March 2012

Implementation of an Emergency Department Split-Flow Process at Saint Vincent Hospital

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Evaluation of the Split-Flow Concept Using Discrete-Event Simulation at Saint Vincent Hospital

Major Qualifying Project Proposal completed in partial fulfillment
of the Bachelor of Science degree at
Worcester Polytechnic Institute, Worcester, MA

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March 1, 2012

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Abstract

Emergency Departments faced with the challenges of increased demand and constrained capacity, resulting in increased patient wait times and decreased patient safety, are looking for ways to improve efficiency and patient care. In response, a few hospitals have recently implemented an emerging management concept known as a split-flow process within their Emergency Department. The purpose of our project was to develop recommendations for the implementation of a split-flow process at Saint Vincent's Emergency Department in Worcester. We observed and collected data on the current Emergency Department process and developed a discrete-event simulation model designed to project the effect of a split-flow process implementation on Emergency Department key performance metrics. We present recommendations for staffing assignments, physical layouts, and resources required for a successful split-flow process implementation. To our knowledge, this is the first simulation model used to guide the implementation of a split-flow process in an Emergency Department.

Acknowledgements

The success of this project could not have been fully realized without contributions from many individuals. We would like to acknowledge the administrative team at Saint Vincent Hospital, in particular Erik Wexler, President and CEO, and Deborah Bitsoli, COO, for sponsoring our project. We would also like to thank all the members of the Saint Vincent Emergency Department for their assistance throughout the extent of this project. In particular we would like to thank Jill Lyons, Dr. Michael Burns, Dr. Doug Scudder, and Cynthia Bresciani for their continued support. Lastly, we would like to thank our advisors, Professor Renata Konrad and Professor Justin Wang, for their contribution and support towards our project.

Authorship

Kristine DeSotto

Kristine worked closely with Allison in developing the ARENA simulation model. She gathered and analyzed hospital data for the model and arranged meetings with the Saint Vincent team. Kristine researched split-flow, observed Saint Vincent ED operations, and contributed to the writing and editing of this report.

Allison Grocela

Allison used her ARENA software experience to lead the development of the model. She worked closely with WPI professors and the Saint Vincent team to ensure the accuracy of the model. Allison researched split-flow, observed Saint Vincent ED operations, and contributed to the writing and editing of this report.

Patrick McAuley

Patrick gathered and analyzed hospital data and worked closely with Kristine and Allison to ensure all the necessary data for the model was available. Patrick researched split-flow, observed Saint Vincent ED operations, and contributed to the writing and editing of this report.

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Executive Summary

The Emergency Department at Saint Vincent Hospital in Worcester, Massachusetts is exploring new ways to combat ED crowding. Crowding is a nationwide issue that leads to long patient wait times and increased length of stay, ultimately jeopardizing patient safety. In response, Saint Vincent has implemented an emerging operational concept, a split-flow process, which has shown to be successful at decreasing patient wait times and total length of stay. Implementation of a split-flow process is different at every hospital and must be customized to fit the capacity, physical layout, and available resources of a particular Emergency Department. To determine the most efficient split-flow strategy for the Saint Vincent ED, our team developed a discrete-event simulation model of the implemented process using historical hospital data and observations. We used the model to experiment with different resource allocation methods and measured the effect each had on key ED performance metrics.

Background

Saint Vincent Hospital was founded in 1893 by the Sisters of Providence and has expanded over the years to provide high quality healthcare to all of the greater Worcester, MA area. Rooted in Catholic tradition, the Saint Vincent mission is to provide "quality patient care with unrelenting attention to clinical excellence, patient safety, and an unparalleled passion and commitment to assure the very best healthcare (Saint Vincent, 2011)." To fulfill this mission, the Saint Vincent management team is constantly seeking new innovative techniques to improve the quality and timeliness of patient care to ensure patient safety. Specifically, the Emergency Department implemented a split patient flow model in January 2012 and is currently trying to identify the most suitable process configuration.

Simulation Model

Our team created a discrete-event simulation model of the newly implemented Saint Vincent ED split-flow process. Simulation is the process of designing and creating a computerized model of a real system for the purpose of conducting numerical experiments to better understand its behavior under certain conditions. An accurately constructed model can measure the effects of various changes to the process without making physical changes to the real-life system. This allows ED management to see the effects of different capacity constraints, patient demand, and physical layouts prior to implementation. As a result, the use of simulation has become popular in the healthcare industry because of its time and money saving potential.

Prior to constructing the model, we analyzed historical patient flow data, observed the process, attended ED department meetings, and interviewed hospital employees. With a strong understanding of patient flow in the ED, we constructed a process map based on our findings. We then built the simulation model by converting the process diagrams into ARENA simulation logic. After constructing the simulation model, our team verified and validated the model to make sure that it ran correctly and was an accurate representation of the Saint Vincent ED. Finally, we experimented with different combinations of ED resources and patient demand levels and recorded how each affected key ED performance metrics.

Conclusions

Our study supports the theory that split-flow is an effective organizational strategy to address Emergency Department crowding. As previous studies have suggested, our model confirmed that split-flow significantly improved key ED performance metrics such as average length of stay and door-to-doctor time. After testing alternative resource allocation strategies, we recommend that Saint Vincent add a doctor to the Yellow Zone or main ED as this scenario showed the most significant decrease in door-to-doctor time and total length of stay. We also suggest that Saint Vincent closely monitor current split-flow performance and work with ED staff members to continuously improve the implementation of the split-flow process.

Chapter 1: Motivation

Hospital-based emergency care is critically important to the health of Americans (Institute of Medicine, 2006). Not only do Emergency Departments (EDs) provide urgent care, but they increasingly serve as adjuncts to community physician practices (Institute of Medicine, 2006). Since the 1980s, ED visits in the United States have steadily increased at an annual rate of approximately 3% (Zilm, 2010). Factors contributing to the increase include an aging population (Zilm, 2010), limited access to medical care from other sources (Hoot, 2008), and a rising trend toward utilizing the ED for non-emergency care (Hoot, 2008) (Welch, 2010). As a result, the Emergency Department has become the main point of entry into hospitals and accounts for more than half of all admissions to hospitals in the United States (Zilm, 2010).

The surge in patient volumes is a significant contributor to the nation-wide phenomenon known as ED crowding (Institute of Medicine, 2006). More than two thirds of US hospitals in urban, suburban, and rural settings are affected by crowding (Pediatric Emergency Medicine, 2004). ED crowding is a situation when the need for emergency services outweighs available ED resources (Case, 2004). A crowded ED produces a series of negative effects. Excessive patient overload leads to medical errors, poor outcomes, patient dissatisfaction, increased patient wait times and creates an unsafe environment for patients and providers (Jarousse, 2011) (Case, 2004). Long wait times result in patients leaving the hospital without being seen by a physician. One study calculated that each patient not seen equates to $8,000-$10,000 in lost revenue (Jensen, 2003). A second study calculated that over $3.8 million in net revenue was lost in one year due to patient diversion and elopement (Falvo, 2007). Not only do lost patients represent lost revenue, recent studies suggest that as the average length of stay of ED patients increases, the risk of death or hospital readmission within the next 7 days increases for those who were released or left without being seen (McCarthy 2011) (Guttmann, 2011).

Saint Vincent Hospital, located in Worcester, Massachusetts, is similarly confronted by ED crowding, long wait times, and poor patient satisfaction. Saint Vincent Hospital, part of the Vanguard Health System, is a 270 bed acute care, community teaching hospital (Saint Vincent Hospital, 2011). Saint Vincent serves not only the greater Worcester area, but also Worcester County at large which has a population of 650,000 (Saint Vincent Hospital, 2011). The ED is the largest department of the hospital, which generates more than half of all hospital admissions, according to Dr. Burns M.D., Chief of Emergency Medicine at Saint Vincent Hospital. Last year, Saint Vincent admitted 18,600 patients and treated over 63,800 patients through their ED (Zuba, 2011).

The Saint Vincent ED management team is struggling to decrease patient wait times, decrease the amount of time a patient must wait to see a doctor, and decrease patients' total length of stay. Last year, this hospital's patient satisfaction scores for the metric "waiting time to see a doctor", when compared with the other 27 Vanguard hospitals, ranked below the 50^{th} percentile (Press Ganey, 2011). In order to make significant improvements in all of these metrics, Saint Vincent ED is looking for a more efficient way to provide patient care.

Recently, some hospitals in the United States have begun to split patient flow by acuity ("split-flow") and by function (commonly called "fast-tracking") in an effort to decrease wait times and promote quality. While fast-track designs have been widely implemented (Oredsson, 2011 and Obrien, 2006 contain recent reviews), the split-flow approach is considered the "new generation of EDs." The central tenet of split-flow is the sooner patients can enter the hospital system, the sooner they are able to be treated and released. Splitting patient flows into two groups of high and low acuity patients ensures that less sick patients are not occupying resources necessary for higher acuity patients. As illustrated in Figure 1, the split-flow process concept replaces traditional triage with a "quick look triage", routes (splits) lower acuity patients as defined by the standard five level Emergency Severity Index (Agency for Healthcare Research and Quality, 2011) in a separate queue from those higher acuity patients who are awaiting placement in a traditional ED bed. Lower acuity patients are seen in a "continuous care area" by a care team comprised of a doctor, a nurse, and a technician.

In a split-flow ED, patients are split because lower acuity and ambulatory patients typically do not require a bed for the duration of their stay. Lower acuity patients have an Emergency Severity Index (ESI) of 5, 4, or sometimes 3, while higher acuity patients have an ESI of 1, 2, or sometimes 3. By moving lower acuity patients through the system quickly and not placing these patients in beds for their entire length of stay, limited bed capacity is better utilized for higher acuity patients requiring a bed immediately. By offering a different treatment model to lower acuity patients, EDs expect to reduce bed occupancy and increase the overall capacity of the ED. As the split-flow approach is still in its infancy, few studies are able to validate this claim.

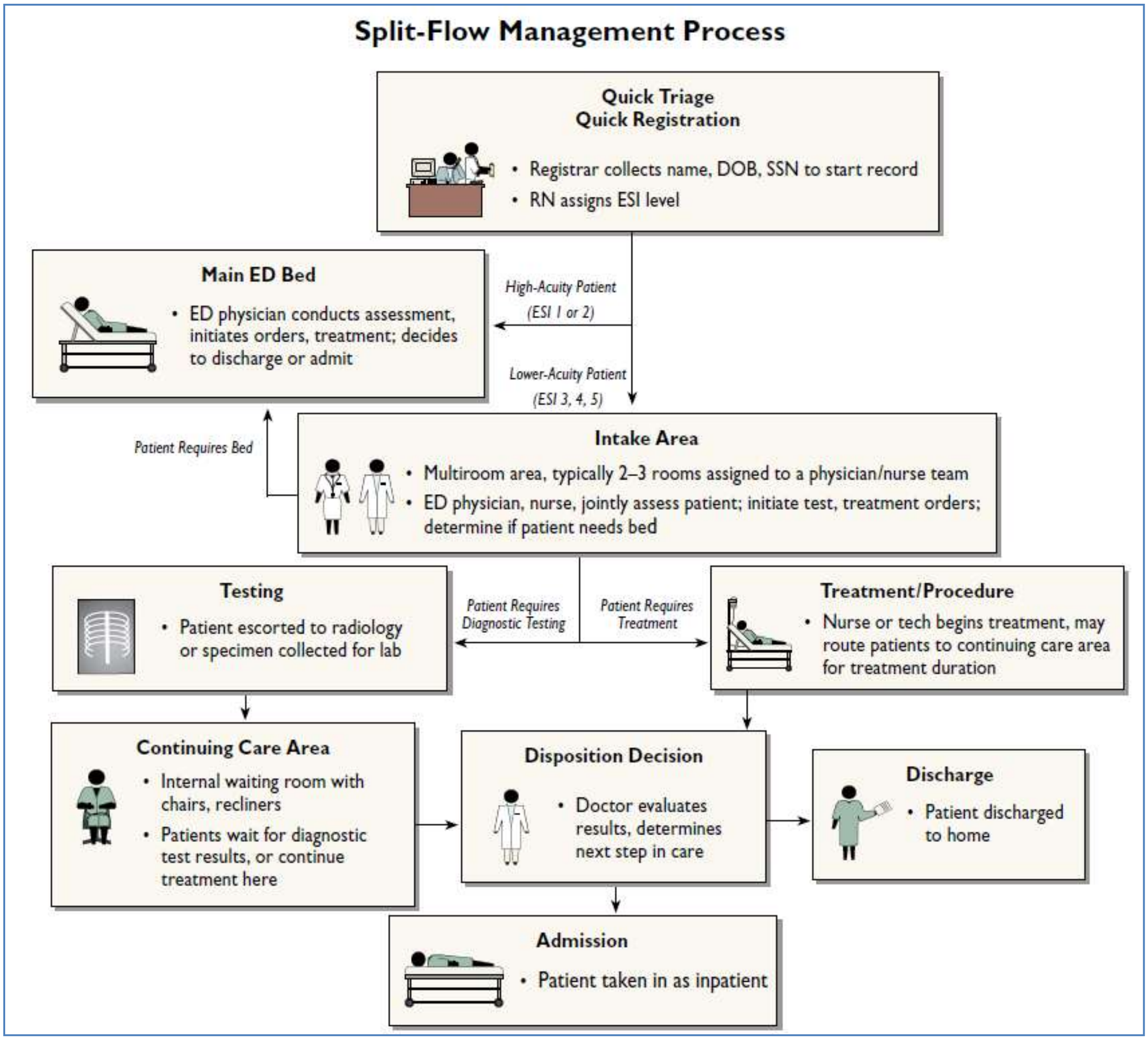

Figure 1: Split-Flow Management Process as Designed by Banner Health (Banner Health, 2011)

Despite the potential benefits of the split-flow concept, operational parameters such as staffing levels and patient routing rules are not well established. Implementation of a spilt-flow process requires significant work reorganization, physical layout changes, and staff training. Implementation is disruptive and requires significant organizational commitment. Although ideas for integrating the split-flow design into hospital workflows are beginning to emerge (Zilm, 2010), hospital managers are unsure of how to configure their operations. The handful of EDs who have implemented the split-flow concept are experimenting with different designs post implementation.

The objective of this project was to evaluate the impact on patient throughput of different split-flow configurations. Our method enables a hospital to quantify the effects of system redesign prior to implementation and to examine how the split-flow concept can best be applied to their particular hospital, ultimately decreasing implementation costs and disruptions. We use discrete-event simulation to create a decision-tool for a community-based ED in central Massachusetts, USA. Our contribution fills a current void in ED implementation research, decision support for split-flow implementation.

In Chapter 2, we include a review of literature on the need for improvement in Emergency Departments, success of the split-flow model at other hospitals, and the use of simulation within Emergency Departments. In Chapter 3, we discuss our methodology which includes collection and analysis of data, analysis of the split-flow model, development of our simulation model, and validation and verification of our simulation model. We also discuss our design methods and their fulfillment of the Accreditation Board for Engineering and Technology related requirements for this project. In Chapter 4, we present the results found after running our simulation model. In Chapter 5, we discuss our conclusions based on our results, our recommendations for Saint Vincent, and several ideas for further work in the future.

Chapter 2: Literature Review

2.1 Stress on Emergency Departments

Several articles discuss the need for improvement in United States Emergency Departments (ED). One article from the Institute of Medicine states that the role of hospital-based emergency care has evolved over the past ten years. Patients are continually demanding more from EDs, but the capacity of the emergency system hasn't changed to reflect that. It is a significant challenge to balance increasing patient volume and limited resources, widening the gap between the quality patients accept and the quality they receive. Likewise, an article published by the American Journal of Medical Quality explores new intake models for Emergency Departments. It was noticed that as door-to-doctor times increased the rate of patients left without treatment (LWOT) increased, which can be attributed to intake times. In 2008, the Board of Directors of the Emergency Department Benchmarking Alliance identified intake as an area in need of improvement. Hospitals have taken different approaches to determine ways to handle the growing stress on EDs. The main areas of our research focused on split-flow concepts and simulation modeling.

2.2 Split-Flow Success

Early implementations of the split-flow concept have resulted in decreased door-to-doctor time, a key performance metric for EDs (Banner Health, 2011), total length of stay ("Split Flow", 2010), and patient satisfaction (Rodi, 2006). Improving these metrics directly correlates to improved patient safety and decreased wait times (McCarthy, 2011) (Jarousse, 2011). For example, Banner Health, implemented the split-flow concept in eight of its Emergency Departments. For these hospitals, the aggregate average door-to-doctor time decreased 58% while the average length of stay decreased 14% (Banner Health, 2011). At St. Anthony's Hospital in Washington State a split-flow process was implemented in 2008. Consequently, its Emergency Department saw a dramatic decrease in door-to-doctor time from 93 to 20 minutes. In 2010 the Baptist Medical Center in San Antonio, Texas implemented a split-flow process in their Emergency Department, resulting in a decrease for the average patient length of stay from 393 to 120 minutes in the ED.

2.3 Simulation in Hospitals

Given the increased need for efficiency in ED systems, coupled with the increased availability of ease-of-use simulation software packages, simulation, particularly discrete-event simulation, has become an effective and efficient means to analyze proposed process improvements for potential cost reductions and productivity improvements prior to their actual implementation (Banks et al., 2005). The use of discrete-simulation in EDs is well documented and there are many examples of articles that exemplify successes of simulation models within hospitals. One case study, from the Children's Hospital Medical Center of Akron, Ohio, describes the use of simulation to model the flow of patients in their emergency room and how this flow was affected whether there were one or two orthopedic groups available. The model revealed that, although the length of stay for patients needing orthopedic care decreased with two orthopedic groups available, the LOS for all patients did not decrease significantly. Since the goal was to reduce the LOS for all patients, this simulation model succeeded in showing the hospital that the addition of a second orthopedic group should be looked into more before any changes were made. The use of the simulation model allowed the hospital to save money that may have been spent on new staff hires and physical layout changes before having an indication of how these changes would affect the Emergency Room.

Another example of a successful simulation model was presented at the 2008 Winter Simulation Conference. A discrete-event simulation was built to test five patient buffer concepts aimed at relieving pressure in Emergency Departments. Data for the model was collected from a hospital in Massachusetts. The first scenario was run with a buffer zone between the ED and the inpatient unit, the second with a buffer for patients who wait a long time to be discharged, and the third with a separate treatment unit for patients with ED occupancy of less than 24 hours. The fourth and fifth scenarios were different combinations of the previous scenarios. Each scenario was run independently, revealing that each concept improved the ED system as a whole. In addition, each scenario was able to run with fewer resources than originally scheduled. The authors of the article state that the results of their model should be supported by further studies through simulations or case studies (Kolb, 2008).

Despite the substantial body of simulation literature describing the causes, effects, and solutions of ED crowding, little evidence evaluates the impact of patient triage alternatives on ED performance. Of note is the study of Connelly and Bair (2004) which compared two patient triage methods using discrete-event simulation: (1) fast-track triage against (2) acuity ratio triage

(ART) approach whereby patients were assigned to staff on an acuity ratio basis. A preliminary comparison of two triage methods showed that the ART approach reduced imaging bottlenecks and average treatment times for high-acuity patients, but resulted in an overall increase in average service time for low-acuity patients (Connelly and Bair, 2004). Garcia et al., simulated an ED with the addition of a fast track area to show that lower acuity patients are treated more quickly without sacrificing the quality of care for higher acuity patients. These findings were confirmed by Al Darrab et al..

2.4 Conclusions

The literature review leads to two important conclusions. First, patient throughput challenges in Emergency Departments are widespread. The review revealed that a handful of hospitals are experimenting with a split-flow design as a means to improve throughput and patient safety. The review affirmed that, to the best of our knowledge, a systematic method does not exist to evaluate split-flow design prior to implementation. Our review also demonstrated that discrete-event simulation is a sound technique to analyze ED processes. Our project is unique because our simulation model helped determine the best split-flow implementation strategy for Saint Vincent's ED. Through scenario analysis we were able to give the hospital recommendations about how to apply split-flow to suit their particular ED. In addition, the results from our model can be used as support for previously conducted studies.

Chapter 3: Methodology

This paper takes a "process" approach to simulation modeling i.e. the simulation is viewed in terms of the individual entities involved, and the programming "describes the 'experience' of a 'typical' entity as it 'flows' through the system" (Law, 2007). This section briefly overviews the data, model, and model validation and verification.

3.1 Data

A thorough understanding of Saint Vincent's current ED process was obtained through on-site observations and interviews with various clinical and non-clinical staff. This method provided abundant information about patient flow at the level of detail required to construct a robust simulation model for analysis.

The majority of the data for our model was extracted from MEDHOST, the hospital's electronic patient database. For the following metrics we pulled data for 2010 during which time approximately 63,828 patients came into the Emergency Department, see *Appendix B* for patient arrival times and *Appendix D* for historical distribution of patients by acuity level at Saint Vincent's.

- Average daily patient arrivals by hour;
- Average number of patients admitted by day;
- Average number of patients discharged by day;
- Average number of patients transferred by day;
- Percentage of Emergency Severity Index (ESI) for patients by day.

Arrival data was analyzed for variation in patient arrivals by season, month, week, day, and hour, but was found not to be statistically significant. Hourly interarrival times were determined for each day of the week. Table 1 summarizes the data gathered and used in our model. We refer the reader to Section 3.3 for a discussion of model outputs.

Table 1: Simulation model inputs and outputs

Inputs		Outputs
Design information	Historic information	State information
• Data flow • Split-flow model • Execution time distributions	• Data value range distributions • Patient arrival rate • Availability pattern of resources	• Total length of stay • Door-to-doctor time • Nurse and doctor utilization

3.2 The Proposed System Design

We refer the reader to the schematic in Figure 2 which outlines the proposed split-flow design. The basic steps of the process include a “quick-look” triage, registration, bed allocation, treatment, and discharge. Upon arrival, a patient will be triaged and assigned an acuity level which determines whether the patient will follow the traditional route (high acuity) or the split route (low acuity). High acuity patients will receive a bed that they will “own” for the entirety of their stay. Low acuity patients will receive a bed for an initial examination, but then will be sent to testing and a “results pending” station thereby releasing their bed. The results pending station will consist of reclining chairs increasing bed capacity while patients wait for test results or discharge instructions. All patients will then either be admitted to or discharged from the hospital. The basic steps in a split-flow process are as outlined in Figure 2.

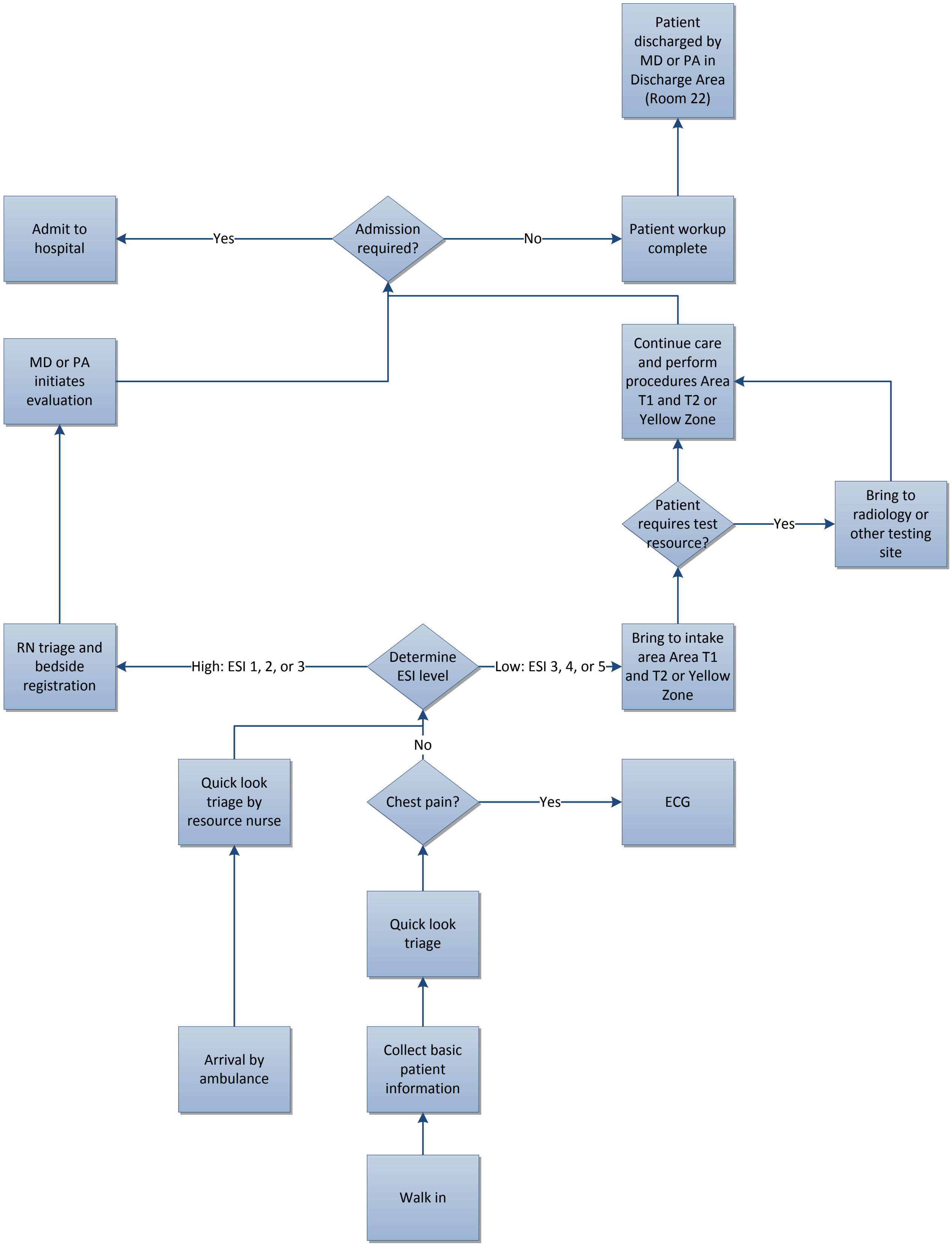

Figure 2: Process map of the proposed split-flow implementation

3.3 Simulation Model

The discrete-event simulation software package ARENA, Version 12.0, was selected on the basis of its graphical user interface, ease-of-use as well as its robust modeling options and features. A description of ARENA and other simulation packages can be found in Kelton (2009). An overview of the logic behind our simulation model can be found in *Appendix G.*

The main objective of the simulation model developed in this paper was to understand the impact of alternative split-flow operational strategies on system performance. The ability to see and treat patients in a timely manner is important to hospital administrators who are focused on reducing patient wait times. Thus, the primary performance measure is the average length of stay (LOS) for all ED patients in a split-flow ED where LOS is defined as the time from the earlier of registration or triage to the time the patient physically leaves the ED. In other words, LOS is the period of time a patient spends within the ED. Secondary performance measures are the door-to-doctor time and resource utilization. The door-to-doctor time is defined as the time from a patient's entrance into the system until the time when they see a primary healthcare provider. Resource utilization is defined as the fraction of time a resource spends in direct contact with a patient compared to the total time they are scheduled to work in the ED. These performance metrics are listed in Table 1.

Once the system performance metrics were identified, we turned our attention to building the simulation model. This was accomplished by modeling the overall patient flow as well as the ED system processes for realistic operating conditions. The simulation model was developed using a number of assumptions to simplify the modeling effort and eliminate any insignificant parameters. It is assumed that each patient arrival corresponds to one person, not including family members or others who will not receive treatment. It is also assumed that there is one doctor continuously treating patients in the area for ESI Level 3-5 patients. The doctors and nurses were only modeled for their direct contact with patient and therefore other activities such as documentation were not considered.

The modeling process began by statistically analyzing the different input data, listed in Table 1, to identify appropriate probability distributions for interarrival rates. Using the patient flow process descriptions and their corresponding activity flow for each patient acuity level, we translated process diagrams into ARENA simulation logic. Results from the simulation model were analyzed using the ARENA Output Analyzer.

We ran the simulation model for one full week, replicated 140 times. To approximate the number of replications, the average half width for all performance metrics was calculated after 5 initial runs and the number of runs was calculated such that the half width of each confidence interval for a performance metric was no more than 5% of the average mean. The results of our base simulation run can be found in *Appendix J*.

To determine impact of changes on the split-flow system, we carried out 17 different scenarios and tested and analyzed their impact on our three performance measures. The majority of the runs tested the impact of an additional resource within the system. Another run evaluated the performance of the system with an increased patient volume. We projected the volume for 2015 using an average increase per year of 2.2%, as demonstrated in *Appendix C*. Two additional scenarios evaluated the impact of a change in the distribution of ESI levels. To calculate these new percentages for the shift to ESI level 5, we increased the amount of ESI level 5 patients by 20%, the amount of ESI level 4 patients by 10% and then adjusted the remaining ESI levels accordingly. We repeated this process for the rest to shift to ESI level 1. For the percentages used in these tests, see *Appendix E*. For all results of our scenario runs, see *Appendix K*.

3.4 Model Validation and Verification

Techniques for increasing the validity and credibility of a simulation model are provided in Law (2007) and Banks et al. (2005). Throughout the design and development of the simulation model, several techniques were employed to validate the model including:

1. Eliminate all error messages: Eliminating error messages ensures that entities are flowing through the model correctly.

2. High face validity in a model: By reviewing the simulation model with clinical staff and management, we validated model logic and assumptions. All physician schedules, nurse schedules, and times were also validated by the hospital. See *Appendix A* for details about the implementation of split-flow at Saint Vincent, as discussed at a staff meeting in September 2011. Also see *Appendix F* for a complete list of the data received from and approved by staff at the hospital.

3. Using quantitative techniques to test the model's assumptions: Input data analysis was validated by using goodness-of-fit tests as well as by graphical methods. A scenario analysis was

also applied to measure the response of model performance results to changes in input parameters. The model was run under extreme conditions and results were analyzed, concluding that the model performed as expected under all conditions. Each condition was run for 140 replications. See *Appendix H* for the results of each run and *Appendix I* for the conclusions of the tests.

3.5 Industrial Engineering Design Component

The Major Qualifying Project (MQP) must satisfy certain design elements in order to meet Accreditation Board for Engineering and Technology (ABET) related requirements. ABET states that the fundamental components of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. These criteria were applied to this MQP. The objective of this project was to design a simulation model of the split-flow concept for the Saint Vincent Hospital Emergency Department, which could be analyzed to generate recommendations for the hospital. We used performance criteria such as door-to-doctor time, total length of stay, and resource utilization to evaluate the split-flow model. We consulted with various members of the hospital and observed the current Emergency Department to gain a broad understanding of the current process within the ED. Using MEDHOST, we analyzed necessary data from the past year to be used as input data for our model and to be used as a comparison with future simulation results. This data was analyzed statistically to determine the most representative distribution for each data type. We constructed the model by creating a flow chart that incorporated split-flow concepts and then translated this flow into ARENA. Flowcharts were developed through interviews and our own observations in the department and were approved by the hospital. We tested the model by running it in ARENA and checking for any programming errors and we then tested the model under several extreme conditions as displayed in *Appendix I.* The output data from the simulation model was then evaluated and conclusions and recommendations were created as a result.

The design process resulted in a relatively accurate and functioning model. However, there are alternatives and constraints that were considered when designing the simulation. The time frame for the project did not allow for the simulation to be an exact replica of the Emergency Department. We had to choose the most important parts to model in detail. For example, we chose to not include ambulance arrivals since they accounted for a small portion of patient arrivals. One of the most significant decisions was how to simulate resources (doctors, nurses, rooms, etc.). The hospital assigns teams of physicians and nurses to a specified set of rooms. They are not required to interact solely with patients in those rooms. If there is an influx of trauma patients during a shift, the staff reacts accordingly. For simplicity, we chose to assign doctors and nurses to specified rooms and did not allow for task or patient sharing. This was the best choice considering the scope and desired goal of the simulation.

Chapter 4: Results

This section reviews our results for our base simulation of the split-flow layout. We compare these simulated metrics with the historical performance metrics within the Emergency Department. We also carried out a scenario analysis of different split-flow configurations including an increase in resources allocated, an increase in patient arrivals, and a change in distribution of patient ESI levels.

Overall, the three performance metrics: (1) total length of stay, (2) door-to-doctor, and (3) resource utilization were significantly better in the simulated split-flow model compared to the traditional ED process. We first compare the performance measures between the simulated split-flow model (base model) and actual performance measures from Saint Vincent's ED 2010 data. Our model incorporated the same number of beds, nurses, and doctors as is currently being used at Saint Vincent's ED. The results of this comparison are found in Table 2. As expected, door-to-doctor and total length of stay significantly decreased. Utilization is low as it only represents the amount of time that doctors and nurses are in direct contact with patients and thus is not a true measure of resource utilization.

Table 2: Performance metrics for the current and simulated ED (based on 140 runs)

	Current ED Performance (2010)	Simulated Split-flow Process (Base Model)
Door-to-doctor (minutes)	64	44.62 ± 0.79
Length of stay (minutes)	240	130.56 ± 1.54
Nurse Utilization	Not Available	24% ± 0.01%
Doctor Utilization	Not Available	29% ± 0.01%

We next assess alternative split-flow configurations of several different scenarios, the most significant of which are highlighted in Table 3. The entirety of the results is located in *Appendix K*. The first scenario that we wish to highlight added a dedicated doctor to the split-flow area, or yellow zone, to help treat lower acuity patients. In the second scenario, an additional dedicated main ED physician was assigned to treat higher acuity patients. Table 3 compares the performance metrics for these alternative configurations against the original model. The door-to-doctor time did not significantly change in either scenario, but the total length of stay did decrease significantly as a result of adding on a doctor in the yellow zone (Scenario 1) and in the main ED (Scenario 2). Nurse utilization significantly changed in both scenarios, while doctor utilization only significantly decreased with the addition of a yellow zone doctor (Scenario 2).

Table 3: Performance metrics with confidence intervals for various resource allocations strategies (based on 140 runs)

	Base Split-Flow Model	Add Yellow Zone Doctor	Add Main ED Doctor
Door-to-doctor (minutes)	44.62 ± 0.79	44.45 ± 0.79	44.64 ± 0.08
Length of stay (minutes)	130.56 ± 1.54	107.17 ± 2.91	126.63 ± 1.54
Nurse Utilization	24% ± 0.01%	21.53% ± 0.01%	18.77% ± 0.01
Doctor Utilization	29% ± 0.01%	26.84% ± 0.01%	29.07% ± 0.01

In addition to evaluating resource configurations, our model examined the impact on performance metrics with anticipated changes in patient arrivals and changes in the distribution of patient acuity. Although EDs across the United States are experiencing an average 3% annual increase in patient arrivals, we investigated the impact of a yearly 2% increase in patient arrivals as this is reflective of the current increase in patient volume at Saint Vincent's ED. The patient volume projections are for the year 2015, with a 10% increase in patient arrivals compared to the 2010 volume. Further, we tested how the three performance metrics would be affected should the distribution of patient acuity change. For the scenario which increased the number of higher acuity patients, we increased the number of ESI-1 patients by 20% and increased the number of ESI-2 patients by 10% and then adjusted the remaining percentages accordingly. A table of the distributions used for each case is located in *Appendix E*. Similarly, for the scenario which increased the number of lower acuity patients, we increased the number of ESI-5 patients by 20% and increased the number of ESI-4 patients by 10%, and then adjusted the remaining percentages accordingly. Table 4 compares the previously mentioned scenarios against the base split-flow case.

Table 4: Impact on system performance with changes in patient arrival and acuity levels (based on 140 runs)

	Base Split-Flow Model	Increase Patient Arrivals	Increase In Lower Acuity Patients	Increase In Higher Acuity Patients
Door-to-doctor (minutes)	44.62 ± 0.79	46.45 ± 1.03	46.00 ± 0.90	45.66 ± 0.85
Length of stay (minutes)	130.56 ± 1.54	139.47 ± 1.90	133.51 ± 2.19	133.05 ± 1.81
Nurse Utilization	24% ± 0.01%	26.68% ± 0.01	25.08% ± 0.01	13.67% ± 0.01
Doctor Utilization	29% ± 0.01%	32.01% ± 0.01	39.70% ± 0.01	19.26% ± 0.01

As expected, the increase in patient arrivals significantly impacted the three performance metrics. As patient arrivals increased all performance metrics declined. The remaining two scenarios did not experience a significant change in the door-to-doctor time, although the length of stay did increase for both scenarios.

Chapter 5: Conclusion

As hospitals in the United States seek to address long, unsafe Emergency Department wait times, hospital management is considering process redesign. The split-flow concept is an emerging approach to manage ED processes by splitting patient flow according to patient acuity. Those patients who are less sick are split off from the traditional ED process flow, which is reserved for higher acuity patients. While early implementations of the split-flow concept have demonstrated significant improvement in patient wait times, a systematic evaluation of operational configurations is lacking. In this paper we build a discrete-event simulation model to evaluate various resource allocation strategies and examine the impact of realistic changes in patient arrival patterns. Our model is applied to a hospital considering split-flow implementation.

As early demonstration projects report in the literature, the simulated split-flow model showed statistically significant improvements in three performance metrics; (1) average length of stay, (2)door-to-doctor time, and (3) resource utilization. When alternative resource allocation strategies were evaluated, the most significant improvement was the addition of a nurse or physician on the door-to-doctor time. From our analysis, we recommend Saint Vincent add a doctor to the Yellow Zone or main ED as this scenario showed the most significant decrease in door- to-doctor time and length of stay.

Several assumptions may limit the effectiveness of our model. When inputting arrival times, a schedule based on average hourly patient arrivals (by day of week) in 2010 was used. By using a schedule, true hourly patient arrival variables were not captured. Further, the time that doctors and nurses spend with their patients varies greatly depending on patient acuity levels but this data was unavailable. Through interviews with clinical staff we obtained estimates for these service times; however time-studies would provide a more accurate reflection of this time.

This study leads to several important conclusions. In particular, split-flow concepts seem to be of interest and importance to Emergency Departments in the United States. Prior to this research, this emerging organizational approach had not been systematically evaluated preceding implementation. This paper confirms that a split-flow process does impact two performance measures of great concern to hospital management; door-to-doctor time and length of stay. At the time of writing, Saint Vincent is considering our recommendations.

To determine the success of the current split-flow process at Saint Vincent, we also compared performance metrics from three different sources: (1) benchmark metrics from

Vanguard, (2) performance metrics from January 2011 to December 2011 at Saint Vincent, and (3) performance metrics from January 2012 at Saint Vincent after the implementation of split-flow. A comparison of this data can be found in Table 5.

Table 5: Performance metrics before and after split-flow implementation, compared to benchmark levels

	Benchmark	Jan. 2011 – Dec. 2011	Jan. 2012
Door-to-doctor	30 minutes	41 minutes	27 minutes
Length of stay	270 minutes	233 minutes	226 minutes
Arrival to in bed time	15 minutes	25 minutes	15 minutes
LWBS	113 pt./month	92 pt./month	53 pt./month

As the January 2012 data shows, the split-flow process showed significant improvements in door-to-doctor time, total length of stay, arrival to in bed time, and the number of patients left without being seen. These improvements are very impressive and demonstrate the success of split-flow at Saint Vincent. Much of this success can be attributed the hospital’s implementation of the process and their inclusion of staff members in all changes.

5.1 ED Staff Feedback

During our literature review, we concluded that one of the few negatives associated with split-flow implementation was the resistance of ED staff to change. Many early adopters of split-flow did not see desired results initially because staff members did not fully buy into the process. Management at these hospitals failed to provide adequate information about the potential benefits of split-flow and the roles ED staff must play prior to its implementation.

As a result of these findings and the encouragement of Saint Vincent management, our team conducted a brief survey to gain ED staff feedback on the new split-flow process. The survey was aimed at answering the following questions: Do staff members think patient wait times are currently an issue? Do staff members feel additional changes still need to be made to the ED? Are staff members willing to change their roles and routines often to continuously improve ED performance? Are staff members well informed about the goals of split-flow?

The survey was conducted at the beginning of February, approximately one month after split-flow implementation at Saint Vincent. The survey results were encouraging as staff indicated that the majority were familiar with split-flow principals and were willing to alter their roles to improve ED performance. Survey results can be viewed in *Appendix L*.

5.2 Future Work

As split-flow is an emerging concept, simulation naturally lends itself as a method to study proposed system configurations. Therefore, further research work in this area is strongly recommended. Further studies may reuse the approach developed in this study to explore implementation risks in alternative hospitals. The results derived from such further studies may be used to compare with the findings of this research, and thus providing a more holistic picture of split-flow prior to implementation.

Simulation can be a useful tool in determining the most efficient way to move patients through the Emergency Department. However, regardless of how efficient the ED is operating, downstream blocking can still occur when there are no available beds for patients being admitted to the hospital. This was a major concern of Saint Vincent's management team during the decision of whether or not to implement split-flow in the Emergency Department. Management stressed that there must be a hospital-wide buy in for split-flow to work to its fullest potential. Future projects may explore possible ways that the Emergency Department and Admissions can work together to decrease or prevent blocking from occurring. A simulation could be done for patient flow through the main hospital and linked to our current model to provide possible solutions.

Another future study could be to examine the current layout of the Saint Vincent Emergency Department. During our observations of ED patients, we concluded that the physical layout of the department is rather confusing and could be significantly improved. During split-flow implementation, ED management was forced to make do with the space available to add areas such as the results pending room. Because management was not able to make major layout changes while switching to split-flow, there are many layout modifications that could further improve patient flow. Many hospitals are not willing to make major layout changes because of the costs associated with doing so; however the benefits may outweigh the costs. Future projects could include exploring alternative ED layouts and determining if it would be financially feasible and ultimately beneficial to the hospital as a whole.

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Appendix A: Emergency Department Staff Meeting

ED Staff Meeting

9/29/2011

Saint Vincent Hospital

5th Floor Conference Room

The goal of this staff meeting, led by Dr. Michael Burns, was to convey the main concepts of the split-flow process to interested Emergency Department staff members. The meeting also gave staff members an opportunity to ask questions and voice concerns about the split-flow process.

There were four assumptions for redesigning the ED that were presented. First, patients come to the ED for one reason. Second, triage is means that there is already a delay, since triage in the traditional sense takes about ten minutes. Third, not every patient needs to own a bed. Fourth, the greatest liability is a fully lobby.

As Dr. Burns explained, split-flow is a process that will require the hospital to break traditional practices in order to embrace high quality care. The outcomes of the process will hopefully be to lower door-to-doctor time, decrease throughput time, decrease percentage of patients who leave without being seen (LWOB), and improve patient satisfaction.

Dr. Burns and other ED leaders, including Jill Lyons and Cynthia Bresciani, stressed the importance of teamwork in creating a successful process. Physicians or Pas, nurses, and technicians must work together and see a patient all at once. This will help the ED shift from a linear to a parallel process which is more efficient since many of the current steps don't need to be completed in sequence. They also stressed that nurses drive the process since they must decide when patients are ready to continue to certain parts of the process, like results pending which is an area where patients wait for discharge instructions. This area will help move patients out quicker because it is a visual sign that a patient is ready to be discharged.

Staff members in attendance had questions about the new "quick-look" triage and how they would determine when patients are ready to move on to the next step in the process. Overall, staff members seemed to buy into the concepts of the split-flow process but were concerned about the details. ED leaders decided to create workgroups to allow staff members to be involved with the development of the process and adaption of the process to the needs and resources at Saint Vincent.

Appendix B: Patient arrival data

Test for seasonal variation

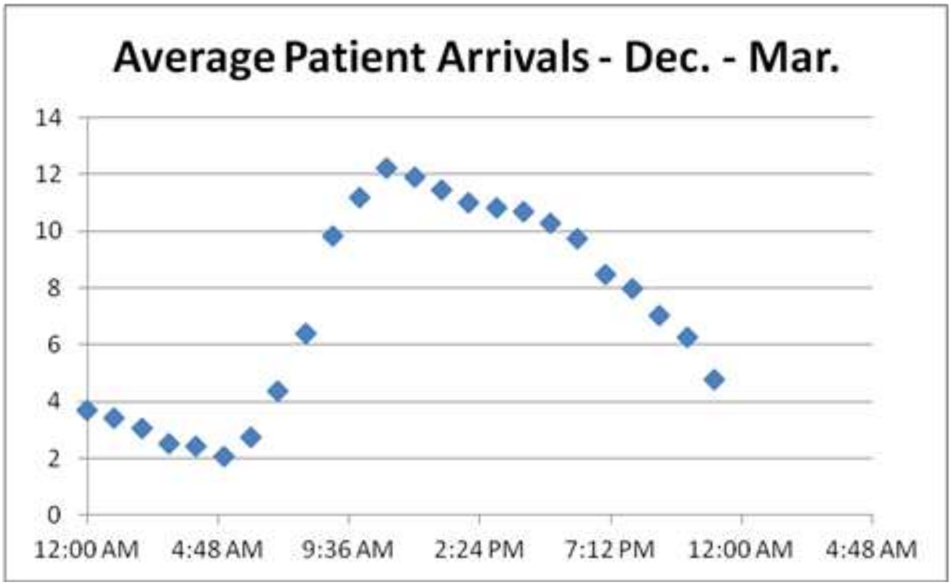

Figure 3: Patient arrival pattern - Winter

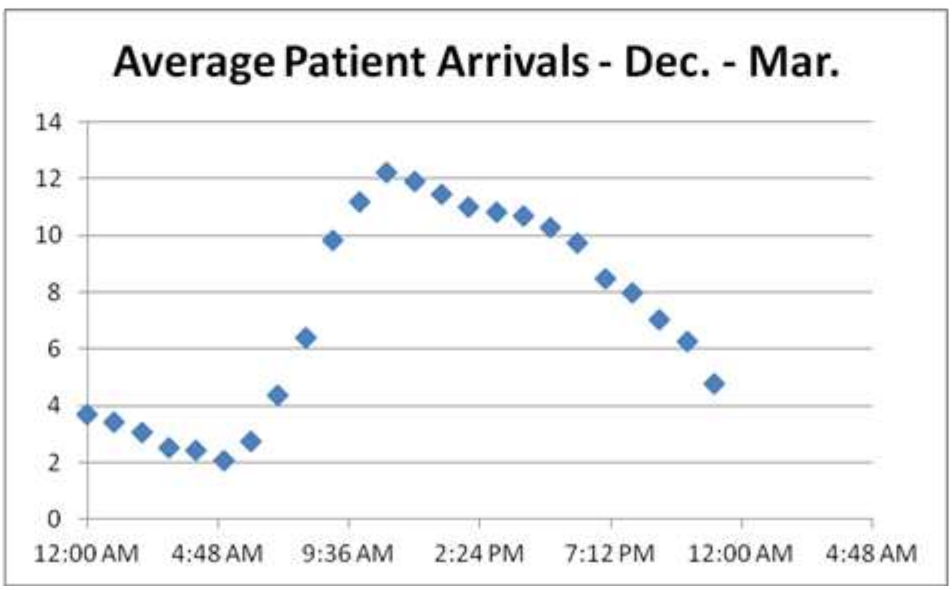

Figure 4: Patient arrival pattern - Spring

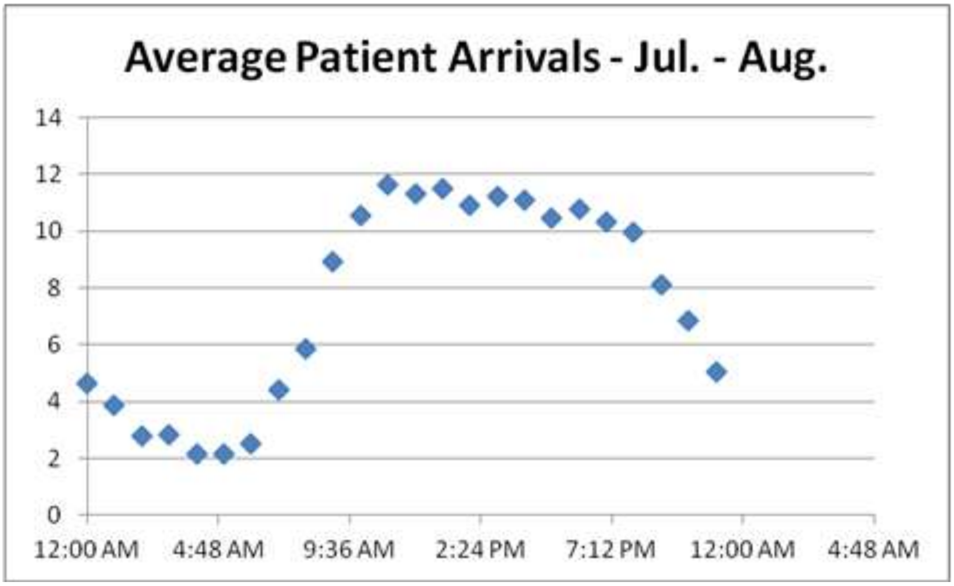

Figure 5: Patient arrival pattern - Summer

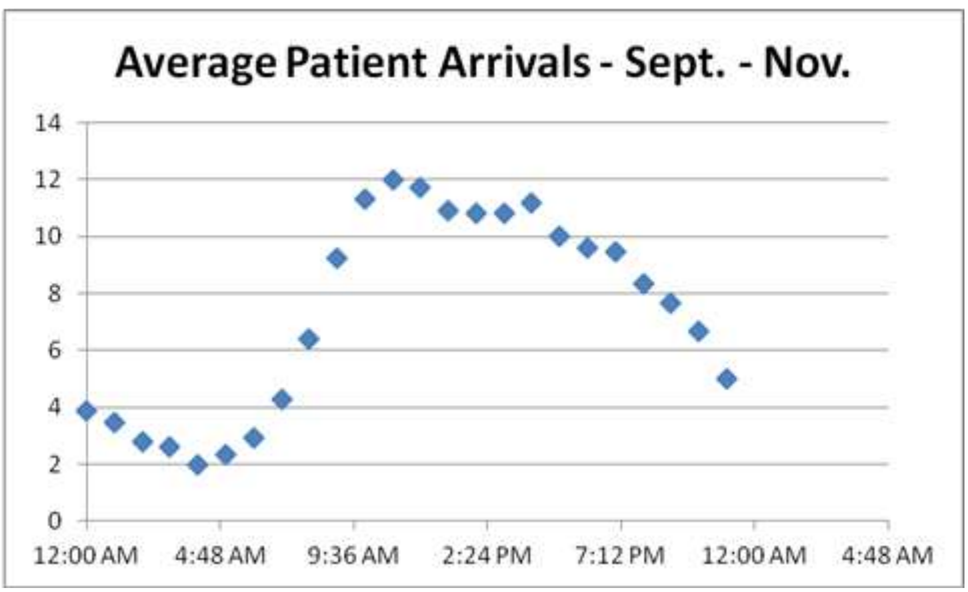

Figure 6: Patient arrival pattern - Fall

Test for weekly variation

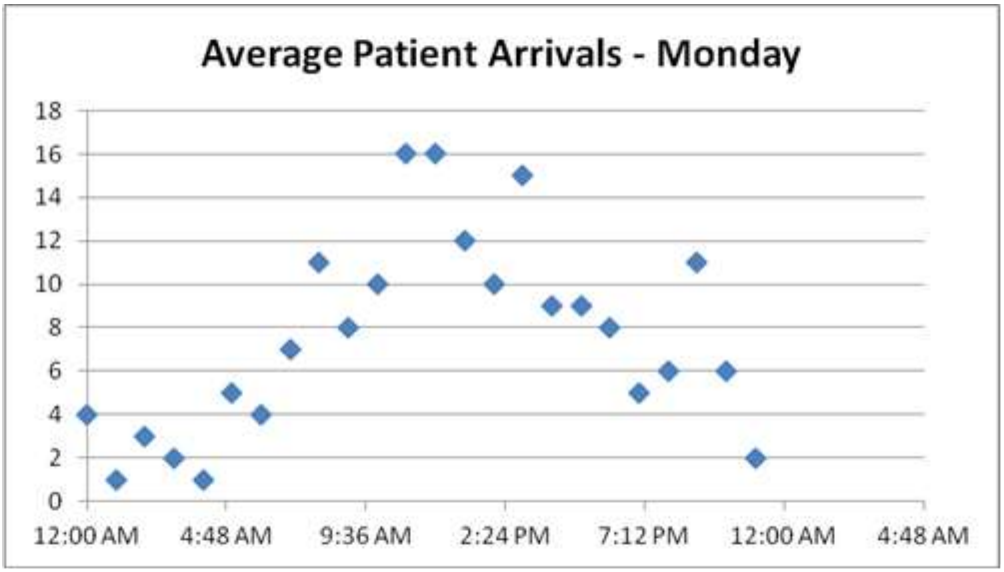

Figure 7: Patient arrival pattern - Monday

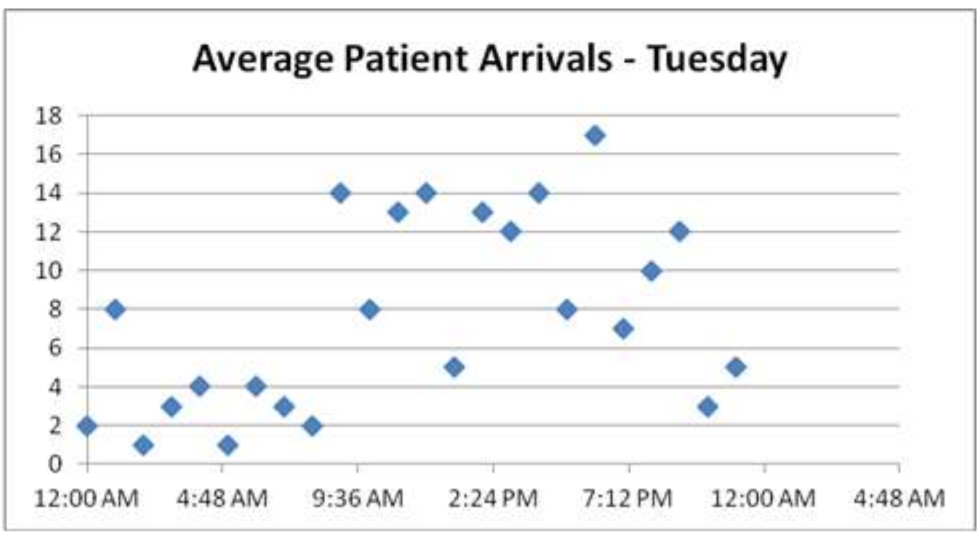

Figure 8: Patient arrival pattern - Tuesday

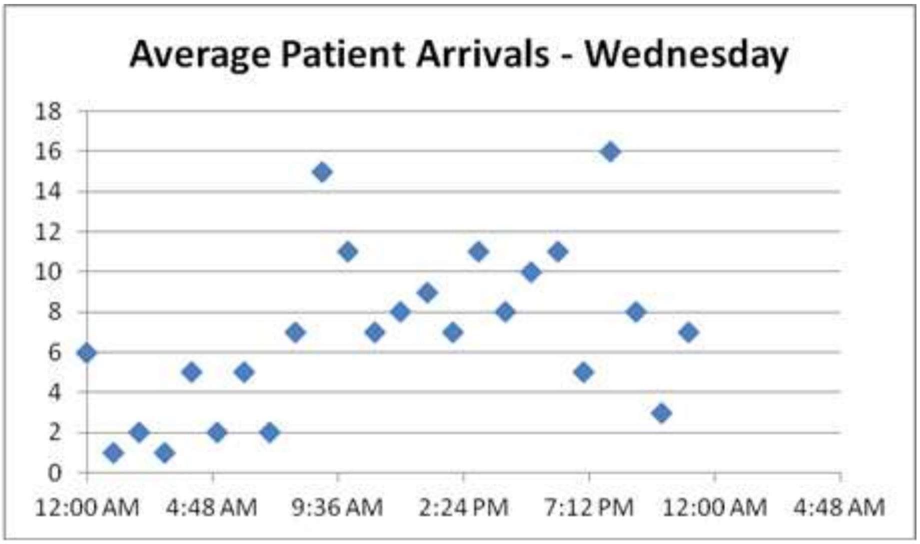

Figure 9: Patient arrival pattern - Wednesday

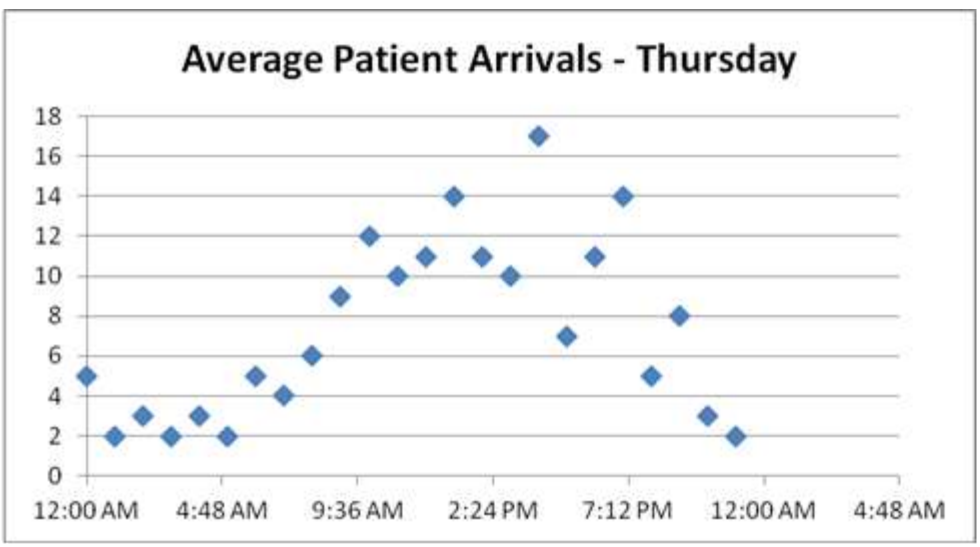

Figure 10: Patient arrival pattern - Thursday

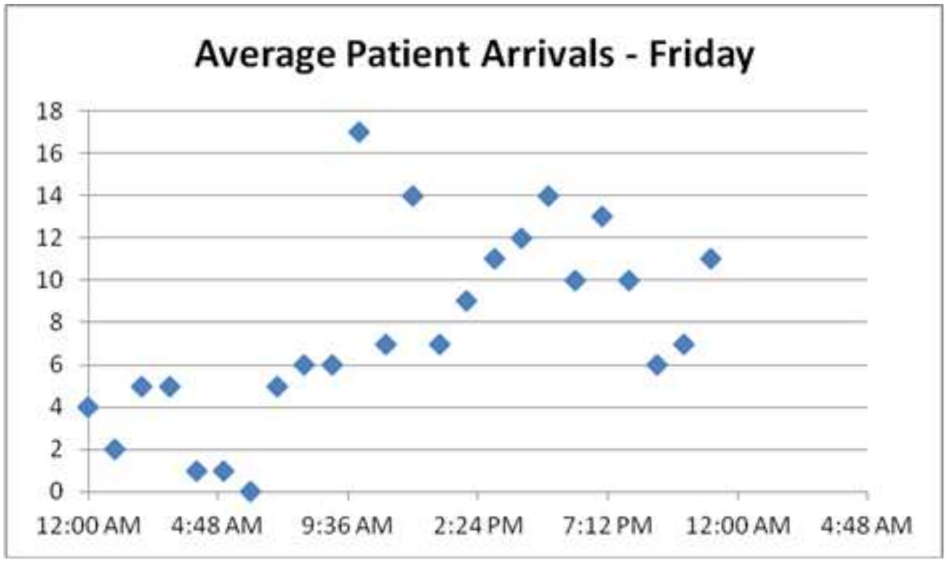

Figure 11: Patient arrival pattern - Friday

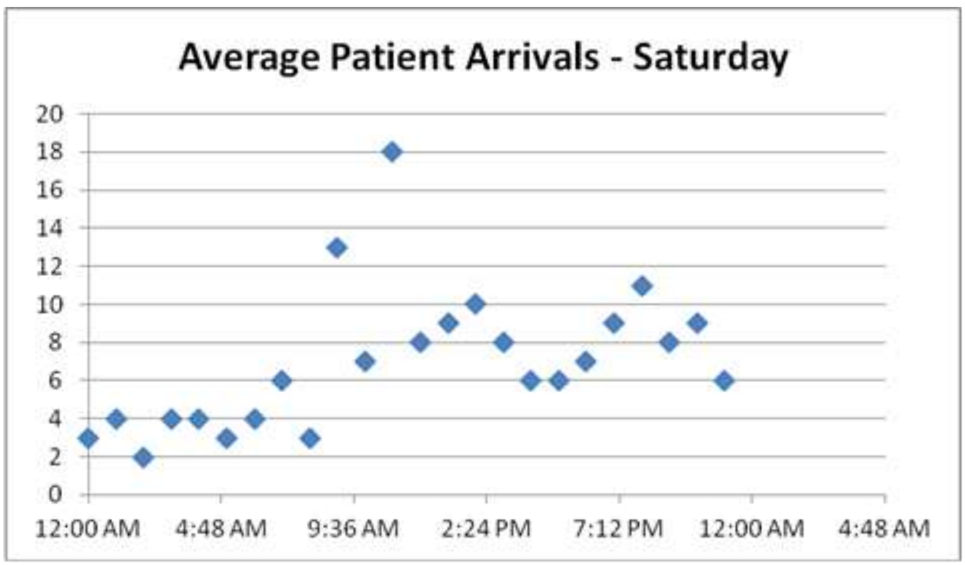

Figure 12: Patient arrival pattern - Saturday

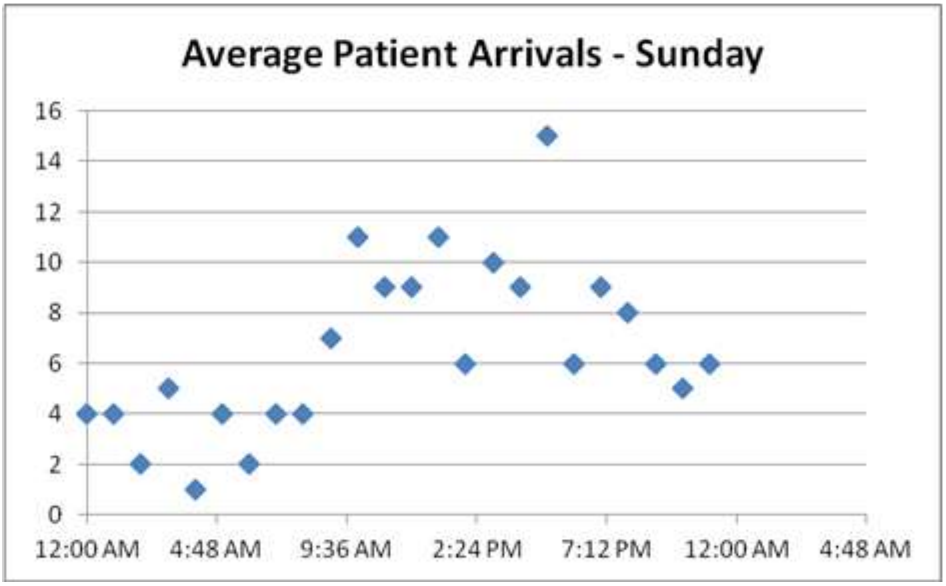

Figure 13: Patient arrival pattern - Sunday

Average patient arrivals 2010

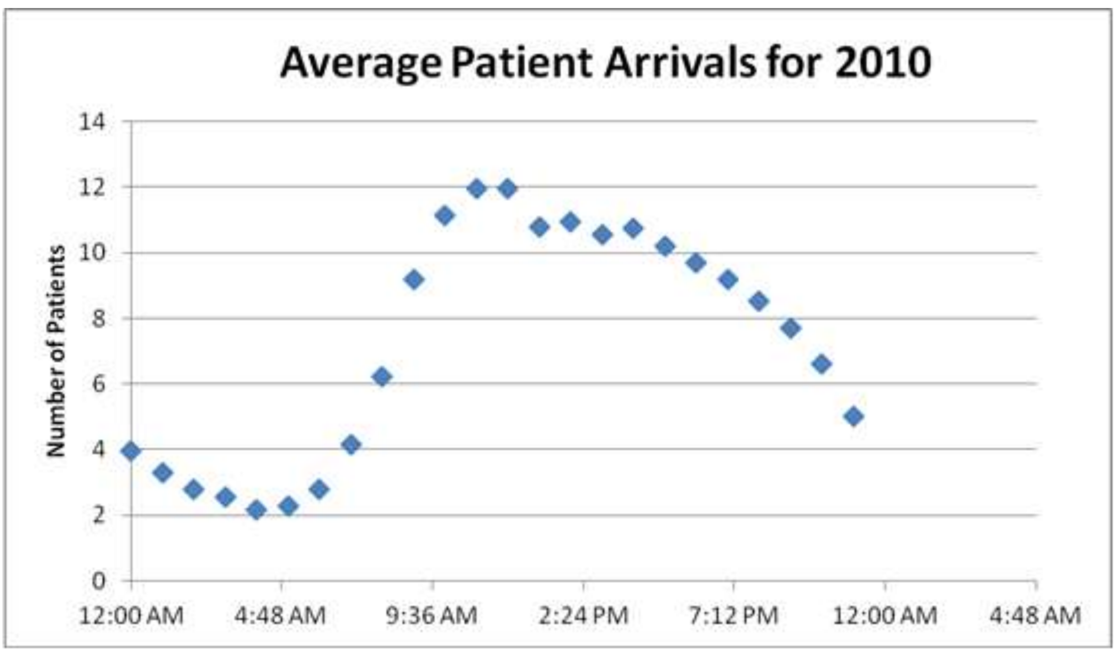

Figure 14: Patient arrival pattern - 2010

Table 6: Average patient arrivals by hour - Monday

MONDAY	
Hour	**Average Patient Arrivals**
12:00 AM	4.17
1:00 AM	3.13
2:00 AM	2.92
3:00 AM	2.17
4:00 AM	2.13
5:00 AM	2
6:00 AM	3.31
7:00 AM	4.69
8:00 AM	7.06
9:00 AM	10.94
10:00 AM	14
11:00 AM	13.33
12:00 PM	13.56
1:00 PM	11.35
2:00 PM	12.17
3:00 PM	11.77
4:00 PM	11.29
5:00 PM	11.63
6:00 PM	10.58
7:00 PM	10.12
8:00 PM	9.25
9:00 PM	7.65
10:00 PM	6.33
11:00 PM	5.21

Table 7: Average patient arrivals by hour - Tuesday

TUESDAY	
Hour	**Average Patient Arrivals**
12:00 AM	4
1:00 AM	3.19
2:00 AM	1.98
3:00 AM	2.37
4:00 AM	2.37
5:00 AM	2.25
6:00 AM	2.48
7:00 AM	4.33
8:00 AM	7.04
9:00 AM	9.96
10:00 AM	11.67
11:00 AM	13.21
12:00 PM	12.02
1:00 PM	11
2:00 PM	10.83
3:00 PM	10.87
4:00 PM	11.15
5:00 PM	10.75
6:00 PM	9.96
7:00 PM	10.02
8:00 PM	8.63
9:00 PM	7.54
10:00 PM	7.35
11:00 PM	5.27

Table 8: Average patient arrivals by hour - Wednesday

WEDNESDAY	
Hour	**Average Patient Arrivals**
12:00 AM	3.67
1:00 AM	2.87
2:00 AM	2.58
3:00 AM	2.29
4:00 AM	1.9
5:00 AM	2.35
6:00 AM	2.62
7:00 AM	4.35
8:00 AM	6.25
9:00 AM	8.87
10:00 AM	10.75
11:00 AM	12.08
12:00 PM	11.92
1:00 PM	11.29
2:00 PM	10.31
3:00 PM	10.62
4:00 PM	11.52
5:00 PM	10.25
6:00 PM	9.83
7:00 PM	9.25
8:00 PM	8.62
9:00 PM	7.42
10:00 PM	6.44
11:00 PM	5.37

Table 9: Average patient arrivals by hour - Thursday

THURSDAY	
Hour	**Average Patient Arrivals**
12:00 AM	3.87
1:00 AM	2.6
2:00 AM	2.33
3:00 AM	2.25
4:00 AM	2.15
5:00 AM	2.38
6:00 AM	2.6
7:00 AM	4.35
8:00 AM	5.87
9:00 AM	9.37
10:00 AM	10.96
11:00 AM	12.15
12:00 PM	11.44
1:00 PM	10.21
2:00 PM	10.92
3:00 PM	10.46
4:00 PM	11.27
5:00 PM	10
6:00 PM	9.52
7:00 PM	8.6
8:00 PM	8.21
9:00 PM	7.69
10:00 PM	6.52
11:00 PM	4.5

Table 10: Average patient arrivals by hour - Friday

FRIDAY	
Hour	Average Patient Arrivals
12:00 AM	3.42
1:00 AM	3.3
2:00 AM	2.96
3:00 AM	2.53
4:00 AM	1.75
5:00 AM	2.17
6:00 AM	2.55
7:00 AM	3.96
8:00 AM	6.58
9:00 AM	9.3
10:00 AM	11.26
11:00 AM	11.3
12:00 PM	12.91
1:00 PM	11.45
2:00 PM	11.23
3:00 PM	11
4:00 PM	11.4
5:00 PM	10.62
6:00 PM	9.21
7:00 PM	8.25
8:00 PM	8.17
9:00 PM	8.57
10:00 PM	6.51
11:00 PM	4.98

Table 11: Average patient arrivals by hour - Saturday

SATURDAY	
Hour	Average Patient Arrivals
12:00 AM	4.25
1:00 AM	3.57
2:00 AM	3.17
3:00 AM	2.91
4:00 AM	2.45
5:00 AM	2.42
6:00 AM	2.79
7:00 AM	3.62
8:00 AM	5.32
9:00 AM	7.32
10:00 AM	9.43
11:00 AM	10.7
12:00 PM	11.19
1:00 PM	10.04
2:00 PM	10.68
3:00 PM	9.92
4:00 PM	9.49
5:00 PM	8.51
6:00 PM	9.15
7:00 PM	9.3
8:00 PM	7.6
9:00 PM	7.34
10:00 PM	6.7
11:00 PM	5

Table 12: Average patient arrivals by hour - Sunday

SUNDAY	
Hour	**Average Patient Arrivals**
12:00 AM	4.31
1:00 AM	4.29
2:00 AM	3.6
3:00 AM	3.27
4:00 AM	2.52
5:00 AM	2.54
6:00 AM	3.08
7:00 AM	3.71
8:00 AM	5.42
9:00 AM	8.67
10:00 AM	9.96
11:00 AM	10.87
12:00 PM	10.77
1:00 PM	10.15
2:00 PM	10.37
3:00 PM	9.21
4:00 PM	9.13
5:00 PM	9.62
6:00 PM	9.73
7:00 PM	8.73
8:00 PM	9.1
9:00 PM	7.83
10:00 PM	6.42
11:00 PM	4.83

Appendix C: Volume Projection

Table 13: Emergency Department historical patient volume data

Month	Volume		
	2009	2010	2011
Jan-09	5052	5266	5408
Feb-09	4735	4768	4857
Mar-09	5273	5272	5533
Apr-09	5165	5032	5225
May-09	5459	5427	5660
Jun-09	5310	5440	5403
Jul-09	5218	5716	5542
Aug-09	5387	5455	5602
Sep-09	5298	5435	5550
Oct-09	5169	5408	5462
Nov-09	5105	5128	5388
Dec-09	4791	5296	5309

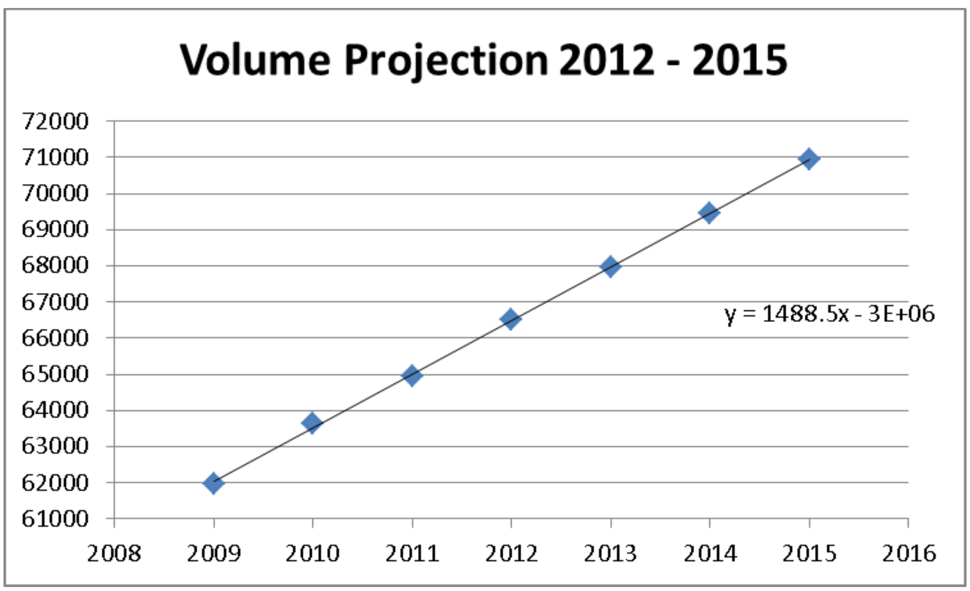

Figure 15: Yearly patient volume projection (Linear Regression)

Table 14: Yearly patient volume projections as a result of linear regression analysis

Year	Volume
2009	61962
2010	63643
2011	64939
2012	66492
2013	67980
2014	69469
2015	70957

$$\text{Volume} = 1{,}488.5 * \text{Year} - 3{,}000{,}000$$

Table 15: Patient arrival projections based on a yearly 2.2% increase in volume

Hour	Average Patient Arrivals	2012	2013	2014	2015
12:00 AM	4.17	4.26	4.36	4.46	4.56
1:00 AM	3.13	3.20	3.27	3.34	3.42
2:00 AM	2.92	2.99	3.05	3.12	3.19
3:00 AM	2.17	2.22	2.27	2.32	2.37
4:00 AM	2.13	2.18	2.23	2.28	2.33
5:00 AM	2	2.04	2.09	2.14	2.18
6:00 AM	3.31	3.38	3.46	3.54	3.62
7:00 AM	4.69	4.79	4.90	5.01	5.12
8:00 AM	7.06	7.22	7.38	7.54	7.71
9:00 AM	10.94	11.18	11.43	11.69	11.95
10:00 AM	14	14.31	14.63	14.96	15.29
11:00 AM	13.33	13.63	13.93	14.24	14.56
12:00 PM	13.56	13.86	14.17	14.49	14.81
1:00 PM	11.35	11.60	11.86	12.13	12.40
2:00 PM	12.17	12.44	12.72	13.00	13.29
3:00 PM	11.77	12.03	12.30	12.58	12.86
4:00 PM	11.29	11.54	11.80	12.06	12.33
5:00 PM	11.63	11.89	12.16	12.43	12.70
6:00 PM	10.58	10.82	11.06	11.30	11.56
7:00 PM	10.12	10.35	10.58	10.81	11.05
8:00 PM	9.25	9.46	9.67	9.88	10.10
9:00 PM	7.65	7.82	8.00	8.17	8.36
10:00 PM	6.33	6.47	6.62	6.76	6.91
11:00 PM	5.21	5.33	5.45	5.57	5.69
12:00 AM	4	4.09	4.18	4.27	4.37
1:00 AM	3.19	3.26	3.33	3.41	3.48
2:00 AM	1.98	2.02	2.07	2.12	2.16
3:00 AM	2.37	2.42	2.48	2.53	2.59
4:00 AM	2.37	2.42	2.48	2.53	2.59
5:00 AM	2.25	2.30	2.35	2.40	2.46
6:00 AM	2.48	2.54	2.59	2.65	2.71
7:00 AM	4.33	4.43	4.53	4.63	4.73
8:00 AM	7.04	7.20	7.36	7.52	7.69
9:00 AM	9.96	10.18	10.41	10.64	10.88
10:00 AM	11.67	11.93	12.20	12.47	12.75
11:00 AM	13.21	13.51	13.81	14.12	14.43
12:00 PM	12.02	12.29	12.56	12.84	13.13
1:00 PM	11	11.25	11.50	11.75	12.02
2:00 PM	10.83	11.07	11.32	11.57	11.83
3:00 PM	10.87	11.11	11.36	11.61	11.87
4:00 PM	11.15	11.40	11.65	11.91	12.18

5:00 PM	10.75	10.99	11.24	11.49	11.74
6:00 PM	9.96	10.18	10.41	10.64	10.88
7:00 PM	10.02	10.24	10.47	10.71	10.95
8:00 PM	8.63	8.82	9.02	9.22	9.43
9:00 PM	7.54	7.71	7.88	8.06	8.24
10:00 PM	7.35	7.51	7.68	7.85	8.03
11:00 PM	5.27	5.39	5.51	5.63	5.76
12:00 AM	3.67	3.75	3.84	3.92	4.01
1:00 AM	2.87	2.93	3.00	3.07	3.14
2:00 AM	2.58	2.64	2.70	2.76	2.82
3:00 AM	2.29	2.34	2.39	2.45	2.50
4:00 AM	1.9	1.94	1.99	2.03	2.08
5:00 AM	2.35	2.40	2.46	2.51	2.57
6:00 AM	2.62	2.68	2.74	2.80	2.86
7:00 AM	4.35	4.45	4.55	4.65	4.75
8:00 AM	6.25	6.39	6.53	6.68	6.83
9:00 AM	8.87	9.07	9.27	9.48	9.69
10:00 AM	10.75	10.99	11.24	11.49	11.74
11:00 AM	12.08	12.35	12.63	12.91	13.20
12:00 PM	11.92	12.19	12.46	12.74	13.02
1:00 PM	11.29	11.54	11.80	12.06	12.33
2:00 PM	10.31	10.54	10.78	11.02	11.26
3:00 PM	10.62	10.86	11.10	11.35	11.60
4:00 PM	11.52	11.78	12.04	12.31	12.58
5:00 PM	10.25	10.48	10.71	10.95	11.20
6:00 PM	9.83	10.05	10.27	10.50	10.74
7:00 PM	9.25	9.46	9.67	9.88	10.10
8:00 PM	8.62	8.81	9.01	9.21	9.42
9:00 PM	7.42	7.59	7.76	7.93	8.11
10:00 PM	6.44	6.58	6.73	6.88	7.03
11:00 PM	5.37	5.49	5.61	5.74	5.87
12:00 AM	3.87	3.96	4.04	4.14	4.23
1:00 AM	2.6	2.66	2.72	2.78	2.84
2:00 AM	2.33	2.38	2.44	2.49	2.55
3:00 AM	2.25	2.30	2.35	2.40	2.46
4:00 AM	2.15	2.20	2.25	2.30	2.35
5:00 AM	2.38	2.43	2.49	2.54	2.60
6:00 AM	2.6	2.66	2.72	2.78	2.84
7:00 AM	4.35	4.45	4.55	4.65	4.75
8:00 AM	5.87	6.00	6.14	6.27	6.41
9:00 AM	9.37	9.58	9.79	10.01	10.24
10:00 AM	10.96	11.20	11.46	11.71	11.97
11:00 AM	12.15	12.42	12.70	12.98	13.27
12:00 PM	11.44	11.70	11.96	12.22	12.50

1:00 PM	10.21	10.44	10.67	10.91	11.15
2:00 PM	10.92	11.16	11.41	11.67	11.93
3:00 PM	10.46	10.69	10.93	11.18	11.43
4:00 PM	11.27	11.52	11.78	12.04	12.31
5:00 PM	10	10.22	10.45	10.69	10.92
6:00 PM	9.52	9.73	9.95	10.17	10.40
7:00 PM	8.6	8.79	8.99	9.19	9.39
8:00 PM	8.21	8.39	8.58	8.77	8.97
9:00 PM	7.69	7.86	8.04	8.22	8.40
10:00 PM	6.52	6.67	6.81	6.97	7.12
11:00 PM	4.5	4.60	4.70	4.81	4.92
12:00 AM	3.42	3.50	3.57	3.65	3.74
1:00 AM	3.3	3.37	3.45	3.53	3.60
2:00 AM	2.96	3.03	3.09	3.16	3.23
3:00 AM	2.53	2.59	2.64	2.70	2.76
4:00 AM	1.75	1.79	1.83	1.87	1.91
5:00 AM	2.17	2.22	2.27	2.32	2.37
6:00 AM	2.55	2.61	2.67	2.72	2.79
7:00 AM	3.96	4.05	4.14	4.23	4.33
8:00 AM	6.58	6.73	6.88	7.03	7.19
9:00 AM	9.3	9.51	9.72	9.94	10.16
10:00 AM	11.26	11.51	11.77	12.03	12.30
11:00 AM	11.3	11.55	11.81	12.07	12.34
12:00 PM	12.91	13.20	13.49	13.79	14.10
1:00 PM	11.45	11.71	11.97	12.23	12.51
2:00 PM	11.23	11.48	11.74	12.00	12.27
3:00 PM	11	11.25	11.50	11.75	12.02
4:00 PM	11.4	11.65	11.91	12.18	12.45
5:00 PM	10.62	10.86	11.10	11.35	11.60
6:00 PM	9.21	9.42	9.63	9.84	10.06
7:00 PM	8.25	8.43	8.62	8.82	9.01
8:00 PM	8.17	8.35	8.54	8.73	8.92
9:00 PM	8.57	8.76	8.96	9.16	9.36
10:00 PM	6.51	6.66	6.80	6.96	7.11
11:00 PM	4.98	5.09	5.20	5.32	5.44
12:00 AM	4.25	4.34	4.44	4.54	4.64
1:00 AM	3.57	3.65	3.73	3.81	3.90
2:00 AM	3.17	3.24	3.31	3.39	3.46
3:00 AM	2.91	2.98	3.04	3.11	3.18
4:00 AM	2.45	2.50	2.56	2.62	2.68
5:00 AM	2.42	2.47	2.53	2.59	2.64
6:00 AM	2.79	2.85	2.92	2.98	3.05
7:00 AM	3.62	3.70	3.78	3.87	3.95
8:00 AM	5.32	5.44	5.56	5.68	5.81

9:00 AM	7.32	7.48	7.65	7.82	8.00
10:00 AM	9.43	9.64	9.86	10.08	10.30
11:00 AM	10.7	10.94	11.18	11.43	11.69
12:00 PM	11.19	11.44	11.70	11.96	12.22
1:00 PM	10.04	10.26	10.49	10.73	10.97
2:00 PM	10.68	10.92	11.16	11.41	11.67
3:00 PM	9.92	10.14	10.37	10.60	10.84
4:00 PM	9.49	9.70	9.92	10.14	10.37
5:00 PM	8.51	8.70	8.89	9.09	9.30
6:00 PM	9.15	9.35	9.56	9.78	10.00
7:00 PM	9.3	9.51	9.72	9.94	10.16
8:00 PM	7.6	7.77	7.94	8.12	8.30
9:00 PM	7.34	7.50	7.67	7.84	8.02
10:00 PM	6.7	6.85	7.00	7.16	7.32
11:00 PM	5	5.11	5.23	5.34	5.46
12:00 AM	4.31	4.41	4.50	4.61	4.71
1:00 AM	4.29	4.39	4.48	4.58	4.69
2:00 AM	3.6	3.68	3.76	3.85	3.93
3:00 AM	3.27	3.34	3.42	3.49	3.57
4:00 AM	2.52	2.58	2.63	2.69	2.75
5:00 AM	2.54	2.60	2.65	2.71	2.77
6:00 AM	3.08	3.15	3.22	3.29	3.36
7:00 AM	3.71	3.79	3.88	3.96	4.05
8:00 AM	5.42	5.54	5.66	5.79	5.92
9:00 AM	8.67	8.86	9.06	9.26	9.47
10:00 AM	9.96	10.18	10.41	10.64	10.88
11:00 AM	10.87	11.11	11.36	11.61	11.87
12:00 PM	10.77	11.01	11.26	11.51	11.77
1:00 PM	10.15	10.38	10.61	10.85	11.09
2:00 PM	10.37	10.60	10.84	11.08	11.33
3:00 PM	9.21	9.42	9.63	9.84	10.06
4:00 PM	9.13	9.33	9.54	9.76	9.97
5:00 PM	9.62	9.83	10.05	10.28	10.51
6:00 PM	9.73	9.95	10.17	10.40	10.63
7:00 PM	8.73	8.93	9.12	9.33	9.54
8:00 PM	9.1	9.30	9.51	9.72	9.94
9:00 PM	7.83	8.00	8.18	8.37	8.55
10:00 PM	6.42	6.56	6.71	6.86	7.01
11:00 PM	4.83	4.94	5.05	5.16	5.28

Appendix D: Distribution of patients by Acuity level

Table 16: Percentage of patients by acuity level

Acuity	Number Of Patients	Percentage
ESI-1	229	0.36%
ESI-2	4,641	7.27%
ESI-3	35,588	55.76%
ESI-4	13,479	21.12%
ESI-5	2,349	3.68%
Unassigned	7,542	11.82%

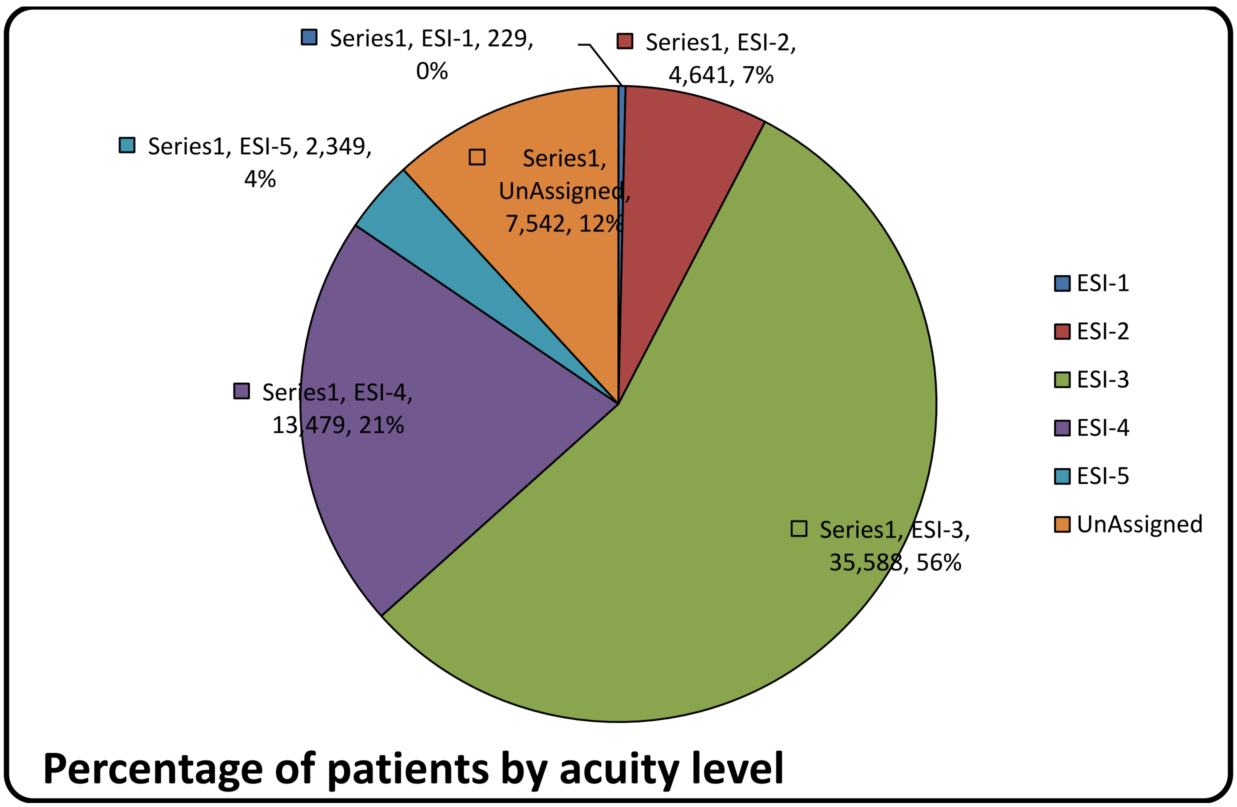

Figure 16: Percentage of patients by acuity level at Saint Vincent's ED in 2010

Appendix E: Shift to ESI 1 and ESI 5

Table 17: Acuity levels with a shift up to ESI level 1 and a shift down to ESI level 5

	Base	Shift to ESI 1	Shift to ESI 5
ESI 1	0.8	1.0	0.6
ESI 2	7.416	8.2	5.3
ESI 3	47.008	31.9	19.4
ESI 4	18.496	11.1	12.2
ESI 5	3.2	1.8	3.8
EKG	23.08	23.08	23.1

Appendix F: Emergency Department staffing levels

St. Vincent Hospital Emergency Department
PA and Resident Schedule
January 2012

Updated: 12/29/2011

Shift	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Happy New Year	2	3	4	5	6	7
Blue 7a-5p	Kelly	Kelly	Kelly	Kelly	Mohammed	Mohammed	Mohammed
Red 7a-5p	Smith	Laventure	Conley	Conley	Breen	Breen	Conley
AM Float 8a-6	Johnson	Short	Johnson	Navin	Navin	Parlin	Breen
Fast Track 11-9	*Flynn*	*Mendillo*	*Flynn*	*Smith*	*Smith*	*Flynn*	*Quist*
R[redacted]A 11a-9p		Smith	Mendillo	Poulin	Conley	Navin	
Extra					Kagels		
Blue 3p-1a	Mohammed	Mohammed	Shah	Shah	Shah	Shah	Kelly
Red 3p-1a	Goosman	Breen	Breen	Case	Case	Vaz	Men
PM Float 5p-3	Murphy	Goosman	Goosman	Flynn	Johnson	Mendillo	Case
Night 9:30p-7:30a	Navin	Case	Vaz	Vaz	Goosman	Johnson	Short
	8	9	10	11	12	13	14
Blue 7a-5p	Mohammed	Shah	Shah	Shah	Shah	Kelly	Kelly
Red 7a-5p	Navin	Breen	Honigman	Conley	Breen	Honigman	Honigman
AM Float 8a-6	Quist	Conley	Johnson	Smith	Navin	Navin	Navin
Fast Track 11-9	*Conley*	*Murphy*	*Mendillo*	*Johnson*	*Flynn*	*Breen*	*Poulin*
R[redacted]A 11a-9p			Murphy	Murphy	Smith	Johnson	
Extra							
Blue 3p-1a	Kelly	Kelly	Kelly	Mohammed	Mohammed	Mohammed	Mohammed
Red 3p-1a	Smith	Navin	Vaz	Case	Case	Mendillo	Goosman
PM Float 5p-3	Flynn	Goosman	Goosman	Vaz	Conley	Flynn	Johnson
Night 9:30p-7:30a	Case	Case	Flynn	Mendillo	Murphy	Smith	Conley
	15	16	17	18	19	20	21
Blue 7a-5p	Kelly	Kelly	Mohammed	Mohammed	Mohammed	Mohammed	Shah
Red 7a-5p	Badalamenti	Honigman	Honigman	Conley	Honigman	Honigman	Laventure
AM Float 8a-6	Quist	Laventure	Case	Smith	Quist	Breen	Short
Fast Track 11-9	*Poulin*	*Badalamenti*	*Mendillo*	*Johnson*	*Smith*	*Flynn*	*Flynn*
RME PA 11a-9p	Short	Mendillo	Murphy	Murphy	Murphy	Conley	
Extra							Kagels
Blue 3p-1a	Shah	Shah	Shah	Shah	Kelly	Kelly	Kelly
Red 3p-1a	Goosman	Breen	Badalamenti	Case	Laventure	Nam	Mendillo
PM Float 5p-3	Johnson	Goosman	Goosman	Vaz	Case	Mendillo	Case
Night 9:30p-7:30a	Navin	Vaz	Laventure	Flynn	Goosman	Johnson	Poulin
	22	23	24	25	26	27	28
Blue 7a-5p	Shah	Shah	Shah	Kelly	Kelly	Kelly	Kelly
Red 7a-5p	Smith	Honigman	Honigman	Conley	Laventure	Honigman	Honigman
AM Float 8a-6	Breen	Smith	Johnson	Smith	Navin	Laventure	Navin
Fast Track 11-9	*Quist*	*Murphy*	*Murphy*	*Johnson*	*Flynn*	*Breen*	*Johnson*
RME PA 11a-9p		Badalamenti	Mendillo	Murphy	Smith	Flynn	
Extra							
Blue 3p-1a	Kelly	Mohammed	Mohammed	Mohammed	Mohammed	Shah	Shah
Red 3p-1a	Flynn	Navin	Badalamenti	Case	Case	Mendillo	Vaz
PM Float 5p-3	Case	Goosman	Goosman	Vaz	Vaz	Case	Murphy
Night 9:30p-7:30a	Laventure	Breen	Breen	Mendillo	Johnson	Badalamenti	Goosman
	29	30	31	Feb. 1	Feb. 2	Feb. 3	Feb. 4
Blue 7a-5p	Mohammed	Mohammed	Mohammed	IM Res	IM Res	IM Res	IM Res
Red 7a-5p	Badalamenti	Honigman	Honigman	Conley	Honigman	Honigman	Laventure
AM Float 8a-6	Breen	Laventure	Laventure	Smith	Navin	Breen	Kagels
Fast Track 11-9	*Johnson*	*Badalamenti*	*Mendillo*	*Johnson*	*Vaz*	*Murphy*	*Breen*
RME PA 11a-9p		Mendillo	Flynn	Vaz	Smith	Conley	
Extra							
Blue 3p-1a	Shah	Shah	Kelly	IM Res	IM Res	IM Res	IM Res
Red 3p-1a	Vaz	Breen	Badalamenti	Case	Case	Flynn	Murphy
PM Float 5p-3	Murphy	Goosman	Goosman	Flynn	Flynn	Navin	Case
Night 9:30p-7:30a	Navin	Smith	Murphy	Goosman	Johnson	Smith	Short

IM Residents	Beeper #
John Kelly, MD., PG1	6604
Mohammed Mohammed, MD, PG2	9584
Dhaval Shah, MD, PG2	9278

EM Residents	Beeper #
Leah Honigman, MD, PG3	90893

To page Honigman pager, dial - 617-632-7243, then beeper #.

Figure 17: Physician Assistant and Resident shift schedule for January 2012

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EMERGENCY DEPARTMENT
ATTENDING SCHEDULE
January 2012

Updated 12/29/2011 9:30

	Shift	Teams	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			Jan. 1	2	3	4	5	6	7
D1	7a-3p	Blue	Lai	Burns	Ciottone	Yerid	Vernon	Vernon	Diaz
D2	9a-5p	Red	Chauhan	Friedberg	Gould	Vernon	Scudder	Paoloni	Burns
Y1	10a-5p			Vernon	Cotter	Bothwell	Gotz	Rifino	Hegedus
D3	2-10p	Blue	Scudder	Paoloni	Scudder	Gould	Chauhan	Gross	Gross
D4	4p-12a	Red	O'Connell	Bothwell	Bothwell	Chauhan	Hegedus	Cotter	Vernon
Y2	4p-1a	FT	Cotter	Hegedus	Chauhan	Hegedus	Yerid	Gould	Rifino
D5	10:30p-7a	All	Yerid	Yerid	Burns	Lai	Bothwell	Gotz	Gould
	On Call		*Friedberg*	*Scudder*	*Paoloni*	*Cotter*	*Burns*	*Bothwell*	*Scudder*
			Burns @ BID 7-3	9	10	11	12	13	14
	7a-3p	Blue	Hegedus	Bothwell	Friedberg	Cotter	Cotter	Lai	Bothwell
	9a-5p	Red	Yerid	Scudder	Gould	Hegedus	Lai	Cotter	Scudder
	10a-5p		Lai	Weill	Yerid	Yerid	Gotz	Hegedus	Gotz
	2-10p	Blue	Bothwell	Paoloni	Scudder	Gould	Diaz	Klausmeier	O'Connell
	4p-12a	Red	Gross	Lai	Gotz	Paoloni	Hegedus	Chauhan	Chauhan
	4p-1a	FT	Rifino	Gotz	Weill	Gotz	Paoloni	Gould	Gould
	10:30p-7a	All	Cotter	Rifino	Burns	Weill	Bothwell	Paoloni	Paoloni
	On Call		*Scudder*	*Hegedus*	*Bothwell*	*Chauhan*	*Gould*	*Weill*	*Lai*
			15	16	17	18	19	20	21
	7a-3p	Blue	Scudder	Friedberg	Ciottone	Yerid	Rifino	Cotter	Lai
	9a-5p	Red	Bothwell	Burns	Yerid	Lai	Lai	Rifino	Yerid
	10a-5p		Hegedus	Paoloni	Bothwell	Chauhan	Hegedus	Burns	Chauhan
	2-10p	Blue	Gotz	Bothwell	Scudder	Gould	Bothwell	Klausmeier	Klausmeier
	4p-12a	Red	O'Connell	Weill	Gould	Paoloni	Chauhan	Friedberg	Friedberg
	4p-1a	FT	Weill	Gotz	Paoloni	Gotz	Gotz	Gould	Weill
	10:30p-7a	All	Chauhan	Cotter	Burns	Weill	Vernon	Bothwell	Hegedus
	On Call		*Ciottone*	*Vernon*	*Vernon*	*Cotter*	*Gould*	*Weill*	*Rifino*
			22	23	24	25	26	27	28
	7a-3p	Blue	Kang	Burns	Hegedus	Cotter	Cotter	Paoloni	Paoloni
	9a-5p	Red	Yerid	Friedberg	Gould	Hegedus	Scudder	Friedberg	Rifino
	10a-5p		Paoloni	Cotter	Cotter	Vernon	Chauhan	Rifino	Cotter
	2-10p	Blue	Friedberg	Paoloni	Scudder	Gould	Rifino	Volz	Volz
	4p-12a	Red	Klausmeier	Rifino	Yerid	Paoloni	Lai	Weill	Vernon
	4p-1a	FT	Weill	Gotz	Paoloni	Rifino	Hegedus	Gould	Weill
	10:30p-7a	All	Hegedus	Chauhan	Burns	Weill	Vernon	Gotz	Gould
	On Call		*Vernon*	*Yerid*	*Gotz*	*Gotz*	*Yerid*	*Lai*	*Chauhan*
			29	30	31	Feb. 1	2	3	4
	7a-3p	Blue	Paoloni	Cotter	Bothwell	Diaz	Rifino	Friedberg	Friedberg
	9a-5p	Red	Cotter	Gotz	Gould	Bothwell	Cotter	Cotter	Burns
	10a-5p		Rifino	Lai	Yerid	Lai	Bothwell	Gould	Scudder
	2-10p	Blue	Weill	Weill	Scudder	Paoloni	Gould	Volz	Volz
	4p-12a	Red	Volz	Chauhan	Vern	Chauhan	Vernon	Rifino	Rid
	4p-1a	FT	Vernon	Vernon	Chauhan	Gotz	Chauhan	Weill	Gould
	10:30p-7a	All	Friedberg	Rifino	Burns	Weill	Lai	Bothwell	Bothwell
	On Call		*Yerid*	*Paoloni*	*Friedberg*	*Hegedus*	*Paoloni*	*Burns*	*Weill*

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Figure 18: Doctor shift schedule for January 2012

Table 18: Nurse and Technician schedule by shift

SVH Emergency Department Daily Assignment			
	Date______________________		
7a-11a	**11a-7p**	**7p-11p**	**11p-7a**
Resource RN *	Resource RN	Resource RN	Resource RN *
Quick Look RN	Quick Look RN	Quick Look RN	Quick Look RN
Quick Look CCT	Quick Look RN	Quick Look RN	Quick Look RN til 3am
	Quick Look CCT	*Quick Look CCT*	
INTAKE RN (10am)	Intake RN	Intake RN	
	Intake RN	Intake RN	
	Intake CCT	*Intake CCT*	
	Intake CCT	*Intake CCT*	
RP (Rm 10)	RP *(Rm 10)*	RP *(Rm 10)*	RP *(Rm 10)*
1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN
1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN	1-6, RH 1 + 2 RN
1-5, 16-19 CCT	*1-6, RH 1 + 2 CCT*	*1-6, RH 1 + 2 CCT*	*1-5, 16-19 CCT*
7 - 9, 11 RH 3 - 4 RN	7 - 9, 11, 12, RH 3 - 6 RN	7 - 9, 11, 12, RH 3 - 6 RN	7 - 9, 11 RH 3 - 4 RN
	7 - 9, 11, 12, RH 3 - 6 RN	7 - 9, 11, 12, RH 3 - 6 RN	
6 - 15 CCT	*7 - 9, 11, 12, RH 3 - 6 CCT*	*7 - 9, 11, 12, RH 3 - 6 CCT*	*6 - 15 CCT*
12-19, BH 5 - 8 RN	14 - 19, BH 5 - 8 RN	14 - 19, BH 5 - 8 RN	12-19, BH 5 - 8 RN
12-19, BH 5 - 8 RN	14 - 19, BH 5 - 8 RN	14 - 19, BH 5 - 8 RN	12-19, BH 5 - 8 RN
	14 - 19, BH 5 - 8 CCT	*14 - 19, BH 5 - 8 CCT*	
Annex 20 - 31 RN	20 - 27 RN	20 - 27 RN	Annex 20 - 31 RN
Annex 20 - 31 RN	20 - 27 RN	20 - 27 RN	Annex 20 - 31 RN
	28 - 31 RN	28 - 31 RN	
20-31 CCT	*20-31 CCT*	*20-31 CCT*	*20-31 CCT*
1:1 /Sitter	1:1 /Sitter	1:1 /Sitter	1:1 /Sitter
Admitting RN	Admitting RN		
* Resource RN covers RP from 0700-0900			* Resource RN covers RP from 0300-0700

Appendix G: Description of Simulation Model

Description of Simulation

This appendix will further explain the simulation model. The information given may be important to students who wish to continue work with the model or modify it. There may be inconsistency in naming throughout the model due to time constraints.

Since this model is simulating a split-flow Emergency Department, patients are moved to an area based on ESI Level. In the model, the yellow zone may be referred to as the ESI 3-5 Route. These names are interchangeable. The main ED area may be referred to as the ESI 1-3 Route. These names are also interchangeable when referring to the model.

Input Data

All of the input data for the model was acquired through MEDHOST. MEDHOST is a program that stores emergency department patient information at Saint Vincent. The following reports were downloaded from MEDHOST and analyzed for the model:

Table 19: MEHOST Reports and data components

Report	Name	Sort by	For	On	Outcome	Time Frame
Hourly Arrival Data	Average Patient Flow by Time of Day	Arrival Time	All Patients			January 2011 – December 2011
Hourly Arrival Data – Monday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Mondays		January 2011 – December 2011
Hourly Arrival Data – Tuesday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Tuesday		January 2011 – December 2011
Hourly Arrival Data – Wednesday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Wednesday		January 2011 – December 2011
Hourly Arrival Data – Thursday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Thursday		January 2011 – December 2011
Hourly Arrival Data – Friday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Friday		January 2011 – December 2011
Hourly Arrival Data – Saturday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Saturday		January 2011 – December 2011
Hourly Arrival Data – Sunday	Average Patient Flow by Time of Day	Arrival Time	All Patients	Sunday		January 2011 – December 2011
Acuity Level	Patient Last Acuity	ESI Level	All Patients			January 2011 – December 2011

Discharge percentage – ESI 1	Average Daily Census	ESI Level	ESI Level 1	Discharged	January 2011 – December 2011
Discharge percentage – ESI 2	Average Daily Census	ESI Level	ESI Level 2	Discharged	January 2011 – December 2011
Discharge percentage – ESI 3	Average Daily Census	ESI Level	ESI Level 3	Discharged	January 2011 – December 2011
Discharge percentage – ESI 4	Average Daily Census	ESI Level	ESI Level 4	Discharged	January 2011 – December 2011
Discharge percentage – ESI 5	Average Daily Census	ESI Level	ESI Level 5	Discharged	January 2011 – December 2011
Transfer percentage – ESI 1	Average Daily Census	ESI Level	ESI Level 1	Transferred	January 2011 – December 2011
Transfer percentage – ESI 2	Average Daily Census	ESI Level	ESI Level 2	Transferred	January 2011 – December 2011
Transfer percentage – ESI 3	Average Daily Census	ESI Level	ESI Level 3	Transferred	January 2011 – December 2011
Transfer percentage – ESI 4	Average Daily Census	ESI Level	ESI Level 4	Transferred	January 2011 – December 2011
Transfer percentage – ESI 5	Average Daily Census	ESI Level	ESI Level 5	Transferred	January 2011 – December 2011
Admit percentage – ESI 1	Average Daily Census	ESI Level	ESI Level 1	Admitted	January 2011 – December 2011
Admit percentage – ESI 2	Average Daily Census	ESI Level	ESI Level 2	Admitted	January 2011 – December 2011

Admit percentage – ESI 3	Average Daily Census	ESI Level	ESI Level 3	Admitted	January 2011 – December 2011
Admit percentage – ESI 4	Average Daily Census	ESI Level	ESI Level 4	Admitted	January 2011 – December 2011
Admit percentage – ESI 5	Average Daily Census	ESI Level	ESI Level 5	Admitted	January 2011 – December 2011
Fall Patient Volume	Average Patient Flow by Time of Day	Arrival Time	All Patients		December 2010 – March 2011
Winter Patient Volume	Average Patient Flow by Time of Day	Arrival Time	All Patients		April 2011 – June 2011
Spring Patient Volume	Average Patient Flow by Time of Day	Arrival Time	All Patients		July 2011 – August 2011
Summer Patient Volume	Average Patient Flow by Time of Day	Arrival Time	All Patients		September 2012 – November 2011

Overall flow

The model is broken into several sub-models for easier understanding. Here is a list of sub-models and a brief description of the main functions performed in each:

Patient Arrivals

- Entities are created
- Each entity assigned an ESI level
- Entities are counted by ESI level and are also totaled
- Entities are time-stamped for arrival time

Entrance

- Entities are assigned a picture according to ESI Level
- For animation purposes only, entities are duplicated
- Begin recording entity statistics
- Identify entities who need EKG

Triage

- Entities go through a quick-look triage
- Entities are routed to proper track of split-flow according to ESI Level

ESI 1-3 Route

- Count number of entities that enter sub-model
- Entities are routed to a room
- Each entity is seen by a nurse and physician
- Entities who require additional testing move to the radiology and testing station
- Identify which entities will be admitted and which will be discharged
- Moved discharged entities to results pending
- Record the total time an admitted patient spends in system

ESI 3-5 Route

- Count number of entities that enter sub-model
- Each entity is seen by a nurse and physician
- Entities who require additional testing move to the radiology and testing station
- Identify which entities will be admitted and which will be discharged
- Record the total time an admitted patient spends in system
- Dispose of entities who are discharged

Results Pending

- Entity waits for results to be discharged
- Record the total time discharged patient spends in system
- Dispose of entities

EKG Room

- Entities who are do not need further attention after EKG leave the model

Parking Lot

- For animation purposes only, cars leave the model

Routes

The flow between sub-models is maintained using station and route modules. Below are tables of the stations and routes and their location within the model.

Table 20: Station location and descriptions

Stations		
Name	**Station Name**	**Sub-model Location**
Arrive at EKG Room	EKG Station	EKG Room
Entrance Area	Entrance	Entrance
Intake Area for ESI1to3 Patients	ESI1to3	ESI 1-3 Route
Rooms1to6 RH1to2	1to6	ESI 1-3 Route
Rooms7to11 RH3to6	7to12	ESI 1-3 Route
Rooms12to19 BH5to8	14to19	ESI 1-3 Route
Rooms20to31	23to31	ESI 1-3 Route
Radiology and Testing ST	Radiology and Testing Station	ESI 1-3 Route
Testing is Complete	Testing Complete Station	ESI 1-3 Route
Intake Area for ESI3to5 Patients	ESI3to5	ESI 3-5 Route
Yellow Zone	Fast Track	ESI 3-5 Route
Radiology and Testing Station	Radiology and Testing Station 2	ESI 3-5 Route
Testing Complete	Testing Complete Station 2	ESI 3-5 Route
Parking Lot	Vehicle Out	Parking Lot
Patients Arrive	Patient Entrance	Patient Arrivals
Results Pending	Results Pending	Results Pending
Triage Area	Triage Station	Triage

Table 21: Route locations and descriptions

Routes		
Name	**Destination Station Name**	**Sub-model Location**
Park Car	Vehicle Out	Entrance
Other Patients to Next Area	Triage Station	Entrance
Route to EKG Room	EKG Station	Entrance
Go to Main ED	ESI1to3	Entrance
To Results	Results Pending	ESI 1-3 Route
To R and T	Radiology and Testing Station	ESI 1-3 Route
To R and T 2	Radiology and Testing Station	ESI 1-3 Route
To R and T 3	Radiology and Testing Station	ESI 1-3 Route
To R and T 4	Radiology and Testing Station	ESI 1-3 Route
Done	Testing Complete Station	ESI 1-3 Route
To Testing	Radiology and Testing Station 2	ESI 3-5 Route
Complete	Testing Complete Station 2	ESI 3-5 Route
Route Patients	Entrance	Patient Arrivals
Next station for ESI 1	ESI1to3	Triage
Next station for ESI 2	ESI1to3	Triage
Next station for ESI 4	ESI3to5	Triage
Next station for ESI 5	ESI3to5	Triage
ESI 3 likely to be discharged	ESI3to5	Triage
ESI 3 likely to be admitted	ESI1to3	Triage

The routes and stations in sub-model ESI 1-3 Route are slightly different than those in other parts of the model. The physicians and nurses work in teams on specific sets of rooms. This is represented in the model by four sets of rooms. Only a specific set of doctors and nurses is allowed to work for each set of rooms.

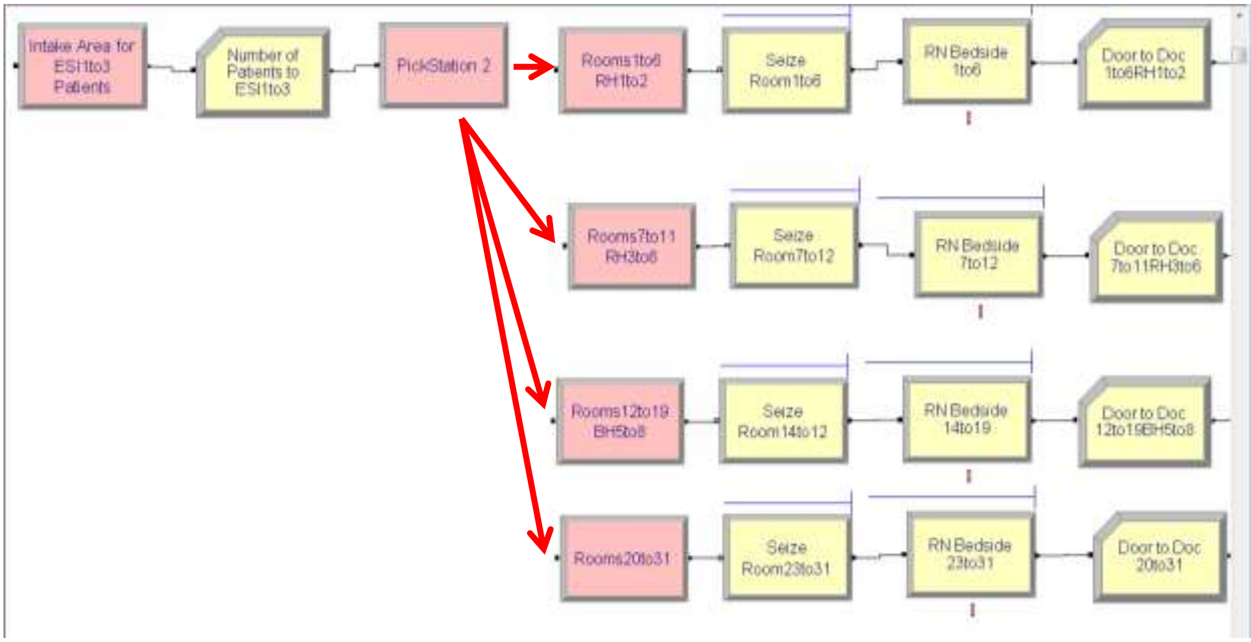


Figure 19: Routes for Pick Station module

The problem was choosing the best way to realistically move the entities to each station. The final decision was to use a Pick Station module. The module picks the station with the least number of rooms being used at that moment.

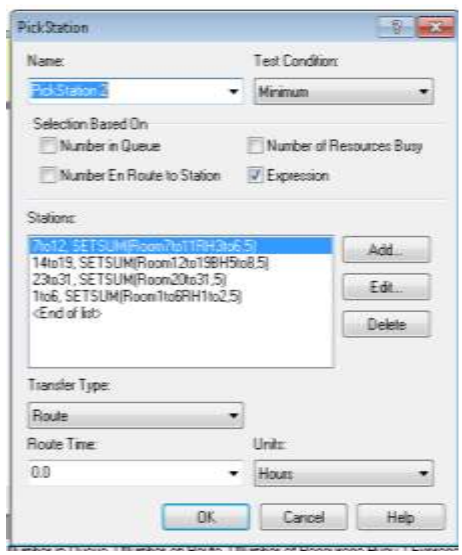


Figure 20: Logic for Pick Station module

Entities

Entities are created based on a schedule called Patient Arrivals. They are then immediately broken into groups by a decision module and an assign module. They move through the model by the station and route modules identified earlier.

Table 22: Assign and Decide module logic for patient ESI levels

Decide Module (Percentages)	Assign Module
0.8	Entity Type, ESI 5; Attribute, Status, 1
7.416	Entity Type, ESI 4; Attribute, Status, 2
47.008	Entity Type, ESI 3; Attribute, Status, 3
18.496	Entity Type, ESI 2; Attribute, Status, 4
3.2	Entity Type, ESI 1; Attribute, Status, 5
Else	Entity Type, EKGPatient; Attribute, Status, 6

Percentages for the decide module are predetermined by the hospital. The data collected from MEDHOST was analyzed to determine the most accurate real-time representation.

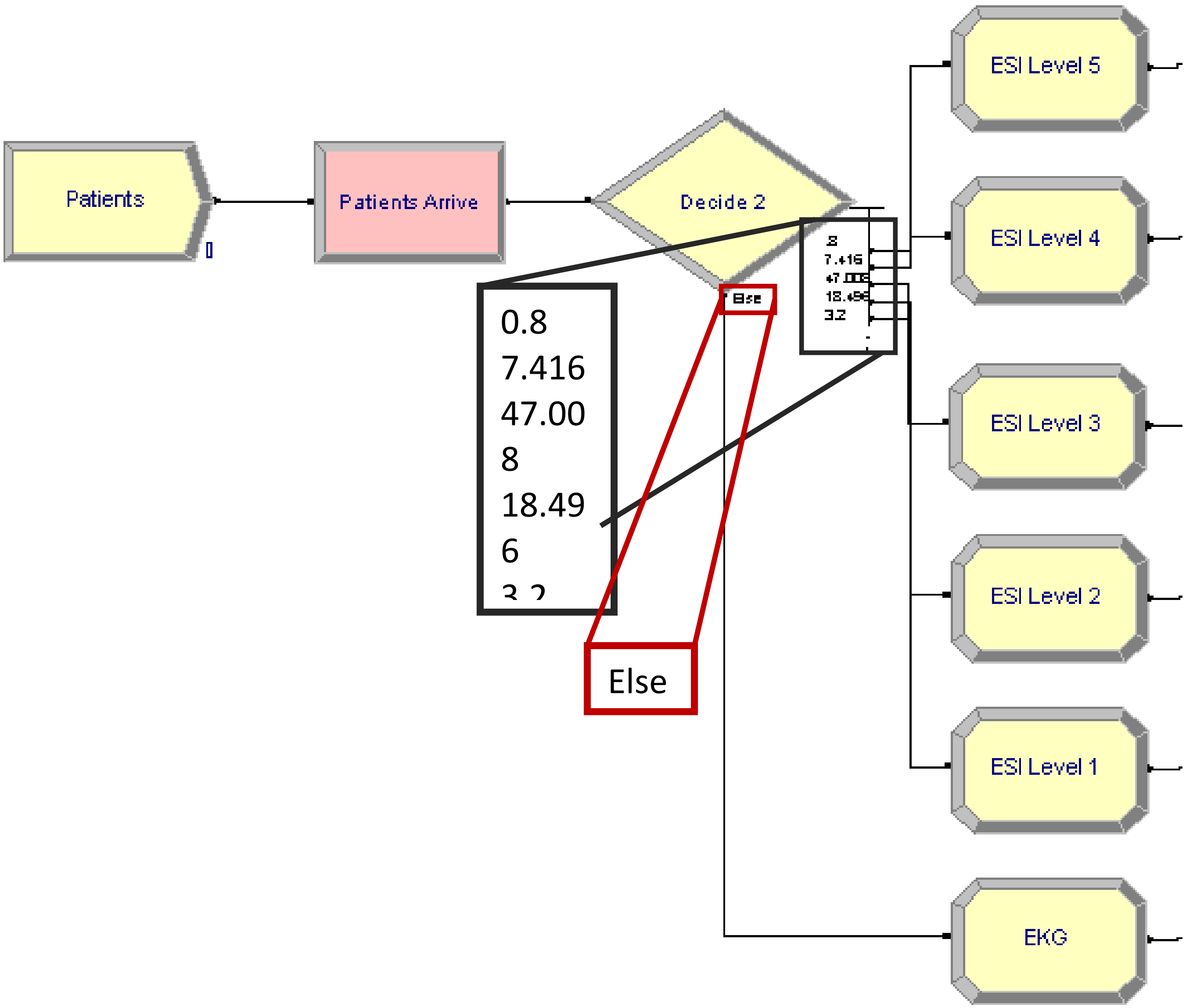


Figure 21: Decide module logic for assigning acuity levels

Resources

There is a large of number of resources in this model that can be broken into clearly defined groups:

- Main ED Rooms/Beds
- Yellow Zone Rooms/Beds
- Doctors/Physicians
- Nurses
- Technicians

In the hospital, teams of physicians, nurses, and technicians are assigned to work on specific sets of rooms. To reflect this, the model uses sets of resources from the basic process panel.

Table 23: Set module logic and included resources

Set Name	Resources
Yellow Zone Bed	FTBed 1 – FTBed 9
Room1to6RH1to2	Room 1 – Room 6; RHBed 1, RHBed 2
Room7to11RH3to6	Room 7 – Room 11; RHBed 4 – RHBed 6
Room12to19BH5to8	Room 12 – Room 19; BHBed 5 – BHBed 8
Room20to31	Room 20 – Room 31
ResultsPending	Room 10
Doctors	Doctor – Doctor5; Resident or PA
Split-Flow Doctors	YellowZone1, YellowZone2
Nurses1to6RH1to2	RN1to6RH1to2, RNResource*
Nurses7to11RH3to6	RN7to11RH3to4, RNResource*
Nurses12to19BH5to8	RN12to19BH5to8, RNResource*
Nurses20to31	RNRm20to31, RNResource*

RNResource is added to these sets to act as a floating nurse - resource can only be seized from one of these sets at a time

All resource capacities and schedules are predetermined by the hospital.

Appendix H: Model Validation Tests

Patient Arrivals

10:30:54PM **Category Overview** February 20, 2012

Values Across All Replications

Unnamed Project

Replications: 140 Time Units: Minutes

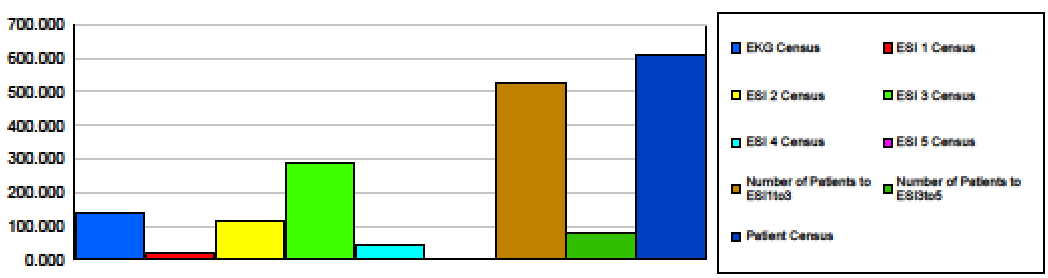
User Specified

Tally

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Door to Doc 12to19BH5to8	49.1727	< 0.08	48.2752	50.3432	33.3288	76.1585
Door to Doc 1to6RH1to2	49.1753	< 0.09	47.9368	50.4721	33.6700	74.5866
Door to Doc 20to31	49.1725	< 0.08	48.2061	50.2715	33.8142	74.6090
Door to Doc 7to11RH3to6	49.1777	< 0.27	45.2019	54.8168	34.0821	73.3031
Door to Doc Time Yellow Zone	21.2957	< 0.10	20.0667	23.3547	13.4459	61.8475
Total Time Admit ESI3to5	114.82	< 6.40	56.9433	259.44	26.2791	641.34
Total Time Discharge ESI 3to5	116.80	< 2.50	83.6977	152.55	27.3143	661.35
Total Time ESI 1to3 Patients	117.60	< 0.50	109.44	124.90	57.6014	235.33
Total Time ResultsPend	146.29	< 3.11	107.73	203.48	94.5050	256.12

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
EKG Census	140.36	< 1.85	117.00	188.00
ESI 1 Census	19.8929	< 0.75	11.0000	29.0000
ESI 2 Census	112.69	< 1.57	80.0000	134.00
ESI 3 Census	285.94	< 2.82	244.00	333.00
ESI 4 Census	45.9500	< 1.08	31.0000	66.0000
ESI 5 Census	5.1929	< 0.36	0.00	12.0000
Number of Patients to ESI1to3	527.71	< 3.49	485.00	596.00
Number of Patients to ESI3to5	79.3071	< 1.38	59.0000	103.00
Patient Census	610.02	< 3.87	557.00	695.00



Output

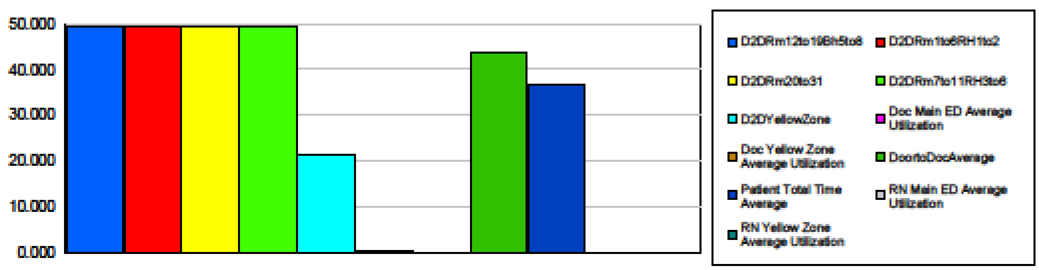
Unnamed Project

Replications: 140 Time Units: Minutes

User Specified

Output

Output	Average	Half Width	Minimum Average	Maximum Average
D2DRm12to19Bh5to8	49.1727	0.08	48.2752	50.3432
D2DRm1to6RH1to2	49.1753	0.09	47.9368	50.4721
D2DRm20to31	49.1725	0.08	48.2061	50.2715
D2DRm7to11RH3to6	49.1777	0.27	45.2019	54.8168
D2DYellowZone	21.2957	0.10	20.0667	23.3547
Doc Main ED Average Utilization	0.1879	0.03	0.00	0.6000
Doc Yellow Zone Average Utilization	0.03571429	0.02	0.00	0.5000
DoortoDocAverage	43.5988	0.06	42.5463	44.7985
Patient Total Time Average	36.8261	0.82	27.8116	52.2725
RN Main ED Average Utilization	0.07823129	0.01	0.00	0.2619
RN Yellow Zone Average Utilization	0.0929	0.05	0.00	1.0000



Remove Main ED Beds

Category Overview

Values Across All Replications

Unnamed Project

Replications: 140 Time Units: Minutes

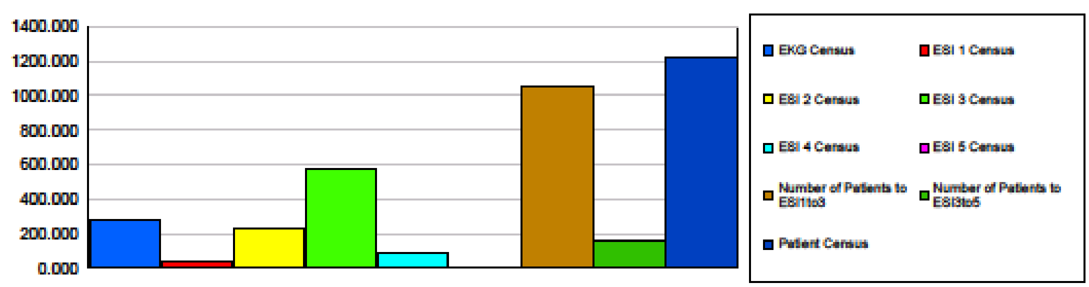
User Specified

Tally

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Door to Doc 12to19BH5to8	49.6726	< 0.07	48.3332	50.6626	33.7529	95.6155
Door to Doc 1to6RH1to2	49.5391	< 0.08	48.3203	50.8689	33.6638	90.8978
Door to Doc 20to31	49.3689	< 0.07	48.4756	50.3760	33.5081	90.9031
Door to Doc 7to11RH3to6	54.8826	< 1.24	48.8824	87.1902	33.6651	587.03
Door to Doc Time Yellow Zone	23.3789	< 0.20	21.0227	28.6473	13.0089	231.93
Total Time Admit ESI3to5	122.89	< 3.89	78.1559	187.03	27.6084	676.07
Total Time Discharge ESI 3to5	123.98	< 1.80	92.4126	168.21	26.3114	690.75
Total Time ESI 1to3 Patients	136.03	< 1.17	122.10	166.48	54.3926	678.91
Total Time ResultsPend	141.47	< 2.79	108.47	199.16	92.1690	230.49

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
EKG Census	282.22	< 3.17	222.00	325.00
ESI 1 Census	39.3857	< 1.11	21.0000	55.0000
ESI 2 Census	225.98	< 2.61	186.00	268.00
ESI 3 Census	572.69	< 3.80	512.00	660.00
ESI 4 Census	90.0357	< 1.54	70.0000	119.00
ESI 5 Census	9.5714	< 0.53	3.0000	17.0000
Number of Patients to ESI1to3	1057.21	< 5.64	980.00	1199.00
Number of Patients to ESI3to5	156.68	< 2.00	126.00	188.00
Patient Census	1219.89	< 6.12	1142.00	1365.00



Output

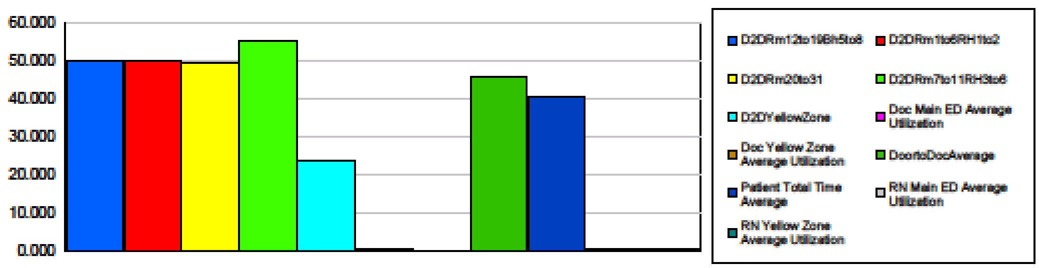
Unnamed Project

Replications: 140 Time Units: Minutes

User Specified

Output

Output	Average	Half Width	Minimum Average	Maximum Average
D2DRm12to19Bh5to8	49.6726	0.07	48.3332	50.6626
D2DRm1to6RH1to2	49.5391	0.08	48.3203	50.8689
D2DRm20to31	49.3689	0.07	48.4756	50.3760
D2DRm7to11RH3to6	54.8826	1.24	48.8824	87.1902
D2DYellowZone	23.3789	0.20	21.0227	28.6473
Doc Main ED Average Utilization	0.2700	0.03	0.00	0.6000
Doc Yellow Zone Average Utilization	0.08571429	0.03	0.00	0.5000
DoortoDocAverage	45.3684	0.26	43.6891	51.6958
Patient Total Time Average	40.3224	0.61	33.1971	52.9439
RN Main ED Average Utilization	0.1786	0.02	0.00	0.4762
RN Yellow Zone Average Utilization	0.2000	0.07	0.00	1.0000



Remove Yellow Zone Beds

Unnamed Project

Replications: 140 Time Units: Minutes

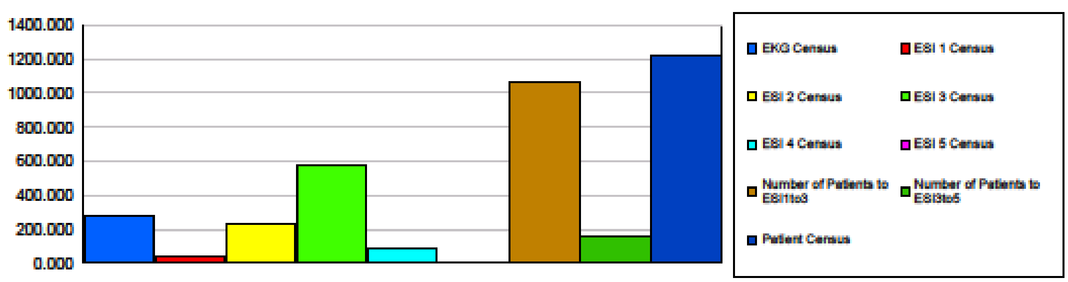
User Specified

Tally

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Door to Doc 12to19BH5to8	49.8234	< 0.07	48.9000	51.0914	33.2494	96.8555
Door to Doc 1to6RH1to2	50.6179	< 0.53	48.6223	73.9305	33.8412	629.41
Door to Doc 20to31	49.4497	< 0.07	48.3074	50.6849	33.2831	90.5878
Door to Doc 7to11RH3to6	49.5940	< 0.12	47.8034	51.4016	33.2160	97.1529
Door to Doc Time Yellow Zone	26.5185	< 0.54	21.8563	37.4885	13.0947	411.46
Total Time Admit ESI3to5	120.44	< 4.62	65.6179	204.21	26.7228	664.74
Total Time Discharge ESI 3to5	121.78	< 2.04	92.1178	150.08	26.1685	685.02
Total Time ESI 1to3 Patients	136.39	< 1.11	124.23	167.20	58.8257	767.57
Total Time ResultsPend	142.07	< 2.92	108.47	199.16	92.1690	257.75

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
EKG Census	283.58	< 2.90	246.00	330.00
ESI 1 Census	37.9286	< 1.01	21.0000	55.0000
ESI 2 Census	226.91	< 2.66	197.00	272.00
ESI 3 Census	574.06	< 3.60	520.00	624.00
ESI 4 Census	89.6000	< 1.45	70.0000	112.00
ESI 5 Census	9.1786	< 0.50	2.0000	19.0000
Number of Patients to ESI1to3	1059.01	< 5.00	997.00	1133.00
Number of Patients to ESI3to5	155.74	< 1.97	127.00	180.00
Patient Census	1221.26	< 5.29	1155.00	1294.00



Output

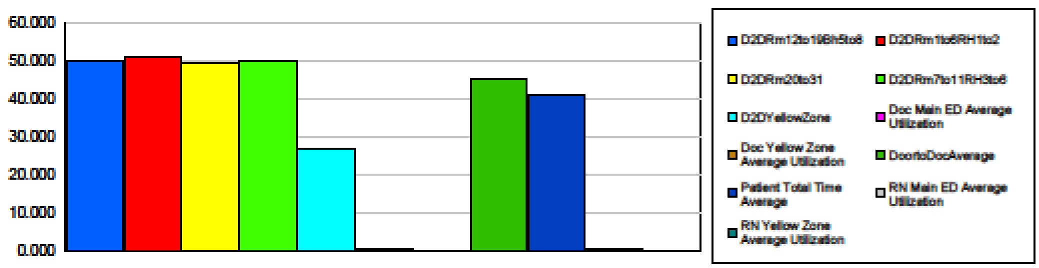
Unnamed Project

Replications: 140 Time Units: Minutes

User Specified

Output

Output	Average	Half Width	Minimum Average	Maximum Average
D2DRm12to19Bh5to8	49.8234	0.07	48.9000	51.0914
D2DRm1to6RH1to2	50.6179	0.53	48.6223	73.9305
D2DRm20to31	49.4497	0.07	48.3074	50.6849
D2DRm7to11RH3to6	49.5940	0.12	47.8034	51.4016
D2DYellowZone	26.5185	0.54	21.8563	37.4885
Doc Main ED Average Utilization	0.3086	0.03	0.00	0.6000
Doc Yellow Zone Average Utilization	0.1107	0.03	0.00	0.5000
DoortoDocAverage	45.2007	0.16	43.6654	49.5423
Patient Total Time Average	40.7190	0.72	32.2345	55.2188
RN Main ED Average Utilization	0.1774	0.02	0.00	0.5952
RN Yellow Zone Average Utilization	0.1143	0.05	0.00	1.0000



Appendix I: Model Validation Results

Table 24: Results of model validation tests

Extreme Conditions		
Condition	**Description**	**Pass/Fail**
Patient Arrivals	The number of patient arrivals per hour was cut in half from the base case. The count of each type of patient (ESI 1, ESI 2, etc…) should also be half of the original base case.	Pass
Remove Main ED Beds	Ten Main ED beds were removed as resources from this run. The expected result is a decrease in total patient output and an increase in total patient times.	Pass
Remove Yellow Zone Beds	Four Yellow Zone beds were removed as resources from this run. The expected results is a decrease in total patient output and increase in total patient times.	Pass

Appendix J: ARENA Reports – Base Case

10:37:19PM **Category Overview** February 20, 2012

Values Across All Replications

Unnamed Project

Replications: 140 Time Units: Minutes

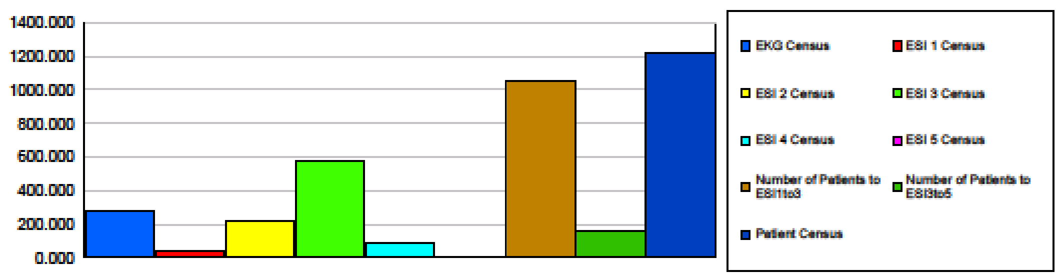
User Specified

Tally

Interval	Average	Half Width	Minimum Average	Maximum Average	Minimum Value	Maximum Value
Door to Doc 12to19BH5to8	49.8152	< 0.08	48.4722	51.0265	33.0848	94.3688
Door to Doc 1to6RH1to2	50.6783	< 0.57	48.7752	74.9418	33.1893	629.41
Door to Doc 20to31	49.3863	< 0.06	48.2960	50.2561	33.4320	91.5348
Door to Doc 7to11RH3to6	49.6849	< 0.12	47.8034	51.5271	33.3493	97.1529
Door to Doc Time Yellow Zone	23.4424	< 0.21	21.2003	30.6639	13.4363	187.95
Total Time Admit ESI3to5	122.63	< 4.06	76.2643	194.25	26.6748	653.15
Total Time Discharge ESI 3to5	121.81	< 1.87	92.1178	160.36	26.9894	692.32
Total Time ESI 1to3 Patients	136.10	< 1.23	123.05	172.87	59.2704	881.03
Total Time ResultsPend	142.07	< 2.92	108.47	199.16	92.1690	257.75

Counter

Count	Average	Half Width	Minimum Average	Maximum Average
EKG Census	279.10	< 2.62	241.00	319.00
ESI 1 Census	38.5214	< 1.12	24.0000	59.0000
ESI 2 Census	224.64	< 2.40	187.00	268.00
ESI 3 Census	574.24	< 3.95	525.00	633.00
ESI 4 Census	89.8571	< 1.51	59.0000	112.00
ESI 5 Census	9.5929	< 0.54	2.0000	18.0000
Number of Patients to ESI1to3	1053.08	< 4.93	976.00	1130.00
Number of Patients to ESI3to5	156.86	< 2.11	128.00	195.00
Patient Census	1215.96	< 4.86	1142.00	1286.00



Output

Model Filename: R:\MQP\SVH-2-17 Page 23 of 24

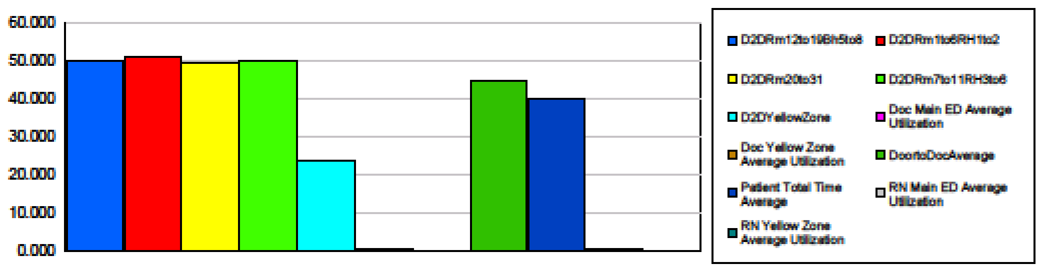
Unnamed Project

Replications: 140 Time Units: Minutes

User Specified

Output

Output	Average	Half Width	Minimum Average	Maximum Average
D2DRm12to19Bh5to8	49.8152	0.08	48.4722	51.0265
D2DRm1to6RH1to2	50.6783	0.57	48.7752	74.9418
D2DRm20to31	49.3863	0.06	48.2960	50.2561
D2DRm7to11RH3to6	49.6849	0.12	47.8034	51.5271
D2DYellowZone	23.4424	0.21	21.2003	30.6639
Doc Main ED Average Utilization	0.3150	0.03	0.00	0.6000
Doc Yellow Zone Average Utilization	0.1036	0.03	0.00	0.5000
DoortoDocAverage	44.6014	0.13	43.6825	49.0344
Patient Total Time Average	39.9552	0.60	33.3268	51.7883
RN Main ED Average Utilization	0.1687	0.02	0.00	0.5476
RN Yellow Zone Average Utilization	0.1286	0.06	0.00	1.0000



Appendix K: Scenario Analysis Results

Table 25: Statistical data of performance metrics for scenario analysis over 140 runs

		Doctor Utilization	Nurse Utilization	Door-to-doctor Main ED	Door-to-doctor Yellow Zone	Total Time Yellow Zone Admit	Total Time Yellow Zone Discharge	Total Time Main ED	Total Time Results Pending
Base	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.91**	**121.77**	**135.92**	**142.36**
	StdDev	0.19	0.14	1.82	1.26	24.40	11.20	7.68	17.34
	CI (95%)	0.01	0.01	0.15	0.21	4.08	1.87	1.28	2.90
Add BH Bed	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Add RH Bed	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Add Yellow Zone Doctor	Average	0.30	0.22	49.84	20.35	119.06	121.32	136.82	143.98
	StdDev	0.19	0.14	1.79	0.62	26.99	11.68	6.78	19.83
	CI (95%)	0.01	0.01	0.15	0.10	4.51	1.95	1.13	3.31
Add Main ED Doctor	Average	0.29	0.19	49.66	23.48	121.69	121.63	122.64	140.57
	StdDev	0.18	0.15	0.55	1.10	25.54	12.06	3.15	17.54
	CI (95%)	0.01	0.01	0.05	0.18	4.27	2.02	0.53	2.93
Add EKG Room	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Add Yellow Zone Bed	Average	**0.29**	**0.24**	**49.89**	**23.31**	**124.08**	**121.59**	**136.61**	**142.07**
	StdDev	0.19	0.14	1.80	1.21	25.90	10.52	7.36	17.43
	CI (95%)	0.01	0.01	0.15	0.20	4.33	1.76	1.23	2.91
Add Main ED Bed	Average	**0.29**	**0.24**	**49.75**	**23.35**	**122.52**	**122.58**	**136.77**	**142.07**
	StdDev	0.19	0.14	0.73	1.06	24.24	11.04	7.64	17.43
	CI (95%)	0.01	0.01	0.06	0.18	4.05	1.84	1.28	2.91
Add Float Nurse	Average	**0.29**	**0.23**	**49.62**	**23.33**	**123.18**	**121.85**	**136.56**	**142.07**
	StdDev	0.19	0.14	1.35	1.09	24.63	10.14	6.26	17.43
	CI (95%)	0.01	0.01	0.11	0.18	4.12	1.69	1.05	2.91
Add Main ED Nurse	Average	**0.30**	**0.23**	**49.77**	**23.52**	**121.02**	**122.72**	**136.88**	**142.07**
	StdDev	0.19	0.13	1.91	1.13	27.98	11.58	7.88	17.43
	CI (95%)	0.01	0.01	0.16	0.19	4.68	1.93	1.32	2.91
Add Yellow Zone Nurse	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Add Quick	Average	**0.29**	**0.24**	**49.95**	**23.45**	**114.93**	**123.03**	**136.56**	**142.07**

Look Nurse	StdDev	0.19	0.14	2.48	1.24	24.14	11.30	6.99	17.43
	CI (95%)	0.01	0.01	0.21	0.21	4.03	1.89	1.17	2.91
Add Quick Look Tech	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Add Tech	Average	**0.29**	**0.24**	**49.89**	**23.44**	**122.63**	**121.81**	**136.10**	**142.07**
	StdDev	0.19	0.14	1.82	1.25	24.27	11.18	7.35	17.43
	CI (95%)	0.01	0.01	0.15	0.21	4.06	1.87	1.23	2.91
Double RP Capacity	Average	**0.29**	**0.25**	**50.25**	**23.56**	**122.04**	**123.81**	**136.62**	**153.44**
	StdDev	0.19	0.17	2.07	1.33	25.40	12.20	6.31	14.79
	CI (95%)	0.01	0.01	0.17	0.22	4.24	2.04	1.05	2.47
Shift to ESI 1	Average	0.29	0.24	51.29	23.16	118.52	121.13	138.99	153.55
	StdDev	0.19	0.14	2.32	0.92	25.94	10.98	7.37	15.89
	CI (95%)	0.01	0.01	0.19	0.15	4.33	1.83	1.23	2.65
Shift to ESI 5	Average	0.30	0.25	52.08	21.66	116.03	118.05	146.24	153.74
	StdDev	0.21	0.15	0.53	0.70	33.30	15.20	8.17	16.61
	CI (95%)	0.01	0.01	0.04	0.12	5.56	2.54	1.36	2.78
Increase in Patient Volume	Average	**0.32**	**0.27**	**52.04**	**24.09**	**128.26**	**126.21**	**160.18**	**143.24**
	StdDev	0.21	0.15	9.28	1.30	26.93	10.83	13.58	17.92
	CI (95%)	0.01	0.01	0.77	0.22	4.50	1.81	2.27	2.99

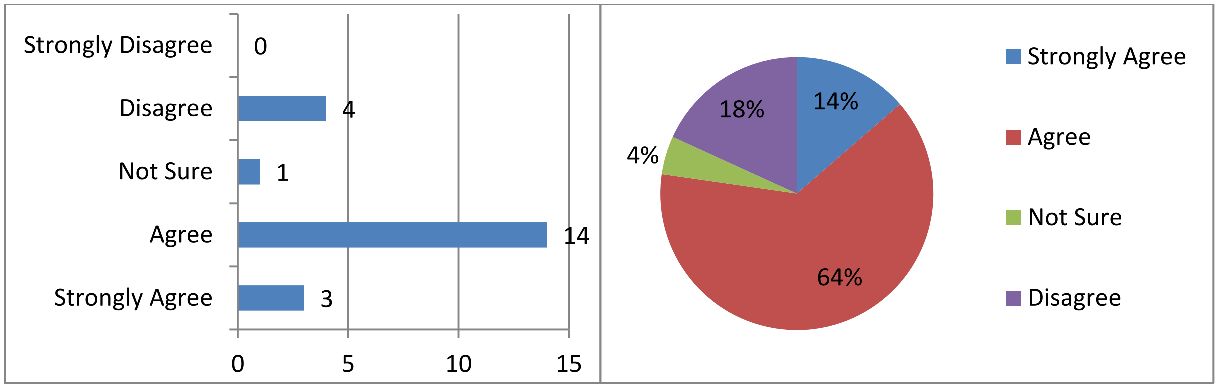
Table 26: Statistical data for aggregate performance metrics across 17 scenarios tested

		Door-to-doctor	Total Length of Stay
Base	Average	44.62	130.56
	Standard Deviation	10.70	18.51
	CI (95%)	0.79	1.54
Add BH Bed	Average	44.60	130.65
	Standard Deviation	10.72	18.51
	CI (95%)	0.80	1.54
Add RH Bed	Average	44.60	130.65
	Standard Deviation	10.72	18.50
	CI (95%)	0.80	1.54
Add Yellow Zone Doctor	Average	44.45	107.17
	Standard Deviation	10.63	35.09
	CI (95%)	0.79	2.91
Add Main ED Doctor	Average	44.42	126.63
	Standard Deviation	10.49	18.51
	CI (95%)	0.78	1.54
Add EKG Room	Average	44.60	130.65
	Standard Deviation	10.72	18.50
	CI (95%)	0.80	1.54
Add Yellow Zone Bed	Average	44.58	131.09
	Standard Deviation	10.77	18.87
	CI (95%)	0.80	1.57
Add Main ED Bed	Average	44.47	130.99
	Standard Deviation	10.59	18.48
	CI (95%)	0.79	1.53
Add Float Nurse	Average	44.36	130.92
	Standard Deviation	10.60	18.34
	CI (95%)	0.79	1.52
Add Main ED Nurse	Average	44.47	130.46
	Standard Deviation	10.58	19.78
	CI (95%)	0.78	1.64
Add Yellow Zone Nurse	Average	43.94	130.30
	Standard Deviation	11.91	20.82
	CI (95%)	0.88	1.73
Add Quick Look Nurse	Average	44.65	129.15
	Standard Deviation	10.85	19.49
	CI (95%)	0.80	1.62
Add Quick Look Tech	Average	44.60	130.65
	Standard Deviation	10.72	18.50
	CI (95%)	0.80	1.54
Add Tech	Average	44.60	130.65
	Standard Deviation	10.72	18.50
	CI (95%)	0.80	1.54
Double RP Capacity	Average	44.91	133.98
	Standard Deviation	10.85	20.49
	CI (95%)	0.81	1.70

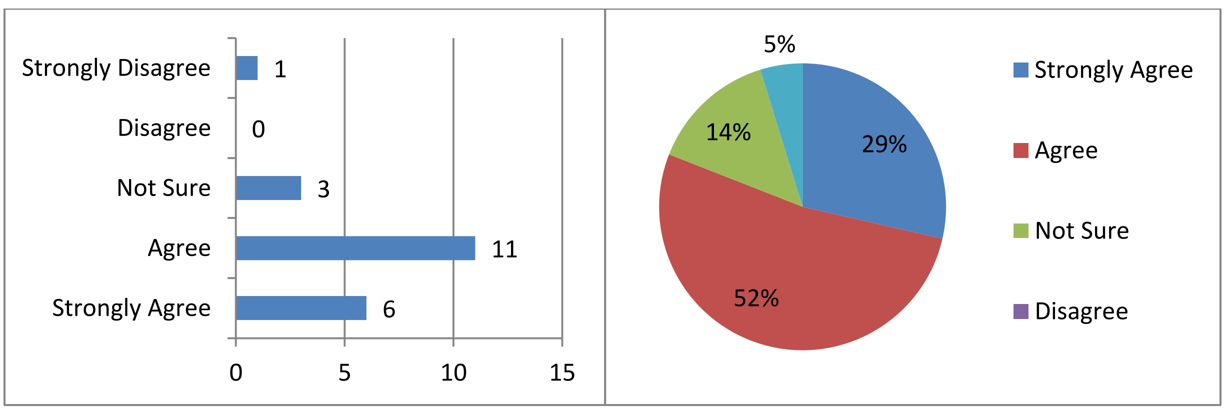
Shift to ESI 1	Average	45.66	133.05
	Standard Deviation	11.45	21.82
	CI (95%)	0.85	1.81
Shift to ESI 5	Average	46.00	133.51
	Standard Deviation	12.18	26.41
	CI (95%)	0.90	2.19
Increase in Patient Volume	Average	46.45	139.47
	Standard Deviation	13.93	22.84
	CI (95%)	1.03	1.90

Appendix L: Saint Vincent ED Employee Survey Results

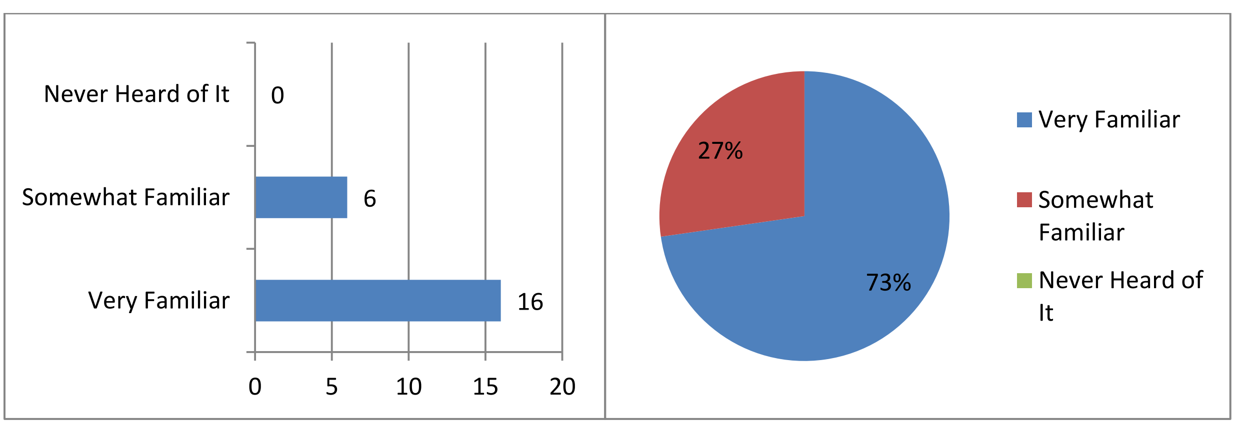
1. The length of patient wait times in the St. Vincent ED is a problem.



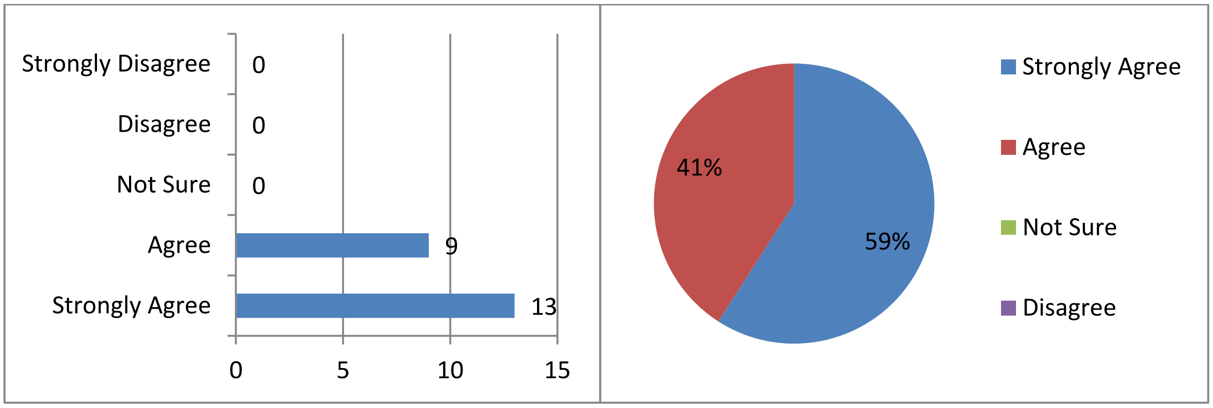
2. There needs to be changes made to the current process in the ED in order to decrease patient wait times.



3. How familiar are you with Split-Flow?



4. As a St. Vincent employee, I am willing to change certain aspects of my job to improve patient wait times in the ED.



5. Additional comments…

- “Feels like more is being passed onto the nurse (triage almost every patient now instead of just ambulance patients) and have to answer phone calls on all patients on team - so now we have to take more time explaining what is going on to another person. Feels busier and also feels like mistakes are easier to make - not a great feeling on some shifts.”

- “Quick look does not always work. Need to find a way to change this due to MD's complaining vitals signs are not in on a timely manner and things are overlooked.”

- “Don’t have nurses do 12 hour shifts or techs in the heavier assignments, as they get tired and slow down, resulting in production.”

- “We are currently using the split flow process. It is unclear if the survey is asking about the old process or the new Split flow process. I think there are times where Split flow can work, but I have seen circumstances where a very sick pt. was brought to a room through the Split flow process and was not seen by an RN or an MD for more than an hour. This is definitely a down side of split flow.”

- “Simple solution of more staff will solve multiple problems, pt will be happier because you can get to them quicker and more often. Pt will be safer due to more staff eye and help around.”

- “The throughput time from admission to inpatient unit needs to be improved thus decreasing ED wait times (there will be stretchers available). Split flow working well upfront (former triage area).”

- “The traditional triage process itself should take 3-5 minutes. The problem we run into is performing too many interventions before bringing the patient in. The only interventions that should be performed in that area are EKGs and labs in Chest Pain patients only and lifesaving interventions. Getting a SAMPLE triage in non-Fast Track patients would not significantly delay the split flow process.”

Appendix M: Journal Article

Submitted to: **Journal of Enterprise Information Management December 2011, currently under review**

Evaluation of the Split-Flow Concept in Emergency Departments Using Discrete-Event Simulation

1. Introduction

Hospitals, particularly Emergency Departments (ED) in the United States are seeking innovative approaches to decrease patient length of stay and improve care quality. Recently some hospitals have begun to split patient flow by acuity ("split-flow") and by function (commonly called "fast-tracking") in an effort to decrease wait times and promote quality. While fast-track designs have been widely implemented (Oredsson, 2011 and Obrien, 2006 contain recent reviews), the split-flow approach is considered the "new generation of EDs". The central tenet of split-flow is the sooner patients can enter the hospital system, the sooner they are able to be treated and released. Splitting patient flows into two groups of high and low acuity patients ensures that less sick patients are not occupying resources necessary for higher acuity patients. As illustrated in Figure 1, the split-flow process concept replaces traditional triage with a "quick look triage", routes (splits) lower acuity patients as defined by the standard five level Emergency Severity Index (Agency for Healthcare Research and Quality, 2011) in a separate queue from those higher acuity patients who are awaiting placement in a traditional ED bed. Lower acuity patients are seen in a "continuous care area" by a care team comprised of a doctor, a nurse, and a technician. In a split-flow ED patients are split because lower acuity and ambulatory patients typically do not require a bed. Lower acuity patients have an Emergency Severity Index (ESI) of 5, 4, or sometimes 3, while higher acuity patients have an ESI of 1, 2, or sometimes 3. By not placing lower acuity patients in beds, limited bed capacity is conserved for higher acuity patients requiring a bed immediately. By offering a different treatment model to lower acuity patients, EDs expect to reduce bed occupancy and increase the overall capacity of the ED. As the split-flow approach is still in its infancy, few studies are able to validate this claim.

Early implementations of the split-flow concept have resulted in decreased door-to-doctor time, a key performance metric for EDs (Banner Health, 2011), total length of stay ([2],2010), and patient satisfaction (Rodi, 2006). Improving these metrics directly correlates to improved patient safety and decreased wait times (McCarthy, 2011) (Jarousse, 2011). A healthcare system in the United States, Banner Health, implemented the split-flow concept in eight of its Emergency Departments. For these hospitals, the aggregate average door-to-doctor time decreased 58% while the average length of stay decreased 14% (Banner Health, 2011).

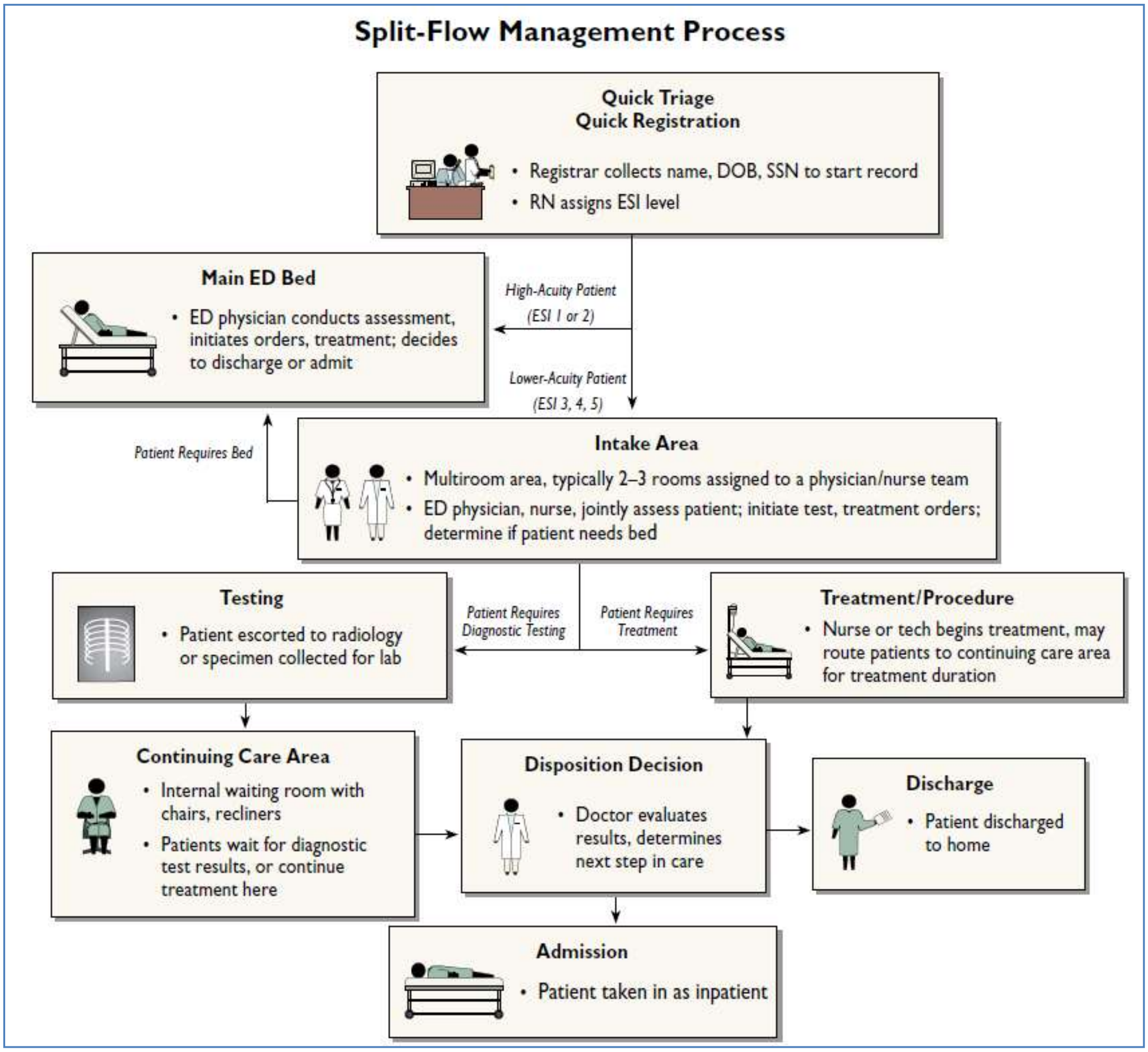


Figure 1: Split-Flow Management Process as Designed by Banner Health

Despite the potential benefits of the split-flow concept, operational parameters such as staffing levels and patient routing rules are not well established. Implementation of a spilt-flow process requires significant work reorganization, physical layout changes and staff training. Implementation is disruptive and requires significant organizational commitment. Although ideas for integrating the split-flow design into hospital workflows are beginning to emerge (Zilm, 2010), hospital managers are unsure of how to configure their operations. The handful of EDs who have implemented the split-flow concept are experimenting with different designs post implementation.

The objective of this paper is to evaluate the impact on patient throughput of different split-flow configurations. Our method enables a hospital to quantify the effects of system redesign prior to implementation and to examine how the split-flow concept can best be applied to their particular hospital, ultimately decreasing implementation costs and disruptions. We use discrete-event simulation to create a decision-tool for a community-based ED in central Massachusetts, USA. Our contribution fills a current void in ED implementation research, decision support for split-flow implementation.

The remainder of this paper is organized as follows. Section 2 describes the motivation of this paper. Section 3 overviews our methods and provides a case study based on data taken from our partnering facility. Section 4 provides a discussion of our results, and Section 5 provides a conclusion and short discussion of future work.

2. Background

2.1 Motivation: The Fragile State of Emergency Department Care

Hospital-based emergency care is critically important to the health of Americans (Institute of Medicine, 2006). Not only do Emergency Departments (EDs) provide urgent care, but they increasingly serve as adjuncts to community physician practices (Institute of Medicine, 2006). Since the 1980s, ED visits in the United States have steadily increased at an annual rate of approximately 3% (Zilm, 2010). Factors contributing to the increase include an aging population (Zilm, 2010), limited access to medical care from other sources (Hoot, 2008), and a rising trend toward utilizing the ED for non-emergency care (Hoot, 2008) (Welch, 2010). As a result, the Emergency Department has become the main point of entry into hospitals and accounts for more than half of all admissions to hospitals in the United States (Zilm 2010).

The surge in patient volumes is a significant contributor to the nation-wide phenomenon known as ED crowding (Institute of Medicine, 2006). More than two thirds of US hospitals in urban, suburban, and rural settings are affected by crowding (Pediatric Emergency Medicine, 2004). ED crowding is a situation when the need for emergency services outweighs available ED resources (Case, 2004). A crowded ED produces a series of negative effects. Excessive patient overload leads to medical errors, poor outcomes, patient dissatisfaction, increased patient wait times and creates an unsafe environment for patients and providers (Jarousse, 2011) (Case, 2004). Long wait times result in patients leaving the hospital without being seen by a physician. One study calculated that each patient not seen equates to $8,000-$10,000 in lost revenue (Jensen, 2003). A second study calculated that over $3.8 million in net revenue was lost in one year due to patient diversion and elopement (Falvo, 2007). Not only do lost patients represent lost revenue, recent studies suggest that as the average length of stay of ED patients increases, the risk of death or hospital readmission within the next 7 days increases for those who were released or left without being seen (McCarthy 2011) (Guttmann, 2011). By incorporating a split-flow process, hospital managers are striving to decrease wait times and crowding to ensure patient safety.

2.2 Split-Flow Success

Split-flow is an organizational response to the ED crowding. Under this model, a dedicated clinical team rapidly triages each patient, thereby accelerating the treatment of less sick patients and quicker admission for those who are very ill and require inpatient care (Agency for Healthcare Research and Quality, 2011). In 2008, St. Anthony's Hospital in Washington State was one of the first hospitals to implement a split-flow process. Consequently, its Emergency Department saw a dramatic decrease in door-to-doctor time from 93 to 20 minutes. In 2010 the Baptist Medical Center in San Antonio, Texas implemented a split-flow process in their Emergency Department, resulting in a decrease for the average patient length of stay from 393 to 120 minutes in the ED. Despite early success stories, implementation requires significant investment and is difficult to plan in advance (Medeiros et al., 2008).

2.3 Discrete Event Simulation of Emergency Departments

Given the increased need for efficiency in ED systems, coupled with the increased availability of ease-of-use of simulation software packages, simulation has become an effective and efficient means to analyze proposed process improvements for potential cost reductions and productivity improvements prior to their actual implementation (Banks et al., 2005).The use of discrete-event simulation to evaluate ED crowding solutions is well documented in literature. Representative examples include Hoot et al. who use simulation to study ED congestion by integrating simulation forecasting with ED information systems and obtain short-term projections of waiting time, occupancy level, and boarding time. Ceglowski et al. use data mining techniques to incorporate core patient treatments into a simulation model, identifying bottlenecks between the ED and a hospital ward. Takakuwa and Shiozaki propose a stepwise operations planning procedure to minimize the patient wait times in the ED. Samaha et al. create a simulation model to evaluate operating alternatives such as a fast-track system to reduce the length of stay of ED patients. The major themes among simulations solutions of ED crowding include additional personnel, hospital bed access, non-urgent referrals, ambulance diversion, and destination control.

Despite the substantial body of simulation literature describing the causes, effects, and solutions of ED crowding, little evidence evaluates the impact of patient triage alternatives on ED performance. Of note is the study of Connelly and Bair (2004) which compared two patient triage methods using discrete-event simulation: (1) fast-track triage against (2) acuity ratio triage (ART) approach whereby patients were assigned to staff on an acuity ratio basis. A preliminary comparison of two triage methods showed that the ART approach reduced imaging bottlenecks and average treatment times for high-acuity patients, but resulted in an overall increase in average service time for low-acuity patients (Connelly and Bair,2004). Garcia et al simulated an ED with the addition of a fast track area to show that lower acuity patients are treated more quickly without sacrificing the quality of care for higher acuity patients. These findings were confirmed by Al Darrab et al.

2.4 The Context: St. Vincent Hospital

Like many hospitals in the United States, Saint Vincent Hospital, located in Worcester, Massachusetts, is confronted by ED crowding, long wait times, and poor patient satisfaction. Saint Vincent Hospital, part of the Vanguard Health System, is a 270 bed acute care, community teaching hospital (Saint Vincent Hospital, 2011). Saint Vincent serves not only the greater Worcester area, but also Worcester County at large with a population of 650,000 (Saint Vincent Hospital, 2011). The ED is the largest department of the hospital, bringing in greater than half of all hospital admissions, according to Dr. Burns M.D., Chief of Emergency Medicine at Saint Vincent Hospital. Last year, Saint Vincent admitted 18,600 patients and treated over 63,800 patients through their ED (Zuba, 2011).

The Saint Vincent ED management team is struggling to decrease patient wait times, decrease the amount of time a patient must wait to see a doctor, and decrease patients' total length of stay. Last year, this hospital's patient satisfaction scores for the metric "waiting time to see a doctor", when compared with the other 27 Vanguard hospitals, ranked below the 50th percentile (Press Ganey, 2011). Saint Vincent ED is seeking to improve these performance metrics by implementing a split-flow process.

The literature review leads to two important conclusions. First, patient throughput challenges in Emergency Departments are widespread. The review revealed that a handful of hospitals are experimenting with a split-flow design as a means to improve throughput and patient safety. The review affirmed that, to the best of our knowledge, a systematic method does not exist to evaluate split-flow design prior to implementation. Our review also demonstrated that discrete-event simulation is a sound technique to analyze ED processes.

3. Methods

This paper takes a "process" approach to simulation modeling i.e. the simulation is viewed in terms of the individual entities involved, and the programming "describes the 'experience' of a 'typical' entity as it 'flows' through the system" (Law, 2007). This section briefly overviews the data, model, and model validation and verification.

3.1 Data

A thorough understanding of Saint Vincent's current ED process was obtained through on-site observations and interviews with various clinical and non-clinical staff. This method provided abundant information about patient flow at the level of detail required to construct a robust simulation model for analysis.

The majority of the data for our model was extracted from MEDHOST, the hospital's electronic patient database. For the following metrics we pulled data for 2010 during which time over 63,828 patients came into the Emergency Department.

- Average daily patient arrivals by hour;
- Average number of patients admitted by day;
- Average number of patients discharged by day;
- Average number of patients transferred by day;
- Percentage of Emergency Severity Index (ESI) for patients by day.

Arrival data was analyzed for variation in patient arrivals by season, month, week, day, and hour, but was found not to be statistically significant. Hourly interarrival times were determined for each day of the week. Table 1 summarizes the data gathered and used in our model. We refer the reader to Section 3.3 for a discussion of model outputs.

Table 27: Simulation model inputs and outputs

Inputs		***Outputs***
Design information (obtained from observations and interviews)	***Historic information*** *(extracted from MEDHOST)*	***State information*** *(extracted from the simulation model)*
• Control and data flow *• Organizational model (roles, resources, etc.)*	*• Data value range distributions* *• Execution time distributions* *• Patient arrival rate* *• Availability pattern of resources*	*• Total length of stay* *• Door-to-doctor time* *•Resource utilization*

3.2 The Proposed System Design

We refer the reader to the schematic in Figure 2 which outlines the proposed split-flow design. The basic steps of the process include a “quick-look” triage, registration, bed allocation, treatment and discharge. Upon arrival, a patient will be triaged and assigned an acuity level which determines whether the patient will follow the traditional route (high acuity) or the split route (low acuity). High acuity patients will receive a bed that they will “own” for the entirety of their stay. Low acuity patients will receive a bed for an initial examination, but then will be sent to testing and a ‘results pending’ station thereby releasing their bed. The results pending station will consist of reclining chairs increasing bed capacity while patients wait for test results or discharge instructions. All patients will then either be admitted to or discharged from the hospital. The basic steps in a split-flow process are of as outlined in Figure 2.

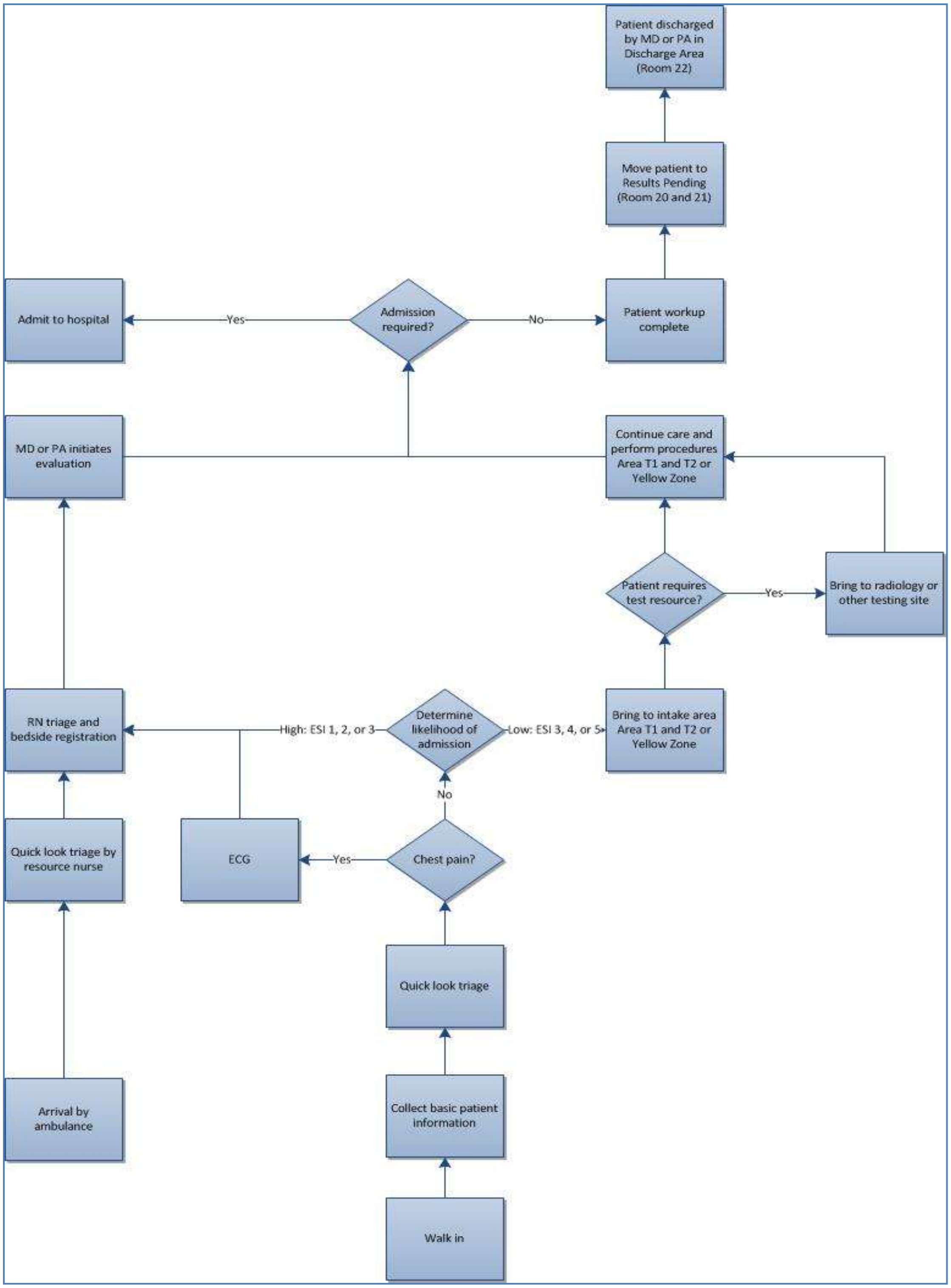


Figure 22: Process map of the proposed split-flow implementation

3.3 Simulation Model

The discrete-event simulation software package ARENA, Version 12.0, was selected on the basis of its graphical user interface, ease-of-use as well as its robust modeling options and features. A description of ARENA and other simulation packages can be found in Kelton (2009).

The main objective of the simulation model developed in this paper was to understand the impact of alternative split-flow operational strategies on system performance. The ability to see and treat patients in a timely manner is important to hospital administrators who are focused on reducing patient wait times. Thus, the primary performance measure is the average length of stay for all ED patients in a split-flow ED where the length of stay is defined as the time from the earlier of registration or triage to the time the patient physically leaves the ED. In other words, LOS is the period of time a patient spends within the ED. Secondary performance measures are the Door-to-doctor time and resource utilization. Door-to-doctor is defined as the time from a patient's entrance into the system until the time when they see a primary healthcare provider. Resource utilization is defined as the fraction of time a resource spends in direct contact with a patient compared to the total time they are scheduled to work in the ED. These performance metrics are listed in Table 1.

Once the system performance metrics were identified, we turned our attention to building the simulation model. This was accomplished by modeling the overall patient flow as well as the ED system processes for realistic operating conditions. The simulation model was developed using a number of assumptions to simplify the modeling effort and eliminate any insignificant parameters. It is assumed that each patient arrival corresponds to one person, not including family members or others who will not receive treatment. It is also assumed that there is one doctor continuously treating patients in the area for ESI Level 3-5 patients. Another assumption concerns the assignment of float and resource nurses in the ED. Saint Vincent uses float and resource nurses in addition to nurses already assigned to specific rooms and beds within the ED. These nurses are utilized by any part of the ED needing additional support to administer diagnostic tests. For the purpose of this model, the float and resource nurses are assigned to specific areas of the ED instead of being utilized throughout the entire ED.

The modeling process began by statistically analyzing the different input data, listed in Table 1, to identify appropriate probability distributions for interarrival rates. Using the patient flow process descriptions and their corresponding activity flow for each patient acuity level, we translated process diagrams into ARENA simulation logic. Results from the simulation model were analyzed using the ARENA Output Analyzer.

We ran the simulation model for one full week, replicated 50 times. To approximate the number of replications, the average half width for all performance metrics was calculated after 10 initial runs and the number of runs was calculated such that the half width of each confidence interval for a performance metric was no more than 10% of the average mean.

3.4 Model Validation and Verification

Techniques for increasing the validity and credibility of a simulation model are provided in Law (2007) and Banks et al. (2005). Throughout the design and development of the simulation model, several techniques were employed to validate the model including:

1. High face validity in a model: By reviewing the simulation model with clinical staff and management, we validated model logic and assumptions.

2. Using quantitative techniques to test the model's assumptions: Input data analysis was validated by using goodness-of-fit tests as well as by graphical methods. A scenario analysis was also applied to measure the response of model performance results to changes in input parameters.

3. Evaluating output: To determine if model output reasonability resembles expected output from the actual system we used a separate data set from the one used to acquire the input probability distributions. The results were then compared to data produced by the actual system, which was obtained from the same time period.

4. Results

Overall, the three performance metrics: (1) total length of stay, (2) door-to-doctor, and (3) resource utilization were significantly better in the simulated split-flow model compared to the traditional ED process. We first compare the performance measures between the simulated split-flow model (base model) and actual performance measures from Saint Vincent's ED 2010 data. Our model incorporated the same number of beds, nurses, and doctors as is currently being used at Saint Vincent's ED. In the base split-flow model one physician and two nurses are assigned to care for the lower acuity patients. The results of this comparison are found in Table 2. As expected, door-to-doctor time and total LOS significantly decreased. Utilization is low as it only represents the amount of time that doctors and nurses are in direct contact with patients.

Table 28: Performance metrics in simulated process compared to historical data

	Current ED Performance (2010)	Simulated Split-flow Process (Base Model)
Door-to-doctor (minutes)	64	71
Length of stay (minutes)	240	122
Nurse Utilization	Not Available	23%
Doctor Utilization	Not Available	35%

We next assess alternative split-flow configurations of three realistic resource allocation strategies. The first scenario added a dedicated split-flow nurse to help treat lower acuity patients. Similarly in the second scenario, an additional dedicated split-flow physician was assigned to treat lower acuity patients. The third scenario added a float nurse to help treat any patients as needed. Table 3 compares the performance metrics for these alternative configurations against the original model. The door-to-doctor time significantly decreased with the addition of float nurse who would be able to attend to patients with lower acuity (Scenario 3). The total length of stay also decreased with the addition of a float nurse (Scenario 3). Nurse utilization did not significantly change in any of the scenarios, while doctor utilization decreased when an additional split-flow doctor was added (Scenario 2).

Table 29: Performance metric sensitivity analysis for resource allocations

	Base Split-Flow Model	Add Split-Flow Nurse	Add Split-Flow Doctor	Add Float Nurse
Door-to-doctor (minutes)	**71**	71	82	69
Length of stay (minutes)	**122**	122	124	119
Nurse Utilization	**23%**	24%	25%	25%
Doctor Utilization	**35%**	35%	24%	35%

In addition to evaluating resource configurations, our model examined the impact on performance metrics with anticipated changes in patient arrivals and changes in the distribution of patient acuity. Although EDs across the United States are experiencing an average 3% annual increase in patient arrivals, we investigated the impact of a 10% increase in patient arrivals as this is reflective of annual increases over the past 5 years at Saint Vincent. Further, we tested how the three performance metrics would be affected should the distribution of patient acuity change. We increased the number of higher acuity patients by 5% in one scenario and did the same for lower acuity volume in the other scenario. Table 4 compares the previously mentioned scenarios against the base split-flow case.

Table 30: Impact on system performance with changes in patient arrivals and acuity levels

	Base Split-Flow Model	Increase Patient Arrivals	Increase In Lower Acuity Patients	Increase In Higher Acuity Patients
Door-to-doctor (minutes)	**86**	129	50	68
Length of stay (minutes)	**122**	165	72	97
Nurse Utilization	**18%**	33%	17%	18%
Doctor Utilization	**28%**	22%	19%	25%

As expected, the increase in patient arrivals and changes in the distribution of patient acuity significantly impacted the three performance metrics. As patient arrivals increased and a greater number of sicker patients arrived all performance metrics declined. As fewer high acuity patients came to the ED, performance metrics improved. We note that the average door-to-doctor time increased by 45%, and that the total length of stay increased by 26% with a ten percent increase in patient volume.

5. Conclusions

As hospitals in the United States seek to address long, unsafe Emergency Department wait times, hospital management is considering process redesign. The split-flow concept is an emerging approach to manage ED processes by splitting patient flow according to patient acuity. Those patients who are less sick are split off from the traditional ED process flow, which is reserved for higher acuity patients. While early implementations of the split-flow concept have demonstrated significant improvement in patient wait times, a systematic evaluation of operational configurations is lacking. In this paper we build a discrete-event simulation model to evaluate various resource allocation strategies and examine the impact of realistic changes in patient arrival patterns. Our model is applied to a hospital considering split-flow implementation.

As early demonstration projects report in the literature, the simulated split-flow model showed statistically significant improvements in three performance metrics; (1) average length of stay, (2)door-to-doctor time, and (3) resource utilization. When alternative resource allocation strategies were evaluated, the most significant improvement was the addition of a nurse or physician on the door-to-doctor time. From our analysis, we recommend Saint Vincent add a float nurse to assist lower acuity patients as this scenario showed the most significant decrease in door-to-doctor time and length of stay.

Several assumptions may limit the effectiveness of our model. When inputting arrival times, a schedule based on average hourly patient arrivals (by day of week) in 2010 was used. By using a schedule, true hourly patient arrival variables was not captured. Further, the time that doctors and nurses spend with their patients varies greatly by patient but this data was unavailable. Through interviews with clinical staff we obtained estimates for these service times; however time-studies would provide a more accurate reflection of this time.

This study leads to several important conclusions. In particular, split-flow concepts seem to be of interest and importance to Emergency Departments in the United States. Prior to this research, this emerging organizational approach had not been systematically evaluated preceding implementation. This paper confirms that a split-flow process does impact two performance measures of great concern to hospital management; door-to-doctor time and length of stay. At the time of writing, Saint Vincent is considering our recommendations. As split-flow is an emerging concept, simulation naturally lends itself as a method to study proposed system configurations. Therefore, further research work in this area is strongly recommended. Further studies may reuse the approach developed in this study to explore implementation risks in alternative hospital settings. The results derived from such further studies may be used to compare with the findings of this research, and thus providing a more holistic picture of split-flow prior to implementation.

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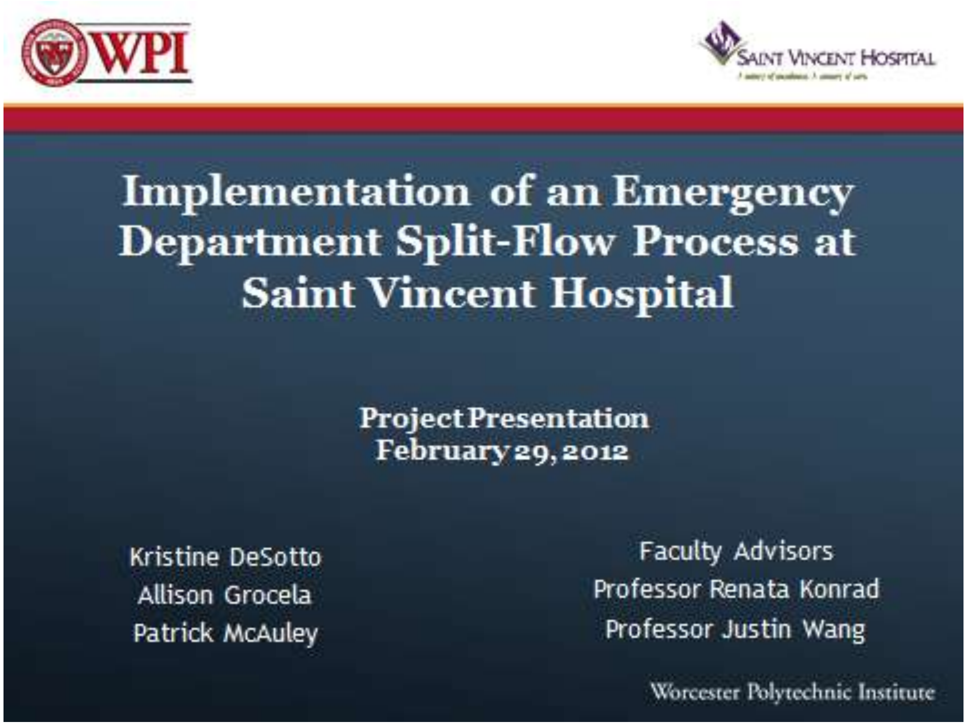
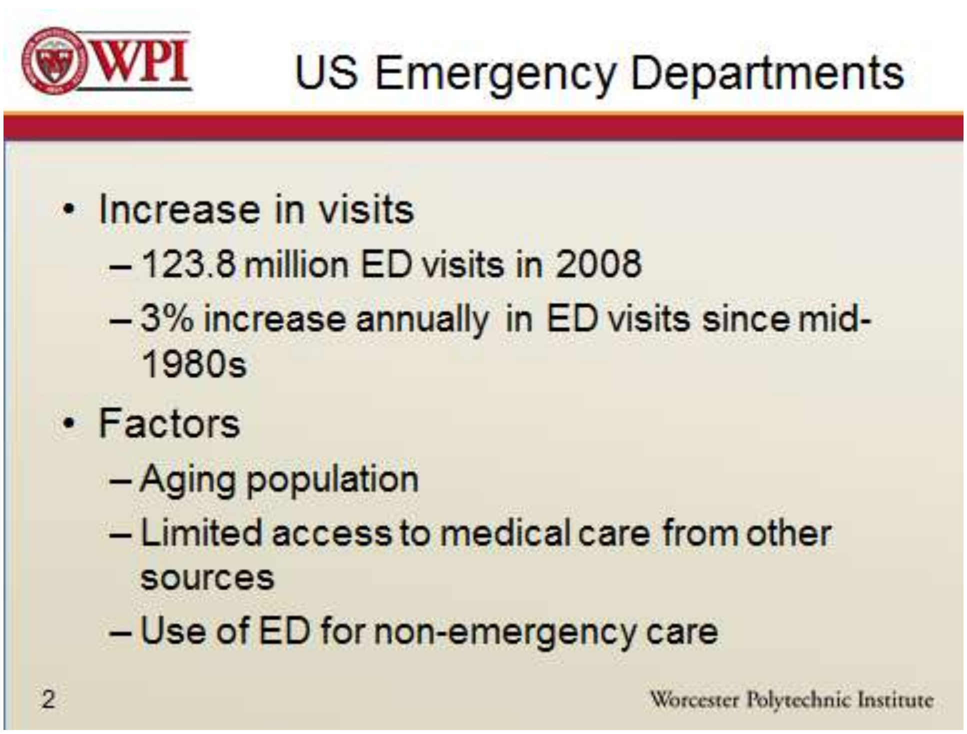
Final Presentation Powerpoint Slides





Saint Vincent Emergency Department
Performance Metrics

- Patient volume
- Patients LWBS
- Patients by acuity level
- Total length of stay
- Door-to-doctor time
- Door-to-treatment time

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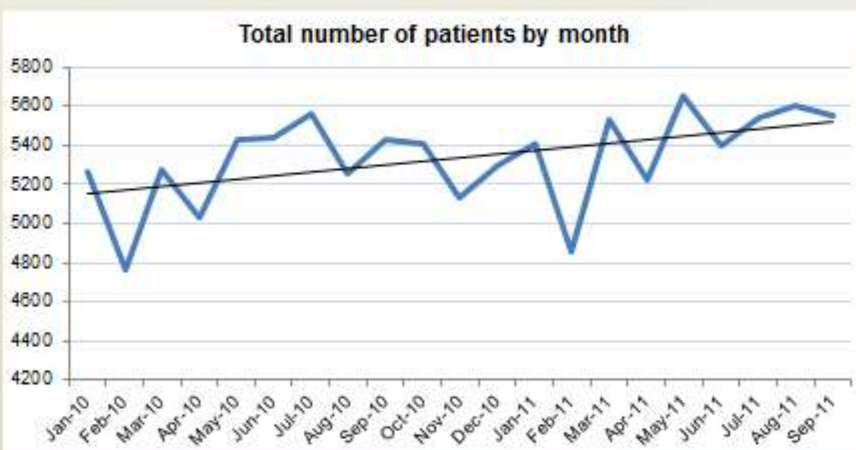
Patient Volume at Saint Vincent



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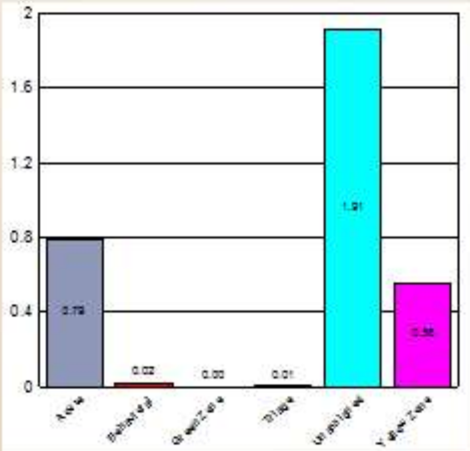
Number of patients LWBS at Saint Vincent



January 2011 – December 2011

- Average 3.08 patients LWBS per day
- 1293 total patients LWBS during year

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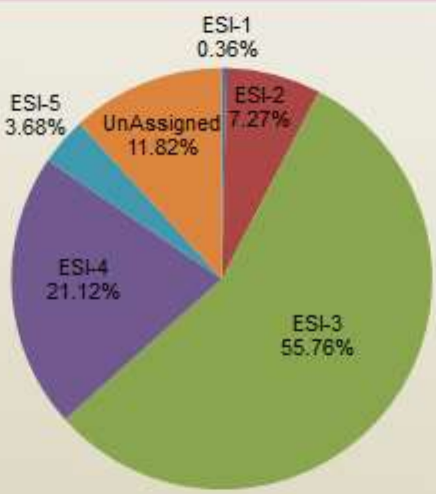
Percentage of patients by acuity level at Saint Vincent



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Additional Metrics: January 2011 – January 2012

Metric	Benchmark	Average times during 2011
Total length of stay	270 minutes	233 minutes
LWBS	113 pt./month	92 pt./month
Door-to-doctor time	30 minutes	41 minutes
Arrival to in bed time	15 minutes	25 minutes

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Split-Flow Concepts

- Quick look instead of traditional triage
- Separation of acuity levels
- Parallel processes
- Movement throughout the system
- Conservation of beds

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WPI Anticipated Split-Flow Improvements

- Low door-to-doctor time
- Low door-to-treatment time
- Decreased total length of stay
- Increased patient satisfaction

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WPI Split-Flow Success Stories

Baptist Medical Center - San Antonio, TX (2010)

- Left without treatment rate decreased 7.3%
- Length of stay decreased from 393 to 120 minutes

*http://go.galegroup.com.ezproxy.wpi.edu/ps/i.do?&id=GALE%7CA218959503&v=2.1&u=mlin_c_worpoly&it=r&p=HRCA&sw=w;

St. Anthony's Hospital – Gig Harbor, WA (2008)

- High patient satisfaction
- Door-to-doctor decreased from 93 to 20 minutes

*http://kpbj.com/feature_articles/2009-10-01/st_anthony_s_split_flow_model_decreases_ed_wait

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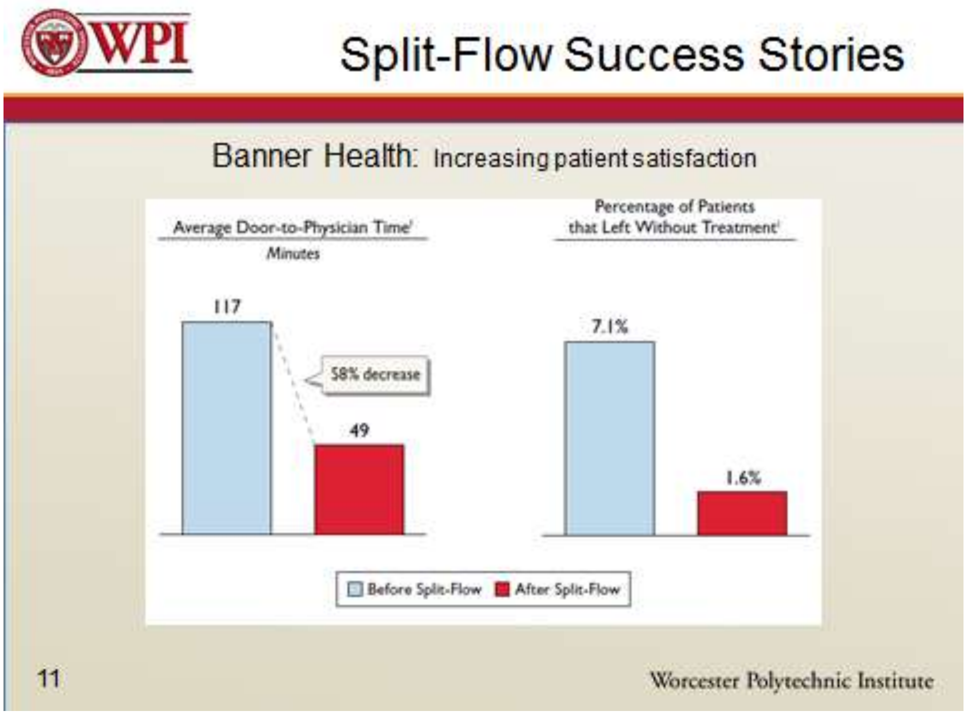
WPI
Split-Flow Success Stories
Banner Health: Increasing patient satisfaction
Average Door-to-Physician Time
Minutes
117
58% decrease
49
Percentage of Patients that Left Without Treatment
7.1%
1.6%
Before Split-Flow
After Split-Flow
11
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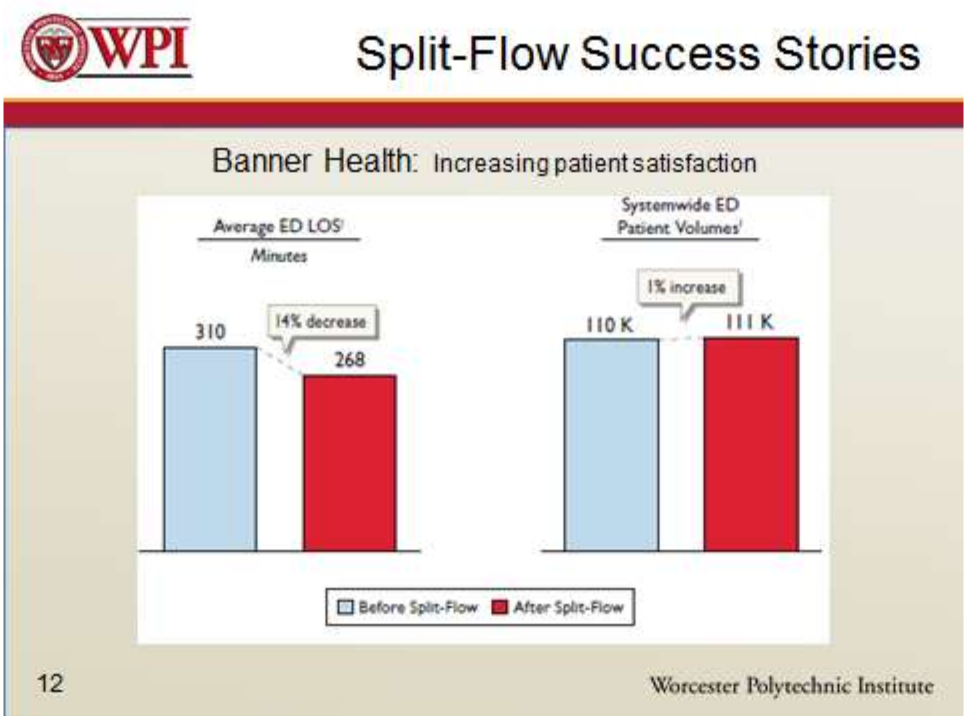
WPI
Split-Flow Success Stories
Banner Health: Increasing patient satisfaction
Average ED LOS
Minutes
310
14% decrease
268
Systemwide ED Patient Volumes
1% increase
110 K
111 K
Before Split-Flow
After Split-Flow
12
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Goal Statement

The project goal is to generate **guidelines for the implementation** of a split-flow process at Saint Vincent and to **analyze the impact** of these changes.

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Proposed Outcomes

- Process maps
- Simulation model for split-flow process
- Evaluation of different configurations
- Suggestions for improvements or changes
- Assessment of staff satisfaction

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Methods

- Data analysis
  - MEDHOST
- Simulation
  - Arena
- Observation

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Simulation is…

Process of **designing and creating computerized model** of a real system for the purpose of conducting **numerical experiments** to better **understand its behavior** under certain conditions

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WPI Simulation at Saint Vincent Hospital

- Input data from MEDHOST
- Allow for evaluation of different configurations
  - Staffing levels
  - Layout changes
  - Patient volumes

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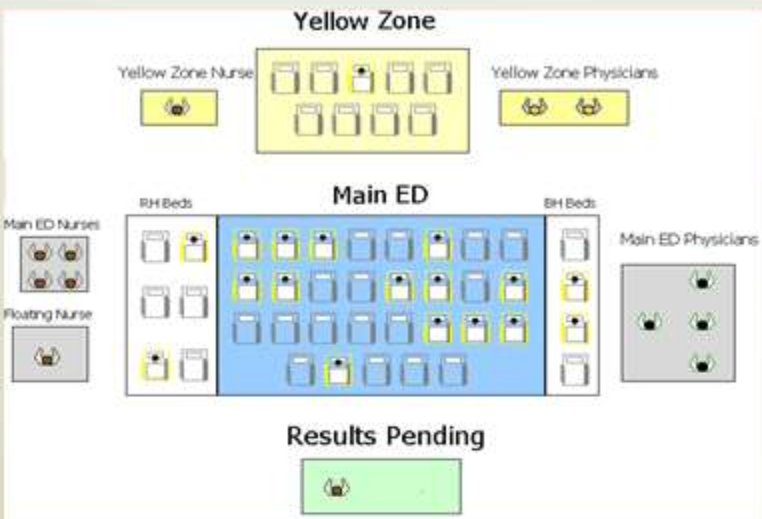
WPI Simulation Model for Split-Flow



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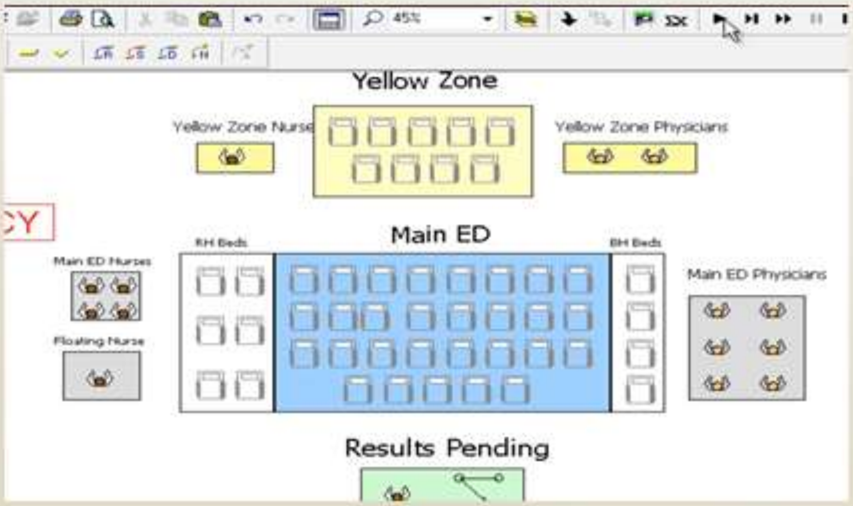
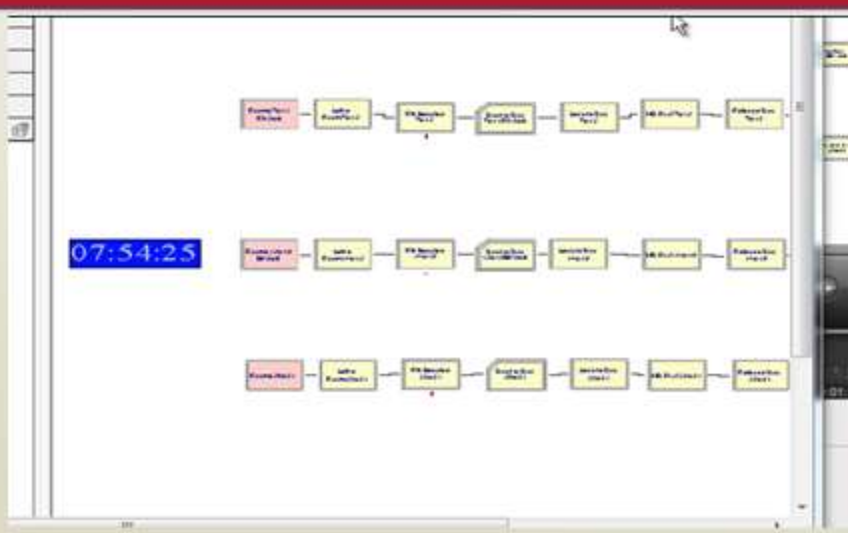
Base Case



Base Case



WPI

Base Model

	Current ED Performance (2010)	Simulated Split-Flow Process (Base Model)
Door-to-doctor (minutes)	64	44.6 ± 0.8
Length-of-stay(minutes)	240	130.6 ± 1.5
Nurse Utilization	Not Available	24% ± 0.01%
Doctor Utilization	Not Available	29% ± 0.01%

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WPI

Scenario Analysis

- Resources available
- Patient volume
- Distribution of ESI levels

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WPI

Resources Available

	Base Split-Flow Model	Add Yellow Zone Doctor	Add Main ED Doctor
Door-to-doctor (minutes)	44.6 ± 0.8	44.5 ± 0.8	44.6 ± 0.1
Length of stay (minutes)	130.6 ± 1.5	107.2 ± 2.9	126.6 ± 1.5
Nurse Utilization	24% ± 0.01%	22% ± 0.01%	19% ± 0.01
Doctor Utilization	29% ± 0.01%	27% ± 0.01%	29% ± 0.01

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WPI

Increase in Patient Volume

	Base Split-Flow Model	Increase Patient Arrivals
Door-to-doctor (minutes)	44.6 ± 0.8	46.5 ± 1.0
Length of stay (minutes)	130.6 ± 1.5	139.5 ± 1.9
Nurse Utilization	24% ± 0.01%	27% ± 0.01
Doctor Utilization	29% ± 0.01%	32% ± 0.01

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ESI Distribution

	Base Split-Flow Model	Shift to ESI 5	Shift to ESI 1
Door-to-doctor (minutes)	44.6 ± 0.8	46.0 ± 0.9	45.7 ± 0.9
Length of stay (minutes)	130.6 ± 1.5	133.5 ± 2.2	133.1 ± 1.8
Nurse Utilization	24% ± 0.01%	25% ± 0.01	24% ± 0.01
Doctor Utilization	29% ± 0.01%	30% ± 0.01	29% ± 0.01

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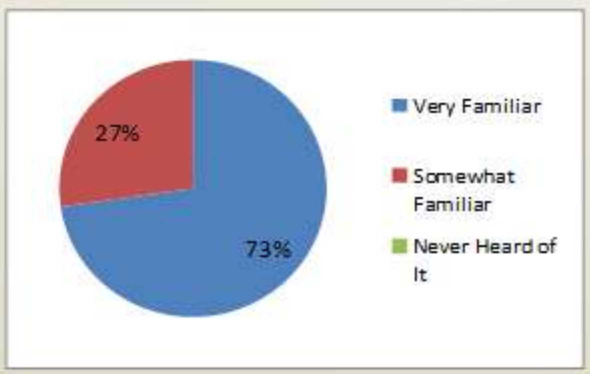
Staff Feedback

How familiar are you with Split-Flow?



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Staff Comments

- "**Quick look does not always work**. Need to find a way to change this due to MD's complaining vitals signs are not in on a timely manner and things are overlooked."
- "**Feels like more is being passed onto the nurse** (triage almost every patient now instead of just ambulance patients) and have to answer phone calls on all patients on team - so now we have to take more time explaining what is going on to another person. Feels **busier** and also feels like **mistakes are easier to make** - not a great feeling on some shifts."
- "The **throughput time** from admission to inpatient unit **needs to be improved** thus decreasing ED wait times (there will be stretchers available). split-flow working well upfront (former triage area)."

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Project Conclusions

- Performance metrics…
  - Improved with the split-flow process
  - Improved with the addition of a yellow zone or main ED doctor
- A 8% increase in patient volume resulted in an increased door-to-doctor time (+ 2 minutes) and an increased total length of stay (+10 minutes)
- Staff feedback

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WPI

Current ED Performance

Metric	Benchmark	Jan. 2011 – Dec. 2011	Jan. 2012
Total length of stay	270 minutes	233 minutes	226 minutes
Door-to-doctor time	30 minutes	41 minutes	27 minutes
Arrival to in bed time	15 minutes	25 minutes	15 minutes
LWBS	113 pt./month	92 pt./month	53 pt./month

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WPI

Recommendations

- Add a doctor to the yellow zone or the main ED
  - This will help ensure satisfactory performance times, even with an increasing patient volume
- Keep track of current split-flow performance and work with staff to continuously improve

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Special Thanks

Jill Lyons, RN, MS, JD
Kimberly Marc
Dianne DesRosiers
Marie Ventimiglia, RN
Cynthia Bresciani, RN, BSN
Doug Scudder, M.D.
Michael Burns, M.D.
Alexandra Weill, M.D.
Kirt Tassmer, Director of Lean
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Final Presentation Poster