UF Health Shands: Shuttle System Improvement Proposal

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Executive Summary

UF Health Shands operates several shuttle routes to service both patients and employees of the surrounding healthcare facilities. These complimentary shuttles currently do not meet the target cycle time of 15 minutes (i.e. a passenger should not wait more than 15 minutes at a stop for a shuttle.) The untimeliness of the shuttles leads to frustration for passengers trying to get to their various destinations around the medical center.

The aim of this project is to identify and correct the inefficiencies present in the current shuttle system through analyzing and changing route structures, stops, paths and other sources of inefficiency. We collected data focused on traffic patterns and ridership through Transloc, a ridership application, as well as through the team's observations on the shuttles and discussions with the shuttle drivers to assist with the analyzing and improvement of current routes.

The optimization methodology will aim to get shuttles to be within the 15-minute cycle time goal by eliminating bottlenecks in the routes. These bottlenecks include, but are not limited to, minimizing left turns, avoiding high traffic areas, and adjusting route stops based on usage. These changes require little on the part of UF Health Shands, but can potentially provide tremendous value to the passengers.

New, theoretically improved routes were obtained by modeling the shuttle system with the Traveling Salesman Problem (TSP), which was used to determine the shortest path between all stops. Field observations and testing were conducted to ensure the proposed route changes were feasible for shuttle drivers to implement. Since it is fairly easy for the drivers to adjust their routes as they are within a relatively small area, this approach will save time and give more realistic results, while incurring no additional costs to UF Health Shands.

While trying to improve the shuttle experience for passengers, there may be subsets of this group who feel that their needs are still not sufficiently addressed by the shuttle changes, despite improvements. In these cases, it might not be globally beneficial to invest in more shuttles, stops, or other routes to marginally better the experience for a few. We have sought to provide the best solution for the most people while keeping within the economic and environmental constraints.

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Introduction

The project focuses on optimizing the shuttle system at UF Health Shands. UF Health Shands operates several complimentary shuttle routes to assist employees and patients in moving around the various hospitals and parking areas in the main medical region at the southeastern section of the UF campus. The Red, Blue, and Purple Lines service UF Health Shands employees while the Pink, Green, and Yellow Lines assist patients. In particular, the Yellow Line patient route services patients with special requests for additional locations not normally serviced by the shuttle system. Refer to the Appendix A for current state shuttle route maps.

The shuttles currently have a 15 minute cycle time goal that is not being met on several routes (i.e. a passenger should not wait more than 15 minutes at any stop for a shuttle.) Beyond this main target metric, it is possible that there are inefficiencies in the route structure and scheduling. Our goal is to find the inefficiencies present in the current shuttle system and correct them by adjusting route structure, stops, and any other sources of inefficiency.

Facts and Assumptions

Making right turns is quicker, safer, and more efficient than making left turns, especially during rush hour traffic. This assumption is based on the study and success UPS had with eliminating left turns from their delivery routes [1]. A national study found that of the accidents that occured at an intersection, 22.2 percent were attributed to making left turns while 12.6 percent were related to crossing over lanes of traffic and just 1.2 percent for right turns[2]. Left turns can be especially troublesome for older drivers[14]. These findings are the basis behind the team’s desire to minimize left turns, along with collecting feedback from the shuttle drivers. The drivers have also expressed the difficulty of safely navigating left turns that were present along several of the current routes.

Another assumption is that the stops should have at least 30 riders a month to be considered necessary for the shuttle to service the stop. The team arrived on this number through the determination that one passenger per day would make the stop worthwhile.

The team also assumed that the data received from Transloc was accurate to a certain degree. We verified this assumption through our sponsor, George Richardson, the Manager of Transportation and Parking at UF Health Shands. Refer to the 'Data Validation' section of the report for further details relating to this assumption.

We assumed drivers do not generally deviate from the specified route under normal circumstances.

Lastly, it is also assumed that drivers will not take breaks for longer than 15 minutes. If they do, we assumed they would call in a backup driver to resume service to their route.

Synopsis of Analysis

Cycle Time Analysis

The data below is derived from Transloc, the ridership app that monitors the vehicles on their respective routes through GPS. After analyzing the app metrics, we identified the key data points needed to highlight the inefficiencies of the overall process. Figure 1 pinpoints which routes are not meeting the cycle time and therefore need to be addressed. The red horizontal line indicates the goal in which each route should be at or below. In this case, the Blue, Green, and Pink Lines are not meeting the target cycle time while the Orange, Purple and Red Lines are. This was the starting point for the optimization process.

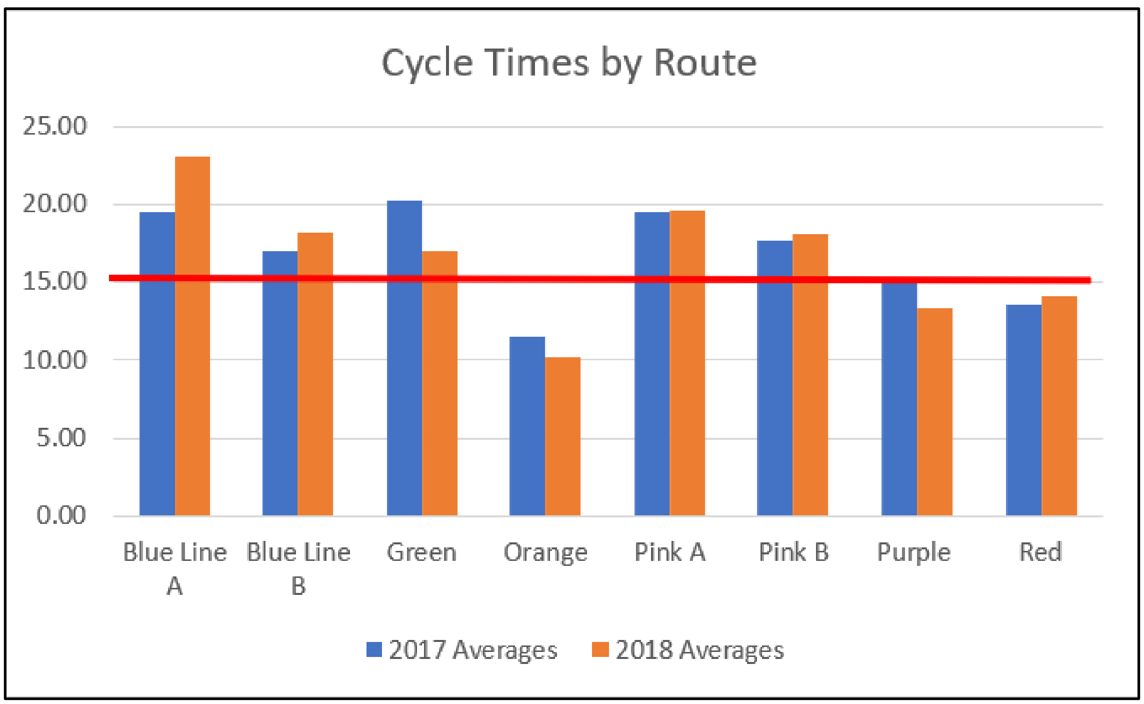


Figure 1: Cycle Times by Route

Comparing the trends between average cycle time per route highlighted which stops took the most time during each route. As Figure 2 displays below, the cycle times vary between stops. This is due to the route cycle time starting when the final passenger ascends the vehicle and lasting until the first passenger exits the vehicle.

The time between the ending of one cycle and the start of another is not counted on that stop’s cycle time but is still counted on other stops. Hence the ones with the shortest cycle times have the most time spent at the stop waiting for passengers to get on and off. The same applies for the opposite: the long cycle times mean very little time was spent at the actual stop. Refer to Appendix B for the cycle time charts of each route.

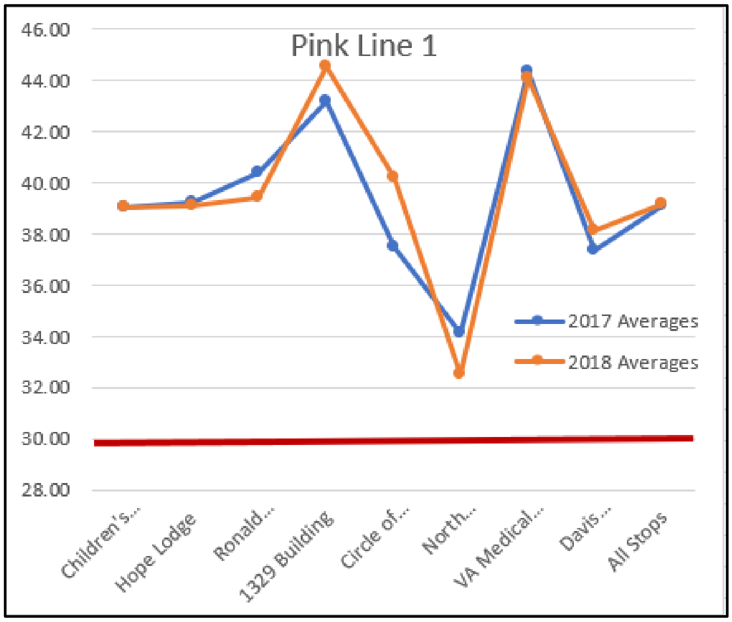


Figure 2: Pink Line Cycle Time by Stop

This data helps identify which stops are busy, which stops the shuttles spend little time waiting at, and which ones may need priority. Additionally, we were able to see which stops were underutilized or unnecessary based on the information found below in Table 1. For example, the VA medical center stop on Pink Line averaged one rider per month. Reference Appendix I for data collecting regarding VA stop utilization. Servicing this stop adds approximately 4 minutes onto each cycle. After gaining approval from our client, George Richardson, this change has the potential to improve the overall cycle time of the Pink Line while having a minimal effect on the overall shuttle system as the stop is severely underutilized.

Ridership Report by Stop				
Stop ID	Stop Name	Stop Code	Boardings	Exits
123361	Garage#2 Roof top	112	5	11
106427	Triangle Lot Staff Parking	101	4233	3123
106437	Ronald McDonald House	106	204	111
106433	Children's Medical Services Center	104	7	38
106441	North Tower Front Circle	108	1946	1957
106443	VA Medical Center	109	1	1
106445	Davis Cancer Pavilion/Medical Plaza	110	1175	1317
123363	Dental Clinics	113	17	25
106435	Hope Lodge	105	97	99
106425	Staff Garage 9	100	6488	6608
124667	Circle of Hope	114	3590	3683
106429	Archer Road RTS	103	5477	5054
106431	1329 Building	102	1369	1710

Table 1: Ridership Report by Stop

Lastly, one of the largest factors for the large cycle times is excessive waiting at the stops by the shuttle drivers. After talking with our sponsor, it was determined that the drivers needed at least one minute of waiting time at each stop. This is due to the Transloc GPS not being entirely accurate and allowing some cushion time for patients and employees to get to the shuttle stops themselves. Keeping this time spent waiting as long as possible is critical for a reduced cycle time. For example, an extra 30 seconds spent at each stop of the Pink Line results in an additional 4 minutes added to the total cycle time. This is an easy adjustment that helps patients and employees get to their stops more quickly.

Shuttle Observation

Each passenger and employee shuttle was observed at least twice to gather information about the routes drivers take, discuss route improvements with the drivers, and receive feedback from the passengers. The drivers provided quality feedback on potential stop changes and insight to the obstacles they regularly face. Drivers on the patient routes have stated that many times, patients have an urgent need to get to their destination because they are feeling unwell or are running late to important appointments. Drivers are very considerate of individual situations and may break route to address the immediate concerns of the patients. The empathy and willingness to adjust to individual situations is highly necessary but causes significant variation in cycle times, among other influences. In turn, this prevents shuttles from having exact scheduled stop times. An in-depth explanation of performance variation is provided below for the individual routes:

Orange Line

The Orange Line services patients and is the shortest and fastest route. Refer to Appendix A for an overview of the route. With only two stops servicing the North and South Towers, this shuttle has an average cycle time of about ten minutes and therefore does not have trouble meeting the 15-minute cycle time goal in its current state. The cycle time could be shorter, but the drivers typically wait at the North and South Towers to ensure the patients have ample time to get to the shuttles, as many wait indoors. Most patients using this route are mobility-impaired or are at the wrong tower for their appointment. It is important to note that the current route follows a temporary detour because of construction around South Tower. The shuttle is taking a temporary route that traverses the Circle of Hope parking lot as opposed to utilizing the entire Circle of Hope loop. Once the construction is completed, the average cycle time will likely be even shorter than the current ten minutes. Most ridership occurs before 3:30 P.M., and ridership is typically light with an average of 35 riders per day.

Green Line

The Green Line is a patient route with three stops servicing the UF Health Davis Cancer Center, South Tower/Circle of Hope, and North Tower. Refer to Appendix A for an overview of the route. Typically, the busiest hours for the Green Line are mornings between 9:00 AM and 10:30 AM and lunch time between 11:00 AM and 2:00 PM. At lunch, employees often ride the Green Line to get to better food options provided at South Tower. This merging of patient and employee passengers can slow down the cycle times as drivers often wait for employees who are running to the stop to board the shuttle.

In general, the client wishes to separate the patient passengers from the medical employee passengers. However, preventing employees from riding the patient routes is outside the scope of this project.

Most riders of the Green Line are going to the Medical Plaza or the North Tower. Patient passengers have occasionally parked in the wrong parking garage and may take Green Line to the location of their appointment. Fridays are the slowest days for the Green Line as there are less patient appointments on these days.

The Green Line is currently running over the 15 minute cycle time goal, averaging about 17 minutes per cycle. A major cause of this excess time is because of the current shuttle stop at Medical Plaza. There is no signage indicating that the area is for UF Health Shands shuttles only. As a result, there are often private buses, food delivery service vehicles, or patients' family members leaving their cars unattended and obstructing the shuttle stop area. Shuttle drivers are forced to wait as they are unable to get around the unwarranted vehicles.

Pink Line

The Pink Line is a comprehensive patient route that currently has the longest cycle time of any route. It is averaging about 37 minutes per cycle, largely due to the number of stops and total area coverage. There are two Pink Line shuttles that have individual cycle time goals of thirty minutes but try to stay on opposite ends of the route so as to circulate around to each stop every 15 minutes. Therefore, the goal for the Pink Line is a thirty-minute cycle time with mirroring shuttles.

The Pink Line encounters the most instances of changing a route due to urgent passenger needs. As the Pink Line primarily serves cancer patients, there are many instances where a patient is not feeling well and will need to go straight home or to an appointment or a parent needs to go from the Ronald McDonald House to see their child quickly. The Pink Line currently makes eight stops within the route. This lengthy route includes a left turn onto 13th Street which is rather difficult to make in general, but especially challenging during rush hour. Refer to Appendix A for an overview of the Pink Line. Drivers reported a fairly steady flow of riders with peaks observed in the mornings and around meal times.

Express Employee Shuttles: Red Line and Purple Line

The Red Line is an employee route that provides direct service to the South Tower from Staff Garage 9 and the nearby parking lot. Currently, it does not follow the planned Transloc route. Instead of taking SW 16th Avenue, the drivers take SW Archer Road to the Circle of Hope from Staff Garage 9 and back in the morning. Refer to Appendix A for further route details. The driver has found that the cycle times for the Red Line decrease when avoiding SW 16th Avenue. This also allows the driver to avoid a dangerous maneuver of crossing two double yellow lines while turning left out of Staff Garage 9 as well as avoid the extensive traffic on 16th Avenue.

Most people on the Red Line stated that the Red Line is a huge improvement from the Blue Line and have exclusively used the Red Line since its recent introduction as an Express Route. Some riders who needed to go to the North Tower preferred the Red Line over all other routes (even the Purple Line), claiming it's the fastest.

The traffic on Archer Road did not substantially increase the overall cycle time. With the previously mentioned construction, however, about one to two minutes of time was added to the current route. According to the shuttle driver, the current stop is not in an ideal location. It can be improved by having a designated shuttle stop area rather than utilizing a stop sign in the complex. Also, signage indicating that the specified area was a shuttle stop, not an unloading zone for cars, would help to decrease the cycle time by discouraging nonessential vehicles from obstructing the stop.

The Purple Line is the employee service route that goes directly to the North Tower from the parking area. Our time study for Purple Line indicated that the shuttle was able to meet the cycle time goal and other key metrics. With other factors such as the traffic during peak time and construction in the South Tower, Purple Line was still able to complete the route within 15 minutes. Therefore, Purple Line will not be considered for optimization as it already meeting the cycle time goal.

Blue Line

The Blue Line is the main employee service route. There is a total of five stops. Its primary purpose is to transport employees from the parking lot and garage to their work locations, stopping at the 1329 building, South Tower, and then the RTS stop on

Archer Road close to the North Tower. During evenings and inclement weather, the shuttle goes into the North Tower loop for safety reasons. This is normally avoided since the North Tower stop is reserved for patient shuttle lines and is often congested with other vehicles. The route runs an additional shuttle during peak hours of the day, generally covering morning and afternoon shift change periods from around 6:30 AM to 10:00 AM and 2:30 PM to 6:00 PM. These two vehicles currently stack up behind one another to provide more seat capacity every 15 minutes when they arrive at each stop, meant to ensure that all riders waiting will be accounted for during that cycle. Further discussion of stacking shuttles can be found in the Project Deliverables section of this report.

This route generally has a cycle time slightly over 15 minutes, with a longer duration during times of heavy traffic. It has the highest rate of dissatisfaction among the employees who utilize the shuttles. Complaints typically refer to the amount of time it takes for the shuttle to reach the riders' destinations. In the mornings, employees traveling to the North Tower are disgruntled, since that stop is the last in the loop. In the afternoons, employees traveling to the parking areas from the 1329 building complain, since they're picked up first in the cycle and have to wait as the shuttle completes the loop before getting to the parking lot or garage.

In addition to rider complaints, there are safety concerns to make note of. The current route has the shuttle picking up passengers at Garage 9 and then making a left-hand turn across double solid yellow lines to head southwest towards the Triangle Lot Staff Parking stop. This left-hand turn is inefficient as traffic is often blocking the way out of Garage 9 during peak times, making it difficult to safely make the turn. Drivers must navigate multiple lanes of oncoming traffic that flow through the intersection of Archer Road and Gale Lemerand Drive and have expressed their concerns with staying on route in this area. Further suggestions can be found in the "Project Deliverables" section of the report.

Optimization Model

After analyzing the quantitative and qualitative data, we realized that we needed to consider re-routing the Pink, Blue, and Green Lines to make significant improvements to the operation of those routes. We used the Travelling Salesman Problem (TSP) and the Nearest-Neighbors Heuristic[6] to attempt a quantitative approach at improving the routes.

Recall, the solution to Travelling Salesman Problem is the shortest Hamiltonian Cycle in a directed graph (i.e. the fastest way to travel between all points in a network where we end up back where we started.) The travelling salesman problem is NP-Complete[13][15], meaning that the number of steps needed to solve the problem grows astronomically fast as complexity increases. As a result, we needed to use a heuristic algorithm to efficiently solve this problem by approximating a close-to-optimal result. We optimized the routes by modeling each as a fully-connected directed graph (or digraph), where the vertices represented the stops for the route, the directed edges represent the shortest route from one stop to another, and the edges are weighted based on the expected travel time driving between those two stops [7]. Refer to Appendix C - The Network Abstractions for each route. After building a digraph for each route, we generated a from/to matrix for each route, where the rows represent the stop we leave from, and the columns represent the stop we arrive at. The value in each cell is the weight of the edge that corresponds to that pair of vertices, and all of the diagonals take the value 0 (as the travel time from a stop to itself is 0 in this case).

With the from/to matrices generated for the Pink, Blue, and Green Lines, we implemented them into a computer as .csv files, and imported those .csv's into R, a statistical computing software[3]. In R, we used the TSP package[4] to solve an Asymmetric Travelling Salesman Problem (because the from/to matrix is not symmetric because in some cases, it takes longer to get between two stops in one direction than another). The TSP package has a variety of heuristic algorithms to solve the problem; we used the Nearest-Neighbors Heuristic, which works by selecting a node on the graph, and selecting the next node that directly connected to the previous node with the shortest connecting distance until all nodes have been selected[6]. We used this specific heuristic because the graph is fully connected—each vertex connects to all other vertices directly in both directions, and a fully connected graph has all other vertices as direct "neighbors." Since we used a heuristic, optimality is not guaranteed, but the results are a good approximation. Therefore, we ran the solver 100,000 times to get a distribution of results for each route and scenario, and looked at the solutions that led to the best (shortest cycle time) route that the shuttles could still negotiate. Refer to Appendix D for the resulting distributions of each route.

Additional Factors

Drivers expressed having navigation issues because many stops they service have one way in and one way out. If anything obstructs the stop, such as an unattended vehicle, the driver could be left waiting for a long period of time until the stop is navigable. One driver reported there was once a fire near a stop, with fire trucks trapping the shuttle until the situation was dissolved. The driver was unable to maneuver out due to the tight space until the fire trucks left.

The team also considered the need to update signage at many of the stops. We found many signs were outdated or confusing for the patients and employees to use. It is critical that shuttle passengers understand the system to optimize efficiency.

Data Validation

To validate the Transloc ridership data, the team conducted field observations by counting on-boarding and off-boarding within hour increments. The goal was to determine the variation, if any, that was present between the data recorded in the Transloc App and the actual ridership that occurred. The team did note slight differences between actual and observed data. Several factors were observed that contributed to the cause of this inaccuracy. The drivers generally have ongoing, friendly relationships with passengers and will take a few moments to greet them upon arrival. Additionally, passengers are often seeking expertise from the drivers to gain insight on what routes to take or which stops the present shuttle services. From the team's observations, drivers are always willing to assist passengers with directions. This service from the drivers is necessary for helping passengers navigate around the extensive hospital network. While these behaviors may contribute to the customer service aspect of the shuttles, they often detract from the accuracy of the total passenger count. Therefore, some variance is expected with regards to the Transloc ridership data due to human variation, but the overall trends for the passenger volume throughout the day are consistent.

From the team's analysis, it is apparent that the variance in ridership data accuracy increases when more passengers are boarding, as it is more difficult for drivers to count and keep track of the people. When passengers board, the count accuracy remains consistent up until around eight passengers, even during peak time the accuracy of the count was within five above or below the actual ridership number. The drivers tend to zero out the counter after the stop where they expect all boarded passengers to off-board. In the mornings, this is the last hospital stop in the loop. In the afternoons, this is the last parking stop.

Conclusions

Red Line

The team would like to make adjustments to the current Red Line route to decrease the average cycle time. By minimizing time on Southwest 16th Avenue, which is heavily congested and lined with multiple stoplights, the Red Line can more optimally service its passengers. The new suggested route would include staying on Archer Road when traveling east and west.

Cancer Pavilion Shuttle Stop Changes

The shuttle stop at the UF Health Davis Cancer Pavilion does not have any signage indicating that there is a shuttle stop or that outside vehicles are not allowed to park in the shuttle stop. The team proposed implementing "No Parking" signs at the shuttle stop to decrease the number of cars that park in front of the shuttle stop. UF Health is not able to ticket cars that park in these zones, but as of now there are no signs deterring cars from parking. With the addition of "No Parking" signs, "Shuttle Stop" signs should be used to assist patients in finding the stop as well as indicating where the Green and Pink Lines go.

Shorter Hours for Orange Line

Based on shuttle observations, ridership data, and driver comments, it was evident that few riders were riding the Orange Line after 3:30 P.M. The team suggested to change Orange Line hours from its original 7:00 AM to 6:00 PM schedule to 7:00 AM to 3:30 PM. With the shorter hours, UF Health saves money by decreasing the number of paid labor hours each day by 2.5 hours.

Stop Elimination

Based on the ridership report, from the month of January to April, the average passengers onboard at VA stop for Pink Line is 6 passengers. Considering such a low usage for Pink Line, it is recommended to remove VA stop from the Pink Line and move the stop to Yellow Line, which is able to take special requests for locations not typically serviced by the shuttles. This stop elimination allows Pink Line cover a more efficient and better utilized route while passengers are still able to navigate to their desired locations. We also evaluated the utilization of the 1329 stop on Pink Line, which houses the Human Resource department. As patients should not typically need access to this stop, it makes sense to remove it from a patient route.

New Signage

From observing the shuttle system, it was noted that patient passengers often had difficulty navigating the shuttles. As a result, patient passengers are often confused about which shuttles to take. They may ask drivers for information about where to go or attempt the system on their own, often taking incorrect or less efficient routes to get to their destination. Even employees who have been using the shuttles for years were not well-informed when changes to the system were made. Signage was not immediately updated when routes were adjusted. The current signs do not sufficiently inform potential riders about which routes to take to their desired destination. While the Transloc application exists (which lists the shuttle locations and route information), much of the rider base is less inclined to utilize the technology.

The team recommends new, streamlined signage that passengers can refer to when navigating the shuttle system. The signs will list potential destinations around the hospital, and then include the routes that may be used to travel there. These will vary depending on the stop at which the sign is posted. Image 1 displays the current signage. Image 2 displays the suggested new signage. The suggested signage drafts are based on designs in industries such as aviation and rail systems, and reference literature about wayfinding and signage systems [9][10][11][12]. Refer to Appendix F for a complete list of suggested signage options.

Image 1: Current Signage

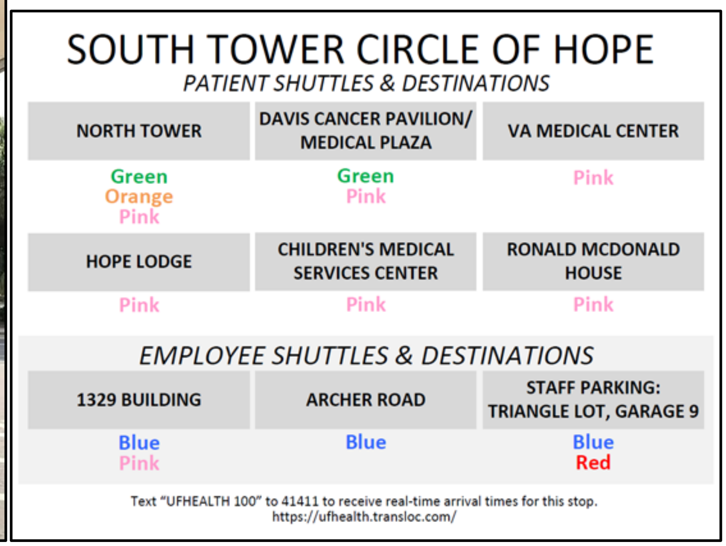


Image 2: Proposed Signage

<u>Eliminating Stacking for Blue Line</u>

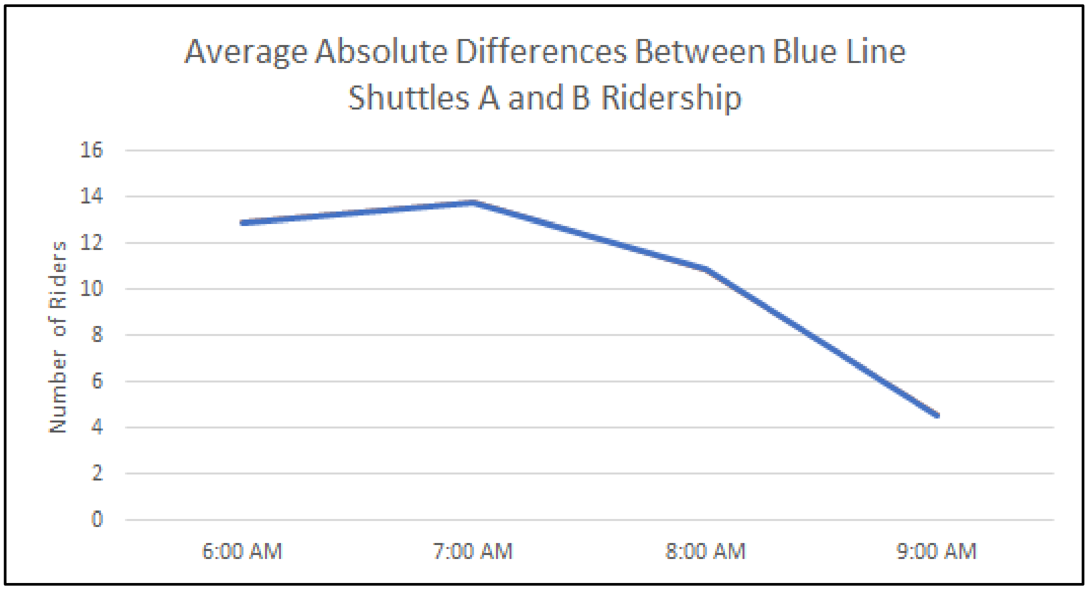
During weekday mornings, there is an influx of hospital employees arriving for work and utilizing the shuttle services. It is critical that the employee shuttles focus on picking up passengers from the parking lots areas and dropping off at the various hospital locations.

The current state of Blue Line is to stack the vehicles within the route during peak times, typically in the mornings from 6:30 AM to 10:00 AM and again in the afternoons 2:30 PM to 6:00 PM. “Stacking” refers to having the shuttles bunch up with one trailing behind the other. Theoretically, the second vehicle will be able to pick up any additional passengers that were unable to fit on the first one. When the shuttles stack, the front shuttle experiences additional delays because there is a greater number of passengers that have been accumulating at the stop. The driver will need to spend extra time allowing the passengers to board. By the time the second shuttle arrives at the stop, there may or may not be overflow passengers, but the number of passengers getting on the second shuttle is typically a lot less, indicating a faster onboarding process.

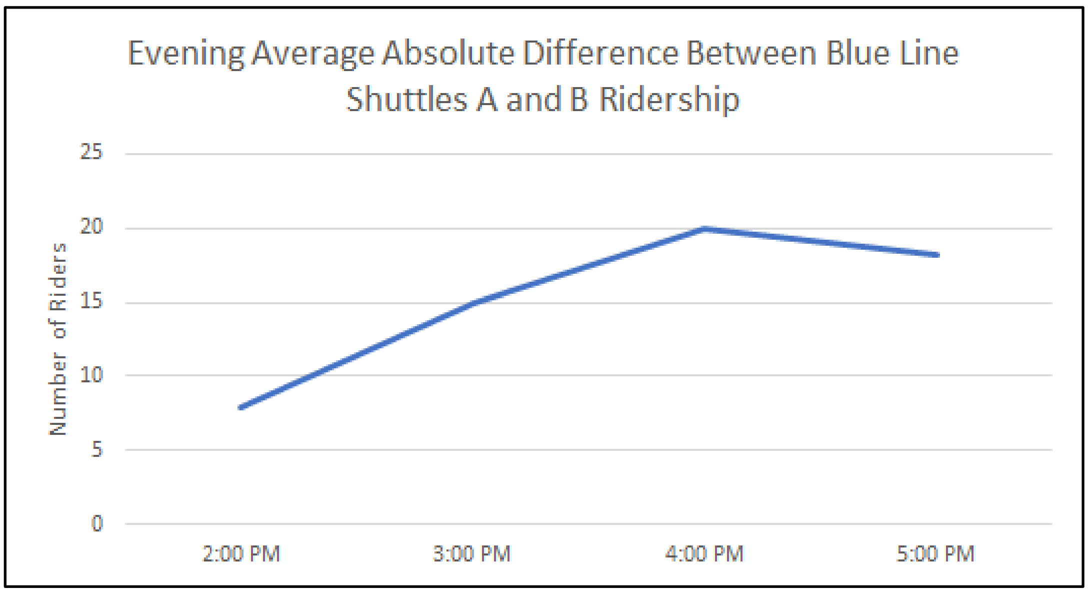
After examining the replay for Blue Line during peak traffic hours, we see a trend that confirms that stacking Blue Line shuttles causes low utilization in the following shuttle. Often the shuttle with low utilization skipped stops or doubled back to the employee garage to pick up passengers. This created a lot of additional travel time in the system, causing waste in resources and longer waiting time for passengers. The team was able to make several observations of the Blue Line when shuttle drivers chose not to stack during peak times. In each of these observations, the shuttles never reached full capacity.

The Graphs 1 and 2 display the absolute value of the difference in passenger count between the two shuttles in the morning and evening, when stacking is occurring. The absolute value was taken because the shuttles did not have a set stacking pattern i.e. sometimes Blue Line ShandsVan A was the leading vehicle and sometimes Blue Line ShandsVan B was.

In the mornings, the average difference in ridership peaks around 7:00 AM at slightly less than 14 passengers. This is saying that around 7:00 AM, one vehicle is averaging nearly 14 more riders than the other. Likewise, the average difference in ridership during the afternoon/evening peaks around 4:00 PM at around 20 passengers.



Graph 1: Average Differences Between Blue Line Shuttles A and B Ridership



Graph 2: Evening Average Difference Between Blue Line Shuttles A and B Ridership

The benefits of having the shuttles bunch up do not outweigh the negative results that occur from this behavior. A study on the effects of bus bunching states: “The bunching will reduce the amount of usable passenger capacity provided, increases passenger loads on the first vehicle in the bunch, increases passengers’ waiting time, and therefore increases their overall travel time, particularly for passengers on an overcrowded vehicle” [8].

The goal is to have a 15-minute cycle time for each of the Blue Line shuttles. By not stacking them, the frequency in which they service the stops could be reduced to about once every eight minutes as opposed to once every thirteen to 15 minutes, helping to reduce overall wait time for passengers.

<u>Route Optimization Tools and Results</u>

In Appendix G, we have the from/to matrices for the four scenarios we ran the optimization model for: Pink Line after removing the 1329 stop, Pink Line without 1329 and the VA, the Blue Line, and the Green Line. The Pink Line matrices are generated in code—for cases where we removed a stop, we just simply deleted a row/column corresponding to that stop. For example, if we were deleting the VA stop, we would remove the 3rd row and 3rd column from the matrix. We input these matrices into R and ran the nearest-neighbors heuristic for each section. The distribution of cycles found by the algorithm for each scenario is in Appendix D. From the distributions, we looked at the cycles that corresponded to the lowest expected cycle time and looked at how they compared to the current shuttle routes.

We concluded that the Green Line and Blue Line routes needed no changes, as the best cycles outputted by the model all matched with the current Green Line and Blue Line setups. In the Pink Line, there was one significant change: we found that having the shuttles travel from the Ronald McDonald House to either the VA or South Tower is best accomplished by driving along 13th Street up to Archer Road, making a left at Archer Road, then proceeding to the respective stop via Archer Road, since we are no longer directly servicing the 1329 stop. Refer to Appendix E for the suggested Pink Line route.

Modeling the improved routes as a computerized simulation would be extremely difficult; we would have to factor in road closures, other vehicles, fuel consumption, etc. By simulating the improved routes in a vehicle as a team, we were able to see how effective our changes would be in an accurate, everyday setting without actually diverting routes until we could confirm benefits, and without the difficulty of implementing simulation methods in a computer. The scope of this system is relatively small, so real-world simulation would be a more effective use of time.

To further assist the management at UF Health Shands, we will include the well-documented R script code that was used to optimize the routes, as that will allow future shuttle system improvements using mathematical modeling.

Discussion

The scope of our analysis goes beyond quantitative measure; we are looking at human factors in these routes as well. Our analysis and implementation involved a two-pronged approach—we analyzed the data to make mathematically-aided decisions about improvement and tested the ideas in the real world rather than simulating the system on a computer. This approach accomplishes two goals: one, it allows for a blend of quantitative and ergonomic factors—we are looking at improving system efficiency while also taking in account the ease of operation and use of the system by and for humans, and two, it will simplify our simulation process.

Beyond single route changes, changing the shuttle operation schedule is also a viable option. Further data and analysis are needed, however, to make any adjustments to the schedule. A structured schedule other than the simple 15-minute goal and action by the drivers does not exist. One possible improvement to this would be to structure the schedule during peak times only, and let the drivers make ad-hoc decisions like they do now during off-peak times.

In the future, there are many different directions that can be taken to expand upon this analysis, and some are already underway: The team was notified that the introduction of a new Brown Line was being considered as a result of rider feedback, and the feasibility of this line can be evaluated with methods similar to those covered by the team's analysis. Based on observations of rider behavior regarding wayfinding around the UF Health campus, further initiatives may be taken to improve the way signage and information is presented to employees and patients in general. For example, a pedestrian tunnel exists that connects the North and South Towers, yet many employees are unaware of this possible path. Further research into economic factors of the shuttles can also add depth to the optimization of shuttle routes. All of these points provide possible areas of opportunity for continued analysis, research and improvement.

Recommendations

Shuttle Line	Recommendation(s)
Pink Line	• Remove the 1329 and VA stops • Minor route adjustments
Green Line	• Add 'No Parking' signs at Davis Cancer Pavilion • Maximum wait time at each stop should be no more than one minute
Blue Line	• Remove 'Stacking' of shuttles during peak time
Red Line	• Utilize Archer Road for east/west travel
Orange Line	• Stop shuttle services after 3:30 PM

Table 2: Summary of Recommendations

Financial Impact of Recommendations

The goal of the project was to improve the shuttle experience for the patients and employees. The team worked with the goal of decreasing cycle time for each route which decreases waiting time for each patient and employee. The cycle times were successfully decreased, but the routes, excluding the Orange Line, will keep the same running times. Therefore, there are not financial savings for decreasing cycle times. The main financial impacts of the proposed recommendations are the purchasing of new signage and the money saved by decreasing the Orange Line times. Each new sign costs $32 a sign, and the team has recommended to purchase signs for stops which receive high passenger traffic volume with access to multiple shuttle lines traveling to diverse locations. This totals $96 for signs at three stops (North Tower, South Tower, Garage 9). The salaries for shuttle drives are not public but decreasing the running time for the Orange Line by 2.5 hours each day saves 625 labor hours per year. In sum, the satisfaction of the riders was the main goal of the project and was improved dramatically by the proposed stop eliminations, new signage, and route adjustments.

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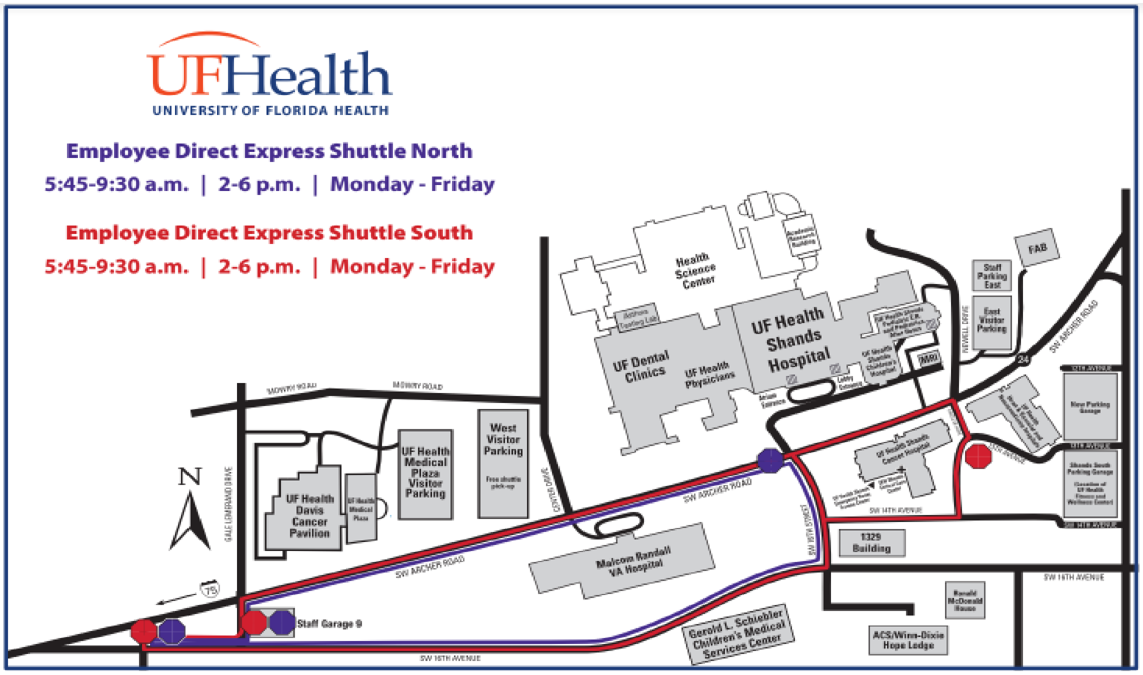
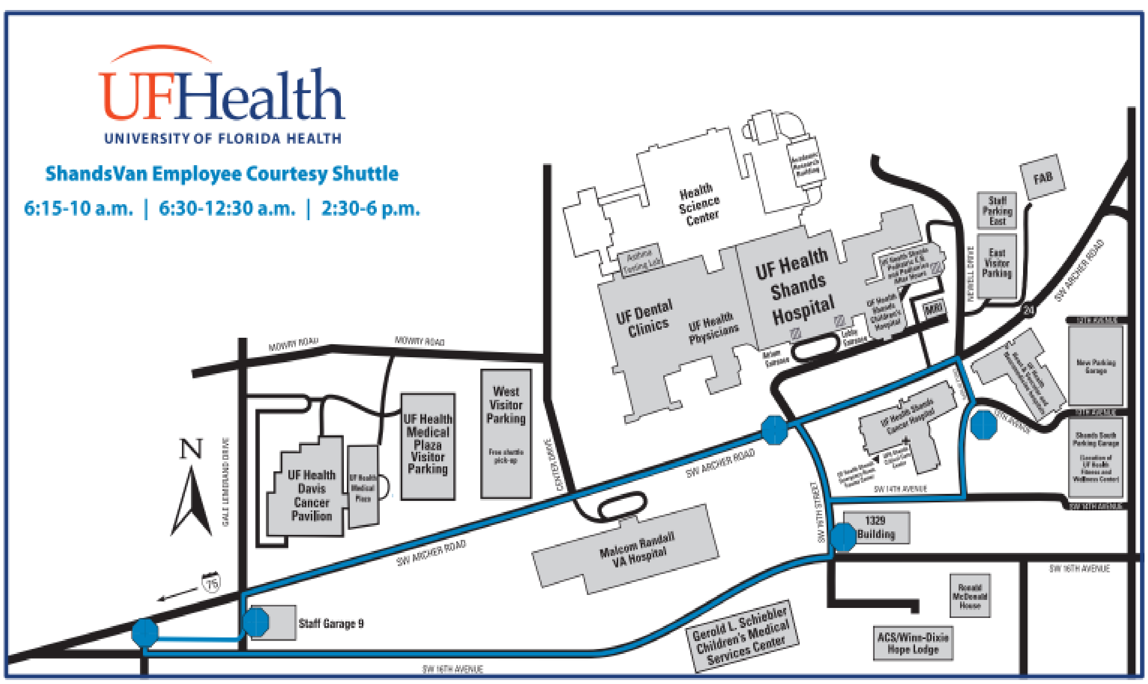
Appendices

Appendix A: Current Route Maps

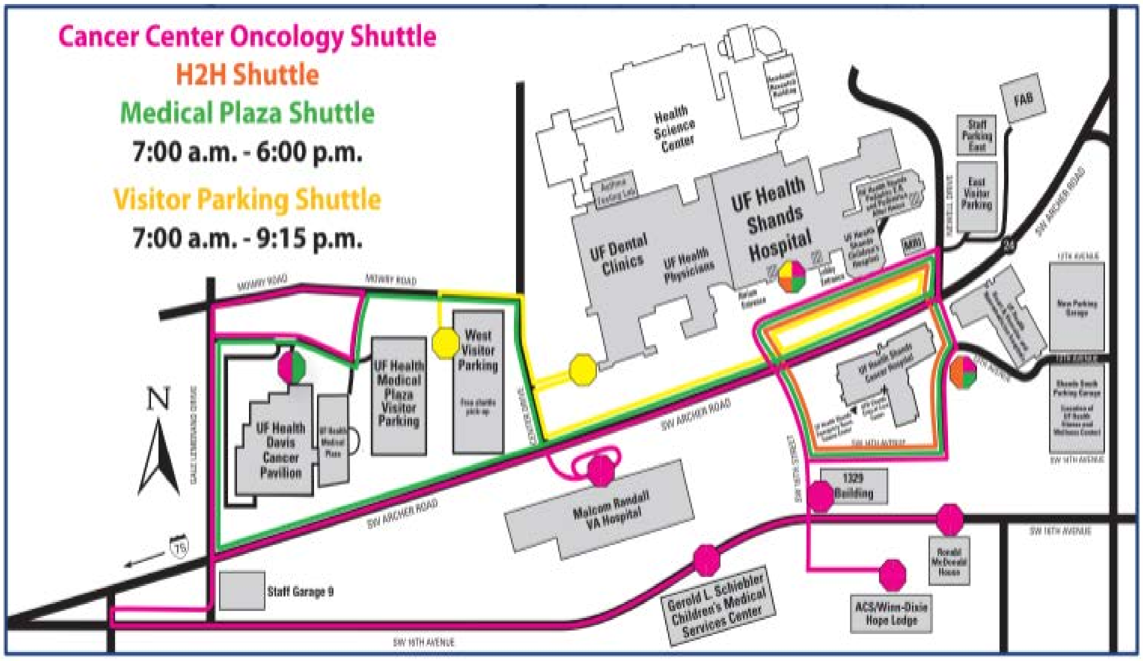
Employee Express Routes



Employee Blue Line Route

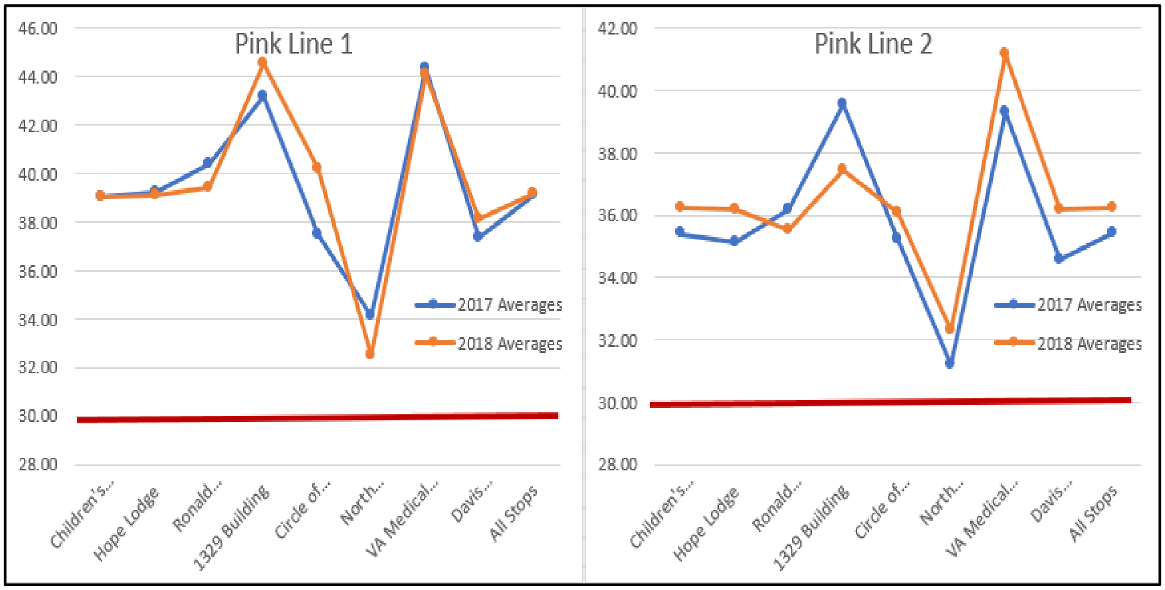


Patient Shuttle Routes

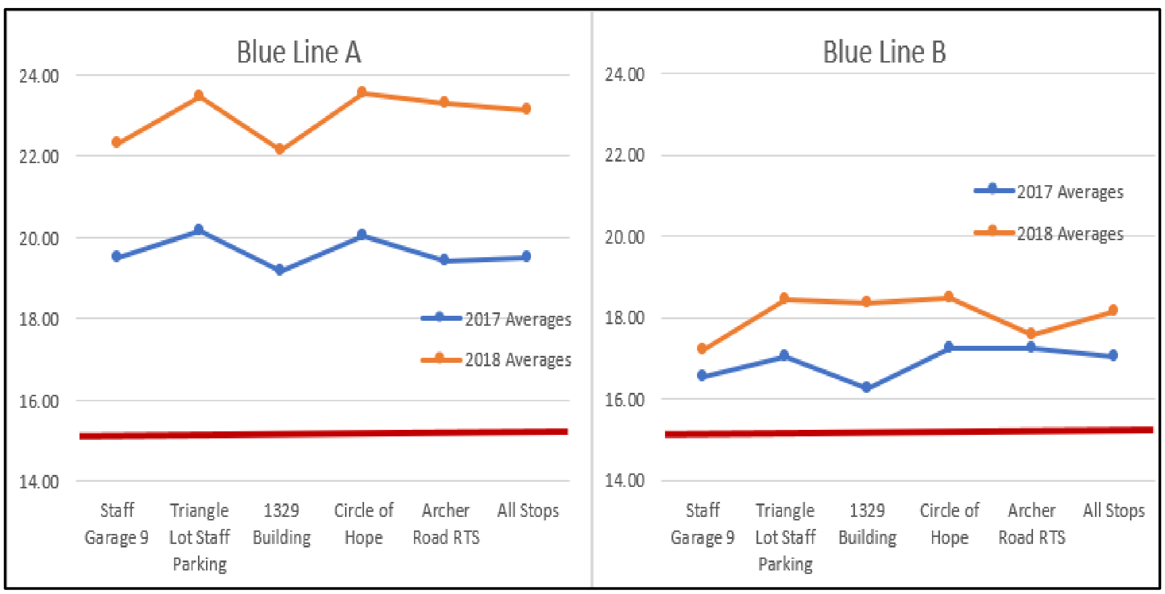


Appendix B: Cycle Times

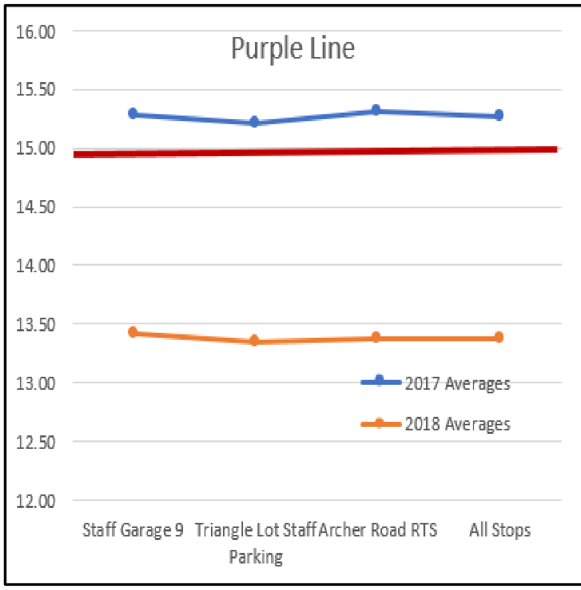
Pink Line Cycle Time by Stops

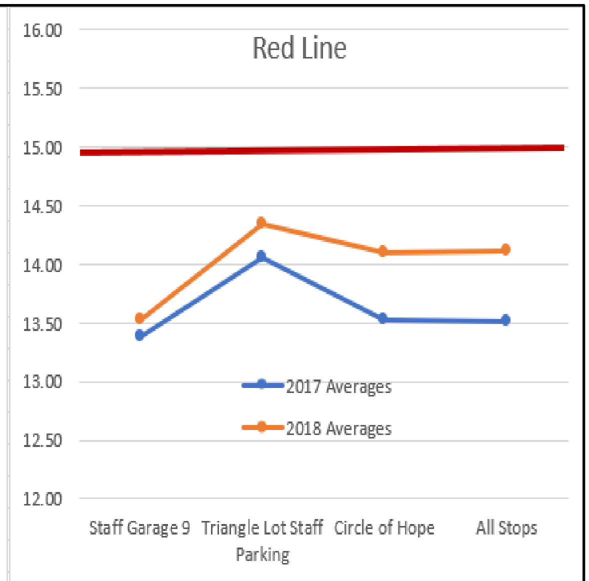


Blue Line Cycle Time by Stops

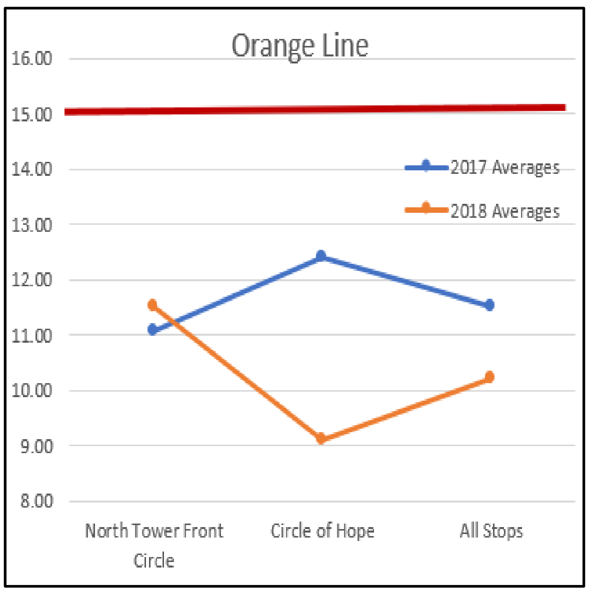


Purple & Red Line Cycle Time by Stop



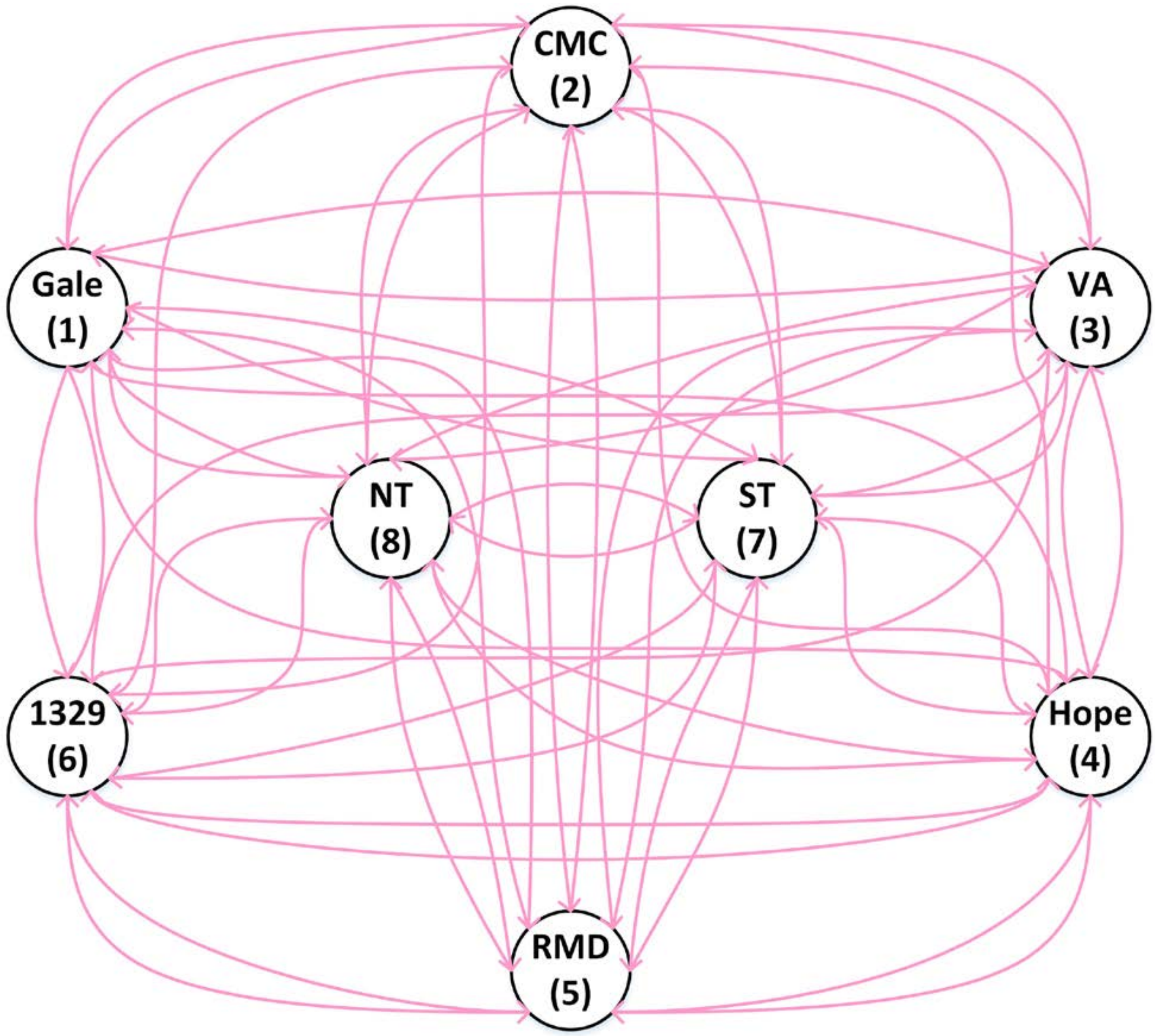


Orange Line Cycle Time by Stop

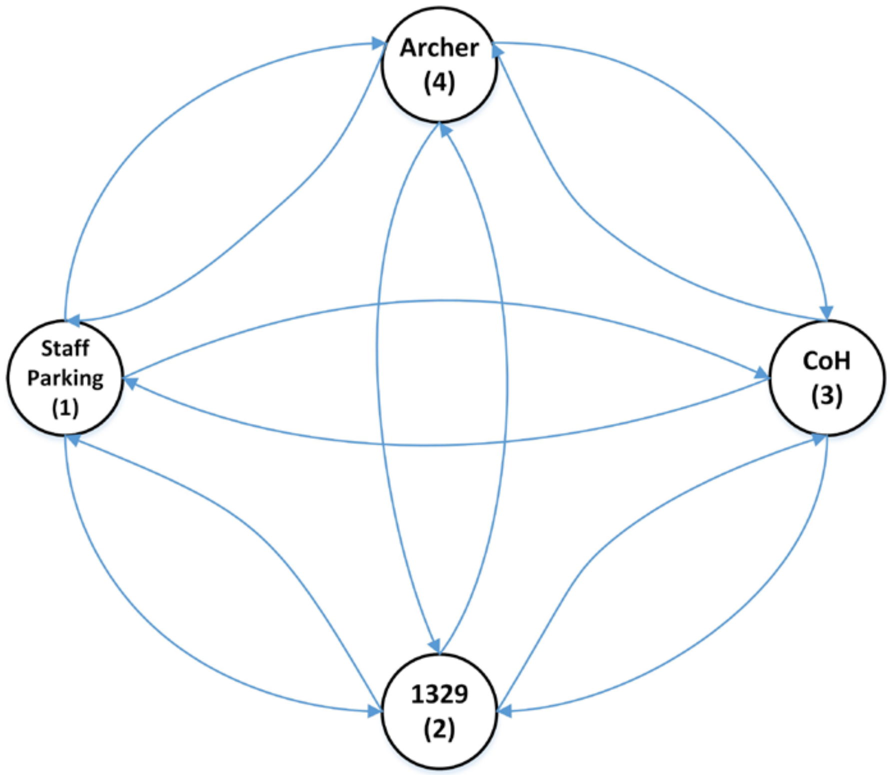


Appendix C: Route Graph Abstractions for Pink, Blue, and Green

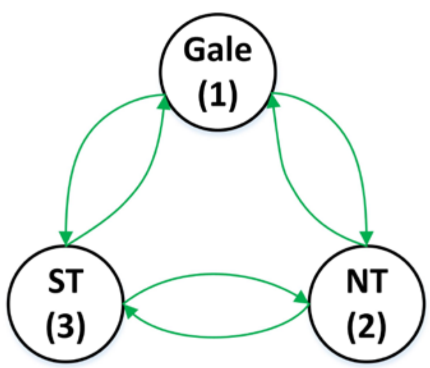
Pink Line Network



Blue Line Network

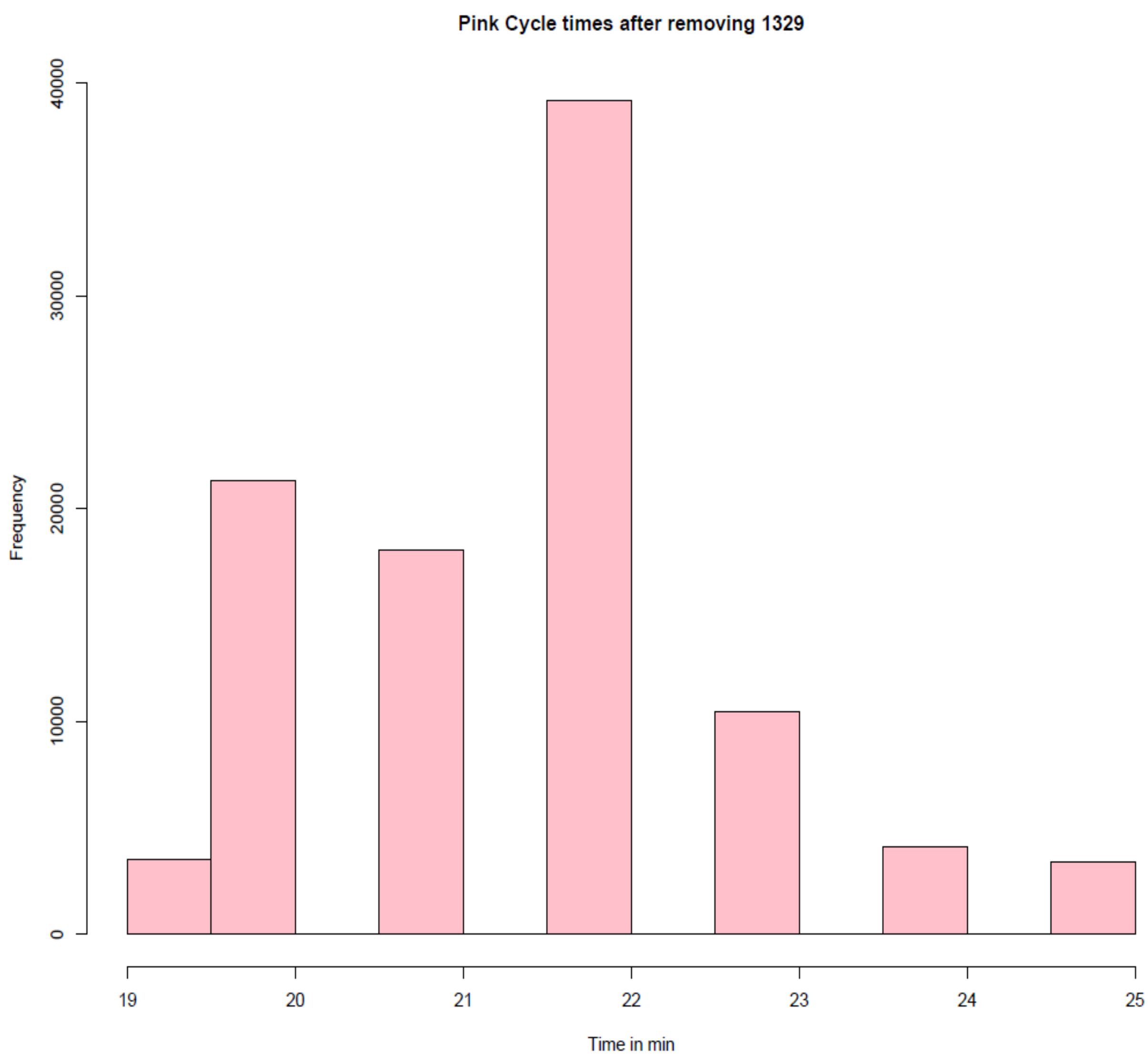


Green Line Network

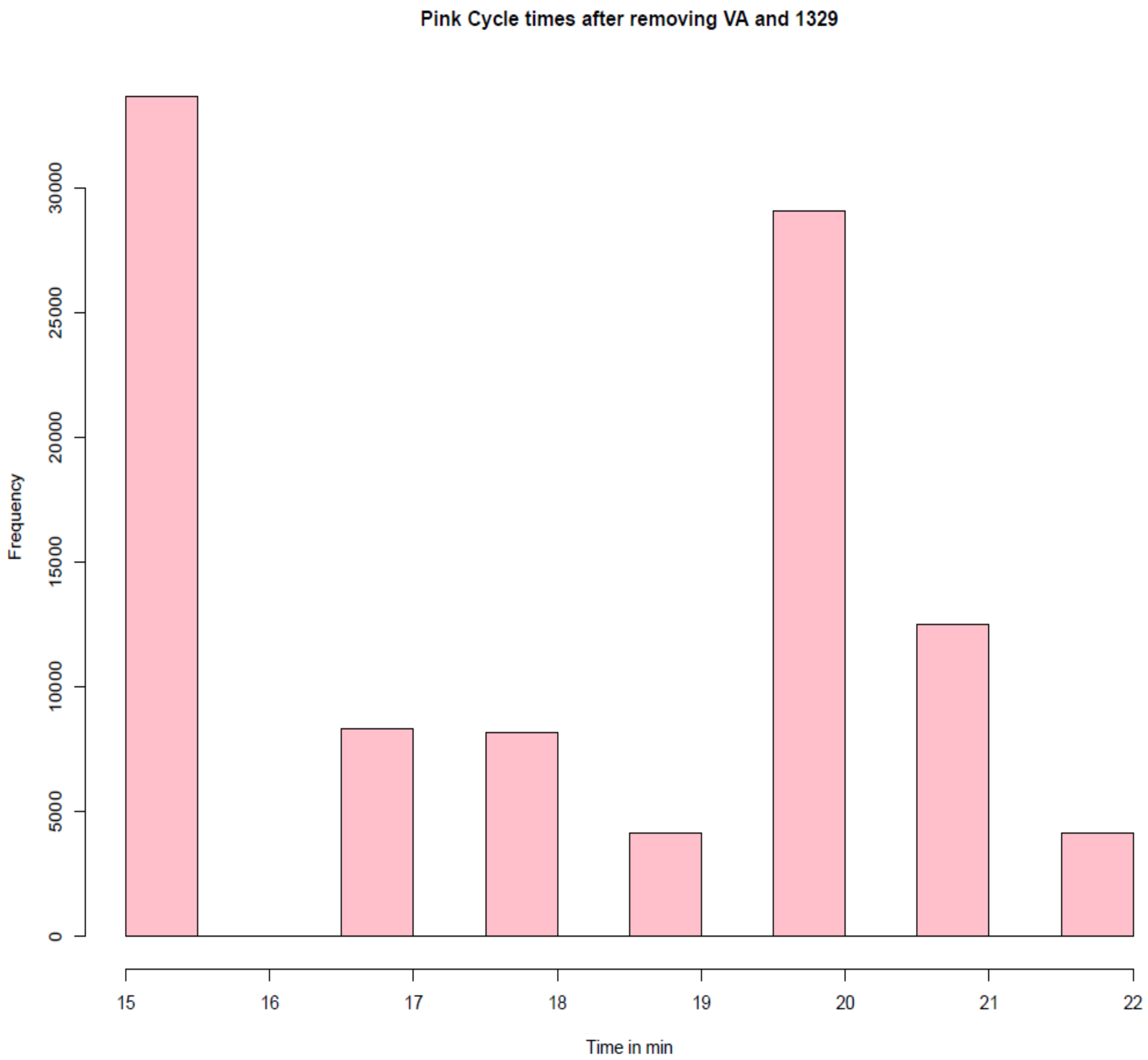


Appendix D: Optimization Results Charts

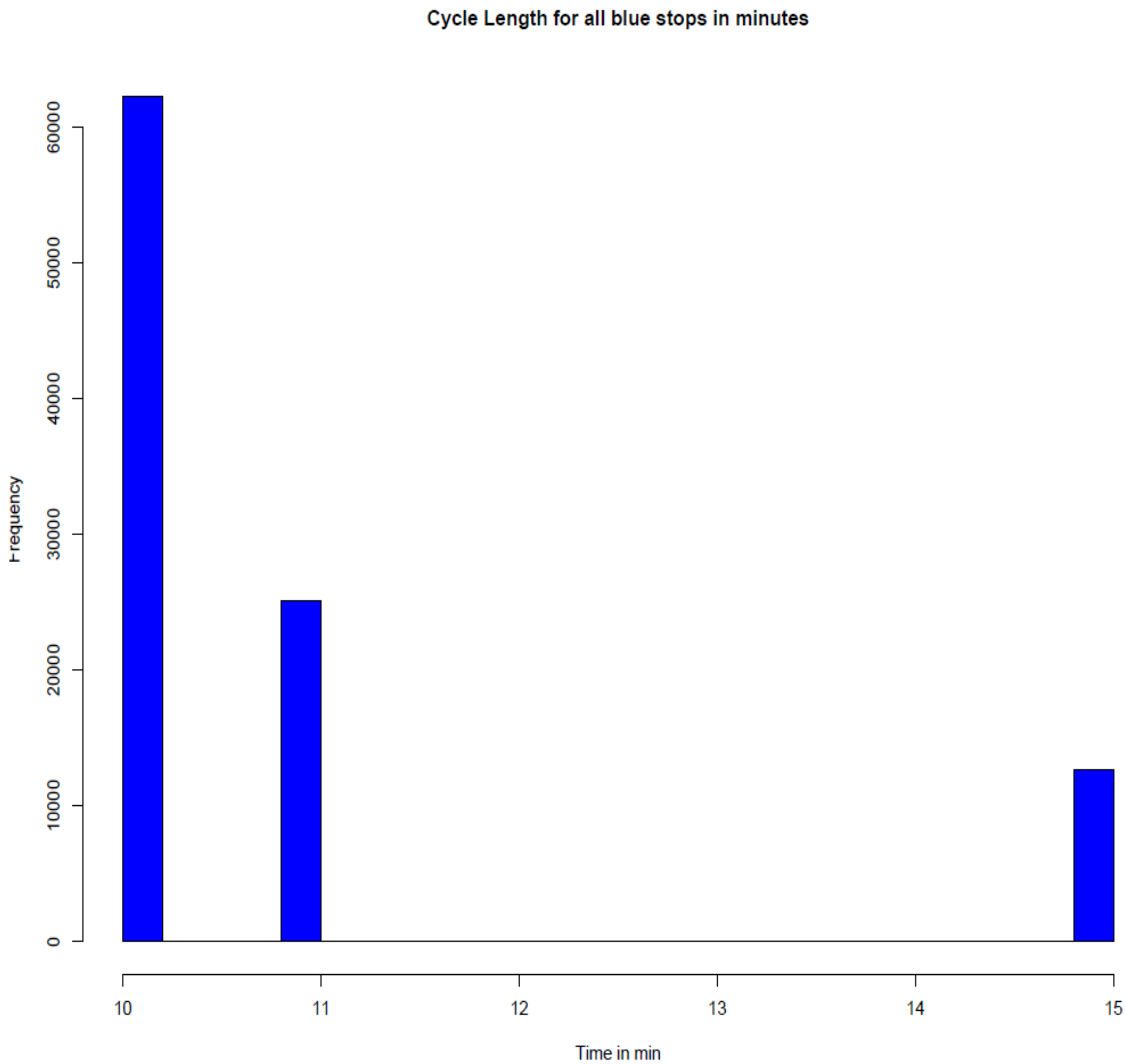
Pink Line Without 1329



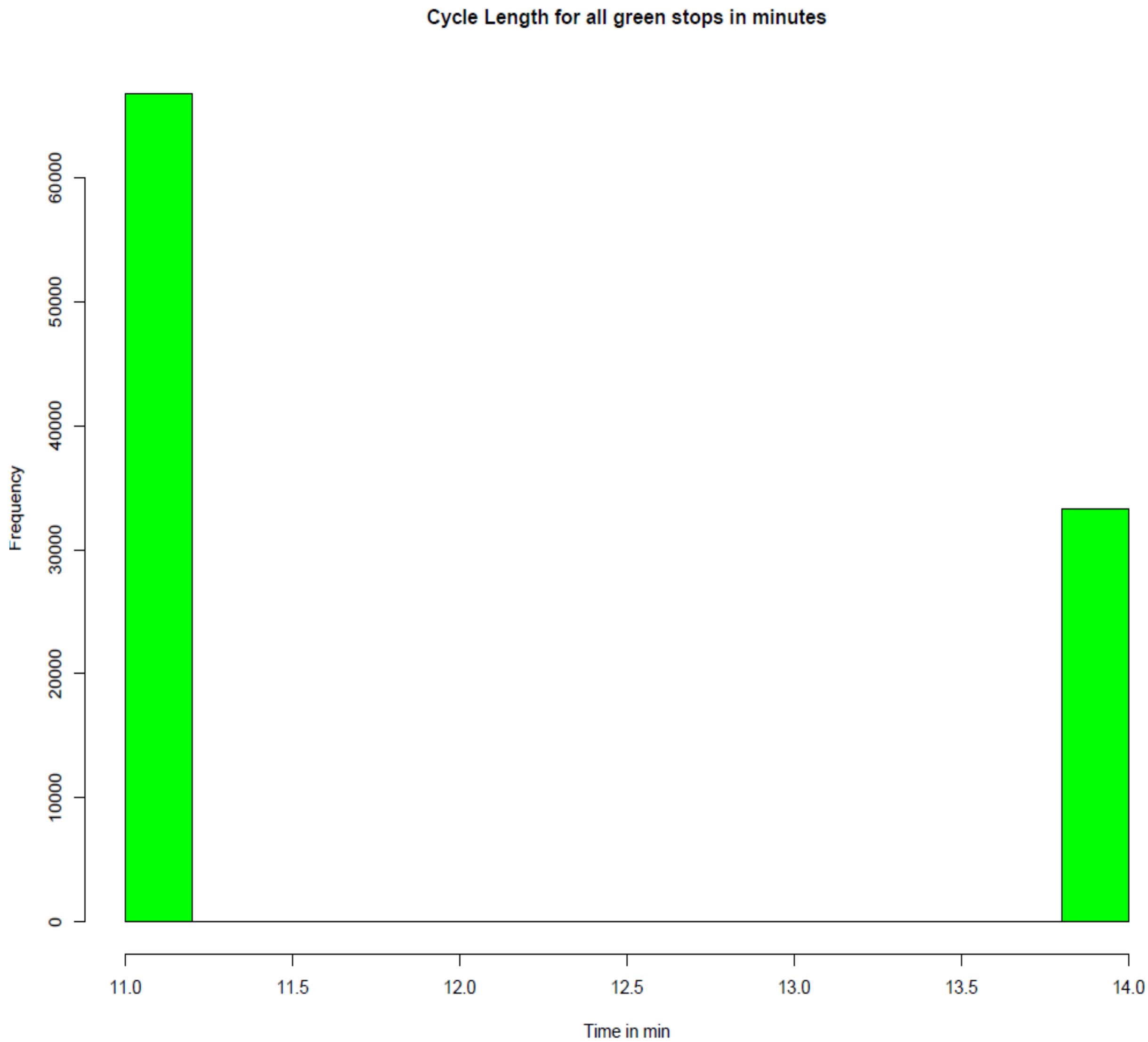
Pink Line Without 1329 and VA



Blue Line


Cycle Length for all blue stops in minutes
Frequency
0
10000
20000
30000
40000
50000
60000
10
11
12
13
14
15
Time in min

Green Line

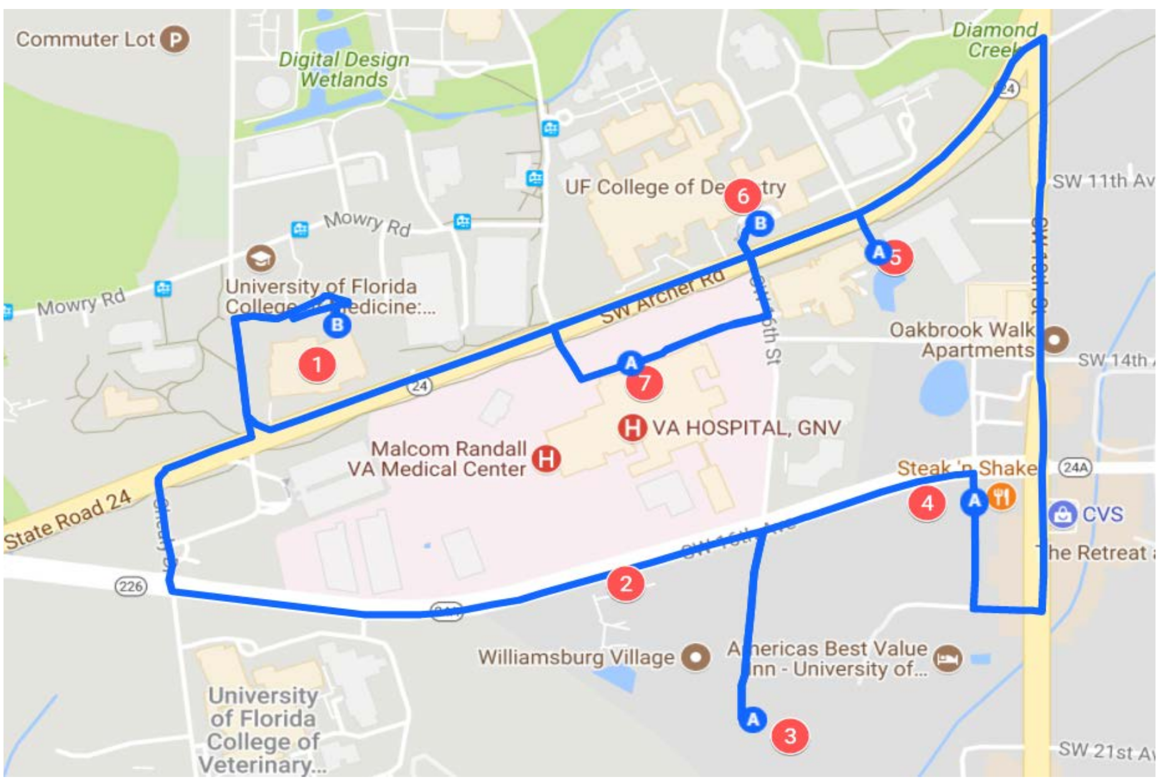


Cycle Length for all green stops in minutes
Frequency
0
10000
20000
30000
40000
50000
60000
11.0
11.5
12.0
12.5
13.0
13.5
14.0
Time in min

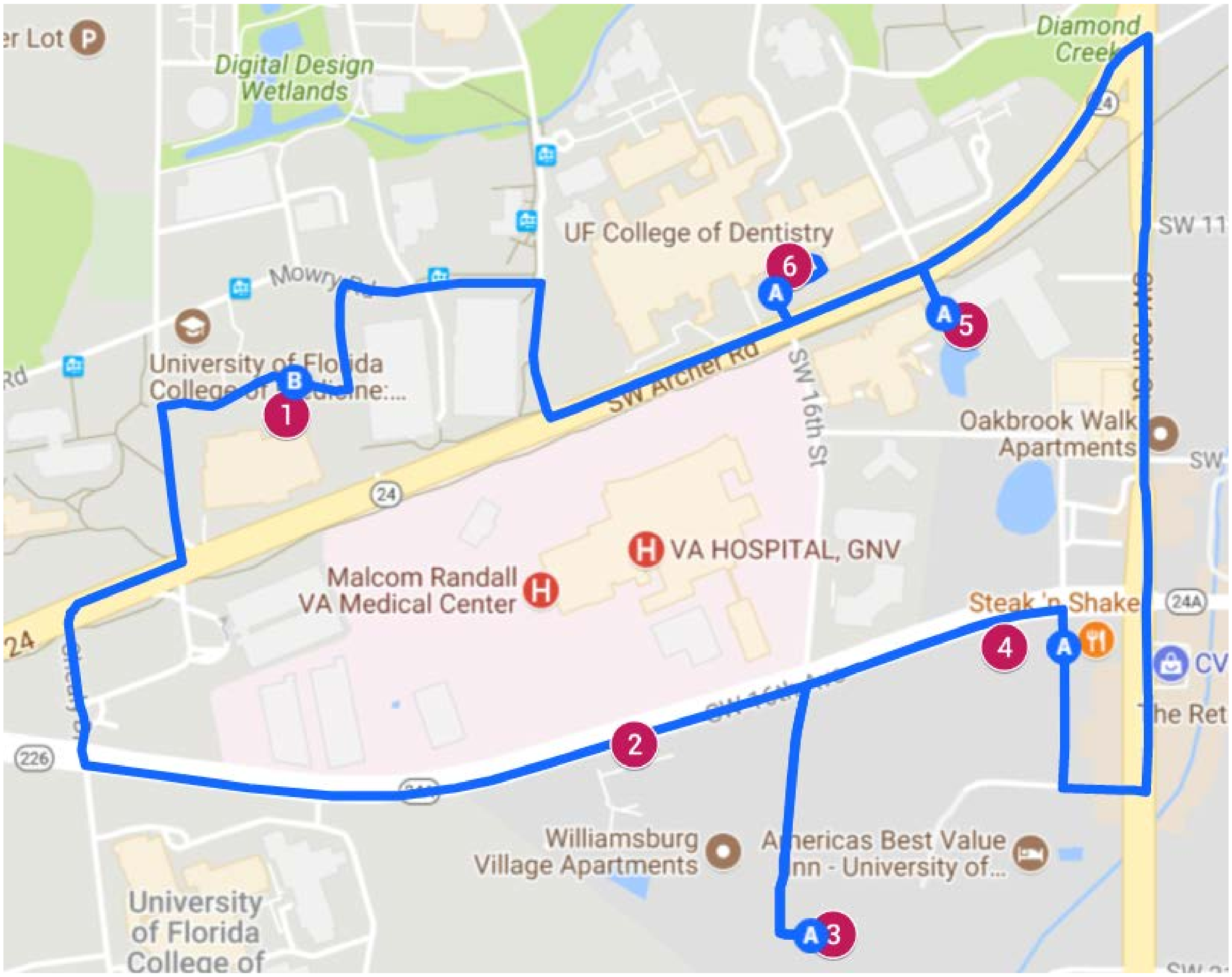
Appendix E: Suggested Route Changes

Pink Line without Stop Removals

Pink Line without 1329



Pink Line without 1329 and VA



Appendix F: New Shuttle System Signage Design Samples

SOUTH TOWER CIRCLE OF HOPE

PATIENT SHUTTLES & DESTINATIONS

NORTH TOWER	Green	Pink	Orange
DAVIS CANCER PAVILION/ MEDICAL PLAZA	Green	Pink	
VA MEDICAL CENTER	Pink		
HOPE LODGE	Pink		
CHILDREN'S MEDICAL SERVICES CENTER	Pink		
RONALD MCDONALD HOUSE	Pink		

EMPLOYEE SHUTTLES & DESTINATIONS

1329 BUILDING	Blue	Pink
ARCHER ROAD	Blue	
STAFF PARKING: TRIANGLE LOT, GARAGE 9	Blue	Red

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

SOUTH TOWER CIRCLE OF HOPE

PATIENT SHUTTLES & DESTINATIONS

NORTH TOWER	DAVIS CANCER PAVILION/ MEDICAL PLAZA	VA MEDICAL CENTER
Green Orange Pink	Green Pink	Pink
HOPE LODGE	**CHILDREN'S MEDICAL SERVICES CENTER**	**RONALD MCDONALD HOUSE**
Pink	Pink	Pink

EMPLOYEE SHUTTLES & DESTINATIONS

1329 BUILDING	ARCHER ROAD	STAFF PARKING: TRIANGLE LOT, GARAGE 9
Blue Pink	Blue	Blue Red

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

SOUTH TOWER CIRCLE OF HOPE

PATIENT SHUTTLES & DESTINATIONS

NORTH TOWER	DAVIS CANCER PAVILION/ MEDICAL PLAZA	VA MEDICAL CENTER
G P O	G P	P
HOPE LODGE	**CHILDREN'S MEDICAL SERVICES CENTER**	**RONALD MCDONALD HOUSE**
P	P	P

EMPLOYEE SHUTTLES & DESTINATIONS

1329 BUILDING	ARCHER ROAD	STAFF PARKING: TRIANGLE LOT, GARAGE 9
B P	B	B R

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

NORTH TOWER FRONT CIRCLE

PATIENT SHUTTLES & DESTINATIONS

SOUTH TOWER	DAVIS CANCER PAVILION/ MEDICAL PLAZA	VA MEDICAL CENTER
Green Orange Pink	Green Pink	Pink
HOPE LODGE	**CHILDREN'S MEDICAL SERVICES CENTER**	**RONALD MCDONALD HOUSE**
Pink	Pink	Pink

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

NORTH TOWER FRONT CIRCLE

PATIENT SHUTTLES & DESTINATIONS

SOUTH TOWER	Green	Pink	Orange
DAVIS CANCER PAVILION/ MEDICAL PLAZA	Green	Pink	
VA MEDICAL CENTER	Pink		
HOPE LODGE	Pink		
CHILDREN'S MEDICAL SERVICES CENTER	Pink		
RONALD MCDONALD HOUSE	Pink		

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

NORTH TOWER FRONT CIRCLE

PATIENT SHUTTLES & DESTINATIONS

SOUTH TOWER G P O	DAVIS CANCER PAVILION/ MEDICAL PLAZA G P	VA MEDICAL CENTER P
HOPE LODGE P	CHILDREN'S MEDICAL SERVICES CENTER P	RONALD MCDONALD HOUSE P

Text "UFHEALTH 100" to 41411 to receive real-time arrival times for this stop.
https://ufhealth.transloc.com/

Appendix G: From-To Matrices

Pink Line

Stop Index Key:

1: Cancer Pavillion (Gale)

2: Children’s Medical Center (16th)

3: VA

4: Hope Lodge

5: Ronald McDonald House

6: 1329 Building

7: Circle of Hope

8: North Tower

	A	B	C	D	E	F	G	H	I	J
1		1	2	3	4	5	6	7	8	<- To
2	1	0	3	2	4	5	4	3	4	
3	2	4	0	3	2	2	1	3	3	
4	3	6	3	0	4	4	2	2	3	
5	4	5	3	4	0	2	2	4	4	
6	5	8	5	5	6	0	5	3	4	
7	6	4	2	3	2	2	0	2	2	
8	7	4	3	3	3	4	2	0	2	
9	8	3	3	2	4	4	2	2	0	
10	^^From									

Blue Line

Stop Index Key:

1: Staff Garage

2: 1329 Building

3: Circle of Hope

4: Archer RTS/North Tower

	A	B	C	D	E	F
1		1	2	3	4	<- To
2	1	0	3	4	5	
3	2	3	0	2	2	
4	3	5	2	0	2	
5	4	3	5	5	0	
6	^^From					
7						

Green Line

Stop Index Key:

1: Cancer Pavilion (Gale)

2: Circle of Hope

3: North Tower

	A	B	C	D	E
1		1	2	3	<- To
2	1	0	7	6	
3	2	3	0	2	
4	3	5	2	0	
5	^^From				
6					

Appendix H: Optimization Results Chart

Pink Line Without 1329

	A	B	C
1	Iteration	Expected Cycle Time - Minutes (not including time for stops)	Path
2	1	20	2 -> 4 -> 5 -> 7 -> 8 -> 3 -> 1
3	2	22	1 -> 3 -> 7 -> 8 -> 2 -> 5 -> 4
4	3	21	2 -> 5 -> 7 -> 8 -> 3 -> 4 -> 1
5	4	22	7 -> 8 -> 3 -> 2 -> 4 -> 5 -> 1
6	5	21	3 -> 7 -> 8 -> 2 -> 4 -> 5 -> 1
7	6	22	3 -> 7 -> 8 -> 2 -> 5 -> 4 -> 1
8	7	21	1 -> 3 -> 7 -> 8 -> 2 -> 4 -> 5
9	8	21	2 -> 5 -> 7 -> 8 -> 3 -> 4 -> 1
10	9	22	3 -> 7 -> 8 -> 1 -> 2 -> 5 -> 4
11	10	21	2 -> 5 -> 7 -> 8 -> 3 -> 4 -> 1
12	11	20	4 -> 5 -> 7 -> 8 -> 3 -> 2 -> 1
13	12	22	7 -> 8 -> 3 -> 2 -> 4 -> 5 -> 1
14	13	23	7 -> 8 -> 3 -> 2 -> 5 -> 4 -> 1
15	14	20	2 -> 4 -> 5 -> 7 -> 8 -> 3 -> 1
16	15	20	4 -> 5 -> 7 -> 8 -> 3 -> 2 -> 1
17	16	21	2 -> 5 -> 7 -> 8 -> 3 -> 4 -> 1
18	17	22	5 -> 7 -> 8 -> 3 -> 2 -> 4 -> 1
19	18	20	4 -> 5 -> 7 -> 8 -> 3 -> 2 -> 1
20	19	23	7 -> 8 -> 3 -> 2 -> 5 -> 4 -> 1
21	20	22	1 -> 3 -> 7 -> 8 -> 2 -> 5 -> 4
22	21	20	2 -> 4 -> 5 -> 7 -> 8 -> 3 -> 1
23	22	24	8 -> 3 -> 7 -> 2 -> 5 -> 4 -> 1
24	23	22	7 -> 8 -> 3 -> 2 -> 4 -> 5 -> 1
25	24	22	1 -> 3 -> 7 -> 8 -> 2 -> 5 -> 4
26	25	25	8 -> 7 -> 4 -> 5 -> 2 -> 3 -> 1
27	26	22	3 -> 7 -> 8 -> 1 -> 2 -> 5 -> 4
28	27	25	8 -> 7 -> 4 -> 5 -> 2 -> 3 -> 1
29	28	22	3 -> 7 -> 8 -> 2 -> 5 -> 4 -> 1

Pink Line Without 1329 and VA (ignore the NA values)

	A	B	C
1	Iteration	Expected Cycle Time - Minutes (not including time for stops)	Path
2	1	15	7 -> 8 -> 1 -> 2 -> 4 -> 5 -> NA
3	2	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
4	3	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
5	4	21	1 -> 7 -> 8 -> 2 -> 5 -> 4 -> NA
6	5	17	2 -> 5 -> 7 -> 8 -> 1 -> 4 -> NA
7	6	15	2 -> 4 -> 5 -> 7 -> 8 -> 1 -> NA
8	7	15	4 -> 5 -> 7 -> 8 -> 1 -> 2 -> NA
9	8	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
10	9	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
11	10	15	7 -> 8 -> 1 -> 2 -> 4 -> 5 -> NA
12	11	15	7 -> 8 -> 1 -> 2 -> 4 -> 5 -> NA
13	12	15	1 -> 2 -> 4 -> 5 -> 7 -> 8 -> NA
14	13	15	4 -> 5 -> 7 -> 8 -> 1 -> 2 -> NA
15	14	20	5 -> 7 -> 8 -> 2 -> 4 -> 1 -> NA
16	15	20	7 -> 8 -> 2 -> 4 -> 5 -> 1 -> NA
17	16	15	4 -> 5 -> 7 -> 8 -> 1 -> 2 -> NA
18	17	20	5 -> 7 -> 8 -> 2 -> 4 -> 1 -> NA
19	18	15	4 -> 5 -> 7 -> 8 -> 1 -> 2 -> NA
20	19	17	2 -> 5 -> 7 -> 8 -> 1 -> 4 -> NA
21	20	19	1 -> 2 -> 5 -> 7 -> 8 -> 4 -> NA
22	21	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
23	22	18	4 -> 5 -> 7 -> 8 -> 2 -> 1 -> NA
24	23	20	1 -> 7 -> 8 -> 2 -> 4 -> 5 -> NA
25	24	15	5 -> 7 -> 8 -> 1 -> 2 -> 4 -> NA
26	25	20	7 -> 8 -> 2 -> 4 -> 5 -> 1 -> NA
27	26	15	5 -> 7 -> 8 -> 1 -> 2 -> 4 -> NA
28	27	21	1 -> 7 -> 8 -> 2 -> 5 -> 4 -> NA
29	28	17	2 -> 5 -> 7 -> 8 -> 1 -> 4 -> NA

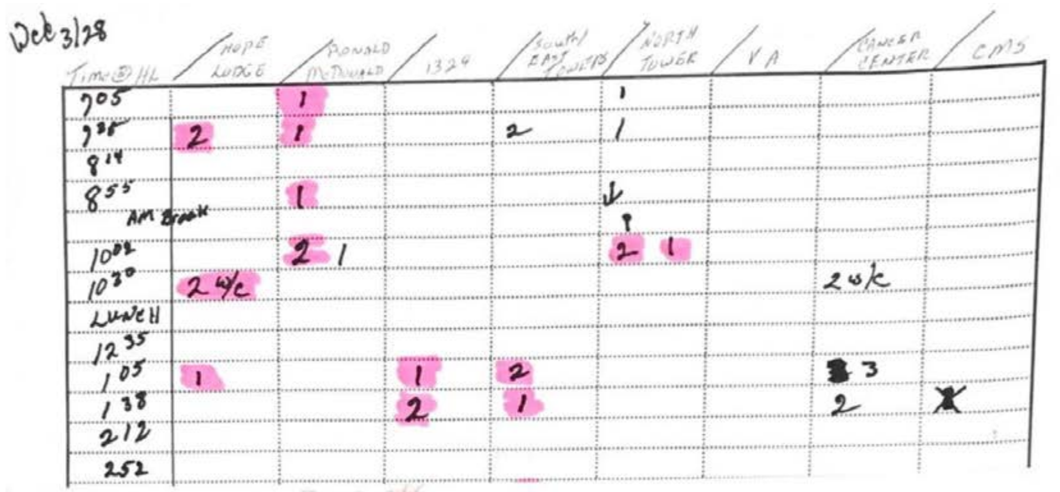
Blue Line

	A	B	C
1	Iteration	Expected Cycle Time - Minutes(not including time for stops)	Path
2	1	10	4 -> 1 -> 2 -> 3
3	2	11	2 -> 4 -> 1 -> 3
4	3	10	3 -> 4 -> 1 -> 2
5	4	11	3 -> 2 -> 4 -> 1
6	5	10	4 -> 1 -> 2 -> 3
7	6	10	1 -> 2 -> 3 -> 4
8	7	15	1 -> 2 -> 4 -> 3
9	8	10	3 -> 4 -> 1 -> 2
10	9	10	4 -> 1 -> 2 -> 3
11	10	10	3 -> 4 -> 1 -> 2
12	11	11	2 -> 4 -> 1 -> 3
13	12	11	3 -> 2 -> 4 -> 1
14	13	10	2 -> 3 -> 4 -> 1
15	14	10	3 -> 4 -> 1 -> 2
16	15	10	1 -> 2 -> 3 -> 4
17	16	10	4 -> 1 -> 2 -> 3
18	17	10	4 -> 1 -> 2 -> 3
19	18	11	2 -> 4 -> 1 -> 3
20	19	10	1 -> 2 -> 3 -> 4
21	20	10	1 -> 2 -> 3 -> 4
22	21	11	3 -> 2 -> 4 -> 1
23	22	11	3 -> 2 -> 4 -> 1
24	23	10	3 -> 4 -> 1 -> 2
25	24	10	3 -> 4 -> 1 -> 2
26	25	10	3 -> 4 -> 1 -> 2
27	26	11	2 -> 4 -> 1 -> 3
28	27	11	2 -> 4 -> 1 -> 3

Green Line

	A	B	C
1	Iteration	Expected Cycle Time - Minutes(not including time for stops)	Path
2	1	14	2 -> 3 -> 1
3	2	11	3 -> 2 -> 1
4	3	11	1 -> 3 -> 2
5	4	14	2 -> 3 -> 1
6	5	14	2 -> 3 -> 1
7	6	14	2 -> 3 -> 1
8	7	14	2 -> 3 -> 1
9	8	11	1 -> 3 -> 2
10	9	14	2 -> 3 -> 1
11	10	11	3 -> 2 -> 1
12	11	11	3 -> 2 -> 1
13	12	11	1 -> 3 -> 2
14	13	11	1 -> 3 -> 2
15	14	11	1 -> 3 -> 2
16	15	14	2 -> 3 -> 1
17	16	11	1 -> 3 -> 2
18	17	11	1 -> 3 -> 2
19	18	14	2 -> 3 -> 1
20	19	14	2 -> 3 -> 1
21	20	14	2 -> 3 -> 1
22	21	14	2 -> 3 -> 1
23	22	11	3 -> 2 -> 1
24	23	11	1 -> 3 -> 2
25	24	14	2 -> 3 -> 1
26	25	11	3 -> 2 -> 1
27	26	11	1 -> 3 -> 2
28	27	11	1 -> 3 -> 2
29	28	14	2 -> 3 -> 1

Appendix I: VA Passenger Volume Recorded by Driver from 3/28/2018 - 4/3/2018

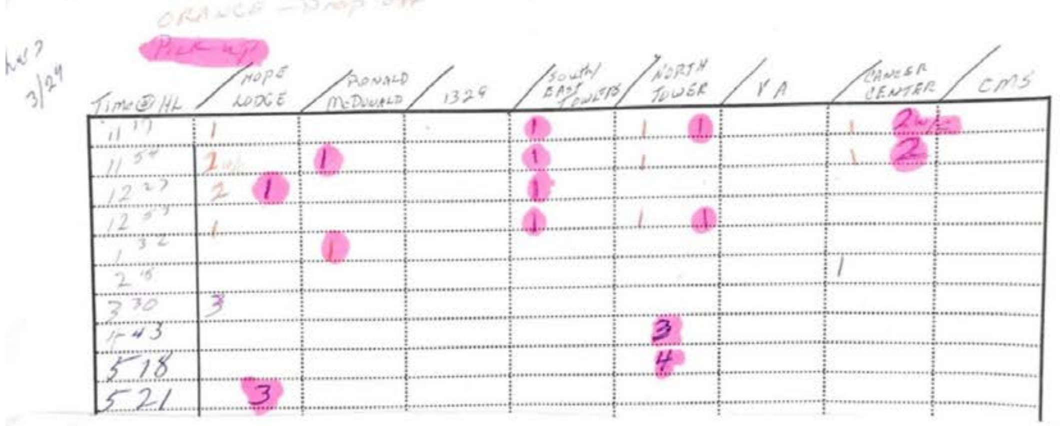


Wed 3/28

Time @ HL	Hope Lodge	Ronald McDonald	1329	South/East Towers	North Tower	VA	Cancer Center	CMS
705		1			1			
735	2	1		2	1			
814								
855		1			↓			
AM Break					1			
1002		2 1			2 1			
1030	2 w/c						2 w/c	
LUNCH								
1235								
105	1		1	2			3	
138			2	1			2	X
212								
252								

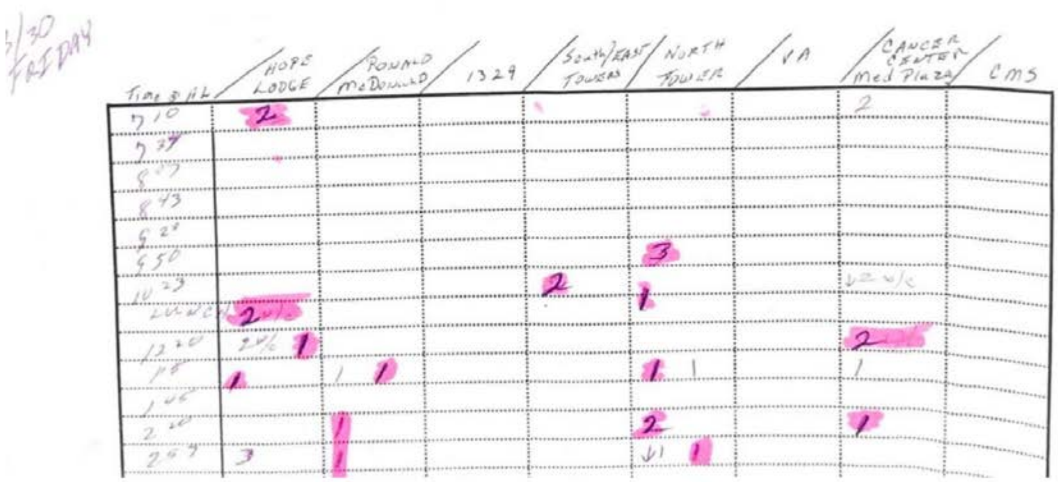
ORANGE – Drop off

Pick up



3/29

Time @ HL	Hope Lodge	Ronald McDonald	1329	South/East Towers	North Tower	VA	Cancer Center	CMS
11 17	1			1	1 1		1 2 w/c	
11 54	2 w/c	1		1	1		1 2	
12 27	2 1			1				
12 53	1			1	1 1			
1 32		1						
2 15							1	
3 30	3							
4 43					3			
5 18					4			
5 21	3							



3/30 FRIDAY

Time @ HL	Hope Lodge	Ronald McDonald	1329	South/East Towers	North Tower	VA	Cancer Center Med Plaza	CMS
7 10	2						2	
7 37								
8 07								
8 43								
9 20								
9 50					3			
10 23				2	1		↓2 w/c	
LUNCH	2 w/c							
12 20	2 w/c 1						2 w/c	
1 05	1	1 1			1 1		1	
1 46								
2 20		1			2		1	
2 54	3	1			↓1 1			

Mon 4/2/18

Time @ HL	Hope Lodge	Ronald McDonald	1329	South East Towers	North Tower	V A	Cancer Center	CMS
7 02 - 7 07								
7 32	2						(2)	
8 00		4		1	(3) 1		(2)	
8 35					3		(1)	
9 10	(4)			4			(4)	
9 50	1							
10 41		10		(10)		1		(1 D[illegible])
Lunch							2 w/c	
12 44	(2 w/c)			10				
1 20		(10)						
1 55				1				
2 20		(1) 1					1	

Tues 4/3/18

Time @ HL	Hope Lodge	Ronald McDonald	1329	South East Towers	North Tower	V A	Cancer Center	CMS
7 00	2						(2)	
7 30					2		(2)	
8 05								
8 40								
9 20		1			(1) 3		(3)	
10 05								
10 40	2 w/c			2	(1)		(3 w/c)	
Lunch								
1 03	1	1				2 (1)	(1)	
1 38		(2)					3	
2 15	(3)							