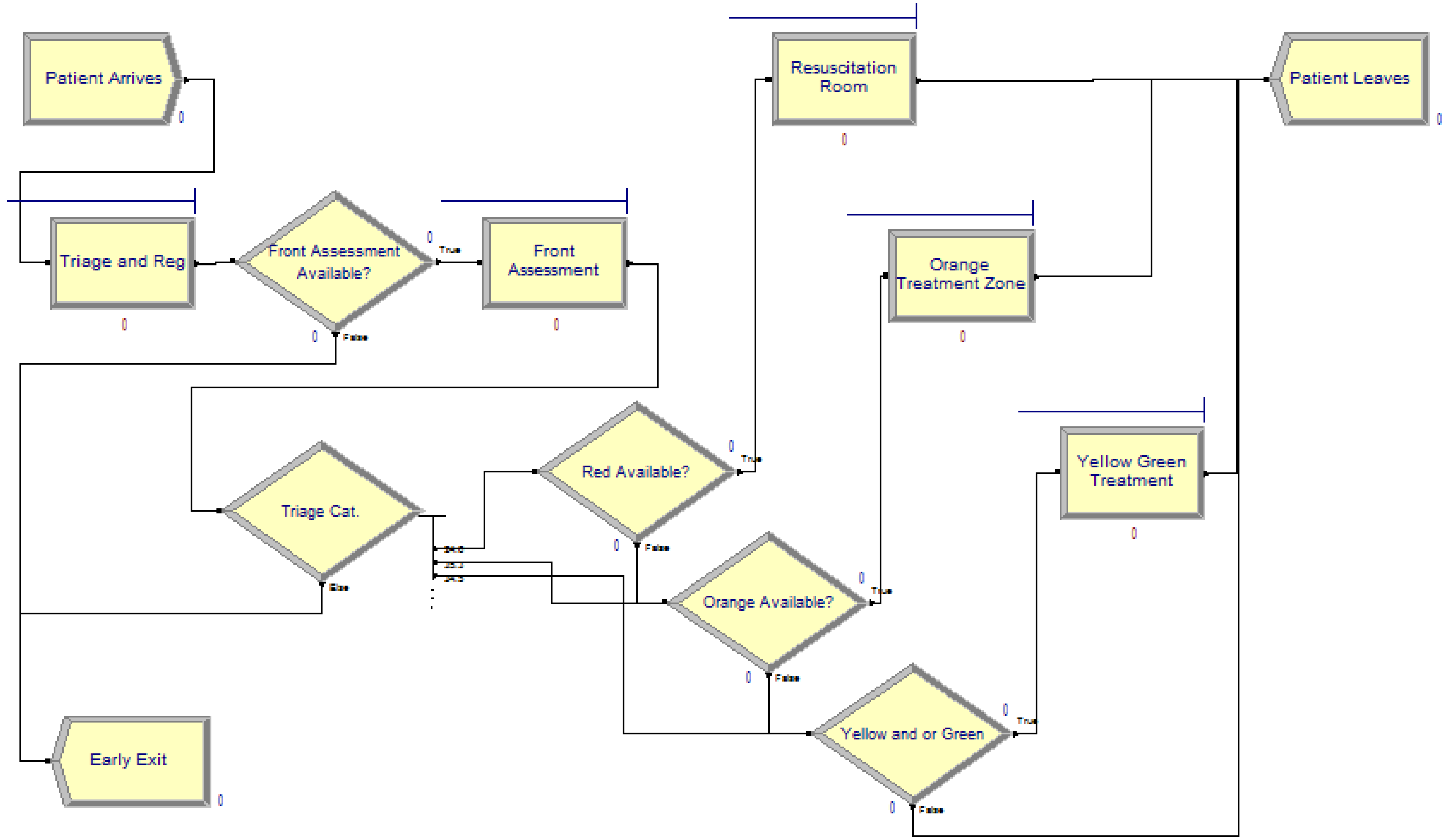

Figure 5.3.1.1 ED Triage Process Model

5.4. Model Verification and Validation

One of the most important steps of simulation modeling is verification and validation. If the model does not reflect the real system, outputs of the model has a bad effect on the reliability and quality of the decision made. Therefore, in order for this model correctly reflects the emergency department process behavior, it is verified and validated. The simulation software Arena is user friendly for testing the model in visual way and in every step it helps the user to control the steps.

In terminating simulations, determining the run length is important to analyze System behavior. Run length determination can be done approximately or by trial and error. (Yemane, 2013)

5.4.1. Verification

Verification is the process of ensuring that the Arena model behaves in a way intended as the modeling assumptions made. Generally, in verification it is assessed the correctness of the model. Different methods have been applied to verify the model.

- One easy verification method is to allow only a single patient to enter into the system and follow that entity to be sure that the model logic and data are correct. In this simulation model, allowing only a single entity to go through the hall system did make any difference compared to the assumptions made.
- Checking how the model behaves under extreme conditions. The researcher has increased and decreased inter-arrival times in each sub activities. No problems have been identified in the overall process.
- Making long runs for different data and observing the summary results for potential problems is another verification method applied.
- Code verification: when Arena simulation run, it examines each option selected in the modules and the data is supplied and then creates SIMAN MOD and EXP files. These are the files that are used to run the simulation. Therefore, the SIMAN code for this model can be viewed using Run/SIMAN/View menu option. The researcher has seen this code to check if the codes are performing as intended.
- The researcher has also tried to use different process times, failure rate etc. to see any difference. The model was allowed to run for extended periods and results from these

runs were carefully reviewed looking for huge queues, unutilized resources, etc. From these it was seen that there is no resource that was not used.

Considering all the assumptions made and limitations faced, the result from the verifications above can be accepted.

5.4.2. Validation

Validation is the task of ensuring that the model behaves the same as the real scenario. The researcher has tried to validate the simulation model by comparing the results of the model with the real emergency department process.

The other validation technique used is inviting the TASH's Emergency Department staff to review the model. Doctors, nurses and other IT engineers has been participated in the process.

5.5. Experimentation and Analysis

After verification and validation of simulation model is done, the next thing to do is statistical analysis of its out puts. However, some factors affecting the kind of analysis done on the model. The first one is the time frame of simulations. As it is known most simulations can be classified as terminating or steady state. (Yemane, 2013). In this thesis the simulation model is decided to be terminating. The reason for avoiding steady state simulation is that, it is a lot harder to carry out anything approaching a valid statistical analysis than in terminating case if anything beyond Arena's standard 95% confidence intervals on mean performance measure is wanted. (W.David Kelton, 2003). In addition the run length for steady state simulation needs to be long. However, the number of entities allowed in the student version of Arena per one replication is not more than one hundred fifty; which of-course is less than the number of patients arriving in the emergency department in a week. Hence, the researcher forced to consider doing the analysis on a daily basis for 24 hours, which is in average 72 new patients arrived. This constraint is another reason to reject steady state simulation because it needs a longer run length.

5.5.1. Number of Replication Estimation

In terminating simulation, it is simple to collect the appropriate data for statistical analysis. It is just to make some number n of independent replication. However, the main question is what number of replication to make. Therefore, the researcher has conducted a few analyses to decide on the number of replications.

First, the model must run some initial set of replication so that sample average, standard deviation and confidence interval are computed. The Largest one, which is 151 replications, is selected.

5.5.2. Simulation Model Run Results Interpretation

The objective of this thesis is to model the TASH ED process, analyze its performance, and finally propose an improved model. The problems identified are low throughput, high length of stay, high waiting time and low productivity, which are due to low resource utilization, unorganized flow of processes etc. Therefore, the performance measures selected to be analyzed are entity, process, queue and resource for each department's model.

Resource Scheduling Efficiency

Resources	Triage & Registration	Front Assessment Area	Red/Resuscitation Zone	Orange Zone	Yellow/Green Zone
Nurses	2	2	2	2	7
Doctors	-	2	1	1	1
Beds	1	2	5	9	10
Patients served at a time	1	2	5	9	10
Utilization	50%	75%	55.5%	75%	23%

Table 5.5.2.1 Resources scheduling efficiency

Chapter Six

6. Proposed Model Development

In this thesis the triage process was selected to model the ED process of Tikur Anbesa Specialized Hospital. The process selected was the most contributor of overcrowding. Therefore a model is built for first triage and recording, front examination and main treatment rooms.

The proposed model is built based on the existing system model. To build the proposed model different analysis and decision-making are used on the existing model. The first analysis performed is identification of critical sub activities contributing to lag the overall process. During this analysis different lagging factors/bottlenecks were identified and eliminated. The bottlenecks were identified based on factors like resources like doctors, nurses and beds utilization and patients waiting time in a queue. To eliminate the bottlenecks identified; idle resources and, similar resources from other process can be reassigned to work in the lagging station. In doing so, no additional cost is incurred to buy beds and to hire doctors and nurses. In addition some kind of attitudinal change on working schedule required for workers to adapt to new schedules they may be assigned.

As it is already mentioned, the modeling of the existing system using ED process is done to make the result of this study more reliable. In addition, since building a simulation model can be a difficult and time consuming task, it will be useful for other decision-makers to reuse the simulation model and change it to solve other similar problems or evaluate another option. Thus, it is desirable to have adaptable simulation models that are easy to change with little or no programming effort. Therefore, the proposed simulation model built in this study is more adaptable to:

- Changes to the real system that the model must incorporate,
- Changes to more detailed specification of the model,
- Changes to the problems encountered to be answered

This is due to the fact that most of the processes in any emergency departments are more or less similar and the proposed model can be applied for different set of problems other emergency departments of healthcare centers with slight modifications.

6.1. Proposed Model Result Analysis

The proposed model results are analyzed based on the objectives set first. The objectives were related to:

- Waiting time reduction
- Length of stay reduction
- Increase resource utilization effectiveness
- Increasing throughput
- Flexibility of resources flow

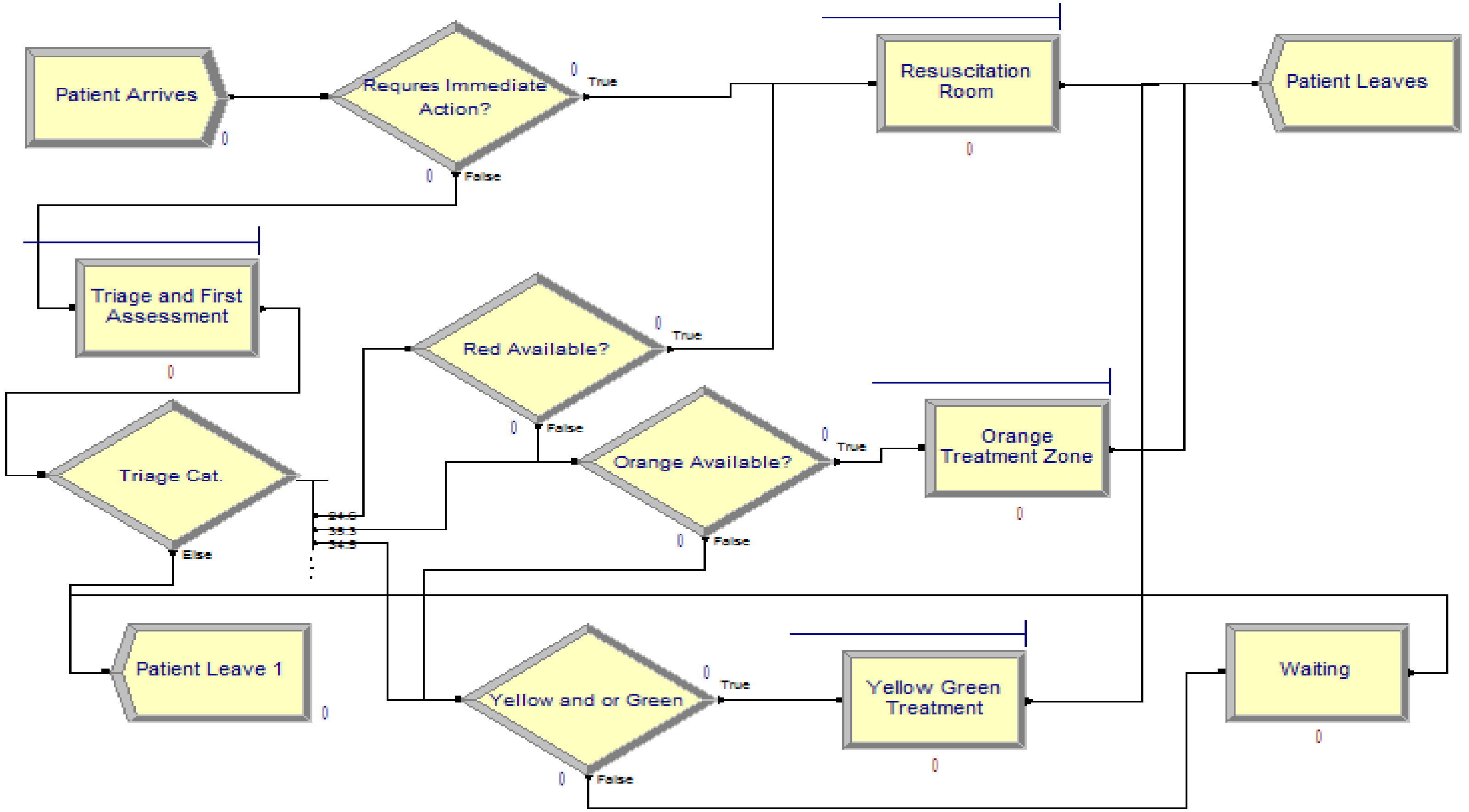

Figure 6.1.1 Proposed Model

Length of Stay

Total time is the summation of waiting time, examination time, assessment time and other value adding and non-value adding times. In order to increase the throughput of any system, the total time must be reduced. This can be done by reducing the waiting time through effective resource utilization and reduction of non-value adding time. Therefore, in the proposed model, the total length of stay is smaller compared to the existing model due to the reduction of waiting time.

Sub Activity	Existing LOS (minutes)	Proposed LOS (minutes)	Reduction by Percentage
First Triage and recording process	17.9	13.3	25.6%
Front assessment process	6.16	5.1	16.23%
Red/Resuscitation process	786	567	27.86%

Table 6.1.1 Length of stay Comparisons

Resources

Most of the resources in Tikur Anbessa Specialized Hospital Emergency Department are underutilized. That is why resources reassignment and rescheduling are used to eliminate the lagging effects identified. This is useful in increasing resource utilization so that the all length of stay has improved.

Resources	Triage & Front Assessment		Red/Resuscitation Zone		Orange Zone		Yellow/Green Zone	
	Existing	Recommended	Existing	Recommended	Existing	Recommended	Existing	Recommended
Nurses	4	4	2	3	2	3	7	6
Doctors	2	2	1	2	1	1	1	1
Beds	3	4	5	8	9	9	10	20
Patients served at a time	3	4	5	8	9	9	10	20

Scheduled resource Utilization	62%	75%	55.5%	88.8%	75%	80%	23%	48%

Table 6.1.2 Proposed resource scheduling

Waiting Time

From the proposed model, it can be seen that the patients waiting in corridors and different zones are minimum. This has impacted efficiency and effectiveness of the overall process. The waiting time is reduced by re-assigning additional idle resources in the busy processes.

Flexibility

Flexibility is seen in relation to process flow and resources. Building an ED process model that can be suit to different models was one of the objectives of the thesis. Different patients with dynamically varying cases and acuity levels are treated in the emergency department. Even though, each patient has its own unique process to make throughout the ED, there are more basic process common to all of them. Therefore, the proposed model is made by taking this basic processes and making room for improvement for specific ones. This flexibility is also made by taking resource sharing concept in to practice. This is because if the resources are flexible, the flow line can also be flexible.

Chapter Seven

7. Conclusion and Recommendation

7.1. Conclusions

In this research ED process modeling and optimization analysis using simulation has been made. The simulation is done by using Arena, student version software. The performance measure used is length of stay and it is directly related to waiting time and resource utilization, and with flexibility of process. Simulation models were built for the triage process, front assessment and treatment zones together.

Based on the results of the simulation runs, the following conclusions are drawn:

- The throughput from the existing system is low due to presence of lagging processes and absence of flexible flow process and etc.,
- The sub-process with the largest queue and low resource utilization are identified as a lagging sub-processes/ bottlenecks,
- The bottlenecks identified are eliminated using reassigning the existing resources and adding few extra resources (nurses and beds),
- In addition to bottleneck elimination, existing system simulation model built using the as-is process model build a more flexible proposed model.

Finally, a new model was proposed and similar simulation runs had been conducted. Accordingly in the proposed model length of stay in first triage and registration, front assessment and red/resuscitation process has decreased by 25.6%, 16.23%, 27.86% respectively due to optimization of resources scheduling. This total length of stay reduction resulted in more than 10 % decrease in the overcrowding of the ED. Therefore, it can be concluded that the proposed model is beneficial to the Hospital.

7.2. Recommendations

Even though Emergency Department of Tikur Anbessa Hospital is one of the leading ED in the country it has been forgotten for long time compared to the newly evolved hospitals like St. Paul's Hospital. Recently new facilities are being built for the facility to overcome the overcrowding in addition few innovative improvements are being done on the existing facility. But still the researcher has observed that the problems identified are still big issues.

Therefore, based on the conclusions drawn the researcher recommends that the TASH ED to implement the proposed model to improve the existing performance of the emergency department by improving resource utilization and making the process flow more flexible. In addition other hospitals' EDs can use the proposed model taking into consideration changes to the real system that the model must incorporate; and changes to more detailed specification of the model and changes to the problems encountered to be answered.

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Appendices

Appendix A: Some data Collected

Daily Arrival Time

Length of Stay

	Red	Orange	Yellow	Green
Day 1	15:30	14:00	0:55	15:30
4/1/2010		16:25	14:00	
		16:50	14:10	
		19:46	14:10	
		20:20	15:00	
		21:42	15:39	
		22:47	15:40	
			16:10	
			16:10	
			17:00	
			18:36	
			19:45	
			20:40	
			20:42	
Day 2	11:04	1:22	0:54	1:36
5/1/2010		8:00	4:23	7:15
		8:46	9:06	7:23
		8:58	9:25	8:50
		9:06	10:25	9:55
		9:30	10:30	10:20
		9:42	10:30	10:55
		9:55	11:15	
		10:58	11:18	
			11:20	
			11:20	
			11:37	
			11:40	
			11:50	

			12:10	
Day 3	12:56	13:37	15:10	17:10
2/1/2010	14:52	15:10	15:30	
	16:26	16:55	15:40	
	17:45	17:45	15:56	
		17:46	16:00	
		18:45	16:15	
		20:00	17:55	
		22:58	18:45	
		23:27	19:37	
			20:48	
			21:44	
			22:47	
Day 4	19:30	2:32	2:43	5:30
3/1/2010		2:35	8:35	7:45
		5:10	9:10	10:05
		11:30	9:40	10:20
		11:50	9:55	10:41
		12:30	10:15	11:05
		20:15	10:20	11:10
		20:00	10:48	11:11
		21:34	19:40	15:35
		21:53	20:10	18:40
		22:00		18:50
		22:20		19:46
				20:20
				20:30
				20:40
				21:00
				21:40
				22:10
Day 5	20:40	0:00	0:00	8:30
4/1/2010		0:55	2:00	9:25
		1:00	2:15	10:00
		1:16	6:37	10:05
		2:30	8:30	11:55
		8:35	8:00	
		10:05	9:10	
		10:30	9:40	

		11:35	9:50	
		18:36	10:00	
		19:46	10:30	
		19:45	10:00	
		20:42	10:05	
		20:20	10:25	
		21:42	10:41	
		22:47	11:05	
		23:00		
Day 6	8:46	8:30	9:14	12:10
9/1/2010	13:59	9:10	15:03	12:38
	15:30	12:11	15:20	14:00
	17:00	12:20	15:54	14:50
	18:50	14:00	20:15	15:09
	23:55	15:10	21:20	22:02
		15:36	22:02	22:07
		17:00	23:00	22:07
		17:12		22:20
		18:45		22:20
		20:10		22:30
		20:40		22:43
		22:43		23:46
		23:25		23:46
		23:57		
Day 7	16:50	2:25	0:30	0:05
10/1/2010		2:30	1:50	4:00
		2:50	4:30	5:30
		4:36	4:35	5:40
		7:45	7:46	9:00
		8:10	8:30	9:00
		9:48	8:40	14:30
		14:55	9:21	15:05
		15:00	9:41	16:50
		16:30	14:30	
		20:12	19:00	
			19:20	
			12:00	
Day 8	1:10	9:30	0:05	9:25
11/1/2010	16:50	10:10	3:00	10:40

	19:50	12:40	4:35	11:05
	21:30	13:00	6:02	11:29
		15:45	8:50	13:40
		17:00	9:10	
		18:00	9:50	
		18:00	9:50	
		19:40	9:57	
		19:50	10:25	
		20:00	10:53	
		20:10	12:45	
		21:30	12:52	
		22:20	13:01	
			14:59	
			15:20	
			15:30	
			15:35	
			16:35	
			16:41	
			20:10	
			22:58	
Day 9	9:56	0:27	8:05	0:00
12/1/2010	10:15	0:27	9:36	0:02
	11:50	9:43	10:34	0:27
	13:50	10:10	14:05	0:34
	14:22	13:00	14:08	10:55
	18:43	13:12	15:32	14:30
	19:35	13:14	15:38	15:00
	20:30	14:06	16:00	15:25
	20:45	16:20	16:10	16:34
	21:28	17:10	16:40	16:40
		23:40	17:00	
			17:06	
			17:30	
			17:30	
			21:42	
			22:03	
			22:14	
Day 10	3:32	1:25	0:20	0:10
13/1/2010	14:30	2:15	1:05	0:25
	18:28	3:40	1:06	2:07

	19:10	15:00	1:07	11:30
	21:43	16:11	1:44	12:01
	23:00	18:10	4:10	13:36
		19:00	9:50	16:10
		23:30	11:00	17:10
			12:54	17:15
			14:05	17:20
			14:44	18:00
			15:05	19:57
			17:25	20:06
			22:13	20:50
			22:15	22:20
			22:40	22:34
				22:46
				22:50
Day 11	1:25	4:43	8:00	1:10
14/1/10	7:00	10:58	9:58	10:10
	7:35	11:00	11:00	20:23
	9:01	12:50	11:40	
	16:20	14:47	12:34	
	21:00	18:46	13:05	
		21:00	14:45	
			15:41	
			16:10	
			20:55	
Day 12				
15/1/2010	10:44	7:15	5:40	4:40
	10:50	9:28	6:30	6:25
	11:25	10:00	7:22	7:40
	11:30	22:15	7:36	8:00
		22:25	11:45	10:05
			12:20	11:20
			14:00	12:10
			14:10	12:40
			14:50	12:48
			15:15	14:00
			15:15	21:20
			15:30	22:00
			15:35	
			15:50	

			16:30	
			17:00	
			17:05	
			17:15	
			17:25	
			21:30	
			22:10	
			22:25	
Day 13	0:40	0:25	8:30	8:30
16/1/2010	15:30	2:55	8:54	9:10
	18:04	13:10	9:10	9:20
		14:45	9:50	17:44
		15:40	10:40	19:10
		16:00	13:10	20:59
		17:50	13:10	21:42
		22:40	15:00	21:56
			15:05	23:30
			17:30	
			17:40	
			17:44	
			17:50	
			17:55	
			22:25	
			23:10	
			23:58	
Day 14	2:10	1:20	3:33	7:00
17/1/10	3:08	4:30	5:23	7:52
	12:30	5:00	6:58	8:45
	16:40	5:10	7:08	9:16
		5:40	7:10	9:40
		7:50	8:30	13:53
		8:20	9:00	14:07
		8:40	9:22	14:38
		10:24	10:26	18:00
		12:56	12:20	18:00
		13:52	15:37	18:14
		15:00		20:40
		18:20		20:42
		18:38		22:10
		20:00		

		20:57		
		22:00		
		22:39		
Day 15	16:47	8:45	8:21	11:00
18/1/10		12:12	9:01	11:09
		12:39	9:43	19:25
		20:40	10:00	
			10:25	
			10:25	
			10:30	
			10:30	
			11:26	
			11:43	
			11:45	
			11:48	
			11:48	
			11:55	
			12:00	
			12:10	
			12:35	
			13:02	
			13:10	
			13:30	
			13:44	
			14:08	
			14:09	
			14:32	
			15:00	
			15:25	
			15:25	
			15:56	
			16:39	
			18:30	
			19:18	
			20:02	
			21:10	
			22:00	
Day 16	3:25	0:10	0:00	8:40
19/1/10	7:08	9:40	1:28	9:00
	8:30	9:50	9:20	9:30

	11:15	10:00	10:00	9:32
		10:50	10:34	9:50
		10:55	11:00	10:00
		14:00	11:45	10:15
		16:45	11:52	13:40
		19:22	11:57	14:43
			13:28	19:38
			16:16	23:04
			16:34	
			16:43	
			21:11	
			22:20	
			23:44	
Day 17	3:10	4:10	1:17	8:40
20/1/2010	4:40	4:50	9:00	11:10
	5:40	8:20	10:29	13:46
	8:32	12:24	11:00	19:15
	15:00	13:20	12:16	
	17:00	13:30	13:32	
	18:00	17:59	17:36	
	18:30	18:50	17:59	
	19:55		19:16	
	21:40		20:30	
			20:50	
			23:28	
			23:53	
Day 18				
21/1/2010	21:35	10:36	7:10	8:00
		11:20	10:45	12:20
		21:34	11:00	1:40
		23:10	3:10	2:40
		23:18	23:00	3:15
				19:05
				20:15
Day 19	11:27	2:10	0:45	8:40
22/1/2010	2:57	5:13	5:50	10:40
	3:00	10:40	8:16	11:05
		0:10	8:40	11:05
		0:50	8:42	11:05

		14:20	3:16	0:30
		14:30	3:12	4:05
		2:40	9:15	
		2:45	10:32	
		3:40	11:10	
		6:20	11:00	
		7:45	11:30	
		12:10	11:45	
		1:30	11:22	
			0:00	
			0:50	
			2:55	
			3:25	
			3:40	
			3:45	
			11:05	
			10:20	
Day 20	14:00	9:45	9:18	10:20
23/1/10	14:56	10:40	10:37	11:04
	16:46	11:05	10:50	11:10
		11:20	11:17	12:00
		11:30	10:10	12:35
		11:57	12:08	13:00
		12:25	12:47	13:35
		13:30	12:57	13:36
		15:25	13:00	15:10
		16:00	13:00	15:40
			13:16	16:20
			14:16	17:44
			14:45	17:50
			15:05	
			15:35	
			14:55	
			15:40	
			15:42	
			16:17	
			16:30	
			17:31	
			17:40	
			17:42	

Day 21		15:20	15:05	8:50
24/1/10		15:55	15:19	16:26
		16:00	15:31	
		19:10	15:37	
		21:50	15:45	
		22:20	15:50	
			15:51	
			16:10	
			16:30	
			16:50	
			17:05	
			17:05	
			19:50	
Day 22	2:00	0:00	0:14	7:20
25/1/10	11:00	1:20	7:40	7:50
	15:14	8:20	8:30	8:40
		9:56	9:00	9:35
		10:40	9:00	9:53
		11:20	9:35	10:19
		13:10	10:10	10:40
		13:51	10:30	10:50
		14:25	11:50	14:46
		15:06	11:55	
		16:25	13:37	
		18:53	13:54	
		20:08	15:00	
		20:33	15:22	
			15:30	
			16:00	
Day 23	12:00	0:25	0:10	9:35
26/1/10	12:30	1:56	1:00	9:47
	12:30	2:28	7:10	10:10
	12:50	8:45	8:17	11:30
	15:20	10:20	8:55	13:25
	15:55	10:42	9:20	15:40
	17:00	11:25	9:40	16:50
	18:00	11:50	10:00	17:35
		12:00	10:00	
		12:30	10:25	
		12:45	10:30	

		15:17	10:48	
		19:30	10:50	
		19:31	11:00	
		21:20	11:10	
			11:25	
			11:40	
			11:55	
			13:30	
			13:47	
			14:00	
			14:10	
			14:18	
			14:47	
			15:00	
			15:31	
			15:46	
			16:10	
			16:20	
			16:20	
			17:30	
			18:30	
			19:30	
			21:00	
			21:20	
Day 24	19:25	8:50	6:40	7:33
27/1/2010	19:35		8:30	
	21:00		8:30	
			18:30	
			20:00	
			21:40	
			22:00	
			23:50	
Day 25	0:49	1:10	2:15	0:16
28/1/10	7:30	5:00	9:20	0:54
	13:21	5:00	10:20	1:45
		7:00	10:45	10:30
		7:30	11:00	14:40
		7:30	11:15	14:54
		7:30	13:27	15:10
		8:00	18:50	

		8:30		
		9:00		
Day 26	1:30	4:00	1:39	0:55
29/1/10	3:09	6:20	3:25	2:40
	5:13	6:50	4:05	10:40
	11:05	8:40	4:10	11:40
	16:40	9:00	8:38	13:44
	20:00	9:20	8:51	13:54
		10:07	9:13	13:55
		10:30	10:30	14:35
		10:55	10:40	15:40
		11:54	11:25	15:49
		12:20	11:30	15:55
		12:32	11:44	16:20
		13:20	12:15	21:40
		13:32	12:38	
		14:00	12:55	
		14:20	13:40	
		15:05	14:55	
		15:14	15:14	
		15:20	15:36	
		15:48	15:57	
		16:00	16:10	
		16:21	16:20	
		17:15	16:23	
		21:47	19:00	
			19:49	
			21:20	
			21:53	
			22:55	
Day 27	9:25	6:57	8:45	8:47
30/1/10	21:12	8:46	8:55	9:02
		10:30	9:20	10:25
		10:30	9:25	11:30
		11:40	9:30	11:35
		14:50	9:40	14:25
		15:55	9:55	14:30
		18:32	10:00	15:00
		18:32	10:10	15:36
		22:20	10:13	16:53

			10:25	20:45
			10:32	
			10:38	
			11:00	
			11:30	
			11:45	
			11:45	
			11:55	
			13:17	
			13:21	
			13:40	
			13:42	
			13:49	
			13:50	
			14:00	
			14:10	
			14:40	
			14:48	
			15:36	
			16:30	
			17:58	
			19:35	
			20:30	
			21:45	
Day 28	10:20	0:38	0:30	9:30
1/1/2010	10:38	2:13	9:00	9:40
		9:50	9:19	9:50
		10:20	9:20	10:00
		10:40	10:02	11:24
		10:55	10:42	11:30
		11:50	11:20	13:30
		11:54	11:16	
		0:15	11:20	
		0:40	11:40	
		0:50	0:10	
		13:12	0:20	
		15:39	0:24	
		16:10	13:37	
		16:35	14:23	
		17:35	14:23	
		17:35	17:00	

		18:55	17:16	
		19:30	19:17	
		20:49	19:44	
		21:05	20:05	
			20:44	
Day 29	10:20	1:03	2:10	3:30
2/2/2010		5:20	7:00	9:40
		8:10	10:30	10:15
		10:40	12:00	10:40
		10:50		10:50
		11:00		10:50
		12:50		11:15
		18:13		11:20
		20:10		21:44
Day 30	12:50	6:30	3:00	14:37
3/2/2010		7:45	6:40	18:40
		11:35	8:50	
		14:22	10:30	
		15:54	10:45	
		16:15	11:00	
		19:23	11:06	
		21:55	11:08	
		12:04	11:10	
			11:15	
			11:29	
			11:50	
			11:40	
			11:45	
			12:35	
			12:42	
			12:59	
			13:24	
			13:23	
			14:15	
			14:38	
			14:45	
			15:30	
			15:50	
			16:00	
			16:44	

			16:55	
			17:05	
			18:30	
			19:25	
			20:38	
Day 31	5:30	7:50	8:13	9:37
4/2/2010	8:20	9:44	9:00	11:55
	20:16	11:40	9:25	14:05
	21:03	16:24	21:13	14:44
	21:00	16:35	18:05	15:39
			18:59	18:50
			19:30	21:35
			20:05	
			21:49	
			22:00	
Day 32	3:44	7:45	0:05	0:38
5/2/2010	7:40	8:05	0:25	7:56
	14:50	9:32	1:17	12:18
	21:55	10:01	6:17	17:53
		10:53	11:05	
		11:20	11:11	
		11:55	11:50	
		13:50	11:56	
		17:45	13:40	
		21:30	15:48	
			16:34	
			16:53	
			17:33	
			19:13	
			19:15	
Day 33	8:20	7:00	0:10	8:10
6/2/2010	20:00	7:26	0:32	10:35
	20:45	8:25	0:37	10:40
		8:29	8:00	18:25
		10:30	9:00	19:30
		10:47	9:17	
		13:53	9:56	
		14:11	10:00	
		15:30	10:04	

		16:00	10:35	
		20:25	10:52	
			16:36	
			17:05	
			17:51	
			19:52	
Day 34	0:10	0:02	8:38	10:42
7/2/2010	10:26	0:17	8:53	10:47
		0:26	9:03	11:53
		9:36	9:30	
		9:40	10:24	
		10:00	10:25	
		11:40	11:35	
		11:40	11:50	
		13:10	11:53	
		13:20	11:53	
		13:25	13:06	
		14:07	14:07	
		16:00	14:30	
		16:26	14:35	
		20:37	15:09	
			16:35	
			18:50	
			19:00	
Day 35	14:49	0:20	0:34	11:05
8/2/2010		0:30	0:59	12:09
		1:50	1:05	13:14
		8:00	3:35	15:10
		9:55	7:30	17:56
		10:30	8:15	19:29
		10:30	9:28	19:51
		11:00	9:48	
		11:30	10:31	
		14:09	10:35	
		16:30	10:38	
		16:30	11:45	
		18:55	11:55	
		19:24	12:02	
			12:12	
			12:22	

			12:42	
			13:30	
			13:35	
			13:57	
			14:38	
			15:40	
			16:22	
			16:55	
			17:30	
			18:40	
			19:10	
			22:31	
			22:36	
			22:38	
			23:00	
			23:55	
			23:57	
Day 36	0:30	0:30	0:00	7:10
9/2/2010	10:40	1:10	0:38	7:45
	14:35	10:06	0:57	8:20
	23:26	10:45	1:35	9:27
		11:30	8:46	11:15
		13:49	8:54	11:16
		14:33	9:35	11:20
		14:40	10:12	14:54
		19:14	11:14	15:49
		21:54	11:24	
			11:58	
			13:00	
			13:55	
			14:13	
			16:20	
			16:25	
			16:46	
			17:05	
			17:10	
			18:06	
			18:28	
			19:56	
			20:05	

Day 37	0:50	0:00	0:06	8:02
10/2/2010	4:46	0:03	2:35	8:57
	11:00	0:13	4:47	10:30
		1:35	7:14	11:52
		2:30	7:42	15:35
		9:18	7:52	21:07
		9:56	9:02	
		10:30	9:07	
		10:51	9:49	
		10:52	9:50	
		11:23	10:02	
		11:40	10:10	
		11:47	10:28	
		14:53	10:32	
		15:26	11:26	
		16:28	11:38	
		17:36	11:58	
		17:43	13:06	
		20:52	13:29	
		21:37	13:56	
		21:57	14:40	
		23:00	14:53	
			15:09	
			15:36	
			15:53	
			16:00	
			16:36	
			17:02	
			18:55	
			20:05	
Day 38	4:23	1:17	5:06	9:30
11/2/2010	12:30	1:47	6:35	9:30
	17:00	9:44	6:40	9:35
	20:51	12:55	9:15	9:40
		14:45	9:57	11:49
		14:45	10:00	12:14
		16:20	10:47	12:15
		22:29	12:47	14:47
			13:18	
			15:04	
			15:05	

			18:00	
			20:31	
Day 39	14:53	2:30	9:57	3:59
12/2/2010	16:40	8:50	10:45	7:33
	18:00	15:19	13:57	11:35
		21:20	15:50	11:50
		21:30	16:11	14:00
			16:18	15:30
			16:18	19:45
			17:45	
			20:39	
Day 40	13:40	0:23	0:00	0:16
13/2/2010		0:28	0:09	9:56
		8:55	0:25	10:52
		9:40	7:24	11:26
		10:12	9:07	12:50
		10:40	9:16	15:16
		10:50	9:51	16:30
		11:23	9:54	16:40
		11:26	11:08	16:50
		11:50	11:26	16:50
		13:00	11:43	17:30
		13:26	14:40	17:50
		13:30	14:40	
		14:10	14:54	
		15:24	15:13	
		15:32	15:32	
		16:03	15:54	
		17:46	16:00	
		18:15	16:13	
		18:25	19:01	
		20:55	20:30	
		23:30		
Day 41	5:30	0:38	2:00	9:20
14/2/10	8:50	3:25	8:15	10:40
	9:40	10:25	9:10	10:49
	13:46	11:30	9:28	12:10
	15:19	11:35	9:40	12:39
	16:50	11:35	10:05	13:33

	17:01	13:10	10:12	14:49
	17:05	14:19	10:30	15:00
	17:56	15:15	10:39	15:08
	20:50	16:10	11:00	15:45
		18:33	11:35	15:57
		21:20	11:55	16:00
		22:50	12:22	16:40
		23:35	12:44	17:10
			12:45	17:21
			13:25	19:30
			14:54	22:35
			15:10	23:40
			15:30	
			15:36	
			21:00	
Day 42	0:05	0:00	1:10	1:28
15/2/10	0:55	0:45	5:00	1:30
	19:30	3:30	6:30	4:22
		6:50	9:32	9:30
		10:24	9:40	11:07
		10:50	9:56	11:57
		10:51	10:16	12:23
		10:52	10:28	12:44
		11:30	11:37	14:05
		12:08	11:47	15:12
		12:14	12:00	16:07
		12:35	12:18	16:12
		15:52	12:58	16:34
		17:35	13:00	
		18:35	14:00	
		21:45	14:48	
		21:50	14:54	
			15:12	
			15:20	
			15:36	
			15:37	
			15:44	
			15:52	
			16:25	
			16:38	
			21:33	

Day 43	0:25	0:00	0:20	0:10
16/2/2010	11:12	0:04	2:10	6:52
	20:32	2:00	2:14	9:00
		4:28	2:45	10:00
		7:54	8:34	10:06
		8:23	8:40	10:47
		9:02	8:50	13:04
		9:05	10:50	21:06
		10:20	11:15	22:10
		10:22	11:24	
		10:54	11:28	
		10:56	15:18	
		11:10	15:30	
		11:33	15:34	
		16:35	15:45	
		16:38	16:54	
		17:00	17:03	
		17:15		
		17:42		
		22:20		
Day 43	2:00	1:37	0:45	6:15
17/2/2010	4:15	10:00	2:15	8:41
	9:40	10:05	3:40	9:03
	9:52	11:27	8:05	9:22
	14:30	12:42	9:14	9:40
		14:15	9:23	10:15
		15:01	9:59	10:22
		17:39	10:00	10:40
		17:46	10:18	10:47
		18:30	10:34	11:23
		18:35	10:35	14:09
		22:10	10:52	15:40
			11:27	16:57
			11:33	17:00
			12:30	
			14:00	
			14:13	
			14:15	
			14:20	
			14:30	

			14:51	
			14:55	
			15:30	
			16:09	
			17:00	
			17:20	
Day 43	0:00	9:10	7:27	14:17
18/2/2010		9:30	9:04	18:45
		10:52	9:10	19:30
		13:30	10:39	21:30
		15:58	10:00	23:41
		20:45	11:00	
		23:52	11:10	
		0:30	13:10	
			15:06	
			15:56	
			16:36	
			19:00	
			20:00	
			21:00	
			22:57	
			23:00	
Day 43	17:01	8:15	7:32	
19/02/2010	17:28	8:30	7:22	
		9:00	8:08	
		10:00	9:10	
		0:34	9:22	
		1:40	9:30	
		14:29	11:35	
		16:28	18:25	
		16:38	19:25	
		17:22	20:47	
		18:19	0:54	
		18:30	1:00	
		21:56	23:03	
		22:10		
Day 44	10:30	8:40	6:38	9:00
20/02/2010	11:20	10:10	7:05	10:49
	11:25	11:00	8:35	11:01

11:05	9:20	12:06
11:20	10:50	12:55
14:50	11:00	13:20
14:50	11:10	13:35
	11:28	14:17
	11:40	14:25
	12:00	14:33
	12:10	14:40
	14:00	15:00
	14:47	16:10
	17:25	16:10
	20:30	16:51
	20:52	23:45
	21:45	
	22:00	

	Day	Meskerem	Tikimt	Hidar	Tahisas	Tir	Yekatit
Tuesday	1	17	48	24	48	42	51
Wednesday	2	34	51	28	69	31	20
Thursday	3	51	44	20	47	58	52

Friday	4	52	27	58	28	54	46
Saturday	5	38	34	65	61	55	75
Sunday	6	47	42	32	54	54	24
Monday	7	48	38	46	26	56	34
Tuesday	8	50	58	48	48	31	67
Wednesday	9	43	47	49	64	19	43
Thursday	10	40	61	76	27	74	52
Friday	11	49	33	27	29	37	82
Saturday	12	48	25	32	71	52	28
Sunday	13	54	57	17	49	50	29
Monday	14	28	64	50	48	59	28
Tuesday	15	46	60	57	57	30	61
Wednesday	16	46	50	39	63	37	36
Thursday	17	49	57	2	32	54	54
Friday	18	44	29	57	27	54	54
Saturday	19	51	28	27	59	52	32
Sunday	20	35	46	36	45	49	34
Monday	21	19	46	31	54	48	18
Tuesday	22	50	64	64	60	36	72
Wednesday	23	59	47	44	35	21	31
Thursday	24	51	56	28	32	41	28
Friday	25	42	38	45	27	52	48
Saturday	26	66	25	24	29	40	44
Sunday	27	25	42	32	38	54	46
Monday	28	26	47	53	49	31	48
Tuesday	29	76	54	47	53	27	49
Wednesday	30	57	51	52	61	53	51

Appendix B: The As-Is model simulation report

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.01737516	< 0.00	0.00	0.05555556	Text Object	0.5000

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	1.9021	< 0.07	0.8974	3.0435	0.00	7.0000

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	1.9195	< 0.07	0.8974	3.0435	0.00	7.0000

Process

Time per Entity

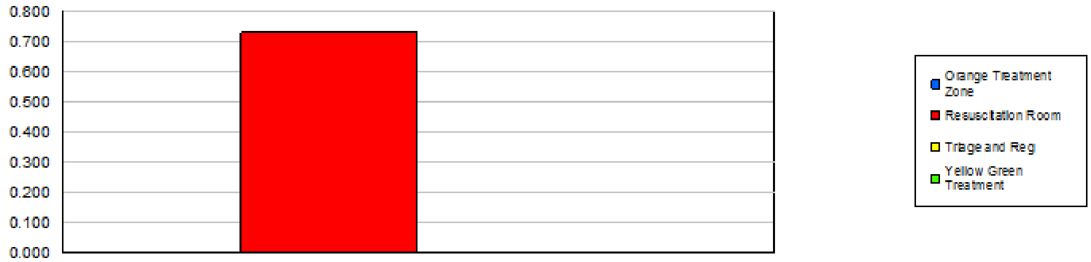
VA Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Orange Treatment Zone	0.00	< 0.00	0.00	0.00	0.00	0.00
Resuscitation Room	0.2743	< 0.03	0.00	0.5000	0.00	0.5000
Triage and Reg	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Front Assessment	0.00	< 0.00	0.00	Text Object	0.00	0.00
Orange Treatment Zone	7.0000	< 0.00	7.0000	7.0000	7.0000	7.0000
Resuscitation Room	0.2656	< 0.06	0.00	1.9375	0.00	3.5000
Triage and Reg	0.00	< 0.00	0.00	0.00	0.00	0.00

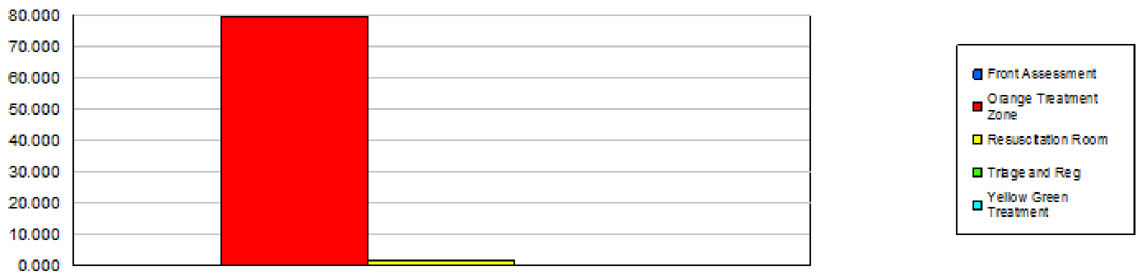
Total Time Per Entity	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Front Assessment	0.00	< 0.00	0.00	0.00	0.00	0.00
Orange Treatment Zone	7.0000	< 0.00	7.0000	7.0000	7.0000	7.0000
Resuscitation Room	0.5399	< 0.08	0.00	2.2500	0.00	3.5000
Triage and Reg	0.00	< 0.00	0.00	0.00	0.00	0.00

Accumulated Time

Accum VA Time	Average	Half Width	Minimum Average	Maximum Average
Orange Treatment Zone	0.00	0.00	0.00	0.00
Resuscitation Room	0.7285	0.10	0.00	2.5000
Triage and Reg	0.00	0.00	0.00	0.00
Yellow Green Treatment	0.00	0.00	0.00	0.00



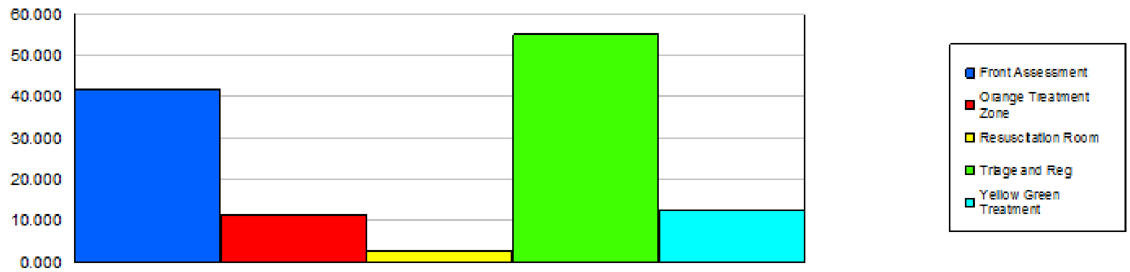
Accum Wait Time	Average	Half Width	Minimum Average	Maximum Average
Front Assessment	0.00	0.00	0.00	0.00
Orange Treatment Zone	79.3179	3.15	35.0000	140.00
Resuscitation Room	1.1159	0.36	0.00	15.5000
Triage and Reg	0.00	0.00	0.00	0.00
Yellow Green Treatment	0.00	0.00	0.00	0.00



Other

Number In

	Average	Half Width	Minimum Average	Maximum Average
Front Assessment	41.5828	0.50	34.0000	48.0000
Orange Treatment Zone	11.3311	0.45	5.0000	20.0000
Resuscitation Room	2.4702	0.25	0.00	8.0000
Triage and Reg	55.0000	0.00	55.0000	55.0000
Yellow Green Treatment	12.6490	0.56	2.0000	23.0000



Queue

Time

Waiting Time

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Front Assessment.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Orange Treatment Zone.Queue	7.0000	< 0.00	7.0000	7.0000	7.0000	7.0000
Resuscitation Room.Queue	0.2656	< 0.06	0.00	1.9375	0.00	3.5000
Triage and Reg.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00

Other

Number Waiting

	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Front Assessment.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Orange Treatment Zone.Queue	3.3049	< 0.13	1.4583	5.8333	0.00	20.0000
Resuscitation Room.Queue	0.04649558	< 0.02	0.00	0.6458	0.00	7.0000
Triage and Reg.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Yellow Green Treatment.Queue	12.6490	< 0.56	2.0000	23.0000	0.00	23.0000

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bed FA	0.00	< 0.00	0.00	0.00	0.00	1.0000
Bed O	0.00	< 0.00	0.00	0.00	0.00	1.0000
Bed Red	0.03035320	< 0.00	0.00	0.1042	0.00	1.0000
Bed Tr	0.00	< 0.00	0.00	0.00	0.00	1.0000
Bed YG	0.00	< 0.00	0.00	0.00	0.00	0.00
Doc FA	0.00	< 0.00	0.00	0.00	0.00	1.0000
Doc O	0.00	< 0.00	0.00	0.00	0.00	1.0000
Doc Red	0.03035320	< 0.00	0.00	0.1042	0.00	1.0000
Doc YG	0.00	< 0.00	0.00	0.00	0.00	0.00
Nurse FA	0.00	< 0.00	0.00	0.00	0.00	1.0000
Nurse O	0.00	< 0.00	0.00	0.00	0.00	1.0000
Nurse Red	0.03035320	< 0.00	0.00	0.1042	0.00	1.0000
Nurse Tr	0.00	< 0.00	0.00	0.00	0.00	1.0000
Nurse YG	0.00	< 0.00	0.00	0.00	0.00	0.00

Number Busy	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bed FA	0.00	< 0.00	0.00	0.00	0.00	2.0000
Bed O	0.00	< 0.00	0.00	0.00	0.00	9.0000
Bed Red	0.1518	< 0.02	0.00	0.5208	0.00	5.0000
Bed Tr	0.00	< 0.00	0.00	0.00	0.00	1.0000
Bed YG	0.00	< 0.00	0.00	0.00	0.00	0.00
Doc FA	0.00	< 0.00	0.00	0.00	0.00	2.0000
Doc O	0.00	< 0.00	0.00	0.00	0.00	1.0000
Doc Red	0.03035320	< 0.00	0.00	0.1042	0.00	1.0000
Doc YG	0.00	< 0.00	0.00	0.00	0.00	0.00
Nurse FA	0.00	< 0.00	0.00	0.00	0.00	2.0000
Nurse O	0.00	< 0.00	0.00	0.00	0.00	2.0000
Nurse Red	0.06070640	< 0.01	0.00	0.2083	0.00	2.0000
Nurse Tr	0.00	< 0.00	0.00	0.00	0.00	2.0000
Nurse YG	0.00	< 0.00	0.00	0.00	0.00	0.00

Appendix B: The As-Is model simulation report

Entity

Time

VA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.03732079	< 0.00	0.00	0.06944444	0.00	0.5000

NVA Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Wait Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.6930	[illegible] Text Object	0.4514	0.9444	0.00	4.5000

Transfer Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Other Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.00	< 0.00	0.00	0.00	0.00	0.00

Total Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Patient	0.7303	< 0.02	0.4653	1.0139	0.00	5.0000

Queue

Time

Waiting Time	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Orange Treatment Zone.Queue	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000
Resuscitation Room.Queue	1.1317	< 0.09	0.00	2.5000	0.00	4.5000
Triage and First Assessment.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Yellow Green Treatment.Queue	1.0000	< 0.00	1.0000	1.0000	1.0000	1.0000

Other

Number Waiting	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Orange Treatment Zone.Queue	0.7745	< 0.02	0.3750	1.1667	0.00	28.0000
Resuscitation Room.Queue	0.4474	< 0.05	0.00	1.2500	0.00	16.0000
Triage and First Assessment.Queue	0.00	< 0.00	0.00	0.00	0.00	0.00
Yellow Green Treatment.Queue	0.8570	< 0.02	0.4583	Max of StatsAndOutputQry.AvgObs (Number)		

Resource

Usage

Number Scheduled	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Bed_O	9.0000	< 0.00	9.0000	9.0000	9.0000	9.0000
Bed_RR	9.0000	< 0.00	9.0000	9.0000	9.0000	9.0000
Bed_TF	4.0000	< 0.00	4.0000	4.0000	4.0000	4.0000
Bed_YG	20.0000	< 0.00	20.0000	20.0000	20.0000	20.0000
Doctor_O	0.9583	< 0.00	0.9583	0.9583	0.00	1.0000
Doctor_RR	2.0000	< 0.00	2.0000	2.0000	2.0000	2.0000
Doctor_TF	2.0000	< 0.00	2.0000	2.0000	2.0000	2.0000
Doctor_YG	1.9167	< 0.00	1.9167	1.9167	0.00	2.0000
Nurse_O	3.0000	< 0.00	3.0000	3.0000	3.0000	3.0000
Nurse_RR	3.0000	< 0.00	3.0000	3.0000	3.0000	3.0000
Nurse_TF	4.0000	< 0.00	4.0000	4.0000	4.0000	4.0000
Nurse_YG	7.0000	< 0.00	7.0000	7.0000	7.0000	7.0000

Scheduled Utilization	Average	Half Width	Minimum Average	Maximum Average
Bed_O	0.00	0.00	0.00	0.00
Bed_RR	0.0995	0.01	0.00	0.1852
Bed_TF	0.00	0.00	0.00	0.00
Bed_YG	0.00	0.00	0.00	[illegible]
Doctor_O	0.00	0.00	0.00	0.00
Doctor_RR	0.1120	0.01	0.00	0.2083
Doctor_TF	0.00	0.00	0.00	0.00
Doctor_YG	0.00	0.00	0.00	0.00
Nurse_O	0.00	0.00	0.00	0.00
Nurse_RR	0.1120	0.01	0.00	0.2083
Nurse_TF	0.00	0.00	0.00	0.00
Nurse_YG	0.00	0.00	0.00	0.00

Max of StatsAndOutputQry.Value (Number)

Total Number Seized	Average	Half Width	Minimum Average	Maximum Average
Bed_O	167.28	5.31	81.0000	252.00
Bed_RR	68.6968	3.31	16.0000	136.00
Bed_TF	259.51	1.49	236.00	284.00
Bed_YG	205.68	5.83	110.00	330.00
Doctor_O	18.5871	0.59	9.0000	28.0000
Doctor_RR	17.1742	0.83	4.0000	34.0000
Doctor_TF	129.75	0.74	118.00	142.00
Doctor_YG	41.1355	1.17	22.0000	66.0000
Nurse_O	55.7613	1.77	27.0000	84.0000
Nurse_RR	25.7613	1.24	6.0000	51.0000
Nurse_TF	259.51	1.49	236.00	284.00
Nurse_YG	123.41	3.50	66.0000	198.00