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PAIRING EMERGENCY SEVERITY INDEX5-LEVEL TRIAGE DATA WITH COMPUTER AIDED SYSTEM DESIGN TO IMPROVE EMERGENCY DEPARTMENT ACCESS AND THROUGHPUT

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ABSTRACT

Patient waiting times and service quality problems characterize emergency departments worldwide. The purpose of this research is to develop a reliable decision support system using the Emergency Severity Index (ESI©) triage method to drive improvements in the care delivery process, as part of a hospital Emergency Care Delivery System. Models were developed using first a relatively low fidelity software, ProcessModel, and then in Arena, a relatively high fidelity simulation software, to test new proposals for service delivery improvements in an academic ED in York Hospital, Pennsylvania, where the ESI© triage system has been implemented. This paper pairs the case mix derived from ESI© triage with simulation to support resource deployment to improve service metrics and support strategic decision making in academic EDs. The lessons learned could be re-analyzed in a simulation model more representative of a non-academic (regular hospital) ED that implements ESI© five level triage.

1 INTRODUCTION

Today, at the beginning of the 21st century, we observe the health care system in the U.S. and elsewhere saddled by inefficiencies and increasing costs. Despite being the No. 1 domestic industry in the U.S. with over $1.2 trillion spent on health care in 1999, the system is characterized by inefficiencies (Carter 2002). Public concern over long patient wait times and deterioration in service delivery has drawn the attention of many and is directly felt by those attempting to deliver health care services. The problem is probably most acute in an emergency department (ED) setting. The ED is recognized by most as the critical entry to the hospital service system, responsible for somewhere between 45%-65% of hospital admissions. EDs are unique in the sense that they are operational 24/7 and visits are not scheduled (Emergency Care Reform 2000). To compound the challenge, the ED health care service delivery system represents one of the most visible service sectors where the effects are very stark. Poor service delivery can make the difference between life and death. The legal consequences of failed service are immense in the U.S. (Griffith 1998). In light of the critically important ramifications of the quality of emergency health care rendered to patients presenting to a hospital seeking emergency services, the authors believe that it is necessary to look at the issue first from a systems perspective to identify root causes; and then propose and test potential solutions without perturbing real patients or real staff.

The health care setting in general, and the ED in particular, have few characteristics with exact parallels in common business firms. The care delivery process in the ED requires a reliable identification method that designates (classifies) presenting patients in a way that facilitates the provision of emergency care in a rational, fair, effective and efficient manner. The surge in demand for care delivery combined with a constantly changing demand case mix makes the delivery of ED-Hospital emergency care service delivery challenging. There were about 107.5 million ED visits in 2001, up 10% from 97.4 million visits in 1997, while the number of hospitals providing emergency care decreased (Heffler et. al 2003). The Center for Disease Control reported that the length of stay of less-urgent patients became longer because of the priority accorded to more critical patients (Emergency Care Reform, 2000). ED length of stay and time to admission for patients presenting for emergency care services have increased nearly universally.

In the face of these challenges several attempts have been made to streamline the ED care delivery processes. Such changes include computerized tracking of patient-care services, bedside registration of patients, installation of new mechanisms to speed up diagnostic tests, and development of new classification mechanisms to drive improvements in patient flows (Spaite 2002). Results in general have been limited and are certainly still far off from what might be considered "world class delivery" in a health care setting. A literature review found that policy-planners have recently emphasized the development of patient classification systems to assist with managing the entire experience of care delivery. Administrative usefulness and process compatibility need to be considered while developing a reliable patient classification system (Arbitman 1986). In order to improve quality of service and be better prepared to handle the increased demand and varied case mixes, managers require reliable and sound decision support tools to understand and analyze a service delivery system and implement appropriate change initiatives (Vissilacopoulos 1985).

Simulation affords a way to imitate a real world operation over time. Simulation is useful for analyzing and describing the behavior of the real system.

2 PROBLEM FORMULATION

The problems that the EDs are facing provided the starting point for the development of the model. Questions pertaining to the impact of policy initiatives at the York ED with respect to the introduction of alternate fast care processing routes for low acuity patients served as the main driver for the model development. The authors developed a simulation model of the entire care delivery system in place in the York ED that has implemented the ESI© 5 level triage. The variation of operating hours for the Alterna Care facility, a fast track care center, and its effect on patient experience in terms of total waiting time has been investigated as part of this research work.

3 ED SETTING

This research is a joint project of the Industrial and Systems Engineering Department at Virginia Tech and the ED of York, Pennsylvania Hospital. York hospital is part of the WellSpan Health System, an integrated health system provider serving the greater Adams-York county region of Pennsylvania. York hospital has been recognized as one of the top 100 hospitals in the U.S. It is a 558-bed tertiary care community teaching hospital and serves a population of 350,000 in south central Pennsylvania (The web site of York Hospital). The ED sees, on average, 67,000 patients annually with yearly growth rates of 5-10% in the recent 3 years. It is an academic environment with emergency medicine residency and medical students in its care provider staff mix. It participates in the hospital's trauma services supplying physician and nursing staff for resuscitation and stabilization of trauma patients. The simulation model was designed to reflect the service delivery processes by first mapping the key processes as defined by the ESI triage.

4 THE SCIENCE OF TRIAGE

Patients entering the ED first undergo triage, a clinical assessment to sort and prioritize patients. Some form of triaging has been in place, formally or informally, since the first ED opened. Most hospitals in the United States use three-level triage and attempt to sort patients into the 3 categories based on the question: "How long can this patient wait to be seen?" Other major triage methods used through out the world are, in Australia, the ATS—The Australasian Triage Scale; in parts of Canada, the CTAS—The Canadian Triage and Acuity Scale; and in the UK, the Manchester Triage Method. Although these methods sort patients into 5 classes rather than 3, all of them attempt to classify patients using the same question: "How long can this patient wait to be seen?" Asking this single question defeats the real intent of an effective ED clinical triage step, which most of us would agree to be "Who should be seen first?" Medical meaningfulness and homogeneity of patient classification is necessary to balance the clinical issues with the administrative challenges of the classification system. Medical meaningfulness refers to comparable clinical states such that they pose similar diagnostic challenges to the care-delivery team. Homogeneity refers to groups that the clinical staff might deem to have similar lengths of stay, resource consumption and treatment protocols (Arbitman 1986).

5 ESI-5 LEVEL TRIAGE

To address the true intent of triage, Eitel and Wuerz (2001), developed a new ED triage method, the Emergency Severity Index (ESI) 5 level triage. This new method is different from the current triage systems used in most EDs in the U.S. ESI 5 level triage represents a new conceptual model of ED triage: not only "Who should be seen first?" (Levels 1 and 2) but then also "What will this patient need, predictably, in terms of resources, to get to an ED disposition?"(Levels 3, 4, and 5) (Wuerz and Milne 2001). The cardinality explains the severity of the case in two contexts. ESI levels 1 and 2 deal with patient acuity, ESI levels 3, 4, and 5 deal with predicted resource needs. ESI-1 is the most severe case, demanding immediate attention. It has been validated that experienced (Wuerz, Milne and Eitel 2001), trained ED nurses can with good reliability, discriminate at triage the low versus high resource intensity users of ED services. Figure 1 illustrates this triage process.

5.1 Data Collection and Analysis

Fidelity of any simulation study depends upon the quality of the data. ESI triage was implemented in the York ED in November of 1999. Two and one-half years of patient data, including ESI case mix data, were used for this model, providing a total of 160,000 patient arrivals. York

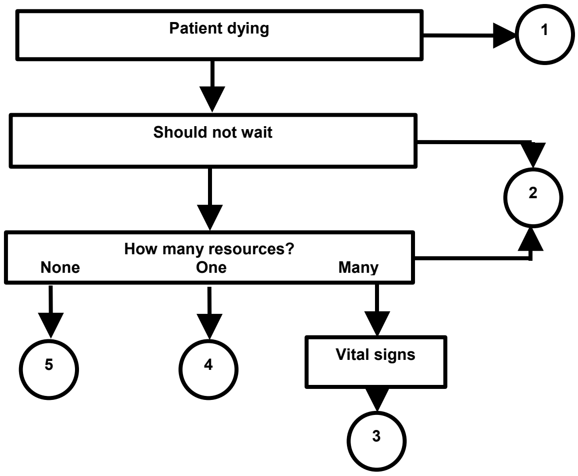

Figure 1: ESI Conceptual Procedure (Eitel and Wuerz 2001)

Hospital is a progressive, forward-looking institution that has had extensive data collection systems in place for a long period of time. These data proved invaluable for model building, verification, and validation. The data comprised the key service times that go into delivery of clinical service, including patient arrival times, waiting times at various stages (used for model validation), the case mix of the patients according to the 5-level triage, the times spent by the patient at various stages of the service delivery process, and staff schedules of ED personnel. Interviews with emergency physicians, residents, nurse administrators, and technicians were conducted to gain valuable insights into the process of ED service delivery in this teaching environment. Direct observation and the judgment of staff directly involved in the service delivery operations were used to derive average processing times and to represent the fluid interactions between the different service delivery processes.

5.2 ED Service Delivery Process

The ED service delivery process can be represented by the following set of activities. These activities occur in a sequential manner and some of the steps are either rearranged or are omitted.

1. Arrival
2. Triage
3. RN assessment
4. MD assessment
5. Initial diagnosis and treatment
6. Diagnostic Testing
7. Junior Doctor Supervision/Teaching
8. Follow up/treatment planning
9. Discharge or admit
10. Access to In-patient Beds and Admitting Physicians

5.2.1 Triage Station

Figure 2 represents patient flow through the system. Arriving patients check in and wait to be triaged by a triage nurse. At the triage station the nurse records patient signs and an ESI level (1 through 5) is assigned depending on both the acuity of the case and the predicted resource needs of the particular patient. After the initial assessment by the triage nurse the patient waits (typically in a waiting room) for an available bed. The ESI level governs the routing of the patient to one of the care delivery units, CCU or ICU/ACU. The low acuity patients are routed to the ACU, or the express care unit if it is open.

Functional analysis of the service delivery protocol listed above can be classified into the following areas of care delivery.

1. Triage Station
2. Critical Care Unit
3. Intermediate Care Unit
4. Alterna Care Unit
5. Diagnostic Testing
6. Patient Discharge/Admit

5.2.2 Critical Care Unit (CCU)

The CCU serves the most acute patient cases. ESI-1s, 2s and 3(geriatrics) are routed to the CCU unit for assessment by a CCU nurse and formal clinical assessment by an emergency physician or a senior resident. Depending on the initial assessment by the physician/resident one or more diagnostic tests are recommended. Based on the outcome of the diagnostic tests the patient is reassessed by the physician or the senior level resident. Finally, the patient is discharged or admitted to the hospital.

5.2.3 Intermediate Care Unit (ICU)

The ICU serves the less acute patient cases. ESI-3s (non geriatrics), 4s and 5s are routed to the ICU unit for initial assessment by an ICU nurse and formal clinical assessment by a emergency physician or a low level resident or a medical student. Any clinical assessment by a medical student is always followed by a repeat assessment by an emergency physician to confirm the assessment. Depending on the initial assessment none, one or many diagnostic tests are recommended. Based on the out come of the diagnostic tests the patient is reassessed by the emergency physician. Finally the patient is discharged or admitted to the hospital.

5.2.4 Alterna Care Unit (ACU)

The ACU is a fast track patient unit operational from 11:00AM -11:00PM daily. The ACU handles the low acuity case patients, the ESI 4s and 5s. This alternate treat-

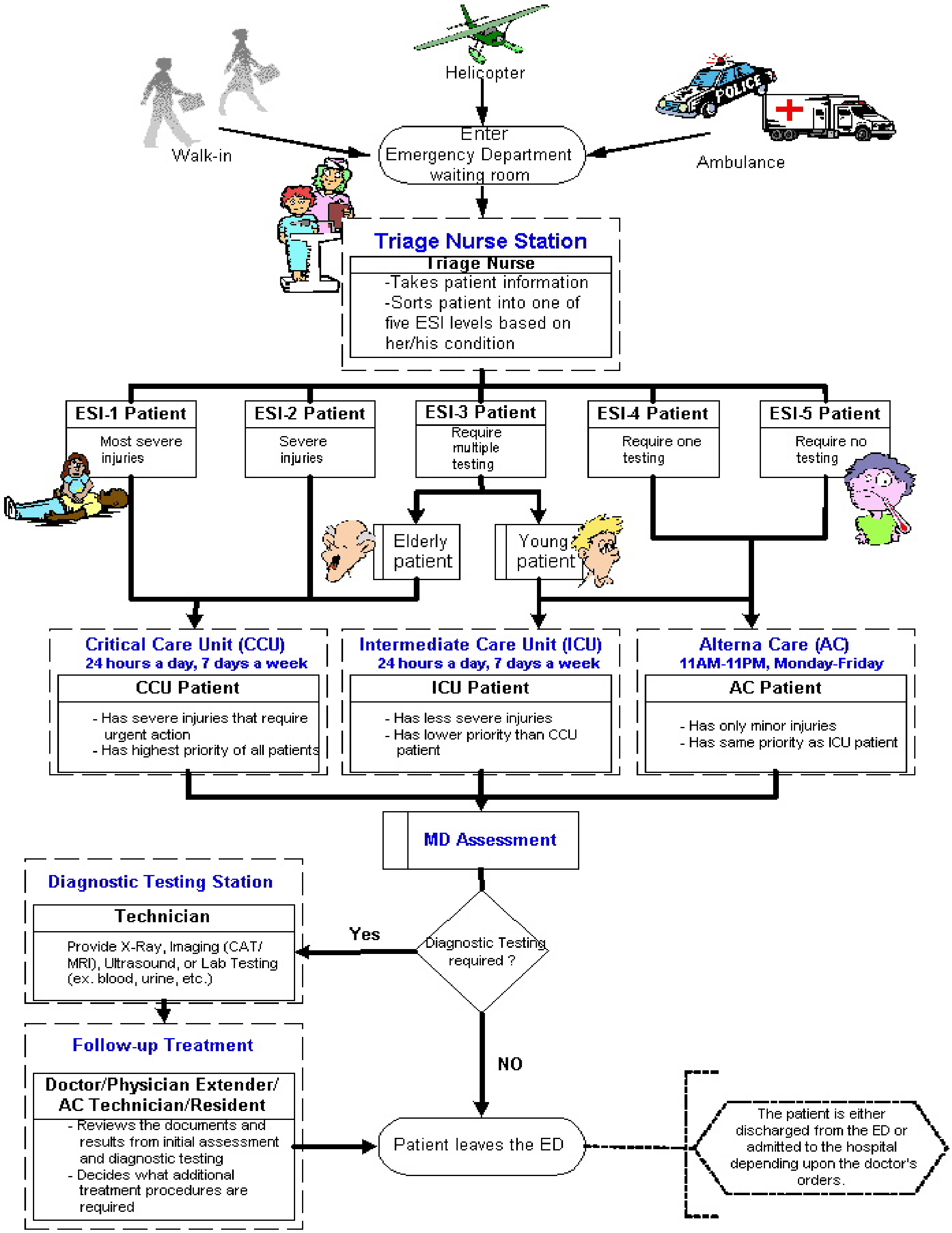

Figure 2 : The Service Delivery Process at the York ED

ment route is one of the many policy initiatives of the senior management of the York ED to bring about reductions in the overall length of stay of the patient. An Alterna Care physician, in tandem with a physician extender(PE), with occasional availability of a emergency care technician, manages the patient disposition at the ACU. We use the term PE to referrer to those professions (such as highly trained nurses) who can provide treatment normally associated with a doctor for low acuity patients.

5.2.5 Diagnostic Testing

Patients from the CCU, ICU and the ACU may undergo diagnostic tests. The diagnostic testing unit may be viewed as a set of sub-systems within a larger system. Diagnostic tests can be categorized into two broad categories - phlebotomy and imaging. The phlebotomy section performs multiple types of blood assays on patient blood samples. The imaging section includes resources for CAT scans, X-Rays and Ultrasounds. These tests help diagnose the nature of the clinical case and permit follow up remedial clinical steps.

5.2.6 Patient Discharge/Admit

Following any diagnostic tests, the patient is reviewed by the physician and or the senior level resident. The review process will result in a recommendation for admission to the hospital or discharge from the ED.

5.2.7 Patient Transportation

Patient wheeling is a critical component of the care delivery process. By patient wheeling the researchers refer to the physical transportation of the patient entity to the different units of the ED. The patient needs to be transported/wheeled to a bed (either in the CCU, the ICU or the ACU) from the waiting room, and back and forth to the diagnostic center.

5.3 Treatment Resources

The ED service delivery process is accomplished through the services of both human and physical resources. The human resources include senior and lower level residents, emergency physicians (EP), nurses, physician extenders (PE) and emergency care technicians (ECT). The senior management at the York ED provided the number of each type of clinical staff and corresponding staff schedules. Since the diagnostic testing center is shared by the hospital, the resources available at diagnostic testing are not considered a part of the ED. The processing times for all healthcare professionals with a particular set of competence working at a specific unit (CCU, ICU or ACU) was assumed to be uniform and constant. Factors pertaining to fatigue and exhaustion have not been included in the model. In real life situation there might be a significant variation due to fatigue and exhaustion, however, for this model staff efficiency was assumed to be constant.

6 ARENA MODEL

ED modeling has been undertaken using the Arena 7.0 simulation package. Arena is a windows based software platform that combines the functionality of high level simulation software with extensive coding capabilities. It supports the entire process of the simulation development cycle, including model building, data analysis, output analysis, and animation. As part of its data analysis capability Arena includes Input Analyzer as a tool for fitting appropriate statistical distributions to input data. Arena's Output Analyzer is a valuable tool for analyzing the output data obtained from simulation runs.

The main objective of the simulation model was to accurately capture the entire service delivery process in the ED. The simulation model follows the patient flow process described in section 5.2. The model has been subdivided into several sub models for ease of use as well as verification and validation purposes. The sub models include weekday period check, time period check, triage nurse station, critical care unit, intermediate care unit, Alterna care, diagnostic testing, and follow up treatment station. To address an important aspect of service where the patient entity seizes the same resource during follow-up treatments specific attributes were assigned to record and match the same resource type for all follow up assessments. The issue is explained at length in sections 6.3 and 6.4. Figure 3 is a snap shot of the Arena simulation model of the ED.

6.1 Weekday Time Period Check/ Weekend Check

This sub-model can be viewed as being comprised of two sub-units, the weekday time period check and the weekend

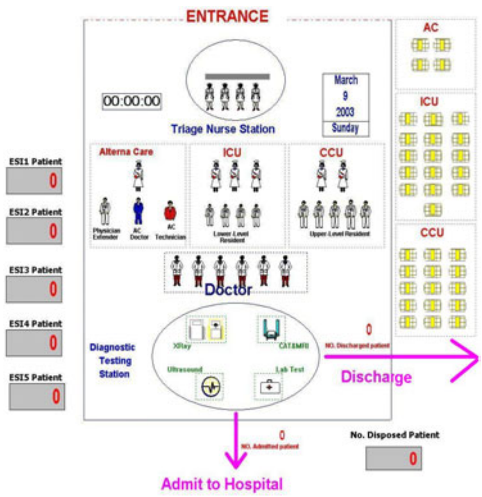

Figure 3: Snap Shot of the Arena Model of the ED

check. Weekend check functionality toggles back and forth between weekday and weekend patient distributions and directs the opening and closing of the AC on a weekly basis. The patient arrival patterns are discussed in section 6.2. The weekday sub module that works as a subordinate to the weekend check, checks the time of the day and the day of the week to govern the patient routings to the ACU.

6.2 Triage Nurse Sub-Model

This is the first service encounter for the patient upon arrival at the ED. On the basis of the historical data provided to us by the York, ED, patient arrivals were modeled as a time dependant Poisson process. Inter-arrival time distributions for two specific time blocks for each of the 5 ESI levels, one for arrivals that occurred from 12 midnight to 12 noon and the other from 12 noon to 12 midnight are generated. Table 1 indicates the mean inter-arrival times for each of the ESI levels through out the week, split into weekdays and weekends.

Table 1: Mean Inter-Arrival Times for 5 ESI Levels

ESI Level	12:00 AM – 12:00 PM		12:00 PM – 12:00 AM	
	Week days	Week ends	Week days	Week ends
ESI-1	323	289	239	270
ESI-2	93.2	96.4	67.3	67.3
ESI-3	38	34.1	21.2	20.2
ESI-4	88.8	69.5	40.4	32.8
ESI-5	199	171	142	120

On the basis of the calculated inter-arrival times probability distributions were fit. Patient routing into one of the care delivery units, CCU, ICU/ACU was achieved after the patient arrival. While ESI 1s, 2s and the geriatric cases of ESI-3 were routed to the CCU, the non geriatric cases of ESI-3 and 4s and 5s were routed to the ICU. The ESI 4s and 5s proceeded to the ACU if it was open (11:00AM-11:00PM).

6.3 Critical Care Unit Sub-Model

In the CCU sub-model, the resource mix includes both human and physical resources. The four types of resources available at the CCU include CCU nurses, CCU beds, senior-level residents and emergency physicians. Each resource type is grouped as a set, for example a CCU nurse set, CCU bed set, etc. Within this sub-model the patient undergoes an initial assessment by a CCU nurse followed by an initial assessment by an EP or a senior level resident. Specific attributes regarding about critical care unit and the critical care unit resource seized in the initial clinical assessment are saved for each patient. The attributes permit the seizure of the same resource (EP or resident) during follow-up assessments after diagnostic tests. Before leaving the sub model the patient releases all resources except his or her bed.

6.4 Intermediate Care Unit Sub-Model

In the ICU sub model, the resource mix includes both human and physical resources. The 5 types of resources include ICU nurses, ICU beds, lower level residents, emergency physicians, and medical students. At the CCU station, the resources are defined as sets, for example, ICU nurse set, ICU bed set, and others. The application of attribute assignment is also followed in this sub model.

6.5 Alterna Care Unit Sub-Model

Patients are routed to this sub-model depending upon of the time of the day and are serviced by both clinical staff and physical resources. AC nurses, AC beds, AC physician, AC technician and PEs. Similar to the CCU and the ICU stations, each resource type is grouped as a set. If the patient leaves the ACU sub-model for diagnostic testing it releases all the resources except the ACU bed.

6.6 Diagnostic Testing Sub-Model

Available data allowed the assignment of attribute values to represent the need for diagnostic testing. All patients entering diagnostic testing undergo one or more tests, including X-ray, blood work, Ultrasound and CAT scan.. The percentages of patients across all ESI levels that require each diagnostic test were obtained by analyzing the patient abstracts made available.

In addition, it is assumed that 95% of CCU patients require a portable x-ray while 95% of ICU patients use a stationary x-ray, when x-rays are needed. The diagnostic testing center is shared by the entire hospital and data pertaining to the resource consumption by other departments of the hospital were not made available to us. Consequently, the testing procedure is considered to be a simple delay with no resources being seized. Equipment downtimes have been ignored for our modeling purposes. Upon completion of the diagnostic testing the patients return to their respective care delivery units.

6.7 Follow Up Treatment Sub-Model

Same human resource the patient initially seized is seized again. One exception to this rule is that when the AC technician is working in the ACU, the AC technician completes the review process instead of the original physician or PE. Upon completion of the reassessment the patient is either admitted to the hospital or is discharged. Available data were analyzed to obtain the admission/discharge incidences for each of the ESI levels. Table 2 shows the admission percentage for each ESI level.

Table 2: Percentage of Patients Admitted to Hospital across each ESI Level

ESI Level	Percentage of Patients Admitted
ESI-1	76.06
ESI-2	56.05
ESI-3	80.70
ESI-4	0.87
ESI-5	0.48

6.8 Model Verification and Validation

Model verification and validation is crucial for the development of a reliable decision support system to drive improvements. Verification and validation was achieved in a variety of ways. The developers were in constant touch with the ED management team in York. This facilitated the capture and translation of the service delivery process to the right level of detail such that no component of the service delivery was missed. Each section of the care delivery process was discussed at length with the care providers at York. The data collection process was executed by the ED management and it included detailed activity times about each care delivery step and the staff schedule for the clinical staff.

The following three strategies were employed for model verification purposes

1. Using the capability of Arena 7.0 software package to find and fix model errors. Examples include the Run/Check option, Break option and others.
2. Animating the simulation model. Animation provided a visual corrective technique for possible modeling errors in terms of the care delivery process. Delays in entity processing provided visual cues to flawed or erroneous model logic.
3. Analyzing in a group setting comprised of graduate students, professors, and Arena experts helped to understand the many nuances of modeling. Improvements emerging from these discussions were incorporated in the model.

For validation purposes the model was executed under the current hospital staffing policy. Run lengths and warm up periods of 35 days, and 7 days respectively were used for each replication to allow for the system to reach realistic operating conditions before collecting appropriate statistics. 10 replications of the simulation have been undertaken.

6.9 Model Experimentation

The response variable includes the total waiting time of the patient as he/she goes through the care delivery process. For experimentation purposes, these statistics were compared for different scenarios of operation for the ACU to improve patient throughput and access. The different scenarios pertaining to the operation of the ACU that were reviewed as part of this research are displayed in Table 3. The researchers, in consultation with the senior management at York ED, adopted these scenarios because during these hours of the day the demand for emergency care peaks.

Table 3. Different Scenarios for the Operation of the Alterna Care Unit.

Scenario 1	9:00AM-9:00PM
Scenario 2	10:00AM-10:00PM
Scenario 3	12:00 noon-12:00 midnight

7 SIMULATION RESULTS

Response variable for each of the scenarios against the current operating hours of the ACU (11:00AM-11:00PM) are presented in this section. The response variable of interest is the overall waiting time incurred by the patients in the course of medicare service delivery process in the ED. The waiting time is defined as the sum total of all waits involved during the care delivery process including the waiting time to secure a bed, waiting time to see a physician, and if necessary waiting time for reassessment following diagnostic testing. Because of the sharing of the diagnostic unit with the main hospital, the waiting time incurred during the diagnostic assessments could not be included in the model. Ten replications of the model for each of the 3 scenarios as well as the current system were run, with each replication consisting of 35 days plus a 7 day warm-up period. Figure 4 shows the waiting times incurred by the patients across the 5 ESI levels across all 4 scenarios including the current system. Visual inspection of Figure 4 reveals that scenario 1 where the AC is operational from 9:00AM-9:00PM presents the least waiting time for patients across all 5 ESI levels.

This is based on the overall weighted average of the average waiting time for each of the 5 ESI levels multiplied with the proportion of the corresponding ESI level. Since ESI-3s and ESI-4s were the most commonly categorized ESI patient types, a significant reduction in the waiting time for these patients as evidenced by Figure 4 lowers the overall patient waiting time in the ED for scenario 1. Figure 5 compares the waiting time of each of the 5 ESI patient types across the current system and scenario 1. Compared to the current system there is a significant reduction in the patient waiting time across all the 5 ESI levels for scenario 1. Table 4 shows the average waiting time for each ESI level for the two scenarios. As evidenced scenario 1 does outperform the current system by reducing average waiting times by 16.48%, 15.82%, 12.43%, 10.90%, and 10.36% for ESI-1, ESI-2, ESI-3, ESI-4, and ESI-5 patients, respectively.

In summary, reduced waiting time in the ED can expedite the turnaround of the patients and hence improve ED access and throughput.

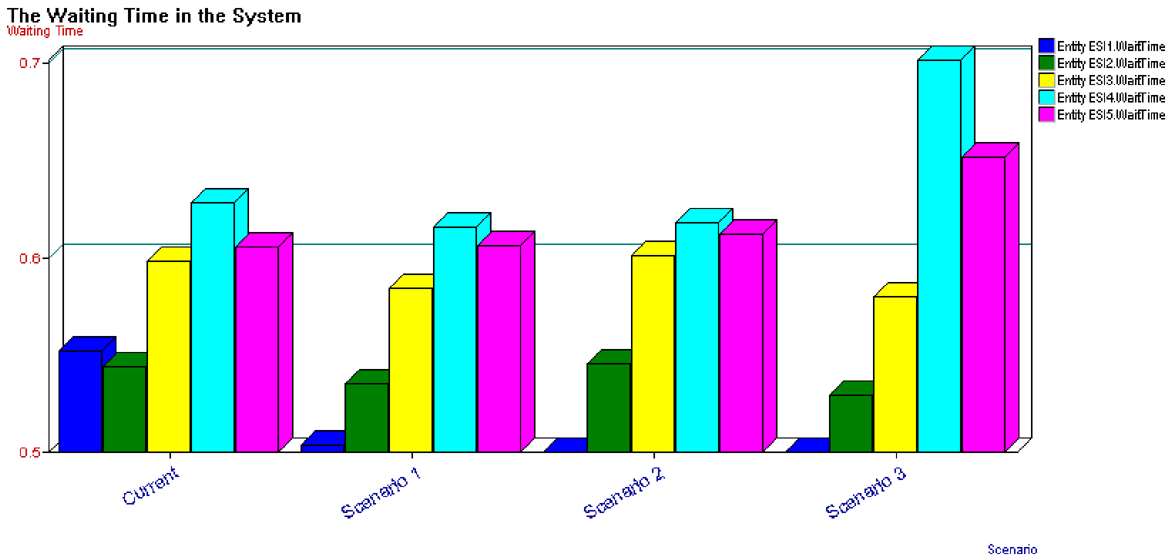

Figure 4: Waiting Time for the ESI Levels across the 4 Scenarios

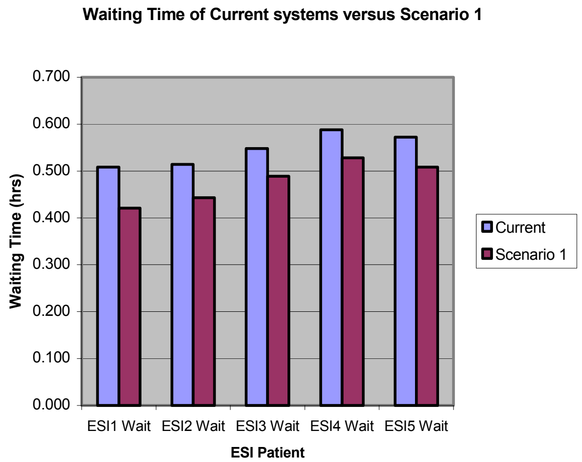

Figure 5: Scenario 1 vs. Current System Waiting Time for each ESI Level

Table 4: Simulation Results from Current and Suggested System

ESI Patient	**Average waiting time (hr)**	
	Current System	Scenario 1
ESI-1	0.5041	0.4210
ESI-2	0.5263	0.4430
ESI-3	0.5583	0.4889
ESI-4	0.5923	0.5277
ESI-5	0.5673	0.5085

8 CONCLUSIONS

The upper management at the York ED was interested in improving ED access and throughput. The results of the three alternatives of the Alterna Care operation, when compared to the current system of operation, can drive strategic decision making. The current system, where the AC is operational from 11:00AM -11:00PM at the York ED, offers scope for improvements in patient throughput. Adoption of scenario 1 (where the AC operates from 9:00AM-9:00PM), can improve ED utilization and enhance patient throughput and access. Scenario 1 as a policy initiative when implemented at the York ED can improve the care delivery process and direct future re-engineering processes in the health care setting in general and York ED in particular. Currently, the research team is engaged in the development of a decision support system to optimize the resource utilization of the clinical staff mix of the ED.

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