ETM540/640: Operations Research

Instructor: Dr. Anderson

Winter 2011

Team Project Report

VA Patient Hospital Transportation for Northern California and Reno, Nevada

Project Team

Keith Chapman

Liliya Hogaboam

Rupha Natarajan

Sevket can Nuhisi

Rajasree Talla

Rajesh Talla

Ken Propst

Contents

Abstract 3

Introduction 4

Data description and formatting 7

Literature Review and Methodologies 8

Problem Implementation in Microsoft Excel 12

- Problem Statement 13
- Network Flow Diagram (Shortest Path model) 14
- Formulating the solution 15
- Defining the decision Variables and Constraints 17
- Spreadsheet solution 18
- Internal Hub optimization spreadsheet 19
- Data Entry 20
- Limits 20
- Data Extrapolation 21
- Assumptions 21
- Limitations 21

Future Research 22

Conclusion 22

References 23

Abstract

The Veterans Health Administration is the division of The US Department of Veterans Affairs that makes health care accessible to Veterans. An important responsibility of the VA is patient transportation to and from medical centers in order to make the healthcare available when required. This paper studies methods to improve efficiency of the VA's existing transportation system in Northern California & Nevada. The objective is to optimize the routes by minimizing the total distance traveled and reduce any overlapping routes. Several approaches that are suitable for this problem are considered while developing the applicable models. They are derived from the study of optimizing/networking procedures from literature review and our course work. This paper details the approach taken to analyze the data received, format it in a functional manner, set scope/objective and come up with relevant models making use of optimizing techniques.

Introduction

The VA's vision is clearly stated in figure 1 below. This project relates to the vision of stewardship, in particular making efficient use of resources. The Veterans Engineering Resource Center (VERC) has identified an opportunity to improve efficiency by evaluating the patient transportation systems within the VA Medical System. Our point of contact at the VA is William "Ike" Eisenhauer who is the National VERC Director as well as a PSU alumnus and an Adjunct Assistant Professor in the Systems Engineering Program at Portland State.

> **Vision**
>
> To provide veterans the world-class benefits and services they have earned - and to do so by adhering to the highest standards of compassion, commitment, excellence, professionalism, integrity, accountability, and stewardship.

Figure 1 – VA Vision [1]

As shown below in Figure 2, the VA has a large network of facilities spread across the continental US as well as many locations world-wide. The scope of our project is limited to the locations within Region 21 (Northern California and a portion of NW Nevada.) There are additional locations in Hawaii, American Samoa, Guam and The Philippines. However, we were not given any data regarding transportation routes in those regions, so they are outside the scope of our project. A complete listing of the facilities in region 21 can be found in Appendix A.

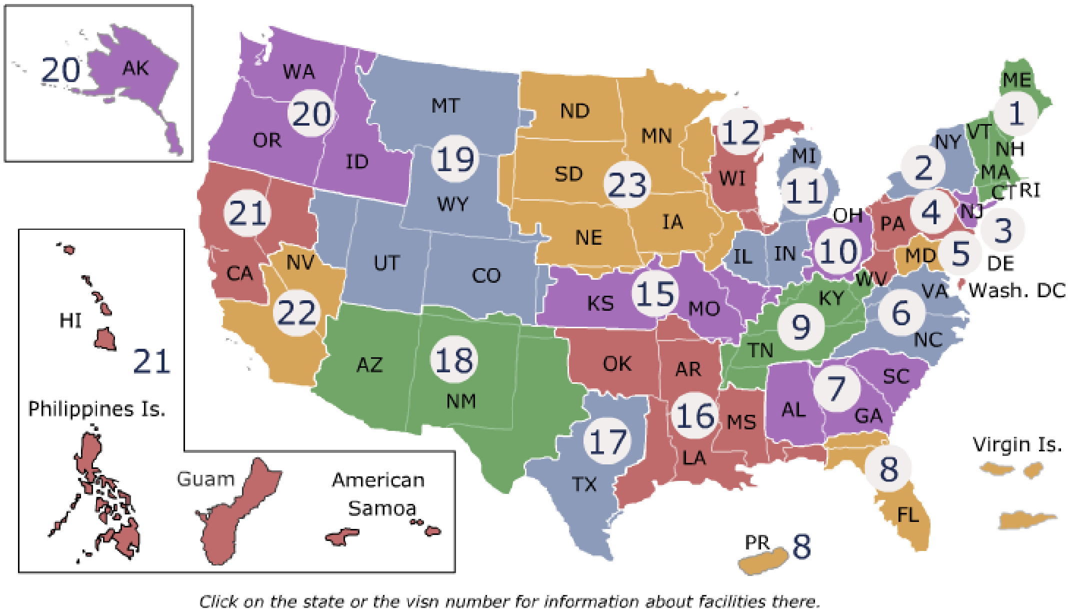


Figure 2 – VA divisions [2]

As shown in figure 3 below, the VA is comprised of a variety of facility types. The scope of this project includes the following 3 categories of facilities: VA Community Based Outpatient Clinics (CBOC's), VA Vet centers, VA Hospitals and possibly a few VBA regional Offices.

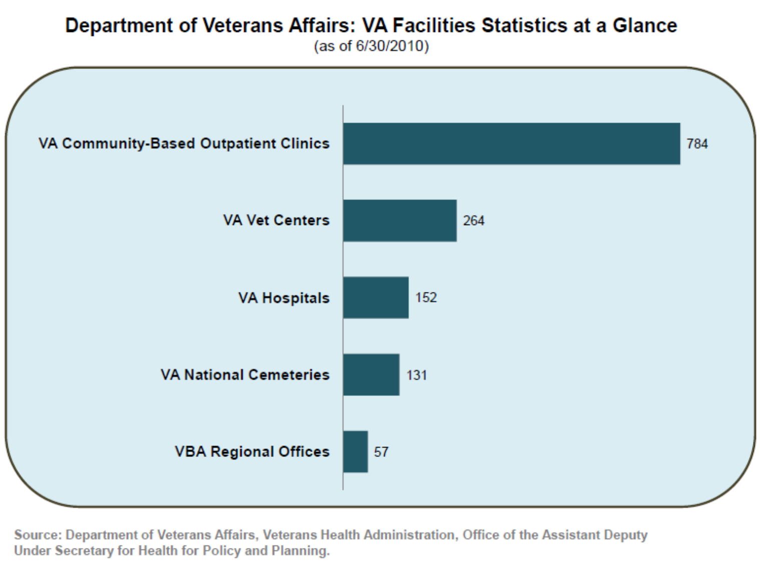


Figure 3 – VA facilities nationwide [3]

In order to visualize the problem, a map was created of all VA locations within the scope of our project. The locations were categorized as Major VA locations (hospitals) and Minor VA locations (CBOC's and Vet Centers.) It should be noted, that in the data as received from the VA, the actual description of each location was not always clear. For example, a location may have been described as an OPC or clinic or CBOC. We made the assumption that all of these are fall into the general category of CBOC's.

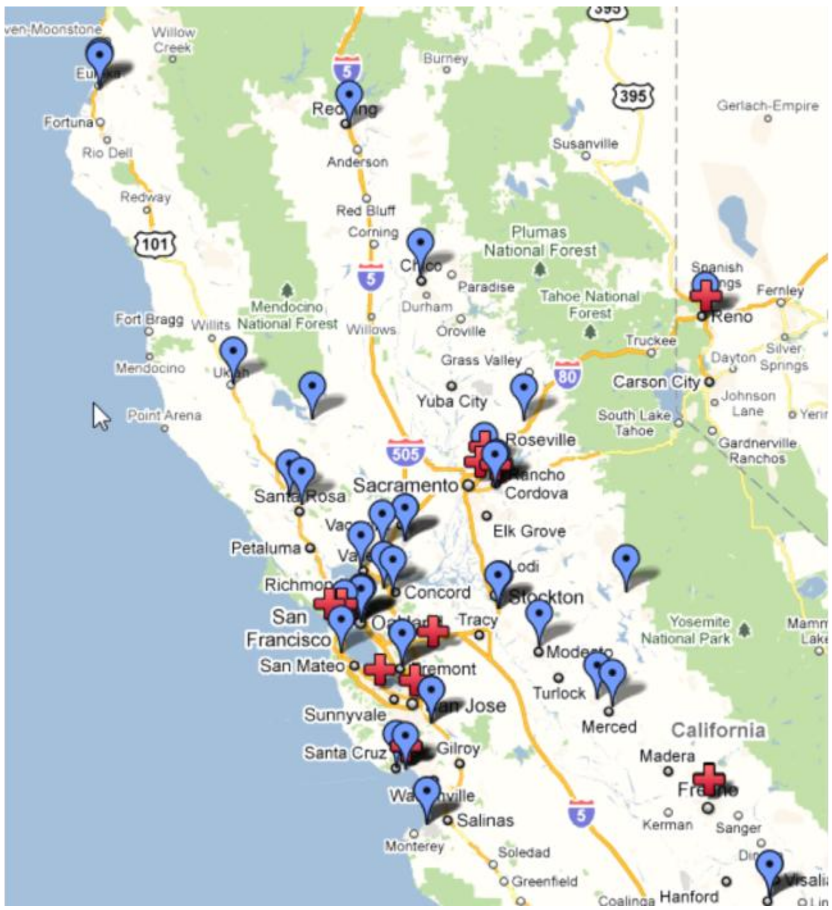


Figure 4 – Major and Minor VA Locations

= Major VA location such as a VA Hospital = Minor VA location such as CBOC or Vet Center

With the overall goal of efficiency improvement, the goals of this project were further defined initially as shown below. After some further evaluation, the decision was made to focus mainly on goal #3 which in retrospect has proven to be quite challenging.

1. Reduce the # of routes
2. Get closer access to Metro points
3. Reduce the miles traveled (resulting in reduction of travel cost)

The scope of our project was also further refined to focus mainly on passenger routes. While there are several routes which are courier routes (transporting files and pharmacy items) or combined courier/patient routes, after consulting with our contact at the VA it was decided that the main focus should be on patient transport and not courier routes.

In addition to the objectives listed above, the team is certainly aware of the importance of customer service. The VA's own vision (as outlined in figure 1) is very clear in this matter. We understand that any solution developed has the underlying goal of serving the needs of the patient.

Data description and formatting

In an attempt to improve efficiency of the VA's transportation network, out team of seven was provided with a variety of data ranging from the time schedules for the various shuttle busses running between the VA facilities, the Google route maps indicating the various pick-up and drop-off points in the different routes, the approximate number of passengers that are expected to be travelling to and from these VA facilities and the distance and travel time involved in transporting the VA patients from one point to the other. Our preliminary raw data was sent to us in the form of a 15 MB Zip file containing over 30 different files in various formats (Excel files, Word documents and some Outlook files.)

Considering the large and varied nature of the raw data that we received, we recognized that in order for us to be able to read and interpret the data, we needed to consolidate the data into a master spreadsheet. Initially, an Excel spreadsheet was made for this purpose. As a temporary measure, this document was converted to a Google spread sheet that could be accessed by each team member to input and populate the raw data. Some of these column heads include: document data taken from, person entering data, route name, departure point, arrival point, travel time, travel distance, average monthly passenger demand, passenger capacity, # of VA stops, transport availability etc. Once the data was compiled in a master spreadsheet, the next question became "what to do with all this data?" One possible tool was developed in the form a consolidated excel spread sheet called the travel_route_planner.xls. It is based on the concept of having 6 regional hubs in Northern California and NW Nevada. We assumed that there will be 1 major VA location in each hub and several minor VA locations. The goal of the spreadsheet is to consolidate the data in a form which will potentially better facilitate the optimization objective of minimizing the distance between any 2 VA locations and eventually reducing the overall travel time and costs.

Literature Review and Methodologies

In our efforts to find the best model for our project, we researched many articles in various journals and searched various websites of relevant organizations (Transportation Science, Management Science, Journal of Urban Economics , IEEE Journals, Operations Research and PICMET to name a few.) With the overall goal of reducing the travelling distances from point A to point B, our goal was to find the best model that suited our project and the data we had for the project. In addition to the previously mentioned journals, we also researched the class textbook "Spreadsheet Modeling and Decision Analysis" [9] with a heavy focus on Chapter 5 (Network Modeling.)

Since the data available for each region was not consistent and the needs of each region may be different, the team agreed on the possibility of using different models for each region. From the articles found and the research being done, the team agreed on 3 different methods that could potentially be used in the project. These models are shown below:

1. Hub-and-spoke

The hub and spoke model graphically resembles a bicycle wheel, it is used extensively in commercial aviation for passengers and freight and has been adopted in the technology sector (hub-spoke networks) [4]. It was pioneered by Delta Airlines in 1955 as well as implemented by FedEx in the 1970s. The network routes in a hub and spoke model (strong central hub with series of connecting spokes) get simplified which can make the whole network more efficient. Hub-and-spoke is an organizational structure in which the single depots cover an area with specific collection and delivery points for each terminal [5]. Figure 5 shows a simple example of a hub and spoke model.

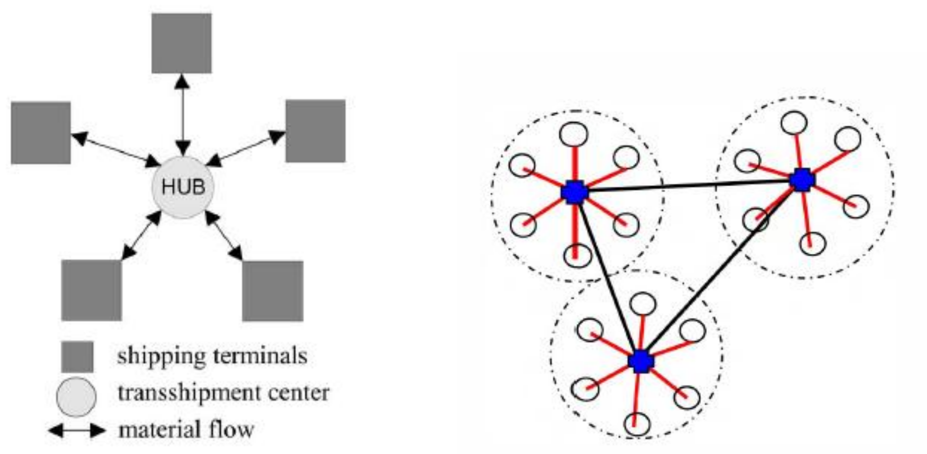


Figure 5[6, 7]

Since a hub-and-spoke has a wide usage, researchers have been working in the field of optimization of those networks. Some quadratic programming and enumeration heuristics have been proposed as well as integer programming and formulations with flow thresholds for spokes [6].

2. Hybrid hub-and-spoke

Pure hub-and-spoke could be extended or reconstructed into hybrid hub-and-spoke or extended hub-and-spoke system, which is pictured in Figure 2 .

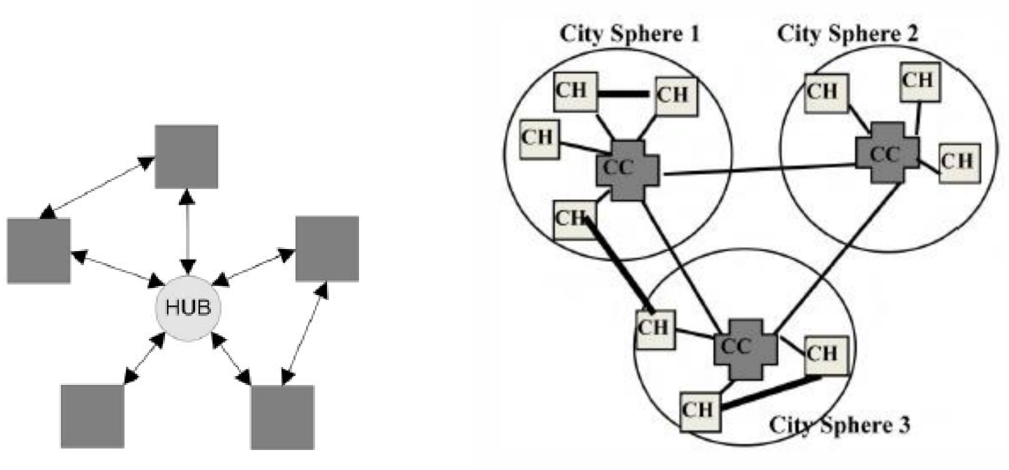


Figure 2[6, 7]

3. The shortest path

The shortest path is the path through the network from a starting node to the end node that is either has the shortest distance traveled shortest time, cost or other attribute. Google maps were used where applicable to find shortest routes in the network, we also used Data Disk (problem 5.7) [9] in several cases to test out the distance. While the shortest path minimizes the distance traveled from point A to point B, some of the disadvantages of it could be overlooking public transit spots, homeless spots and traffic jams while purely focusing on the shortest distance.

4. Hybrid hub-and-spoke with a minimal spanning tree problem

Minimal spanning tree involves determining the set of arcs, which connect all the nodes in a network and at the same time minimize the total length (or other attribute) of the selected arcs. [9]. One of the definitions for a spanning tree is that it is a subset of n-1 edges that form a tree. [1] Minimal spanning tree could be used for spikes networks as well as major nodes in this version of hybrid hub-and-spoke. Some of the common algorithms include Prim's and Kruskal's. [2] The simple steps in the minimal spanning tree problem algorithm:

[1] Spanning Tree. Available online: http://mathworld.wolfram.com/SpanningTree.html
[2] Minimum Spanning Tree. Available online: http://mathworld.wolfram.com/MinimumSpanningTree.html

1. Select any node in the network, creating a new sub-network.

2. Add to the newly created sub-network the cheapest arc that connects any note in our original network to the newly created sub-network (ties are considered arbitrarily).

3. Repeat step 2 until the all the nodes are in the newly created sub-network – the minimal spanning tree problem is optimized.

As a result of our deep literature research, the best fit model appears to be a HYBRID HUB-AND-SPOKE model used in a paper published by the IEEE Journal in 2009 [8]. We have also used a hybrid hub-and-spoke with a minimal spanning tree problem as well as shortest path optimization wherever possible with Excel or Google maps. The objectives outlined in this article are very similar to the objectives of our project. Both projects have the overall goal of trying to optimize a transportation network using different constraints such as cost, service capacity and so forth. In addition, the transportation network described and pictured in this article has a fair amount of similarity to the transportation network in this project.

It should be noted, that while the hybrid hub and spoke model described in this paper appears to be a good fit, the equations utilized in the article (as is) do not appear to be well suited for our project. However, it is a very good resource and may serve as point of departure for future research and learning. In addition, considering that a successful approach to optimization may include several methods or techniques, this is certainly an article and optimization method that is worth further review.

By using the Hybrid Hub and Spoke model, we would be able to divide the existing transportation network into regions and optimize them taking in considerations the specifics of each region.

Benefits of hub-and spoke models, including hybrid hub-and-spoke:

1. Centralized control allows fewer resources (buses, personnel etc.)
2. For freight the sorting of all packages can be done in the hub which also can save time and resources and reduce the risk of error
3. Ensures close to maximum capacity for routes

Some disadvantages of hub-and-spoke models, including hybrid hub-and-spoke:

1. Any disruptions at the hub can create delays throughout the system[8]
2. The capacity of the hub can limit the overall operating efficiency
3. Might create longer routes for some categories of passengers

Problem Implementation in Microsoft Excel

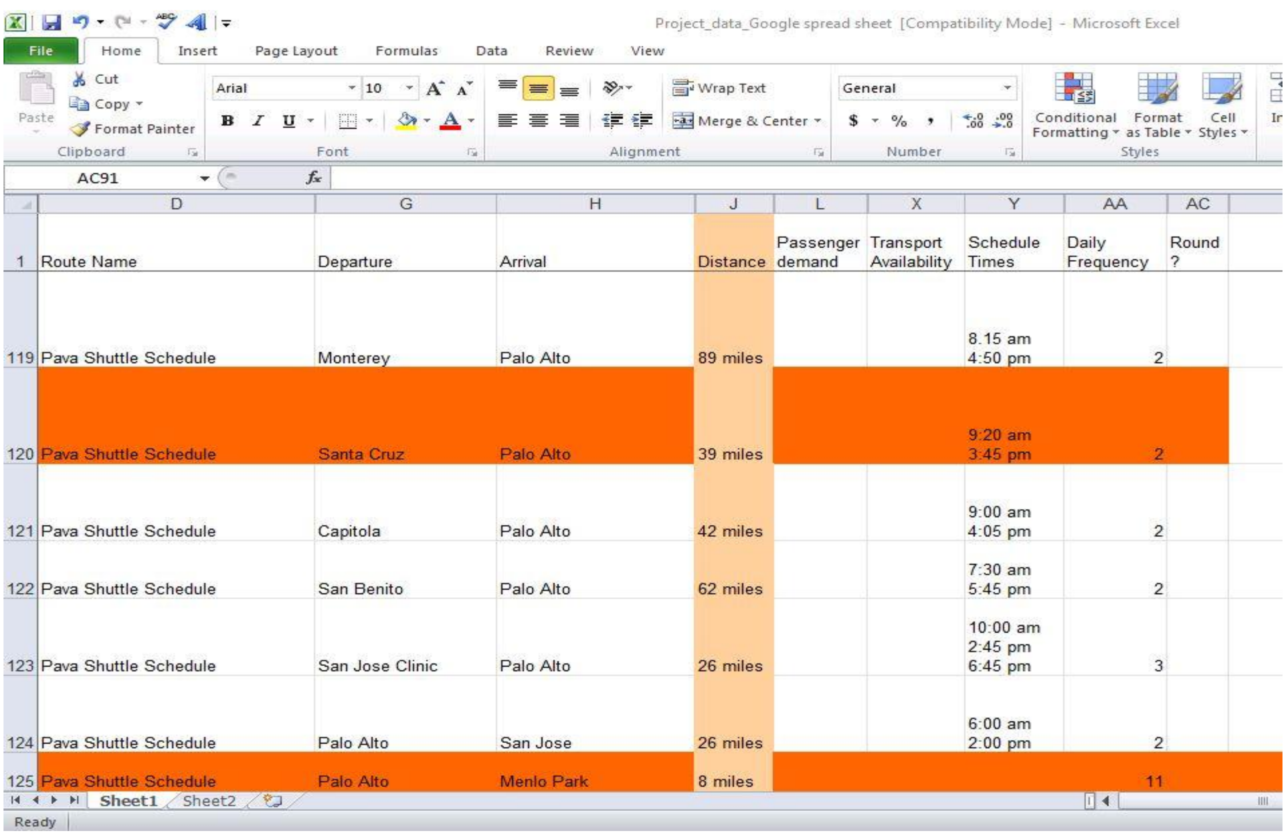
The purpose of the spread sheet developed was to capture key concepts associated with planning and executing a successful transportation system for the Veterans' Association patients. The idea was to capture how and how many destinations could be linked, the number of shuttles needed to support routes, the total distances to be traveled, and limitations of the system. This would allow for planning of how a shuttle route system could be implemented to improve the transportation of patients and minimize distances travelled. Improvement of the transportation system will not only improve patient support but if done properly reduce costs for the system.

The concept behind this problem is to implement the data regarding point to point patient transfer for the Veterans' Association to generate information regarding the number of shuttles needed and the active routes needed. The hope is to streamline the process of patient transfer to improve travel of the patient while reducing the number of shuttles needed and optimizing travel routes. Several pieces of data that can be generated outside of just the shuttles needed are the departure and arrival times of shuttle servicing a route. Due to the nature of this problem it was implemented in the spread sheet as a regional problem. Each sheet will represent an optimized map area to service, with data particulars for that region. This will allow for some level customization and the daily changes that a region may experience to be uploaded and the relevant data for that day generated.

Problem Statement

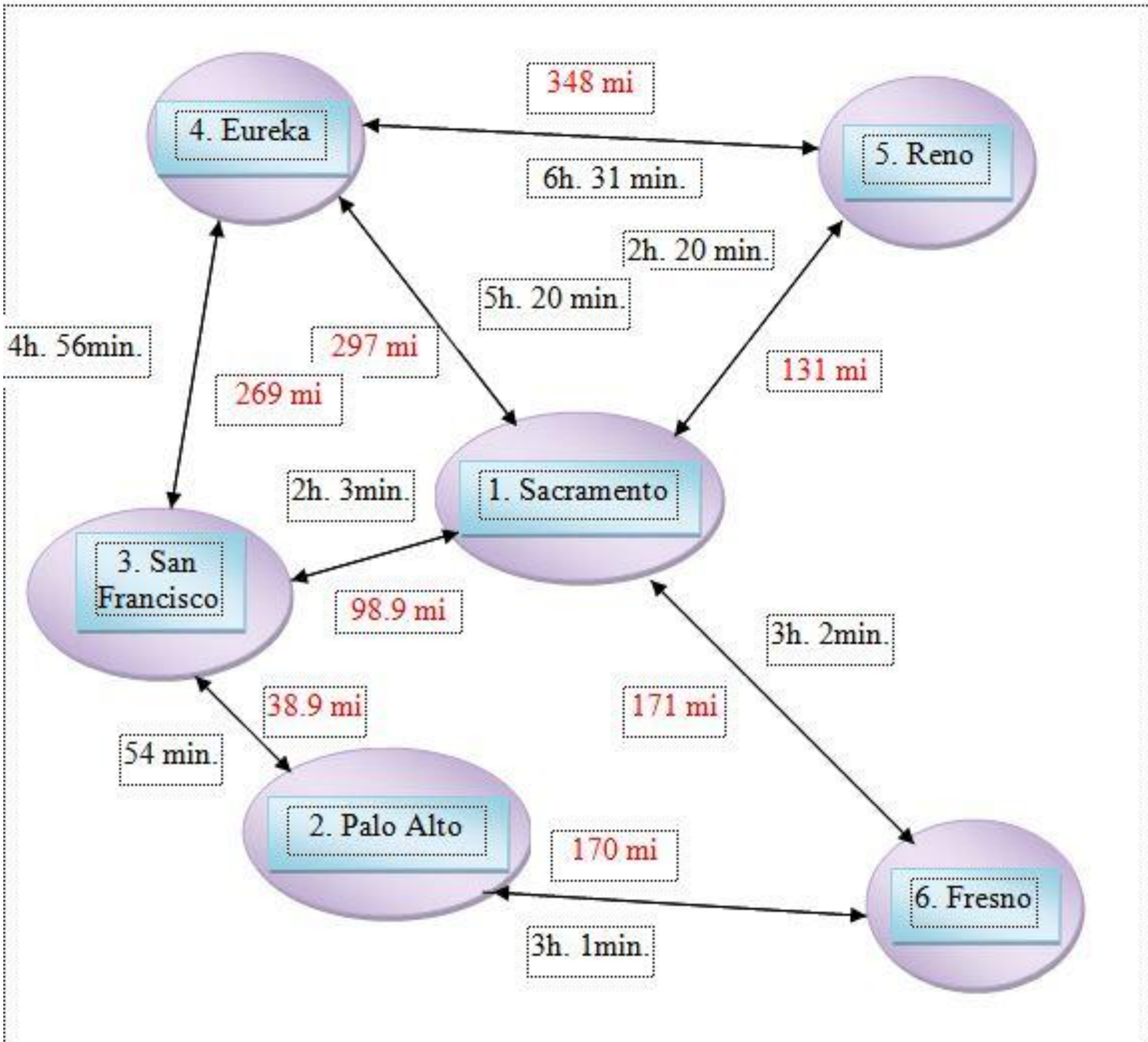
VA Health Care is part of the Department of Veteran Affairs that is aims to providing quality medical services to veterans in and around the United States. They would like to optimize the shuttle routes by minimizing the total distance traveled for patients travelling from different parts of Northern California to the various major and minor VA hospitals by eliminating redundant routes and . They feel that the improvement of the transportation system will not only improve patient support but if done properly reduce costs for the system. The number of patients travelling each route each day differs based on fluctuating patient demand and the shuttle capacity (optional constraint). The maximum distance a shuttle can travel is fixed at 340 miles and the maximum shuttle capacity is assumed at 12 per shuttle bus. Each tip is evaluated one way and the passenger demand varies to and from each VA location.

The following table summarizes the shuttle runs: (complete spreadsheet available in Appendix CD)

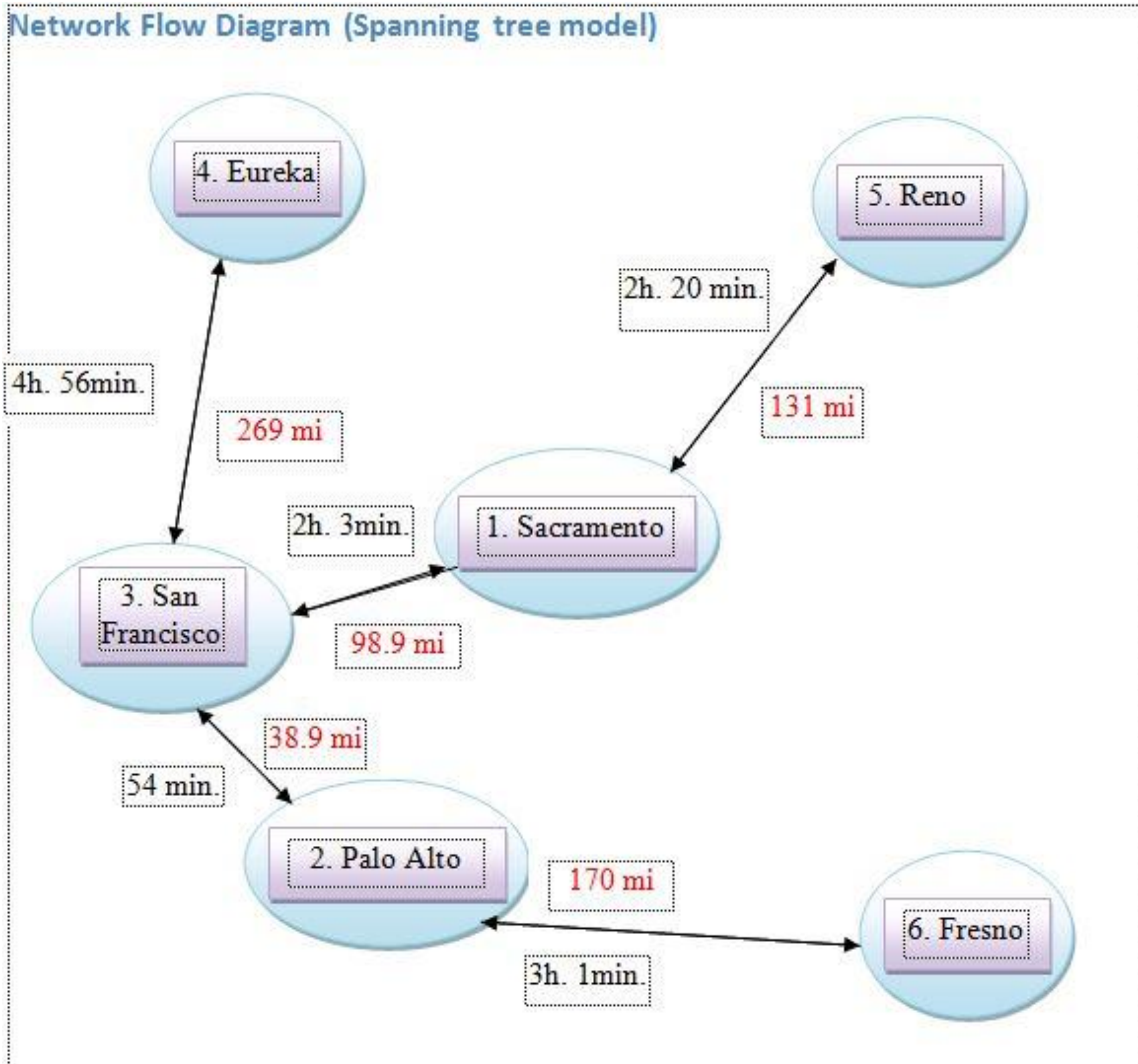


	Route Name	Departure	Arrival	Distance	Passenger demand	Transport Availability	Schedule Times	Daily Frequency	Round ?
119	Pava Shuttle Schedule	Monterey	Palo Alto	89 miles			8.15 am 4:50 pm	2	
120	Pava Shuttle Schedule	Santa Cruz	Palo Alto	39 miles			9:20 am 3:45 pm	2	
121	Pava Shuttle Schedule	Capitola	Palo Alto	42 miles			9:00 am 4:05 pm	2	
122	Pava Shuttle Schedule	San Benito	Palo Alto	62 miles			7:30 am 5:45 pm	2	
123	Pava Shuttle Schedule	San Jose Clinic	Palo Alto	26 miles			10:00 am 2:45 pm 6:45 pm	3	
124	Pava Shuttle Schedule	Palo Alto	San Jose	26 miles			6:00 am 2:00 pm	2	
125	Pava Shuttle Schedule	Palo Alto	Menlo Park	8 miles				11	

Network Flow Diagram (achieved with shortest path methodology in Google Maps):



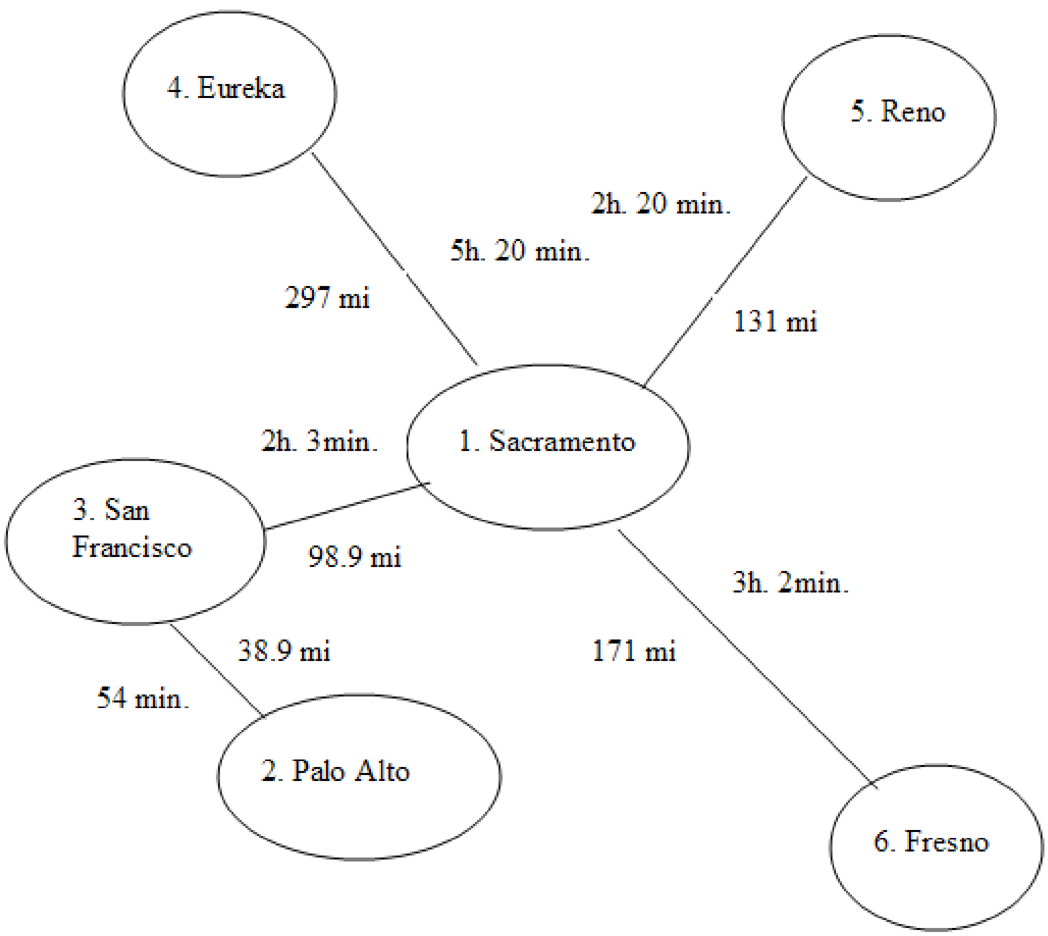
The following diagram shows the minimal spanning tree methodology (described in Literature and Methodologies section of this paper) applied to the above network diagram.



Formulating the solution

Based on the complexity of the problem and its close relation to the network flow problem that the Spreadsheet Modeling and Decision Analysis V-5e book illustrates in chapter 5, we demonstrate the minimal shortest path methodology to optimize the travel for VA patients between the 6 hubs selected.

The below mentioned process tries to optimize the transportation from Fresno (Node 6) to Eureka (Node 4). The following diagram shows the optimized network from using shortest path methodology for the travel from Fresno (Node 6) to Eureka (Node 4) and the minimal spanning tree method later on. Since the route capacities might be different throughout the hubs, we included both optimizations: minimal spanning tree and shortest path + spanning tree. We believe it will be useful for VA to consider both methodologies.



Defining the decision Variables and Constraints

X_{ij} = The number of shuttles travelling from node i to node j

Therefore the LP formulation of this model requires the following decision variables :

X_{62}= the number of shuttles travelling from Fresno (Node 6) to PaloAlto (Node 2)

X_{26}= the number of shuttles travelling from Node 2 to Node 6

X_{61}= the number of shuttles travelling from Node 6 to Node 1

X_{16}= the number of shuttles travelling form Node 1 to Node 6

X_{23}= the number of shuttles travelling from Node 2 to Node 3

X_{32}= the number of shuttles travelling from Node 3 to Node 2

X_{31}= the number of shuttles travelling from Node 3 to Node 1

X_{13}= the number of shuttles travelling from Node 1 to Node 3

X_{34}= the number of shuttles travelling form Node 3 to Node 4

X_{43}= the number of shuttles travelling from Node 4 to Node 3

X_{14}= the number of shuttles travelling from Node 1 to Node 4

X_{41}= the number of shuttles travelling from Node 4 to Node 1

X_{51}= the number of shuttles travelling from Node 5 to Node1

X_{15}= the number of shuttles travelling from Node 1 to Node 5

X_{45}= the number of shuttles travelling from Node 4 to Node 5

X_{54}= the number of shuttles travelling form Node 5 to Node 4

The Objective function for this problem is expressed as :

MIN: $170X_{62} + 170X_{26} + 171X_{61} + 171X_{16} + 38.9X_{23} + 38.9X_{32} + 98.9X_{31} + 98.9X_{13} +$
$269X_{34} + 269X_{43} + 297X_{14} + 297X_{41} + 348X_{45} + 348X_{54} + 131X_{51} + 131X_{15}$

Subject To:

$+X_{26} - X_{26} + X_{62} - X_{62} + X_{61} - X_{61} + X_{16} - X_{16} = 0$ [flow constraint for Node 6]

$+X_{23} - X_{23} + X_{32} - X_{32} = 0$ [flow constraint for Node 2]

$+X_{31} - X_{31} + X_{13} - X_{13} + X_{34} - X_{34} + X_{43} - X_{43} = 0$ [flow constraint for Node 3]

$+X_{41} - X_{41} + X_{14} - X_{14} + X_{45} - X_{45} + X_{54} - X_{54} = 0$ [flow constraint for Node 4]

$+X_{51} - X_{51} + X_{15} - X_{15} = 0$ [flow constraint for Node 5]

$X_{ij} \geq 0$ for all i and j [nonnegativity conditions]

Binary Constraints :

Where, $Y_{ij} = [1$ if there are passengers and 0 if no passengers $\forall$ i, j

All Y_{ij} must be binary

Spreadsheet solution

Shortest Path proble from Fresno to Eureka									
Ship	**From**		**To**		**Distance**	**Nodes**		**Net Flow**	**Supply/Demand**
0	1	Sacramento	3	San Francisco	98.8	1	Sacramento	0	0
1	1	Sacramento	4	Eureka	297	2	Palo Alto	0	0
0	1	Sacramento	5	Reno	131	3	San Francisco	0	0
0	1	Sacramento	6	Fresno	171	4	Eureka	1	1
0	3	San Francisco	1	Sacramento	98.8	5	Reno	0	0
0	4	Eureka	1	Sacramento	297	6	Fresno	-1	-1
0	5	Reno	1	Sacramento	131				
1	6	Fresno	1	Sacramento	171				
0	2	Palo Alto	6	Fresno	170				
0	6	Fresno	2	Palo Alto	170				
0	2	Palo Alto	3	San Francisco	38.9				
0	3	San Francisco	2	Palo Alto	38.9				
0	3	San Francisco	4	Eureka	269				
0	4	Eureka	3	San Francisco	269				
0	4	Eureka	5	Reno	348				
0	5	Reno	4	Eureka	348				
		Total Transportation Distance			468				

The above spreadsheet tries to solve for the shortest path to transport a patient from Fresno to Eureka based on the shortest time taken to travel. This is arrived at 468 miles with the shuttle bus travelling from Fresno to Sacramento and from Sacramento to Eureka. This optimization model varies based on the start and end nodes.

Key Cell Formulas			
D6		=VLOOKUP(E26,$I$6:$J$11,2)	D7 to D21
F6		=VLOOKUP(E27,$I$6:$J$11,2)	F7 to F21
K6		=SUMIF($E$6:$E$16,D28,$B$6:$B$16)-SUMIF($C$6:$C$16,D28,$B$6:$B$16)	K7 to K11
G23		=SUMPRODUCT(A12:A27,F12:F27)	

Internal Hub optimization spreadsheet

The 6 regions of California and Nevada were strategically assigned to each of the contributors in the group in an attempt to give them an opportunity to identify the different optimization approach that can be applied. Based on a final discussion and analysis we decided to utilize and extract the following data heads for analysis purposes.

Selected Route for the day	From: Node Number	From: Node Name	Depature Time	To: Node Number	To: Node Name	Arrival Time	Distance, ml	Drive Time, min
1	1	VAFF OPC	7:00 AM	2	SR CBOC	8:33 AM	76	93
1	2	SR CBOC	7:35 AM	3	SR OPC	7:36 AM	0.1	1
1	3	SR OPC	8:00 AM	4	MI OPC	9:05 AM	54	65
1	4	MI OPC	9:00 AM	9	OAK VC	9:57 AM	39	57
1	5	CRD VC	10:35 AM	6	MTZ OPC	10:45 AM	5	10
1	6	MTZ OPC	11:10 AM	7	OAK OPC	11:38 AM	24	28
1	7	OAK OPC	7:00 AM	8	OAK VC	7:04 AM	1	4
1	8	OAK VC	8:30 AM	9	OAK VC	9:06 AM	17	36
						Total	216.1	294

RED CELLS = Data we don't have but would be nice to build a more robust model with
YELLOW CELLS = Data we have to assume to build the model

Node Number	Node Name	Net Flow	Node Arc / Route	# of Shuttles Needed for Route	Shuttle Capacity	Route Passengers	Total Shuttles Needed	Max Distance Allowed, ml	Max Drive Time Allowed, hr
1	VAFF OPC	-1	1 to 2	1	12	10	1	340	
2	SR CBOC	0	2 to 3	1	12	10			
3	SR OPC	0	3 to 4	1	12	10			
4	MI OPC	0	4 to 9	1	12	10			
5	CRD VC	-1	5 to 6	1	12	10			
6	MTZ OPC	0	6 to 7	1	12	10			
7	OAK OPC	0	7 to 8	1	12	10			
8	OAK VC	0	8 to 9	1	12	10			

Key formula Cells		
A3	=IF(R3>0,1,0)	A4 to A10
C3	=VLOOKUP(B3,$K$3:$L$17,2)	C4 to C10
F3	=VLOOKUP(E3,$K$3:$L$17,2)	F4 to F10
G3	=D3+TIME(0,I3,0)	G4 to G10
M3	=SUMIF($E$3:$E$24,K3,$A$3:$A$24)-SUMIF($B$3:$B$24,K3,$A$3:$A$24	M4 to M10
P3	=INT(R3/Q3)+1	P4 to P10

The above excel snapshot for the San Francisco hub tries to minimize the distance travelled. The input cells are the yellow cells and the changing cells are the pink cells. The spreadsheet shows that if a patient has to be transported between Node 1 (VAFF OPC) to Node 2 (SR CBOC), the travel depends on the number of patients waiting to be transported. Our spreadsheet works on the assumption that the maximum shuttle capacity is 12 and that the distance travelled is fixed and not variable per travel. We can also see that the maximum distance that can be travelled is also fixed at 340 considering the average miles that a shuttle can travel at a time without any breaks. Thus based on the number of patient demand to be transported and the shuttle departing availability per day, we predict to cover up to 216 miles in distance to transport the VA patients from the different VA health facilities within the hub named San Francisco. (Please refer to the San Francisco hub map to identify the number of departure and arrival points)

Data Entry

Several key pieces of route information must be entered at a manual level in this current iteration of the Excel Spread Sheet that is being used to analyze the problem. This would include identifying point to point locations and the distance and typical travel for that arc or route between those points. Departure times will need to be added as well to determine arrival times from one node or point to the next. The number of passengers for that route will also need to be determined and entered. One can also select whether or not a route is used for that period or not.

Limits

The spread sheet also takes into account variables that would impact transportation. This would include the passenger limit of the shuttle and the maximum distance or time a driver would be allowed for a shuttle. Setting these limits will help determine the number of shuttles needed to support the system. These limits can have several driving factors including laws for professional drivers and the time that one may want limit passenger travel to health reasons.

Data Extrapolation

Based on the input data one should be able to derive a potential shuttle route schedule and number of shuttles needed to support the routes. The number of shuttles needed is based on the expected passengers and shuttle carry capacity and the maximum allowed distance a shuttle can travel. Arrival times for a destination are determined based on the assigned departure time and travel time for that arc or route. The sheet will also show a flow number between locations or nodes to indicate whether more shuttles arrived or needed to leave a certain location. All this data would hopefully help in planning activity and services for the shuttles.

Assumptions

Several assumptions relative to just the spread information had to be made; this was due to the data that had been made available not necessarily containing all the information needed. Maximum shuttle travel distance is assumed at 440 miles with the assumption that same shuttle will return along the same path it left. This will give an estimated number of shuttles needed. Travel time could also be substituted for distance to take into account other factors such as stop time along a route and other constraints that a driver may face. Shuttle capacity was also assumed to be 12 persons as this is a typical passenger capacity of shuttle passenger vans. As data was not in general available for all routes a selected number of five passengers were chosen for each route. The model is capable of showing that extra shuttles would be needed if a route passenger quantity exceeds the carrying capacity of a single shuttle.

Limitations

Currently the model has several limitations in its capability set. The model does not have all the data that would be desired related to the actual routes. There is a significant amount of data that still has to be processed manually, but this could be resolved with a more capable model tool or with a better reference data base to pull information out of then we were able to implement in the time given. Some improvements in how the tool can show stops not being needed or how to implement an additional node to node route due to passengers exceeding a single shuttle capacity would be desired. It would also be desirable to implement a method of linking the departure node time to a previous arrival time if it not the first node in a route. These are limitations of the current model that could most likely be addressed with additional effort.

Future Research

Due to the time and limited access to data, exploring this transportation problem left many open ends that require further research. This study can be extended to include multiple objectives to make it closer to a real time scenario. It is inherent from the approach to applicable models earlier in the paper, that not all constraints and variables are included which exist in real world. Some information we felt required during the analysis are

1. Acceptable time or distance for passenger to be in travel
2. Exact requirement regarding usage of transportation. For instance is it used just for passengers or supplies, mail, pharmacies are also expected to be included.
3. Schedule of transportation
4. Passenger capacity
5. Including patient pick up points in the model.

There are different applicable models discussed in this paper. Effort for comparing the optimizing solutions between all these models will provide a better understanding of which procedure to adopt. As there is a possibility of changing data, including more flexibility in to the model will a better approach to get closer to real time scenario. Using optimization tools that will meet the desired requirements can expand this analysis.

Conclusion

The optimization techniques studied in this operations research course and literature review provided many good potential approaches to solving a transportation problem such as this one. The analysis and research conducted in this project study can be considered as a starting point for developing a model that incorporates more variables and constraints. It is our belief that with such a large and varied transportation network, there is likely opportunity for optimization. However, in order to attain such optimization, the VA will likely need to invest further time and resources to study the feasibility of attaining that optimization. This paper should serve as useful resource for the VA in continuing to support the VA's greater vision of improving transportation system to serve our veterans.

References

1. About VA. US Department of Veteran Affairs. Available online:http://www.va.gov/landing2_about.htm Last retrieved 3/10/2011.

2. Veterans Health Administration. US Department of Veteran Affairs. Available online: http://www2.va.gov/directory/guide/division_flsh.asp?dnum=1. Last retrieved 3/10/2011.

3. National Center for Veterans Analysis and Statistics. US Department of Veteran Affairs. Available online: http://www.va.gov/vetdata/. Last retrieved 3/10/2011.

4. What is the hub and spoke model? Available online: http://www.wisegeek.com/what-is-the-hub-and-spoke-model.htm. Last retrieved 3/10/2011

5. Zapfel, G, and M Wasner. "Planning and Optimization of Hub-and-Spoke Transportation Networks of Cooperative Third-Party Logistics Providers." International Journal of Production Economics. 78.2 (2002): 207-220.

6. Sun Li, Zhao Lindu. Research on Optimization of Hub-And-Spoke Logistics Network Design with Impedance Effect. Institute of Systems Engineering, Southeast University, Nanjing, Jiangsu, China, POMS 20th Annual Conference, May 1 to May4, 2009, Orlando FL, p.4

7. G. Zapfel, M. Wasner. Planning and optimization of hub-and-spoke transportation networks of cooperative third-party logistics providers Int. J. Production Economics 78 (2002) p.209

8. Zou Xueding et al. Transit Lines Optimization Model Research Based on the Lowest Total Cost of Hybrid Hub-and-Spoke Road Freight Transport Network. 2009 IEEE

9. Cliff T. Ragsdale. Spreadsheet Modeling and Decision Analysis: A Practical Introduction to Management Science, Fifth Edition. Thomson South-Western. 2007

Additional Resources (Researched, but not cited in the report):

- Ching-Sheng Chiu, A Genetic Algorithm for Multi objective Path Optimization Problem. 2010 IEEE

- Waiel F. Abd El-Wahed, A multi-objective transportation problem under fuzziness. 2001 Elsevier Science B.V.

- Meiping Yun, Xiaoguang Yang, An Optimization Model of Road Networks Subarea Districting for Incident Management Systems, 2003

- J.K Sharma, Extensions and Special Cases of Transportation Problem, 1977

- Sun Jian, Wang Heng The Optimization of Traffic Count Location on Network Based on Two-Stage. 2008 IEEE

- http://mathworld.wolfram.com/CycleGraph.html (a late find which may be useful in forming routes.) viewed 3-18-2011

Appendix