Optimizing Paratransit System Inefficiencies for King County Metro

Emily Andrulis, Anat Caspi, Kivan Polimis, Kristen Garofali, Frank Fineis, Rohan Aras, and Valentina Staneva

Abstract—Paratransit is a demand responsive mode of public transportation where passengers with disabilities are picked up at or near their doorstep and delivered to their specified destination. There has been little investment and research about the technical complexities of delivering ADA paratransit. Currently within King County Metros system, a paratransit trip costs Metro approximately ten times as much as an equivalent trip on the fixed-route service and has consistently risen faster than the pace of inflation. If the cost of the paratransit program can be contained through greater efficiency, Metro could provide far more trips and enhance the mobility of people with disabilities through greater investment in both ADA paratransit and its fixed-route network. The objective of this project was to take current system information, using access to eighteen months of back data as well as fifteen minute streaming data, and both analyze historical data to give insights into spending in the system and also provide a prediction algorithm for real time cost analysis thereby helping dispatchers and schedulers make informed, efficient routing decisions in the case of disaster events.

1 Introduction

The Americans with Disabilities Act of 1990 [1] mandates that each metropolitan area provide some form of paratransit system that compliments the services offered by the typical fixed route bus system. Paratransit provides a vital link to mobility for people who are unable to use traditional fixed route services. For King County Metro, this paratransit service comes in the form of Access buses, which provide a dial-a-ride door-to-door transportation service that reaches all across the county, and even exceeds the five mile radius from fixed route services that the ADA mandates. Although King County Metro aims to minimize cost for this program while also staying within the ADA regulations, a recent look into their finances showed that each Access bus cost per boarding cost about ten times as much as a cost per boarding on the fixed routed service system. Since there is one fixed budget that combines both systems, this means that the cost inefficiencies in the paratransit system are taking away money from the fixed route services, and any cost savings would help both systems. One of the ways King County Metro has tried to lower the crippling cost of the paratransit system is by creating a high barrier to entry, and instead directing citizens to other public transit options when applicable. Seattle citizens must undergo a thorough process to become an eligible Access rider, where they must fill out the appropriate forms as well as attend an examination done by certain physicians at a testing facility who will determine if Access buses are the clients best means of transportation. Once enrolled in the program, the client may call anywhere from one to fourteen days in advance to schedule a ride, and after some negotiation they are given a half hour window for when they can expect to be picked up. Each request must be given a negotiated time, and if the client accepts, King County Metro is mandated by the ADA to fulfill this request within the thirty minute time frame. This means that all requests must always be fulfilled, and there is no prioritizing of trips based on reason of trip, length, time of day, or any other factors. At King County Metro, each evening at 5:00 PM they use Trapezes patented software to optimize and schedule all the routes for the next day. While this helps optimize the system for most routes, Trapezes current system has

no way of reoptimizing in the event of disaster events, i.e. bus breakdowns, lengthy delays due to traffic, etc. In this project we attempt to help King County Metro lower costs of the paratransit system both by analyzing historical data to help predict better ways to cut costs wherever possible, and by using streaming data to create additional software that can deal with disaster recovery in a more cost effective way than the system currently in place.

2 Related Work

Little research has been done to explore the inefficiencies present in most paratransit systems. Namely, there is one study that was done using Minnesota's paratransit system [2] that worked to try and reoptimize already scheduled routes, which presents a problem that is unique to paratransit in that it is rerouting with time windows where each request must be fulfilled. Additionally the same study provided some base analysis on how using non-dedicated service vehicles (i.e. taxis) could create cost savings. In our work, we expand on some of these ideas, but we are limited in the amount we can do to reoptimize routes, given that King County Metro goes through a patented software rerouting service, Trapeze. Some of our analyses looked into how switching costly rides to taxis might help cut down costs, but the complexities that arise with this great and should not be underestimated when looking at only the numbers. Mainly, there are many clients, about one in two, that need wheelchair access and when trying to provide taxi rides for them one should be aware that in all of King County there exist only some forty or so taxis that can provide wheelchair access. At the same time, these clients must agree to taking a taxi, and the taxi drivers are not contracted and therefore not bound to servicing Access clients over any other citizens, therefore during peak hours there is no guarantee that these non-dedicated vehicles will be available to them. For these reasons, in our analyses we try to bear in mind that the number of clients we will be able to switch to taxis is limited, and we try to analyze only how moving over the most costly trips would affect the system.

3 Approach

King County Metro provided us with three main sets of data to work with: a four month data set of historical data with restricted data; an eighteen month data set, containing the four month, with expanded data provided, and streaming data coming in fifteen minute intervals that showed the current systems schedule. To best improve and optimize both efficiency and cost savings to the system, we took a three pronged approach to working with the data. First, we were asked to help reduce cost inefficiencies by providing them with more accurate projections for hourly provider usage. Next, we wanted to analyze the historical data we were given to provide some insights as to what factors were causing the most cost, and give a look into what King County Metro had been referring to as "ugly rides" or trips that were extensively costly to the system. Our final portion of the project was the most rigorous and labor intensive because we worked to create an application for dispatchers to use to help do disaster recovery rerouting in an optimized manner and in real time.

3.1 Projections

Approximately three or four times a year King County Metro meets with their contract providers to renegotiate how many operation hours they will require for each hour of each service day. While underestimating the number of necessary hours can be detrimental because it will cause them to request more work the day of, a situation that is to be avoided, over estimating the number of hours of operation they will need can be very costly for the paratransit system. To help King County Metro better predict how many operational hours will be needed at each hour of the day for each day of the week in the quarter, we analyzed historical data and created projections. These projections are comprised of separate graphs for each day of the week that trace past usage from similar days. The real functionality from these graphs comes from the way they plot the average usage for the day of the week over the given time period, and the user can easily see what amount of hours would be necessary,

using predictions that are either exactly on average or any number of standard deviations above or below that average.

3.2 Cost Analysis

Given eighteen months of historical data, King County Metro was very interested to see what conclusions we could make about how money is spent within the system and if there were any ways we could see to cut out cost inefficiencies. One of the main methods we used to go about this was by examining what King County Metro affectionately terms "ugly rides". These are the rides that seem to tie up a lot of the system's resources, either in the length of the trip or the way the trip necessitates that only one rider or a limited number are riding on a bus at a time. Ideally, buses would be at full capacity for as much time as possible, while also finishing routes as quickly as possible so that less operational hours were needed. "Ugly rides" referred to any trips that King County Metro deemed something that extremely deviated from this goal. However, to better understand what these "ugly rides" were we had to investigate how to classify them more officially, and then examine what characterized them, to see if eventually we could find a way to predict "ugly rides" and deal with them more effectively when they are first scheduled.

3.3 Disaster Recovery

Currently King County Metro uses Trapeze software to schedule buses and do routing. However, their system does this at 5:00 PM the night before each business day, and the system does not have any means to provide just in time rerouting with cost analysis in the event of same day disaster events (i.e. bus breakdowns, schedule delays, event mix-ups). Therefore, King County Metro was very interested in the idea of a rerouting software that could use Trapeze's already made schedule for the day and show possible solutions each with their associated cost for rescheduling certain passengers, or whole buses, back into the system. Without this software, dispatchers in disaster situations are forced to just use their intuition to determine what we be best in these cases where rescheduling is needed. However, once this new software is in place, dispatchers will be given a display of the different options with their associated costs, therefore saving King County Metro money in the way that they deal with these disaster recovery situations.

4 Results

At the end of our ten week project we presented our work to King County Metro, and left it in their hands to use these new tools and pieces of information to better optimize the paratransit system. The following details the deliverables we presented to them.

4.1 Projections

For the projections we created a VBA macro that can be used directly from the Access database that contains the historical data. This macro can also be ported to other future databases that King County Metro might use, since they often store their information in Access databases. The macro queries the data and formats it into an Excel sheet so that one can see the number of buses out for each hour of any given day in the dataset. From there, this same macro creates the projections by making graphs that show the usage for any given day, as well as the average usage for that day along with the standard deviation at each hour.

4.2 Cost Analysis

To analyze what King County Metro was referring to as "ugly rides" we first had to define what an "ugly ride" in fact was. We decided to classify these as trips that were in the top ten percent for most expensive cost per boardings. However, we also used a more nuanced definition of cost per boarding to get a better picture of which riders were really taxing the system the most. Previously, King County Metro used cost per boarding to signify the amount of time a passenger spends on the bus divided by the total number of passengers that were on that bus throughout the day. We took this a step further and defined cost per boarding as the sum cost of each leg that the passenger was on the bus for their trip, where the cost of each leg

is the amount of time for the leg divided by the specific number of passengers onboard during that leg. This gives a more accurate picture of the true cost per boarding and better penalizes those trips that create minimal usage of the total bus capacity. After this initial reevaluation of cost per boardings, we saw that there were some trips that created cost per boardings upwards of $100. By identifying these rides as "ugly rides" we tried to analyze how we might be able to reduce these costs. An initial inspection into how much these ugly rides would cost on taxis instead showed that while the majority of these rides were still more cost effective on bus, some of the most expensive of the ugly rides were much more cost effective on taxis, with some that could create savings in the hundreds of dollars for a single trip that was rerouted onto taxi. In order to reroute trips that are "ugly rides" though, we would need to be able to accurately predict which rides these are before they are put into the day's schedule. To try to better identify characteristics of "ugly rides" analyses were done looking into the percentage of deadheading in each bus run, the date in relation to cost per boarding, and various other factors, but so far our efforts have been inconclusive as to which factors most heavily play into creating a typical "ugly ride". Due to the short time period we had for this project, and the amount of data we had to work with and sort through, there is still much more that we would have liked to do to analyze how cost savings could be made by better identifying and rerouting "ugly rides".

4.3 Disaster Recovery

Our final disaster recovery deliverable is an application that King County Metro dispatchers can load onto their computers and interface with to figure out what the most cost effective ways are to reroute passengers in the event of a disaster. The rerouting application provides the dispatcher with a web application where they can provide access to the day's schedule, and then specify either a broken bus number or a list of booking IDs taht need to be rescheduled, and the program will find the most optimal solutions for rescheduling in real time. The program will return a list of options ranked by cost effectiveness and allow the dispatcher to click on each option to find out more information or see alternative options if for any reason the most optimal solution is not realistically viable. The algorithm behind this program was written in python and the web application front end was created using Flask. Our program follows a number of complicated steps, but the basic procedure is as follows: read in the day's schedule and reformat information into the neccessary types, do a preliminary bus elimination based on those that are not within a certain radius of the pickup location, check at which points buses will have the capacity to pick up the unscheduled request, check the feasibility for a pickup with the unscheduled request and then also a dropoff within the given time windows and keeping track of any lateness in the schedule that occurs, choose the bus rerouting with the least cost (in terms of lateness caused), and choose the best option with the least cost given the options of rerouting onto the already scheduled buses, putting on a taxi, or sending out a whole new bus run. It performs this task for each unscheduled request and gives the output for the most optimized solution after going through all possibilities.

5 Conclusion

Our work provides an initial attempt at using historical as well as streaming data to reduce cost inefficiencies in King County Metro's paratransit system, Access. Through a three pronged approach we found and created ways to cut costs, while also analyzing which aspects of the system are currently playing important roles in creating the high costs of the system. The projections for negotiated hours of service will help cut organizational costs, while the disaster reocovery application will help maximize efficiency and cost effectiveness in the event of bus breakdowns or great delays. Future work in this area of research might try and continue our analyses and dive deeper into the concept of "ugly rides" and other possible solutions for lowering their costs.

REFERENCES

[1] http://www.ada.gov/pubs/ada.htm
[2] Gupta, Diwakar; Chen, Hao-Wei; Miller, Lisa; Surya, Fajarrani. (2008). Improving Capacity Planning for Demand-Responsive Paratransit Services. Minnesota Department of Transportation. Retrieved from the University of Minnesota Digital Conservancy, http://purl.umn.edu/151441.