Analysis of a Hospital Network Transportation System with Discrete Event Simulation

by

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ABSTRACT

VA New England Healthcare System (VISN1) provides transportation to veterans between eight medical centers and over 35 Community Based Outpatient Clinics across New England. Due to high variation in its geographic area, it has been a continuous challenge for VISN1 to develop an optimal transportation system that has low operation costs, little or no wait time for patients and drivers, and meets demand 100% of the time. Furthermore, complexities of operating a healthcare system have side effects on the transportation system, such as the inconsistencies in the patient scheduling system. Past research suggest that the decentralized nature of the VISN 1 transportation system has further negative effects on performance and that having a central transportation administration will increase efficiency and utilization of resources to improve both patient flow and quality of the current transportation system. This thesis attempts to illustrate the current issues of transportation with system design tools. Changes include having a centralized transportation system to standardize processes, reduce variation, and as a result, reduce variation and cost, while improving patient flow.

In particular, discrete event simulation is used to analyze the flow of patients to the Boston medical center, the hub of VISN1 medical centers. Although many shuttles come to Boston medical center daily, the ones that bring in the most number of patients were analyzed: Manchester, Togus, and White River. Two variables were tested: arrival times of shuttles and shuttle capacity. After generating simulation data and validating the results, the following trends were identified: (1) increasing the time interval between shuttles arrivals reduces patient wait

time and (2) an extra shuttle is needed to accommodate patients when demand for transportation exceeds shuttle capacity.

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I would like to thank Professor Deborah Nightingale, for allowing me a wonderful opportunity to work with one of her students, Jordan Peck, PhD Candidate in ESD. Jordan gave me the chance to work on a healthcare project with the VA.

I performed research in healthcare under the guidance of Jordan, and in return, learned a great deal about the different techniques such as DES, engineering system design, and stakeholder analysis, in identifying the underlying problems of VISN1 transportation system from multiple aspects. This transportation project was built upon the work of MIT student teams who performed the lean analysis, whom I would like to acknowledge.

I would like to express my gratitude to the VA New England Healthcare System. From the Boston VA transportation department: Tracy Sweeney, Chief of Patient Transportation, Carol Mallard, and Vernalle Cannady, travel clerk. From the New England Veterans Engineering Resources Center (NE VERC): Janis Hersh, Co-Director of NE VERC and Kyaani Robinson, industrial engineer. From the clinical side: Dr. James Schlosser, Director of VISN Improvement Resource Office, Dr. Mary Daly, Chief of Ophthalmology, and Joan Clifford, Deputy Nurse Executive.

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List of Acronyms

avg – average

Bed Days of Care (BDOC)

DES - Discrete Event Simulation

JP – Jamaica Plains

MIT - Massachusetts Institute of Technology

NEHCEP - New England Health Care Engineering Partnership

pts - patients

std – standard deviation

VERC - Veterans Engineering Resource Center

VISN 1 - VA New England Healthcare System

I. Introduction

1.1 Veterans Affairs Healthcare System

The Veterans Affairs New England Healthcare System (VISN 1) is one of 21 Veterans Integrated Service Networks (VISNs) within the U.S. Department of Veterans Affairs (VA). VISN 1 is a healthcare system comprised of eight medical centers located in the six New England states:

- Connecticut - VA Connecticut Healthcare System
- Maine - Togus VAMC
- Massachusetts - Bedford VAMC, VA Boston Healthcare System, Northampton VAMC
- New Hampshire - Manchester VAMC
- Rhode Island - Providence VAMC
- Vermont - White River Junction VAMC

In addition, VISN1 has over 35 Community Based Outpatient Clinics (CBOCs), six nursing homes and two domiciliaries.

VISN 1's mission is to provide quality health care and related services to eligible veterans in New England. Comprehensive care offered by VISN1 includes primary care, acute medical and surgical care, psychiatric care, long-term care, nursing home care and ambulatory surgery and offer the full range of healthcare services from basic outpatient care to open heart surgery, radiation therapy, and kidney transplantation.

VISN1 covers an area with a total veteran population of approximately 1.3 million and employs approximately 10,000 staff. In addition, numerous clinical and administrative trainees assist them in providing care and services. Annually VISN1 treats more than 240,000 veterans and holds approximately 2.5 million outpatient appointments at Medical Centers and community based outpatient clinics.

1.2 VISN1 Mission, Vision, and Values

The following are stated in the VISN1 Resource Handbook.

Mission: Honor America's veterans by providing exceptional health care that improves their health and well-being.
Vision: To be a patient-centered integrated health care organization for veterans providing excellent health care, research and education; an organization where people choose to work; an active community partner' and a back-up for National emergencies.
Core Values: Trust, respect, excellence, compassion, and commitment.

1.3 VISN 1 Transportation services

The New England facilities have an integrated shuttle service to transport veterans between veteran's hospitals. Due to variation of specialty services offered at different locations, patients are often referred to other more distant clinics. Thus, many of the patients need transportation services between hospitals. The VISN1 transportation network provides free transportation for patients.

1.4 Literature Review

Two previous studies were conducted by group of MIT students on the VA transportation as part Prof. Nightingale's class: Integrating the Lean Enterprise (ESD.61/16.852J) in the Fall 2009, and Enterprise Architecting (ESD.38J / 16.855) in Spring 2010.

1.4.1 Fall 2009 Enterprise Analysis

The research evaluated how the VISN1 enterprise delivers value to stakeholders through the transportation process, and found opportunities to remove waste. Using the LAI's Enterprise Strategic Analysis for Transformation (ESAT) methodology, (MIT LAI 2008) the team evaluated the process flow in terms of resources, budgets, and cycle time, as well as information flows, technologies and metrics in identifying the following problems:

1. Specialty services are available only in hub medical centers.
2. Highly decentralized structure.
3. Little support from management to think about improvements requiring change.
4. Dearth of data and automation.

After a careful analysis of the problems, the team developed a Lean vision for the enterprise that delivers value to stakeholders in a more streamlined, waste-free manner. The following steps were identified in transitioning to the Lean Vision state:

1. Share knowledge, identify and spread best practices, metrics, and communication across VISN1.
2. Train executives, physicians, nurses, and transportation staff in continuous improvement methods so it can be integrated easily into their daily task force.
3. Have automated systems for scheduling and tracking to keep costs low while increasing productivity of staff members.
4. Look at patient transfer data to determine where specialty services can be added in the VISN to reduce demand for transportation.

1.4.2 Spring 2010 Enterprise Architecting Study

Building off the work of Fall 2009 team, the Spring team incorporated new metrics and insights using the enterprise systems architecting method to design and analyze enterprise architectures based on goals and the vision of the fall report. Using this method, the team took a holistic view of the large-scaled and complex system as well as its enterprise level interactions and socio-technical interfaces (Nightingale & Rhodes, 2004) to identify an ideal VISN1 transportation system. In particular, the ideal VISN1 transportation system

1. Normalizes patient flow throughout the day
2. Centralizes logistics and control of resources
3. Moves patients in small batches
4. Incorporates a communication strategy that ensures patients, facilities staff and transportation coordinators to have accurate up to date information.

Their research uncovered inefficiencies in the delivery of patients between medical centers, and highlighted practices with potential national adaptability.

1.5 Current study

These two reports brought attention to the VISN1 administration the need to improve the current transportation services through centralization, coordination and data collection. To follow up, the board requested New England Veterans Engineering Resource Center (NE VERC) to explore possible ways to implement changes to the current transportation system. As a result, the project described in the rest of this paper was initiated to further investigate the transport system from many stakeholders' point of views, collect data to analyze supply and demand, and apply systems engineering to offer possible solutions to the board.

II. Discrete Event Simulation

Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system (Shannon, 1975). Discrete Event Simulation (DES) is a powerful computing technique used to understand the behavior of systems. A system consists of entities that interact over time. Based on the verified and validated simulation model, different experiments with the model can be designed and run to gain insights into the behavior of the system and evaluate different strategies for operation of the system. DES allows modeling of the processes, entities and resources in a system leading to emerging dynamics, which, if programmed and validated correctly, resemble those of the true system.

Numerous studies show us that DES is being used as a tool to show improved results in a "what if" scenario. For this reason, DES has been widely used in many fields of research. In one study by Cheng and Duran (2004), DES and stochastic optimal control were used to provide decision makers with insights to evaluate various strategies for the design and operation on transportation of crude oil. Dealing with a large complex system, Chen and Duran (2004) decomposed it into individual subsystems for each demand location. Furthermore, the simulation model was verified to show that their model behaves as expected. They note, however, that more experiments should be conducted to validate the model using the data and observations collected from the statistics of the real system. This study mentions the need to validate simulation model through multiple experiments using data from real life. Another takeaway from this paper is that it was necessary to break down a large complex system into sub components.

DES studies can range from simple to complex. In a study done by Kolb, Lee, and Peck (2007), only one input and output was sufficient to accomplish the task of keeping track of walk-in patients in an emergency room. However, Peck (2008) analyzes more complex systems with various sub models that required multiple entities and resources. As a result, multiple metrics and stakeholders were taken into account.

III. Problem Statement

VISN1 covers a wide area varying from dense, urban centers to sparsely populated rural areas, making transportation a continuous challenge for VISN1. The problem is exacerbated by inconsistencies in patient scheduling systems across locations, decentralized organization of the transportation system, and a demanding patient population. These issues increase variation and prevent "efficient" transport of patients. We attempt to illustrate the current issues of the VISN1 transportation system.

The transportation problem was originally taken up by the VISN 1 Bed Days of Care (BDOC) due to concerns that transportation difficulties were causing patients to miss their shuttle home, incurring an unnecessary admission overnight and a great deal of stress for the patient. However what exactly should or could be done remained unclear. For this reason the BDOC approached the NE VERC for assistance. In response a team of MIT students performed a lean enterprise analysis of the VISN 1 transportation system.

3.1 Key Questions

Because each stakeholder had different complaints and it was unclear what the major problems were, an effort was taken to identify them. We focused on the following areas:

- Location of services – treatment requiring specialists are only offered in certain locations, mainly in Boston, the hub of VISN1, requiring patients to travel many miles.
- Transportation options – these include shuttles, individual pick up, public transit, and BeneTravel (reimbursement for patient travel). Can we combine or eliminate some of these options to reduce overall travel costs? Why are BeneTravel costs rising?

- Decentralized transportation system and budget – each hospital manages its own travel logistics, creating variation across board and discrepancy between who pays for transporting patients.
- Shuttle scheduling and routing –if coordinated with other campuses, resources (drivers, shuttles) required to transport patients can be reduced significantly.
- Data on patient movement and shuttle usage – if closely tracked, transportation costs can be determined.
- Patient demand – how to allocate resources efficiently while meeting individual need?
- Individual pick up – drivers have to travel many miles to pick up patients from rural area, when drivers are unavailable, contractors are sent to pick up patients

3.2 Stakeholders

To better understand the transportation system, it is important to look at it from the stakeholders' points of views and their performance metrics. We focused on the following areas:

- Patients would like to see reduced **wait time** at the clinics. When the shuttle arrives at clinics, patients are often not seen for many hours. Long wait times could lead to frustrations and increase of complaints. Furthermore, patients prefer decrease in **travel distances**. Lastly, shuttle patients would not want to have **missed appointments**, due to late shuttles or doctor cancellations. The doctor cancellations is especially detrimental to patients travelling many miles, because by the time doctors call in sick or leave, many of these patients have already left and are on their way to Boston. Improved coordination and data flow may allow such information as doctor's cancellation to reach the patients before they board the shuttle.

- Drivers tend to adhere to the schedule and to avoid **delayed shuttle departure times**. This problem can happen for two reasons. 1) Patients are not seen at their appointment times or 2) treatment complications can occur, requiring further treatments. However, frequency of such issues can be decreased by improved coordination of appointment and shuttle schedules.
- Clinicians would like to see a continuous **flow of patients** rather than large batch of patient arrivals. The current system is designed to have all shuttle patients arrive at once, spiking up services demand, leading to a supply demand mismatch and long wait times. This is

especially true for eye clinic, as most of the shuttle patients are eye clinic patients. Clinicians would like to see improved shuttle scheduling system that would ease patient flow and reduce backlog.

- The BDOC observation of **unnecessary admissions** is based on the instances when a patient's treatment or appointment is delayed beyond the times the shuttles are able to wait for the patients, leaving them behind.

- Transportation office would like to have an easy patient tracking system, in which they can identify the mode of transport the patient took, the starting and final destinations. The office is also interested in reducing **transportation costs**, while improving the current shuttle system to increase the satisfaction of the veterans.

IV. Simulation

As we are dealing with a large organization that cannot be easily changed, DES is used as an alternative to experiment and find potential improvements for the current transportation system.

4.1 Discrete Event Simulation for VA Transportation Network

In the current VISN1 VA transportation system, hospital patients spend a great portion of their healthcare time on travelling and waiting, categorized as non value added time, compared to the time they receive for actual care, which is value added time. Long waits and travel times not only drive up the cost of transportation but also create an inconvenience for patients using these services. Thus, it has become imperative to study ways to improve the existing transportation system. There are many factors that affect this system such as location of services, number of shuttles, frequency of shuttles, etc. To analyze the effects of these factors, I modeled a DES model of a simplified VISN 1 transportation system comprised of four VA hospital campuses: Boston, Manchester, White River, and Togus using Arena®, a commercial discrete event simulation modeling and analysis package developed by Rockwell Software (Kelton et al., 2007).

Arena is helpful in demonstrating, predicting, and measuring system strategies for effective, efficient and optimized performance. Using Arena is a good alternative to testing the changes in the system in virtual life (computer) versus in real life, of which can be both time and labor intensive. The simulation software was used to analyze the impacts of "what-if" scenarios, without causing disruptions in service on the following topics.

Another discrete event simulation software is Dynamic Network Assignment-Simulation Model (DYNASMART). DYNASMART was released by the Federal Highway Administration through McTrans in February 2007. DYNASMART is different from Arena in that its macroscopic simulation models do not keep track of individual vehicles. Rather, DYNASMART moves vehicles individually or in packets, keeping a record of the locations and itineraries of the individual entities, as noted in a study done by Mahmassani (2001).

4.2 Data Collection

Our study is based on the VISN1 New England Healthcare System, which provides free transportation to eligible veterans. There are eight medical centers across New England providing this service. Out of the eight, the VA Boston Healthcare System is the largest consolidated facility in VISN 1, which encompasses three main campuses: the Jamaica Plain campus, located in the heart of Boston's Longwood Medical Community; the West Roxbury campus, located on the Dedham line; and the Brockton campus, located 20 miles south of Boston in the City of Brockton.

Thus, it is not surprising to see massive volumes of patients come to VA Boston medical centers everyday. Of the many clinical services it offers, the eye clinic is highly demanded among the patients taking the shuttles due to the lack of eye clinic services offered elsewhere.

Patients arrive at Boston VA medical center using various modes of transportation, including individual cars, VA shuttles, contract or vendor shuttles, MBTA rides, wheelchair cars, and ambulances. For the purposes of this study, we will focus mainly on patients who come to Boston Medical Centers via VA shuttles.

4.2.1 Shuttle data

To better understand the shuttle system, we collected usage data was collected for trips to Boston from: Togus and White River Junction during May and June, Manchester during March through June, and Worchester during June. Appendix 2 shows the details of this travel data including the total number of patients and which clinics they used. Table 1 summarizes this data:

Table 1. Shuttle usage data during months of May through August 2010.

	Manchester	Togus	White River Jxn
Avg Patients/day	16.4	10.1	4.7
Std deviation/day	5.1	3.5	2.5
Avg Patients/month	343.3	176.0	89.5
Std deviation/month	37.0	7.1	14.8
Top clinics	Radiation, eye	eye	eye

With the knowledge of average and standard deviation of patients using the shuttles, I can calculate the supply and demand match between number of patients demanding transport and the number of seats available on the shuttle. I calculated the number of seats required on the shuttle to meet patient demand 68%, 95%, 99.7% of the time. These percentages correspond to 1, 2, 3 standard deviation from the mean respectively and can be expressed mathematically as

$$\mu \pm \sigma, \qquad \mu \pm 2\sigma, \qquad \mu \pm 3\sigma$$

where μ is the average and σ is the standard deviation. This can be also shown graphically in Figure 1.

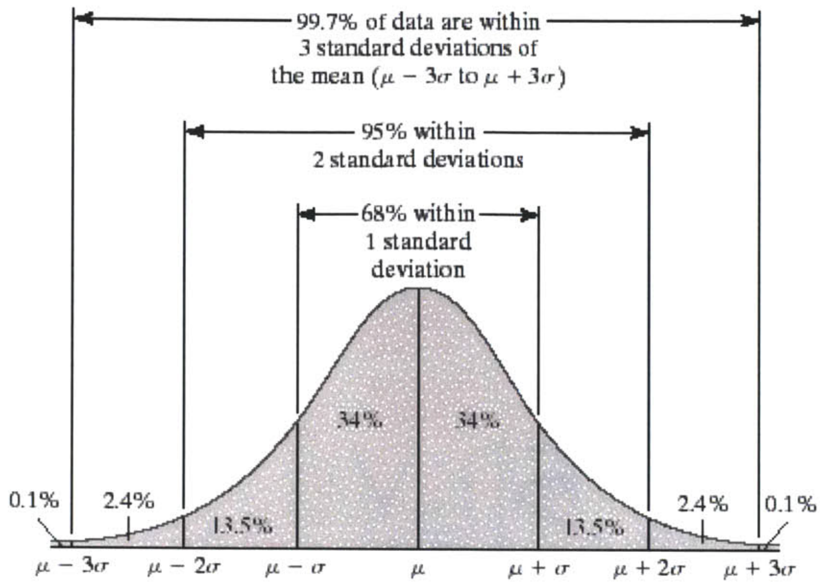


Figure 1. 68-95-99.7 rule.

Using the above equation and inputting the average and the standard deviation from Table 1, I obtained the following results in Table 2.

Table 2. Number of seats required to meet patient demand with a certain level of confidence on any particular day.

Demand	1 std dev, 68%	2 std dev, 95%	3 std dev, 99.7%
Manchester	22	27	32
Togus	14	17	21
White River Junction	7	10	12
Worchester	21	24	27

4.3 Schedules and Mapping

The eight main campuses spread throughout six New England states. These include the Boston Healthcare System, Connecticut Healthcare System, Togus VAMC, Bedford Veterans Memorial Hospital, Northampton VAMC, Manchester VAMC, Providence VAMC, and White River Junction (WRJ) VAMC.

The complexity and the breadth of the VISN1 shuttle transport system is shown in Table 1. Shuttle routes to Boston from three clinics with highest patient volume: Manchester, Togus, and White River are shown in Figure 2.

Figure 2. "Shuttle routes to Boston" Google Maps.

Table 3. Shuttle Schedule of VISN1 shuttles arriving and departing Boston

From	Arrival time	Departure time
Manchester	9:20 AM	12:00-3:30PM
White River	9:30 AM	2:30-3:00PM
Togus	11:00 AM	2:30-3:00PM

Creating an optimal scheduling system would take years of trial and error. To accurately model the system, we need to input real time data into the simulation software.

4.4 Process Flow

There are many processes in the transportation system. The primary process involves providing roundtrip services to veterans between non-Boston VA hospital and VA Boston. In this simulation, we examined the process from the use end point of view, from the start to finish. I used two entities in this system, the patient and the shuttle.

4.4.1 Top level

Top level refers to the VISN1 wide level. Figure 3 shows a picture of VISN1 (top level) with each individual medical centers (submodel): Manchester, Togus, White River, and Boston. Clicking on the submodel will take you to that particular hospital site.

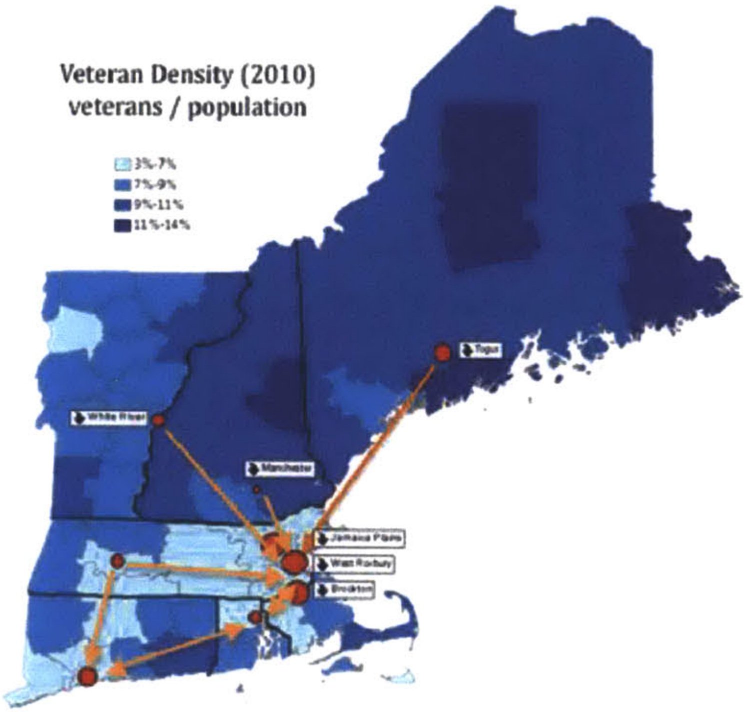


Figure 3. Top level map of VISN1 with sub models shown as blocks.

4.4.2 Submodel

Submodels refer to individual medical centers: Manchester, Togus, and White River. In all three cases, patient and shuttles are created using the same methods described below.

4.4.2.1 Patients

From left to right in Figure 4, patients are created via create module. The two subsequent record modules keep track of how many patients are created, and the time of creation their creation. The separate model then creates a duplicate of the patient entity. The patients then wait in queue until they are picked up by the shuttle.

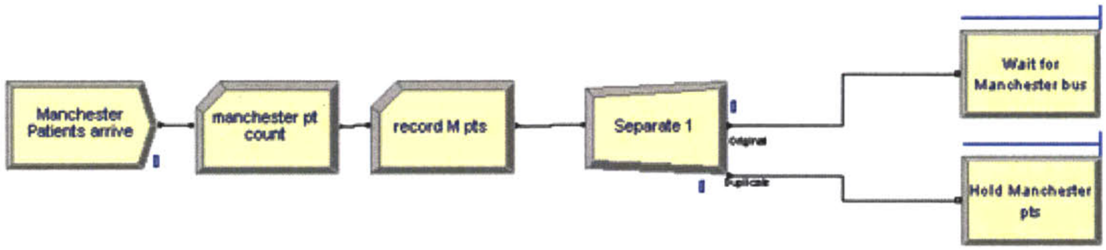


Figure 4. Patient entity creation.

4.4.2.2 Shuttles

From left to right on Figure 5, shuttle is created via create module. The two subsequent record modules keep track of how many shuttles are created, and the time of creation the creation. The decide module checks how many patients are currently in line waiting for the bus. If the number of patients waiting at the bus station is less than the capacity of the shuttle, the shuttle picks up everyone. If it if greater, the shuttle picks up only to max capacity of the shuttle. The shuttle then proceeds to Boston campus.

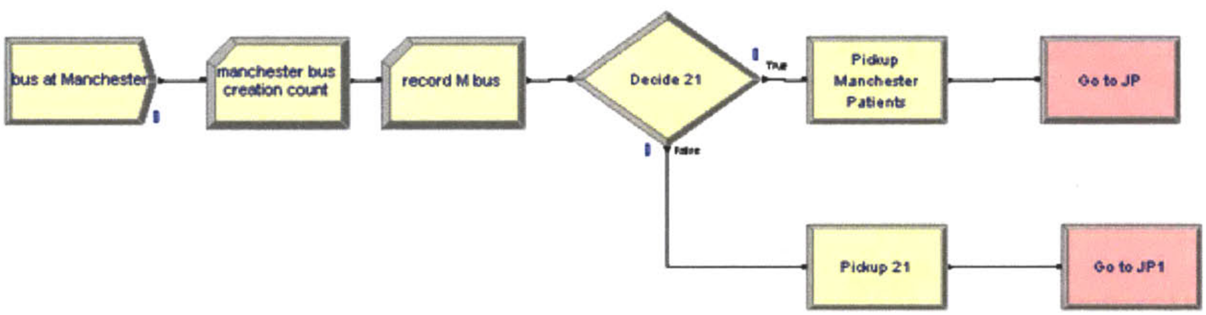


Figure 5. Shuttle entity creation.

4.4.3 Submodel: Boston

The VA Boston Healthcare System's consolidated facility consists of three campuses: Jamaica Plain, West Roxbury, and Brockton. Each campus has multiple clinics and resources. However, I have simplified it to one clinic for Boston to reduce complexity. Furthermore, patients can move freely between each of the three campuses using the internal shuttle services, thus maintaining the total number of incoming patients to Boston the same.

Boston is a much more complex network compared to the other three sites. Patients come to be treated from all over New England. Boston is known for its top quality services in many different areas.

All the shuttles arrive at Boston campus, then drops off the patients. The shuttles proceed onto the decision module, where it identifies each shuttle and filters to their respective waiting areas.

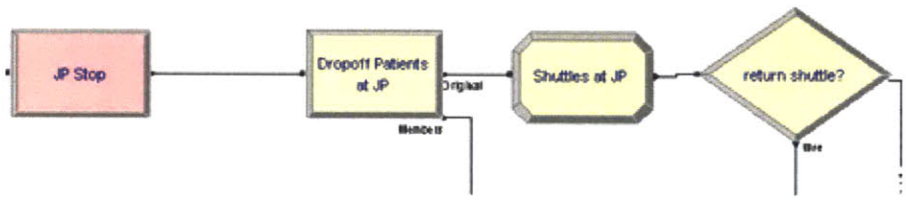


Figure 6. Boston campus, the hub of all the medical centers in VISN1.

Once the shuttles are filtered, the record module takes note of time of arrival at Boston campus. Hold module is used to hold the shuttle until all the patients the shuttle dropped off. Once all the patients are finished with their treatments, the shuttle picks up its patients from the waiting area and returns to their respective campuses.

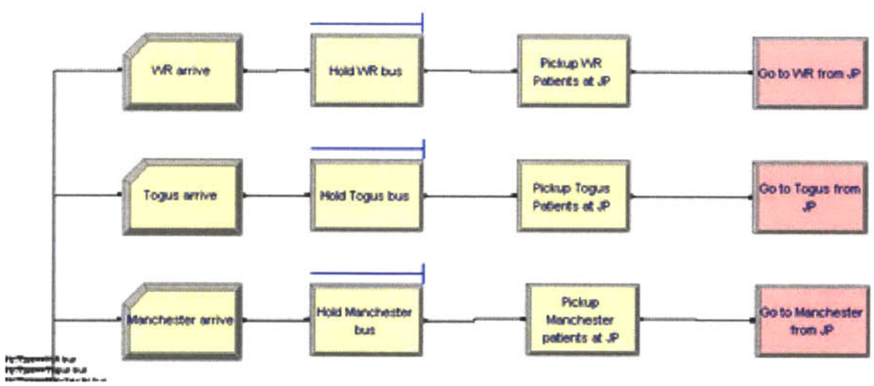


Figure 7. Shuttles wait in their respective areas until their patients are done with treatment.

On the patient side, after the patients are dropped off, a decision module decides whether the patient needs treatment or discharge. The patients who are discharged are those which Boston is a final destination. Most patients need treatment, and thus proceed. The patients gets treatment by seizing a resource, a doctor, for a given amount of time, determined by a triangular distribution ranging from 10 to 60 minutes. When no resources are available, the patient waits in queue until a doctor becomes available. Meanwhile, local patients from Boston are created by the create module. The time of creation is recorded. It then goes and waits in the same line as all the other shuttle patients to see a doctor.

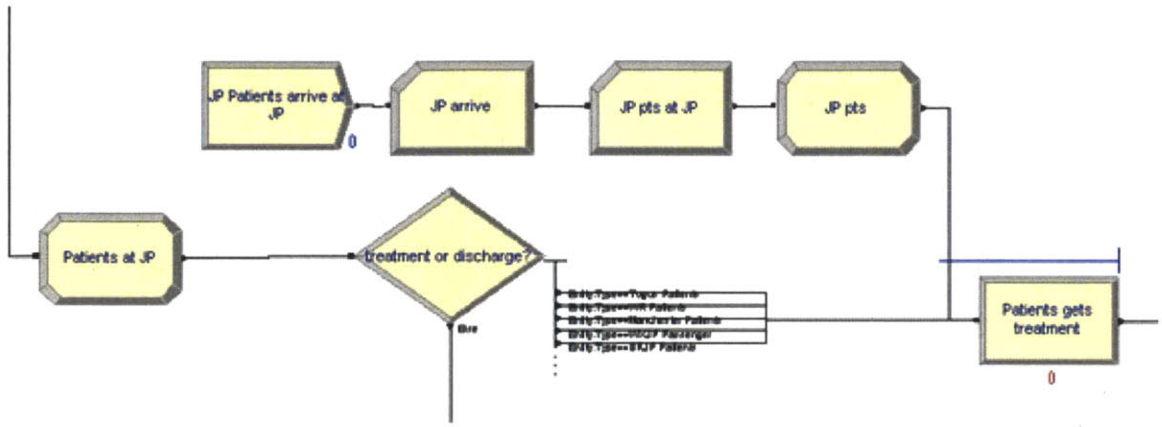


Figure 8. Local patients and shuttle patients get treated at Boston campus.

Once the patients are done with treatment, it goes through a decision block, which filters patients from different campuses and sends them to appropriate bus stations. After the patient gets treated, the time gets recorded. The shuttle patients wait at the bus stop until all the other patients from the same campus gets treated. The local patient gets discharged as they do not need to wait for a VA shuttle back home.

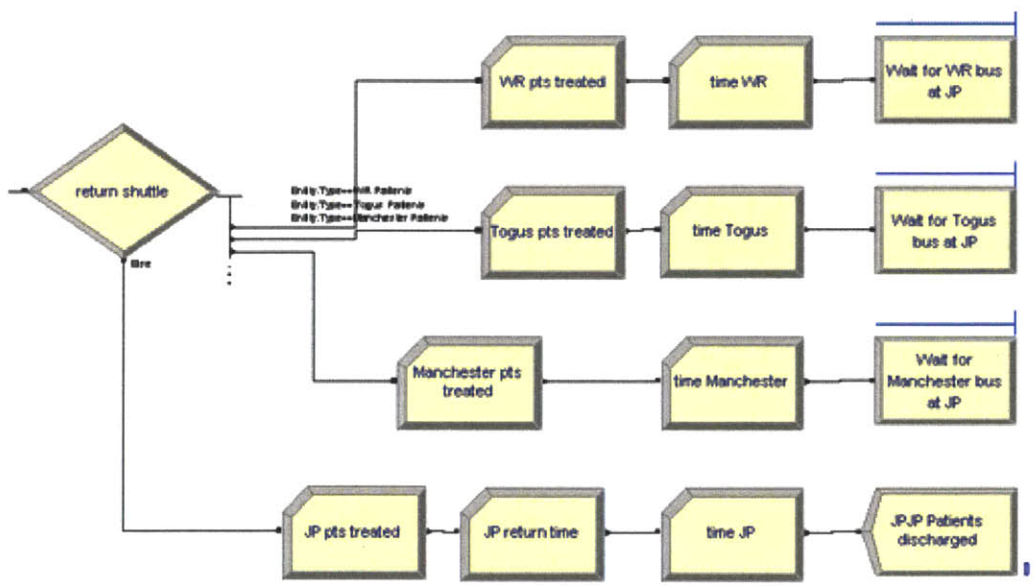


Figure 9. Decision module filters patients to its respective waiting shuttle stations.

4.4.4 Shuttle and patient return

After all the patients get treated, the bus picks up the patients, and returns to home campus. Once it arrives at each respective campus, the shuttle drops off all the patients. Finally, the shuttle and the patients exit the system via the dispose module.

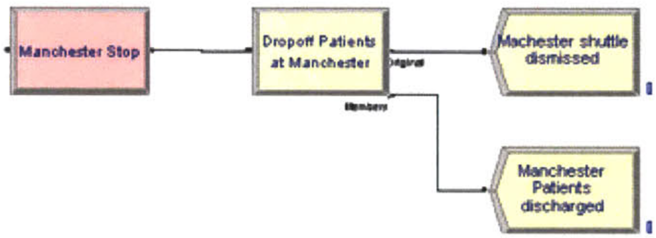


Figure 10. Shuttle returns, shuttle and patients exit the system.

1. Patient arrives at home VA hospital.
2. Patient **waits** for shuttle.
3. Patient gets on shuttle and leaves home VA to Boston VA at a designated time.
4. Patients get dropped off at Boston VA hospital.
5. Patient **waits** to get treated by doctors.
6. Patient gets treated. (only value added time)
7. If there exists more than one return shuttle, patient **waits** for the next leaving shuttle.
8. If there is only one return shuttle, patient **waits** until all other patients are done with treatment.
9. Patient gets on return shuttle and leaves Boston VA for home VA.

Four out of the nine steps mentions patients waiting, and two out of the nine mentions patients travelling. Only one step mentions patients getting treatment, the only value added time.

V. Analyzing Process Flow

In order to achieve the goal described above the team was tasked with creating a process map. There are many processes that occur in the transportation system on a daily basis, therefore one specific primary process was identified for the meeting, this process was that of transporting veterans from one (non-Boston) hospital, to VA Boston and back. Even this single process can become too large without setting specific boundaries. For this case the boundaries were set to start when a patient needs an appointment and stop when a patient is delivered back to the original hospital. The final process map can be found in appendix X.

VI. Validation and Verification of simulation models

It is important to verify the simulation model so that the behavior of the simulation model corresponds to a real system. Based on the verified and validated simulation model, I can design and run different experiments using the model to gain insights into the behavior of the system and evaluate different strategies for operation of the system.

6.1 Four Methods to validating a simulation.

One approach is for the model developer to make the decision as to whether a simulation model is valid. A decision is made based on results of various tests and evaluations conducted as part of the model development process. However, if there are only a small number of developers making this call, it is better to have developers interact with users of the model.

Another way is "Independent verification and validation" (IV&V), which uses a third party to decide whether the simulation model is valid. The third party is independent from both simulation developer and user, but should have a thorough understanding of the intended purpose of the simulation model to validate it. This third approach is mainly used for large-scale simulation models, involving several teams. The third party can conduct IV&V either concurrently with the development of the simulation model or after the simulation model has been developed. In the concurrent method, the developer receives input from third party regarding verification and validation while the model is being created. In the latter way, the IV&V is conducted after the model has been completely developed. In this case, the evaluation performed can range from simply evaluating the verification and validation conducted by the model development team to performing a complete verification and validation effort. This can be costly and time consuming.

The fourth method is using a scoring model. Scores are determined subjectively when conducting various aspects of the validation process and combined to determine category scores and an overall score for the simulation model. Simulation model is valid if its overall and category scores are greater than passing scores. However, this last method is rarely used.

6.2 Techniques used to validate and verify model

- Animation: model's operational behavior is displayed graphically as the model moves through time. Arena does this particularly well, and in my model patients and shuttles actions are displayed as can be seen on Figure 11.

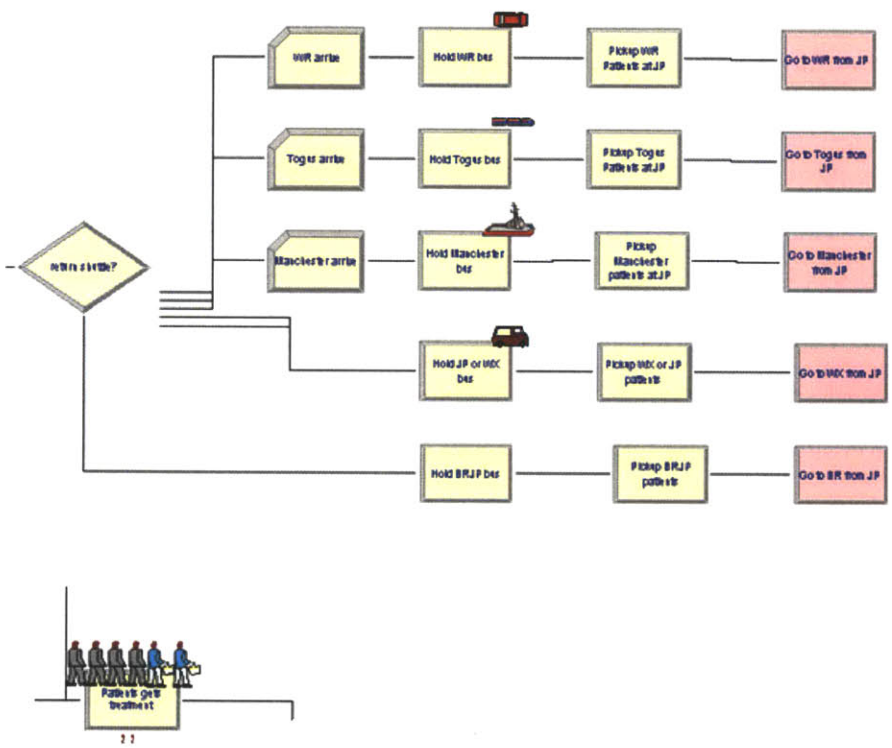


Figure 11. Graphic display of VISN1 transportation model as it moves through time.

- Degenerate tests: The degeneracy of the model's behavior is tested by appropriate selection of values of the input and internal parameters. In my model, I used values that were reasonable and within range of real parameters obtained from data collection.

- Event Validity: The events of occurrences of the simulation model are compared to those of the real system to determine if they are similar. My results closely matched the events of a real system.
- Extreme Condition Tests: The model structure and outputs should be plausible for any extreme and unlikely combination of levels of factors in the system. During control tests, I input extreme values such as having shuttles depart at 1am.
- Historical Data Validation: Data collected is used to build the model and determine whether the model behaves in accordance with the system. Shuttle data was collected and used to obtain results from the simulation to see if it behaves like the real system.
- Internal Validity: Several replication of a stochastic model are made to determine the amount of stochastic variability in the model. Large amount of variability may cause model's results to be questionable and if typical of the problem entity, may question the appropriateness of the policy or system being investigated. I ran several reiterations of my stochastic model to see that there was variation in shuttle arrival times at Boston due to road traffic.
- Operational Graphics: Values of various performance measures, such as number in queue and percentage of servers busy, are shown graphically as the model runs through time. Arena simulation shows in real time, the number of patients waiting in queue (Figure 12).

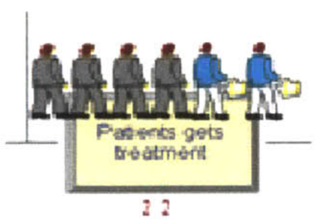


Figure 12. Shows number of patients in queue as model runs through time.

- Parameter Variability – Sensitivity Analysis: this technique consists of changing the values of input and internal parameters of a model to determine the effect upon the model's behavior or output. Different shuttle departure times were inputted to determine effects on patient waiting time.

- Predictive Validation: Model is used to predict the system's behavior, and then comparisons are made between the system's behavior and model's forecast to determine if they are the same. My simulation results were used to predict and confirm that patient wait times are reduced when shuttles arrive throughout the day rather than all at once.
- Traces: The behavior of different types of specific entities in the model are traced through the model to determine if the models' logic is correct and if they necessary accuracy is obtained. Behavior of shuttles and patients were tracked to determine my models' logic is correct and that it acted in correspondence to those behaviors in real system.

6.3 Graphical Data

The behavior data of the model and the system are graphed for various sets of experimental conditions to determine if the models' output behavior has sufficient accuracy for the model's intended purpose. Three types of graphs are used: histograms, box and whisker plots, and behavior graphs using scatter plots.

VII. Simulation Results: Shuttle Arrival Times

7.1 Control Test

To make sure my simulation is working properly, I ran a control test. When the variable "Mbus" is set to a value, it executes the simulation by inputting that value. The Manchester bus picks up 10 patients from Manchester site, departs at value of Mbus, and drops them off at Jamaica Plains (JP) campus. Then those patients are treated by doctors at JP by seizing a resource. After treatment, the Manchester patient wait at the Manchester bus station until all the Manchester patients are treated. Values in the four columns: Manchester pts treated, Togus pts treated, WR pts treated, and JP pts treated, show that 10 patients from each site are treated at JP. Table 4 shows the results of the control test from running the Arena simulation. Columns "record T bus" and "record WR bus" show values 7 and 8. This indicates Togus and White River shuttle arrival times at JP campus, at 7am and 8am, respectively.

Table 4. Results of control test after running Arena simulation.

	Scenario Properties				Control	Responses						
	S	Name	Program File	Reps	Mbus	record M bus	Manchester pts treated	record T bus	Togus pts treated	record WR bus	WR pts treated	JP pts treated
1		Scenario 1	36 : Boston T	10	1.0000	1.000	10	7.000	10	8.000	10	10
2		Scenario 1	36 : Boston T	10	2.0000	2.000	10	7.000	10	8.000	10	10
3		Scenario 1	36 : Boston T	10	3.0000	3.000	10	7.000	10	8.000	10	10
4		Scenario 1	36 : Boston T	10	4.0000	4.000	10	7.000	10	8.000	10	10
5		Scenario 1	36 : Boston T	10	5.0000	5.000	10	7.000	10	8.000	10	10
6		Scenario 1	36 : Boston T	10	6.0000	6.000	10	7.000	10	8.000	10	10
7		Scenario 1	36 : Boston T	10	7.0000	7.000	10	7.000	10	8.000	10	10
8		Scenario 1	36 : Boston T	10	8.0000	8.000	10	7.000	10	8.000	10	10
9		Scenario 1	36 : Boston T	10	9.0000	9.000	10	7.000	10	8.000	10	10
10		Scenario 1	36 : Boston T	10	10.0000	10.000	10	7.000	10	8.000	10	10
11		Scenario 1	36 : Boston T	10	11.0000	11.000	10	7.000	10	8.000	10	10
12		Scenario 1	36 : Boston T	10	12.0000	12.000	10	7.000	10	8.000	10	10
13		Scenario 1	36 : Boston T	10	13.0000	13.000	10	7.000	10	8.000	10	10
14		Scenario 1	34 : Boston T	10	14.0000	14.000	10	7.000	10	8.000	10	10
15		Scenario 1	36 : Boston T	10	15.0000	15.000	10	7.000	10	8.000	10	10

7.2 Control Test with real time variables

After verifying my results work using constant values, I tested my simulation using data from the real system. Instead of 10 patients for each location, I used standard and average deviation values derived from the months of patient shuttle usage data collection from each clinic (appendix 2).

Table 5. Shuttle Patient Data.

Home Clinic	Avg number of shuttle patients	Std
Manchester	16	5
White River	5	3
Togus	10	4

I did not have any information on the local patients from Boston, thus I used an exponential distribution of 10 patients throughout. This is to replicate behavior of local patients who arrive throughout the day rather than in batches like the shuttle patients.

Table 6. Travel times to Boston's main campus: 150 S. Huntington Avenue Boston, MA 02130

Home Clinic	Avg travel time to Boston	Std
Manchester 718 Smyth Road Manchester, NH 03104	0.9 hr	0.1 hr
White River Junction 215 North Main Street White River Junction, VT 05009	1.9 hr	0.1 hr
Togus 1 VA Center Augusta, ME 04330	2.9 hr	0.1 hr

The standard deviation accounts for traffic on the road and average travel time to Boston is derived from asking the drivers, confirmed by estimated travel time on Google maps.

Last but not least, the number of doctors was reduced to two. I chose this number after trial and error. Since I am not accounting for all the clinics present at Boston clinic, nor all the patients coming to Boston for treatment, I scaled the number of doctors proportionately to give a reasonable output time of shuttle departure time from Boston. In my simulation, as done at the VA, the drivers do not leave until all the patients he brought down are done with treatment, unless the patient is scheduled to stay overnight. A reasonable departure time frame lies between 12pm-4pm. The Jamaica Plains campus shuts down at 5pm so all the shuttle patients need to be escorted before then. Using 2 doctors yields departure times within the range.

Using all of these parameters, I ran the simulation using process analyzer, and got the following results:

Table 7. Results of control test ran with real time variables.

	Scenario Properties				Controls				Responses														
	S	Name	Program File	Reps	JPtime	Mbus	Wbus	Tbus	JP arrive	Manchester	WR arrive	Togus arrive	JP pts	Manchest	WR pts	Togus pts	time JP	time Manch	time WR	time Togus	Manchester return time	WR return time	Togus return time
1		Scenario 1	9 : varied time	10	4.0000	4.0000	4.0000	4.0000	4.000	4.892	5.794	6.580	10	16	6	9	1.411	3.654	4.669	6.099	11.273	12.949	16.688
2		Scenario 1	9 : varied time	10	5.0000	5.0000	5.0000	5.0000	5.000	5.912	6.586	7.822	10	16	6	9	1.442	3.533	4.909	5.839	12.232	14.031	17.753
3		Scenario 1	9 : varied time	10	6.0000	6.0000	6.0000	6.0000	6.000	6.886	7.754	8.728	10	16	6	9	1.578	3.854	4.992	6.339	13.500	15.300	16.859
4		Scenario 1	9 : varied time	10	7.0000	7.0000	7.0000	7.0000	7.000	7.892	8.849	9.862	10	16	6	9	1.421	3.580	4.985	6.439	14.336	16.434	17.933

Table 8. Description of terms used in control test.

Name	Meaning
JPtime	When local patients depart JP.
Mbus	When Manchester shuttle departs home clinic.
Wbus	When White River shuttle departs home clinic.
Tbus	When Togus shuttle departs home clinic.
JP arrive	When local patients arrive at JP.
Manchester arrive	When Manchester arrive at JP.
WR arrive	When White River arrive at JP.
Togus arrive	When Togus arrive at JP.
JP pts	Number of local patients treated
Manchester pts	Number of Manchester patients treated
White River pts	Number of White River patients treated
Togus pts	Number of Togus patients treated
Time JP	Total time of local patients waited at JP
Time Manchester	Total time of Manchester patients waited at JP
Time White River	Total time of White River patients waited at JP
Time Togus	Total time of Togus patients waited at JP
Manchester return time	Time Manchester arrives at home clinic
White River return time	Time White River arrives at home clinic
Togus return time	Time Togus arrives at home clinic

7.3 Staggered arrival times for one shuttle

To test the effects of varying shuttle arrival times, I worked with four different batches of patients: local, Togus, Manchester, and White River. I set one batch as a variable and the rest as constants. Then I ran the simulation using range of arrival times from 8am – 4am for the variable "Mbus" while having all other batches arrive at 10am and monitored how patient wait times varied.

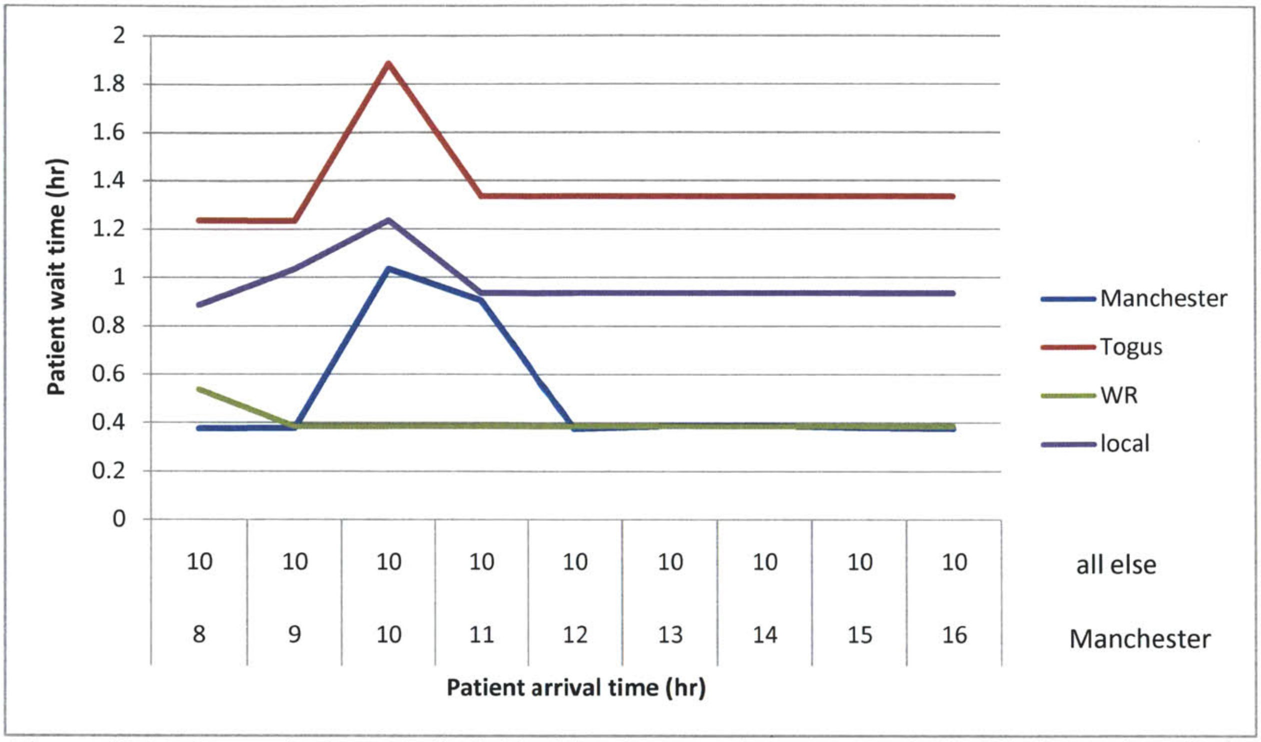


Figure 13. Patient wait times for individual batches are shown as result of differing arrival time of Manchester shuttle.

In this case, Manchester shuttle was chosen as the variable shuttle. The same trend will follow for any shuttle chosen. Notice in Figure 13 there is a sudden increase in patient wait time at hour 10, when all the shuttles arrive at once. When the Manchester shuttle arrives before the other shuttles at hour 8, the total patient wait time decreases for everyone. When Manchester shuttle arrives after the other shuttles, the overall patient wait time decreases, but is slightly higher than the previous scenario when it arrives before everyone else, as now Manchester patients have to wait in queue to be treated after the patients who arrived before them.

When patients arrive at the clinic, they have to wait in line to be treated when all the resources (doctors) available are seized by entities (patients). Patient wait time increases as more patients arrive but there is a limited number of doctors. This results in patient overload and subsequent delay. A similar study by Nagarajan, Vial, and Awyzio, (2002) points out that the delays occur due to the lack of resources available in the network. In their case, delays were caused by heavy traffic and overloading problems in the network.

7.4 Staggered arrival for all shuttles

In addition to changing arrival times for one shuttle at a time, I tested the effects of staggering arrival times for all shuttles. To determine which shuttles to arrive first, I took a look at the distance required to travel to Boston campus.

Table 9. Distance and hours required to travel to Boston campus via shuttle.

From	Distance	Shuttle Travel Time
Local	<5 mi	N/A
Manchester	52.7 mi	1 hr
White River	133 mi	2 hr
Togus	170 mi	3 hr

From this information, it made sense to have the patients arrive in order of their proximity to the Boston campus. This way, patients and drivers can leave at more reasonable hours from their home clinic, unlike the current model which forces them to leave early in the morning. After determining order of shuttle arrivals to Boston, I tested time intervals between shuttle arrivals.

Table 10. Simulation results of varying time intervals between shuttle arrivals.

	Scenario Properties				Controls				Responses											
	S	Name	Program File	Reps	JPtime	Mbus	Wbus	Tbus	JP arrive	Manchester arrive	WR arrive	Togus arrive	JP pts treated	Manchester pts treated	WR pts treated	Togus pts treated	time JP	time Manchester	time WR	time Togus
1		Scenario 1	13 : varied tim	10	7.0000	6.5000	6.0000	5.5000	7.000	7.371	7.809	8.277	10	16	6	9	1.524	4.200	5.800	7.631
2		Scenario 1	13 : varied tim	10	7.0000	7.0000	7.0000	7.0000	7.000	7.892	8.849	9.862	10	16	6	9	1.421	3.580	4.985	6.439
3		Scenario 1	13 : varied tim	10	7.0000	7.5000	8.0000	8.5000	7.000	8.462	9.741	11.279	10	16	6	9	1.404	3.131	4.218	5.199
4		Scenario 1	13 : varied tim	10	7.0000	8.0000	9.0000	10.0000	7.000	8.955	10.771	12.771	10	16	6	9	1.448	2.815	3.849	4.382
5		Scenario 1	13 : varied tim	10	7.0000	8.5000	10.0000	11.5000	7.000	9.428	11.725	14.292	10	16	6	9	1.440	2.555	3.209	3.331
6		Scenario 1	13 : varied tim	10	7.0000	9.0000	11.0000	13.0000	7.000	9.908	12.823	15.874	10	16	6	9	1.441	2.065	2.195	2.009

Having local patients arrive at 7am in all scenarios, I spaced out the subsequent shuttle arrivals in increments ranging from 0.5 hr to 3 hr and monitored resulting patient wait times. As expected, increase in time between shuttle arrivals decreased overall patient wait time.

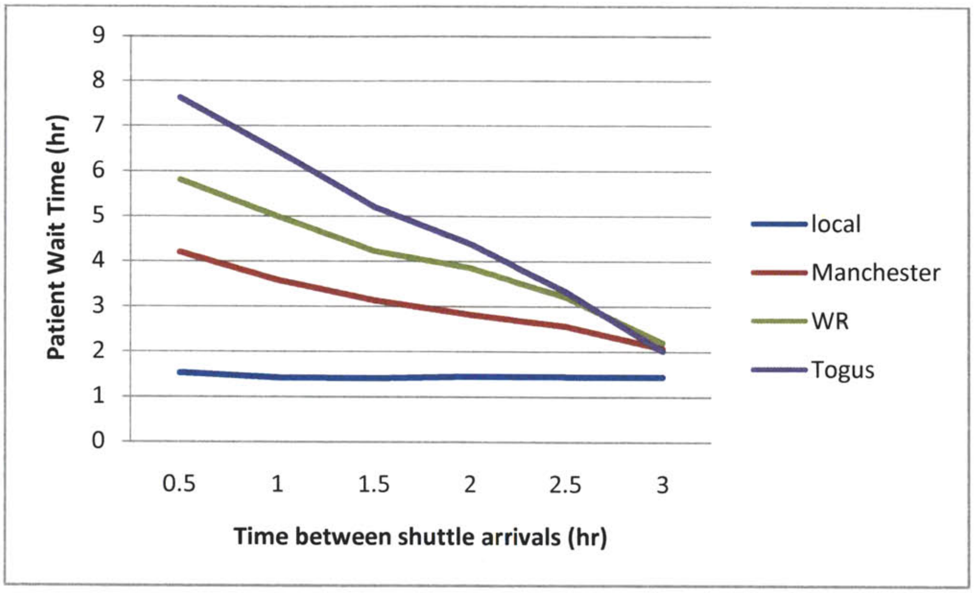


Figure 14. Patient wait time decreases as time between shuttle arrivals increases.

Togus patients experience the greatest benefit, where 3 hour gap between shuttle arrivals can reduce wait time as much as 75%.

7.5 Summary Report

Currently at Boston all the shuttles arrive at once around 10am. This simulation was tested to show that patient wait time spikes up as a result. However, when shuttles arrivals are staggered throughout the day, spreading out patient demand, patient wait time can be reduced dramatically. As simulation results shows us, wait time is at its lowest when the gap between each shuttle arrivals is the greatest.

7.6 Implementation

The results are proven to work via simulation model, but in order to implement this change, we must also first take a look at each of our stakeholders' viewpoints. Simulation results may promise great things, but it will only be truly appreciated when it is implemented.

7.7 Stakeholders

- Patients would appreciate that they will no longer wait as long in the hospital as before. Also, by having shuttles arrive at different times of the day, we can adjust the schedule accordingly so patients do not have to leave so early. Currently, Togus shuttle departs at 7am to make it to Boston by 10am. For Togus patients to catch the 7am shuttle, many have to leave their homes as early as 4am. With the staggered shuttle arrival times, Togus shuttle can arrive at Boston as late as 1pm. Back tracking, the Togus shuttle can leave its home station at 10am. Togus patients can now leave their homes at 7am, a much reasonable hour than 4am. With the wait time decrease in wait time of 3 hours, the Togus patients are still done by 5pm, arrive at Maine campus by 8pm, and their respective homes by 11pm, opposed to 10pm with the current system.

Meanwhile, the local patients can arrive early on campus at 8am and be guaranteed to be done with their treatment by 10am, which removes the frustration of having to wait all day long for shuttle patients to be treated first.

- Drivers wait time would be decreased as a result of decrease in patient wait time. Currently, drivers have to wait until all the patients are done with their treatments. These drivers have to wait long, with nothing to do. With the new staggered arrival system, their wait time will be reduced, along with patient wait time.

- Clinicians would still treat the same number of patients per day, but the patient demand will be spread more evenly throughout the day. No longer will all the patients be arriving all at once causing unnecessary stress. Clinicians and nurses will deal with less stressed patients as patients' overall wait time decreased significantly.

- Transportation office would benefit from higher productivity rates of the drivers. This will ultimately drive down the cost to transport each patient.

- VISN1 Serving the veterans is the reason VA healthcare exists. If overall patient satisfaction increases, VISN1 will receive positive public press, and praise from local congressman.

VIII. Simulation Results: Shuttle Capacity

The VA Healthcare Transportation Services make every effort to accommodate the veterans, even at the last minute. When a veteran needs shuttle services from home clinic to Boston clinic, the appointment is made ahead of time to avoid last minute hassle. However, these mishaps still occur. Patients forget to set up the appointment ahead of time, and show up on the day of the appointment with no other means of transportation. When this occurs, the transportation staff has to run around to find available driver and vehicle to take the patient to designated hospital. This costs the VA time and money, as often last minute scheduling means paying drivers overtime, or renting a lease vehicle if no VA shuttles are available. To avoid this mishap, I took a look at patient demand and supply.

8.1 Manchester

Based on data collection of Manchester shuttle patients from March to June, 2010, the only data readily available at the time of collection, I obtained the following values:

- average number of patients/day = 16, std = 5
- average number of patients/month = 343, std = 37

With current shuttle capacity of 14, 8, and 4 passengers, it is necessary 66.67% of the time to send down a combination of 2 vans whenever patient demand exceeded 14 (occurred 56 out of 84 days). To have 68% confidence level that all the patients scheduled for a particular day will have a seat, there needs to be enough room for 22 patients. For 95% and 99.7%, there needs to be room for 27 and 32 patients, respectively.

8.2 Togus

Based on data collection from May to June, 2010, I obtained the following values:

- avg. number of patients/day = 10, std = 4
- avg. number of patients/month = 176, std = 7

With current shuttle capacities of 3 vans which seats 9, 14, and 20 passengers, we are 95% confident that single 20 passenger van would meet demand. Passenger demand was met 100% of the time with the 20 passenger van, during the months of May and June. During second week of August, the 20 passenger van broke down, and two 10 passenger buses were used.

8.3 White River Junction

Based on data collection from May to June, 2010, I obtained the following values:

- avg. number of patients/day = 5, std = 3
- avg. number of patients/month = 90, std = 15

With current shuttle capacities of 3 vans which seats 10, 10, and 20 passengers, we are 95% confident that one 10 passenger van would meet passenger demand. Only 2.6% of the time (1 out of 39 days), did WRJ exceeded 10 patients and had to use the 20 passenger van. Passenger demand was met 100% of the time, during the months of May and June.

8.4 Simulation

The above results can be replicated using simulation. Using the statistics from the data collection, and shuttle capacities, I was able to show that not all patients can get picked up in one shuttle. As the bigger vans tend to break down often and often out of service, I chose the van sizes that are most frequently used for the three sites: Manchester, 14 patients, Togus, 9 patients, and White River, 10 patients.

Table 11. Simulation results for limited shuttle capacity.

	Scenario Properties				Responses					
	S	Name	Program File	Reps	manchester pt count	Manchester pts treated	togus pt count	Togus pts treated	WR patient count	WR pts treated
1		Scenario 1	7 : limited shuttle capacity.p	10	18	14	10	8	4	4

As can be seen in Table 11, patient count does not always equal the number of patients treated. The discrepancy between the two values indicates that not all the patients were picked up due to limited space on the shuttle. On average, 18 Manchester patients needed a ride, but only 14 were picked up and treated at Boston. Likewise, 10 Togus patients needed a ride, but only 8 were picked up. Lastly, 4 White River patients needed a ride, and all of them got a ride. The simulation results show that on average, two vans are needed per day to accommodate both Manchester and Togus patients, while only one is needed for White River. My simulation accurately reflects the true system as the results confirm the numerical calculations performed earlier.

IX. Conclusion

VISN 1 provides transportation to eligible veterans in need of assistance travelling from home to designated medical center. Escalating costs of transportation, increasing number of patients staying overnight due to missed shuttles, and past MIT research brought attention to the VISN1 executive board that there was a need to change the current system. With the recent focus on improving patient flow, there exists strong support for change.

Two scenarios were tested: staggered shuttle arrival times and shuttle capacities. A simulation model of the VA transportation was created to test the different parameters without the need of disturbing the real system. The simulation was then validated and verified using techniques stated previously. After a careful analysis, the following trends were identified: 1) staggered arrival times decreased patient wait times 2) when patient capacity exceeded shuttle capacity, more than one shuttle was necessary to accommodate patients' transportation needs. These findings fully support recommendations made in the MIT reports in Fall 2009 and Spring 2010.

If the recommendations are implemented to the current VISN1 transportation system, patients and drivers would experience less wait time, clinicians would see more evenly spread out patient demand, and transportation will see reduction in overall costs.

X. Future Work

In August 2010, Tracy Sweeney, the Chief of Patient Transportation, and I have put together a proposal to the Central Business Office to be part of the new Veterans Transportation Service Pilot Program dedicated to enhancing existing transportation programs of local VA Medical Centers. As a result, VISN1 was chosen to be a pilot site to improve its current transportation systems. The amount of $307,851 has been awarded to launch this new pilot project which demands a list of suggested performance improvement metrics (Appendix 1).
This would be a great opportunity for VISN1 transportation to implement the changes as recommended in this paper.

I would also like to explore the cost of transporting patients. Cost metric can be used to prioritize routes and the distribution of services throughout VISN1. However, I was not able to use the cost metric due to some difficulties in obtaining cost data. Due to the variance in how transport is managed and funded at each hospitals there was little consistency in how the funds are broken down. To gain a comprehensive view of the transportation costs, I imagine the most common costs associated with VA transportation stems from salaries to staff members (drivers, travel clerks, shuttle desk worker), maintenance of vehicles, contract services including ambulance services and lease of vehicles from the government, and Benetravel, a reimbursement system for patients who provide their own means of transportation.

Appendix 1

Metric Name	Method (Discussion)
Cost per Patient Mile	Total costs divided by total patients carried (to/from) multiplied by total patient miles traveled
Average Cost per Patient Trip	Cost divided by total number of trips
Average Cost per Passenger Trip	Cost divided by total number of trips
Beneficiary Travel Cost Avoidance	Compare notional estimate of BT reimbursement per trip, versus Average Cost per Trip
Unique Patients	Count of unique patients utilizing VTS
Patients	Count of patients utilizing VTS (includes repeat users)
Average Trips per Month per Patient	Average number of trips per patient measured on monthly basis
Miles Traveled	Aggregation of total miles traveled
Average Length of Trip	Average duration per trip (may be very difficult)
Average Vehicle Capacity Used per Trip	Percent of Capacity Utilized per each trip ((actual riders)/(total number of trips by total seats))*100
Number of Patients Picked up at Home	Count of patients picked up at home (versus trunk route)

Continued…

Number of Immobile Patients Transported	Count of immobile patients transported
Average (and total) Family Attendants per Trip	Count of family attendants (total) and total/number of trips
Average (and total) VA Escorts per Trip	Count of VA escorts (total) and total/number of trips
Veteran Satisfaction	Patient Satisfaction Postcard on VTS vehicle (incl. dependability, cleanliness, comfort, driver, likelihood to continue use)
Helped Make Appointment	Patient Satisfaction Postcard on VTS vehicle
Has Patient Missed Appointment b/c of Transportation	Patient Satisfaction Postcard on VTS vehicle
Missed Appointment Percent	Measured from cohorts of patients (pre/post)

Appendix 2

Togus Shuttle (May, 2010)

Clinics visited	3-May	4-May	5-May	6-May	7-May	10-May	12-May	13-May	14-May	17-May	18-May	20-May	24-May	25-May	26-May	27-May	28-May	total/month	% of pts
eye clinic	1	2		3	2	1		3	3		4	3		2		1	2	27	15.8
ENT			1	1	1	1	1	3	2			3	2			1		16	9.4
VASC				3				1				5				5		14	8.2
ortho		1	1	1		1		1	1		3	1	2	1	1			14	8.2
surg	1	1	1				2	1		3	1		2	2				14	8.2
neuro			4				3						2		3	1		13	7.6
pre-op		2		1	1	1		1		2	1				1		1	11	6.4
visitor				3	1		1		1	2	1		1		1			11	6.4
heme/oncol	1	1	1			2	1	1			1	1		1				10	5.8
derm		1				1			1	2	1		1			1	1	9	5.3
lodge		1								2								3	1.8
post-op		2												1				3	1.8
plastics				1				2										3	1.8
urol						1	1								1			3	1.8
thor											1			2				3	1.8
cardiology			1							1								2	1.2
pacemaker										1			1					2	1.2
CT scan											1			1				2	1.2
echo																1		1	0.6
allergy		1																1	0.6
Pulm			1															1	0.6
dental				1														1	0.6
gi clinic														1				1	0.6
podiatry																	1	1	0.6
arrhythmia												1						1	0.6
risk asmt															1			1	0.6
nuc mdcn																1		1	0.6
renal						1												1	0.6
motility				1														1	0.6
pain clinic																			
	3	12	10	15	5	9	9	13	8	13	14	14	11	11	8	11	5	171	
																	avg/day	10.1	
																	std/day	3.5	

Togus Shuttle (June, 2010)

clinics visited	1-Jun	2-Jun	3-Jun	4-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	14-Jun	16-Jun	17-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	29-Jun	total/month	% of pts
eye clinic	4	1	1	1	1	1		2		2	1	1		2		2	1	3	23	12.7
pre-op	1				3	1	2			1	2		2	2	2			2	18	9.9
derm	1	1	1	1					1	1			2	3	1		1	2	15	8.3
neuro		1				1	3		2		2	1	1		3			1	15	8.3
surg	2									2	4		1	3				2	14	7.7
VASC			2									6				4			12	6.6
ortho			1	1					2	1				2		2			9	5.0
ENT				1			1	1	2							2	1		8	4.4
visitor		1						2	1	1						1	1		7	3.9
heme/oncol			1									2	1	1				2	7	3.9
lodge			2			2	1			1									6	3.3
plastics			1					1				1				3			6	3.3
cardiology			1			1	1				2	1							6	3.3
thor	1						1							1				2	5	2.8
radiation				1				1	2										4	2.2
post-op														1				2	3	1.7
allergy				1		2													3	1.7
echo	1														1				2	1.1
radiology		1			1														2	1.1
pacemaker													1		1				2	1.1
CT scan	1																	1	2	1.1
Pulm		1	1																2	1.1
podiatry				1													1		2	1.1
urol														1					1	0.6
dental																1			1	0.6
gi clinic									1										1	0.6
genetic				1															1	0.6
arrhythmia						1													1	0.6
risk asmt							1												1	0.6
ep										1									1	0.6
nuc mdcn														1					1	0.6
pain clinic																				
	11	6	11	8	5	9	10	7	11	10	11	12	8	17	8	15	5	17	181	
																		avg/day	10.1	
																		std/day	3.6	

White River Junction Shuttle (May, 2010)

clinics visited	3-May	4-May	5-May	6-May	7-May	10-May	11-May	12-May	13-May	14-May	17-May	18-May	19-May	20-May	21-May	24-May	25-May	26-May	27-May	28-May	total/mon	% of pts
eye clinic	1	2	3	1	1	2	5	5	3	3	5	3	3	3	4	2	1	3	5	1	56	70.9
neuro			2						1				2	1				1		1	8	10.1
ortho							1	1	1					1			1		1		6	7.6
pre-op									1				1								2	2.5
radiation & oncology															1				1		2	2.5
women's clinic												1							1		2	2.5
surg																1					1	1.3
CT scan													1								1	1.3
plastics																			1		1	1.3
pain clinic																						0.0
kidney																						0.0
mamogram																						0.0
derm																						0.0
dental																						0.0
urology																						0.0
ultrasound																						0.0
thorasic																						0.0
eye surgery																						0.0
heart clinic																						0.0
alergy																						0.0
x-ray																						0.0
	1	2	5	1	1	2	6	6	6	3	5	4	7	5	5	3	2	4	9	2	79	
																				avg/day	4.0	
																				std/day	2.2	

White River Junction Shuttle (June, 2010)

clinic visited	1-Jun	2-Jun	3-Jun	4-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	14-Jun	15-Jun	16-Jun	17-Jun	21-Jun	22-Jun	24-Jun	25-Jun	29-Jun	30-Jun	total/month	% pts
eye clinic	4	2	3	2	2	7	5	2	3	2	5	2	7	2	7	8	4	2	2	71	71.0
neuro							1				1		1		1		1			5	5.0
surg										1					2			1		4	4.0
ortho						1			1		1				1					4	4.0
radiation & onocology																1	1			2	2.0
dental				1											1					2	2.0
pain clinic		1																		1	1.0
kidney																			1	1	1.0
mamogram																			1	1	1.0
derm																		1		1	1.0
pre-op												1								1	1.0
women's clinic														1						1	1.0
urology													1							1	1.0
ultrasound											1									1	1.0
thorasic											1									1	1.0
eye surgery										1										1	1.0
heart clinic					1															1	1.0
alergy				1																1	1.0
x-ray			1																	1	1.0
	4	3	4	4	3	8	6	2	4	4	9	3	9	3	12	9	6	4	4	101	
																			avg/day	5.3	
																			std/day	2.8	

Manchester Shuttle (March, 2010)

clinics visited	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	15-Mar	16-Mar	17-Mar	18-Mar	19-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	29-Mar	30-Mar	31-Mar	total/month	% visited
eye clinic		4		4	2	1	2	1	1	2	1	6	4	3	2	1	2	1	4	1		2	2	46	13.0
radiation	4	1	2	2	1	5	1	1	1	1	3	1	1	1	1	2	2	1	1	1	1	2	1	37	10.5
ortho	3	1	2	3	1		3		2	1	2	1		3			5		1	1	1	1	2	33	9.3
neuro	1	2	2	1	2	4		4	4			1	2	1	2	1		1		2				30	8.5
pain clinic		2	1	3		1	1	2			1	2	4	1	1	1	1	1	2		1		2	27	7.6
pre-op		1	2	2			1	1				1	3	1			3	1			2	2	3	23	6.5
surg	1	4	2				4		1			2		1			1				1	1	1	19	5.4
VASC	1		2	1					3				1	3		1		1	3	1			1	18	5.1
cardiology	2	1			2	1					1		1		2	1							1	12	3.4
mhc	1				1	1		1		1	2				1	1				1	2			12	3.4
sds						2	1	1	1		1								1				2	9	2.5
plastics				2					1					2					3					8	2.3
ENT	1		1	1	1				1				1		1			1						8	2.3
endo		1					1	1	1			1				1						1		7	2.0
urol					1									1		1	1	1	1		1			7	2.0
pacemaker	1	2				1					1				1	1								7	2.0
ultrasound		1		1								1	1	1				1					1	7	2.0
derm		1									1		1	1					1					5	1.4
CT scan				1								1						1				1	1	5	1.4
thor		1															2					2		5	1.4
dental						1					1					1					1	1		5	1.4
nuc			1	1									1											3	0.8
renal	1												1											2	0.6
gi clinic		1														1								2	0.6
podiatry															1	1								2	0.6
rms						1	1																	2	0.6
echo	1						1																	2	0.6
Pulm																		1						1	0.3
cath																	1							1	0.3
emg																						1		1	0.3
radiology	1																							1	0.3
bariatric						1																		1	0.3
c&p						1																		1	0.3
mri													1											1	0.3
ptsd																1								1	0.3
rehab																	1							1	0.3
sleep																	1							1	0.3
sci																			1					1	0.3
																								349	
	18	23	15	22	11	20	16	12	16	5	14	17	22	19	12	15	20	11	18	7	10	14	17	349	
																							avg/day	15.4	
																							std/day	4.7	

Manchester Shuttle (April, 2010)

clinics visited	1-Apr	2-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	19-Apr	20-Apr	21-Apr	22-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr	total/month	% visited
radiation	4	6	3	6	1	7	5	9	12	7	6	7	8	4	7	4	3	8	5	7	5	124	39.0
eye clinic	1	2		2		3	2	4	3	2	1	1	2	2	3	1		3	3	4	2	41	12.9
ortho	2	3	1	3		3	2	1	5	1	1	2	2		1	1	1	4	1	2		36	11.3
surg			3	4	1				4	2	2		1	5	1			3	2			28	8.8
pre-op	1	1	1	1		1	1	1	3		1		1	1	1	2		2	1			19	6.0
cardiology		2	2		2	2		2				3	1	1		1			1		1	18	5.7
ENT	2		1			3	2			1		3				2	1				1	16	5.0
pain clinic	1					1		2			3	1	1		1	1			3	1		15	4.7
neuro		1				2		1		2		2	1	1			1	1	1	2		15	4.7
plastics	2					2					1					1				4		10	3.1
mhc		1	3				1	1			1	1					1				1	10	3.1
VASC	1					1				1	2				1				1			7	2.2
pacemaker			2	1				1			1						2					7	2.2
sds	1		1			1	1				1								1			6	1.9
urol									1		1									1	1	4	1.3
CT scan				1						1		1										3	0.9
renal														1	1				1			3	0.9
gi clinic				1				1				1										3	0.9
post-op	1													1								2	0.6
derm							1							1								2	0.6
Pulm												1				1						2	0.6
dental										1	1											2	0.6
ultrasound																				1	1	2	0.6
endosc	1														1							2	0.6
rsch study														1		1						2	0.6
rheum	1																					1	0.3
thor				1																		1	0.3
pcc																		1				1	0.3
podiatry					1																	1	0.3
allergy							1															1	0.3
wm's hlth													1									1	0.3
intake			1																			1	0.3
rt cons														1								1	0.3
motility																				1		1	0.3
rt f/u																				1		1	0.3
echo																					1	1	0.3
mri																					1	1	0.3
	18	16	18	20	5	26	16	23	28	18	22	23	18	19	17	15	9	22	20	24	14	391	
																					avg/day	18.6	
																					std/day	5.3	

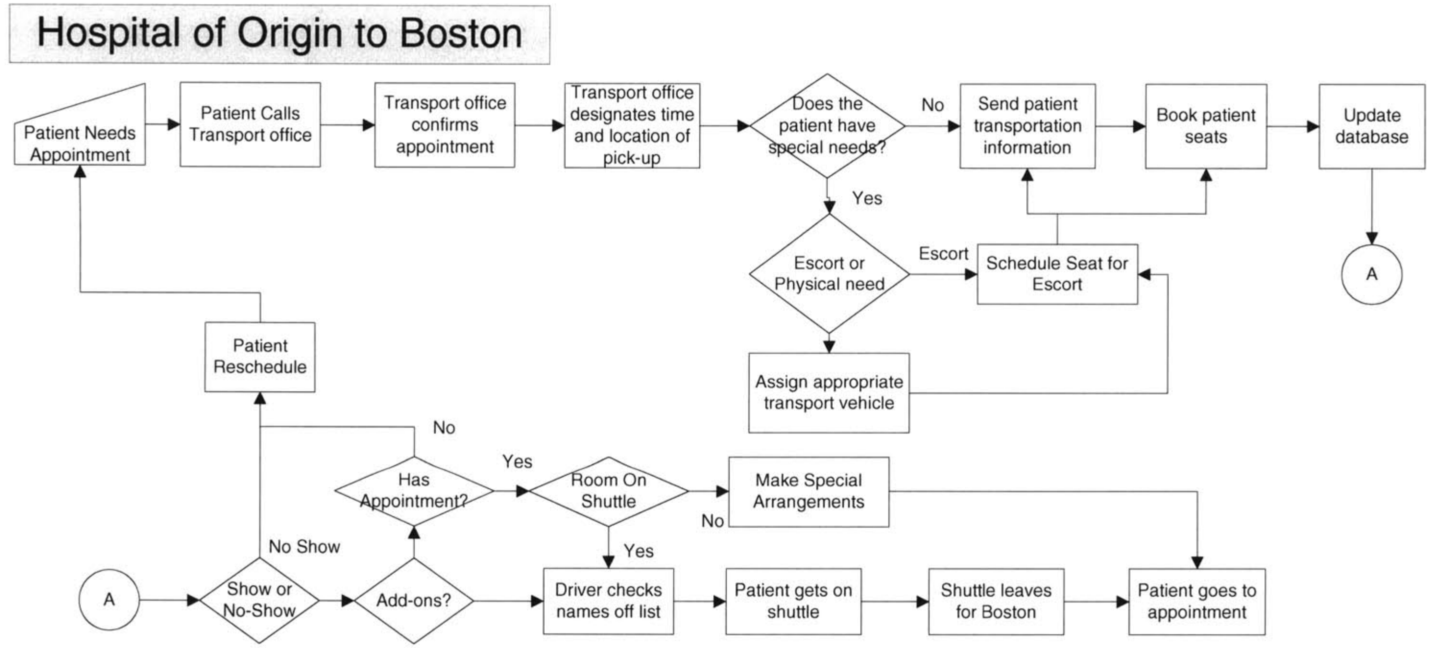
Manchester Shuttle (May, 2010)

clinics visited	3-May	4-May	5-May	6-May	7-May	10-May	11-May	12-May	13-May	14-May	17-May	18-May	19-May	20-May	21-May	24-May	25-May	26-May	27-May	28-May	total/month	% visited
radiation	3	3	2	2	1	3	2	2	1	2	3	3	2	2	1	3	3	2	3	2	45	13.6
ortho	2	2	3	3	1	1	4		4	1	2	4		4		1	5	3	2	1	43	13.0
eye clinic	1	2	1	2		1	2		3	1	2		3		3	2	7	2	1		33	10.0
pain clinic		1	3	4		1	2	3	3			1		1				1	1		21	6.4
cardiology	1					1	1			1	2	1	1	1	3		1	1	3	1	18	5.5
surg		3		2	1	1	3		1			1	1	1		1	2				17	5.2
VASC			2	1				1	4	1				2				1	3		15	4.5
pre-op				2			1	1	2	3	1	2			1		1	1			15	4.5
ENT				1		1		2		1	1		1	1	1			1	2	3	15	4.5
pacemaker	4	1			1	1		1			1			1		3			1		14	4.2
neuro		1	1	2	1			1	1		1		1			1				1	11	3.3
urol		1		1	1		1		1			1			1	1	1		1	1	11	3.3
plastics				3					2		1			3					1		10	3.0
sds								2	1	2	1			1		2			1		10	3.0
heme/oncol	1			1	1	1		1	1		1	1				1					9	2.7
mhc	1				1				1	2					1				1	1	8	2.4
derm						2				1											3	0.9
thor		1										1					1				3	0.9
rms				1									1				1				3	0.9
endosc					1	1			1												3	0.9
CT scan		1															1				2	0.6
renal							1												1		2	0.6
dental		1					1														2	0.6
ultrasound									2												2	0.6
prosthetics								1												1	2	0.6
bne density	1	1																			2	0.6
nuc med		1															1				2	0.6
rheum						1															1	0.3
Pulm	1																				1	0.3
gi clinic												1									1	0.3
podiatry																		1			1	0.3
allergy					1																1	0.3
stress							1														1	0.3
PT								1													1	0.3
spinal cord injury									1												1	0.3
eeg									1												1	0.3
	15	19	12	25	10	15	19	16	30	15	16	16	10	17	11	15	24	13	21	11	330	
																			avg		16.5	
																			std		5.3	

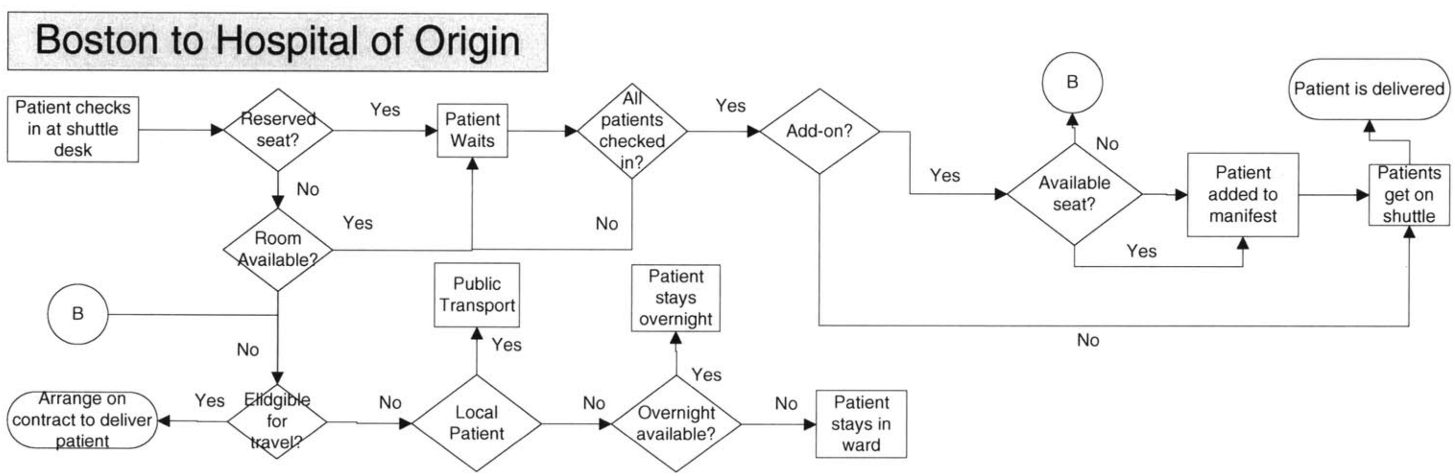
Manchester Shuttle (June, 2010)

clinics visited	1-Jun	2-Jun	3-Jun	4-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	14-Jun	15-Jun	16-Jun	17-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	29-Jun	30-Jun	total/month	% visited
eye clinic	5	2	2		1	4	2	2		1	5	2	1	2	3	2	5	3	2		44	14.5
ortho	4		2	2	1	3	1	3	1		2	1	2	2	5	1	3	1		1	35	11.6
pain clinic	3	2	3		2	4	4	1	1		3	1	3	1		3	3				34	11.2
surg	3					1	2			3	3	1	2	2	2				1	2	22	7.3
neuro		1	3	2				2		1		4	2		1	2			1	1	20	6.6
pre-op	1	1		2	1	1	2			1	1	2		1	1	1				2	17	5.6
VASC			2					1				1	3	1	1	1	3			1	14	4.6
radiation	2	2	4	2													2	1	1		14	4.6
ENT		1	1	1				1	1	1			2			1	2	2			13	4.3
cardiology				2			1	1		2	1						1	3			11	3.6
pacemaker				1		1	1		1	3	1			1						1	10	3.3
urol			1					1	1				1				1		0	1	6	2.0
derm	2						1		1			1									5	1.7
CT scan						2						2							0	1	5	1.7
sds		2								1									1	1	5	1.7
plastics								1					3								4	1.3
mhc		1		1					1									1			4	1.3
renal						2	1	1													4	1.3
dental	1							1						1		1					4	1.3
gi clinic		1								2	1										4	1.3
heme/oncol						1				1									1		3	1.0
rheum			1					1													2	0.7
eye surg			1							1											2	0.7
Pulm						1												1			2	0.7
ultrasound												2									2	0.7
podiatry														1				1			2	0.7
emg																	2				2	0.7
allergy	2																				2	0.7
post-op																1					1	0.3
grecc						1															1	0.3
thor						1															1	0.3
cath							1														1	0.3
pre car								1													1	0.3
heart cath										1											1	0.3
pcc											1										1	0.3
adtc																		1			1	0.3
rms																			1		1	0.3
prosthetics	1																				1	0.3
wm's hlth	1																				1	0.3
total	25	13	20	13	5	22	16	17	7	18	18	17	19	12	13	13	22	14	8	11	303	
																			avg		15.2	
																			stdev		5.2	

Appendix 3



Hospital of Origin to Boston
Patient Needs Appointment
Patient Calls Transport office
Transport office confirms appointment
Transport office designates time and location of pick-up
Does the patient have special needs?
No
Send patient transportation information
Book patient seats
Update database
Yes
Escort or Physical need
Escort
Schedule Seat for Escort
A
Assign appropriate transport vehicle
Patient Reschedule
No
Has Appointment?
Yes
Room On Shuttle
Make Special Arrangements
No
Yes
No Show
A
Show or No-Show
Add-ons?
Driver checks names off list
Patient gets on shuttle
Shuttle leaves for Boston
Patient goes to appointment



Boston to Hospital of Origin
Patient checks in at shuttle desk
Reserved seat?
Yes
Patient Waits
All patients checked in?
Yes
Add-on?
B
Patient is delivered
No
Yes
Available seat?
Patient added to manifest
Patients get on shuttle
No
Yes
Room Available?
No
Yes
B
Public Transport
Patient stays overnight
No
No
Yes
Arrange on contract to deliver patient
Yes
Eligible for travel?
No
Local Patient
No
Yes
Overnight available?
No
Patient stays in ward

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