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SHS Flexsim Simulation Competition

UW - Madison

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Executive Summary

Susquehanna Health, a four-hospital, not-for-profit health system, has deployed an Emergency Department (ED) Leadership Team to reduce expenses and optimize operations at their flagship hospital, Williamsport Regional Medical Center (WRMC). The Emergency Department has been experiencing pressure from a recently enacted marketing campaign that ensures patients are seen by a provider in 30 minutes or less at two competitor hospitals in the region. This campaign concerns Susquehanna Health because their current average door to provider time is 42.7 minutes with peak times as long as 140 minutes. As a result, 2.8% of their patients are leaving without being seen.

The Susquehanna Health System needs to be competitive in order to face today's healthcare trends of declining reimbursement, increasingly high debt, and greater focus on outpatient services. The Emergency Department Leadership Team reached out to UW-Madison's Industrial & Systems Engineering students to assist them in creating a simulation that will help them improve patient safety, staff productivity, and overall efficiency.

The UW-Madison Industrial & Systems Engineering students developed a discrete-event simulation of WRMC Emergency Department's traditional triage and bed process using FlexSim HC simulation software. Input data consisted of processing time distributions and probabilities supplied from the Emergency Department Leadership Team. To enhance the accuracy of the model, the team also collaborated with physicians at the University of Wisconsin Hospitals and Clinics (UWHC) to gather information on average processing times. Based on best practices in other institutions, simulation models were created to represent the two additional delivery methods: PITT and PITT/Super Fast Track.

After the modeling process was completed the team ran a series of experiments to determine the optimal delivery method and staffing levels. Super Fast Track appeared to be the best delivery system, however the team recommends that this analysis be redone on a more powerful machine. The machine used for modeling was not powerful enough to run the simulation experiments needed for statistical certainty.

The team views this as the first phase of a longer term project. The team will continue to refine the model and run new experiments once a new machine is procured. Collaborators at the UW – Madison, School of Medicine and Public Health, have asked the team to build a second set of models to be used for the UW Health ED.

Current System

Introduction

Emergency Departments (EDs) are often considered the most important areas in medicine. Some of the most intense and critical care happens in EDs across the United States. With the changing landscape of healthcare in America, the ED's role in delivering care efficiently will need to be reexamined, redesigned, and optimized.

Between 1990 and 2005, ED visits increased by approximately 30 million patients, but the number of EDs decreased by about 560 [1]. Prior research has shown that the consequences of ED crowding, which include delayed treatment, patient elopement, prolonged transport, increased mortality and financial losses, affect the entire healthcare system.

To help solve these problems, decision makers within the ED have turned to simulation to forecast demand and test new staffing models. When a real-life test is not a viable option, simulation allows users to modify inputs and analyze outputs with ease, giving a clear, concise view of a model [2].

The not-for-profit health system, Susquehanna Health, is a four-hospital. Recently, they created an Emergency Department (ED) Leadership Team to improve their flagship hospital, Williamsport Regional Medical Center (WRMC). Williamsport Regional Medical Center is a 230-bed hospital that sees an average of 166 patients per day. Each patient stays at the hospital an average of 3.85 days. The ED at WRMC had 45,000 patients in the past year, and 52% of hospital admissions come from the ED. Since the ED is integral to WRMC's operations, it was imperative that the ED Leadership Team reduces expenses and optimizes operations.

To justify the use of a particular care delivery method and optimize staffing levels in the ED, the Leadership Team sought the help of HealthIE, a team comprised of students at the University of Wisconsin-Madison. HealthIE used FlexSim simulation software to model the three proposed delivery methods and determine appropriate staffing levels.

A New Opportunity

The Emergency Department (ED) at WRMC has been experiencing pressure from a recently enacted marketing campaign that ensures patients will be seen by a provider in 30 minutes or less at two competitor hospitals in the region. This campaign concerns Susquehanna Health because their current average door to provider time is 42.7 minutes with peak times as long as 140 minutes. As a result, 2.8% of their patients are dissatisfied and leaving without being seen. According to research, the primary drivers behind patient dissatisfaction are waiting time (67%) and the absence of an effective relationship with medical care teams (19%), which justifies the importance of the marketing campaign. [3]

Recently, a state-of-the-art, 36-bed ED was opened at WRMC. The new ED consists of private rooms, a six-bed fast track section, two cardiac resuscitation rooms, adjacent X-ray and CT scan rooms, and a secured, four-bed behavioral health pod.

Due to declining reimbursements in the current healthcare environment, Susquehana believes it is essential to streamline operations and reduce expenses. Susquehana aims to match the metrics of the top 35th percentile of like-sized hospitals, and, in order to do so, must reach 2.8 worked hours per patient visit and improve door to provider time such that 95% patients are seen by a provider within 20 minutes.

The Leadership Team explored best practices and considered three potential delivery methods: Traditional Triage and Bed, Provider in Triage Team (PITT), and PITT/Super Fast Track. In this report, the team of UW-Madison students, HealthIE, compared simulation outputs for each of the these three delivery systems using FlexSim simulation software. The overall goal of HealthIE is to find the most efficient and effective delivery method and staffing plan for the WRMC ED.

WRMC’s Demographics

Because it is an Emergency Department, WRMC sees a wide range of patients with varying demographics and treatment options [4]. WRMC is located in Williamsport, PA, the birthplace of Little League Baseball and the annual home of the Little League World Series. For approximately two weeks in August every year, teams from around the world compete for the World Series title. With these teams come thousands of spectators, so the hospital must be able to care for and treat any of these individuals should need they ED services.

To account for this mix of patients, WRMC uses the Emergency Severity Index (ESI) to triage patients and prioritize them according to the severity of their condition. Patients range from ESI 5, which is the least severe condition, to ESI 1, the most severe condition [5].

Below is a table with descriptions and examples for each ESI level:

Patients	Description
ESI 1	Patient requires immediate life-saving intervention e.g. patient had a heart attack and arrived via ambulance
ESI 2	Patient is in severe pain, in a high risk situation, or is confused/disoriented e.g. patient shows signs of stroke
ESI 3	Patient requires many resources e.g. patient has lower abdomen pain, nausea, and no appetite
ESI 4	Patient requires few resources e.g. patient can’t hold weight on one leg and might have a broken ankle
ESI 5	Patient requires limited resources e.g. patient seems to have a rash from poison ivy
Mental Health	Patient is dealing with psychological issues and could potentially hurt oneself or others e.g. patient is having a mental health crysis

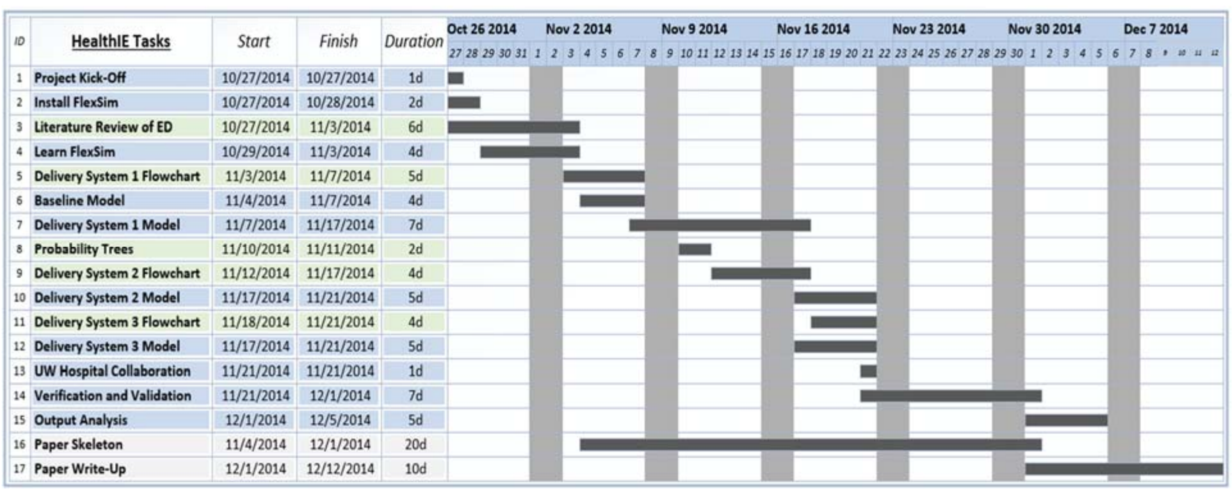
Modeling Approach

The UW-Madison Industrial & Systems Engineering team, HealthIE, devised a systematic approach to satisfy the Emergency Department (ED) Leadership Team's goal and measures for this project. HealthIE formed a strategic internal infrastructure, which consisted of process modelers and simulation modelers. The two-group formation reflected a real-life scenario in which simulation experts consult professionals involved in the process to learn how the system operates. In addition, this framework also allowed the groups to double-check each other's work so the models could be continuously improved.

At the start of the project, both modeling groups created a plan to tackle the problem statement provided by the ED Leadership Team. **HealthIE aimed to determine the most efficient and effective delivery model by producing process maps, building a representative FlexSim simulation model, and comparing alternatives.** To finish the project by the deadline, HealthIE created a Gantt chart to benchmark major milestones. Process modelers generated accurate process maps to represent the alternative delivery models for each ESI patient level by using the case study information and conducting ED literature reviews. At the same time, the simulation modelers brought these process maps to life through simulation. After both groups completed their tasks, HealthIE then validated the accuracy of the simulation model. Lastly, the simulation group optimized the model based off FlexSim's output analysis tools. The primary metrics HealthIE used to measure resource optimization and patient satisfaction were average patient length of stay and door to provider time [6].

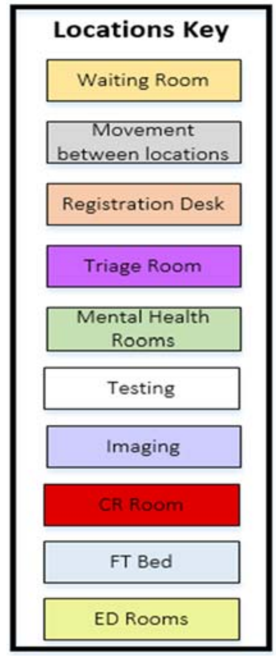
Timeline

For project planning, HealthIE used the Gantt chart seen below to keep them on task. Simulation modeling milestones are denoted in blue, process modeling milestones are denoted in green, and gray milestones represent assignments relevant for both groups.



ID	HealthIE Tasks	Start	Finish	Duration
1	Project Kick-Off	10/27/2014	10/27/2014	1d
2	Install FlexSim	10/27/2014	10/28/2014	2d
3	Literature Review of ED	10/27/2014	11/3/2014	6d
4	Learn FlexSim	10/29/2014	11/3/2014	4d
5	Delivery System 1 Flowchart	11/3/2014	11/7/2014	5d
6	Baseline Model	11/4/2014	11/7/2014	4d
7	Delivery System 1 Model	11/7/2014	11/17/2014	7d
8	Probability Trees	11/10/2014	11/11/2014	2d
9	Delivery System 2 Flowchart	11/12/2014	11/17/2014	4d
10	Delivery System 2 Model	11/17/2014	11/21/2014	5d
11	Delivery System 3 Flowchart	11/18/2014	11/21/2014	4d
12	Delivery System 3 Model	11/17/2014	11/21/2014	5d
13	UW Hospital Collaboration	11/21/2014	11/21/2014	1d
14	Verification and Validation	11/21/2014	12/1/2014	7d
15	Output Analysis	12/1/2014	12/5/2014	5d
16	Paper Skeleton	11/4/2014	12/1/2014	20d
17	Paper Write-Up	12/1/2014	12/12/2014	10d

Processes



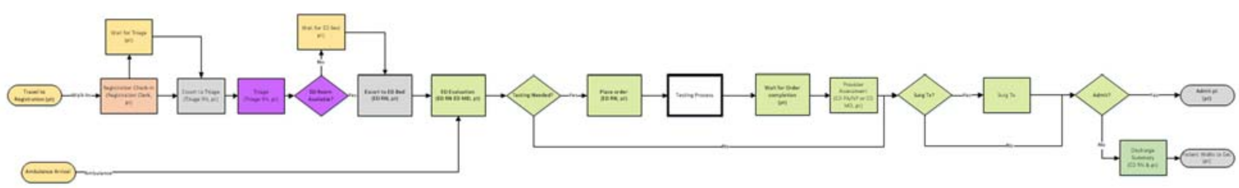
When analyzing potential process changes at the WRMC Emergency Department (ED), HealthIE considered three different ED delivery methods: Traditional Triage, Provider In Triage Team (PITT), and Super Fast Track (FT)/PITT. Using the color-coding system shown in the key on the right, flowcharts were created to represent the patient's path through the ED for each of the delivery methods. The following sections highlight the differences in patient flow between delivery methods.

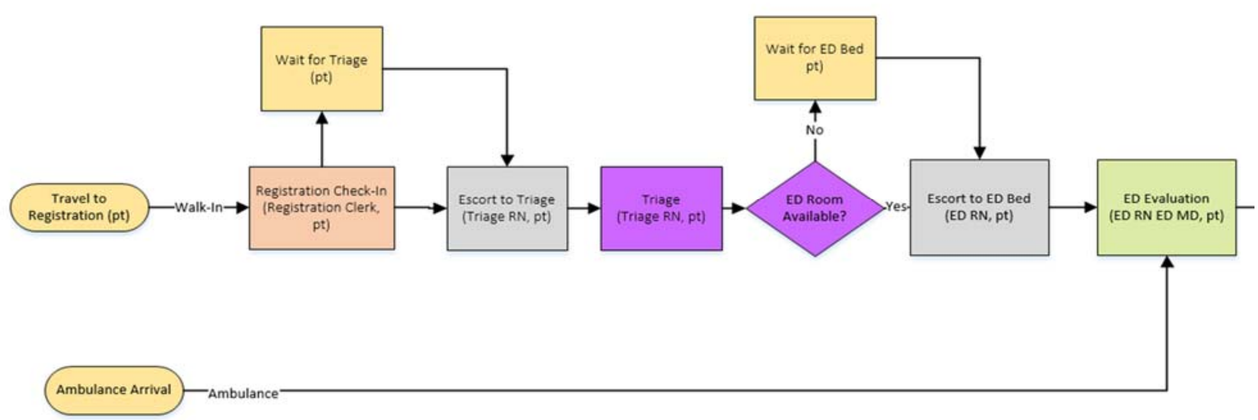
Alternatives Considered

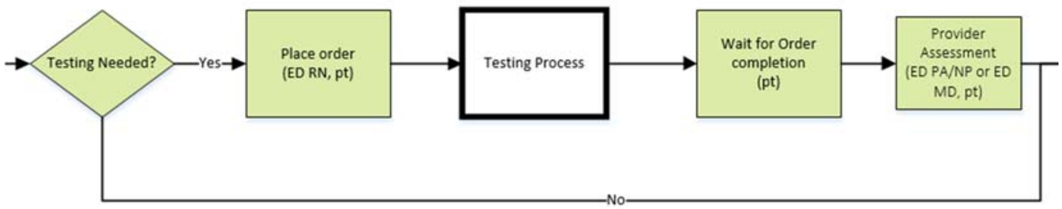
Baseline: Traditional Triage and Bed

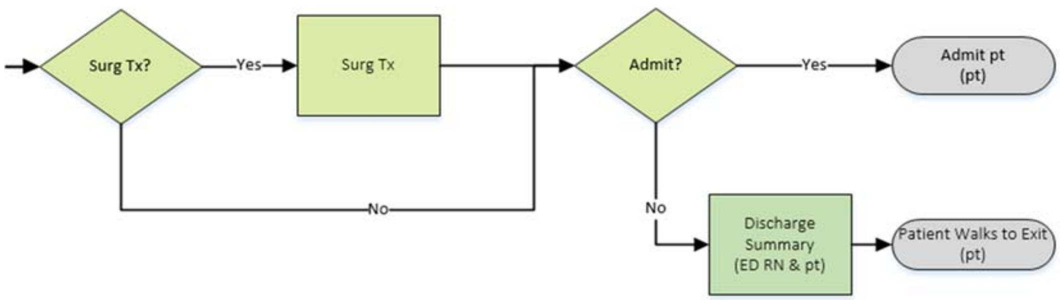
The traditional triage and bed process for an ESI 3 patient and other high acuity patients such as ESI 1 and ESI 2 is represented below. However, it's important to note that ESI 1 and ESI 2 are not triaged like ESI 3.

Traditional Process (ESI 3)



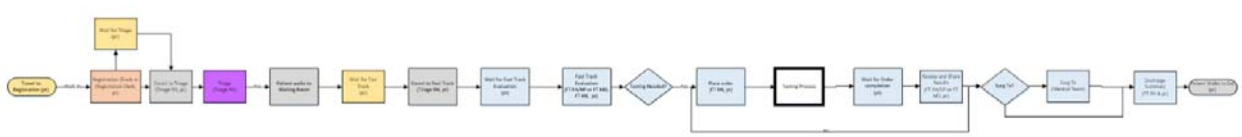


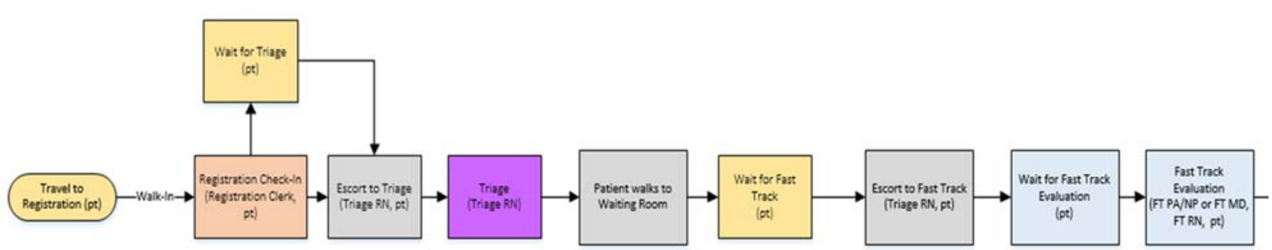


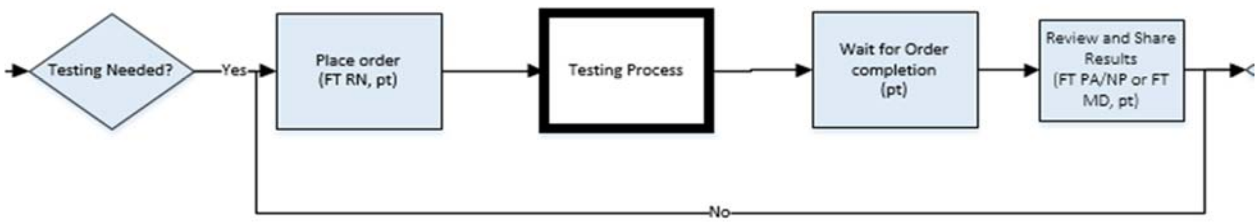


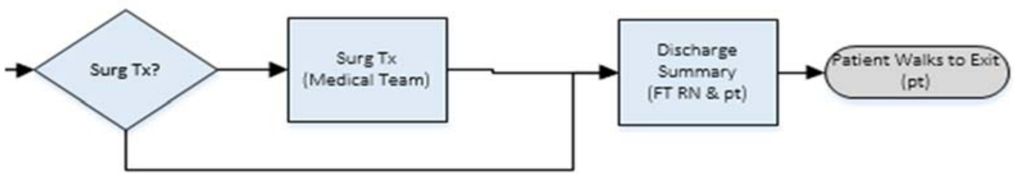
For low-acuity patients, the ED process is similar. To take advantage of differing provider scopes of practice (PA, CNP, and MD), the traditional triage delivery method sends ESI 4 and ESI 5 patients to fast track beds. During the fast track process, a patient has an RN evaluation followed by a PA or CNP evaluation, which expedites the care of patients with less severe conditions.

Traditional Process (ESI 4)



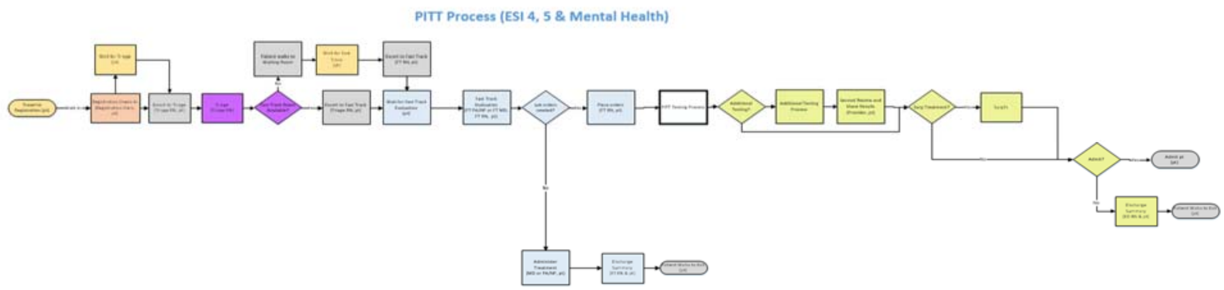


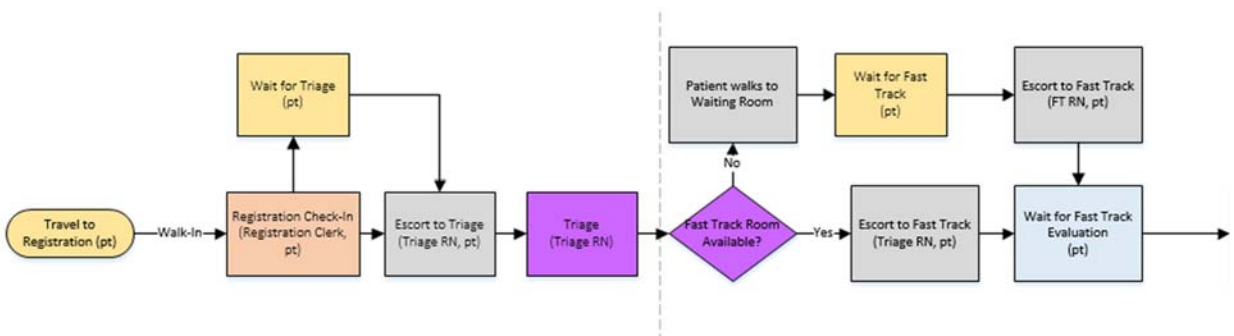

Testing Needed?
Yes
Place order
(FT RN, pt)
Testing Process
Wait for Order
completion
(pt)
Review and Share
Results
(FT PA/NP or FT
MD, pt)
No

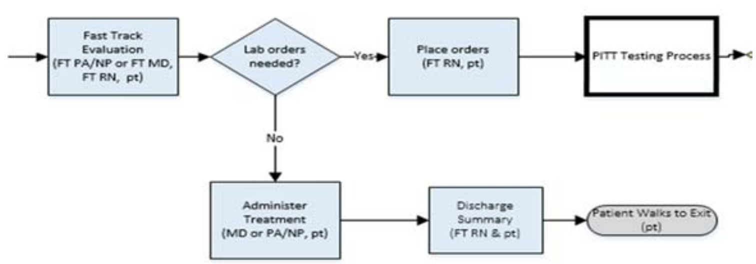

Surg Tx?
Surg Tx
(Medical Team)
Discharge
Summary
(FT RN & pt)
Patient Walks to Exit
(pt)

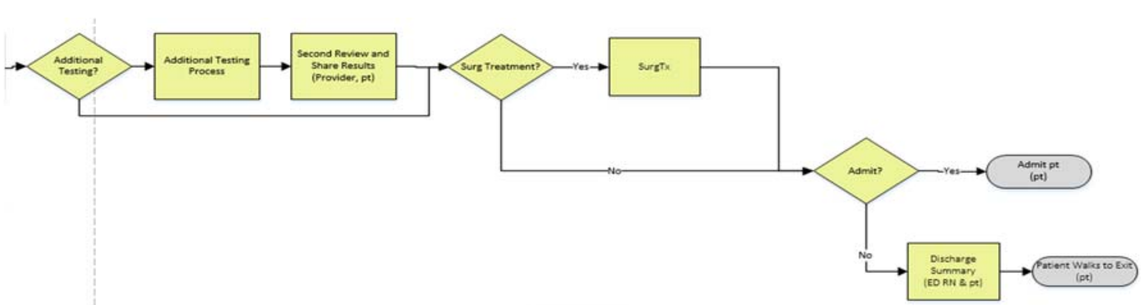
PITT

Provider in Triage Team (PITT) is a delivery method where a PA evaluation takes place before ESI 3, 4, and 5 patients are roomed. After being evaluated, patients' lab samples are taken immediately and the patients are escorted to a bed to undergo any other necessary testing. For ESI levels 1 and 2, however, nothing changes.



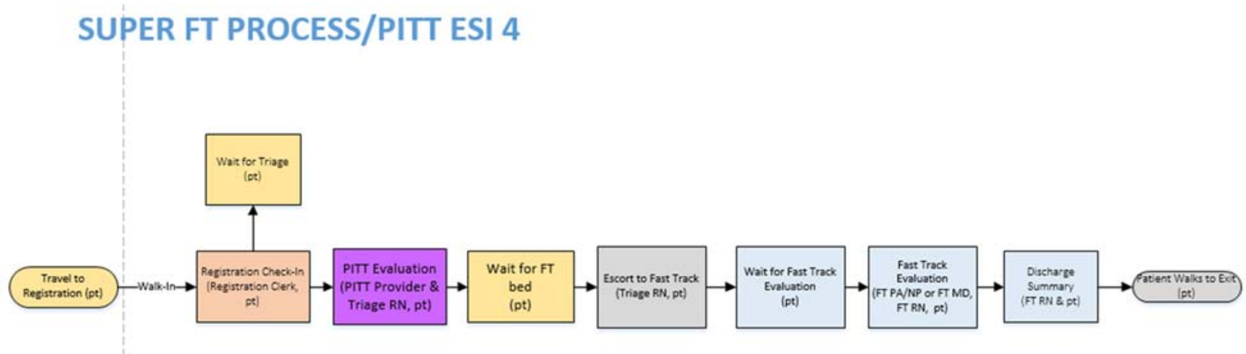


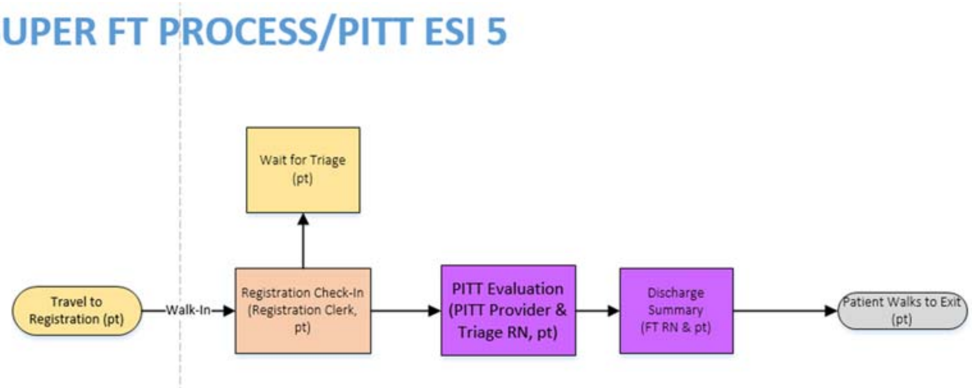




Super FT/PITT

For this delivery method, super fast track and PITT are combined. Patient entry is identical to the PITT process, but there are slight differences following the triage evaluation. ESI 5 patients are treated and discharged immediately while ESI 4 patients are moved to fast track beds and cared for by the PITT provider from their initial assessment. All higher acuity patients move to ED beds just as they did in the PITT delivery method.





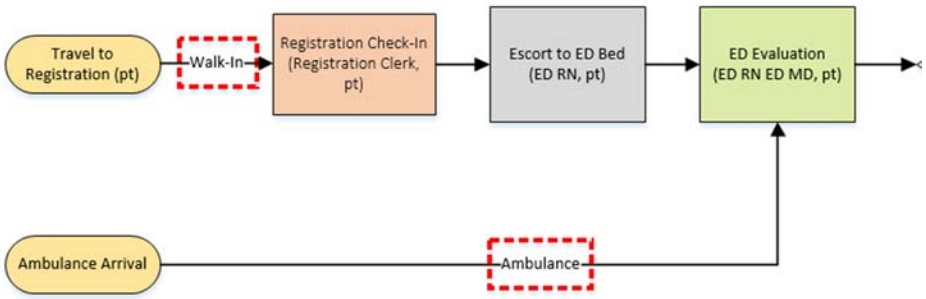
Process Mapping

After HealthIE made flowcharts for each delivery method, they reached out to their UW Health contacts to get feedback to make revisions. Dr. Patterson, University of Wisconsin-Madison School of Medicine and Public Health faculty member and Emergency Department researcher, offered detailed insight into the ED processes under consideration. By networking with experts in the field, HealthIE was able to ensure the flow of patients through the ED was accurate for all delivery methods.

Once finalized, the flowcharts consisted of five key processes: arrival, triage, rooming, testing and analysis. These five processes are shown in the ESI 3 flowchart below.

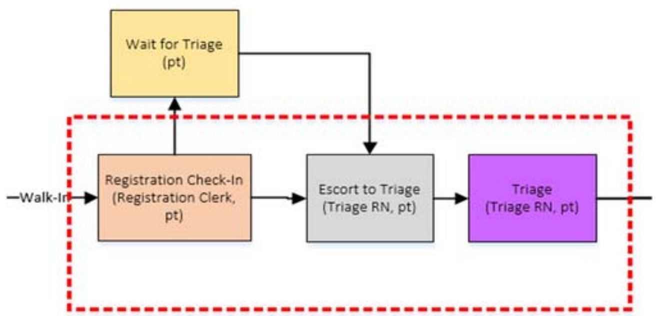
Arrival Subprocess

Patients can arrive via ambulance or walk-in, and both entryways are included in the model.



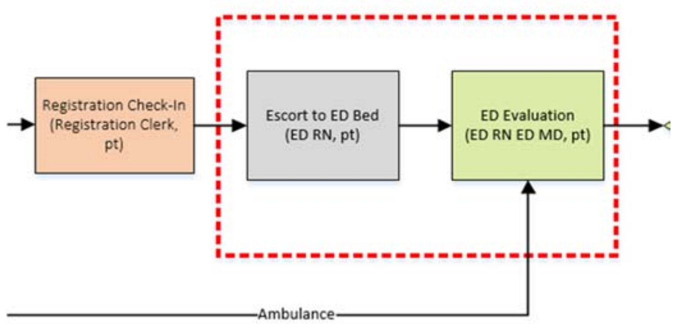
Triage Subprocess

In the triage subprocess, ED staff assigns an appropriate ESI level to the patient. A Triage RN conducts an initial assessment, which includes recording the patient's history, current medications, and vitals.



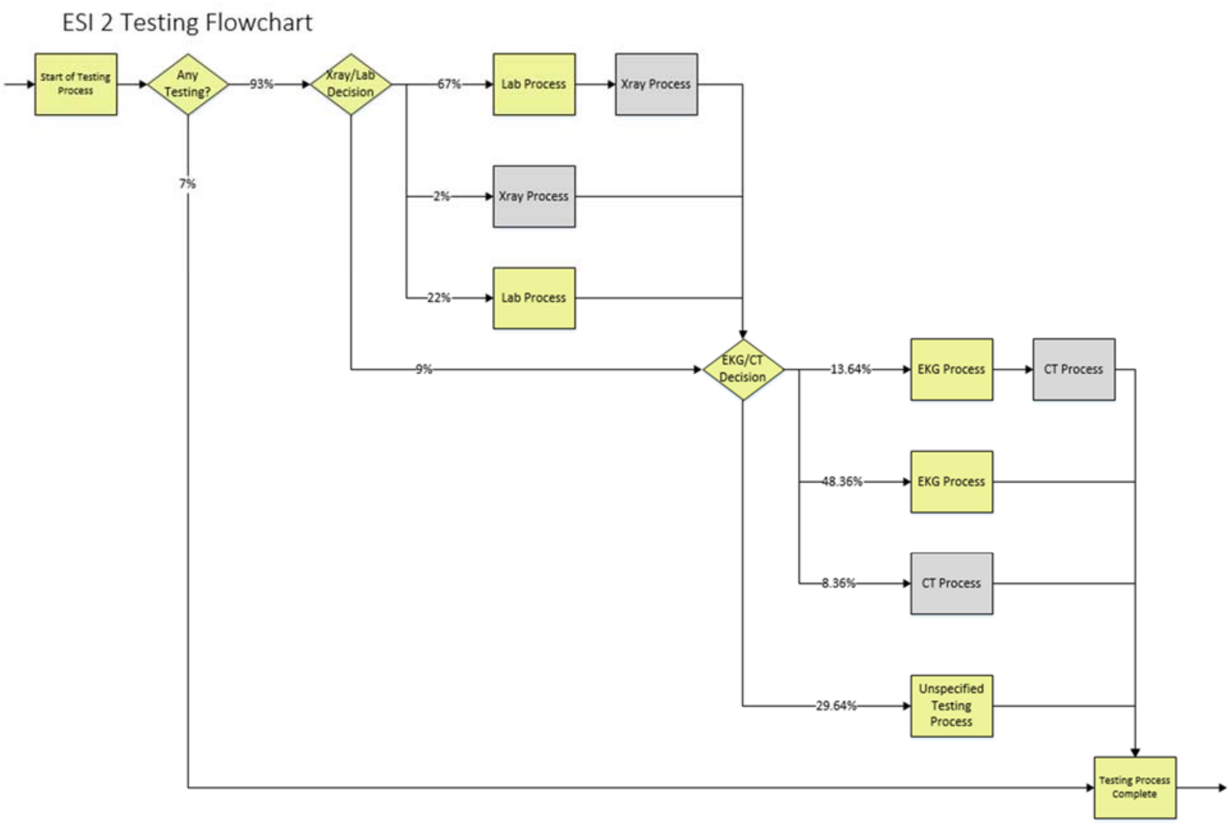
Rooming Subprocess

The rooming subprocess has the patient taken to an ED or FT bed depending on their acuity. By rooming patients according to their ESI level, patients can be seen by an appropriate provider more quickly and effectively.



Testing and Analysis Subprocess

For the patient “testing” process, there are many different pathways. First, there’s a decision node to determine whether or not patient require any testing. If patients need testing, they can go through any combination of the following procedures: labs, X-ray, EKG, and CT scan. The probability a patient undergoes a certain testing procedure differs for each ESI level based on the case study information provided. After a testing procedure is performed, lab specimens and images are analyzed while the patient proceeds to the next testing process. The testing pathways for ESI 2 patients are shown below.



Model Building

"All models are wrong, but some are useful"
G. Box

Scope

When modeling the system, the team aimed to include all essential details so that the model reflected reality as close as possible. Given such a limited timeframe to construct the model, however, HealthIE often needed to decide what aspects of the Emergency Department (ED) were most important to include. In the end, the team's primary goal was to create a useful model that could help support ED decision-making.

HealthIE's two-group structure helped achieve this goal. As each group worked through their models, they independently identified processes and characteristics they felt were relevant to the problem. Any discrepancies between the models were then discussed before coming to a consensus about what ultimately made it into the final simulation model. By leveraging this team dynamic, HealthIE was able to prioritize which factors to include and create a model that captured the most vital features of an ED.

Assumptions

As HealthIE crosschecked their models, numerous assumptions were made regarding the case. Since all team members had prior experience in a healthcare setting, they made conscious efforts to model this ED's processes as closely as possible to an actual ED. The team also consulted Dr. Patterson, an ED physician at UWHC, to understand the ED from a provider perspective, and Lou Keller from FlexSim, who aided HealthIE when specific simulation questions arose.

A summary list of the project's assumptions is listed below. For the full list of assumptions, please see the Appendix.

Arrivals

"No two days of the week look the same … [and] no two time periods look alike."
-Lou

Ambulance Arrivals

Patients arriving via ambulance are assigned top priority and are treated by a specialized ED physician and RN until their condition stabilizes.

Charting
Computers are assumed to be present in every patient room so the staff and providers can instantly access medical records, test results, and patient statuses, which represent industry best practices [6].

CR Room
The Cardiac Resuscitation room is reserved for ESI 1 patients for the entirety of their visit since it is outfitted with specialized equipment that will be needed during their treatment process.

Delivery Methods
PITT
In the PITT delivery method, patient flow only changes for ESI 3, 4, and 5 walk-in arrivals. These patients are evaluated in two parallel triage rooms by 2 RNs and one PA, and lab samples are taken immediately after the evaluation.

Super Fast Track/PITT
For the third delivery method, ESI 4 and 5 arrivals are the only patients whose experiences differ from PITT. The primary change in these patient flows is the removal of unnecessary testing procedures.

Escorting
When patients are escorted, wheelchairs are used and are always immediately available to the transportation staff. Although the use of wheelchairs is not depicted in the simulation model, it is assumed that this has no effect on the model's outputs.

Equipment
There are sufficient amounts of portable equipment and tools at the ED to provide treatment without creating a bottleneck.

Expiration
ESI 1 patients are the only arrivals who are expected to die from their conditions, and this occurs after the full treatment process.

Lab
The ED's lab is outfitted with a sufficient number of machines so analysis can occur in parallel for all samples with only one technician present.

Locations
When staff and providers are idle they return to their nurse stations and resident areas to complete work indirectly related to patient care.

Imaging
X-ray and CT Scan machines are operated by separate technicians. These images are read by off-site radiologists who are not included in the model.

Medical Decision Making

Based on the information provided in the case study, it's assumed that the X-ray and lab processes are dependent and occur first and that the EKG and CT Scan processes are independent and occur second. All other tests and decisions are assumed to be independent.

Mental Health

Following any testing procedures, mental health patients begin their one-hour observation period while the tests are analyzed. Physicians share test results once the observation period has ended.

Metrics

To allow comparison of delivery methods, "Door to Provider" time is assumed to be when the patient first sees a provider, even if it is a triage provider. If this were not the case, ESI 5 patients would not have a provider milestone and accurate comparisons therefore could not be made between delivery methods.

Process Flow

Medication and Surgical Treatment occur at the end of the process. All other patient flow assumptions are made based on HealthIE's knowledge of ED operations.

Staffing

Process assignment is modeled to represent realistic ED responsibilities. An employee can be substituted for another only if they are able to be substituted for all of the other employee's tasks.

FlexSim

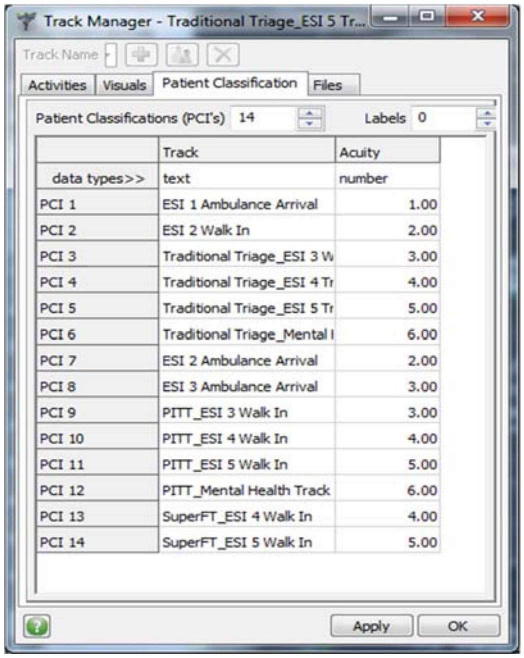
To implement the model, HealthIE used FlexSim simulation software. FlexSim is a state-of-the-art program that allows users to visualize the simulation by depicting the model in 3D space. The main advantage of using FlexSim is that it closely mimics a real-world simulation by incorporating a facility's floor plan to make accurate walking time estimates.

Patients

Within the simulation, HealthIE used different colors to represent patients for each ESI level so that the patients could be tracked more easily as they flowed through the ED. Below are pictures for each patient type.

Patient Type	Picture	Patient Type	Picture
ESI 1		**ESI 4**	
ESI 2		**ESI 5**	
ESI 3		**Mental Health**	

HealthIE then used ESI levels and delivery methods to assign arrivals to different patient tracks. Outputs based on ESI levels were recorded according to the patient's "Acuity", and delivery methods were made distinguishable using "Track" descriptions. Below is a list of all tracks and associated acuity values.



	Track	Acuity
data types>>	text	number
PCI 1	ESI 1 Ambulance Arrival	1.00
PCI 2	ESI 2 Walk In	2.00
PCI 3	Traditional Triage_ESI 3 W	3.00
PCI 4	Traditional Triage_ESI 4 Tr	4.00
PCI 5	Traditional Triage_ESI 5 Tr	5.00
PCI 6	Traditional Triage_Mental I	6.00
PCI 7	ESI 2 Ambulance Arrival	2.00
PCI 8	ESI 3 Ambulance Arrival	3.00
PCI 9	PITT_ESI 3 Walk In	3.00
PCI 10	PITT_ESI 4 Walk In	4.00
PCI 11	PITT_ESI 5 Walk In	5.00
PCI 12	PITT_Mental Health Track	6.00
PCI 13	SuperFT_ESI 4 Walk In	4.00
PCI 14	SuperFT_ESI 5 Walk In	5.00

WRMC Staff

Once patients arrive at the ED, they are cared for by a variety of staff and providers. Since some patient care tasks could be performed by several different employees, HealthIE created employee groups to indicate which workers were interchangeable. Employees were assigned to specific groups only if they could perform all tasks required of that group. Costs associated with employee wages were then used as a secondary consideration to prioritize employees for certain tasks. The tables below show a breakdown of the primary employee groups.

FT Care Group	FT Medical Group
RN	CNP
PA	PA
CNP	

ED Care Group	ED Medical Group
RN	MD

Triage Care Group	Triage Provider Group
RN	PA

X-ray Transport Group	CT Scan Transport Group	Morgue Transport Group
PCT	PCT	PCT
X-ray technician	CT technician	

Tasks were divided up among these employee groups based on the information from the case study and what made the most sense according to HealthIE's healthcare background. The table below shows task assignment for the Traditional Triage and PITT delivery methods.

	Triage	Room Patient	FT Eval.	ED Eval.	Lab Draw	EKG Process	Review Results	Med Tx	Surg Tx	Discharge Process	Admit Process	PITT Vitals	PITT Eval
FT Care		X			X					X	X		
FT Med			X				X		X				
ED Care		X			X	X		X		X	X		
ED Med				X			X		X				
Triage Care	X											X	
Triage Provider													X

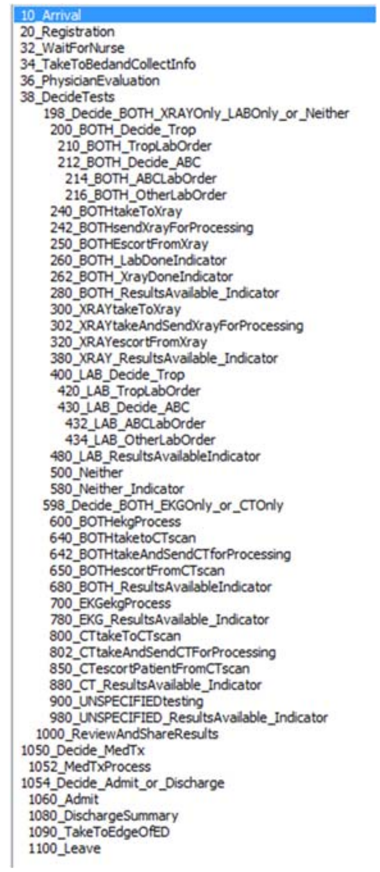
	Reception	Take X-ray	Take CT Scan	Move to X-ray	Move to CT Scan	Move to Morgue
Receptionist	X					
X-ray Tech		X				
CT Tech			X			
X-ray Transport				X		
CT Scan Transport					X	
Morgue Transport						X

Simulation Model

After assigning tasks to each employee group, HealthIE then began building out the FlexSim model with increasing complexity in each iteration. Since the flowcharts were a collaborative effort that combined the team's healthcare experience with the information from the case study, these documents provided a detailed roadmap for the development of the simulation.

The simulation group started with the simplest ED operations and added granularity into the model as they progressed. ESI 5 patient flows were the first to be modeled because these patients had the fewest possible tests and additional procedures. This approach allowed the simulation team to identify and address areas where their understanding of the software was lacking and resolve any issues before modeling the flow of higher acuity patients or alternate delivery methods. When finalized, the model contained patient tracks for all ESI levels, patient arrival types, and healthcare delivery methods.

Throughout the simulation process, HealthIE attempted to create as much built-in consistency and flexibility within the model as possible. To maintain visual consistency, for example, the team used the same color-coding in both the flowcharts and the simulation.



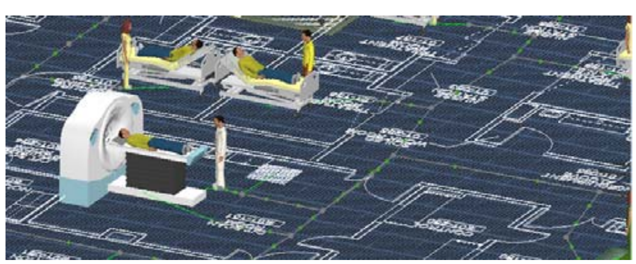
Likewise, in the model's logic, a standardized numbering convention was used for patient tracks, which enabled the team to easily compare patient flow for different ESI levels and delivery methods. This convention helped when debugging the model and also provided room to include additional processes if needed.

For future flexibility, the team incorporated variables for all processing times, which could be used to quickly make changes to every patient track. Although these features do not affect the model outputs, they were critical for comprehending and developing the simulation at a rapid pace.

Building off this structure, the team was able to add a fair amount of realism into the simulation. One of the primary strengths of the simulation model is that several processes can occur in parallel. Rather than having patients wait until individual test results came back before allowing them to proceed to the next test, the simulation team used conditional statements and separate item processing objects to allow patients to go through additional testing procedures while their labs and images were analyzed.

This feature, along with the logical assumptions the team made based on their knowledge of healthcare operations, resulted in a model that was more akin to reality and therefore more reliable when the team eventually drew conclusions.

Unfortunately, elements that were less essential for making conclusions were often not included. Procedures like patients being escorted by wheelchair or lab samples being physically deposited into a pneumatic tube were not modeled due to the scope of the project. Visually, these additions would have been appealing, but they are relatively unimportant for analyzing processing times and therefore were not included. Although the simulation team was not able to incorporate the level of detail they would have liked, the model still contains the fundamental components of an ED and provides a reasonably accurate representation of patient treatment processes despite a relatively short timeframe.



Implementation

Input Analysis

Arrivals

The case study provided a great deal of information about the arrival of patients to the Williamsport Regional Medical Center (WRMC) Emergency Department (ED), which meant most of the critical analysis had already been completed for the arrival distributions. This information was presented as total patient arrival rates for every hour of every day, ESI classification distributions broken up into 12 segments for each day, and percent arrival by ambulance.

Time	*Sunday*	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*
0000--0059	3.9(2.6)	2.8(1.5)	2.7(1.9)	4.1(1.5)	1.9(0.5)	2.4(1.7)	3.7(1.7)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2200—2259	5.2(2.3)	6.0(2.9)	3.8(1.7)	6.2(0.5)	5.7(2.2)	7.6(1.8)	6.9(1.8)
2300—2359	3.9(1.5)	2.4(1.3)	4.6(1.0)	2.4(2.1)	4.1(2.1)	4.6(1.0)	3.0(1.6)

Time	*ESI -1*	*ESI-2*	*ESI-3*	*ESI-4*	*ESI-5*
0000---0159	0.3%	12.2%	53.3%	31.1%	3.1%
⋮	⋮	⋮	⋮	⋮	⋮
2200—2359	0.1%	11.6%	47.2%	37.3%	3.8%

	ESI -1	*ESI-2*	*ESI-3*	*ESI-4*	*ESI-5*
Arrive By Ambulance	100%	32%	32%	32%	32%

In order to get the distributions into a format usable for FlexSim, the team wrote a program in Python to build .csv files for both walk-in and ambulance arrival doors. The program took in two files, one for arrival rates and the other for ESI distribution, and returned two .csv files with four columns:

- Start Time
- End Time
- Distribution of Total Arrivals
- Distribution of PCI

Each .csv file had 168 rows, one for every hour of the week, and could be imported directly into FlexSim.

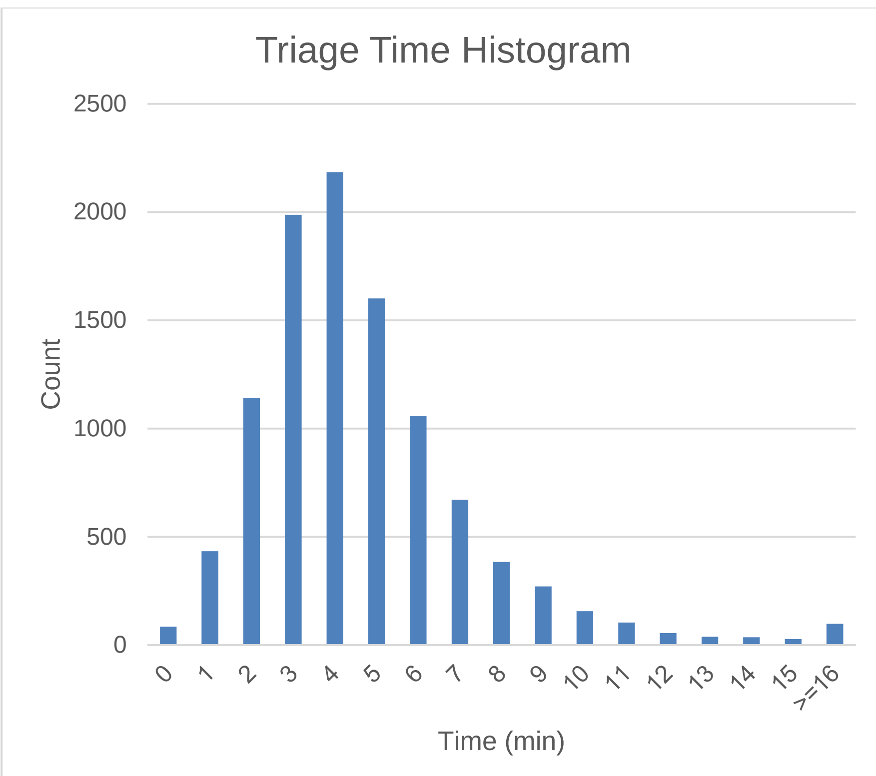
Processing Times

Inputs for processing times were based on a combination of the information provided by the case study and also data from the UW – Madison Emergency Medicine Department (UW-EMD).

If a processing time distribution was specified by the case study, it was used to model the process within the simulation. However, there were also some instances where the team wished to model sub-processes that were not mentioned in the case study, such as *discharge conversation time*. In these cases, the team worked with the UW-EMD to collect and analyze data or asked for expert opinions on processing times.

Note: The team made a mistake and forgot that the "triage time" was specified by the case study. The team decided to go with this data since they had collected it and analyzed it.

One example of this is the *triage time*. The team pulled a large set of data from the UW-EMD's operational database and was able to collect summary statistics and make histograms on the time it takes to from the start to the end of the triage process.



Statistic	*Value*
n	10329
Mean	4.72
S. Deviation	2.87

From these histograms and summary statistics the team sought to fit best distribution possible. For example the distribution fitted to Triage Time was N ~ (4.72, 2.87). The team has several other examples of their input analysis, however those were not included in this report owing to the fact that the team did not have enough time to get some of the data approved before it could be published.

The team initially sought to do more sophisticated input distribution fitting, however restraints placed on the data due to privacy issues and time pressure did not allow for a full-scale input data analysis. In the future, HealthIE hopes they will be able to dig deeper into the UW-EMD operational database and draw more descriptive input distributions.

Verification and Validation

When building the model, the team repeatedly performed cycles of verification. After a patient track for an ESI level or delivery method was completed, the simulation group would verify that the model was performing as intended and correct any issues they observed. If instances of inaccurate patient flow or treatment were noted, the simulation team was careful to fix these problems before continuing with the simulation. By making small improvements in each iteration, the team was able to ensure that the model was functioning properly at every point in the project.

In addition to debugging the model, the team also checked that their work was valid. Again, this was an area where the team's two-group structure proved invaluable. Using knowledge of real-world ED operations and input from Dr. Patterson, HealthIE inspected their process maps to determine if they were realistic. Any differences between the models and an actual ED were discussed and addressed, which helped further refine the simulation. Since all team members had a different healthcare background, these individual assessments resulted in a simulation that converged on something close to real life. As a final step in the validation process, the simulation outputs were also compared to facility performance data, which can be found in the following section.

Finding the Baseline

Since the case study provided the team with a great deal of information about WRMC's current ED operations, the given metrics were used to find a valid baseline for the model. Using the assumption that the ED currently employs the traditional triage delivery method, HealthIE used an experiment to approximate the current ED staffing levels.

Because this experiment involved altering staffing levels for several different employees, the team used an approach known as factorial experimental design that will be discussed in length in the **System Optimization** section.

During the experimental process, the team recorded the average LOS, the average LOS for each ESI level, and average Time to Provider (TTP) for each experimental setup. Once all the experiments were conducted, the experimental setup that yielded the closest results to the given average LOS, ESI LOSs, and TTP was chosen as the baseline.

	Triage RN	*Triage PA*	*Fast Track RN*	*Fast Track RN*	*ED RN*	*ED MD*	*PCT*
Traditional Baseline Staffing	1	NA	1	1	3	3	7

Output Analysis

Note on Experimental Setup

All experiments were conducted over a simulated two-week timeframe. HealthIE felt it was important to collect output data while the ED was in steady state, so the team had the simulation run for a week before collecting data to allow time for the system to "warm up". Following the warm-up period, outputs were then measured during the second week in the simuation.

Caveat Reader

A major caveat must be addressed before the discussing the team's output analysis. The computer the team used for modeling was decrepit and underpowered. For the task of building the models, this did not prove to be a major issue, however, when it came time to run experiments, the computer was unable to handle experiments with more than two replications. Because of this limitation, a great deal of the teams output work relies on experiments with runs that have two replications. HealthIE feels that while this is good preliminary work, the data is not strong enough evidence to conclusively prove that any one method is vastly superior to another. As such, HealthIE feels this data should primarily be used as a guide.

HealthIE is currently working on procuring a more powerful machine. If given the opportunity to present at the SHS conference, the team will present data collected from experiments with far more than two replications.

Dashboard

The team built a simple dashboard to display experimental results. The dashboard had four main areas of concentration:

- Throughput
- Utilization
- Census
- Process Improvement

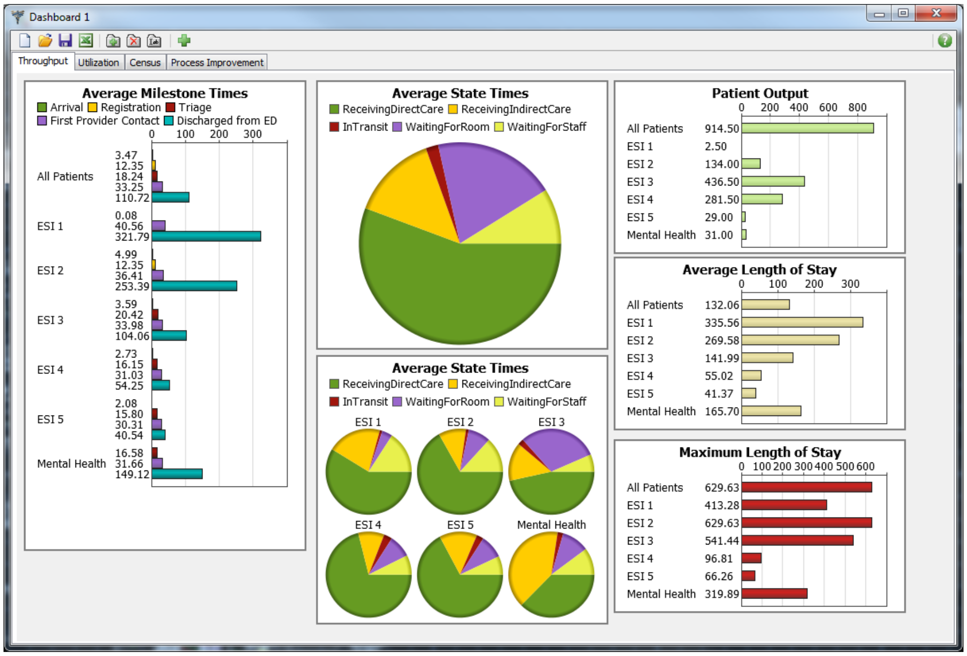
The dashboard was used to track the key performance indicators of Average LOS and Time To Provider. Created using the graphs that FlexSim provided, the dashboard represents charts that a clinic manager will use on a day-to-day basis.

In addition to being useful for data collection, these dashboard tabs proved to be critically important in helping the team find bugs in the model. The dashboard tabs are shown in detail below.

Note: The dashboard displays below do not correlate to any particular experimental setup.

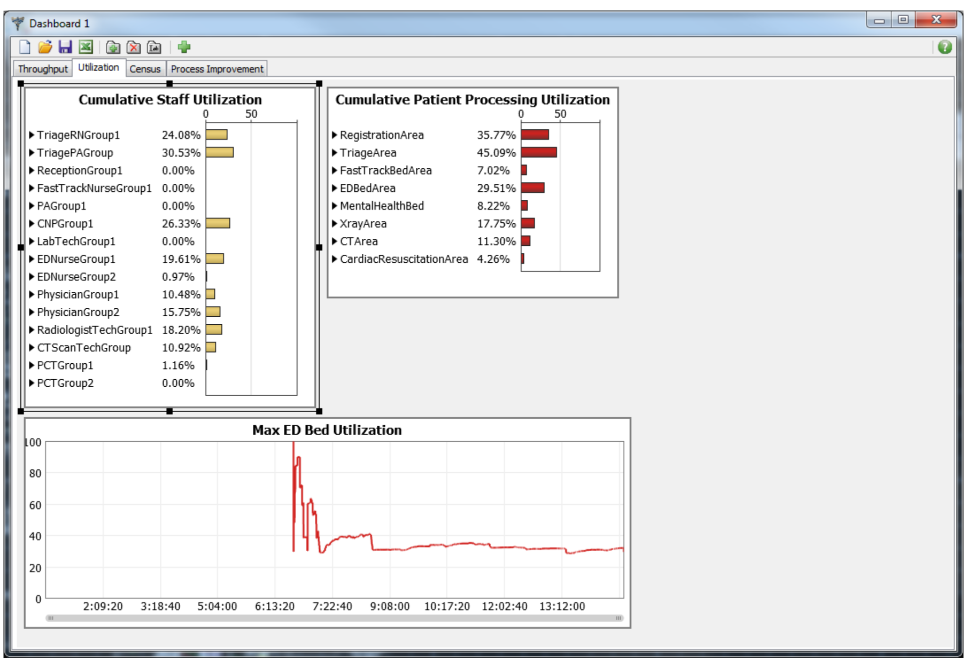
Throughput

The throughput tab shows the performance of the ED in terms of how quickly patients are being seen and put through the system. In addition to having information about each ESI level's average LOS and TTP, this tab also provides information on the average amount of time each type of patient spends in a given state.



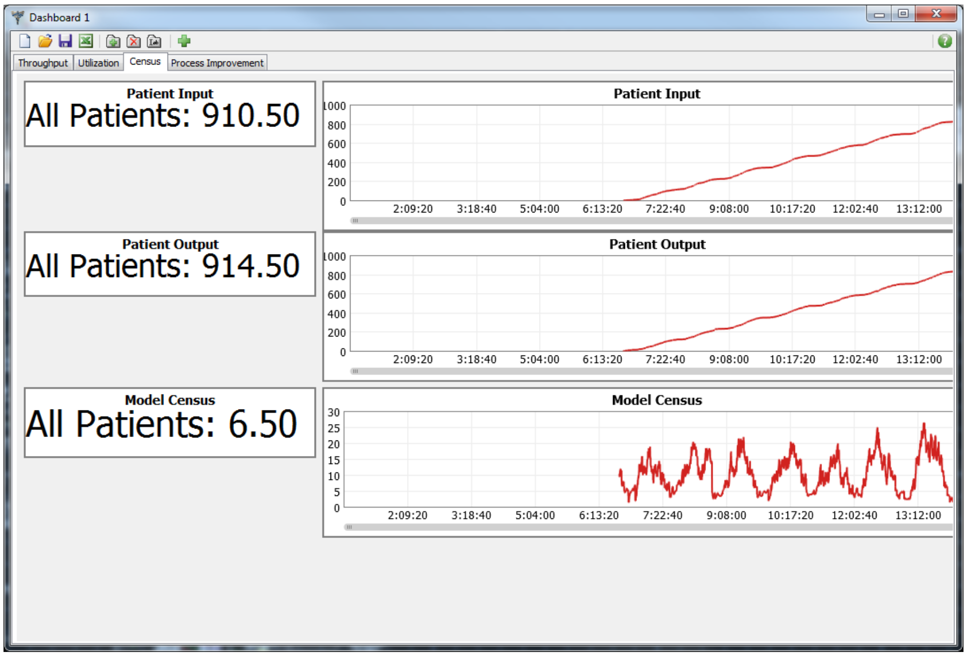
Utilization

The utilization tab provides the users with instantaneous information about ED bed utilization and average utilization of staff and processing areas.



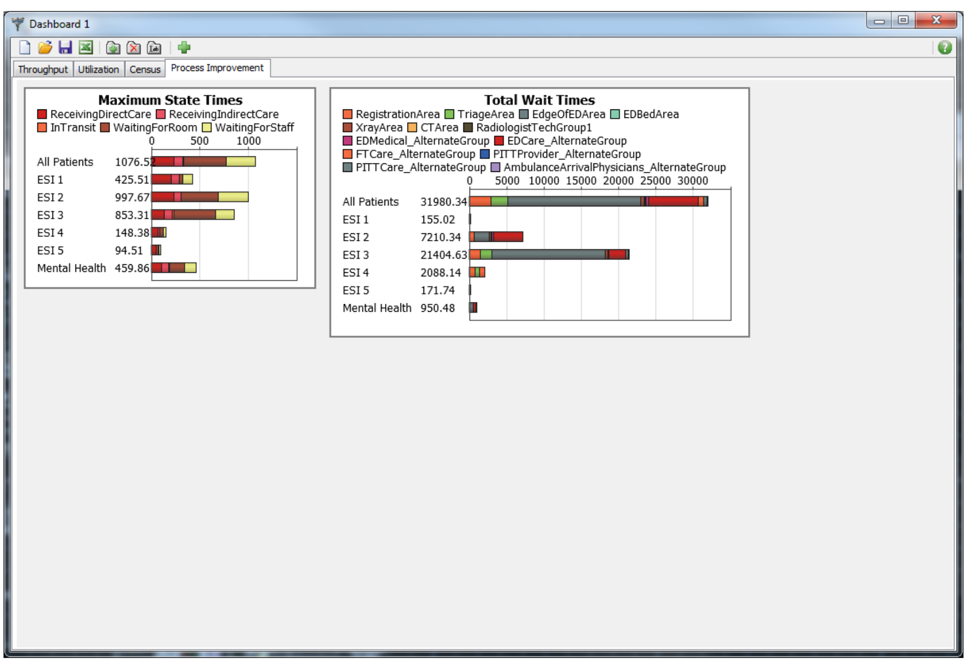
Census

The census tab is a graphical display of the current ED census, its trends over time, and the total number of patients the ED cares for.



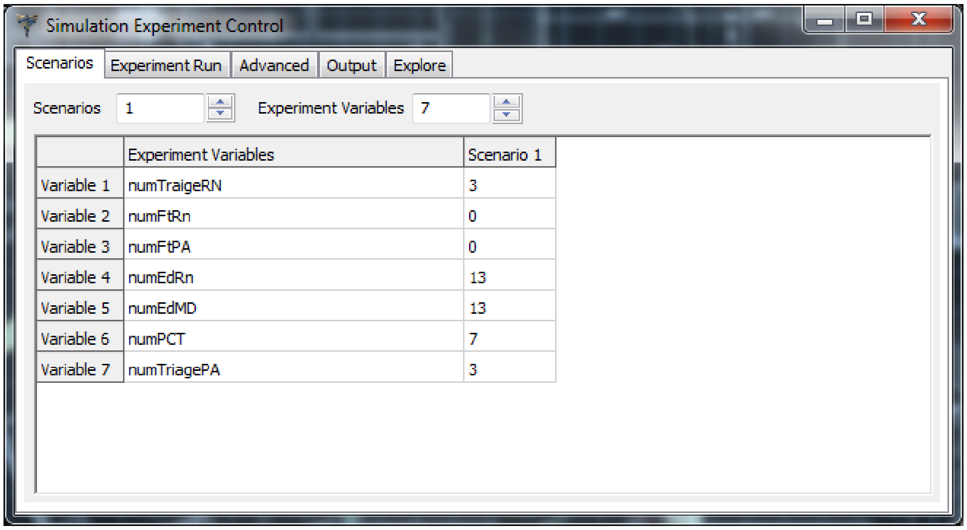
Process Improvement

Although the process improvement tab has yet to be refined, it can be used to identify areas for improvement within the ED.



Parameters

The main control variables the team had at its disposal were the staffing levels of various care providers. In order to simplify experimentation, the team decided not to vary the "back-of-the-house" providers and staff and instead kept them set at a constant level. This simplification meant there were a total of 7 different provider staffing levels HealthIE could adjust.



For ease of control, HealthIE used the FlexSim's Experiment Control module to adjust staffing level variables.

System Optimization

To choose the optimal delivery method, HealthIE used an approach borrowed from linear programming. In linear programming, an objective is determined, a set of constraints is identified, and a number of variables are adjusted. The approach HealthIE used is shown below.

Objective:

- Minimize average LOS

Constraints:

- Minimum staffing requirements

Setting variables:

- Choice of delivery method
- Range of staffing levels

Ideally, HealthIE would have liked to find the best staffing level for each shift of the day, but they ran into time constraints and had to approach the experimentation in the most efficient manner possible.

Note: Given the assumption that ED arrival rates cannot be the same for different periods of time, it was important that the team model an entire weeklong duration of the ED.

Experimental Set Up

For the optimization process, HealthIE designed a sequential experiment. First, the best delivery method was found using baseline staffing levels. Following this determination, HealthIE then optimized ED staffing levels for this delivery method.

It's important to note that HealthIE did not vary the delivery method or staffing levels over the course of the simulated week. These additional complexities were not possible due to the computer's limited capabilities and the project's overall time constraints. Once HealthIE has a new computer, a greater variety of delivery method and staffing level combinations will be considered.

Best Delivery System

The approach HealthIE used to find the best delivery method was rudimentary. After the team found the best staffing level for the traditional triage delivery method, they then tested this staffing level with the Provider in Triage Team (PITT) and Super Fast Track (SFT) delivery methods.

The delivery method that yielded the lowest average LOS, Super Fast Track, was chosen as the preferred delivery method.

Best Staffing Model

With the optimal delivery method determined, the team then considered the best staffing level. The staffing level experimentation was quite similar to the method used to determine the baseline staffing level of the traditional delivery method. A factorial design experiment was used to find the best levels of staffing.

Before designing the factorial matrix, a quick sanity check was done to find reasonable staffing combinations. Minimum staffing levels were calculated using projected patient arrivals and the guidelines of patient to provider ratios provided by the case study requirements.

	Critical RN	FT RN	PCT
Bare-minimum (meet requirements 50% of time)	2	1	2
Aggressive-minimum (meet requirements >95% of time)	5	2	7

Using these values, HealthIE then designed a sequential factorial experiment to find the best staffing for the SFT delivery method.

The delivery system was broken into two sections that were treated as if they were practically independent in order to reduce the number of runs that were needed. With 5 factors* each with 3 or more staffing levels, the experiment would've required 5^3 runs if it were not simplified.

Maximum levels were found through discussion with the UW – Emergency Medicine Department.

*Note: *For SFT, the Fast Track PA group was merged with the Triage PA group, and the Fast Track RN group was merged with the Triage RN group.*

Triage Optimization

For the simplified experiment, the team designed a smaller experimental matrix using 2 variables with 3 different staffing levels. HealthIE then dropped combinations if they thought the scenarios were dominated by a run that was already chosen. One example of this was when the number of Triage PAs was greater than the number of Triage RNs.

Throughout the Triage Optimization experiment, all ED staffing levels were set at their midpoints.

	tRN	*tPA*	*edRN*	*edMD*	*PCT*
sft_1	2	2	11	7	8
sft_2	3	2	11	7	8
*sft_3**	3	3	11	7	8
sft_4	4	3	11	7	8
sft_5	4	4	11	7	8
sft_6	3	2	11	7	8
sft_7	3	3	11	7	8
sft_8	4	2	11	7	8

sft_9	4	3	11	7	8
sft_10	4	4	11	7	8
sft_11	5	3	11	7	8
sft_12	5	4	11	7	8
sft_13	5	5	11	7	8

ED Optimization

Once triage staffing had been optimized, HealthIE then experimented with ED bed staffing. In a similar modified factorial matrix, the team considered scenarios of logical ED RN and ED MD staffing level combinations.

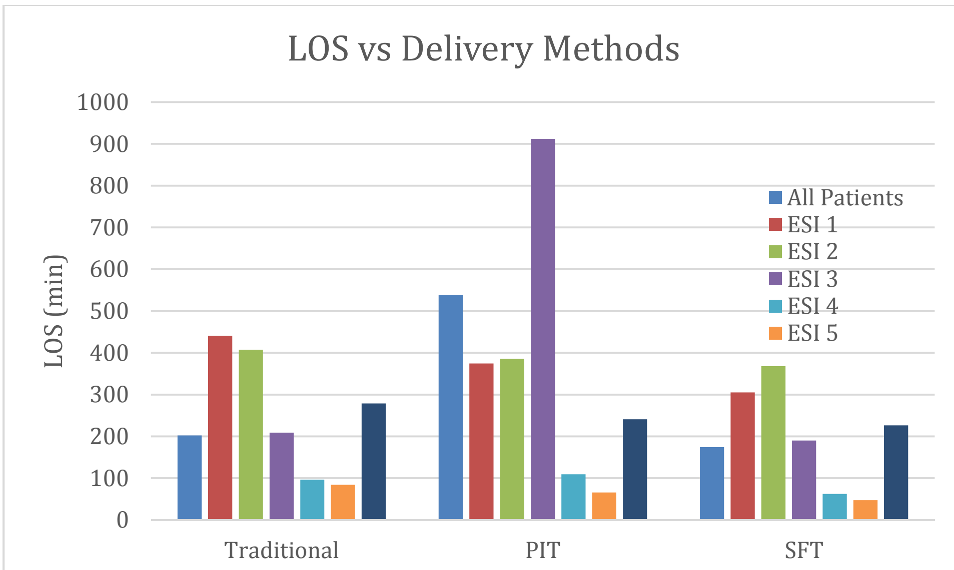
	tRN	*tPA*	*edRN*	*edMD*	*PCT*
e_1	opt tRN	opt tPA	4	4	8
e_2	opt tRN	opt tPA	7	4	8
e_3	opt tRN	opt tPA	7	7	8
e_4	opt tRN	opt tPA	11	4	8
e_5	opt tRN	opt tPA	11	7	8
e_6	opt tRN	opt tPA	11	11	8
e_7	opt tRN	opt tPA	14	7	8
e_8	opt tRN	opt tPA	14	11	8
e_9	opt tRN	opt tPA	14	14	8

Results & Recommendations

Results

Based on the experimentation and output analysis, HealthIE was able to develop some very preliminary results about the best delivery method and the optimal staffing level associated with it. It should be noted, however, that these results are from a limited number of replications and probably have little to no statistical significance. Although the results are reasonable, HealthIE would have preferred to run a much higher number of replications on a more powerful machine before they would publish the results with confidence.

Delivery Methods

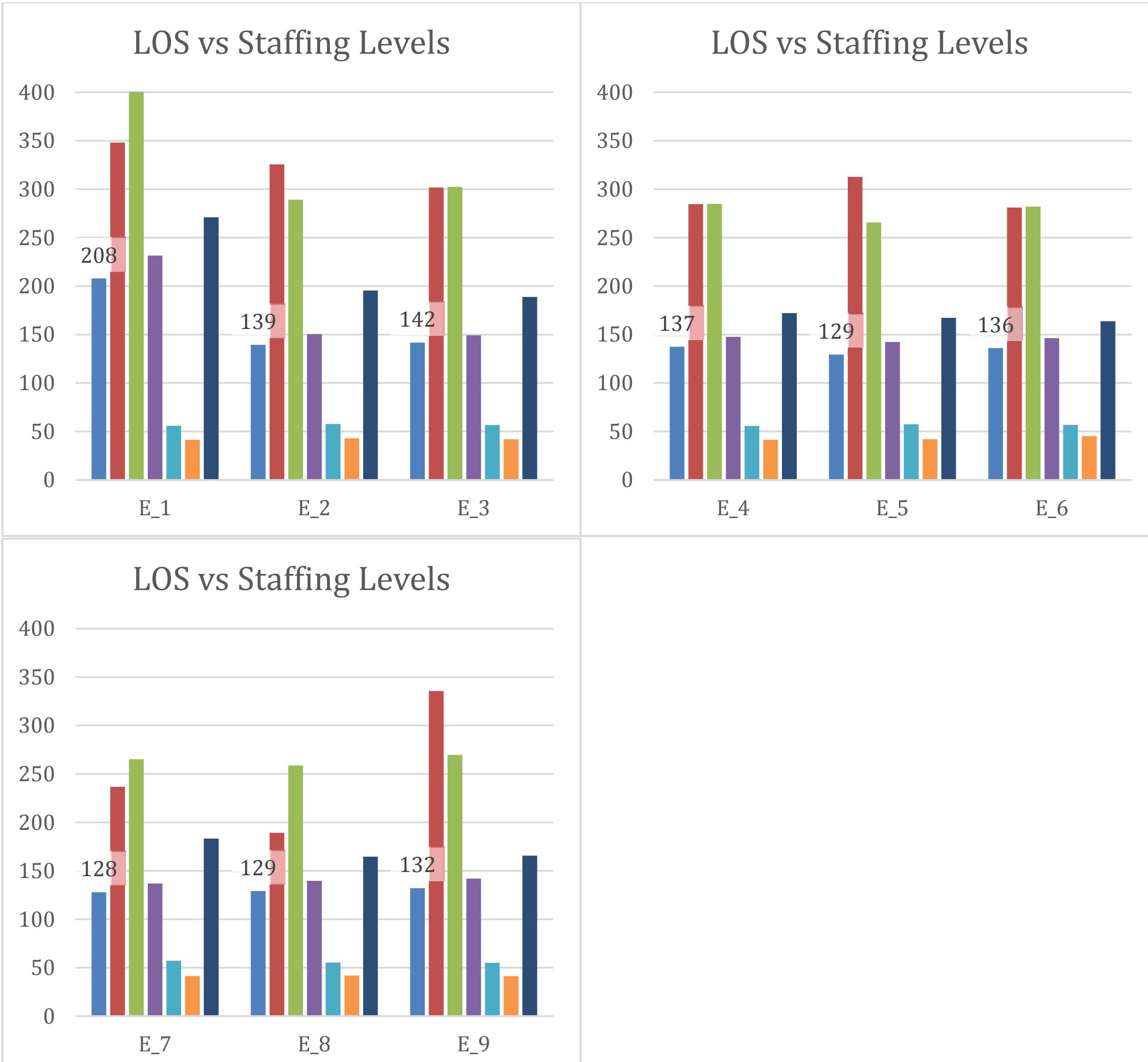


LOS performance of each delivery system with the baseline staffing.

Note: SFT appears to be dominant on both other methods.

Staffing Levels

LOS performance of various staffing levels of the optimal delivery system.



LOS performance of various staffing levels of the optimal delivery system.

By analyzing these graphs and other data HealthIE was able to come up with preliminary results for an optimal delivery method and staffing level combination. The graphs above show that the Super Fast Track is the best delivery method and that the optimal staff would be three triage RNs, three triage PAs, eleven or more ED RNs, seven or more ED MDs, and eight PCTs.

	tRN	*tPA*	*edRN*	*edMD*	*PCT*
optimal	3	3	11+	7+	8

It is important to note that these are only preliminary results. HealthIE is currently trying to find a new machine to run their models on. Once the team has procured a more powerful machine, they will redo their experiments to confirm whether or not this staffing model is significantly better than the others in terms of average LOS. HealthIE also is currently working on a program that will automatically extract the results from FlexSim output files and compute which setup is optimal in terms of LOS, TTP, and costs.

With the additional time, the team will also work to ensure that the staffing model makes sense from a financial standpoint. There is a great deal of work that needs to be done in order to verify that this staffing model yields the best results financially.

Finally, during the course of these additional analyses, the team also plans to evaluate the staffing model from an efficiency standpoint and make sure that the selected model meets the target efficiency metrics.

Recommendations

In writing recommendations, the team realizes that there are number of factors that affect staffing beyond what can be accounted for in our model. The team also realizes that the experimentation work being done on the model is only just the beginning and that it is not statistically prudent to commit to delivery system and staffing model with so little data. With these limitations acknowledged, however, HealthIE believes the Super Fast Track delivery model will yield the most benefit when the analysis is redone on a more powerful machine in the future.

Super Fast Track appears to be the best delivery system, and HealthIE believes that this is the route Susquehanna Health should take. However before the team makes a firm recommendation they would like to redo the experiments with more replications on a more powerful machine. The machine used for modeling was not powerful enough to run the simulation experiments needed for statistical certainty.

The team anticipates views this as the first phase of a longer term project. The team will continue to refine the model and run new experiments once a new machine is procured. Additionally, collaborators at the UW – Madison, School of Medicine and Public Health, have asked the team to build a second version of the models of the WRMC ED to be used for the UW Health ED.

Project Discussion

Lessons Learned

HealthIE learned a number of valuable lessons regarding timing and data validity during this project that they can use to improve their future work.

In order to meet the project deadline, HealthIE learned the importance of dividing large projects and trusting group members. To help better estimate time commitments, HealthIE realized they should have incorporated time into their Gantt chart to resolve mistakes in the simulation model. Since modeling is an iterative process, including time to refine the model would have helped make the project more manageable. In addition, HealthIE learned that spending more time learning the full extent of FlexSim's functionality would have been beneficial to identify pitfalls earlier on. HealthIE also realized the importance in finding a computer that has the capability of running all FlexSim functionality. During output analysis, the computer HealthIE was using had difficulty running experiments efficiently. Although HealthIE was able to coordinate their work fairly well overall, these improvements would have helped further streamline the process.

Besides determining how to structure their time most effectively, HealthIE also learned that careful consideration should be used when making assumptions. In general, HealthIE found that simulating a real-world ED would have been more beneficial than attempting to piece together broken strands of data. Because of the insufficient input data, the number of assumptions that were required increased dramatically, which made validation more difficult to perform. When completed, a model should accurately reflect a real-life simulation, so collecting raw data might have made it easier to troubleshoot problems and make progress in the simulation model. This project helped HealthIE realize the importance of working with ED doctors who are involved in the process every day to ultimately decide what assumptions to include in the model.

Limitations

As with any project, there are several limitations worth noting. The most significant limitation in this project was that the team was unable to physically collect data on the process they were modeling. When simulating a system, it's crucial to have an in-depth understanding of its operations. With just a case study to work from, however, it was not possible to watch processes occur at the ED or record procedure times. This limitation prevented HealthIE from verifying the reliability of the data or addressing inconsistencies in the provided information, which negatively affected the simulation's validity. In future work, the team would make it a priority to visit the ED being simulated to avoid these deficiencies.

Additionally, as mentioned earlier, not all characteristics of the ED were captured in the simulation model. Given the complexity of ED operations, it would have been impossible to include every detail, so processes had to be prioritized based on their potential to affect output metrics and alter conclusions. For this reason, processes like providers physically going to a computer to check results and patients leaving without being seen were not modeled. While the exclusion of these aspects does have some effect on the simulation's primary output metrics, the impact is relatively insignificant compared to that of the processes HealthIE did model. With an extended timeframe, however, these characteristics would have been included.

Another limitation is that the Medication Treatment (MedTx) process requires an RN present for an unrealistic amount of time. Although this decision was based on information provided in the case study, the team does not think it is representative of real-world ED operations, which makes it, seem like higher levels of RN staffing are required when that likely is not the case. To address this shortcoming, the simulation team would divide the MedTx procedure into two separate processes so an RN is only present for a much smaller portion of the total MedTx time. Once again, this is a scenario where the team would want to check the accuracy of this assumption by observing the ED in person. With this change, though, the team believes the time required for a nurse to perform the MedTx process would be far more reasonable.

The hospital admission process is similarly impractical. Currently, patients are immediately admitted under the assumption that inpatient beds are always available. In reality, this wouldn't be the case because patients usually have to wait for an inpatient bed to open up. This limitation means the simulated ED can actually care for a greater number of patients because admitted patients never "block" an ED room. One way to resolve this problem would be to have the patients wait a certain amount of time after the decision has been made to admit them, which would make the simulation's output metrics more accurate.

For the PITT delivery method, one limitation is that the additional testing decision does not consider what tests have already occurred or how the patient's health state might have changed during their visit. Without this information, the time required to perform additional testing procedures cannot be accurately adjusted, which adds uncertainty into the model. If data could have been collected from the ED, the team would have included probabilities related to differential diagnosis and changes in health states. Since this data was not available, however, the additional testing process is not as realistic as it could be.

Finally, because of inadequate processing power on the computer HealthIE used to run the simulation, robust experimentation was not possible. Although the primary objectives of determining the best delivery method and staffing levels were met, HealthIE was not able to test additional changes within the simulation model. Considerations like "What would happen if two FT beds were replaced by two triage stations?" are scenarios HealthIE would have considered with a more powerful machine, but wasn't able to test due to the limited capabilities of the computer they used. Provided more time, the team would install the software on a different machine so these experiments could be conducted.

Future Work

Beyond addressing the model's limitations, the team also intends to expand upon their work in a number of ways.

Using what was learned during this project, the team plans to work with their contacts at the UWHC to model the medical center's existing ED. Since the UWHC ED is located just a few miles from the University of Wisconsin - Madison campus, the team will have direct access to the data and resources needed to accurately model its operations. Once completed, the team will be able to analyze a variety of "What if" scenarios within the simulation model and provide evidence-based improvement recommendations. Based off HealthIE's ability to utilize FlexSim in the case study, stakeholders at the UWHC ED believe the simulation will offer a tremendous amount of value and have pledged their support for the team's future efforts.

Following the creation of the UWHC ED model, the team also intends to build a generic model that could be easily altered for standard ED configurations. Eventually, Dr. Patterson would like to have this model work in conjunction with an ED database that he is developing so that the simulation software could be applied to a variety of EDs. To accompany this model and increase its utility, the team plans to develop an easy-to-follow guide to help ED decision makers better understand the simulation process. With this work, Dr. Patterson hopes other EDs and healthcare systems will be able to see the benefits of simulation modeling.

Acknowledgements

HealthIE is very thankful for all of the support, help, and advice that the group received while working on this project. The following individuals and organizations have played a significant role in the case study's success.

Gratitude must go to Dr. Brian Patterson, University of Wisconsin-Madison School of Medicine and Public Health, Emergency Medicine Department faculty member, for the processing time data and insight into ED procedures. From his expertise, HealthIE gained a better understanding of the ED and the delivery methods presented.

Second, HealthIE would like to thank two University of Wisconsin-Madison ISyE faculty members, Dr. Patricia Brennan and Dr. Laura McLay. Dr. Brennan provided the team with a computer and location to work on FlexSim while Dr. McLay can be credited for providing the team with background simulation knowledge.

University of Wisconsin-Madison Industrial & Systems Engineering Department has provided HealthIE with the tools and theory necessary to complete this case study. Due to University of Wisconsin-Madison's strong ties with healthcare, HealthIE was inspired to apply their skills toward solving healthcare-related problems.

Finally, HealthIE is grateful for the opportunity to participate in the Society of Health System's case study competition and for the additional resources that were offered to help the team succeed. Notably, the guidance and expertise provided from Lou Keller, the trial software and help documentation from FlexSim, and the Society of Health Systems for the organization of the competition.

References

[1] Hoot, Nathan R., et al. "Measuring and forecasting emergency department crowding in real time." *Annals of emergency medicine* 49.6 (2007): 747-755

[2] Brenner, Stuart, et al. "Modeling and analysis of the emergency department at University of Kentucky Chandler Hospital using simulations." *Journal of Emergency Nursing* 36.4 (2010): 303-310.

[3] Ajami, Sima, et al. "Waiting time in emergency department by simulation."*ITCH*. 2011.

[4] Garcia, Tamyra Carroll, Amy B. Bernstein, and Mary Ann Bush. *Emergency department visitors and visits: who used the emergency room in 2007?*. US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics, 2010.

[5] Gilboy, Nicki, et al. "Emergency Severity Index (ESI): A Triage Tool for Emergency Department Care, Version 4. Implementation Handbook 2012 Edition. AHRQ Publication No. 12-0014." *Rockville, MD* (2011).

[6] King, Diane L., David I. Ben-Tovim, and Jane Bassham. "Redesigning emergency department patient flows: application of Lean Thinking to health care." *Emergency Medicine Australasia* 18.4 (2006): 391-397.

[7] Kelton, W. David, Randall P. Sadowski, and Deborah A. Sadowski. *Simulation with ARENA*. Vol. 3. New York: McGraw-Hill, 2002.

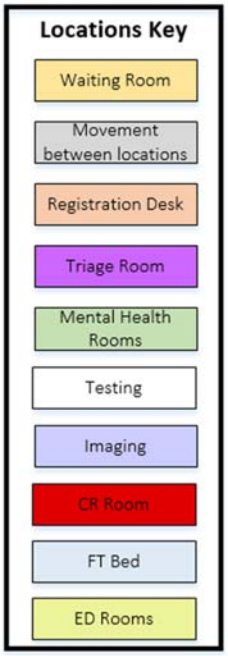
[8] Law, Averill M., W. David Kelton, and W. David Kelton. *Simulation modeling and analysis*. Vol. 2. New York: McGraw-Hill, 1991.

[9] Medeiros, Deborah J., Eric Swenson, and Christopher DeFlitch. "Improving patient flow in a hospital emergency department." *Proceedings of the 40th Conference on Winter Simulation*. Winter Simulation Conference, 2008.

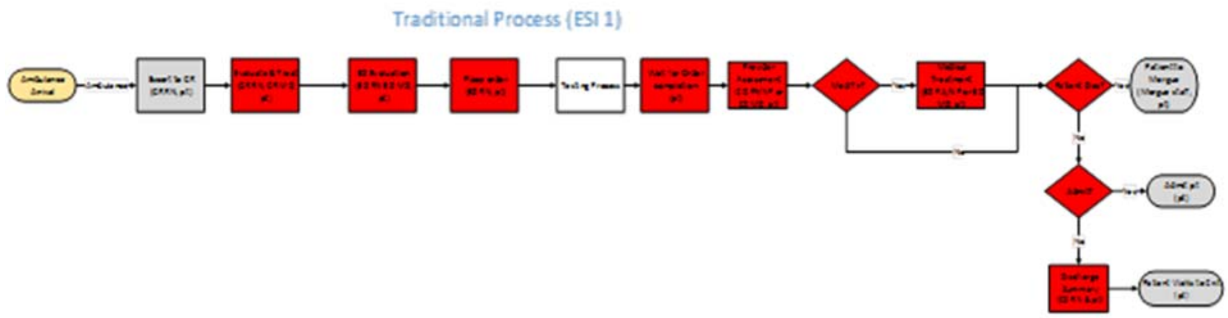
Appendices

A1. Process Maps

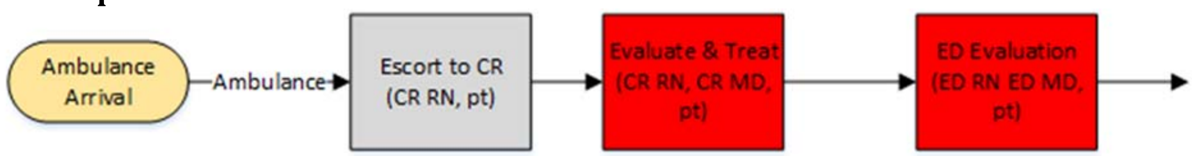
Process Map Key



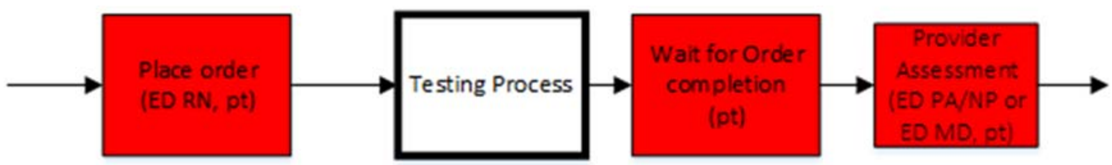
Overview Traditional Triage & Bed ESI 1



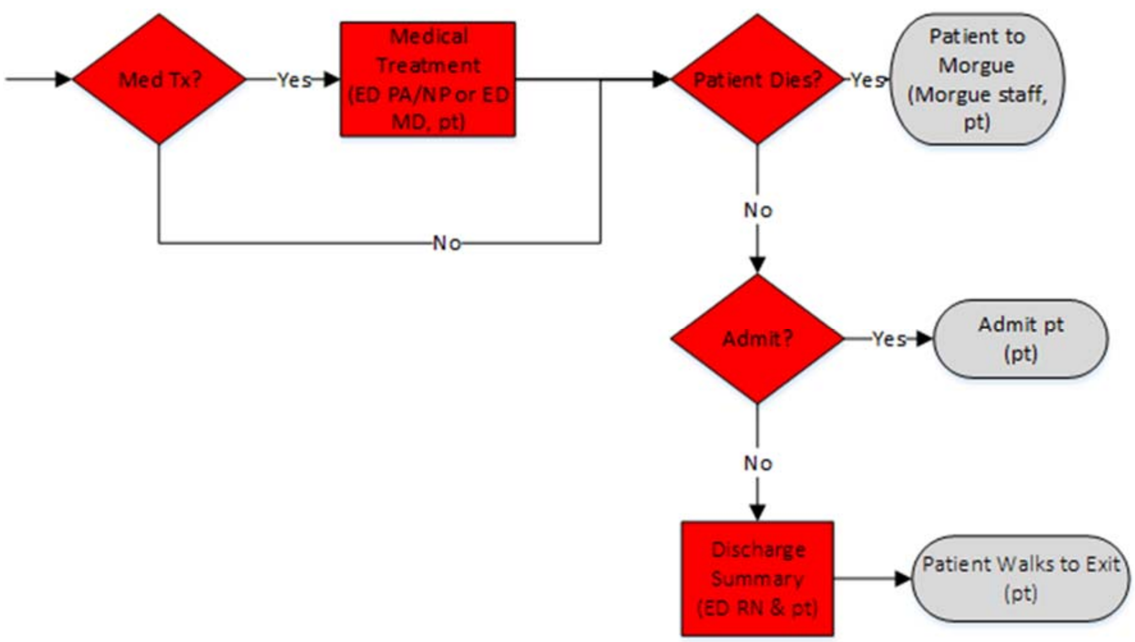
Close-Up



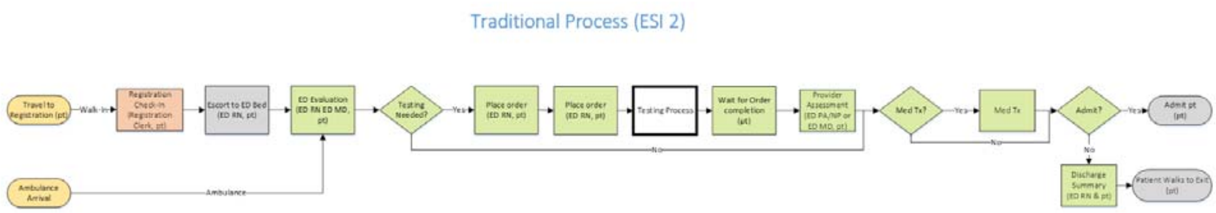
Close-Up



Close-Up



Overview Traditional Triage & Bed ESI 2



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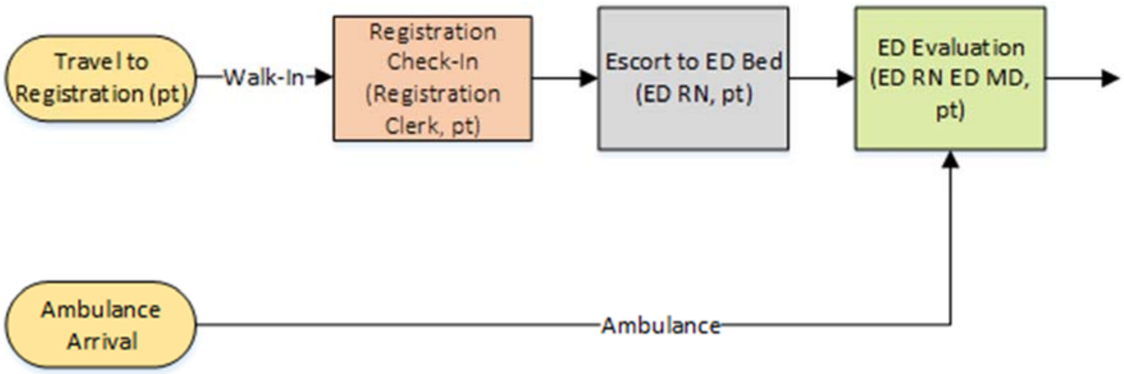
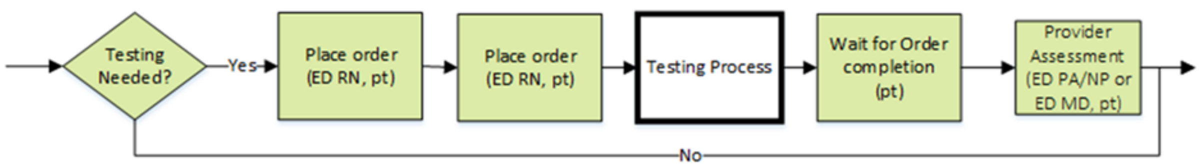
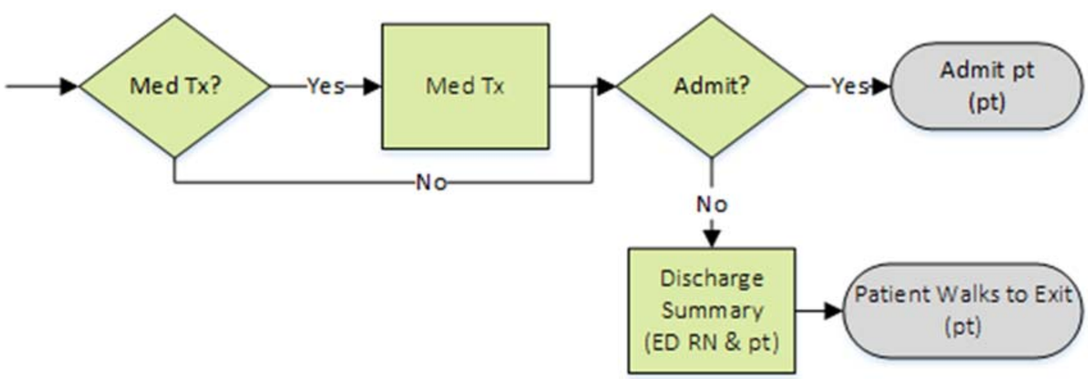


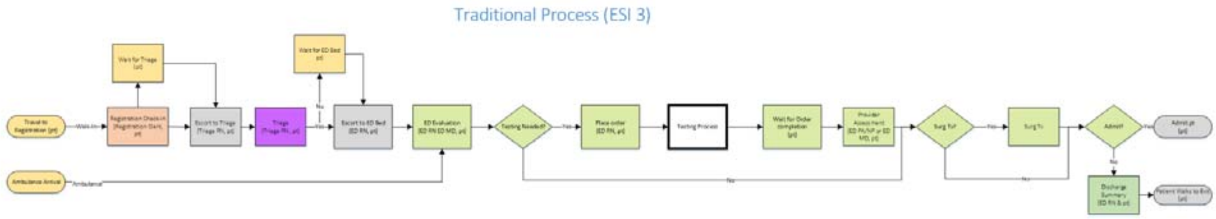
Close-Up



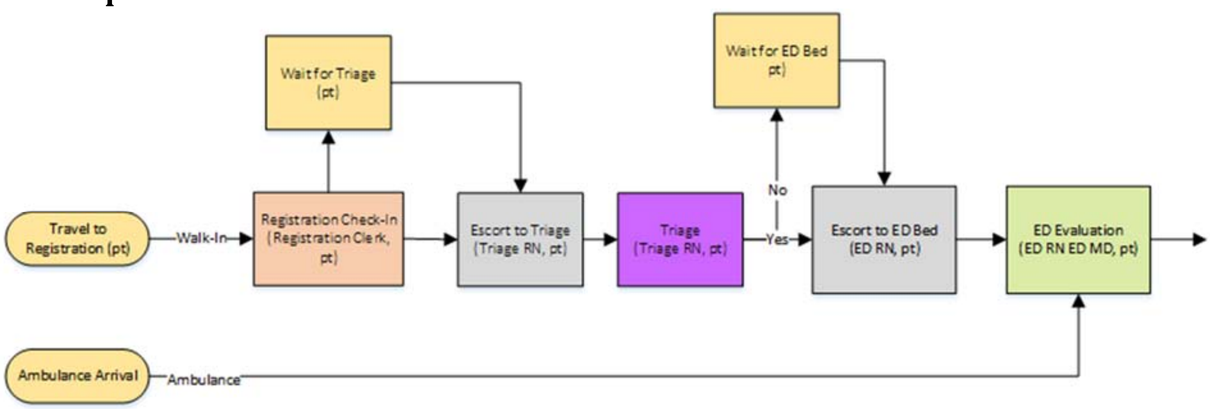
Close-Up



Overview Traditional Triage & Bed ESI 3



Close-Up



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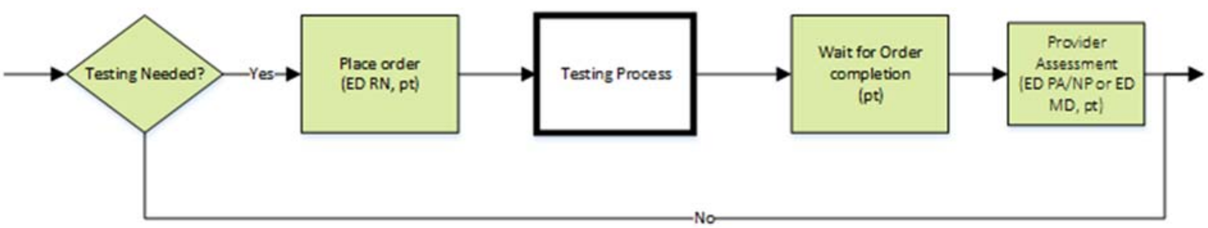

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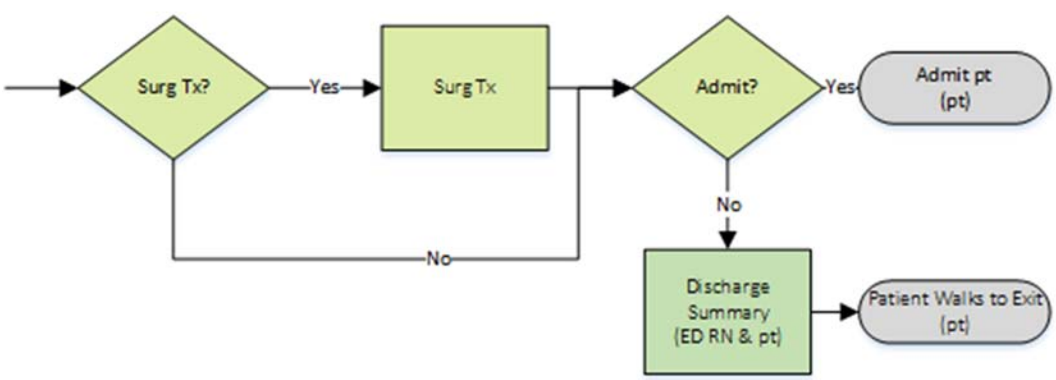
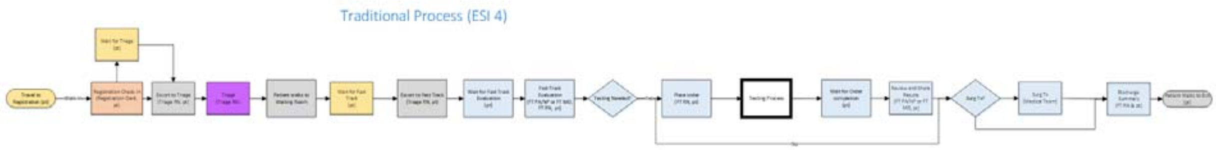


Overview Traditional Triage & Bed ESI 4



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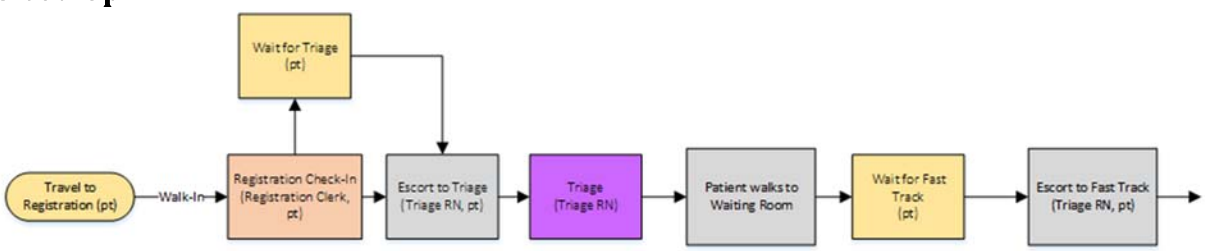
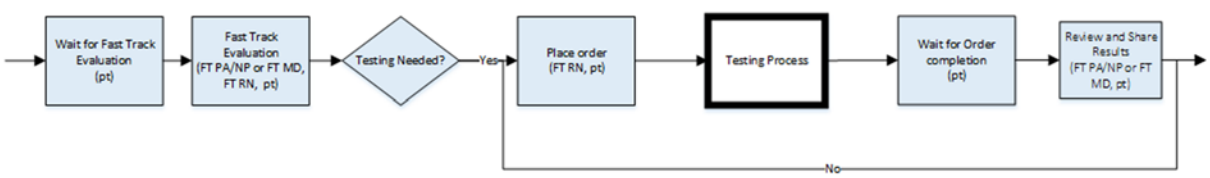
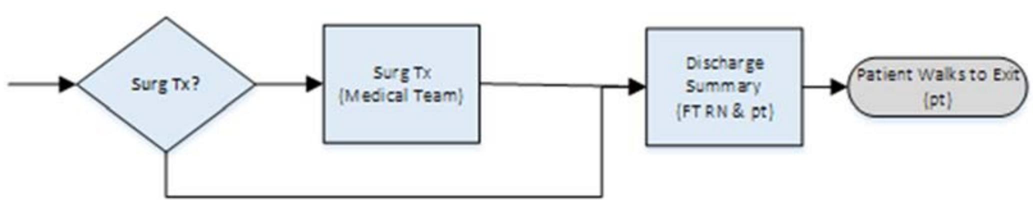


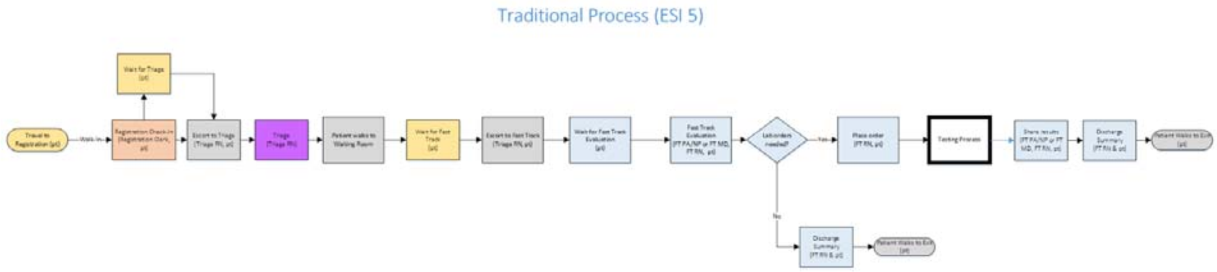
Close-Up



Close-Up



Overview Traditional Triage & Bed ESI 5



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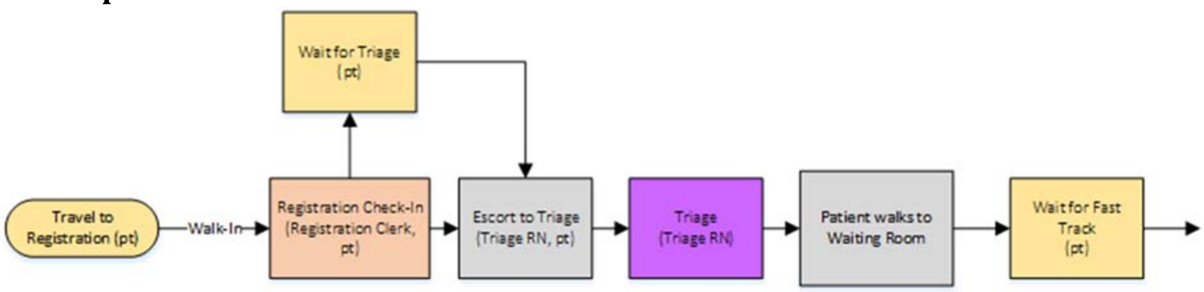

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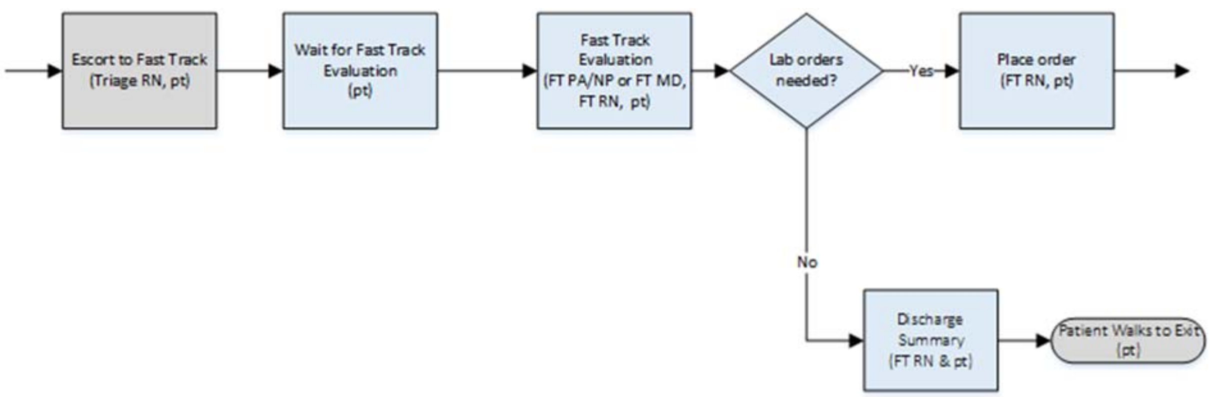

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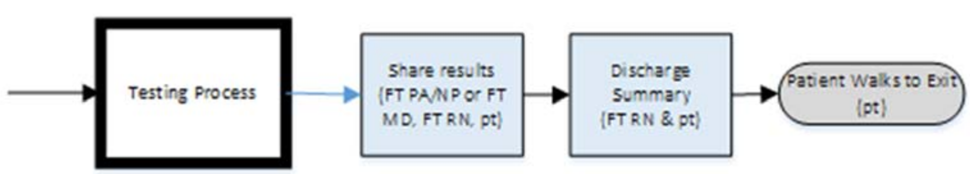
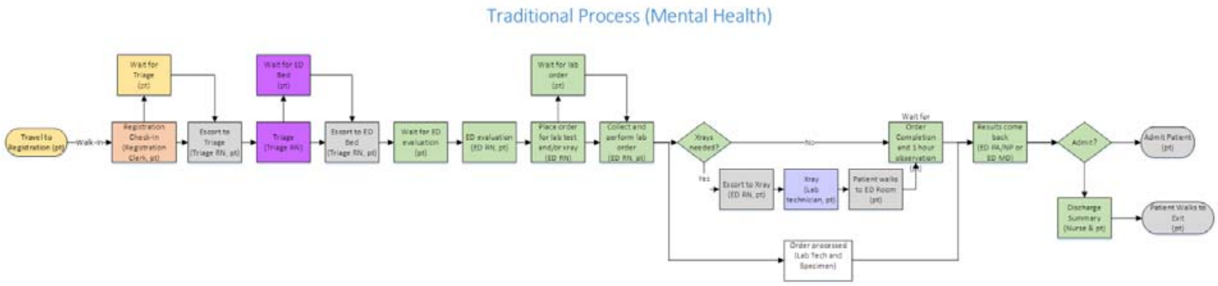


Overview Traditional Triage & Bed Mental Health



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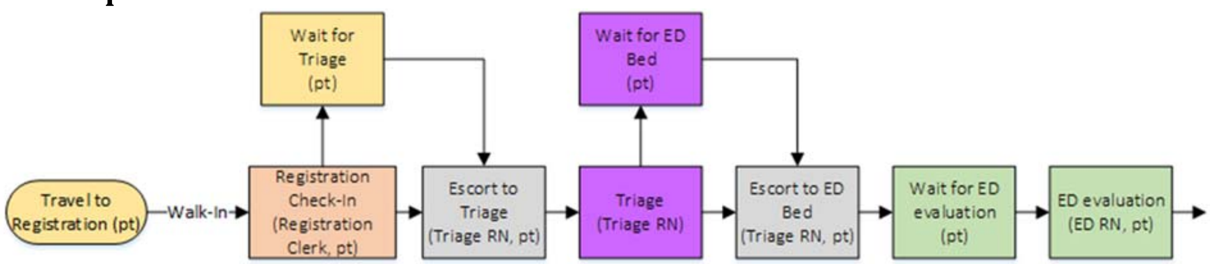
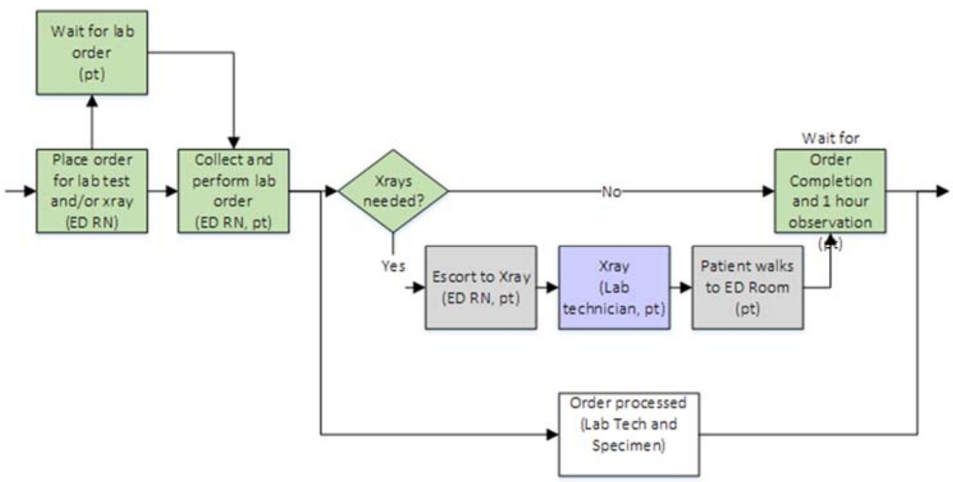


Close-Up



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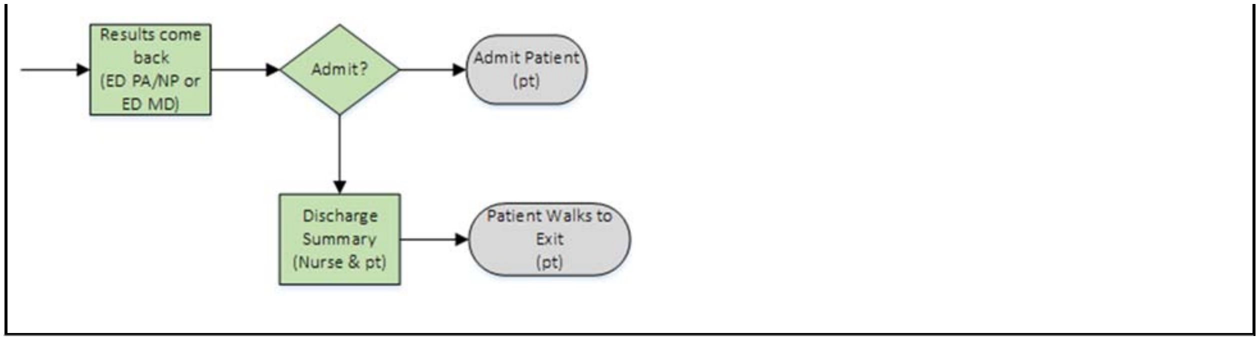
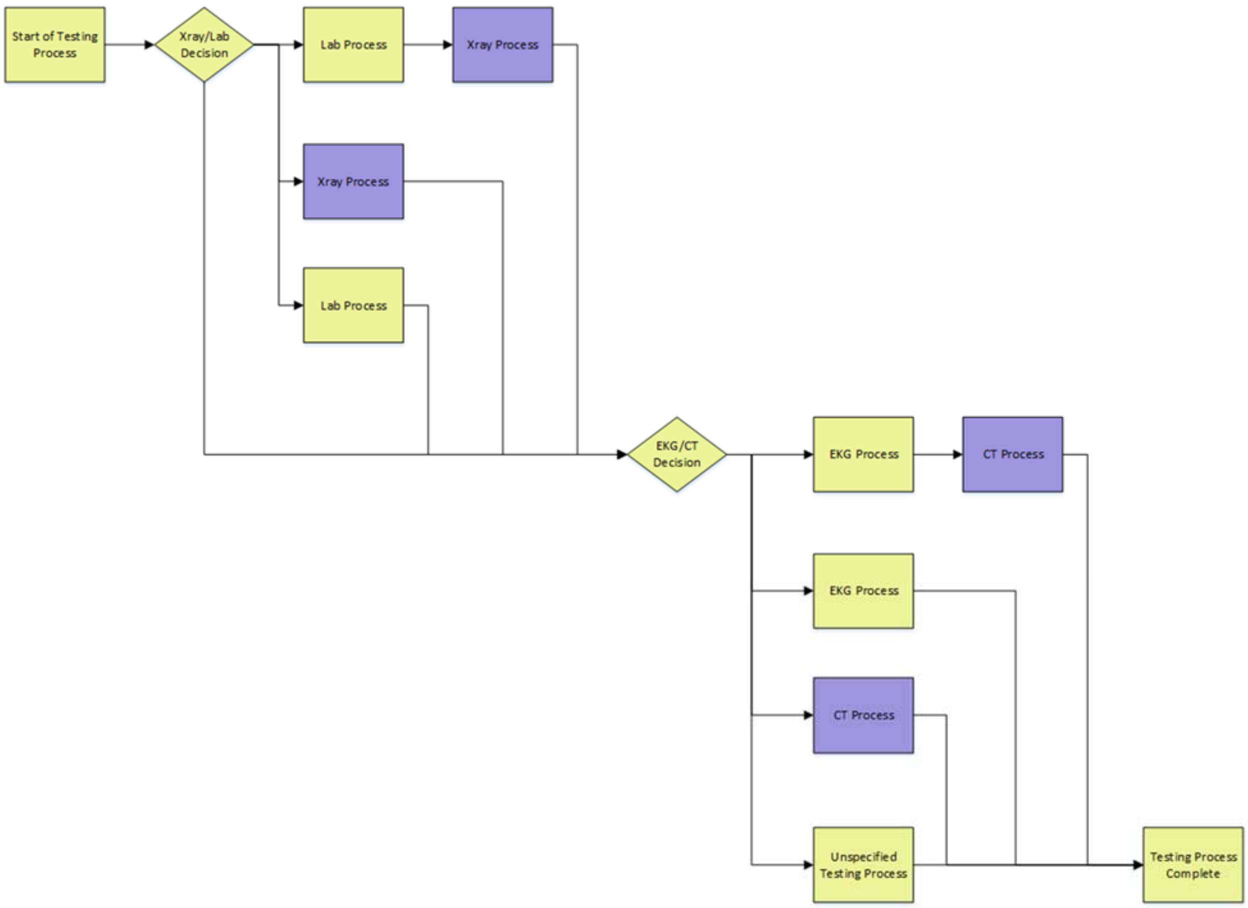
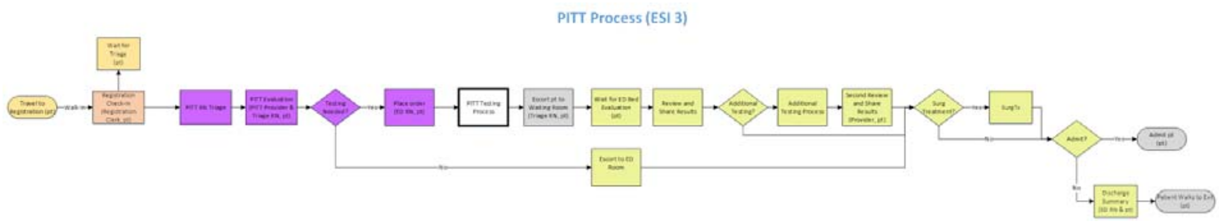


Traditional Testing Process



PITT Process Maps

Overview PITT ESI 3



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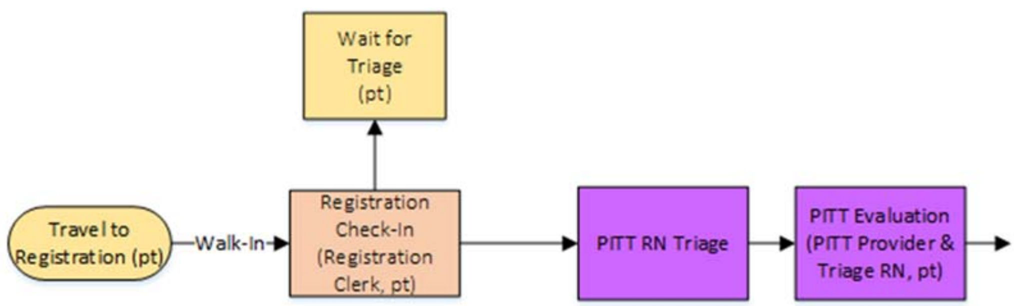

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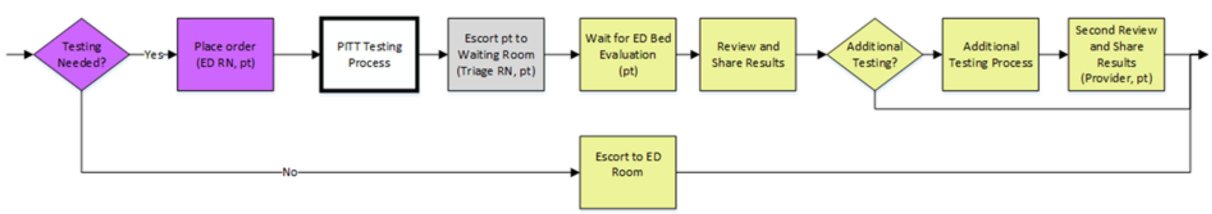

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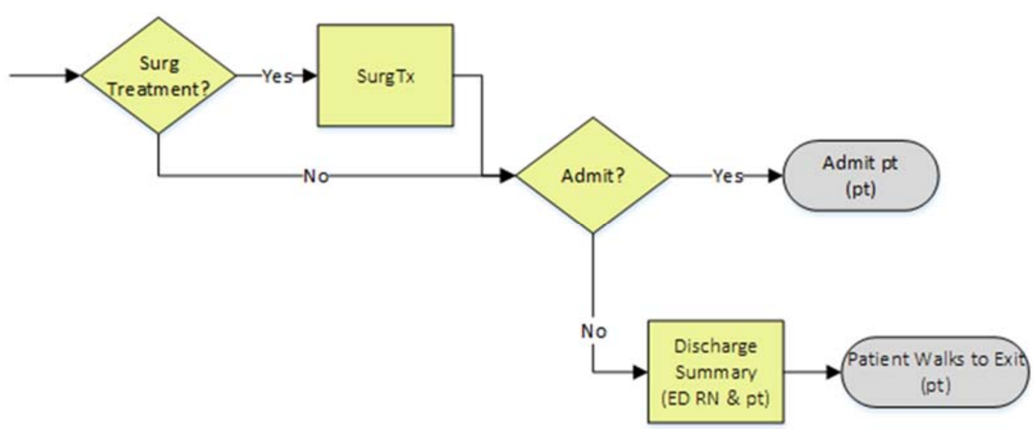
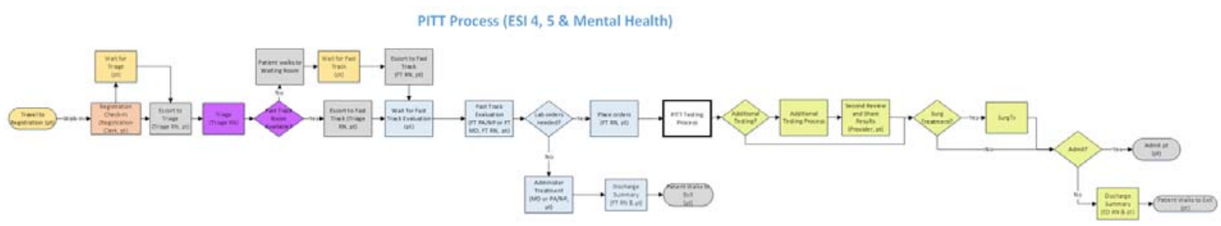


Overview PITT ESI 4, ESI 5 & Mental Health



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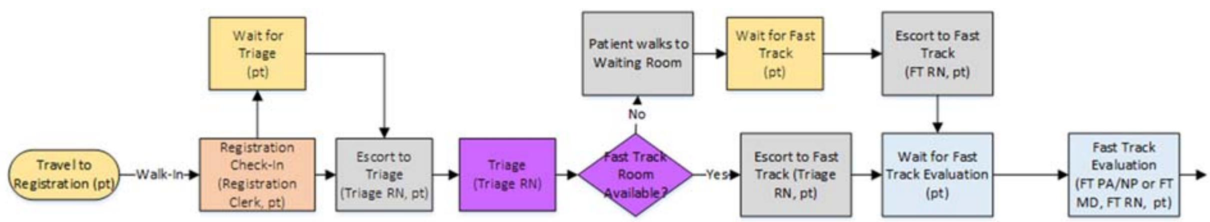

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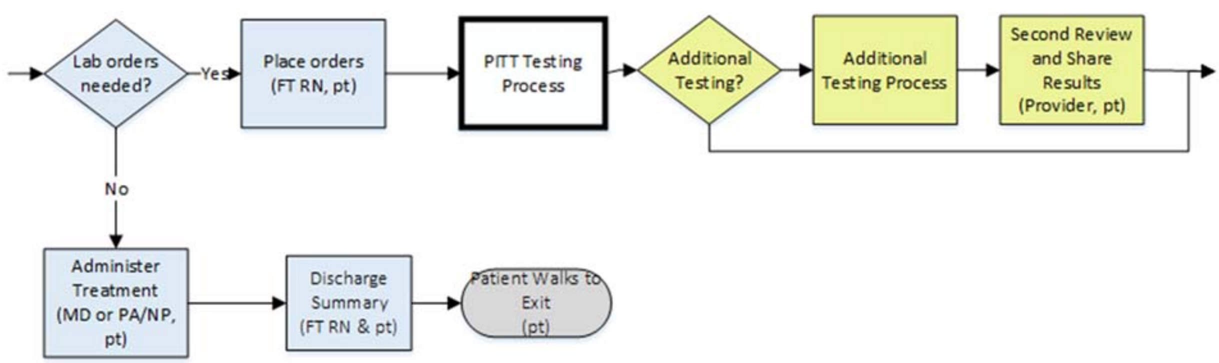
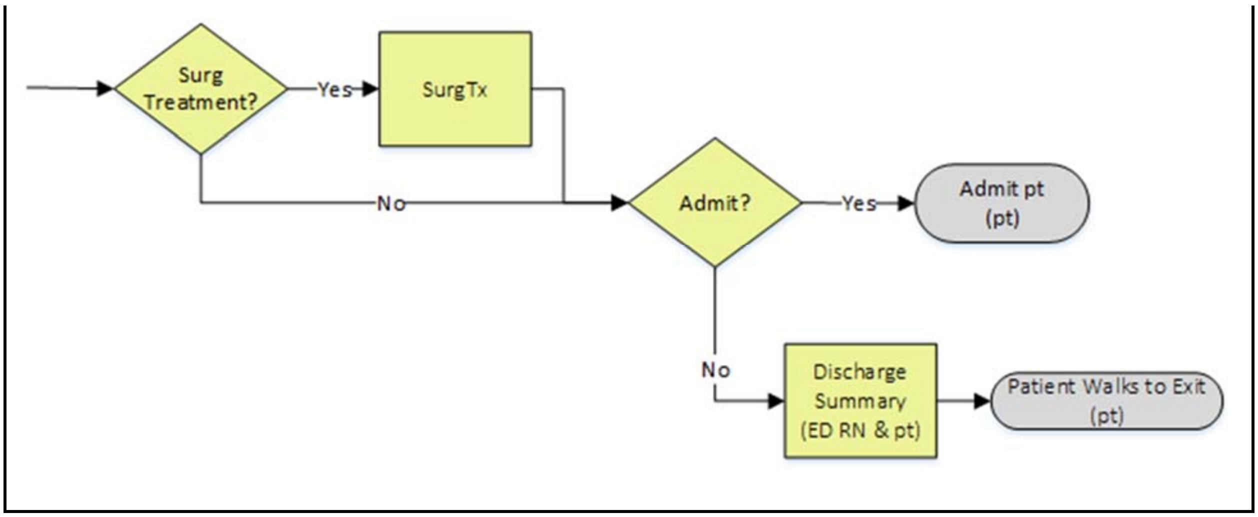
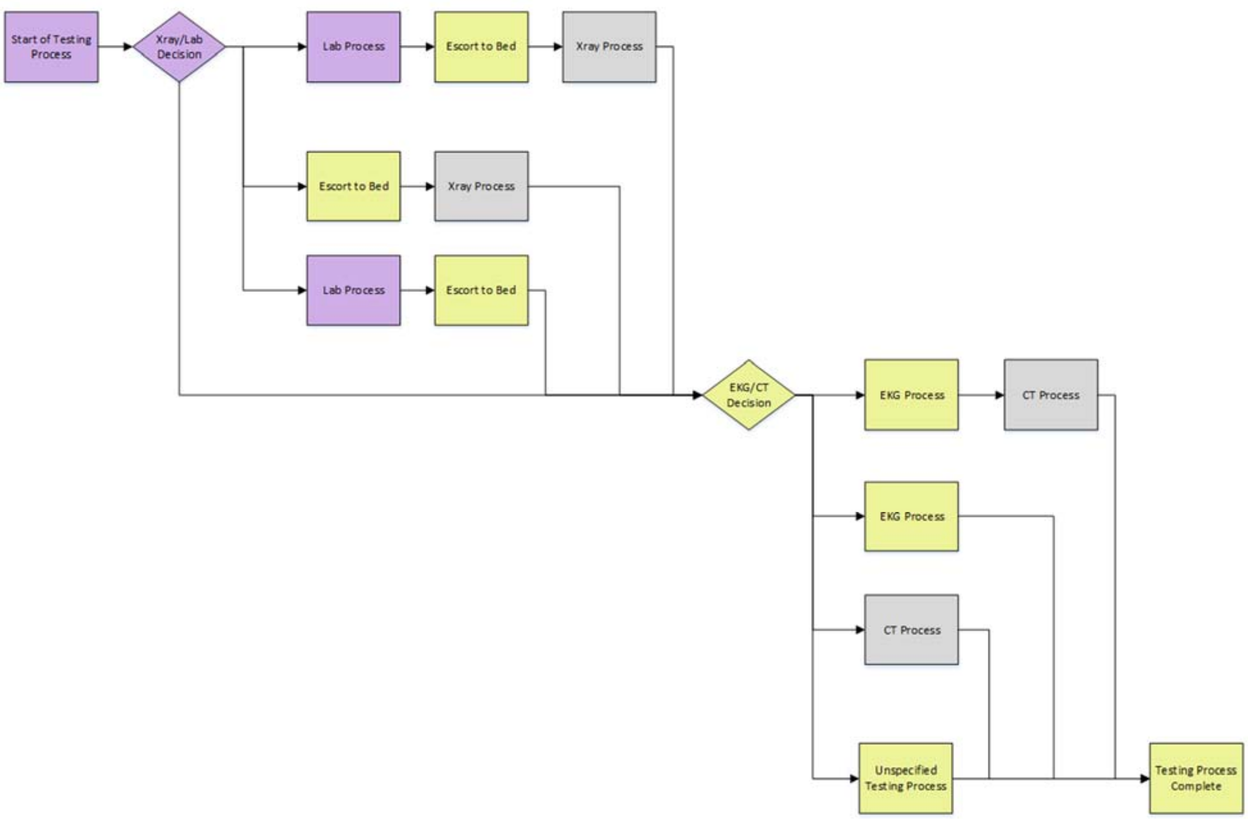


Close-Up



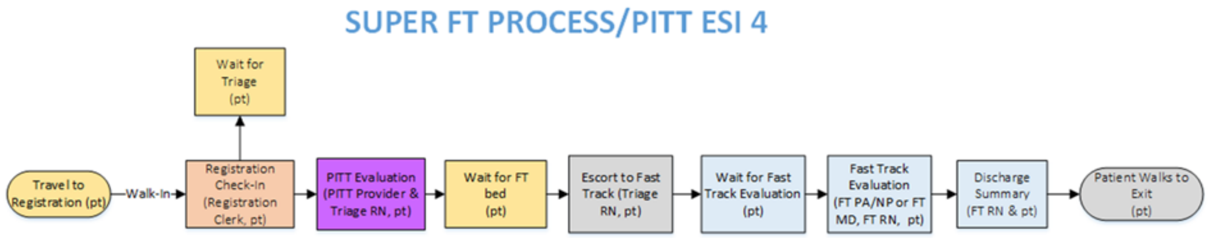
PITT Testing

**subject to ESI probabilities

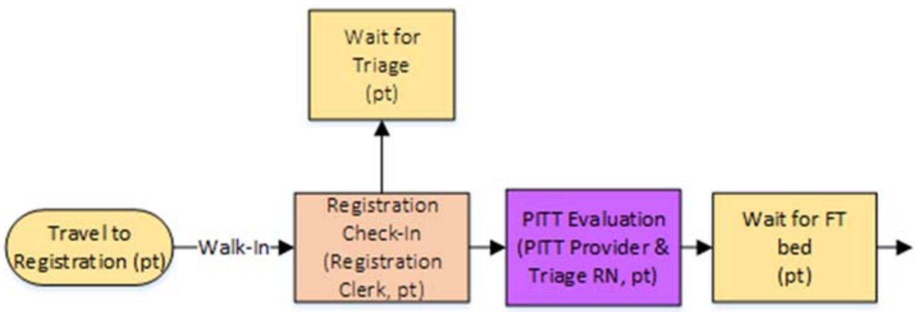


Super FT/PITT Process Maps

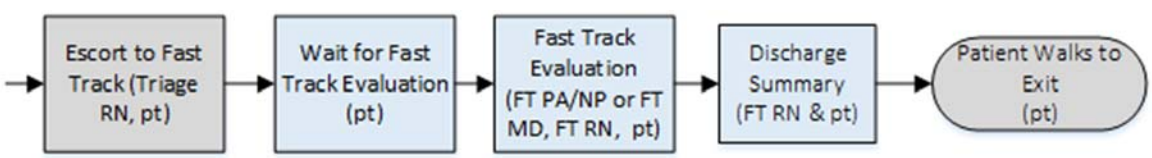
Overview Super FT/PITT ESI 4



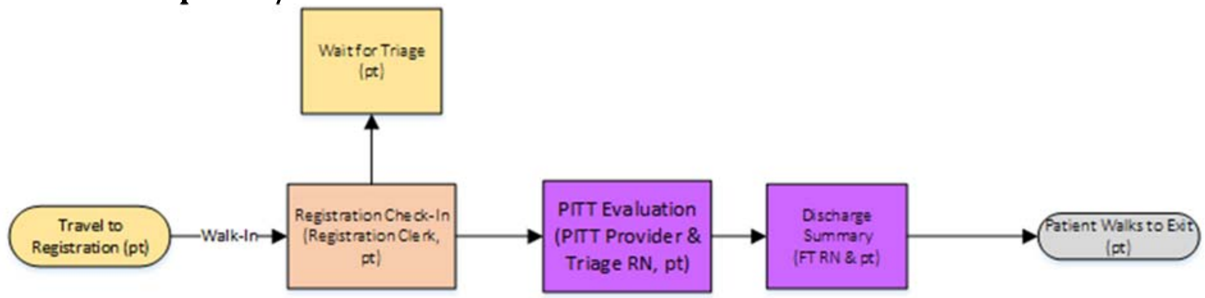
Close-Up



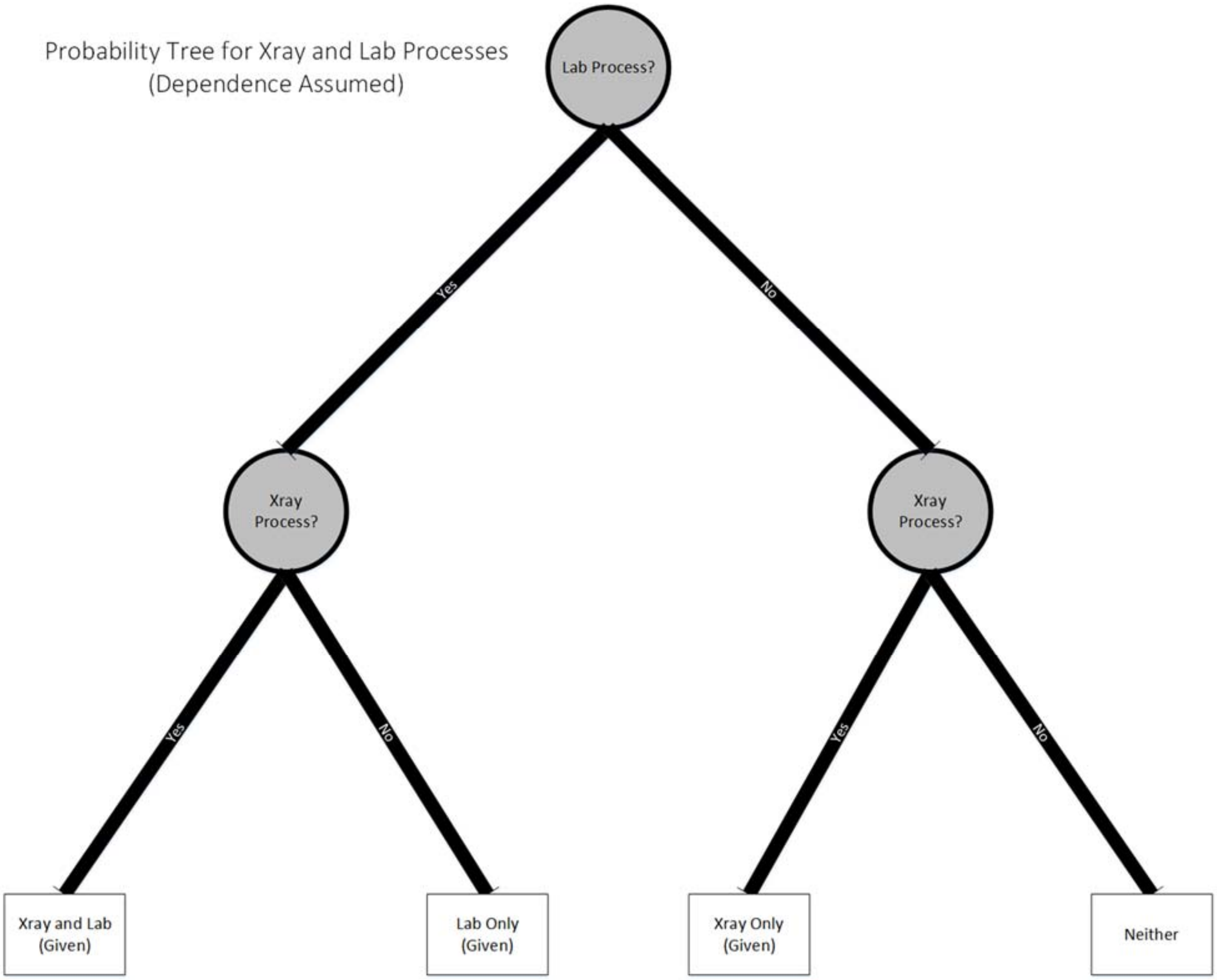
Close-Up



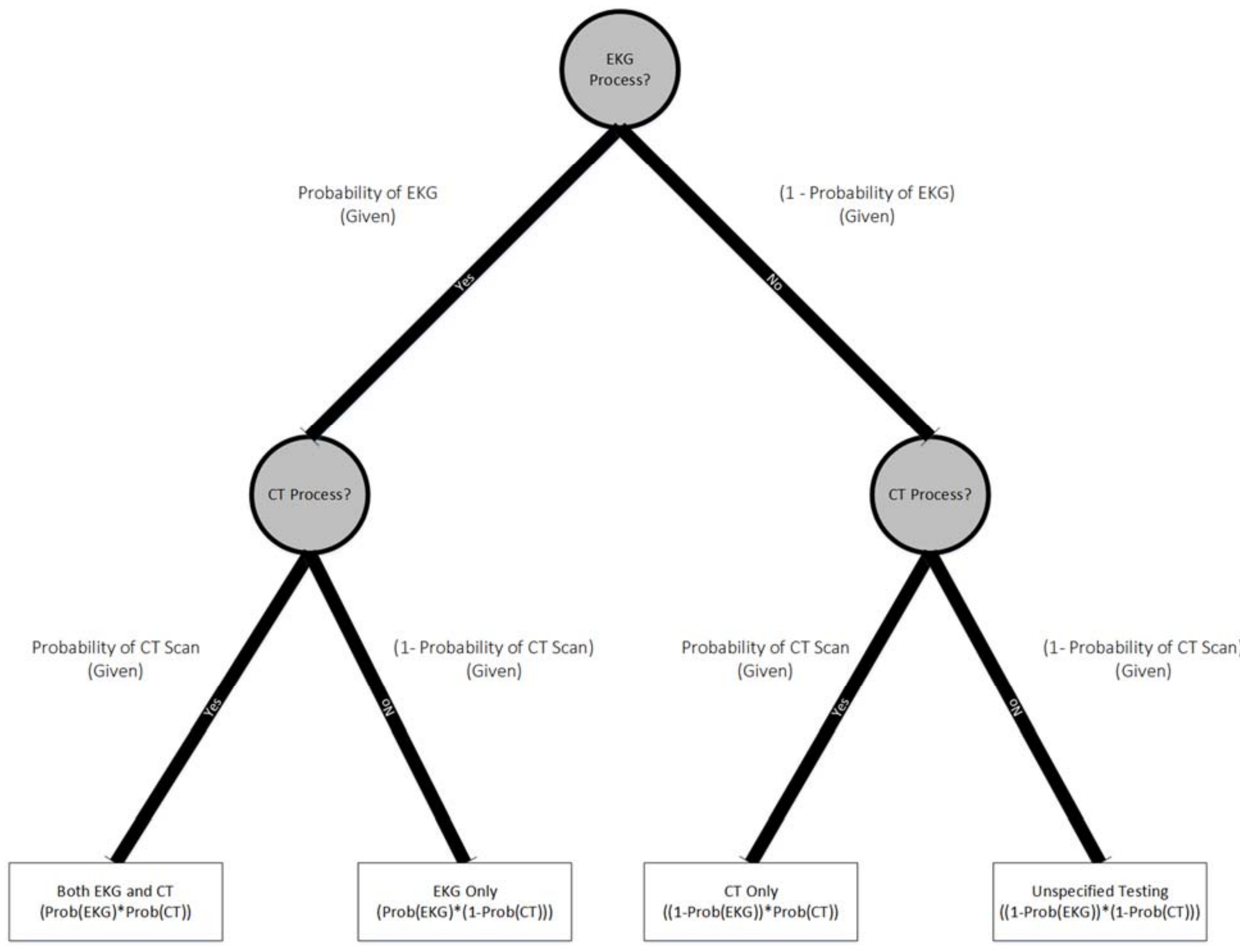
Overview Super FT/PITT ESI 5

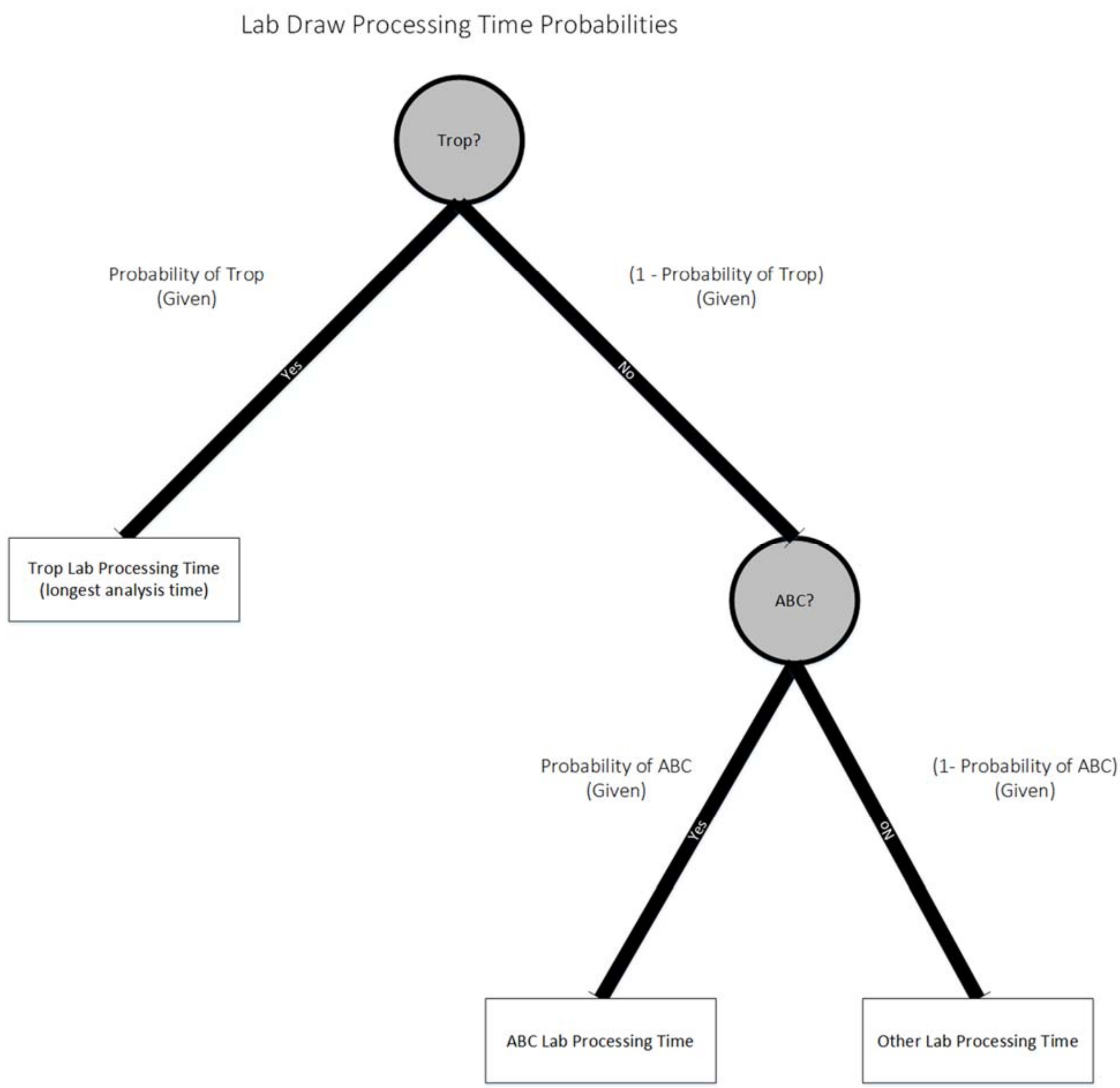


Testing Probability Trees



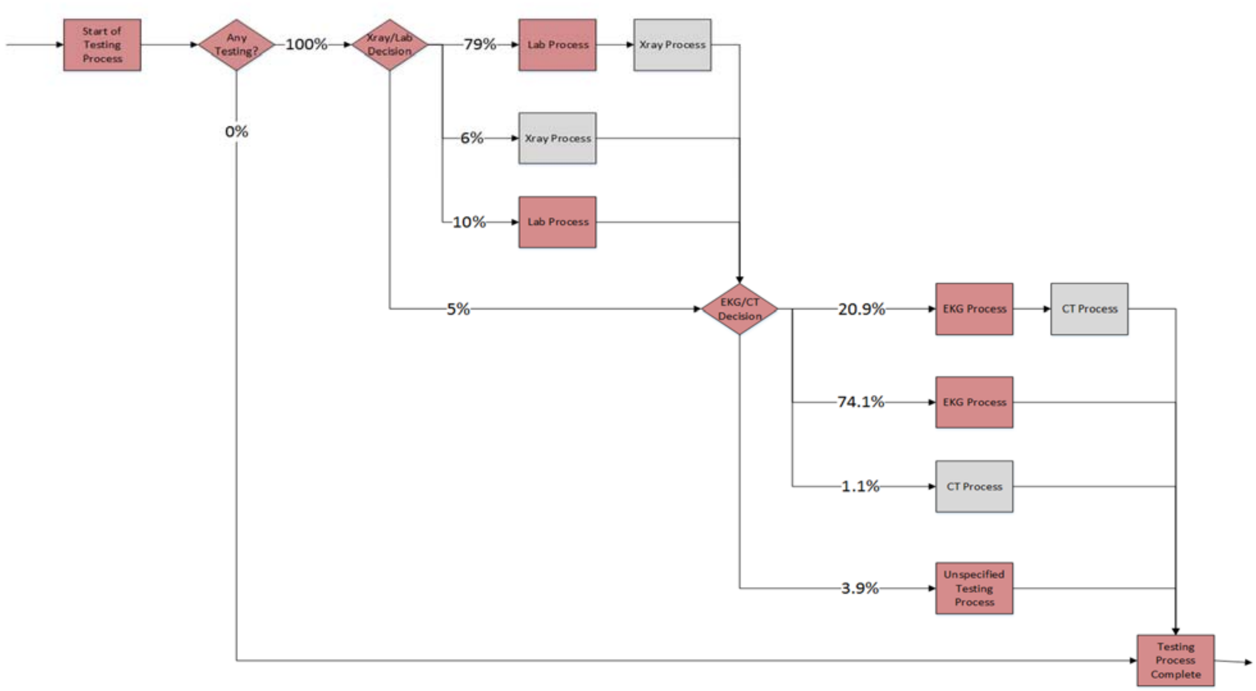
Probability Tree for EKG and CT Processes
(Independence Assumed)



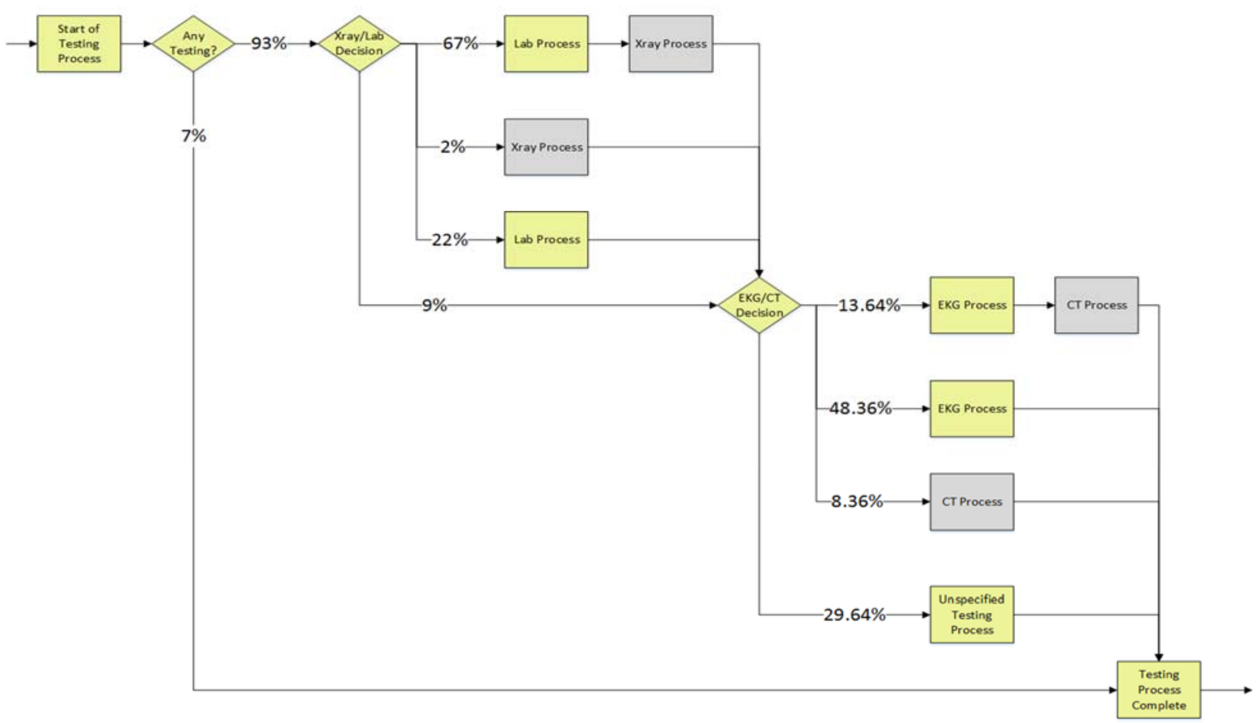

Lab Draw Processing Time Probabilities
Trop?
Probability of Trop
(Given)
(1 - Probability of Trop)
(Given)
Yes
No
Trop Lab Processing Time
(longest analysis time)
ABC?
Probability of ABC
(Given)
(1- Probability of ABC)
(Given)
Yes
No
ABC Lab Processing Time
Other Lab Processing Time

Probability Tree by Patient Level

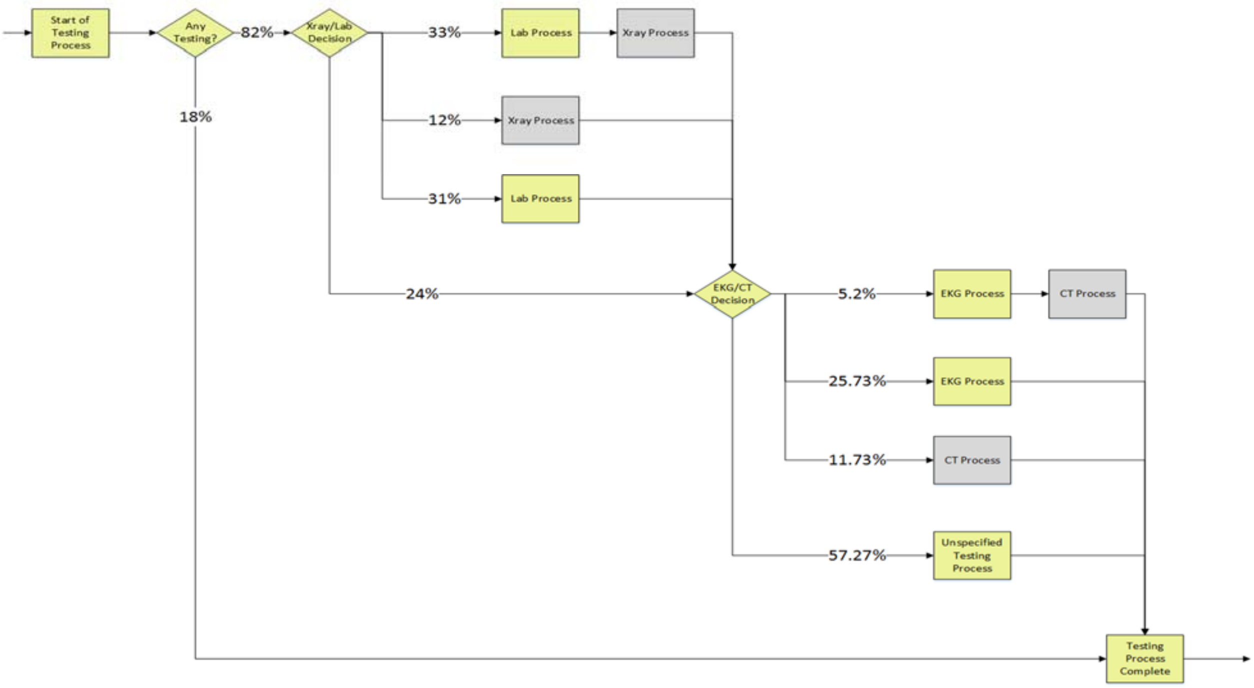
ESI 1 Testing Flowchart



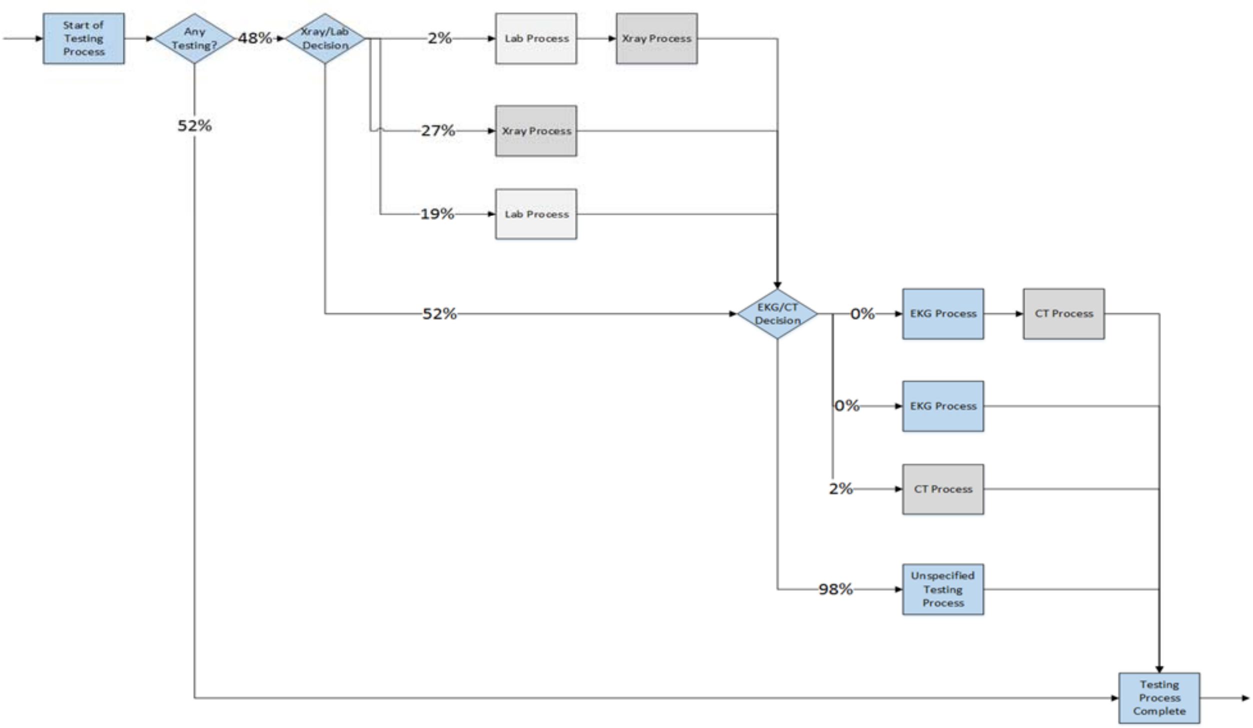
ESI 2 Testing Flowchart

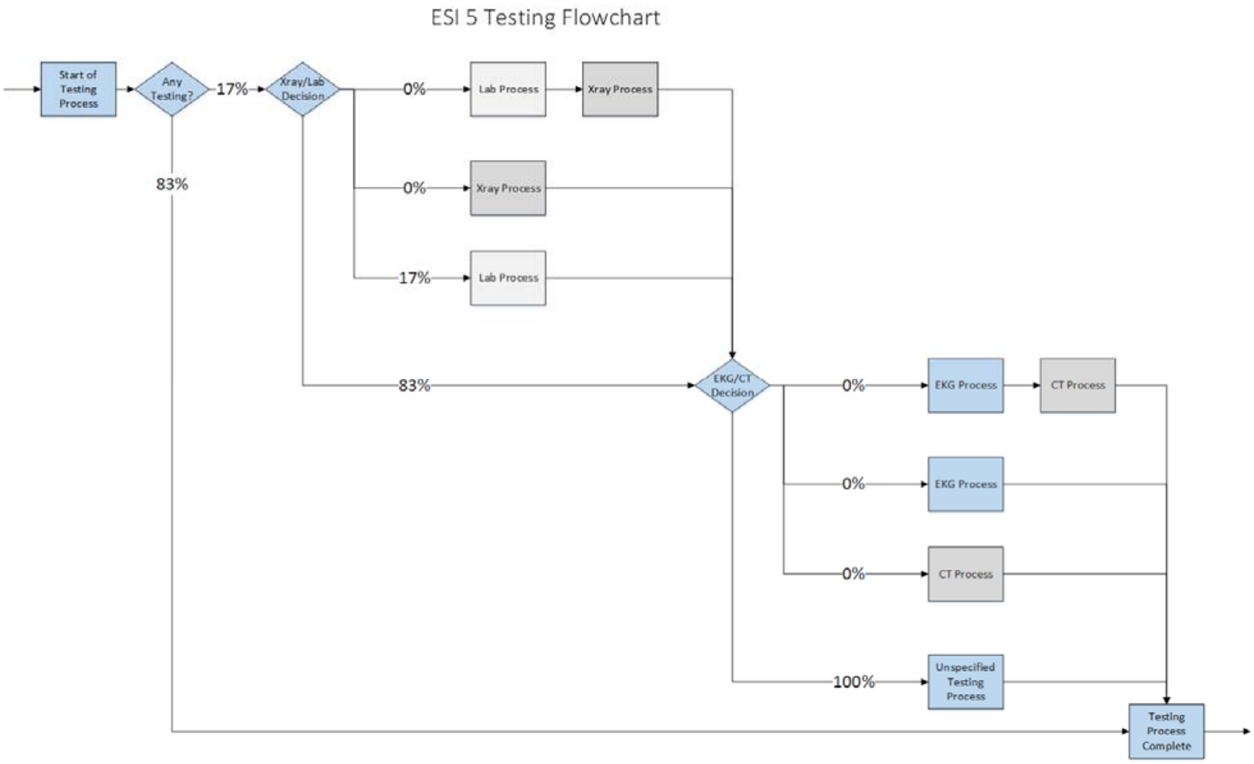


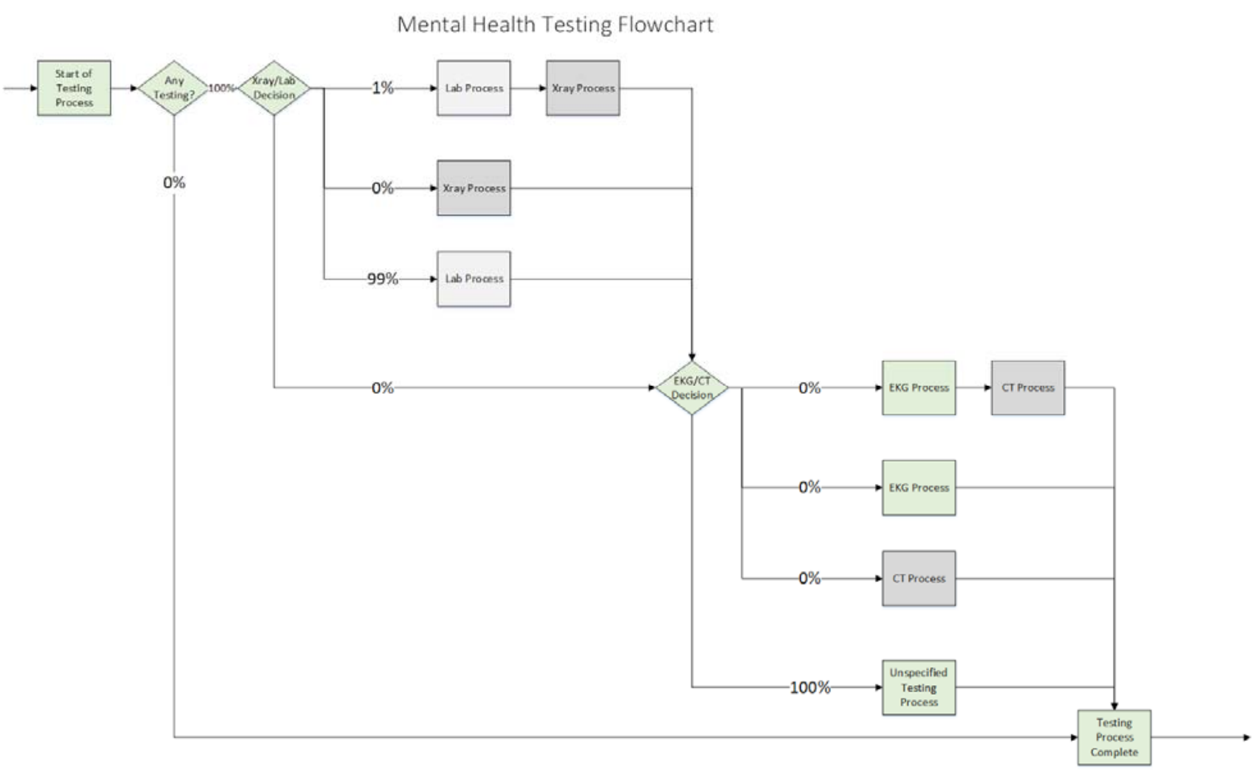
ESI 3 Testing Flowchart



ESI 4 Testing Flowchart




ESI 5 Testing Flowchart
Start of Testing Process
Any Testing?
17%
83%
Xray/Lab Decision
0%
Lab Process
Xray Process
0%
Xray Process
17%
Lab Process
83%
EKG/CT Decision
0%
EKG Process
CT Process
0%
EKG Process
0%
CT Process
100%
Unspecified Testing Process
Testing Process Complete


Mental Health Testing Flowchart
Start of Testing Process
Any Testing?
100%
0%
Xray/Lab Decision
1%
Lab Process
Xray Process
0%
Xray Process
99%
Lab Process
0%
EKG/CT Decision
0%
EKG Process
CT Process
0%
EKG Process
0%
CT Process
100%
Unspecified Testing Process
Testing Process Complete

A2. Assumptions List

Ambulance Arrivals

- Physicians are “preempted” from their current ED task to care for ambulance arrivals until they are “stabilized”
- Both physician and ED RN are needed to transport ESI 1 patients
- Any arrivals via ambulance receive higher priority than walk-ins
- There are a subset of ED nurses and ED physicians that handle ambulance arrivals
- Patients who arrive via ambulance are considered “stable” and have same priority as walk-ins after first provider contact
- Physician caring for patient needs to collect same information that an RN would when rooming a patient

Charting

- There are computers are in every room for bedside order entry
- Nurses watch for orders and respond immediately
- Time required to review and share results is always the same
- Provider reviews results in room and then shares them with the patient

CR Room

- ESI 2 and 3 do not go to CR Room
- A patient that needs the CR room will use the CR room for their entire visit

Delivery Model 2 - PITT

- Nothing changes in the PITT process for ESI 1 and 2. Additional testing for other ESI levels is only because the triage evaluation is less accurate than traditional evaluation
- Provider evaluation in triage takes the same time as traditional provider evaluation
- Triage RN always takes the patient’s vitals
- Triage Provider always does the evaluation
- Both the RN and the provider see the patient during triage
- There are two parallel triage stations. Vitals, evaluation, and lab draws take place in those stations
- Nurse who rooms PITT patient still collects the patient’s information
- Additional testing is its own process and the processing time is based on ESI level
- Patients have labs drawn in the triage room and the labs are analyzed while the patient is roomed
- RN performs any additional testing
- Since ESI 2 go from Registration immediately to an ED bed in the “traditional triage” delivery method, they do the same for PITT and SuperFT

- Patients stay in Triage room for blood work/urine specimen because the resources could easily be moved and this makes the process more efficient by saving movement time
- EKG takes place in ED room for ESI 2 and 3 because it's portable and that's how it happened in "traditional triage"
- Two RNs and one Provider (PA) are used for both PITT and SuperFT
- There can be a maximum of two rounds of testing

Delivery Model 3 - Super Fast Track/PITT

- Nothing changes in the SuperFT/PITT delivery method for ESI 1 and 2
- There is no change to ESI 3 from the PITT delivery method
- ESI 5 patients receive no testing and are immediately discharged after their triage evaluation
- ESI 4 receive no testing, but are taken to a FT bed because provider needs to determine if they need SurgTx and provides it if needed

Escorting

- While it is not shown in the model, all transportation groups use wheelchairs to escort patients and there is no delay in wheelchair retrieval

Equipment

- There are a sufficient number of EKG machines to ensure they are not a bottleneck
- ESI 1, 2, and 3 have IVs and equipment in room to do blood draws and stuff there
- Surg Tx doesn't require equipment because the patient only needs stitches

Expiration

- Only ESI 1 patients can die, and they do so at the end of the process
- Patients who die are taken to a morgue exit and aren't counted as inpatients or outpatients

Lab Analysis

- All lab processing can occur in parallel because processing is done by machines and there are enough machines so that there is never a wait for lab analysis to begin
- Only the longest lab processing time is modeled. If a patient needs both ABC and Trop, only Trop is modeled because ABC would be completed during the same timeframe
- There is only one lab technician and he never becomes the bottleneck
- If neither Trop or ABC labs are needed, the "Other" processing time is used

Locations

- Nurses return to nurse stations when they are performing work unrelated to patient care

- Physicians stay in resident or nourishment areas when they are not caring for a patient

Imaging

- There are different technicians for the X-ray and CT machines
- CT scans are ordered without contrast
- There is no wait time for radiologist to read imaging studies

Metrics

- Assume "discharge" means discharged from the ED, which could be a death, admit, or discharge
- When patient sees Triage Provider in the PITT and SuperFT delivery models, it is considered "Door to Provider" time

Mental Health

- The one-hour observation period for mental health patients starts after labs are drawn and X-rays are taken, but before results come back.
- The ED physician waits until the end of the one-hour observation period to review and share results with the mental health patient

Medical Decision Making

- There is independence between testing processes and death
- The same percentage of patients are admitted regardless of what tests are performed
- Trop, ABC, and Other testing procedures are independent
- Lab samples are the first things that are done because a nurse can do them right away
- Unspecified testing occurs if no other testing occurs
- If a patient doesn't receive any testing, they can still receive MedTx or SurgTx

Process Flow

- MedTx occurs at the end of the process and doesn't require equipment to be brought to the room
- Surg Tx occurs at the end of the process in the patient's room
- If a patient needs more than one lab, both are drawn at the same time
- FT patients are taken to Room 2 to get labs drawn and then are taken back to their room before being escorted to X-ray or CT
- Lab draws occur in the patient's room for patients in ED beds, Mental Health Pods, or CR rooms
- ESI 5 patients are only escorted to FT beds
- Patients move to the triage waiting room without being escorted
- "Unspecified testing" is instant
- Inpatient beds are always available

Staffing

- Providers are designated to either ED or FT
- Prioritization of staffing is done by assigning the jobs to the roles that make the most sense. Cost is used as a secondary consideration
- If an employee can alternate for a process, they should be able to alternate for all other processes
- The RN Supervisor is not assigned clinical duties
- Registration is handled by the registration clerk
- Lab technician only does lab analysis
- PCT is mostly in charge of moving
- Triage is done by an RN in the traditional delivery method

Staff	Medical Team (Assess, Review Results, Surg Tx)**	Care Team (Admit, RN Assess, EKG, Draw Labs, Med Tx, Discharge)**	X-ray	CT	Move to CTT	Move to X-Ray	Move to Morgue	PITT Team
MD	ED							1
PA	FT (2)	FT (2)						
RN		ED, FT (1)						1
CNP	FT (1)	FT (3)						2*
PCT					1	1	1	
CTT			1		2			
XRT				1		2		

A3. Team Bios

April Soler

April Soler is an undergraduate student at the University of Wisconsin-Madison, Department of Industrial and Systems Engineering. Her focus is in healthcare engineering and patient safety as she interns at Northeastern's Healthcare Systems Engineering Institute (HSyE) and University of Wisconsin Hospital and Clinic's Quality, Safety and Innovation lab. Consulting for numerous hospitals, April's past projects include reducing excessive radiation for breast cancer patients, optimizing cancer patients scheduling, and redesigning OR inventory. April plans to continue her education as a graduate student of the Department of Industrial and Systems Engineering, Healthcare Systems Engineering.

Erkin Otles

Erkin Otles is an ISyE graduate student supervised by Dr. McLay at University of Wisconsin – Madison. Along with his duties as a Research and Teaching Assistant for the UW – Madison ISyE Department, he also holds an adjunct position in the UW - Madison School of Medicine and Public Health's Emergency Medicine Department. Erkin completed his undergrad in IE in 2011 and upon graduation he joined Epic as Technical Services Engineer up until he started his master's program. Erkin plans to complete his master's in Industrial and Systems Engineering, Decisions Science and Operations Research in Spring of 2014.

Samuel Schmitt

Samuel Schmitt is an undergraduate student at the University of Wisconsin - Madison, Department of Industrial and Systems Engineering pursuing a focus in healthcare and quantitative reasoning. Some of his previous work includes a process improvement project at a pulmonary clinic, a simulation of a restaurant on campus, and a technical report that analyzed the use of Real-Time Location Systems in emergency departments. Following the completion of his undergraduate degree, Samuel plans to continue his education at the University of Wisconsin - Madison as a graduate student in the Department of Industrial and Systems Engineering.

Michael Russo

Michael Russo is an undergraduate student at the University of Wisconsin - Madison, pursuing a degree in Industrial and Systems Engineering. His interests lie mainly in manufacturing, but he enjoys using his knowledge of manufacturing in healthcare related projects at the University of Wisconsin Hospital's Quality, Safety, and Innovation Lab. Past projects include a resource analysis at the kidney transplant center, inefficiency reduction in the the cardiac and vascular surgery unit, and a scheduling redesign in the radiation oncology clinic. After graduation in the spring, Michael will be working full time in Halliburton's Supply Chain Management Program.

Brian Patterson, MD

Dr. Patterson joined Emergency Medicine at the University of Wisconsin School of Medicine & Public Health in July 2013. After graduating from Penn State with a B.S. in bioengineering, he completed a master's degree in public health and a medical degree at Northwestern University's Feinberg School of Medicine. He continued at Northwestern for his residency training in Emergency Medicine, where he served as Chief Resident. Dr. Patterson focuses on health services research with specific interests in operations, informatics, and cost-effectiveness in emergency medicine. In 2009, he was recognized by the Society for Academic Emergency Medicine (SAEM) with a Midwest regional award for Best Resident Presentation.