DISASTER RECOVERY PLAN DEVELOPMENT FOR THE EMERGENCYDEPARTMENT - CASE STUDY

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ABSTRACT

Simulation is a powerful tool that can be utilized to measure and improve the performance of healthcare systems, such as the Emergency Department (ED). Simulation models were developed in this research to evaluate the performance of the normal operation of a specific ED. The study uses simulation to develop two models. The first model represents normal operations for an ED used as a case study. The second model represents the operations of the ED during disaster times. Real data was collected from the ED and used to check the validity of the simulation model for normal operations. The original model was modified to simulate several scenarios for disaster recovery plans. The impact of different scenarios generated during unusual conditions for all models were analyzed. These models only considered activities performed inside the ED which starts with the patient registration and ends when the patient is either discharged or admitted into the hospital.

Hospitals regularly develop and revise their disaster recovery plans. However, the objective of these plans is to maximize the readiness of the ED and their facilities to enable them to carry out an unusual load created in the event of a disaster. The authors used an ED as a case study to set a procedure to develop several scenarios. The performance of the ED is evaluated under these conditions with the objective to maximize the ED readiness, maximize the patient throughput by minimizing the patient flow time.

Keywords: Healthcare, Simulation, Emergency Department, and Disaster Recovery Plan

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INTRODUCTION

Healthcare is a rapidly developing industry that faces many challenges. Simulation is proven tool to enhance system ability to keep up with the demand for higher quality of service and lower cost. The main issue in the healthcare is characterized by patient waiting time in emergency departments. The emergency department is one of the few systems where seconds can be critical to the patient's life. The ED operates around the clock and receives different number of patients with various symptoms and degrees of severity. Moreover, the complexity of the relationships among different sections of the ED does exist. Understanding these relationships may help to improve performance of the ED system. Several studies have used simulation methods as a tool to imitate the real-life of the ED system over time. This is particularly useful to analyze and describe the behaviour of complex systems. Moreover, simulation tools can be used to study the behaviour of a certain system under extreme conditions to enhance the ED's readiness when these conditions actually occurred. It is the first step towards investigating different alternatives to achieve the best performance, Kattan and Abboud (2008).

Disaster management plans are specially designed to maximize the readiness of the EDs in order to reduce the impact of the disaster. However, it is difficult to examine the efficiency of these plans before such a disaster takes place. Therefore, simulation models can test the efficiency of available resources inside the ED, define bottlenecks and suggest ways to improve system performance. In this research simulation models were developed to achieve the following objectives:

1. Simulate the current operation to identify the bottlenecks
2. Modify the present situation to develop different scenarios for disaster mode
3. Prepare the disaster recovery plans and identify all requirements.
4. Improve the performance of the ED by maximize the patient throughput and minimize the patient flow time.

ED PATIENTS CLASSIFICATION

Currently, there are three different triage systems worldwide; the Manchester Triage Scale; the Canadian Triage Scale and the Australian Triage Scale. The ED under study implements the Manchester Triage Scale. It classifies patients into five scale, with T1 being the most critical, and T5 the least critical. The classification of patients received by the ED is according to the severity of the case. The term 'Triage' refers to the process of sorting patients according to the urgency of their need for medical treatment. After registration, patients are evaluated by a qualified triage nurse. If a patient is found to have a problem in any of these categories T1 through T5, he/she should be admitted directly to the main ED. T1 patients have the highest priority and admitted at resuscitation room. If the triage nurse completes primary assessment of the patient and finds no life-threatening situation, the secondary assessment is conducted. By collecting a variety of data about the patient, the triage nurse will be able to classify the patient into T2, T3, T4, or T5. Next step is to admit the patient to a specific ward by informing the in-charge nurse in that ward. Once a bed and necessary instruments are ready, the patient will be sent to the hospital, along with the medical record. At this time, the patient is considered to be out of the ED service.

The ALERT mode is activated if there is a disaster alert, or a situation arises in which the potential for damage is limited in terms of anticipated patient load/severity. The MINOR mode is applied when the existing on-site capabilities are deemed adequate for the anticipated patient load/severity. The MAJOR mode is generally applied when the anticipated load/severity is likely to overload existing on-site resources to the extent that additional staffing are required, as stated in the General Authority for Health Services for Emirate of Abu Dhabi, External Disaster Code, 2005. In this study the authors developed five simulation models. The first one is for current ED operation. The second is for base disaster model, and the other three are for different disaster levels used for the development of the recovery plans.

LITERATURE REVIEW

Simulation tools was used as early as 1974 to analyze hospital emergency department as stated by Hannan et al (1974). They used FORTRAN to evaluate the potential influence of new patient demand patterns and different decision policies upon the effectiveness of the hospital emergency department. Saunders et al (1989) developed modelling for emergency department operations using advanced computer simulation systems. Their model, however, does not reflect the real operating system because it assigns each patient to an individual nurse and physician, which is not the case in the ED as a physician will examine two or more patients in parallel. Draeger (1992) developed simulation models for three emergency departments at Bethesda Hospitals Inc. The patient waiting and treatment time, staff, and facility utilization were included in the results. However, the purpose behind this model was to evaluate alternative nurse staffing and patient population scenarios. McGuire (1994) had used simulation to reduce length of staying in the EDs. Following the same logic, the author has developed a model for a specific ED clinic to decrease the patient waiting time. At the beginning of the study, the patient average waiting time was 157 minutes. After testing several scenarios and adopting the best combination, the average was reduced to 107 minutes. A case study conducted by Weng (1999), analyzed the impact of different scenarios on total time a patient spends in the system using simulation. The overall processes time in the ED was improved. The author focused in two main areas of performance of the clinic; maximize the patient throughput and minimize the patient flow time. Coats et al (2001) stated that an extension to their original mathematical model was crucial to get more accurate results. They had to collect additional data and modified the original model.

The readiness for disaster recovery was explored in several articles. Albores and Shaw (2005) developed two models ‘in support of developing a national plan in respond to a major and catastrophic terrorist attack by getting the right person with the right skills and equipment at the right time. They stated that planning is a complex task, especially when it requires responding to combination of incidents happening simultaneously. The model explored different allocations of the resources for both centralized and decentralized cases. Another effort by Jain and McLean (2003) developed a framework for modelling and simulation for emergency response. They stressed on the need of integration of multiple models required to complete modelling of a single emergency incident. Their framework is a large scale considering different party involved in emergency response, such as first responder, police, and hospitals EDs. Ohboshi et al (1998) used different approach that introduced a workflow model for the ED in catastrophe cases. Their models were based on the data obtained at the time of the Great Hanshin–Awaji earthquake, during which more than 6,000 people died. This case led to change normal assumptions for the ED. For example, the arrival rate was assumed to be a Poisson distribution with an average of 30persons/hour. Moreover, the ratio of the severely injured victims group known as T-1 and T-2, increased by 20% as recommended by Ohboshi et al. Takeucho et al (2002) have developed an integrated earthquake disaster simulation system. The study aims to connect a dozen of simulators for individual natural phenomena and human activities. To reduce throughput time is considered a measure of performance improvement in the ED processes. In a study conducted by Ruohoen and Teittinen (2006), they found that if the operation was as effective as staff had estimated, there would be a 26% reduction in average throughput time.

Takakuwa and Shiozaki (2004) concluded that patients spend the longest part of their waiting time depending on the number of patients to be processed. They developed a stepwise procedure of operations planning to reduce the patient waiting time. Through a series of simulation experiments, patient waiting time could be minimized by adding appropriate numbers of doctors and medical instruments. The National Hospital Ambulatory Medical Care Survey conducted by Craig and Burt (2005) for the emergency department, concluded that, on average, patients spent 3.2 hours in the ED, of which 46.5 minutes were spent waiting to see a physician. Dag et al (2005) have found that simulation offers the most efficient accessory in education and "refresher" training of medical personnel. The paper discusses problems of a large scale "just-in-time" training, and initial solutions for a simulation-based preparation of medical personnel using multiple simulators and simulator sites separated by ultra-long distances. Peltokorpi et al (2008) conducted a discrete-event simulation model and provided new information about the effects of multi-intervention changes on operating room cost per patient.

EMERGENCY DEPARTMENT CASE

The layout of the ED is a standard design with a reasonable in size as described in this section. The walk-in patients enter from the front door of the ED while ambulance and helicopter patients enter from another entrance directly to the main ER. The walk-in patients are received by a registrar, followed by a triage nurse. However, if a patient is found to be a life threatening situation, he or she will enter the main ER directly. After being evaluated in one of the five triage rooms, the patient will wait in the assigned waiting rooms. The main ER consists of 23 treatment cubicle-beds and 3 resuscitation rooms for treatment of T1 patients. The hospital has modern facilities with a capacity of 100 beds. Other related facilities such as x-rays and the laboratory are located just behind the ED and are easily accessible. All treatment cubicles and resuscitation rooms are fully equipped with standard medical devices. In addition, a central control station is installed to monitor important parameters for all patients in the main ER. All information is transferred to the nurse’s station, and alarms are initiated when a patient gets into a critical situation.

A total of four registrars are available to perform administrative activities related to patient files, insurance, billing, and discharge. There are two triage nurses who are qualified to perform the triage process. A total of 16 staff nurses work in the main ER and perform all required medical activities, assisting doctors during examination and treatment times. They carry out all medical documentations about the patient. A total of 7 full time doctors are available at any time with 23 available beds. The resources needed to perform activities in the ED are either shared between the ED and other departments in the hospital or fully dedicated to ED operations. Shared resources are x-ray and laboratories. Dedicated resources are registrars, triage nurses, staff nurses, ED doctors and beds. On-call specialists are dedicated for the ED only when they are needed. There are two assumptions with respect to this issue helps the modelling. First, staff will be available on duty time and they will leave when their duty is over, unless a patient is still under treatment. Second, similar staff needs same time to perform same job (e.g. all doctors need the same time to examine a certain patient). This assumption is applicable because processing times tend to be relatively widely distributed to compensate for the individual differences in treatment times among staff members.

Data Collection

Reliability of any simulation study depends on the assumptions and the quality of the input data. The authors used data from hospital database, direct observations and expert opinion. Miller et al (2006) explored in their articles the use of Radio Frequency Identification (RFID) technologies. This technology could be utilized to replace the estimation of the activity duration conducted in the traditional way. They concluded that RFID technology will likely become more popular method for data collection. Consequently, data collection will be more accurate to enhance building better simulation model in the future. The following assumptions were used for data collection:

1. Huge data may be required in order to get good estimate of the input values.
2. Data from multiple sources need to be rectifying the estimated input parameters.

3. There is a high variability in the patient care requirements that must be modelled with random variables or complex model.
4. Integration of multiple modelling techniques may be necessary for model building.
5. Patient arrival rates can vary within the day time, or day of week and/or seasonal time.
6. There may be high variability in model outputs due to the high variability in patient behaviour and care requirements.

Data collection is crucial to the success of any simulation output. This study conducted upon request of the hospital. The hospital collaboration helps to collect data for a period of six months. The available data for this research was used to generate charts that are used to anticipate the behaviour of patient arrival at the ED. The total number of patients arrived daily from the period 1/1/2007 to 30/6/2007 was plotted in Exhibit 1. The time period under study is 181 days, during which patients arrived at the ED 24 hours/7 days a week. The total number of patients received in this period was 47,248. In the six-month period, the number of patient arrived daily was varied between 194 to 329 patients. The average number of arriving patients was 261/day. The data was very useful for developing and testing the simulation model. Using the hospital database assisted to extract the average number of patients arrived at the ED, classified patients according to their triage status (T1 to T5), and determined the treatment time. Moreover, waiting times are easily calculated and used in the Arena model. The majority (53.1%) of received patients were type T4. On the other hand, T1 patients constituted only 0.8% of the arrivals. Exhibit 2 illustrates the distribution of the arrivals according to triage status for duration of 181 day.

Although this database provides information about the ED performance, more data has to be collected in order to run, test and validate the model. The hospital database did not include the initial examination time, waiting for on-call specialist, registration time, triage time, and the time patients spend in x-rays/laboratory work. Therefore they were collected by direct observation and sampling from patient files. A sample of 90 file of volunteer patients were used to collect these additional information. Each activity is characterized by a triangular distribution with approximate values of minimum, mode and maximum. The same patient files were used to calculate percentages of patients for whom additional test were required to perform consultation with the on-call specialist, and the percentage of patients who needed additional tests required by the specialist. Analyzing patterns of patient's arrival to the ED may be useful in many respects. It could help in the designing of staff scheduling where more resources are available and more patients are expected to arrive. This will have a direct impact on the ED performance, without adding extra resources.

PROPOSED MODEL

The ED is a restricted system where the arrived entities processed by specific resources and passes through several predefined paths until the patient leaves the system. However, several issues related to simulation should be considered throughout the modelling phase. The complexity of system's behaviour is highly varied. Therefore, it is necessary to have some assumptions that make modelling the system more realistic. The following assumptions were applied to achieve simplicity of building the model:

1. Each patient retains a single triage classification throughout his/her presence in the ED.

2. Transfer time needed for different activities is inherent in the activity itself. That is, delay time for x-rays includes an approximate time needed to complete an x-ray job.

3. Staff resources are available without break. Doctors and nurses will conduct duty if any patient in the system needs them.

4. Doctor starts the initial examination of the patient accompanied with a staff nurse.

5. On-call specialists are not considered resources in the ED. They are available only when needed.

6. A bed is assigned to the patient upon entering the main ER. This bed will be released only when the patient leaves the system.

The model for the ED is developed using ARENA® simulation software, (Kelton, 2007). The main model is for the normal operation of the ED, which consists of five sub models as shown in Exhibit 2. However, Submodels are used to reduce the complexity of the model. The model starts with the submodel of Patient’s arrival with five outputs. One of these output leads entity to the T1 Patient submodel, while the other four lead to the registration and triage submodel. After passing through registration and triage, entities will move to the main Emergency Room (ER) submodel. Finally, all entities are directed to the departure submodel. Following is a brief description for each submodel.

Patient Arrival

Submodel Patient Arrival, starts by creating number of entities representing number of patients arrived to the system. The arrival rate is assumed to be exponentially distributed. According to Lowery (1998), ‘It is possible to use theoretical distributions that have been found to effectively represent healthcare processes. He added that, the arrival of emergency patients to healthcare facilities is exponentially distributed used routinely for simulation model. As per the hospital’s database, the average number of patients arriving was 261per day, which is equivalent to exponential distribution with inter arrival 5.5 minutes. Patients are classified according to their percentage of arrival as shown in Exhibit 3. These percentages of each type were extracted from the hospital’s database.

Registration and Triage

This submodel, receives all patients except T1. The arrived Patients in this submodel were directly sent to the registration, which is performed by one of the four available registrars. Before sending the patients to main ER submodel, the triage process is done by a triage nurse. Registration duration is found to be uniformly distributed between 2 and 5 minutes.

Main Emergency Room

Upon entering the ER, a nurse will guide the patient to a cubicle where vital signs are measured. This process is represented in the Vital Signs Monitoring module. Vital signs include checking blood pressure, ECG and SpO_2. After recording all required data, the patient file waits in the queue until the ER doctor is ready to diagnose the patient symptom. Diagnose time, initial ER diagnosis Time, was defined for each type of patient depending on data taken during observation. After diagnosis, the patient may need an x-ray or laboratory test. The modules set to distinguish patient's types and priority that need to be examined by a specialist. If needed, then the patients will wait for a maximum of twenty minutes as per hospital rules. After diagnosed by the specialist, it is decided whether the patient needs further investigation. If so, the patient will be sent again either to the x-ray department or laboratory and the results will be reviewed by the specialist. Following that, treatment is provided for the patient and all medical issues are explained. The second branch of this submodel directs patients to the Perform Treatment and Explanation module, where the same ER doctor is assigned to treat the patient, explain his/her medical status, and give permission for discharging the patient.

Patients Type T1

This submodel deals with the most critical patients in the ED so called T1 Patients. T1 patients represent very low percentage of admitted patients. However, considering them in the model is important for three reasons. First of all, their life is threatened and the ED performance is directly involved in their survival. Second, they utilize important resources in the ED and their presence could delay treatment for other patients. Finally, it is assumed that the percentage of T1 patients will increase dramatically with any catastrophic situation. Because these patients have a high life-threatening condition, all necessary resources should be available as early as possible. Major resources needed here are two doctors and two nurses. A patient is resuscitated, a process of life recovery, where staff try to save the patient's life. At the same time, on-call specialists are called and are available within the next twenty minutes as per hospital regulations.

Patient's Departure

The last submodel is the Patient's departure. The statistics output of this module trace all type T1 through T5 and classified all entities based on the total time spent in the ED. In addition, the total time a patient spent in the hospital are categories into five groups: less than one hour, between one hour and two hours, between two hours and three hours, between three hours and for hours and finally, more than five hours. The importance of this lies in the validation process, where the values obtained from the model are compared with the real values.

Model Validation

Validation is a process of ensuring that the model and its assumption are consistent with the actual system behaviour. The validation process is repeated until the desired level of correctness is obtained for the model's output. All proposed assumptions were tested by comparing the output of both systems; the actual system's operation and the simulation model. The model was run for a total of 100 replications. Each replication consists of 13 days, where the first three days represent a warm-up period. The total number of patients received at the ED in this time period was 2615 patients, with an average of 262 patients daily. The total number discharges by the first ED doctor (without need to a specialist) was 1620 patients, which is 62% of total number of arrivals to ED. The balance 967 patients, who represent 38%, were discharged by a specialist.

The logic of each submodel was discussed in detail with ED expert and staff. The original assumptions were modified after observing day-to-day activities within the ED.

ANALYSIS AND DISCUSSION

Several key performance indicators were developed to evaluate the ED and to analyze the results obtained from the simulation models. According Smith et al (2008), the

United Kingdom Department of Health introduced a list of key performance measurement. However, the study emphasised on; the waiting time of the patient from arrival until seen by a doctor or a trained nurse; and the total time of the patients spent in the ED. The results obtained for disaster model excludes information about T4 and T5 patients. As per external disaster plan, these patients are discarded to enter the ED at the times of the disaster. However, their situation will be evaluated only after triage. Therefore, the model will generate entities that represent the patient but these entities will be intact after triage process. The patient's waiting times are very critical in a disaster situation. A delay in treating a severely injured patient may lead to more complications, or even to the death. The results show that T1 patients have to wait in the disaster model much more than normal operation. The historical data and the output of the simulation model show that the average waiting time for T1, T2 and T3 patients during the normal operation are; 3.6, 12.5, and 14.2 minutes respectively. While the average waiting time for T1, T2 and T3 patients during the disaster models are; 11.7, 16.56, and 113.9 minutes respectively. However, the total time spend in the system is different. Exhibit 4 illustrates these results comparing the total time patients spend during the normal operation versus the disaster model.

The queue length in any stage of the ED is very important and has direct effect on the performance of any ED system. They identify the bottlenecks and help to improve system design. Analyzing the average wait time in these queues clearly shows that beds availability is the most critical issue in the disaster situation. The base model for disaster shows that an average of 63 beds needed, while currently there are only 23 beds. The high demand on beds among the other resources is because a bed will be reserved for the patient all the time he/she spends in ED. On the other hand, other resources like doctors and nurses will be utilized by the patient for a partial time. This implies that doctors and nurses serve more than one patient with a shorter time. Improving performance of the ED in the disaster plan should consider adding more beds to the ED upon a disaster announcement. Or to be able to do so, specific logistical issues should be prepared ahead of time. These include, for example, equipment, space, and location. The effect of adding extra beds improve the efficiency of disaster recovery plan. The recommendations for disaster recovery plan for all scenarios submitted to the ED hospital.

Resuscitation and initial examination queues have very close average waiting time. Activities associated with these two queues represent the first interaction point between doctors and patients in all categories. T1 patients will interact with doctors in the resuscitation process, while all other patients will interact with doctors in the initial examination by the ER doctor. The effect of adding more doctors in the disaster plan is recommended. Other queues are found to have a low average waiting time. Triage queue is important in the disaster plans for two reasons. First, it is the first point where patients' clinical status is evaluated. Second, all victims, either life-threatening or not, will be received by triage. Patients with more life-threatening situation will have to wait while other less-urgent patients are utilizing the triage nurses. This has a direct impact on life-threatening patients especially in t he disaster situations. For these reasons, it is essential to have a low average wait time in triage queue.

Disaster Model Analysis

The authors conducting sensitivity analysis for different scenarios at different severity level of the disaster with corresponding arrival rates and the percentages of patient types. According Ohboshi et al (1998), he found that for a major disaster an increased of 20% of the severely injured victims group known as T-1 and T-2. In this research we developed a base disaster plan and three additional scenarios. Exhibit 5 shows different values for different levels of severity of the disaster. The base model for disaster plan uses an arrival rate of 800 patients with an increase for T1 and T2 to 10% each. The first scenario represents an Alert for disaster case uses the same percentages 10% for T1 and T2 as used in the base model with an arrival of 1000 patients per day. The second scenario represents a minor disaster case increases percentage of T1 patients from 10% to 20% while keeping T2 percentage and arrival rate as per the base model. The third scenario is the extremist condition represents a Major disaster case. It assumes 25% patients more than the base model with 20% of T1 patients and 15% of T2 patients. The complete results from running the simulation model for these scenarios are shown in Exhibit 6.

CONCLUSION

The models developed throughout this study aimed to evaluate performance of the ED disaster recovery plans. The first simulation model imitates the normal operations of the ED. The validity of the output of this model was benchmarked with real data obtained from the ED under study. This model was then used to build the second model that simulates the base model for disaster recovery plan. Several values have been used to estimate the rate of arrivals and types of victims received at the ED. Performance of the ED under these conditions were evaluated based on international standards. Three scenarios with different combination of arrival rate for alert, minor and major disaster cases with appropriate arrival rate, T1 percentage, and T2 percentage have been generated.

Using the current disaster recovery plan will result in shortage of two important types of resources. Firstly, available beds will not be adequate to handle the large number of expected victims. To solve problems associated with shortage of resources, the author suggests signing agreements with doctors and nurses from outside the hospital. These doctors and nurses should be available as early as possible in the case of any major disaster occur. To improve their performance, regular training sessions should be conducted. On the other hand, the ED management should plan to purchase necessary equipment, consumables, and tools required in disasters recovery. Under the base model conditions, the result indicates that T1 patients have to wait an average of 11.7 minutes with an average of 63 beds needed and 17% of the T1 patients spend more than 4 hours in the ED as shown in Exhibit 6. In the extreme case (major disaster) with an arrival rate 1000 patients/day with T1 20% and T2 15% the average waiting time is 111 minutes. This implies that improving performance of the ED is hardly needed to reduce these waiting times. Finally, the results of extending the model to include other departments in the hospital will be a useful tool for evaluating the effects of integration of these departments. The performance of the ED is evaluated under these conditions with the objective to maximize the ED readiness, maximize the patient throughput by minimizing the patient flow time. Reducing throughput time is widely considered a measure of improvement in the ED.

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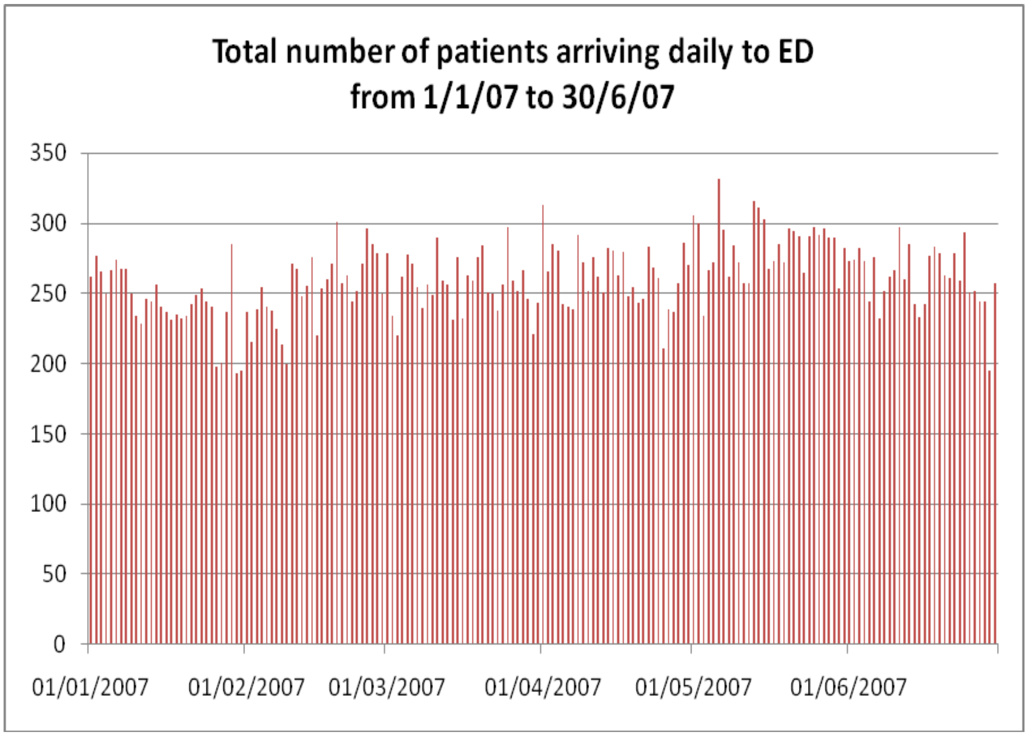

Exhibit 1 Total Number of patients arriving daily at the ED
from 1/1/07 to 30/6/07

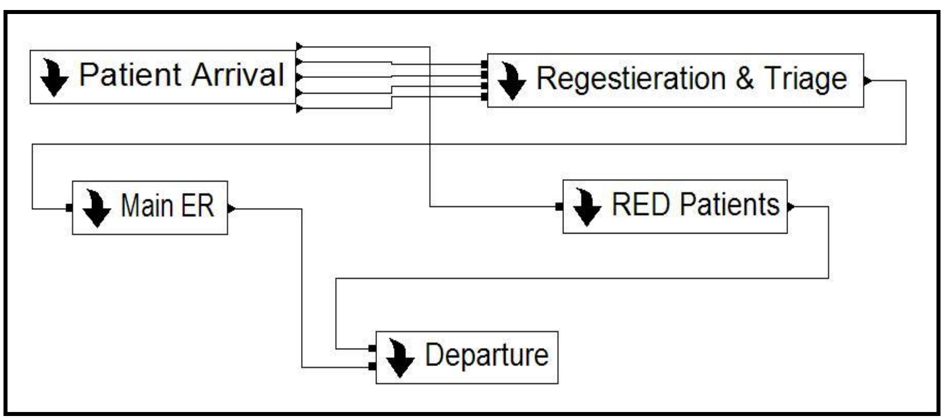

Exhibit 2 Simulation of the Main Model

	T1	T2	T3	T4	T5	Total
Total number received	382	1710	17924	25099	2133	47248
Daily Average	2.1	9.4	99.0	138.7	11.8	261
Percentage	0.8%	3.6%	37.9 %	53.1 %	4.5%	100.0 %

Exhibit 3 Summary of different types of patients arrived to ED during 181 day

Type the model	Total Time in minutes		
	T1	T2	T3
Normal Operation	62.9	124.2	109.9
Disaster Plan	57.0	96.3	193.8
Percentage of difference	- 10%	-29%	+76%

Exhibit 4 Comparison of total time in normal operation model and disaster model

Model	**Arrival rate**	**T1 percentage**	**T2 percentage**
Normal operation	261 patient/day	0.8	5
Base Disaster Plan	800 patient/day	10	10
Scenario 1 **Alert Case**	1000 patient/day	10	10
Scenario 2 **Minor Case**	800 patient/day	20	10
Scenario 3 **Major Case**	1000 patient/day	20	20

Exhibit 5 Input data for different scenarios - Disaster model

Simulation Model	Average waiting time for					
	T type -patient			Seize Bed queue	Initial examination queue	patients spent more than 4 hours
	T1	**T2**	**T3**			
Base model (T1=10%) 800 patient/day	11.7	16.6	113.9	63	11.0	17 %
Scenario 1 (T1=10%) 1000 patient/day	11.8	21.0	320.9	227	12.9	46 %
Scenario 2 (T1=20%) 800 patient/day	37.9	23.2	404	261	20.9	47 %
Scenario 3 (T1=20%) 1000 patient/day	111	31	878	650	26	60%

Exhibit 6 Complete results of running the simulation model for these Disaster scenarios