UNIVERSITY OF CINCINNATI

Date: June 02, 2006

I, Ashwini Tamhane,

hereby submit this work as part of the requirements for the degree of:

Master of Community Planning

in:

College of Design, Architecture, Art and Planning

It is entitled:

Personal Rapid Transit in Uptown Cincinnati:
Broadening Travel Options

This work and its defense approved by:

Chair: Dr. David J. Edelman
Dr. Xinhao Wang
Dr. Heng Wei
Conrad C. Haupt

University of Cincinnati

Personal Rapid Transit in Uptown Cincinnati:
Broadening Travel Options

A thesis proposal submitted to
Dr. David J. Edelman, Ph.D., Head of the Department,
College of Design, Architecture, Art, and Planning
School of Planning
in partial fulfillment of the
requirements for the degree of
Master of Community Planning

By
Ashwini Tamhane
B.Arch. Visvesvaraya National Institute of Technology, India, 2003.

May 2006

Thesis Committee:
Dr. David J. Edelman
Dr. Xinhao Wang
Dr. Heng Wei
Conrad Haupt

ABSTRACT

Transportation has become an important issue today with the soaring gas prices and urban spatial problems faced due to the automobile. Personal Rapid Transit (PRT) offers innovative alternatives to some of the current urban transportation problems. It combines the comfort of a private ride with public transportation. This thesis is a transportation planning study which applies and tests the solutions offered by PRT in an 'Urban Campus Setting' of the University of Cincinnati.

ACKNOWLEDGEMENTS

I would like to extend my heartfelt thanks to everyone who has made a contribution to this thesis. First of all, I would like to thank University of Cincinnati and the School of Planning, for providing me the opportunity to work on this thesis. I am also grateful to Dr. David J. Edelman for all his support, guidance, and encouragement throughout the period of my graduate study.

I would like to thank Novitran and especially Bud Haupt for giving me this opportunity to work on PRT. This work would not have been possible without Bud's timely help, moral support, personal time, encouragement, and most of all his trust in my capability to manage a research of this nature. I am grateful to Taxi 2000, Dr J. Edward Anderson, the People Mover team at West Virginia University and Stan Young for providing me with the articles and information on PRT. I am especially grateful to Jeral Poskey for providing his technical skills and guidance.

I am grateful to Dr. Xinhao Wang and Dr. Heng Wei for their technical and critical input. Their patience and the personal time they invested throughout my thesis work are much appreciated. I am also thankful to Scott Enns, University of Cincinnati's Architect's Office, and Ohio-Kentucky-Indiana Regional Council of Governments for providing the data on Uptown.

I would also like to thank Abhay for all his help and support throughout these two years at UC and his valuable inputs in my thesis work. And I am especially grateful to my family in India for their unconditional love and support throughout my life and career. I dedicate this thesis to my dearest parents, *Anil and Jyoti Tamhane*. I owe all my success to their hard work, support, and love.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

List of Figures

List of Tables

Background

I came as an international student to the University of Cincinnati in Cincinnati, Ohio about 1.5 years back. The first thing I noticed about the university campus was the limited amount of vehicular traffic through the campus. In addition, the thing that was different about the city was that it was structured in such a way that nothing was within walking distance, neither grocery shops, nor restaurants. The nearest grocery shop was a twenty-minute walk away from my house. My perception about the ‘city’ always relied on images of Indian cities where getting around was not as tough. I did not own a car during my graduate studies at University of Cincinnati, and the problems that arose due to it were typical to most of my international friends. Grocery shops, post office, restaurants, were a long walk away from home. It became especially difficult during the winter months. I remember my first winter in Cincinnati when it snowed so much that all businesses closed down and people could not get out of their houses for three days. Many residential streets remained snow covered, as the snow removal vehicles did not clear the smaller streets. Even the taxi service was not running and walking through half feet of snow was near hazardous. We ran out of food and could not go out for groceries. That is when it struck me; nobody can survive without a car in the United States. The following quote by Catherine Burke aptly describes the case of transportation in U.S.:

> Nearly everything Americans do, from mailing a postcard to walking on the moon, depends on transportation. Transportation is essential for the supply of food, clothing, and shelter, for national defense and employment, for education and recreation, for the international exchange of goods and ideas (Burke Catherine G., 1979).

I started to think about people who did not own a car or could not drive due to old age or personal handicap. I wondered how those people got through their day, having to depend on someone else to give them a ride or use public transportation. I can count on fingers how many times I rode a bus to go to the mall and every time I detested having to take a bus. In addition, I had to be very particular about the bus schedule as the frequency of the buses was very low and if I missed a bus, the wait for the next one was no less than half an hour. The bus does not go everywhere, so shorter distances or places not on the bus route are near inaccessible for a person who does not own a car. Having faced all such problems by not owning a car, when I first heard about Personal Rapid Transit, it really impressed me (Figure I). Imagine automated taxicabs running on elevated rails. No driving involved, no parking issues, no traffic jams, and you do not have to own a vehicle since it is a public transit system.

An estimated 87.9% of people in the USA used motor vehicle as a means of travel to work according to 2000 population census report. This percentage has steadily grown from 64% in 1960 to 86.5% in 1990 (Census, 2000). Inspite of its wide popularity, the motor vehicle has created more problems than it has solved. Some of the problems experienced because of our current transportation system are congestion, road casualties, inaccessibility and car dependence, air pollution, water pollution, noise and vibration, energy consumption and global warming, imbalance of economic activity, high land and property prices, decaying urban fabric, urban sprawl and peripheral development (European Conference of Ministers of Transport, 1995). Scientists are always in search of new alternatives to mitigate problems. Some alternatives try to improve the current technology, for example alternative fuels is just an improvement in the current technology. While some new concepts like the PRT, are changing the technology itself, altering the perception of urban travel. The SkyWeb Express PRT system developed by Dr Edward J. Anderson in University of Minnesota, Minneapolis, is one such revolutionary concept.

About Personal Rapid Transit

PRT is a public transit system with the comfort and reliability of a car. PRT with its driverless, small, computer controlled vehicles is one of the most personalized public transit system. Even though the technology developed in the 1950's, apprehension for this technology kept it away from implementation in urban areas. Roller coasters, on the other hand, which are very close in concept to PRT, have become a source of entertainment in all the modern day amusement parks. People accept them without any skepticism or issues of safety.

Figure I. Personal Rapid Transit Vehicle

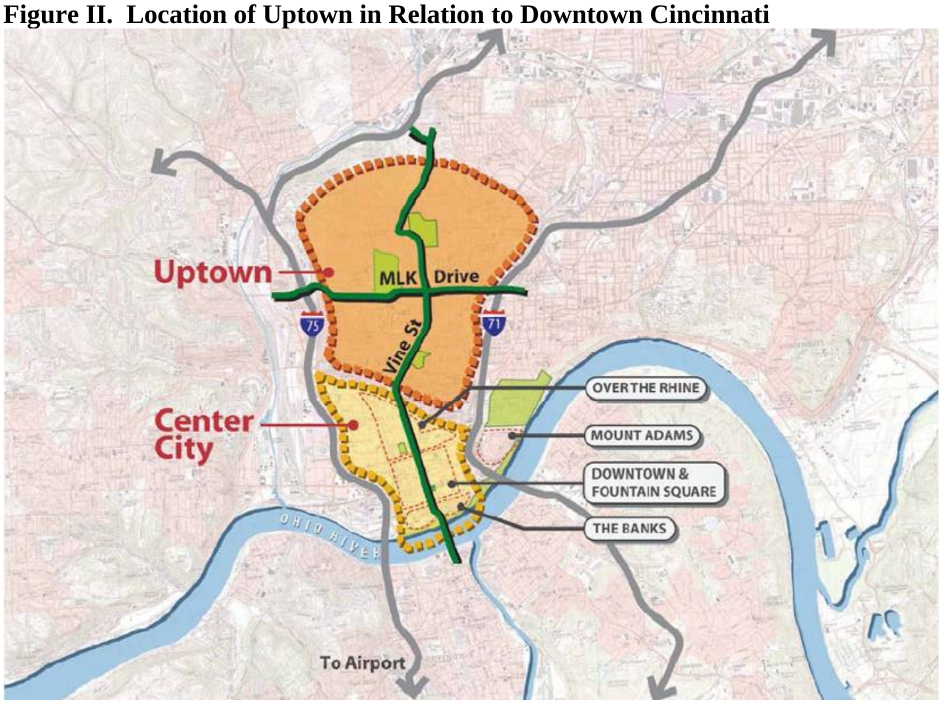
Source: Author

> Personal rapid transit (PRT) is the class of fixed-guideway systems in which automated vehicles no larger than small automobiles carry people and/or goods nonstop between any pair of stations in a network of slim guideways which may serve major activity centers, airports, etc. or may span an entire urban area. PRT vehicles are occupied by a single individual or by people traveling together and may be captive to the guideway or have the capability of operating on both the guideway and street systems, i.e., dual-mode (Anderson Edward J., Romig Sherry H., 1974).

This study tries to investigate if PRT is a feasible solution for an urban area. Can the 21st century cities integrate PRT as an urban transportation mode along with other modes?

About the study area

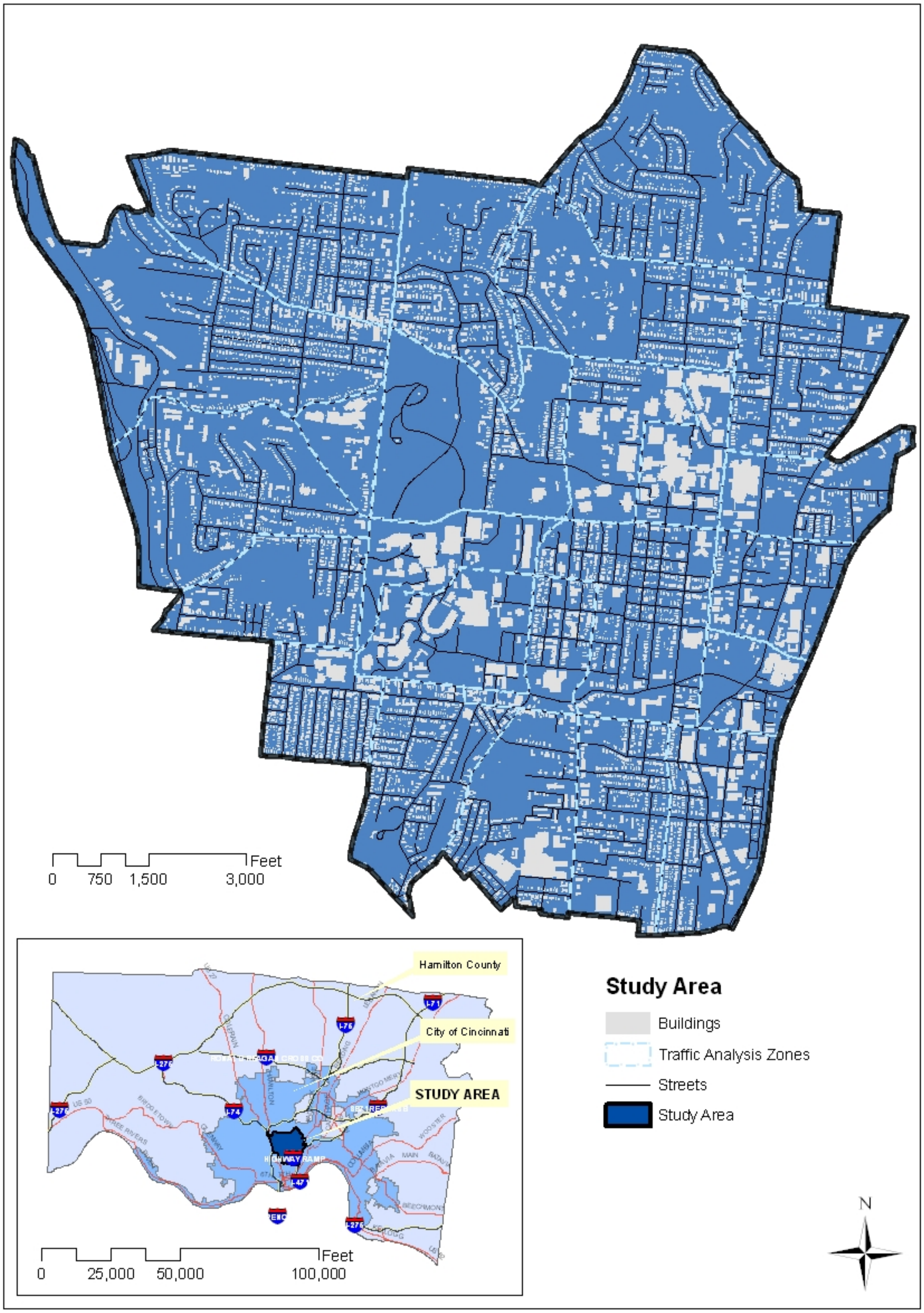
Figure II. Location of Uptown in Relation to Downtown Cincinnati



Source: http://uptownconsortium.org/report-vision.pdf

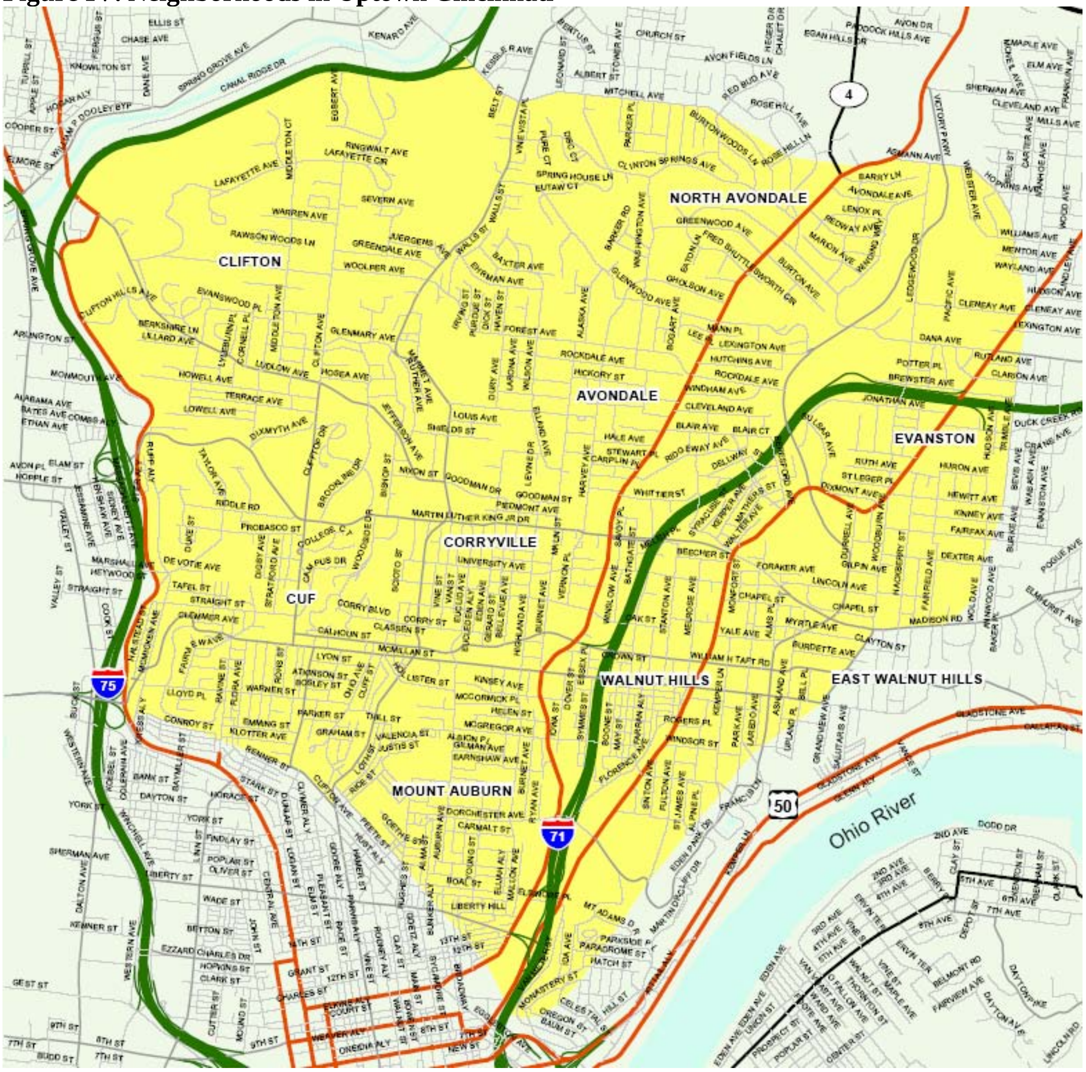
The urban area selected for this study is unique in its setting. The area surrounding the University of Cincinnati, now officially coined as Uptown Cincinnati, has a unique combination of landuses. Uptown Cincinnati is located to the north of downtown Cincinnati (Figure II). University campus, hospitals, offices, retail districts, and residential landuses are located within a close proximity to each other. It comprises of the neighborhoods of Avondale, Clifton, Clifton Heights, Corryville, Fairview, Mt. Auburn, and University Heights (Figure IV).

Figure III. Uptown Cincinnati



Data Source: CAGIS 2002

Figure IV. Neighborhoods in Uptown Cincinnati



Source: http://www.uptowntransportationstudy.org/maps/UptownStudyAreaMap.pdf

Thousands of people come to Uptown daily for employment, education or for health care. Heavy traffic in the peak office times leads to the congestion at major intersections. The following factors play a major role in the traffic congestion in Uptown

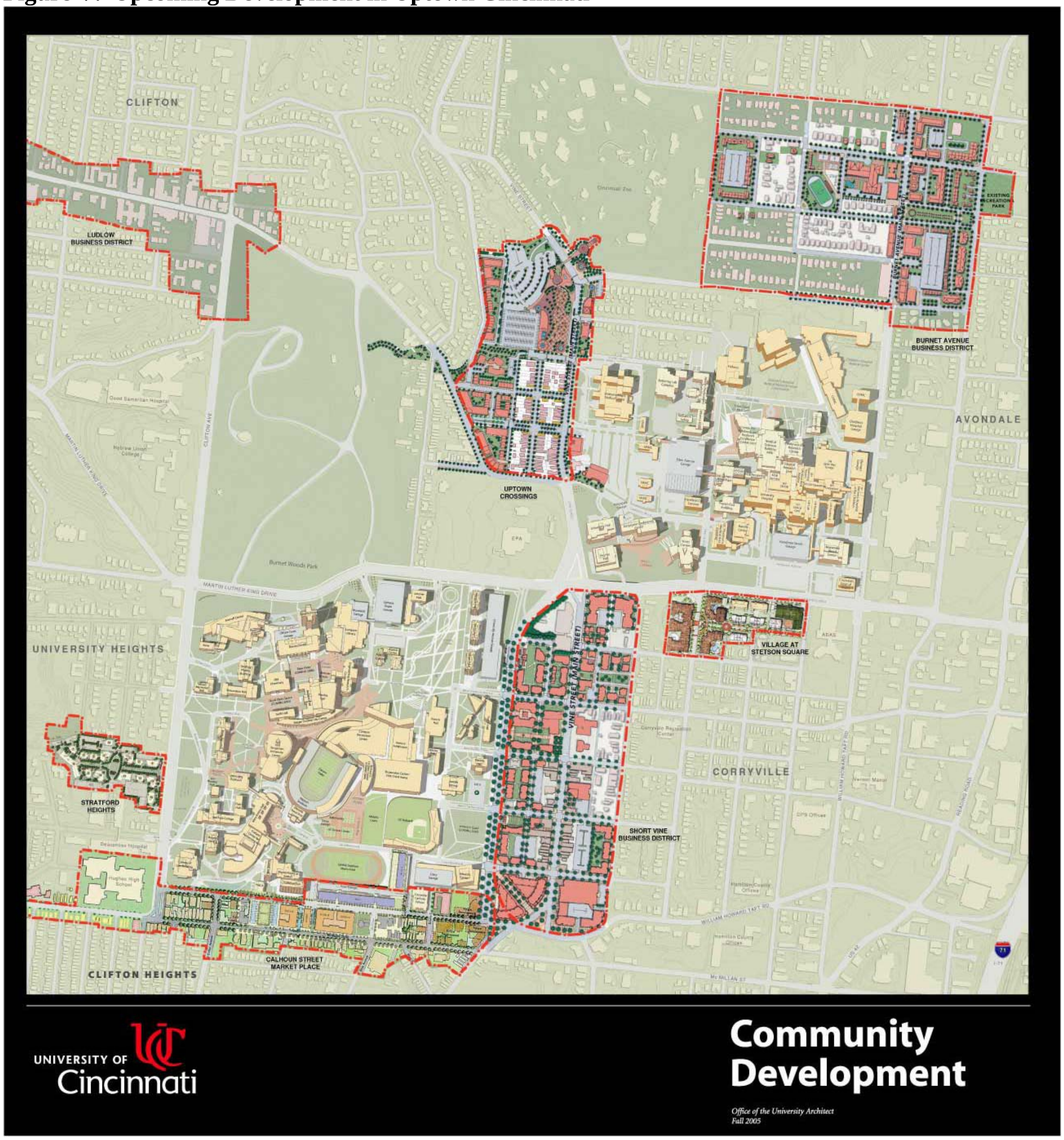
1. Over 35,000 students enrolled for the year 2005-2006 in University of Cincinnati (Uptown Transportation Study, 2005).

2. Uptown's population is just over 51,000. Out of the 51,000 people who live in uptown, more than 13,000 people work in Uptown (Uptown Transportation Study, 2005).
3. 302,000 vehicles per day enter and leave Uptown (Uptown Transportation Study, 2005).
4. Higher housing densities in areas adjoining University campus as students tend to live in large clusters. This causes traffic disproportionate to the community size causing bottlenecks at major intersections
5. Pedestrian oriented campuses try to maintain the 10 min access time while scheduling classes. 10 min pedestrian access time limits the expansion of campuses. This leads to the creation of auxiliary campuses that need to be connected.
6. Amount of parking is limited in Uptown (Uptown Transportation Study, 2005).

The Uptown Transportation Subcommittee has inferred from the Uptown Transportation Study that the existing roadway network has a finite capacity. Moreover, that it is important to slow the growth of traffic and divert future travel to other modes e.g. transit, bicycle.

The uptown area is slated for development over the course of next 10-15 years. New housing, retail and recreational facilities have been planned which will give rise to increased activity in the area (Figure V). The Uptown Consortium, which is one of the biggest employers in Uptown, has a target of 15,000-25,000 new jobs in the area by the year 2030. Increase in activity will in turn affect the already congested transportation network in the area. It has been realized that roads have limited capacity, and alternatives modes of transport are necessary to solve the congestion problem.

Figure V. Upcoming Development in Uptown Cincinnati



Source: Office of the University Architect

Figure 5 shows the upcoming development projects in Uptown Cincinnati. These projects are Short Vine Redevelopment, Uptown Crossings, Burnet Avenue

Business District, Village at Stetson Square, Calhoun Street business district, and the Stratford Heights housing.

Currently the Ohio-Kentucky-Indiana Regional Transportation Authority (OKI) is conducting a study to estimate the future travel demand in the Uptown area. OKI will be working closely with community leaders and organizations to provide a comprehensive community transportation study, incorporating economic development and land use components into the transportation decision-making process (Uptown Transportation Study, 2005). The study aims to improve road connectivity, looking for alternative transit options like light rail, transit and shuttle route improvements, increase parking capacity, proposing new bicycle and pedestrian routes etc. The transportation study provides an opportunity to investigate the case for PRT as some of the transportation data is made available to public. This thesis will use the same raw data of the OKI study to test PRT system for uptown area. The very fact that the study is being carried out by DOT at this time is a good indication that Uptown's future travel plan is being sketched out now. This research is an attempt to test the 'uncharted option' and plan for a better future for everyone.

Study Aim

The question now is can personal rapid transit prove to be a step ahead from the conventional modes of transportation? Will the new technology that combines the speed, comfort and privacy of a car in a public transit system, be able to solve our current transportation problems? Will this new green technology be able to solve our pollution and energy problems? This study aims to find answers to some of these problems.

Increasing gas prices and current safety issues with mass transit gives rise to the need to look for alternatives for a public transportation mode. Can PRT provide personal travel options and freedom of movement like the car?

Research Questions

1. Does personal rapid transit offer an effective alternative to the automobile in urban districts like the uptown in Cincinnati in terms of
    - Travel cost;
    - Travel time;
    - Environmental impact;
    - Equity in transportation;
    - Safety, and
    - Land Use benefits.
2. Is PRT a transportation option for institutional campuses like universities?
3. What are the benefits and costs associated with using such a system in terms of economic, social, and environmental benefits?

Objectives

This thesis attempts to study an alternative mode of transportation for the uptown area. It tries to analyze if a new technology like PRT can be a good solution to our current transportation problems. It aims to find if the new technology can serve the current transportation needs in an urban setting of Uptown and at the same time cater to the needs of an institutional campus. This would be done through the design and testing of a Personal Rapid Transit system for the Uptown area. The PRT layout will be assessed by comparing it with other transportation technologies. Comparisons will be based on efficiency, ridership, cost, and other social, economical, and environmental factors.

Expected Findings

A possible range of conclusions are:

1. PRT is feasible;
2. Feasible with some changes in city fabric and planning;
3. Feasible with technology enhancements; or
4. Not feasible at all.

Study Structure

The rest of this thesis is structured as follows:

The second chapter is literature review, which discusses history of the technology and issues related to PRT. Through case study, this chapter provides justification behind using PRT as an urban transit option. The methodology chapter gives a systematic account of design of the PRT layout. The chapter on analysis and findings states the results of different simulations and testing done on the PRT layout. The last chapter on discussion & conclusions states the feasibility of the PRT system based on ridership, cost, social benefits, economic benefits, and environmental benefits. This chapter also states the conclusions of the study and provides suggestions for future work on this topic.

Introduction

Literature review is the main step in building up the case for the study. Literature review will provide an introduction to the concept of Personal Rapid Transit. The system and its working will be introduced in this section. A case study of the Morgantown People Mover will help analyze the working of such a system in operation since the past 30 years. The case study will also investigate how PRT has performed and if it is a successful mode of transit. The case study will investigate if PRT can be used as a mode of travel in urban areas.

What is Personal Rapid Transit?

Historically the term "Personal Rapid Transit" or PRT referred to a system which might be regarded as an automated taxicab system. A system of small three to six passenger automated vehicles for the private use of the traveler and his traveling companions, but not shared with strangers. The traveler is carried nonstop and without any transfers from his origin station to his destination station. Later personal rapid transit was used to refer to any automated guideway system, regardless of the type of service provided or the size of the vehicles, although typically they were much smaller than conventional rail cars.

PRT is a class of Automated Guideway Transit system. Automated guideway Transit (AGT) is defined to be any transit system carrying completely automated vehicles on fixed guideways along an exclusive right of way. The guideways may be underground, at ground level or elevated, but in any event they are grade separated from street and pedestrian traffic, so that such traffic will not penetrate the right of way of the automated vehicles. Three major categories of AGT systems have been defined:

- Shuttle-Loop Transit (SLT);
- Group Rapid Transit (GRT), and
- Personal Rapid Transit (PRT) (Irving 1978, 4).

Shuttle Loop Transit (SLT) is a simple loop system in which vehicles stop at each station along a route. An example of this system is the Westinghouse Electric system installed at the Seattle-Tacoma Airport. In a SLT system, all the stations are online and hence the headway between vehicles is typically 60 sec or greater. **Group rapid transit** (GRT) systems may be considered as an automated bus or jitney service where a passenger must share a vehicle with others. Examples of GRT systems are the Boeing system in Morgantown, West Virginia, and LTV's Airtrans system at the Dallas-Fort Worth Airport. The GRT system can be designed to make scheduled stops or intermediate stops on demand. GRT system requires longer waiting times at stations till the vehicle fills up to an adequate capacity; the system is inflexible in catering to varying demands and passengers have to travel with strangers. Another disadvantage is that during off-peak times, the vehicle does not fill up to an adequate capacity.

Personal Rapid Transit (PRT) systems are intended for mostly private use. Stations, with a few exceptions are all offline, and the vehicles carry the passengers from their origin to their destination station without intermediate stops. Empty vehicles queue up at the station so that passengers can board immediately for departure. Vehicle occupancy would be similar to that of the private vehicle i.e. 1.1 to 1.5 people/vehicle. Somewhat higher occupancies can be obtained by 'voluntary PRT pooling' if the fare is charged per vehicle rather than per person. Due to the low occupancy, the minimum required headway can be less than 3 sec.

In PRT systems, guideways are generally elevated to avoid traffic interference, but sometimes they can be underground or even integrated with the road network according to site conditions. Lines in residential areas would be mainly arterial or shopping streets with a minimum walk of about 2-3 city blocks. In the shopping district (CBD), the lines would be much closely spaced for easier access and more line capacity. Where lines cross, they would be at different elevations. In most areas the guideways would form a one-way network in which any arterial street will carry a line running only in one direction, say north, and the next parallel arterial would carry a line running south. In this way one minimizes the investment per street, minimizes the visual impact and shadowing, and only two turn ramps are required per intersection, as contrasted with eight ramps at an intersection of a two way network. When a vehicle is to enter a station, it leaves the through-line at line speed and decelerates on the siding, and when it leaves the station it accelerates on the siding before joining the through-line.

A typical PRT (home to work) trip would start with walking from home to the nearest PRT station about two city blocks away. Assuming that the guideway would be elevated above the street level, a passenger would take a lift up to the boarding level. Then he can use a PRT card with magnetic strip or a cash card to pay for his trip and punch in the destination station code. He would be assisted by PRT personnel if he cannot feed in the information of his trip into the system. After paying for his trip, he can proceed to the boarding platform and swipe his card in the slot next to the gate, which opens the station gate and vehicle door simultaneously for him to enter. The magnetic card feeds the information about the trip into the system. The person then just sits back and enjoys the view while the system takes him directly to his destination station. The passenger need not worry if the vehicle is traveling in the opposite direction, the system will configure the optimum path for the trip and take him to his destination without any transfers or stops. The system is comparable to a private automobile in the sense that the journey is directly from origin to destination, the difference being, the vehicles are not caught up in the traffic congestion on the roads. The trip is less costly and the passenger can sit back, relax and enjoy the view during their journey.

The features of personal rapid transit system can be summarized as follows:

- No waiting time;
- Simple destination selection with convenient kiosks or on board touch screen;
- Non stop service from origin to destination;
- Off line stations;
- Low cost operation;
- Modern image;
- On-board communication;
- Small guideway;
- Private ride;
- High safety standards;
- Zero emissions, and

- Visual and architectural integration with buildings.

The different components of a PRT will be discussed further: For this, the taxi 2000 prototype will be discussed. Taxi 2000 is one of several companies marketing PRT. The prototypes patented by this company were developed by Dr. Edward J. Anderson.

The Vehicle

The SkyWeb Express vehicle, (Figure VI), has a single seat 1372 mm (54 in) wide similar to the back seat of a taxicab and permits a maximum passenger load of 295 kg (650 lb) counting baggage. This interior width permits a wheelchair to enter and rotate forward with two of the three seats folded up, and to be accompanied by an attendant. Also, a bicycle and rider can be accommodated. A larger vehicle will have increased weight; hence guideway weight, station length and cost will increase proportionally, all without a commensurate increase in ridership.

Figure VI. Interior View of a PRT Vehicle.

Source: Skyweb Express 2005

The vehicle has a weight of 522 kg (1150 lb), and has a pleasing aerodynamic shape. It has a parking and emergency brake consisting of a pair of high-friction surfaces that press down on the guideway by means of a spring and are released by a ball screw actuator.

The vehicle is supported on pneumatic tires and as mentioned is propelled and braked by a pair of LIMs mounted at the bottom of the chassis. Use of LIM propulsion permits the tires and the running surface to be smooth so that the main-support wheels need not steer, thus simplifying and minimizing the cost of the design. Polyurethane-tired wheels provide lateral support. The stiffness of all of the tires and the position of the switch arm has been determined by detailed dynamic simulations of the motion of the vehicle, particularly through merge and diverge sections of the guideway (Warner et al., 2004).

Guideways

Recognizing that a truss is the lightest-weight structure that can be devised to support a weight across a span without resorting to cable suspension, it was selected for the guideway configuration of the SkyWeb express prototype. The system of guideways and posts is designed to withstand 240 kph (150 mph) crosswinds, and fully loaded vehicles nose-to-tail.

The guideway is shown covered in (Figure VII). It has a slot 102 mm (4 in) wide at the top to permit the 76-mm (3-in)-wide chassis to pass through, and a slot 152 mm (6 in) wide at the bottom to let any snow, ice, or debris fall through. Some of the vehicles equipped with specially shaped plows that pick up snow on the running surface and throw it down the bottom slot will be operated continuously during a snow or ice storm to prevent accumulation (Warner et al., 2004).

Figure VII. Guideway

Source: Skyweb Express 2005

The covers keep out ice and snow while permitting access for maintenance. They provide electromagnetic shielding, noise shielding, and ultraviolet shielding for the tires. They shield the power rails from frost formation; they markedly diminish differential thermal expansion in the truss structure; they reduce air drag from winds by use of curved surfaces at the upper and lower edges; and they permit the community to match the physical appearance of the guideway to the surroundings (Warner et al., 2004).

The Switching Mechanism

The switching assembly, (Figure VIII) consists of a pair of arms with polyurethane-tired wheels on each end fixed to and rotating together about a common longitudinal shaft. One arm is mounted near the front of the vehicle and one near the rear. The arms are shaped so that the line of force on a wheel engaged with one of a pair of switch rails passes through the center of the rotational axis, thus making the switch self-centering. The longitudinal axis is positioned based on a comprehensive dynamic analysis of motion of the vehicle through a merge or diverge section of guideway subject to extreme wind, passenger, and centrifugal loads.

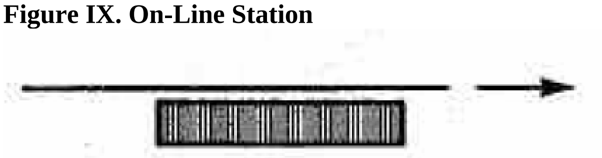
Figure VIII. Switching Arm

Source: Skyweb Express 2005

The switch arms are rotated by means of a pair of rotary solenoids and are made bi-stable by means of a pair of springs. To switch to the right, the switch arm is rotated counterclockwise until the right wheel is horizontal and positioned to engage the right switch rail. With this kind of switching capability, networks of any configuration can be built (Warner et al., 2004).

The Station

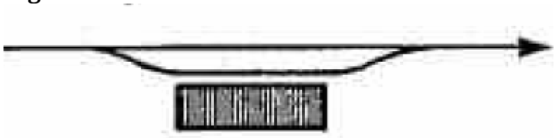
Figure IX. On-Line Station



Source: Analysis and Simulation of Automated Vehicle Stations

The design of a station is a critical part of any PRT layout. An on-line station is the one located on the main guideway (Figure IX). Since all the stations are on-line, the headway between vehicles has to be greater (min 60 sec) thus reducing the overall travel time.

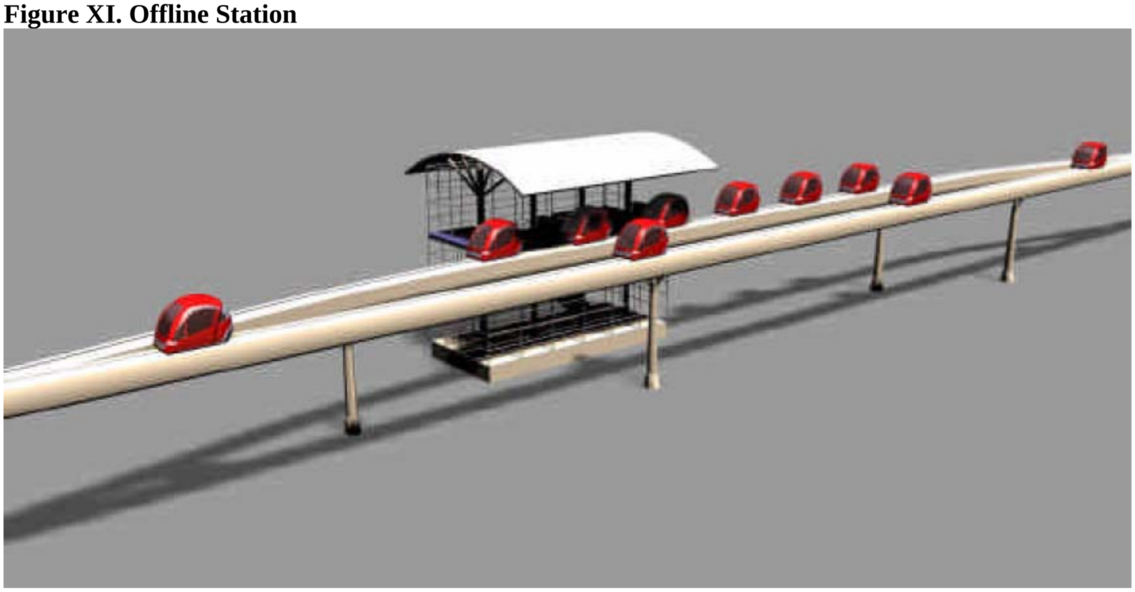
Figure X. Off-Line Station



Source: Analysis and Simulation of Automated Vehicle Stations

An Offline station is the one that is situated on a separate guideway away from the main line (Figure X). In such a setting, only the vehicles that have to be unloaded can pull into the station and rest of the vehicles can continue their journey on the main line. A minimum headway of 0.5 sec can be achieved in this type of configuration depending on the length of the incoming line, and the length of the platform. Figure 6 shows a scale model of an offline station. Vehicles wait for passengers to board at an offline station instead of people waiting for the vehicle. Other vehicles can continue their journey to their final destination without stopping (Warner et al., 2004).

Figure XI. Offline Station



Source: Skyweb Express

Personal Safety and System Safety Issues

One of the many safety features of a PRT system is the emergency stop button for passengers. The vehicle would have an emergency stop button on-board, which when activated would cancel the trip and take the vehicle to the nearest station. This button can be used by passengers in case they have an emergency on-board or they wish to terminate their trip in between.

System considerations for a PRT extend beyond just vehicle and guideway configuration to the complete design of the layout, ridership analysis, headway calculations, system capacity analysis etc. Selection of a system will greatly determine how the complete system works. This paper covers the basic concept of PRT and discussion of the SkyWeb Express system. It does not cover the design considerations for the layout which will be discussed later.

Rationale for PRT

Table 1. Analysis of Strengths, Weaknesses, Opportunities, and Threats

STRENGTHS	**WEAKNESSES**
1. Personalized 2. Clean technology 3. Relieves congestion 4. No waiting time 5. Caters to individual needs 6. Desegregating people 7. Works in snow 8. Automated 9. Promotes walking 10. No accidents	1. Aesthetic impact 2. Right of ways required 3. Impact on roadside businesses 4. Cost of construction 5. No built example
OPPORTUNITIES	**THREATS**
1. Walk-able communities 2. Compact cities 3. Equity in transportation 4. No pollution 5. Caters to individual demand 6. Saving in travel time 7. Energy saving	1. Storage 2. Bad effects not known 3. Turning radius 4. More number of vehicles required 5. Energy sources

Source: Author

Why Should Planners be Concerned?

1. Applications for transportation, environmental, economic and landuse planning

PRT has several benefits for various planning field. This technology was developed by transportation, civil and mechanical engineers in the mid 20th century to deal with transportation problems. It has been largely researched within the engineering field, but lacks support from the planning field. Unless planners see the benefits offered by the new technology and support it, the transition from promotional exhibits to real world will be difficult.

2. Can change how we design our cities

Transportation has shaped cities through ages. When walking was the most used mode of travel, cities were rather compact and different landuses were placed within walking distance. Cities started to expand out with the use of horse drawn carriages. With the advent of railroad and the street car, cities sprawled further out. Automobiles had the most effect, both on urban density and environmental quality. PRT can give an impetus to compact city design once again. PRT can be a solution for sprawl in the cities and may help to solve the problems posed by the current transportation systems.

3. Is an equitable mode of transportation for the 21st century

Automobile has grown from being a luxury to being a necessity in every home of America. But automobile is not an affordable mode for low income people. It is seldom an accessible mode for the physically challenged and older people. Hence there is a need to plan for a new mode which is equitable and accessible for all. PRT is an automatic system (driverless vehicles) which can be used by all. PRT is ADA compliant and can also be used by elderly and by people who cannot drive.

4. Will shape Transit Oriented Development

PRT can give an impetus for development of travel oriented community and mixed land use. PRT significantly reduces parking requirements. Parking lots occupy prime retail space and escalate real estate prices. With reduce parking requirement, investment for parking structures will reduce. Mixed land uses can also be integrated within the community. All activities can be planned within a compact framework for easy access from PRT stations. It will help build compact cities and reduce sprawl.

5. Solution to our current transportation problems

PRT vehicles are zero emission vehicles which will significantly reduce the green house gases and help in pollution mitigation. It will also free up roads for pedestrian use and reduce congestion on highways. PRT is a very safe mode for transportation as the vehicles are fully automated, hence chances of accidents due to human error is almost none. PRT will promote walking, thus reducing obesity and health problems.

6. Affordable technology with flexibility of an automobile

The installation costs of a PRT system are significantly lower than light rail systems. It is also has the benefit of being a flexible mode of travel with wide area coverage. Larger area of a city can be covered by single guideway PRT network while light rail transport serves a single corridor. Light rail transport requires dependence on a second mode of travel to reach the stations i.e. car or bus. On the other hand people can easily walk to a PRT station and dependence of car is eliminated. Also the requirement of building huge parking lots near stations is also eliminated. A PRT vehicle can access all stations in the network and thus enjoy the flexibility of the car. LRT on the other hand is very rigid with regard to the area it serves.

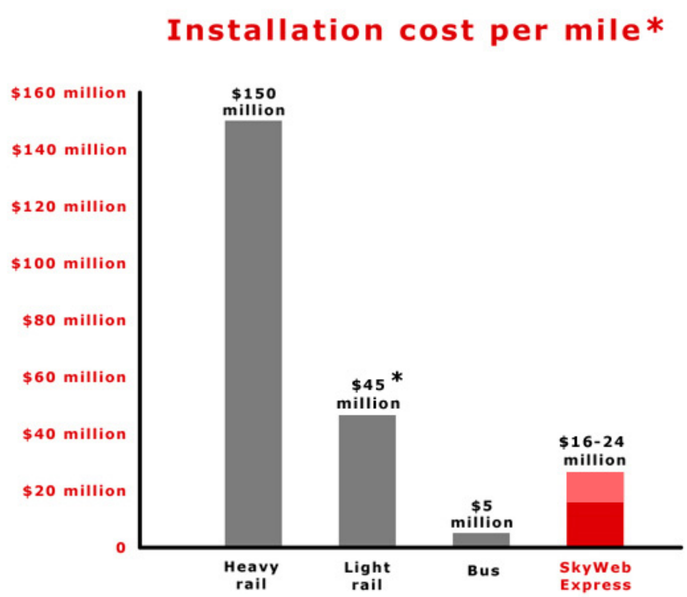
7. Less footprint than automobiles or trains

PRT guideways occupy very less area along roads. PRT uses 1% of land vs. 30-50% by autos in urban areas. Freeway vs. SkyWeb Express land use is 626:1

8. Affordable technology

Installation costs for SkyWeb Express (Figure XII) are significantly lower than conventional rail. The system is highly modularized and light weight hence can be easily installed. There is minimized disruption to traffic and businesses during installation. Due to its modular design, stations and loops can be added easily when required.

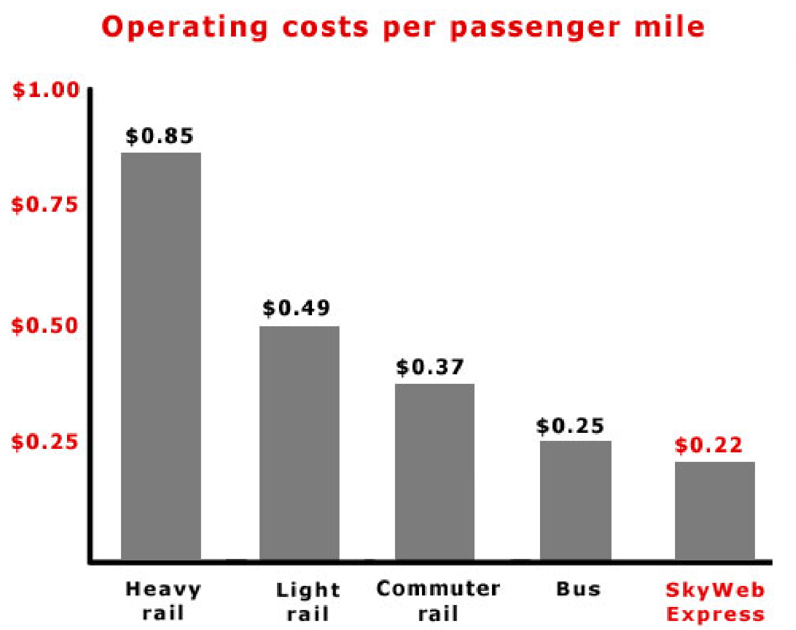
Figure XII. Installation Cost per Mile for Heavy Rail, Light Rail, Bus, and PRT



Source: SkyWeb Express

It has lower operation costs (Figure XIII) than conventional rail and buses. A PRT network has many small vehicles hence there is minimized unit repair, maintenance & replacement costs and out-of-service impact on the system. With high ridership and low operating costs, PRT does not need heavy public or governmental subsidy. It can be funded as private, public or public-private partnership.

Figure XIII. Comparison of Operation Costs per Passenger Mile for Heavy Rail, Light Rail, Commuter Rail, Bus and PRT



Source: SkyWeb Express

Case Study: Morgantown People Mover

Introduction

Morgantown People Mover (Figure XIV) was authorized by the 1966 amendment to the Urban Mass Transportation Act of 1964. It was envisioned as a 'demonstration project' to assess the new PRT concept. The Phase I of the project was dedicated in 1972 and underwent an extensive test program. Morgantown presented an ideal test city due to the climate, the hilly terrain, traffic problems and the university setting. Phase I opened for operation in 1975 while Phase II opened in 1979. The total track is 8.7 lane miles and today the system carries over 2 million passengers annually and up to 30,000 people each day. The Morgantown PRT was actually developed in three phases. The phase IA was the prototype design and testing phase. Phase I B was passenger service test period while phase II was the final design stage (Hendershot, 2005).

Figure XIV. View of Morgantown PRT Vehicle

Source: Author

The system operates in 3 dispatching modes. During off-peak traffic periods, the system operates in a demand mode. During peak traffic periods, the system operates in a scheduled mode with a capacity of eight seated and up to twelve standing passengers (Hendershot, 2005).

The Vehicles

The vehicles are fully automatic, and operated under computer control to reduce the use of manpower. The vehicles operate at 15 sec headway. The vehicles have their own right of way and operate on rubber tires. Power is supplied to the system through three phase 575 Volt electrical supply. A redundant four-wheel hydraulically operated disc braking system provides vehicle braking for normal and emergency conditions.

The vehicle accepts velocity and other control commands into the on-board portion of the control and communication system. The commands are transmitted from communication loops embedded in the surface of the guideway, received by the vehicle antennas, and translated by the vehicle into operations necessary for the transportation of the passengers. A steering wheel axle assembly is mounted at the front of the vehicle which rides against the vertical surface of the steering rail attached to the guideway structure. Vehicle suspension by a system of air bags contributes to smooth riding qualities (Anderson, 1973).

The Guideway

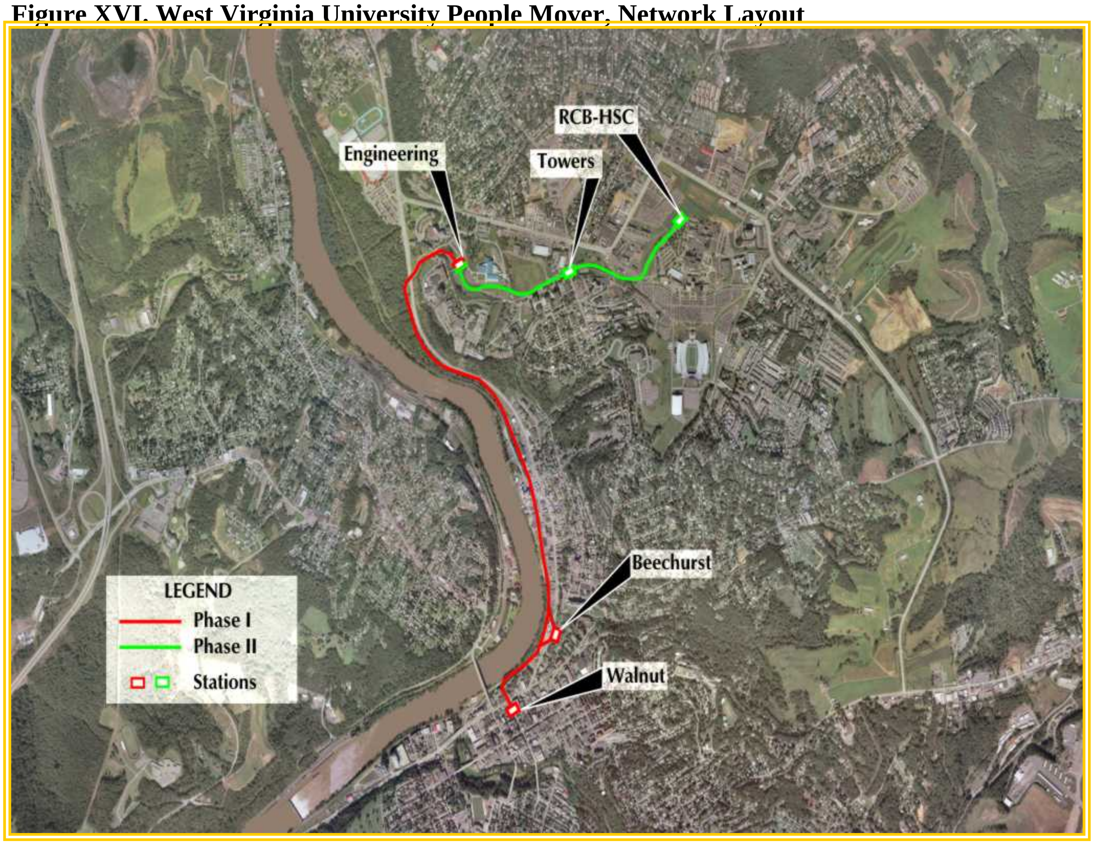
The guideway (Figure XV) is mostly above ground to avoid interference with pedestrian and vehicular activity. The guideway has concrete running pads for the vehicle, and houses the communication lines, collision avoidance sensors, and a grid of heating pipes for melting snow and ice.

Figure XV. View Showing Part of the Guideway and Vehicles Pulling into a Station

Source: Author

The piers for the guideways are also constructed out of concrete. The vertical sections of the sides of the guideway house the steering rail and the electrical power rails for power pick up. One of the power collector heads of the vehicle is extended so that it makes sliding contact with the guideway power rails for power pick up (Anderson, 1973).

Figure XVI. West Virginia University People Mover, Network Layout



Source: Presentation made by Robert Hendershot at the Alden Seminar at WVU, 2005.

The Stations

The WVU system has six stations (Figure XVI). Three stations (which are located at the route ends- Walnut, Coliseum and Medical center stations) are on-line. The Downtown campus, Engineering and Forestry stations are off-line. Within the station, there are two platforms for passenger loading and unloading, four turn-around channels and two stop berths on each channel for simultaneous loading and unloading. Passengers entering the station on the concourse or street level are directed to the proper platform for their desired destination by the platform assignment display. A coded pass inserted into a fare collection unit opens the entry gate and activates the destination selection unit (Figure XVII). The coded pass is issued periodically to students, or may be purchased from the University (Anderson, 1973).

Figure XVII. Fare Collection Units

Source: Morgantown PRT

The passenger pushes the button for his destination station which then lights up to acknowledge the selection. The passengers proceed to the boarding position which is indicated by a display. Each loading position indicates vehicle destination information (Anderson, 1973).

Communication and Control

The most critical part of the system is communication and control. Generally it is expected to provide an efficient and fail safe real time computerized control of the vehicle as it moves on the guideway. It also has provision of manual control override in event of an emergency and to establish a communication service within itself. The central computer carries out the automatic system management functions, receiving destination requests from the station and transmitting commands to the stations. The station computer receives inputs from passengers through the destination selection units and gives passengers instructions via the passenger advisory displays. The station computer manages vehicle movements and receives status information via the data handling unit. Communication with vehicles is through inductive communication loops in the guideway surface. Speed commands, station-stop commands, steering switch signals, and calibration signals are transmitted from the guideway communication loops (Anderson, 1973).

The independent collision avoidance system brings cars to an emergency stop when conditions occur that otherwise could cause collisions. Detectors sense and indicate the presence of a car on the guideway. The vehicle on-board controller must receive a safe tome signal from communication loops on the guideway to proceed with travel. Thus if spacing between two vehicles is reduced to where it approaches an unsafe condition, the following vehicle will enter a sector without a safe tone and its emergency brakes will be applied. The spacing between vehicles must be greater than the safe emergency stopping distance at the appropriate speed. The independent collision-avoidance units are overlapped near the merge point of two guideway sections so that competition for the same slot will bring the vehicles to an emergency stop (Anderson, 1973).

Maintenance and Control Center

The maintenance center and control center provide space and support services for vehicle maintenance equipment, control and communication equipment and personnel to operate and maintain the system (Anderson, 1973).

The maintenance facility includes a vehicle storage yard, maintenance loop, and a maintenance building. The maintenance building provides space for vehicle repair, maintenance, washing, lubrication, steering wheel alignment, and diagnostic testing. It also includes space for power distribution system, air conditioning plant, battery racks for an uninterrupted power source, battery maintenance area, spare storage, tool room, painting booth, maintenance office, mechanical and electrical work bench areas, and electronic and instrument repair room (Anderson, 1973). During its 28 years of operation, WVU people mover had over 100,000 hours of operation, over 23 million vehicle-miles of travel, carried over 63 million passengers and has maintained its 98% service reliability (Anderson, 1973).

Safety and Security

Apart from the collision avoidance system, WVU people mover system also has 24 hours station surveillance for passenger safety (Figure XVIII). All the stations are monitored by close circuit TV and a public address system. The staff in central command can keep a watch on the stations and at the same time can instruct people on the stations in case of emergencies (Hendershot, 2005).

Figure XVIII. Close Circuit Cameras in Central Control

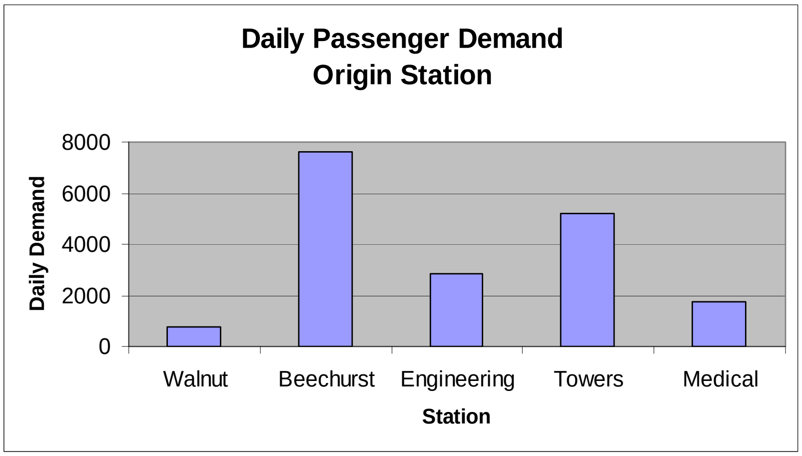
Source: West Virginia University People Movers

All the stations are connected by direct voice service to central command. A passenger in need of help has to just pick up a phone located in the station and start talking to central command. The vehicles too are equipped by voice communication system for direct contact with central command. In case of emergency on-board the vehicle, the passengers can talk directly to central command and receive instructions from them (Hendershot, 2005)

Passenger Demand

Figure XIX depicts the station demand based on station of origin. The maximum demand is at the Beechurst and Towers stations.

Figure XIX. Daily Passenger Demand



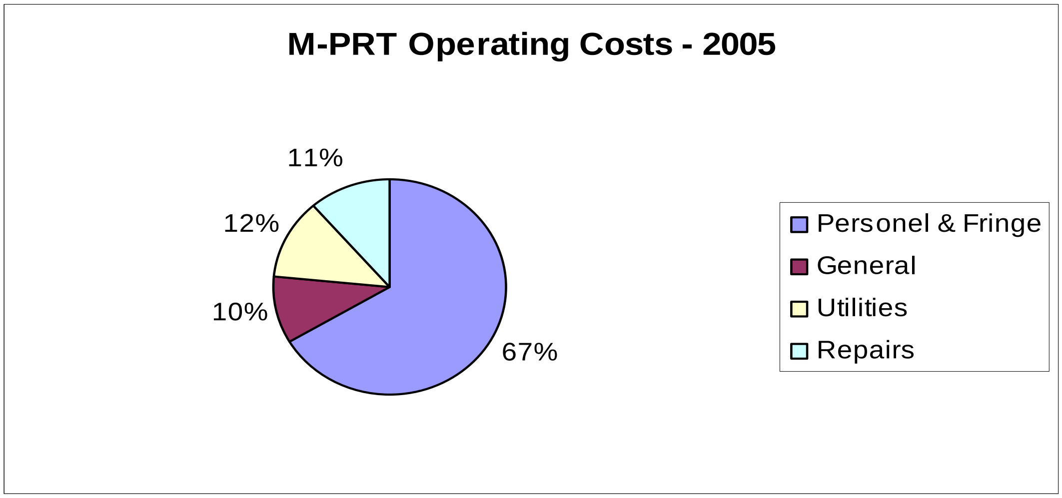
Source: Taken from the presentation made by Robert Hendershot at the Alden Seminar at WVU, 2005.

As many as 15,000 people ride the Morgantown PRT system on an average weekday. On busy days, the traffic gets as high as 25-30,000 people in a day (Hendershot, 2005).

Operating and Maintenance Costs

The following chart (Figure XX) depicts the share of expenses for operating the Morgantown PRT system. The annual maintenance cost of the Morgantown PRT system for the year 2004-2005 was $3,422,044 (Hendershot, 2005)

Figure XX. Breakdown of Operating Costs for the Morgantown PRT System



Source: Presentation made by Robert Hendershot at the Alden Seminar at WVU, 2005.

Inferences

1. The Morgantown People Mover System has been serving the university campus since the last 30 years. Hence, it is safe to say that it is a proven technology.
2. Surrounding communities are requesting extension of people mover service in their neighborhoods. This is a significant sign that PRT is functioning well in Morgantown and popular among locals.
3. The Morgantown system is an old system and bulky as compared to some recent prototypes. Changes in the design of PRT guideways is a major improvement in aesthetics of the system. The Taxi 2000 prototype is less intrusive aesthetically and requires less right-of-way as compared to Morgantown People Mover.
4. PRT is a reliable mode of travel in extreme weather conditions like snow and frost.
5. Cost of heating the guideways is high for the Morgantown People mover, nevertheless, recent guideway designs do not require heating and hence are more cost efficient as compared to the old prototype.

6. There have been no casualties on the Morgantown People Mover system. Hence, it is an extremely safe system as compared to motor vehicles.
7. PRT systems can be operated with the conventional sources of electricity.

This case study provides a valid foundation for proposing PRT in urban areas. It is a unique solution for congested areas and helps in reducing the pressure on existing road network. The Morgantown-PRT system has been in operation since the past 30 years, which is a significant time interval to test a new mode of transit. Hence, it can be inferred from the case study, that PRT can be used in an urban setting. The following chapter on methodology gives a systematic account of design of the PRT layout for Uptown Cincinnati.

Introduction

This thesis aims at testing the feasibility of a personal rapid transit system in Uptown Cincinnati. This would involve design and testing of a PRT layout in Uptown. An important component and also as a base information, the travel demand has to be computed for the area. This travel demand will help in the simulation and testing of the layout. The research methodology will have the following steps:

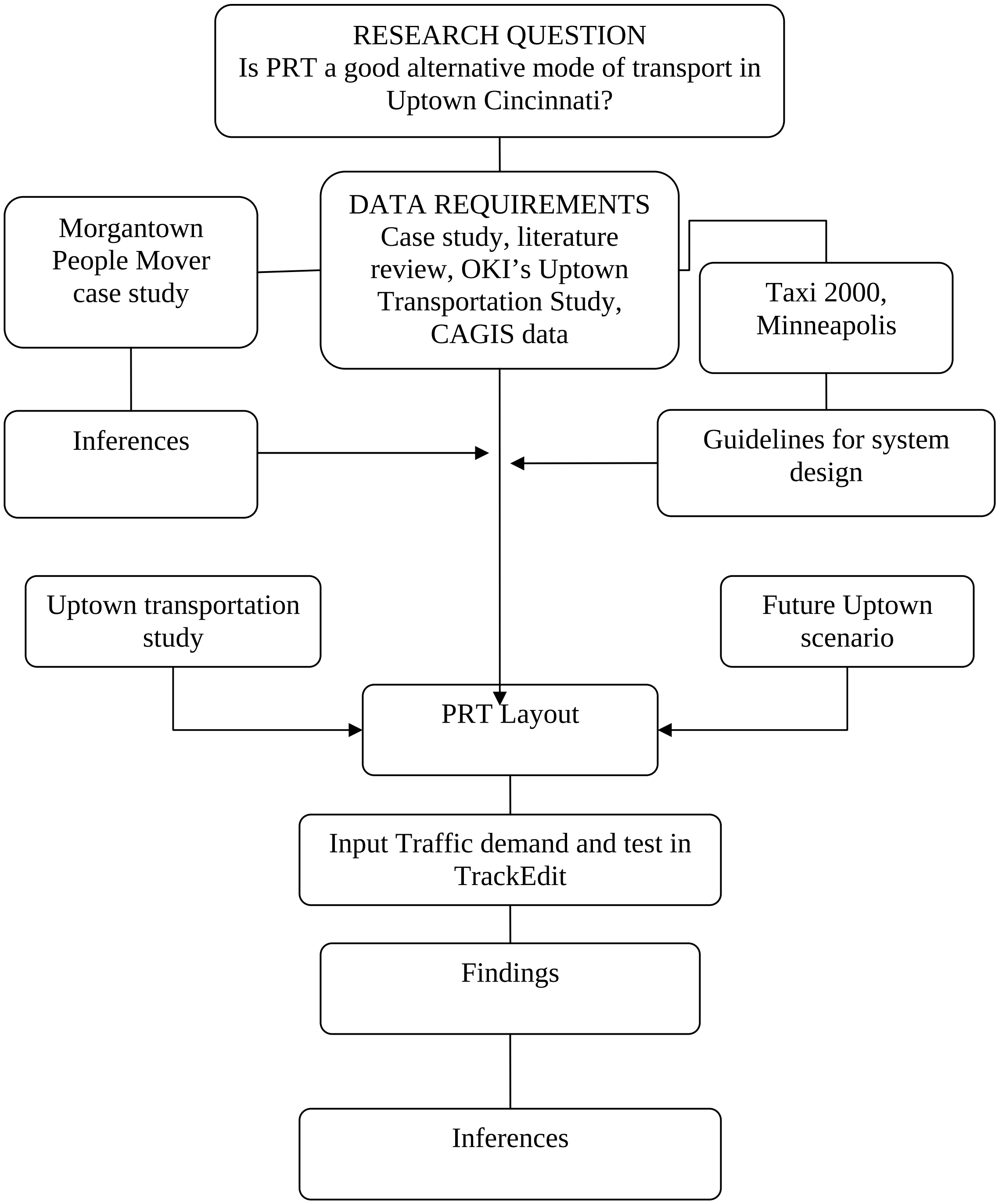
1. Identifying station location
2. Identifying the travel demand in Uptown based on landuse
3. Design of a PRT layout
4. Simulation of the layout through TrackEdit, which is PRT simulation software, to test if the system can handle the morning peak hour demand.
5. Conclusions based on the results of the simulations

The first step would be to identify station locations for PRT. This would be done through suitability analysis in GIS. The next step would be computing the travel demand for uptown. This will involve identifying the land use class for every parcel from GIS database, identifying building gross square footage, identifying the employee number for some institutions like the EPA, Children's Hospital and student enrollment at University of Cincinnati. The Institute of Transportation Engineer's 'Trip Generation Handbook', gives the summary of trip generation numbers for every land classification in an urban area. Number of trips generated per day by every land use class will be compiled in a table form. These trip numbers will be attributed to the corresponding parcel in GIS. The trip generation numbers are based on specific criteria's like number of dwelling units if it is a residential landuse, gross square feet of built-up area if it's an office or commercial use, per student of universities etc. different factors will be used for different landuses according to the best information available. These trip generation numbers will be converted into peak demand. This peak demand will be used for the simulation in TrackEdit.

Based on the above findings, a PRT layout will be proposed for Uptown Cincinnati. The network layout will be based on the product specifications mentioned in the company guidelines. Simulation of the demand matrix for the layout will be done in TrackEdit. The simulation results will be used to refine and modify the layout till an acceptable solution is achieved.

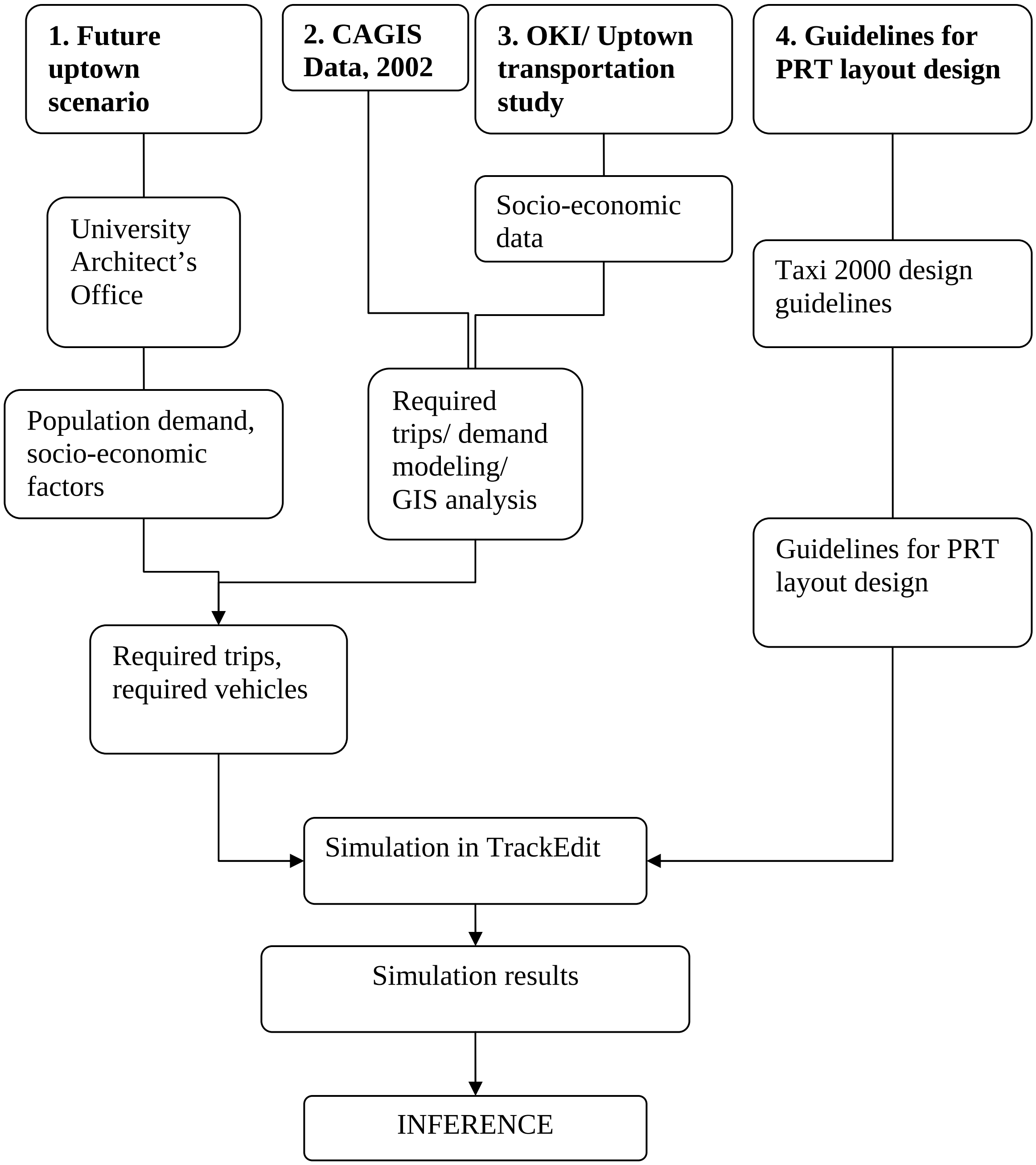
The analysis of the final layout will be done to establish its benefits or drawbacks as compared to other modes. For this, final design layout will be compared to other modes of transportation to assess ridership, cost, socio-economic and environmental impact for different modes. Depending on the findings of this comparison, a case will be made for PRT.

Figure XXI. Methodology



Data Requirement

Figure XXII. Data Requirement, Sources, and Analysis



Personal Rapid Transit Network Design

Suitability Analysis

Suitability analysis will identify areas/sites suitable for location of PRT stations. The most important part of any PRT layout would be to identify the location of PRT stations so that it is highly accessible to users and serve all the areas that need transit service. Some of the factors used in transportation planning and design study that influence trip generation are landuse, population, and economic activity. The suitability of the site will depend on the following criteria:

1. Household density in the Traffic Analysis Zone (TAZ);
2. Income level in the TAZ;
3. Employment in the TAZ;
4. University enrollment in the TAZ;
5. Land use of the parcel, and
6. Parking location

The five factors listed above are based on travel demand forecasting models, which use similar criteria to forecast traffic volume. The purpose of doing such an analysis is that it helps in delineating areas for location of PRT stations. It is a base work for the next step in the design of a PRT layout i.e. station location. However since the PRT is being developed primarily for the institutions in Uptown, the PRT stations can be located closer to such buildings/ places.

The following steps explain the methodology for the suitability analysis.

1. The first step in beginning any GIS analysis would be to migrate the data in GIS format. The census and traffic data obtained from OKI was in the excel sheet format. The primary unit of classification of the data was by TAZ. Demographic

information was compiled in an excel format for each TAZ. The study area consisted of 24 TAZ. The demographic data for the year 2030 was obtained from OKI. The first step was to join this excel data to a GIS dataset. The Join command in ArcMap was used to join the demographic data for the year 2030 to a TAZ dataset in GIS.

2. The second step was to convert individual fields in the dataset into raster format to be used in the suitability analysis later on. The outline of the suitability analysis is as follows:
    a. Convert feature data to raster data using ‘convert to raster’ command in spatial analyst. Different raster datasets were prepared for each field i.e. household density, income, employment, university enrollment, parking and landuse.
    b. The second step was to reclassify the raster datasets into 10 classes in ascending order so that the field with the highest priority will have the greatest weight. For example, while reclassifying the raster dataset for household density, the greater the value of household density, the greater the value attributed to the field. The TAZ with the lowest household density will score a value of 1 in the reclassification criteria. Similarly, employment was reclassified into 10 groups in ascending order. The greater the employment in a TAZ, the higher will be the relative score of the TAZ on a scale of 1 to 10. The reclassification criteria used for this was the Jenks Natural Breaks, criteria in GIS. Jenks Natural Breaks was used as it evenly distributes the classes depending on the range of the

data. Income dataset was reclassified in the descending order i.e., the lower the median income in a particular TAZ, the higher its score on a scale of 1 to 10. That means, if the people are poor in a particular area/TAZ, more priority is given to them for location of a public transit system. This type of scaling ensures equity in planning of transportation systems. Landuse classification was done on the basis of propensity of a particular landuse to generate traffic. For example, a commercial landuse has a propensity to generate more traffic volume as compared to a residential landuse. Comparative scaling judgment was used in deciding the weight of each land use. An in depth analysis might generate more accurate results, but do to the limited scope of this study, a very broad classification criteria was used for the reclassification. Parking dataset was not classified into 10 classes. Any place that had parking was assigned a value 5. In an ideal case scenario, the parking layer should have been classified according to the number of parking spaces in a particular parking lot. However due to lack of information, an average value 5 was assigned to the parking dataset, implying that wherever a parking lot is situated, that place is more suitable for location of a PRT station.

The following data ranges were used to reclassify each dataset

i. Household density: Higher the household density, higher the class weight

Table 2. Original Household Density Classification Range

Class	Range	
1	0	1.02
2	1.03	1.69
3	1.7	3.86
4	3.87	4.45
5	4.46	5.24
6	5.25	5.83
7	5.84	7.97
8	7.98	13.16
9	13.17	18.82
10	18.83	34.63

Source: Author (OKI & CAGIS data)

ii. Income level: Lower the income, higher the class weight

Table 3. Original Income Classification Range

Class	Range	
1	26191	46932
2	22769	26190
3	21633	22768
4	21090	21632

5	20651	21089
6	19798	20650
7	18359	19797
8	16251	18358
9	12358	16250
10	11142	12357

Source: Author (OKI & CAGIS data)

iii. Employment: Higher the employment, higher the class weight

Table 4. Original Employment Classification Range

Class	Range	
1	1	2
2	3	3
3	4	4
4	5	8
5	9	10
6	11	19
7	20	24
8	25	46
9	47	57
10	58	143

Source: Author (OKI & CAGIS data)

iv. Enrollment: higher the college enrollment, higher the class weight

Table 5. Original College Enrollment Classification Range

Class	Range	
1	0	
2	1	259
3	260	622
4	623	968
5	969	1751
6	1752	2416
7	2417	4064
8	4065	7184
9	7185	16311
10	16312	27289

Source: Author (OKI & CAGIS data)

v. Land use: higher the number of trips generated, higher is the class weight

Table 6. Land Use Classification Range

Land Use	Classification
Two Family	2
Single Family	1
Vacant	0
Multi Family	5

Public Service	7
Commercial	7
Institutional	10
Not Applicable	0
Office	8
Educational	7
CH Commercial Hospital	8
Mixed Use	9
Light Industrial	4
Public Utility	6
Public R	7
Heavy Industrial	6

Source: Author (OKI & CAGIS data)

vi. Parking: Parking lots are more suitable for location of PRT stations

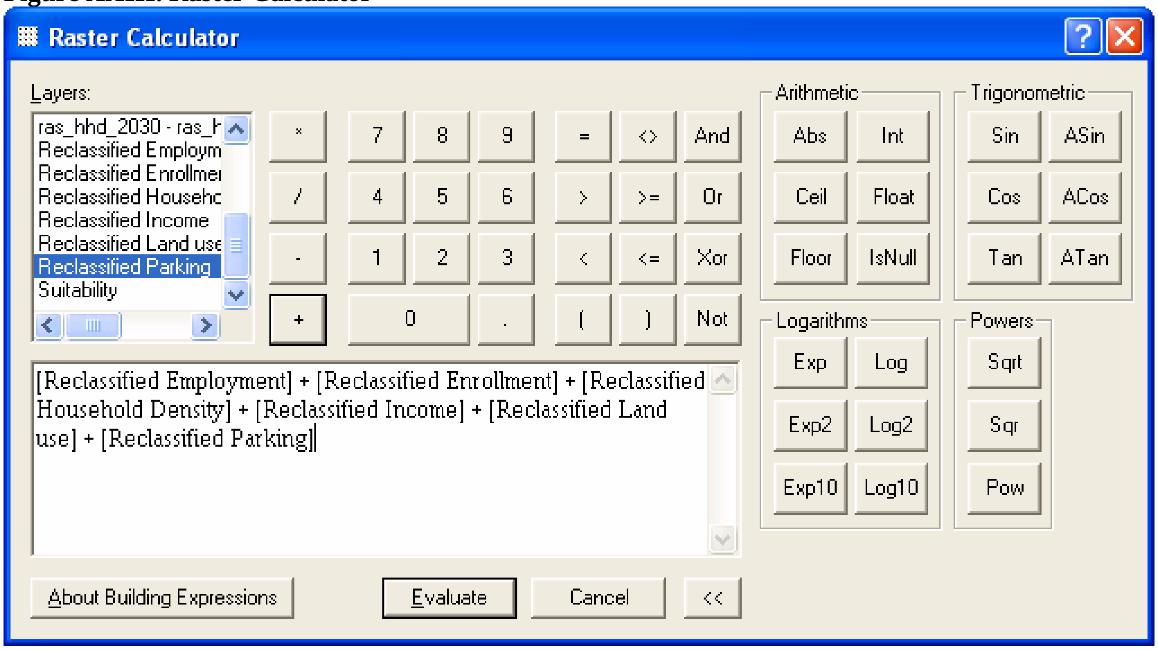
Table 7. Parking

Class	Range
Parking	5

Source: Author (OKI & CAGIS data)

c. The next step in the suitability analysis is to combine all the different layers to determine the areas more suitable for location of PRT stations. This was done by adding all the layers in the spatial analyst function called raster calculator (Figure XXIII). The raster Calculator combines all the layers into one layer by adding-up all the layers.

Figure XXIII. Raster Calculator

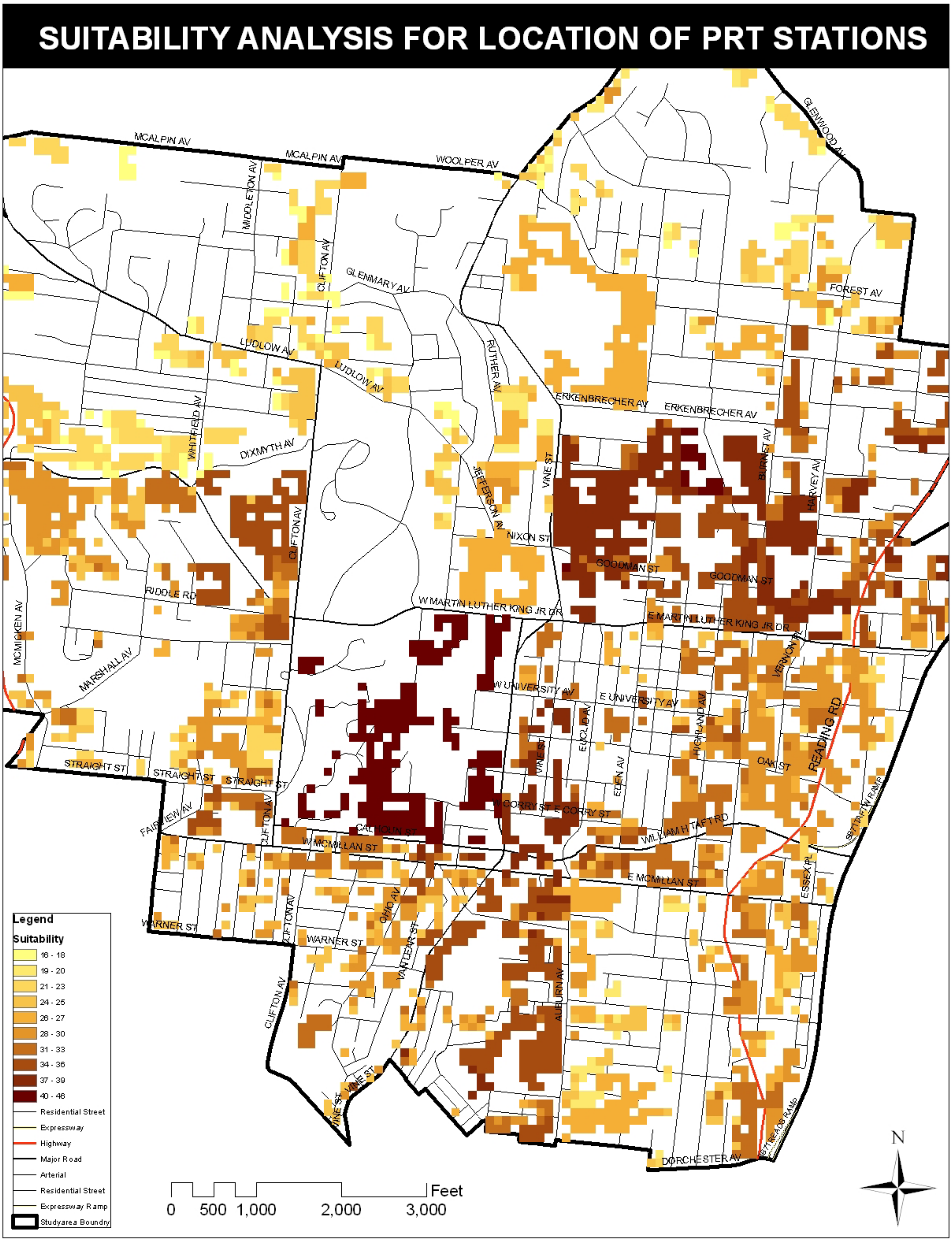


d. The resultant layer shows the areas more suitable for location of PRT stations. The higher the suitability value, the greater is its eligibility for location of PRT station. Suitability is represented by color in the map; greater the suitability, darker the color.

Results

University of Cincinnati’s Central Campus East and Central Campus West scored high in this analysis (Figure XXIV). All the hospitals like Good Samaritan on Clifton Avenue, Deaconess on Clifton Avenue, Children’s Hospital and Tri Health on Burnet Avenue scored high in suitability. Parcels surrounding Reading Road also scored high in this analysis. Suitability Analysis is the basis for determining location of PRT stations. Many other criteria will come into consideration in the final location of PRT stations. As a design and policy decision, all PRT guideways are to follow the road network in this thesis. PRT guideways can also be located through private property lines. But as a policy guideline, I decided to locate the PRT lines only through public right-of-ways. People doing further analysis on this layout may consider other options.

Figure XXIV. Suitability Analysis for Location of PRT Stations



Data Source: CAGIS 2000 & OKI Data Center

Location of PRT Stations

This next step in station location would involve identifying sites for stations based on aerial images and the suitability analysis. Some guidelines were defined as a basis for location of PRT stations.

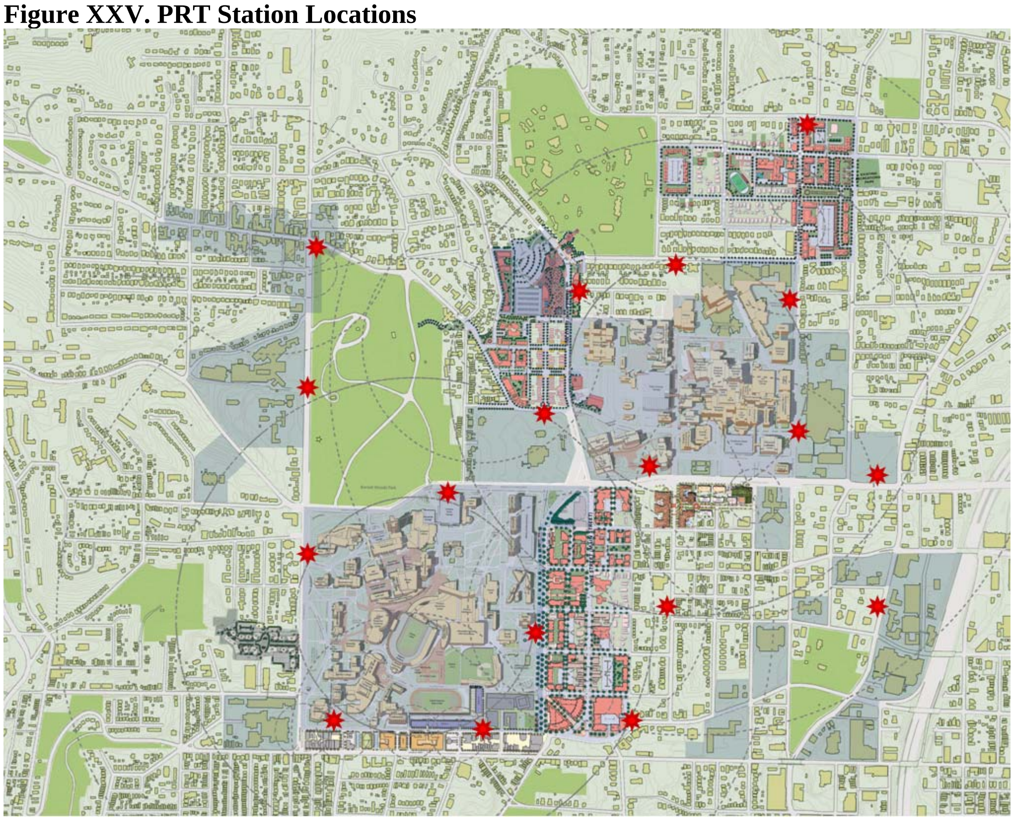
Guidelines for location of PRT stations are as follows:

1. PRT guideways and stations will be located along the existing road network. The guideways will not intrude any private property.
2. PRT stations will be located on vacant plots as far as possible. There will be no taking of private property for location of PRT stations.
3. The distance between two consecutive PRT stations will not exceed half mile.
4. Institutions that require direct access to PRT stations will voluntarily provide space for location of PRT stations on their property.
5. PRT stations will be connected to/or located close to parking lots. This will facilitate people to park their vehicles at remote parking places.

Through the study of aerial images of the Uptown area, probable sites for station location were identified. Google map and CAGIS maps were used for this analysis. After the station locations were identified through aerial images, the next step was site-visit for the identified sites. The site visits helped to verify if the selected sites could accommodate the PRT stations. Knowledge about upcoming development in Uptown was also a major factor in location of PRT stations.

Public parcels were preferable for location of PRT stations, as they would not require taking of private land. On the other hand, most of the right of way required for guideway and stations would be located along roads owned by the City of Cincinnati. The posts for the guideways would be located along sidewalks, and hence would not intrude private property. This also means that the cost for acquiring right of ways would be low in the case of PRT. Identifying station locations was an iterative process. During the initial stages, nearly 35 locations were identified as suitable for PRT station location. Many of these locations had to be discarded after the site visit as the parcels were too narrow to accommodate a station. In addition, many sites had to be discarded, as the distance between consecutive PRT stations was less than what was needed to justify an additional station. This process of selection of station location went on until a satisfying solution was reached. Based on the guidelines, the following locations (Figure XXV) were identified as final locations for PRT stations.

Figure XXV. PRT Station Locations



Source: Author

Service Area Analysis & Ridership Analysis

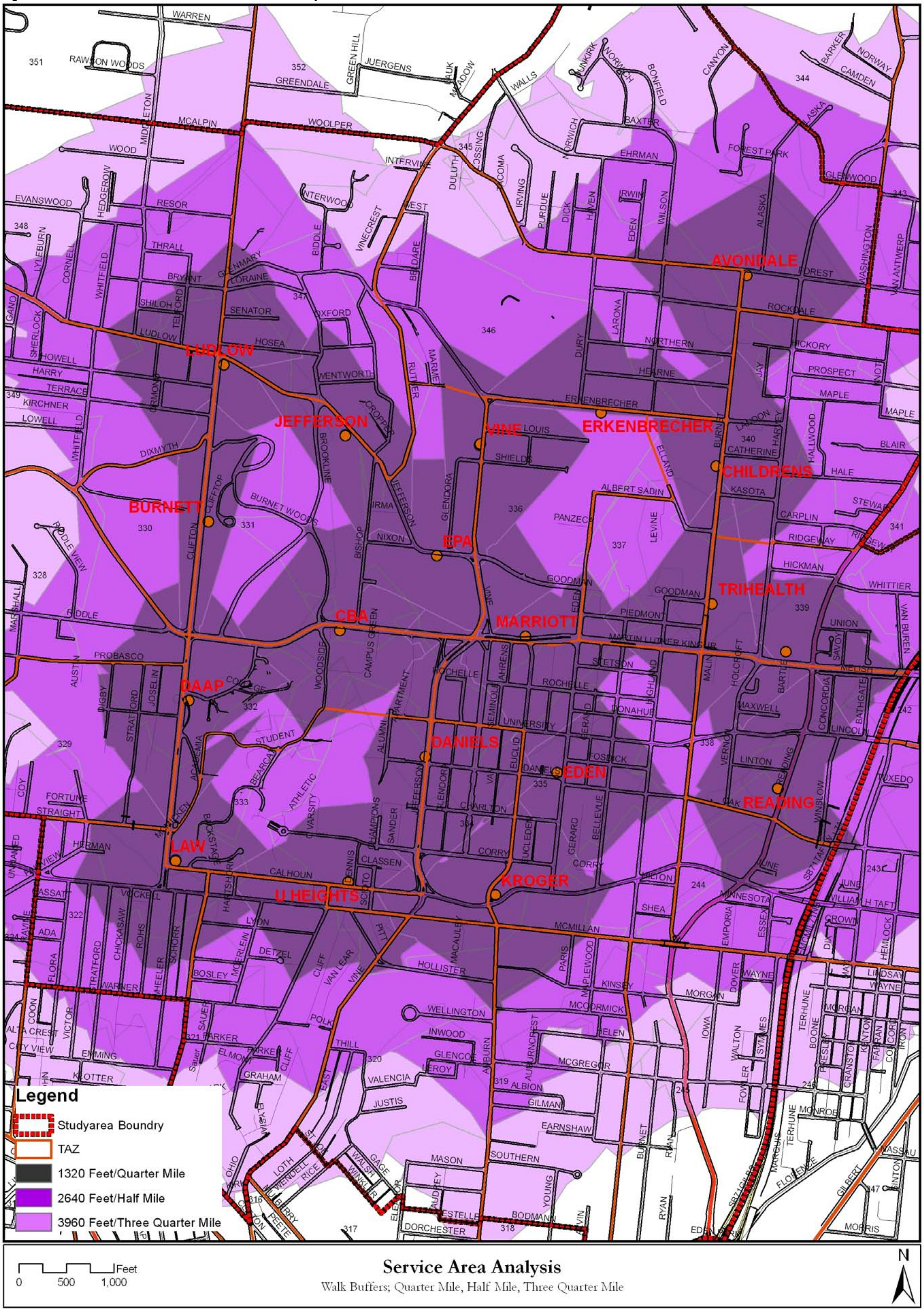
Service area analysis will be performed for all the stations. A buffer of quarter mile, half a mile, and three quarter mile would be considered for every station. The number and type of land uses within these buffers will be analyzed for the ridership study.

To prepare the dataset for this study, parcel polygon dataset was joined with Building dataset to attribute the parcel landuse information to the building. The parcel based dataset has the information on landuse, while the building dataset has information on built-up area. Both these factors will be useful in allocating trip generation numbers to specific landuses. The following is a description of methodology used for service area analysis:

1. **Calculation of quarter mile, half mile and three quarter mile walk distances**

This was done in the network analyst of ArcView GIS. The network analyst has the ability to measure distances based on street length. Street length was considered an important factor as people are expected to walk to the nearest PRT station. Walking distances of a quarter mile, half mile and three quarter mile were considered for analysis. A quarter mile walk distance is also a 5 minute walk distance, a half mile walk distance is a 10 minute walk distance, while a three quarter mile walk distance is about 15 minute walk distance. The station locations were input as points of origin for the calculation. The network analyst created buffers of quarter mile, half mile and three quarter mile around every station based on the street length (Figure XXVI).

Figure XXVI. Walk Buffers Based on Network Analyst



Source: CAGIS 2002

2. **Identifying the number of parcels in each buffer**

The next step was to identify the number of parcels in each buffer. This was done by ‘select attribute by location’ tool in GIS. This tool selects objects (in this case parcels) that lie within another object (in case buffers). Parcels that had their centers in a specific buffer were selected. After the selection process, the following numbers of parcels were selected in each buffer:

Table 8. Results of GIS Service Area Analysis

Description	**Number of Parcels**
Number of parcels within quarter mile of all stations	17,162
Number of parcels within half mile of all stations (includes parcels from beyond the study area boundary)	81,670
Number of parcels within three quarter mile of all stations (includes parcels from beyond the study area boundary)	1,99,176
Number of parcels in the study area of Uptown	28,576

Source: Author

Identifying Parcel Based Land Use Information

The next step was identifying the trip generation numbers for each land use. Landuse classification was based on the land use classes specified by the Hamilton County Auditor. The ‘ITE Trip Generation (5th edition)’ book specifies the number of trips generated by each parcel based on the land use classification. The following table shows the land use class and the trip generation number used for each as taken from the ITE Trip Generation Book.

Table 9. ITE Trip Generation Numbers According to Land Use

CATEGORY	DESCRIPTION	DEPARTMENT OF TAX EQUALIZATION	HAMILTON COUNTY	ITE Trip rate	Unit
INDUSTRIAL	VACANT LAND	300	300	0	
INDUSTRIAL	FOOD/DRINK PROCESSING	310	310	3.85	per 1000 SF
INDUSTRIAL	MEDIUM MANUFACTURING	330	330	3.85	per 1000 SF
INDUSTRIAL	LIGHT MANUFACTURING	340	340	3.85	per 1000 SF
INDUSTRIAL	WAREHOUSE	350	350	4.88	per 1000 SF
INDUSTRIAL	OTHER	399	399	0.79	per 1000 SF
COMMERCIAL	APARTMENTS - 4 TO 19 UNITS	401	401	6.47	per Dwelling Unit
COMMERCIAL	APARTMENTS - 20 TO 39 UNITS	402	402	6.59	per Dwelling Unit
COMMERCIAL	APARTMENTS - 40+ UNITS	403	403	4.2	per Dwelling Unit
COMMERCIAL	RETAIL - APARTMENTS OVER	404	404	6.47	per Dwelling Unit
COMMERCIAL	RETAIL - OFFICES OVER	405	405		per 1000 SF
COMMERCIAL	RETAIL – STORAGE OVER	406	406	40.67	per 1000 SF
COMMERCIAL	FORESTRY	407	407		
COMMERCIAL	MOTEL & TOURIST CABINS	410	410	10.19	per Occupied room
COMMERCIAL	HOTEL	411	411	8.7	per Occupied room
COMMERCIAL	NURSING HOME / PRIVATE HOSPITAL	412	412	16.78	per 1000 SF
COMMERCIAL	DAYCARE/PRIVATE SCHOOLS	418	418	10.72	per 1000 SF
COMMERCIAL	OTHER COMMERCIAL HOUSING	419	419	5.86	per Dwelling Unit
COMMERCIAL	SMALL DETACHED RETAIL (10,000)	420	420	40.67	per 1000 SF
COMMERCIAL	SUPERMARKET	421	421		per 1000 SF
COMMERCIAL	DISCOUNT STORES	422	422	70.13	per 1000 SF

CATEGORY	DESCRIPTION	DEPARTMENT OF TAX EQUALIZATION	HAMILTON COUNTY	ITE Trip rate	Unit
COMMERCIAL	NEIGHBORHOOD SHOPPING CENTER	425	425	0.625X+ 5.1039	X=1000 SF
COMMERCIAL	COMMUNITY SHOPPING CENTER	428	426	0.635X+ 3.867	X=1000 SF
COMMERCIAL	OTHER RETAIL STRUCTURES	429	429	0.635X+ 3.867	X=1000 SF
COMMERCIAL	RESTAURANT, CAFETERIA OR BAR	430	430	96.51	per 1000 SF
COMMERCIAL	OFFICE - APARTMENTS OVER	431	431	6.47	per Dwelling Unit
COMMERCIAL	BARS	434	434	15.49	per 1000 SF
COMMERCIAL	DRIVE-IN RESTAURANT OR FOOD SERVICE	435	435	632.12	per 1000 SF
COMMERCIAL	OTHER COMMERCIAL	436	436		
COMMERCIAL	OTHER FOOD SERVICES	439	439	786.22	per 1000 SF
COMMERCIAL	DRY CLEANING PLANTS / LAUNDRIES	440	440	0.79	per 1000 SF
COMMERCIAL	FUNERAL HOMES	441	441	4.16	per 43560 SF
COMMERCIAL	MEDICAL CLINICS & OFFICES	442	442	23.79	per 1000 SF
COMMERCIAL	BANKS	444	444	140.61	per 1000 SF
COMMERCIAL	SAVINGS & LOANS	445	445	61	per 1000 SF
COMMERCIAL	OFFICE (1 TO 2 STORIES)	447	447	11.5	per 1000 SF
COMMERCIAL	OFFICE BUILDINGS		447		
COMMERCIAL	OFFICE WALK-UP (3 STORIES PLUS)	448	448	.756X+3 .765	X=1000 SF
COMMERCIAL	OFFICE, ELEVATOR (3 STORIES PLUS)	449	449	6.27	per 1000 SF
COMMERCIAL	AUTOMOTIVE SERVICE STATION	452	452	15.86	per 1000 SF
COMMERCIAL	CAR WASH	453	453	108	no. of stalls

CATEGORY	DESCRIPTION	DEPARTMENT OF TAX EQUALIZATION	HAMILTON COUNTY	ITE Trip rate	Unit
COMMERCIAL	AUTO SALES & SERVICE	454	454	47.91	per 1000 SF
COMMERCIAL	LODGE HALL / AMUSEMENT PARKS	465	465	75.76	per 43560 SF
COMMERCIAL	DWELLING USED AS OFFICE	470	470	11.5	per 1000 SF
COMMERCIAL	DWELLING USED AS RETAIL	471	471	40.67	per 1000 SF
COMMERCIAL	WAREHOUSE	480	480	4.88	per 1000 SF
COMMERCIAL	TRUCK TERMINAL	482	482		
COMMERCIAL	AIR RIGHTS	488	488		
COMMERCIAL	UTILITY	489	489	2.62	per 1000 SF
COMMERCIAL	MARINE SERVICE FACILITY	490	490		
COMMERCIAL	MARINAS	498	498		
COMMERCIAL	OTHER STRUCTURES	499	499	2.62	per 1000 SF
RESIDENTIAL	SINGLE FAMILY	510	510	9.55	per Dwelling Unit
RESIDENTIAL	FORESTRY WITH BUILDINGS	517	517		
RESIDENTIAL	TWO FAMILY DWELLINGS	520	520	6.47	per Dwelling Unit
RESIDENTIAL	THREE FAMILY DWELLINGS	530	530	6.47	per Dwelling Unit
RESIDENTIAL	P.U.D. (LANDOMINIUM)	555	555	6.47	per Dwelling Unit
RESIDENTIAL	COMMON AREA OR GREENBELT	556	556	6.47	per Dwelling Unit
RESIDENTIAL	MOBILE HOMES	560	560		
RESIDENTIAL	OTHER STRUCTURES	599	599	6.47	per Dwelling Unit
PUBLICLY OWNED	FEDERAL	600	600	12	per employee
PUBLICLY OWNED	STATE OF OHIO	610	610	2.37	per student
PUBLICLY OWNED	METROPOLITAN HOUSING AUTHORITY	645	645	6.59	per Dwelling Unit
PUBLICLY OWNED	BOARD OF EDUCATION	650	650	10.9	per 1000 SF
PUBLICLY OWNED	PARK DISTRICT	660	660		

CATEGORY	DESCRIPTION	DEPARTMENT OF TAX EQUALIZATION	HAMILTON COUNTY	ITE Trip rate	Unit
PUBLICLY OWNED	COLLEGES / UNIVERSITIES / ACADEMIES	670	670	2.37	per student
PUBLICLY OWNED	CHARITIES, HOSPITALS & RETIREMENT HOMES	680	680	2.15	per Dwelling Unit
PUBLICLY OWNED	PUBLIC WORSHIP	685	685	9.32	per 1000 SF

Source: ITE Trip Generation Handbook & Author

Input of ITE Trip Generation Rates for Each Land Use Based on the Land Use Classification

All the trip generation numbers were input in the parcel-building dataset. Trips for residential land uses depend on number of dwelling units. The information about number of dwelling units is available in the CAGIS dataset. Some of the landuses like commercial, or office use, trip generation depends on employment; these numbers were referred-to from the OKI data. Built-up space was a factor under consideration for some land uses like commercial & office uses. Some of the landuses like hotel, the trip number depend on number of occupied rooms. The data on number of occupied rooms was unavailable, hence ignored. Similarly wherever data was not available to compute trip rates, such landuses were not considered. Hence the data on trip generation is not accurate due to lack of data and resources. An in-depth analysis can be undertaken to compute the trip generation by calculating the trip rates from the ITE handbook. However due to the limited scope of this thesis, an in-depth analysis was not possible.

Identifying the Number of Trips in First Quarter Mile of Each Station

Summation of trip generation numbers was obtained from the first quarter mile of the study area. Parcels that were within a quarter mile of any station were selected and the trip generation numbers for all the land uses were summarized. The summation of all the trips for a given station indicated the total number of trips (including inbound and outbound) generated by that landuse.

Table 10. Trips Originating Within Quarter Mile Distance of Each Station per Day

Description	Trips per day within quarter mile
Ludlow station	17949
Jefferson & Bishop	7393
Burnet in Avondale	8746
Burnet, Children's Hospital	24786
Burnet, TriHealth	9789
Reading	11305
WH Taft near Kroger	11656
Eden & Daniels near Corryville Recreation Center	14246
UC East Campus, near Marriott	6917
UC West Campus near Daniels Hall	6236
CBA Garage, MLK Drive	12434
Clifton Avenue, near DAAP	22307
Burnett Woods, near Good Samaritan Hospital	18702
College of Law, UC West Campus	25000
University Heights, Calhoun street	12347
Erkenbrecher, near Holmes Hospital	5002
Vine Street, Zoo	15803
Maintenance Yard, MLK Drive	
EPA on Jefferson	18078

Source: Author

Assimilation of Data to Identify Number of Peak Hour Trips and Number of Vehicle Trips for Each Station

The next step was calculating the peak hour demand. This process was done in several steps as follows:

a. **Finding out the trips with origins and destinations within the study area**

The Uptown Transportation Study results indicated that that 37% of people who live in Uptown also work in Uptown. This factor was applied to all the trips in Uptown by multiplying them with a factor of 0.37. The resultant numbers were the number of trips that originate in Uptown and also have their destination in Uptown.

Table 11. Trips with Their Origins and Destinations within Uptown

Description	Trips per day within quarter mile	37% factor	Net
Ludlow station	17949	37%	6641.13
Jefferson & Bishop	7393	37%	2735.41
Burnet in Avondale	8746	37%	3236.02
Burnet, Children's Hospital	24786	37%	9170.82
Burnet, TriHealth	9789	37%	3621.93
Reading	11305	37%	4182.85
WH Taft near Kroger	11656	37%	4312.72
Eden & Daniels near Corryville Rec Center	14246	37%	5271.02
UC East Campus, near Marriott	6917	37%	2559.29
UC West Campus near Daniels Hall	6236	37%	2307.32
CBA Garage, MLK Drive	12434	37%	4600.58
Clifton Avenue, near DAAP	22307	37%	8253.59
Burnett Woods, near Good Samaritan Hospital	18702	37%	6919.74
College of Law, UC West Campus	25000	37%	9250
University Heights, Calhoun street	12347	37%	4568.39
Erkenbrecher, near Holmes Hospital	5002	37%	1850.74
Vine Street, Zoo	15803	37%	5847.11
Maintenance Yard, MLK Drive		37%	0
EPA on Jefferson	18078	37%	6688.86

Source: Author

b. **Vehicle occupancy factor**

The average vehicle occupancy in United States in 1977 was 1.89 while in the year 1995 it was 1.59. The average vehicle occupancy of a PRT vehicle is comparable to a car; hence ITE trip generation numbers can be used as vehicle trips for this study.

c. **Mode share**

The mode share was considered as 100% initially.

Table 12. Mode Share

Description	Trips per day within quarter mile	37% factor	Net	Mode share	Net
Ludlow station	17949	37%	6641.13	100%	6641.13
Jefferson & Bishop	7393	37%	2735.41	100%	2735.41
Burnet in Avondale	8746	37%	3236.02	100%	3236.02
Burnet, Children's Hospital	24786	37%	9170.82	100%	9170.82
Burnet, TriHealth	9789	37%	3621.93	100%	3621.93
Reading	11305	37%	4182.85	100%	4182.85
WH Taft near Kroger	11656	37%	4312.72	100%	4312.72
Eden & Daniels near Corryville Rec Center	14246	37%	5271.02	100%	5271.02
UC East Campus, near Marriott	6917	37%	2559.29	100%	2559.29
UC West Campus near Daniels Hall	6236	37%	2307.32	100%	2307.32
CBA Garage, MLK Drive	12434	37%	4600.58	100%	4600.58
Clifton Avenue, near DAAP	22307	37%	8253.59	100%	8253.59
Burnett Woods, near Good Samaritan Hospital	18702	37%	6919.74	100%	6919.74
College of Law, UC West Campus	25000	37%	9250	100%	9250
University Heights, Calhoun street	12347	37%	4568.39	100%	4568.39
Erkenbrecher, near Holmes Hospital	5002	37%	1850.74	100%	1850.74
Vine Street, Zoo	15803	37%	5847.11	100%	5847.11
Maintenance Yard, MLK Drive		37%	0	100%	0
EPA on Jefferson	18078	37%	6688.86	100%	6688.86

Source: Author

d. **Calculating morning peak**

The next step was calculating the morning peak hour demand for specific stations based on dominant land use. To calculate the morning peak trips, the daily trips had to be converted to peak hour trips. For this analysis, the dominant land use for every station area was identified. The morning peak hour factor for a specific landuse is available in the ITE Trip Generation book. Conversion factor for trips from daily to peak hour trips is

$$\text{Peak hour percentage} = \frac{\text{Peak hour trips}}{\text{Daily trips}} \times 100$$

The following table is the list of dominant land uses for every station location that has been used in this study

Table 13. Dominant Land Use

Description	**Dominant Landuse**
Ludlow station	specialty retail
Jefferson & Bishop	apartments
Burnet in Avondale	Single family detached
Burnet, Children's Hospital	hospital
Burnet, TriHealth	hospital
Reading	retail+ hospital office
WH Taft near Kroger	specialty retail+ residential
Eden & Daniels near Corryville Rec Center	Single family detached
UC East Campus, near Marriott	Mixed use
UC West Campus near Daniels Hall	high rise apartments
CBA Garage, MLK Drive	university/college
Clifton Avenue, near DAAP	university/college
Burnett Woods, near Good Samaritan Hospital	hospital
College of Law, UC West Campus	university/college
University Heights, Calhoun street	high rise apartments
Erkenbrecher, near Holmes Hospital	hospital+residential
Vine Street, Zoo	Single family detached
Maintenance Yard, MLK Drive	
EPA on Jefferson	Office

Source: Author

e. **Daily rate and peak rate factor**

Applying the peak hour factor to total trips, the number of peak hour trips was obtained for every station.

Table 14. Peak Hour Trips

Description	Net	Dominant Landuse	Daily Rate	Peak Rate	Peak %	Peak Veh. Trips
Ludlow station	6641.13	specialty retail	40.67	6.41	0.15761003	1046.70871
Jefferson & Bishop	2735.41	apartments	6.47	0.51	0.07882535	215.619645
Burnet in Avondale	3236.02	Single family detached	9.55	0.74	0.07748691	250.749194
Burnet, Children's Hospital	9170.82	hospital	16.78	1.16	0.06912992	633.978021
Burnet, TriHealth	3621.93	hospital	16.78	1.16	0.06912992	250.383719
Reading	4182.85	Retail+ hospital office			0.109348	457.386282
WH Taft near Kroger	4312.72	Specialty retail+ residential			0.11754847	506.953644
Eden & Daniels near Corryville Rec Center	5271.02	Single family detached	9.55	0.74	0.07748691	408.435058
UC East Campus, near Marriott	2559.29	mixed use			0.08924041	228.392099
UC West Campus near Daniels Hall	2307.32	high rise apartments	4.2	0.3	0.07142857	164.808571
CBA Garage, MLK Drive	4600.58	university/college	2.37	0.19	0.08016878	368.822869
Clifton Avenue, near DAAP	8253.59	university/college	2.37	0.19	0.08016878	661.680211
Burnett Woods, near Good Samaritan Hospital	6919.74	Hospital	16.78	1.16	0.06912992	478.361049
College of Law, UC West Campus	9250	university/college	2.37	0.19	0.08016878	741.561181
University Heights, Calhoun street	4568.39	high rise apartments	4.2	0.3	0.07142857	326.313571
Erkenbrecher, near Holmes Hospital	1850.74	hospital+ residential			0.073	135.10402
Vine Street, Zoo	5847.11	Single family detached	9.55	0.74	0.07748691	453.074492
Maintenance Yard, MLK Drive	0					0
EPA on Jefferson	6688.86	Office	2.4	3.2	0.13333333	891.848

Source: Author

f. **Enter and exit quantity**

The ITE trip generation book specifies the out bound and inbound percentage of trips for every land use. This factor was used to convert the total trips into inbound and outbound trips. The following table (Table 15) shows inbound (enter) and outbound (exit) trips at each PRT station.

Table 15. Enter and Exit Trips

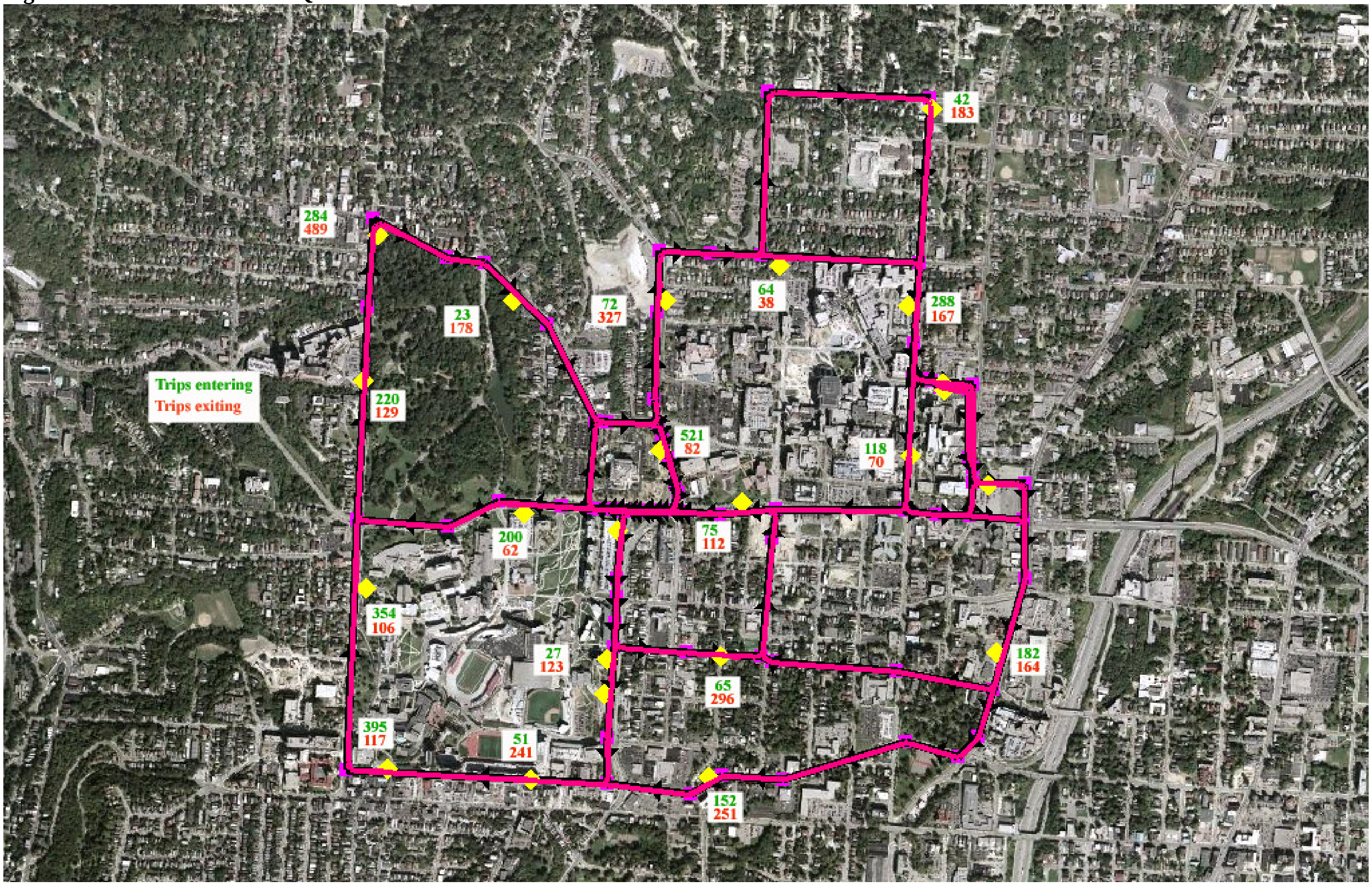
Description	Net	Peak Vehicle Trips	Entering %	Exit %	Enter quantity	Exit quantity
Ludlow station	6641.13	1046.70871	48%	52%	502.4	544.3
Jefferson & Bishop	2735.41	215.619645	17%	83%	36.7	179.0
Burnet in Avondale	3236.02	250.749194	26%	74%	65.2	185.6
Burnet, Children's Hospital	9170.82	633.978021	71%	29%	450.1	183.9
Burnet, TriHealth	3621.93	250.383719	71%	29%	177.8	72.6
Reading	4182.85	457.386282	62%	38%	283.6	173.8
WH Taft near Kroger	4312.72	506.953644	48%	52%	243.3	263.6
Eden & Daniels near Corryville Rec Center	5271.02	408.435058	26%	74%	106.2	302.2
UC East Campus, near Marriott	2559.29	228.392099	50%	50%	114.2	114.2
UC West Campus near Daniels Hall	2307.32	164.808571	25%	75%	41.2	123.6
CBA Garage, MLK Drive	4600.58	368.822869	82%	18%	302.4	66.4
Clifton Avenue, near DAAP	8253.59	661.680211	82%	18%	542.6	119.1
Burnett Woods, near Good Samaritan Hospital	6919.74	478.361049	71%	29%	339.6	138.7
College of Law, UC West Campus	9250	741.561181	82%	18%	608.1	133.5
Uni. Heights,	4568.39	326.313571	25%	75%	81.6	

Calhoun street						244.7
Description	**Net**	**Peak Vehicle Trips**	**Entering %**	**Exit %**	**Enter quantity**	**Exit quantity**
Erkenbrecher, near Holmes Hospital	1850.74	135.10402	71%	29%	95.9	39.2
Vine Street, Zoo	5847.11	453.074492	26%	74%	117.8	335.3
Maintenance Yard, MLK Drive	0	0		100 %		
EPA on Jefferson	6688.86	891.848	89%	11%	793.7	98.1

Source: Author

The map on page 67 (Figure XXVII) graphically depicts enter and exit quantities at stations. Exit quantities are the trips originating at a particular station while enter quantities are the trips ending at a particular station. Exit trips depict the traffic generated at a particular station.

Figure XXVII. Enter and Exit Quantities for PRT Stations



Source: Author

g. **Demand matrix**

The final step in the travel demand forecasting would be to find the inter-zonal trips. For this analysis, the outbound trip quantity was considered. The attractiveness of every station would be its ability to attract a certain number of trips out of all the destination trips. The stations weight was determined by dividing the enter quantity at the respective station with the summation of all the destination trips. For example the weight of Ludlow station would be it's enter quantity trips (502.4) divided by the total destination trips i.e. (4902.4), so its weight would be 0.102. By multiplying the origin trips at every station with the destination weight of every other station we can compute the number of trips getting attracted to those stations. The summation of weight of attraction of all stations is one. The following table shows the demand matrix showing the inter-zonal trips.

Table 16. Demand Matrix

		Station	**Ludlow**	**Jefferson**	**Avondale**	**Children's**	**TriHealth**	**Reading**	**Taft**	**Eden**	**Marriott**	**Daniels**	**CBA**	**DAAP**	**Burnett Woods**	**Law**	**U Heights**	**Erkenbrecher**	**Vine**	**Store 1**	**EPA**
		Total destination.	502.42	36.66	65.19	450.12	177.77	283.58	243.34	106.19	114.20	41.20	302.43	542.58	339.64	608.08	81.58	95.92	117.80	0.00	793.74
		Dest. weight	0.10	0.01	0.01	0.09	0.04	0.06	0.05	0.02	0.02	0.01	0.06	0.11	0.07	0.12	0.02	0.02	0.02	0.00	0.16
Station	Total origins	Station no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Ludlow	544.29	1	0.00	4.07	7.24	49.97	19.74	31.48	27.02	11.79	12.68	4.57	33.58	60.24	37.71	67.51	9.06	10.65	13.08	0.00	88.12
Jefferson	178.96	2	18.34	0.00	2.38	16.43	6.49	10.35	8.88	3.88	4.17	1.50	11.04	19.81	12.40	22.20	2.98	3.50	4.30	0.00	28.98
Avondale	185.55	3	19.02	1.39	0.00	17.04	6.73	10.73	9.21	4.02	4.32	1.56	11.45	20.54	12.86	23.02	3.09	3.63	4.46	0.00	30.04
Children's	183.85	4	18.84	1.37	2.44	0.00	6.67	10.63	9.13	3.98	4.28	1.55	11.34	20.35	12.74	22.80	3.06	3.60	4.42	0.00	29.77
TriHealth	72.61	5	7.44	0.54	0.97	6.67	0.00	4.20	3.60	1.57	1.69	0.61	4.48	8.04	5.03	9.01	1.21	1.42	1.74	0.00	11.76
Reading	173.81	6	17.81	1.30	2.31	15.96	6.30	0.00	8.63	3.76	4.05	1.46	10.72	19.24	12.04	21.56	2.89	3.40	4.18	0.00	28.14
Taft	263.62	7	27.02	1.97	3.51	24.20	9.56	15.25	0.00	5.71	6.14	2.22	16.26	29.18	18.26	32.70	4.39	5.16	6.33	0.00	42.68
Eden	302.24	8	30.97	2.26	4.02	27.75	10.96	17.48	15.00	0.00	7.04	2.54	18.65	33.45	20.94	37.49	5.03	5.91	7.26	0.00	48.94
Marriott	114.20	9	11.70	0.85	1.52	10.49	4.14	6.61	5.67	2.47	0.00	0.96	7.04	12.64	7.91	14.16	1.90	2.23	2.74	0.00	18.49
Daniels	123.61	10	12.67	0.92	1.64	11.35	4.48	7.15	6.14	2.68	2.88	0.00	7.63	13.68	8.56	15.33	2.06	2.42	2.97	0.00	20.01
CBA	66.39	11	6.80	0.50	0.88	6.10	2.41	3.84	3.30	1.44	1.55	0.56	0.00	7.35	4.60	8.23	1.10	1.30	1.60	0.00	10.75
DAAP	119.10	12	12.21	0.89	1.58	10.94	4.32	6.89	5.91	2.58	2.77	1.00	7.35	0.00	8.25	14.77	1.98	2.33	2.86	0.00	19.28
Burnett Woods	138.72	13	14.22	1.04	1.84	12.74	5.03	8.02	6.89	3.00	3.23	1.17	8.56	15.35	0.00	17.21	2.31	2.71	3.33	0.00	22.46
Law	133.48	14	13.68	1.00	1.78	12.26	4.84	7.72	6.63	2.89	3.11	1.12	8.23	14.77	9.25	0.00	2.22	2.61	3.21	0.00	21.61
U Heights	244.74	15	25.08	1.83	3.25	22.47	8.87	14.16	12.15	5.30	5.70	2.06	15.10	27.09	16.95	30.36	0.00	4.79	5.88	0.00	39.62
Erkenbrecher	39.18	16	4.02	0.29	0.52	3.60	1.42	2.27	1.94	0.85	0.91	0.33	2.42	4.34	2.71	4.86	0.65	0.00	0.94	0.00	6.34
Vine	335.28	17	34.36	2.51	4.46	30.78	12.16	19.39	16.64	7.26	7.81	2.82	20.68	37.11	23.23	41.59	5.58	6.56	0.00	0.00	54.28
Store 1	0.00	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EPA	98.10	19	10.05	0.73	1.30	9.01	3.56	5.67	4.87	2.13	2.29	0.82	6.05	10.86	6.80	12.17	1.63	1.92	2.36	0.00	0.00

Source: Author

Linking the Stations with Guideway

The next step was connecting the stations with guideway and determining the link direction. Various options were tried out. Some of the important criteria for placement of guideways were

1. Side of road where there would be minimal disruption to activity in the buildings. Avoiding residential streets.
2. Leaving enough space for maneuvering a minimum curve radius of 36 feet at intersections.
3. Optimizing link directions to have shorter trips.
4. Adding by-pass links

Provision of Offline Guideway, Storage and Maintenance Yards

Storage yards are an important aspect of any PRT layout. Empty vehicles are stored on offline guideway and recalled according to demand. It is important to provide offline storage at different points instead of a central storage yard, as it reduces conflicts due to empty vehicles traveling on the guideway and also reduces the wait times at stations. Five storage spaces were provided at various points to store empty vehicles.

Simulation

Various simulations were run for the initial layout and it was reconfigured at various points to handle the demand. Changes included, adding storage, increasing the number of berths at stations with heavy demand, changing link directions, adding more links in the network for pass-by trips, changing the demand load to factor in mode share. Each simulation runs for a period of two hours, and at the end, three types of reports are generated indicating the performance of the system.

Reports

Every simulation generates 3 summary reports indicating the performance of the system under the given demand. The types of reports generated are:

1. System summary report: this report states the general assumptions that were used by the software to run the simulation. It has indicators such as number of vehicles required, number of completed trips, number of people carried, and number of conflicts arising in the system and energy usage.
2. Station berth report: this report indicates the number of boarding's and de-boarding at every berth of every station.
3. Wait time report: this report indicates the average, mean, 3-Sigma and maximum wait time at every station. It also tells you what percentage of people had to wait less than 3 minutes to board a vehicle and the maximum number of people waiting at any station.

Having applied the methodology outlined in Chapter 3, the outcome of the findings section will determine if PRT would be a successful and efficient system for Uptown. Would PRT be more useful in University campuses? Does the Uptown area have potential for PRT? Will it will help relieve congestion and be a good alternative to cars in Uptown Cincinnati.

Reports

Ten different simulations were run for the PRT track. The last 5 levels of simulations has significant results and are included in this thesis. The level of reports changed due to change in assumptions. The following are the basic assumptions for the final 5 levels:

1. Level 5 with 0.5 second headway, smaller berths;
2. Level 6 still with 0.5 second headway but considerable expansion of station berths;
3. Level 7 change in headway to 2 seconds and change in ramping;
4. Level 8 with 2 seconds headway but a new demand matrix, and
5. Level 9 new demand matrix with 70% demand covered and 2 second headway.

The following is the summary of various reports run for the network. The network was modified and expanded depending on the summary reports from the simulation. The criteria for analyzing the simulations were observing the simulation to identify vehicle conflicts and analyzing the station berth report and wait time report to identify problem spots. For example if the wait time at certain station was high or there was a large group of people waiting to board, the remedy was to increase the number of berths at that station. Several refinements were made to the network to achieve the best results. The following is a summary of the reports for every trial run.

1. **Level 5** (Ash-5-biggerstation.trk)

This report at level 5 has the following assumptions:

1. 0.5 second headway between vehicles;
2. Smaller stations with less number of berths;
3. 14 stations;
4. 3 storage areas;
5. 76 berths total for all stations;
6. 310 storage berths (Storage yard);
7. 386 vehicles;
8. For initial 15 minutes, the system handles 30% of the demand.;
9. The simulation runs for the next 1hour 45 minutes and handles 60% of the demand, and
10. The system can complete a maximum of 2261 trips in one hour.

The total number of passengers waiting at all stations at different time intervals during the two-hour simulation are as follows:

1. 15 min – 47;
2. 30 min – 140;
3. 45 min – 128;
4. 60 min – 87;
5. 1:15 – 73;

6. 1:30 – 69;
7. 1:45 – 74;
8. 2:00 – 80, and
9. 2:04:51 – 0.

Wait times report showed high waits at some stations. The longest wait was 9.8 minutes at station 9, followed by 8.26 at station 3, 7.78 at station 7, and 7.75 at station 14. 9 of 18 stations had maximum waits above 5 minutes. 9 of 18 stations had 3-sigma waits above 5 minutes. The maximum number of waiting passengers was at stations 14, 12 and 1, where at peak 70, 56 and 20 passengers were waiting, respectively.

The station berth report indicates additional optimization is necessary. Overload of berths were visible at stations 4 (193 passengers used the final berth), 1 (187 passengers used the final berth), 17 (155), 14 (88) and 23 (77). Stations 14 and 17 were already at 8 berths, meaning space becomes a consideration for expanding the stations further, and it might be advisable to research the possibility of adding a reliever station near these. Additional testing will determine whether this is necessary.

22 wave-offs were recorded at station 17 and 1 at station 1. In a subsequent run, 22 wave-offs were recorded at station 17, with 6 at station 4, and none at station 1. This indicates the importance of testing with multiple simulation runs before making a final conclusion.

Remedies:

Storage capacity is assumed fixed. Station sizes will be increased by 3 berths at stations 1, 4, 12, 14 and 17.

2. **Level 5 (Ash-5-bigger2.trk)**

This report at level 5 has the following assumptions:

1. Simulation was run with ramping 20% for 15 minutes, 40% for 15 minutes, and 70% for 90 minutes;
2. 0.5 second headway between vehicles;
3. 14 stations;
4. 3 storage areas;
5. 76 berths total for all stations;
6. 310 storage berths (Storage yard), and
7. 386 vehicles.

The total number of passengers waiting at all stations at different time intervals during the two-hour simulation are as follows:

1. 15 min – 2;
2. 30 min – 43;
3. 45 min – 127;
4. 60 min – 172;
5. 1:15 – 196;
6. 1:30 – 229;
7. 1:45 – 237;
8. 2:00 – 197, and
9. 2:09:33 – 0.

While the 70% level of demand is stable, it does not appear to have satisfactory waiting times. 14 of 18 stations had 3-sigma wait times above 5 minutes, and 9 stations had wait times above 10 minutes.

At this point, a reconfiguration of the network was attempted.

3. Level 6 (Ash-6a-2nd swtichback.trk)

At level 6, the simulation was run with 0.5 second headway but considerable expansion of station berths. A second switchback was added by the EPA building. Due to space constraints, the EPA station was shrunk by 1 berth to 4 berths.

Overall performance was substantially better. Only 8 stations had waits greater than 5 minutes, with the longest being 8.6 at station 14 (EPA). 4 stations had 100% of waits less than 3 minutes, and 13 of 18 had at least 80% of waits less than 3 minutes. Station 14, with 42%, was the worst performer, indicating that additional berths will be necessary.

The berth report indicates a need to increase berths at stations 1, 2, 4, 14, 17, 18, and 23.

4. Level 6 (Ash-6b-larger.trk)

Stations 2, 4 and 14 were expanded by 2 berths. Stations 1, 17, 18, and 23 were expanded by 3 berths each.

The total number of passengers waiting at all stations at different time intervals during the two-hour simulation are as follows:

1. 15 min – 0;
2. 30 min – 38;
3. 45 min – 155;
4. 60 min – 37;
5. 1:15 – NA;
6. 1:30 – 54;
7. 1:45 – 20;

8. 2:00 – 47, and
9. 2:05:03 – 0.

These results show much better performance. There were no wave-offs. There were still some large crowds gathered at stations 1, 13, and 14, with queues peaking at 46, 24 and 63 people respectively. 8 stations of 18 still had 3-sigma and maximum wait times above 5 minutes.

The berth report indicates that little return is expected from increasing station sizes more. The busiest stations were those that were heavily weighted as destinations, and since there were no wave-offs, there is little gain from expanding the stations. The stations with large wait times did not show heavy usage of the last berth.

Together, these imply that the remaining area for system improvement is by bringing additional vehicles into the system, which is not currently possible as the client has indicated there is no more desirable space for storage stations.

10. Level 7 (Ash-7a-2s headway.trk)

At Level 7, two changes are made to the assumptions. First, we will no longer use the assumption of 0.5 second headways between vehicles; 2 seconds will be used. This change has been made as 2 second is a more acceptable headway as compared to a 0.5 second headway between vehicles. In addition, the following demand ramping schedule is applied to the simulation:

1. 10 minutes at 20% demand;
2. 10 minutes at 40% demand;
3. 10 minutes at 60% demand;
4. 10 minutes at 80% demand;

5. 40 minutes at 100% demand;
6. 10 minutes at 80% demand;
7. 10 minutes at 60% demand;
8. 10 minutes at 40% demand, and
9. 10 minutes at 20% demand.

Due to limitations in the program (currently a maximum of 8 time periods), it has been divided:

1. 20 minutes at 20% demand i.e. 754 trips/hr;
2. 20 minutes at 40% demand i.e. 1507 trips/hr;
3. 40 minutes at 60% demand;
4. 20 minutes at 40% demand, and
5. 20 minutes at 20% demand.

It has been peaked at 60% of the potential maximum flow to see whether it is possible to handle this at 2 second headways.

First, a run with the new ramping but still 0.5 s headways yielded the following results:

The total number of passengers waiting at all stations at different time intervals during the two-hour simulation were:

1. 15 min – 0;
2. 30 min – 25;
3. 45 min – 47;
4. 60 min – 63;
5. 1:15 – 56;
6. 1:30 – 8;

7. 1:45 – 0;
8. 2:00 – 2, and
9. 2:01:43 – 0.

Under this ramping and with a 60% max instead of 70%, it is much easier on the system.

Now, we try it with 2s headway.

The total number of passengers waiting at all stations at different time intervals are as follows:

1. 15 min – 2;
2. 30 min – 38;
3. 45 min – 46;
4. 60 min – 112, and
5. 1:15 – 261.

Program terminated early due to overload

With a 50% max instead of a 60% max

The total number of passengers waiting at all stations at different time intervals are as follows:

1. 15 min – 0;
2. 30 min – 40;
3. 45 min – 32;
4. 60 min – 61;
5. 1:15 – 54;
6. 1:30 – 54;

7. 1:45 – 9, and
8. 2:00 – 0.

The system showed very good results here. 10 of 18 stations had 100% of wait times less than 3 minutes. Stations 9, 13 and 14 still had poor wait times, with only 63, 54 and 35 percent of waits less than 3 minutes, respectively. Additional berths do not appear to help station 14, so we just have a shortage of vehicles. Station 4 had 48 wave-offs, so it needs additional berths.

6. Level 8 (ash-8-revdemand-50)

At this stage, there was a revision in the demand matrix. At new total demand in the system was 3133. The simulations were run at 50% with the ramping of

20 minutes @ 20%;

20 minutes @ 40%;

40 minutes @ 50%;

20 minutes @ 40%, and

20 minutes @ 20%.

The system handled the demand well at this level. 12 out of 18 stations had 100% of wait times less than 3 minutes. Station 11 had the worst wait time, with only 46% of people had to wait less than 3 minutes. The maximum waiting time at station 11 was 7.99 minutes. But the maximum number of people waiting at station 11 was 11 which were acceptable. Since the system handled the demand well, the next simulation was run with greater demand.

7. **Level 8 (ash-8-revdemand-60A)**

This simulation was run at 60% of demand. 11 stations out of 18 had 100% of wait times less than 3 minutes (Figure XXVIII). Stations 11 & 12 had worst wait times, with only 68% and 61% of people waiting for less than 3 minutes respectively. The maximum waiting times were at stations 11 and 12, where people had to wait 6.57 minutes and 6.16 minutes respectively. The median waiting time for all stations was less than 2.5 minutes, where 12 stations had a median wait time of 0 minutes. The maximum people waiting at a station were at stations 16 and 13, where 16 and 14 people were waiting respectively.

The simulation was run a second time at 60% demand, and the results were comparable to the previous simulation. Station 11 improved in terms of percentage of people waiting less than 3 minutes, but stations 12 got worse with only 49% of people waiting for less than 3 minutes. The maximum number of people waiting at stations was 15 and 16 at stations 1 and 12 respectively.

Since the results at 60% demand were acceptable the demand was ramped up in the next simulation to 70% to see if the system can handle more demand.

8. **Level 8 (ash-8-revdemand-70)**

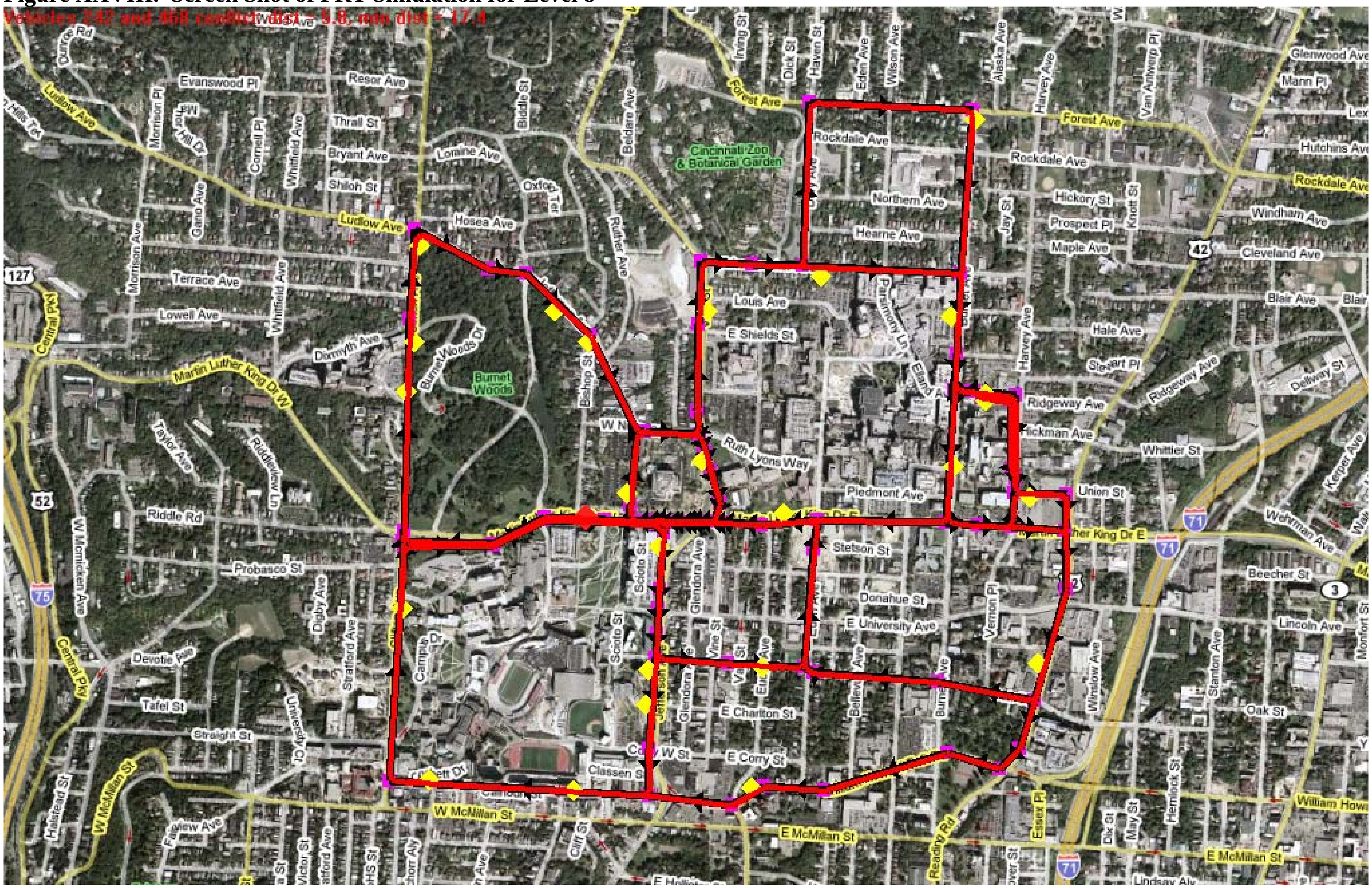
This simulation was run at 70% demand. At this demand, only 8 out of 18 stations had people waiting less than 3 minutes to board a vehicle. The maximum number of people waiting at any station went up at stations 1, 5 and 12 with more than 20 people waiting to board. The maximum waiting time was at station 12, where some people had to wait for 6.79 minutes to board a vehicle. Even at this demand, the system performance was acceptable, so the demand was ramped up to 80 % in the next simulation.

9. Level 8 (ash-8-revdemand-80)

At this demand level, 5 out of 18 stations had less than 90% of people waiting for less than 3 minutes to board. Stations 11 & 12 particularly had maximum wait times of 7.88 and 6.57 minutes. 3 sigma wait times for stations 7, 9, 11 & 12 were more than 5 minutes. At this stage it was decided to improve stations 11 and 12.

Even though the stations had few people boarding at the last berth, the wait times were particularly long. As observed from the simulation, the empty vehicles took longer time to come to these stations. Adding more offline storage would not have helped the cause. Hence the berths were increased at stations 11 and 12 to 9 and 12 respectively. (Figure XXVIII) on page 83 depicts the simulation for level-8 PRT layout.

Figure XXVIII. Screen Shot of PRT Simulation for Level 8



Source: TrackEdit

10. Level 9 (ash-9c-larger 11 12-A-WaitTimes)

This report at level 9 has the following assumptions:

1. 18 stations;
2. 5 storage areas;
3. 123 berths;
4. 393 vehicles, and
5. Demand at 70%.

Ramping goes up in the intervals of 20 minutes each:

1. 20 minutes @ 20%;
2. 20 minutes @ 50%;
3. 20 minutes @ 70%;
4. 20 minutes @ 70%;
5. 20 minutes @ 50%, and
6. 20 minutes @ 20%.

4 reports were run at this configuration . (Figure XXIX) Shows the final PRT layout for Uptown Cincinnati.

A. 9 stations out of 18 had 100% people waiting for less than 3 minutes at stations. The maximum wait time of 7.15 minutes was at station 11. The median wait time at all the stations was less than 2 minutes except station 11 where it was 3.67 minutes. The maximum number of people waiting at stations was at station 5 where 20 people were waiting at the same time.

B. Percentage of people waiting more than 3 minutes was low at stations 7, 12 & 13 where 65, 72, and 70% of people had a wait time more than 3 minutes. The maximum numbers of people waiting were at stations 1 and 13 where 20 and 25 people respectively were waiting at the same time. The median wait time for all the stations was less than 2 minutes. The maximum wait time of 7.06 minutes was at station 9.

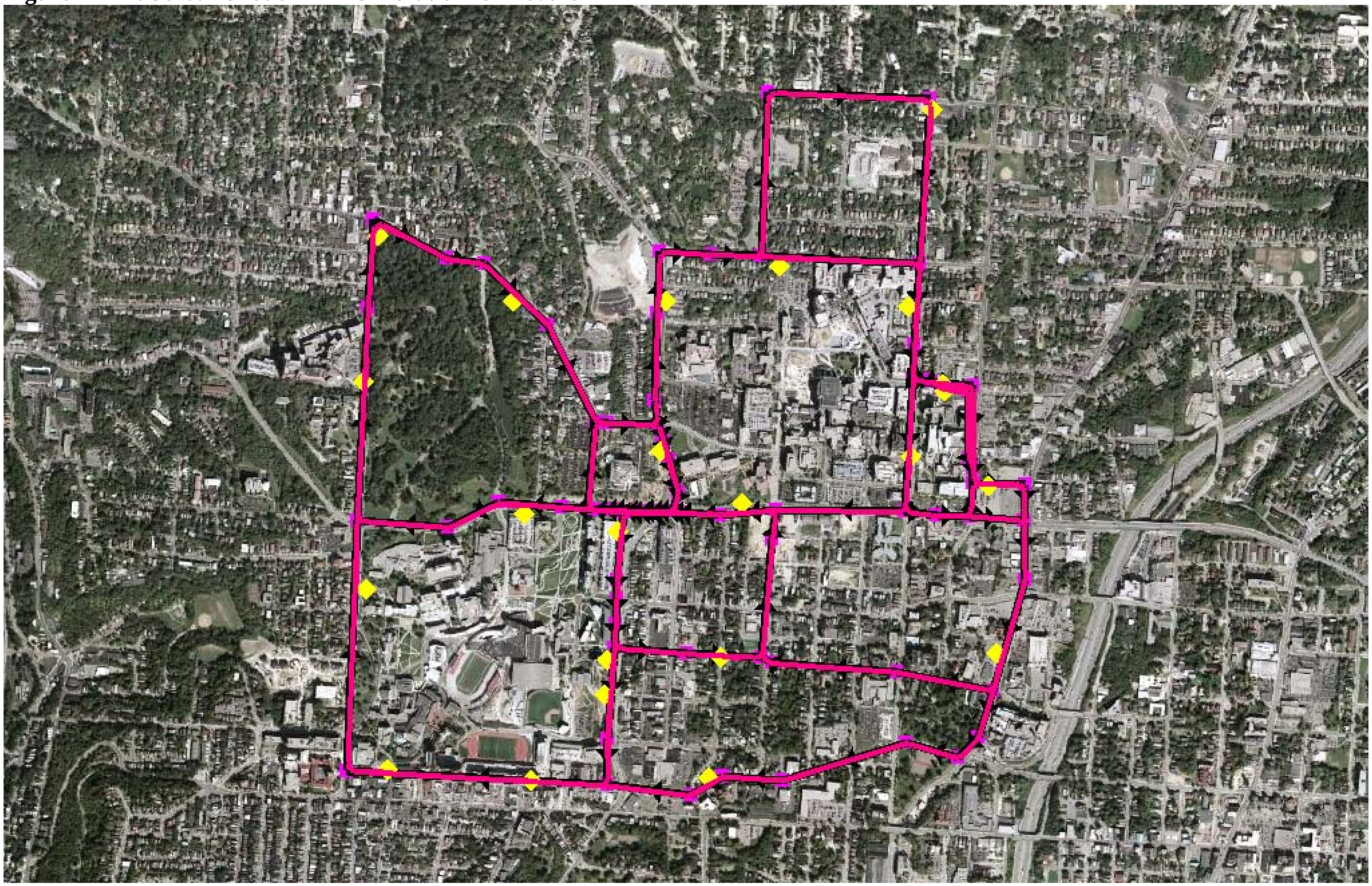
C. Percentage of people waiting for less than 3 minutes was low at stations 6 & 7, where 76 & 71 percent of people had to wait for more than 3 minutes. The maximum number of people waiting to board at the same time was found to be 19 at stations 5 & 13. Maximum wait times were found to be 5.89 and 5.18 at stations 6 & 9 respectively.

D. Except stations 5,7,11 & 13, all other stations had more than 90% of people waiting less than 3 minutes. The maximum number of people waiting to board was found to be 23, 19 and 19 at stations 1, 5 and 13 respectively. Maximum wait time was found to be 8.04 at station 11.

It was decided to stop at this stage where acceptable wait times and ridership had been achieved for the PRT layout.

Layout 9 was the final PRT layout for Uptown Cincinnati (Figure XXIX).

Figure XXIX. Screen Shot of PRT Simulation for Level 9

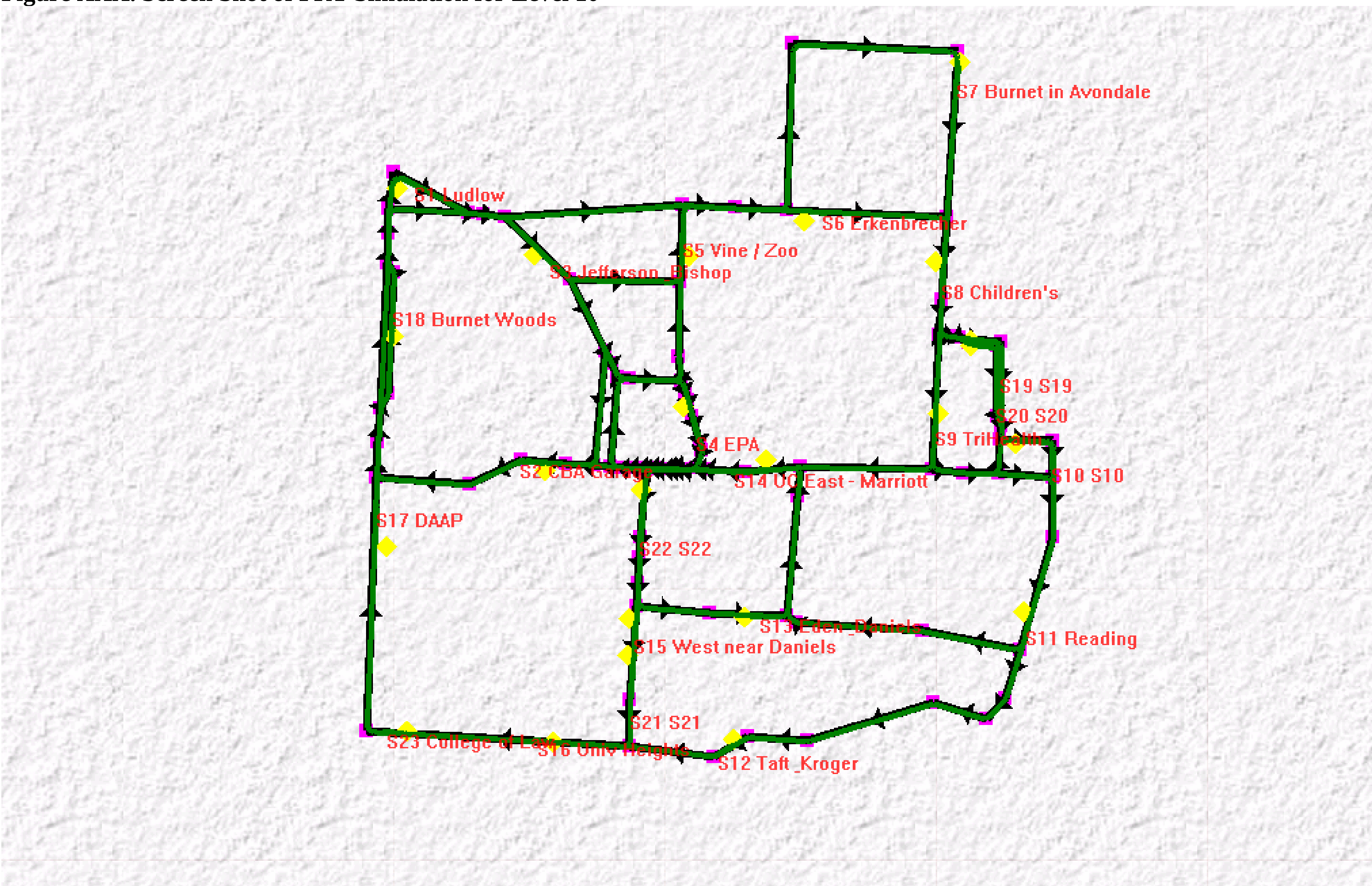


Source: TrackEdit

11. Level 10 (ash-10d-90)

The Simulations at this level were able to carry 90% of the peak hour demand in two hours i.e. about 45% of mode share in the peak hour (Figure XXX). The wait time was a little longer at 7.82 minutes at station 12, never the less, the system was able to handle the demand. The maximum numbers of people waiting were 24, 25, 25 and 26 at stations 5, 7, 12 & 13 respectively. The percentage of people who had to wait for more than 3 minutes to board a vehicle was 37, 35, and 47 at stations 7, 12 and 13. This performance was achieved by adding considerable amount of additional guideway to the network. This exercise is a demonstration of how the network can grow over time with increase in demand.

Figure XXX. Screen Shot of PRT Simulation for Level 10



Source: TrackEdit

This chapter provides the answers to the questions posed at the beginning of this study, "Is PRT a feasible solution for Uptown?" the simulation results show that the present network can carry 80% of the peak hour demand in two hours i.e. about 40% mode share in one hour of morning peak. How does this figure translate in terms of reduce traffic on the roads? Imagine 40% of traffic during morning peak hour taken away from the roads. Apart from the relief from traffic congestion, the following are some of the other benefits of this system.

Benefits

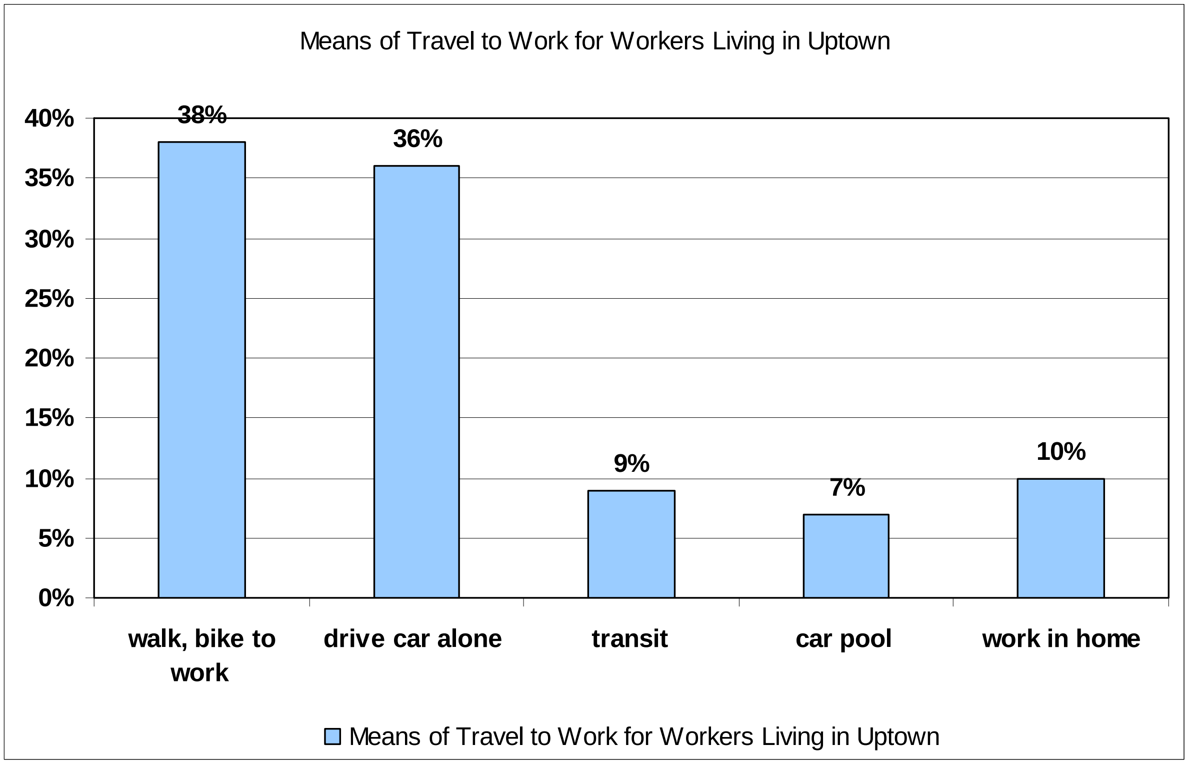
1. **System Performance**

The layout simulation shows that the system can handle 80% of demand in the two hours of AM peak. The wait times at stations are considerably less with median wait time of 0.38 minutes and a maximum wait time of 5.89 minutes. The system performance is acceptable at most of the stations barring a few. These parameters will change at the off peak times, when the demand reduces, reducing the wait times drastically.

2. **Mode Share**

A mode share of 46% at the peak hour is a considerable number in urban areas. At present the automobile's share in transportation is about 91.39% in the Cincinnati Metropolitan Area, where as the share of public transit is only 2.93%. If 46% of urban area traffic is diverted to the PRT system, it will help relieve congestion on roads. Figure 19 shows the percentage of people who live and work in Uptown. The Uptown transportation study indicates that 38% of people, who live and work in Uptown, walk or bike to work every day (Figure XXXI). Given the percentage of people who walk, PRT has the potential to attract greater percentage of home to work trips.

Figure XXXI. Means of Travel to Work for Workers Living in Uptown



Source: Report to Uptown Consortium Board, Uptown Transportation Subcommittee, 17 October 2005

3. Off-Peak Mode Share

The system can handle 40% of peak hour mode share. During the off peak times the waiting times at stations would reduce considerably as compared to the peak time. If the peak is extended over a longer time, it will ensure very low wait times at stations and efficient working of the system.

4. Level of Service

The level of service on MLK Drive near University of Cincinnati is of level 'D' or worse at several intersections such as Clifton Avenue, Vine Street, Burnet Avenue, and Dixymyth Avenue as found in the Uptown Transportation Study. If PRT helps relieve the congestion on roads near the University, street expansions would not be necessary in this area.

5. Health Benefits (Promotes Walking and Cycling)

The present concern for OKI for this region is the service for people who walk or bike to work. About 38 % of people living in Uptown who also work in Uptown, walk or bike to work. PRT promotes and depends on walk from home to the nearest PRT station. Of the 36% of people who live and work in Uptown but drive to work, a large number of people can be attracted to PRT. People prefer to drive if the distance between home and work is greater than three quarter miles. 26508 parcels out of 28576 total parcels (92.7%) lie within a range of three quarter miles of the PRT network. Bike racks can be provided at every PRT station for people. Bicycles can be carried aboard a PRT vehicle, which is an added advantage of the system.

6. Parking

The Uptown Transportation Study has estimated that parking supply will be deficient by 5, 530 spaces by the year 2015 in Uptown (OKI's Advisory Committee Meeting, May 18, 2006). This is a matter of concern for the all the employers in uptown, specially the hospitals and the University. Building multi-level multi-billion dollar parking lots, by taking over vibrant residential neighborhoods are some of the options being considered by the OKI team. Is such a demand justified at the cost of loss in housing? Bigger hospitals are choosing to relocate to suburbs primarily as their customers stay in that region, but also because people are hesitant to drive to the Uptown area due to lack of parking and congestion on the streets. A system like PRT would promote use of public transit for travel within the Uptown area. With the provision of remote parking lots on the periphery of Uptown, the people who commute from outside the study area would have the option of parking at these remote locations with reduced parking charges, and take a PRT ride to their destination within Uptown.

7. Integration with the Existing Urban Fabric

PRT systems can be integrated with urban fabric without displacement or major intrusion for right of ways. A system like Light rail on the other hand requires huge amount of right of ways for a two way track, which would eventually add up to displacement of thousands of people. In this light, PRT is a better option for transit in developed urban areas like Uptown Cincinnati.

8. Cost

The cost per mile for a PRT network is 25 million per mile as specified by Taxi 2000. The current layout is 11.39 miles (18,337 meters) long. At the rate of 25 million per mile, the cost of the proposed layout would be 284.75 million. This length includes station offline and storage guideway. At present the offline storage is a bit extra than what is required. Small adjustments in the length in offline guideway can bring the project cost to about 250 million USD.

The operating cost will vary for each PRT prototype and will require detail analysis. Taxi 2000 quotes an operating cost of 22 cents per mile. The average vehicle mile traveled per trip is 2.45 miles according to the TrackEdit simulation result. Hence, the operating cost per trip would be (0.22 X 2.45) i.e. 54 cents/trip. However, the operating cost will vary according to the PRT prototype and should be calculated accordingly.

9. Funding

'Small starts'

Small Starts is a Discretionary grant program for public transportation capital projects that run along a dedicated corridor or a fixed guideway, have a total project cost of less than $250 million, and are seeking less than $75 million in Small Starts program funding. On August 10, 2005, President Bush signed the Safe, Accountable, Flexible, and Efficient Transportation Equity Act--A Legacy for Users (SAFETEA-LU). SAFETEA-LU created the new Small Starts program category by amending section 5309(e) of Chapter 53 of Title 49, United States Code. The new program, ``Small Starts'', is a component of the existing New Starts program, but will offer project sponsors an expedited and streamlined application and review process.

Consistent with the intent and provisions of the new public transit statute, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act--A Legacy for Users (SAFETEA-LU), FTA hopes to simplify the planning and project development process for proposed Small Starts projects in a number of ways. The project justification criteria are simplified, focusing on three criteria--cost-effectiveness, public transportation supportive land use policies, and effect on local economic development.

Uptown Consortium

In their report to the Uptown Consortium Board, the Uptown Transportation Subcommittee has indicated that the Consortium would be willing to contribute to capital cost of an Uptown shuttle system if operations were fully funded by some public mechanism. They have also recommended to OKI Consultant team to consider Uptown Streetcar System with ability to connect to transit hub downtown, and future light rail.

Since the Consortium is already suggesting a need for better public transit, and options like streetcar in Uptown, it considerably strengthens the case for PRT in Uptown. If the Consortium were willing to share the cost of a PRT system, it would eliminate the need for additional funding through increase in public taxes.

10. Equity

PRT stations are ADA compliant. Hence, elderly people who cannot drive can take a comfortable ride on PRT, for their local travel needs. People who do not own a car such as low-income people and students would find PRT as an attractive option of travel within Uptown. Since the ride with PRT is private, people who are averse to traveling by public transit would find PRT attractive. A PRT ride is comparable to a car ride where people do not have to share their ride with strangers.

11. Safety

Safety on public transit is a matter of concern for everyone. In the light of bombing of the London metro system, mass transit networks have become easy targets for attack. Due to the same reason, people choose not to travel by mass transit modes and choose to drive alone. Since the PRT network does not congregate people in one vehicle, the system is less attractive target for such destructive actions.

12. Innovation

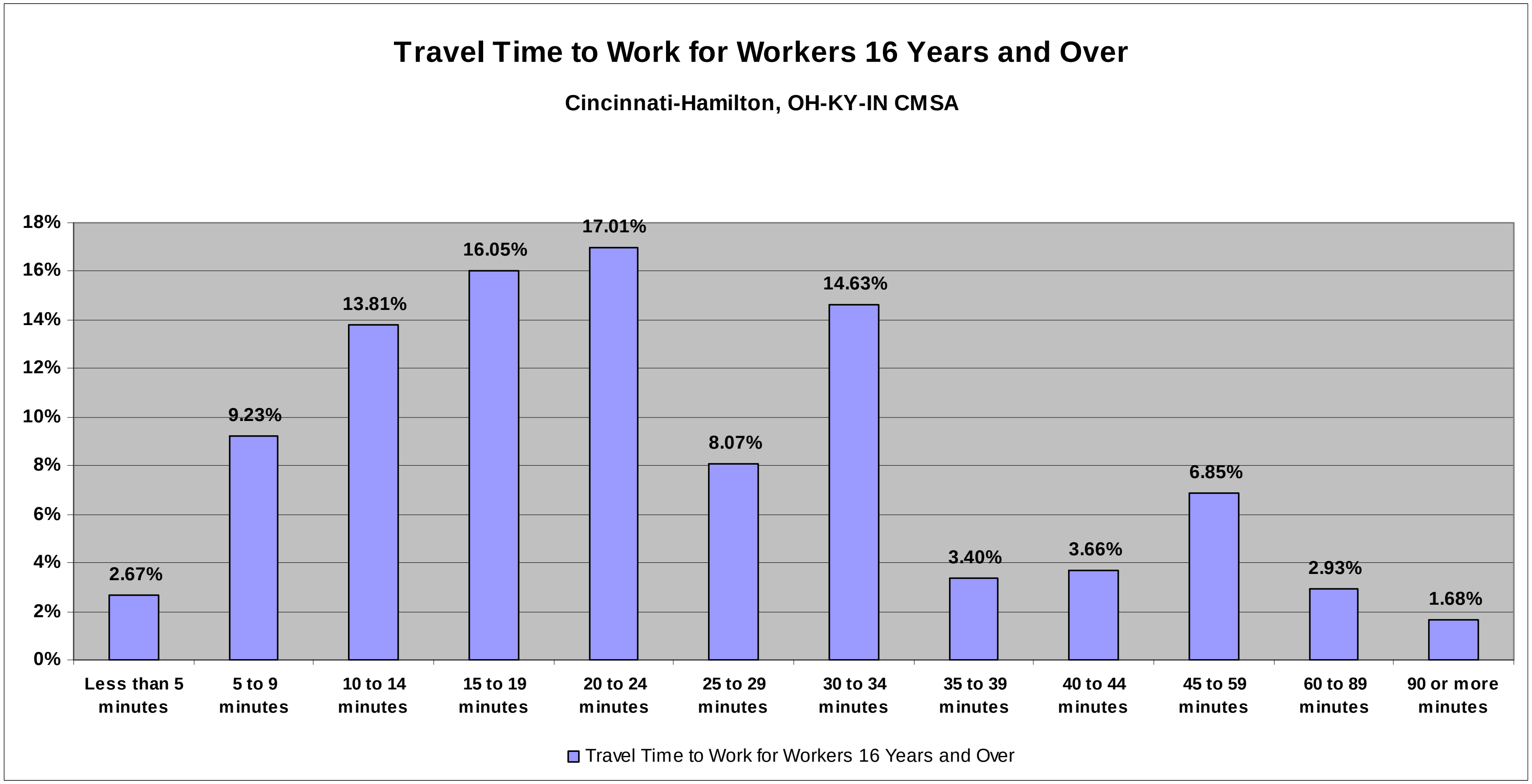
If a PRT system is built in Uptown Cincinnati, it would set a benchmark in urban travel. People would not give up driving even though gasoline prices are increasing and people are experiencing the effects of global warming until and unless other satisfactory mode of travel is available. The new mode of transit will have chances to succeed if it is as efficient, fast, and comfortable as the car.

13. Average Travel Time

Average riding time on PRT is just about 6 minutes. While average trip time, including station waits, is 6.8 minutes approximately. As the PRT vehicle does not have to stop at every signalized intersection, the average trip time is considerably low.

The average travel time to work for people in Cincinnati is more than 20 minutes for more than 58% of the population (Figure XXXII). Even after including a maximum walk time of 10 minutes, the average PRT journey would not be longer than 20 minutes.

Figure XXXII. Travel Time to Work for Workers 16 Years and Over



Source: OKI Regional Council of Governments

14. Integration with Other Regional Modes of Transportation

PRT is a public transit solution for a region like Uptown Cincinnati. It can handle travel within a zone or limited area. Even though the network can be expanded as demand increases outside the zone, it would be difficult to provide elevated guideways for the entire city for example. For regional transport, mass transit solutions are needed to handle bigger demand. PRT layout can be integrated with regional transportation network to eliminate the use of automobile completely. A central transit hub can connect all the regional modes of travel with PRT. People traveling from the suburbs should be able to transfer to the PRT network to travel within Uptown. This will eliminate or reduce the need for remote parking locations for people traveling from outside the study area.

15. Green Technology

PRT is a cleaner and greener technology since there are no emissions from the vehicles. The reduced emissions will in turn enhance the air quality in the region. Reduction in pollution related diseases like asthma and lung diseases will save money spent in the health care sector.

Limitations

1. Data

The most important criteria for any transportation study is the accuracy of data. PRT study requires micro level data collection i.e. parcel and building level data. Some of the data like employment, amount of lease able space, or number of occupied rooms etc. cannot be determined with precision. Data collection and cleaning of the data would need man-power, time and proper access to present day data and proposed future development. The limitation of this study is that since man-power and time was restricted, the amount of data collection that should have been done was not possible. If time and additional man-power was available for data collection and validation, it would increase the dependability of the travel demand forecast numbers.

2. Software Limitations

Limitation in the way GIS works is another factor that affects the trip generation numbers. During the course of demand forecasting, some of the parcel were double-counted for two different stations as they were within a quarter mile from both the stations. Most of the data was cleaned up to avoid such double counting. The demand matrix was modified from level 8 to level 9 for the very same reason. The cleaning-up was done for big numbers that were causing excessive demand at some stations. Parcels that generated less than 38 trips per day were not cleaned up due to time limitation.

3. Cleaning Parcel Based Data

Parcel based information is difficult to clean up. Some times more than one parcel has the same group parcel ID i.e. one property may be divided into several parcels. When parcel based trip generation numbers are attributed to the parcel dataset, the trip numbers are attributed to all the parcels. This increases the demand unrealistically because even though its only one property, due to more than one parcel, the trip demand gets attributed to all the parcels, driving up the demand. A lot of cleaning up is needed to rectify this problem in GIS. Due to time constraints, cleaning up could not be done for all the parcels. But some of the bigger demand areas such as the University, hospitals and the zoo, this cleaning up was done in the second demand matrix.

4. Planning Study

Many engineering studies related with the mechanism of PRT system have been done and are being done. This study does not provide engineering solution for PRT. Rather it is a planning study which studies the social, economic and environmental impact of PRT and analyzes its feasibility.

5. Site Considerations

Conditions and assumptions made for design of PRT layout will vary depending on the location. Due consideration should be given to this aspect.

6. Company Standards

The design of the PRT layout is based on guidelines/ standards provided by one PRT company (Taxi 2000). These standards may vary from one company to another.

7. Future Technological Enhancements

The design of PRT layout is based on current technology. The assumptions might change with the improvement in technology.

8. Social Perception

Social behavior is difficult to predict. The use of the system depends on various factors such as perception of people. For example if people perceive PRT as any other transportation system (bus for example) the attractiveness would be low. However, if people perceive it was a future technology it might appeal to the masses and increase its use.

9. Assumptions for Future

The dynamics of real life cannot be predicted by trip generation modeling. Since future is uncertain, it cannot be said with certainty what will cause a change in the city. Say for example if PRT is built in Cincinnati, and the gasoline prices skyrocketed making it unaffordable to drive an automobile, people may actually choose to give up driving and ride PRT. Planning for the future depends on many sets of assumptions which may vary from person to person.

Conclusion

This study has been successful in the planning and testing of a personal rapid transit system. It has proved that the PRT network designed for study purposes can handle 46% of the morning peak-travel-demand i.e. nearly half of the traffic volume during the morning peak hour. The study has also provided new areas of research in the transportation-planning field. Transit-Oriented-Development and multimodal transportation systems can help increase the benefits of PRT. Further research and refinement in PRT planning studies can provide significantly accurate results.

Planning after all is ‘finding possibilities’. People should never underestimate the power of dreaming and never give up the hope for a better tomorrow. I believe PRT has potential to change our future. I believe planners need to step out of academic stereotypes and venture into new options and that my study was a step in the right direction.

REFERENCES

1. Anderson Edward et al., eds. (1974). Personal Rapid Transit II. Minneapolis, University of Minnesota.
2. Bandrapalli, Suman (1998). My Mass Transit. Christian Science Monitor. Online. Vol. 90, Iss. 249; p. 11.
3. Burke, Catherine (1979). Innovation and public policy: *the case of personal rapid transit*. Lexington, Massachusetts: Lexington Books.
4. Driehaus, Bob (2001). “OKI rejects 'sky loop' elevated rail system.” The Cincinnati Post. Available online [http://www.cincypost.com/2001/sep/26/oki092601.html]. Accessed on 19 September 2005.
5. European Conference of Ministers of Transport (1995). Urban travel and sustainable development. Paris, France: Organization for Economic Co-Operation and Development.
6. Federal Transit Administration (2006). U.S. Department of Transportation. Available online [http://www.fta.dot.gov/17973_18017_ENG_HTML.htm]. Accessed on 27 May 2006.
7. Griebenow, Robert and Tadi, Ramakrishna (2001). Automated People Movers 2001. Moving through the millennium: Eighth International Conference. Reston, VA: ASCE.
8. Hendershot, Robert (2005). William L. Alden Seminar. Morgantown PRT O&M Issues. Morgantown, VA: Advance Transit Association.

9. Irving, Bernstein, Olson and Buyan (1978). Fundamentals of personal rapid transit: *based on a program of research, 1968-1976 at the Aerospace Corporation, El Segundo, California.* Lexington, Mass.: Lexington Books.
10. Johnson, Walter, and Wild (1975). Analysis and Simulation of Automated Vehicle Stations. Denver, CO: International Conference on Personal Rapid Transit.
11. Komerska, Rick (2002). What is personal rapid transit? Available Online [http://faculty.washington.edu/~jbs/itrans/PRT/Background.html]. Accessed on 13 September 2005.
12. Report to the Uptown Consortium Board (2005). Presented on behalf of the Uptown Transportation Subcommittee. Available through University Architect's Office, University of Cincinnati. 17 October 2005.
13. Taxi 2000 Corporation (2005). SkyWeb Express. Available online [www.skywebexpress.com]. Accessed on 19 September 2005.
14. Turabian, Kate (1987). A Manual for Writers of Term Paper, Theses, and Dissertations. 5th ed. Chicago: The University of Chicago Press.
15. Warner, Wilde eds. (2004). The Design, Operation and Benefits of SkyWeb Express: An Essential Technology for a Sustainable World. Minneapolis, MN: Taxi 2000 Corporation.
16. CAGIS 2002
17. www.Census.gov

APPENDIX

Appendix, Figure I. PRT Station at DAAP

Source: Author

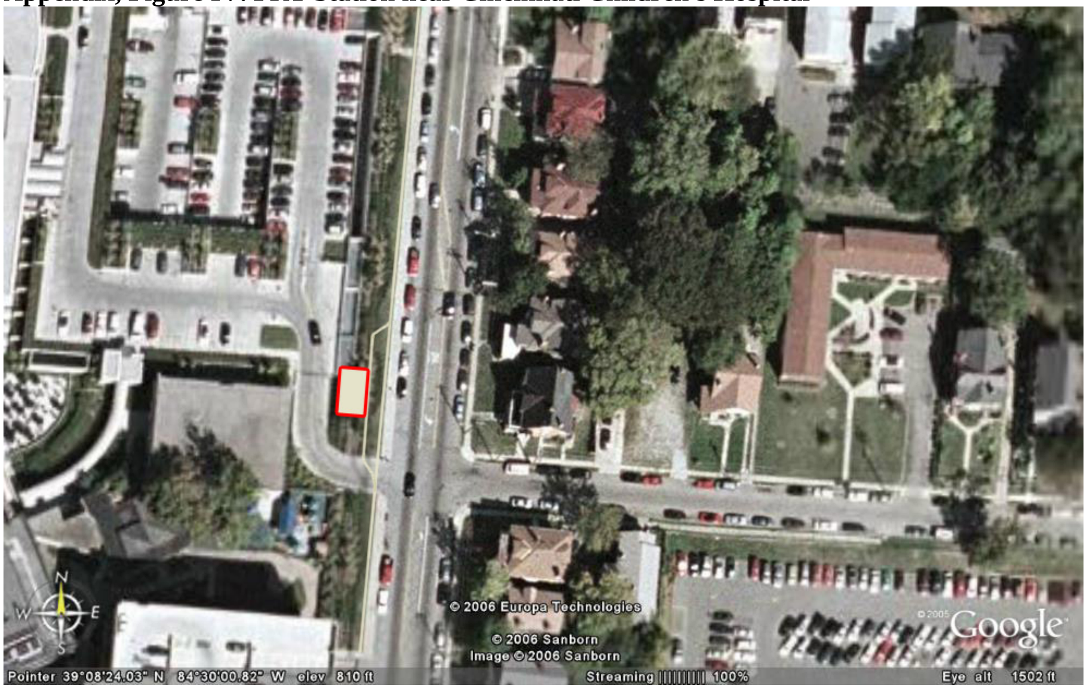
Appendix, Figure II. PRT Station on Vine Street near Cincinnati Zoo

Source: Author

Appendix, Figure III. PRT Station at Burnet Avenue

Source: Author

Appendix, Figure IV. PRT Station near Cincinnati Children's Hospital



Source: Author

Appendix, Figure V. PRT Station near Tri Health Hospital

Source: Author

Appendix, Figure VI. PRT Station on Reading Road

Source: Author

Appendix, Figure VII. PRT Station near Kroger on Taft Road

Source: Author

Appendix, Figure VIII. PRT Station near Daniels Hall on Jefferson Avenue

Source: Author

Appendix, Figure IX. View of PRT Guideway Located Along Clifton Avenue

Source: Author

Appendix, Figure X. View of PRT Guideways Located Along Jefferson Avenue, Near Daniels Residence Hall

Source: Author

Appendix, Figure XI. View of PRT Guideways along Calhoun Street near University Heights Residence Halls

Source: Author

Note: All of the following simulation reports have been generated in TrackEdit software during the analysis of PRT network.

Appendix, Figure XII. Summary Report (Ash-5-biggerstation.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-5-bigger2.trk
05/21/06 20:59:47 SUMMARY

Minimum line headway, seconds	0.5
Number of vehicles in system	401
Number of extra waiting berths in passenger stations	3
Duration of demand, minutes	120
Total number of passengers arriving at stations	4499
Number of completed passenger-trips	4499
Total passenger-km traveled	15129.1
Total vehicle-km traveled	21730.2
Mean loading time, sec	6.0
Standard deviation in loading time, sec	2.5
Maximum loading time, sec	18.0
Minimum loading time, sec	2.0
Average passengers per occupied vehicle	1.00
Average passengers per vehicle including empties.	0.70
Average riding time, min	7.10
Average trip time counting station wait, min	10.97
Average trip length, km	3.36
Maximum line speed, m/s	9.0
Average passenger speed of travel, m/s	7.9
Average trip speed counting station wait, m/s	5.1
Number of station-entry denials	0
Number of second station-entry denials	0
Number of resolved merge conflicts	1777
Largest Slip, m	40.18
Peak kilowatts	6211
Total propulsion energy use, kWhr	4929
Average watt-hours per vehicle-km	227

Appendix, Figure XIII. Wait Time Report (Ash-5-biggerstation.trk)

TAXI2000 Corporation System Simulated: ash-5-bigger2.trk						
Station	Average	Median	3 Sigma	Maximum	%<3 min	Max # waiting
2	0.87	0.67	3	3.02	99	7
4	0.72	0.5	2.83	2.83	100	4
6	0.98	0	5.5	5.62	87	2
8	5.24	0	17.67	17.78	56	9
11	4.77	4	12.5	12.63	35	18
12	5.02	5.83	10	10.03	30	28
13	4.66	5	8.17	8.29	19	23
14	4.17	4.17	6.83	6.89	8	66
15	5.06	6.17	11.17	11.24	32	14
16	6.65	8.33	13.5	13.62	26	20
17	1.16	1.17	2.83	2.86	100	15
18	2.58	2.33	6.33	6.38	62	11
23	0.94	0.83	3.33	3.38	99	6
Averages	3.87	3.66	9.1	9.17	0.8	

Appendix, Figure XIV. Boarding and Deboarding Report (Ash-5-biggerstation.trk)

TAXI2000 Corporation TRANSPORTATION NETWORK SIMULATOR System Simulated: ash-5-bigger2.trk 05/21/06 20:59:47 BOARDINGS & DEBOARDINGS Number of boardings and deboardings at each berth:												
	WO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1|	0	334	232	193	159	117	98	69	50			
2|	0	267	205	87	30	18	19	34				
3|	0	136	49	10								
4|	0	234	212	118	77	60	47					
5|	0	127	34	10								
6|	0	44	11	6								
7|	0	141	33	8	1	0						
8|	0	40	7	9	1	2						
9|	0	120	19	4								
11|	0	222	58	13								
12|	0	213	86	28	6	3	3					
13|	0	203	82	29								
14|	0	313	222	190	169	151	133	116	81	58	54	42
15|	0	126	40	8	0							
16|	0	93	12	4	0							
17|	0	246	263	237	213	219	203	187	161	132	103	79
18|	0	218	66	26								
23|	0	226	129	60								

Appendix, Figure XV. Summary Report (Ash-5-bigger2.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-5-bigger stat.trk
05/21/06 20:02:22 SUMMARY

Minimum line headway, seconds 0.5
Number of vehicles in system 386
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 3789
Number of completed passenger-trips 3789
Total passenger-km traveled 12968.6
Total vehicle-km traveled 18304.0
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.71
Average riding time, min 7.32
Average trip time counting station wait, min 8.65
Average trip length, km 3.39
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.7
Average trip speed counting station wait, m/s 6.5
Number of station-entry denials 28
Number of second station-entry denials 1
Number of resolved merge conflicts 1037
Largest Slip, m 24.99
Peak kilowatts 5933
Total propulsion energy use, kWhr 4401
Average watt-hours per vehicle-km 240

Appendix, Figure XVI. Wait Time Report (Ash-5-bigger2.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-5-bigger stat.trk
05/21/06 20:02:22 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	3.85	3.83	6.17	6.34	17	51
2	0.22	0	2	2.04	100	4
3	1.36	0.83	5.67	5.7	87	10
4	0.53	0.33	2.83	2.99	100	4
5	1.01	0	6	6.09	88	11
6	0.41	0	4	4.02	94	2
7	1.16	0	8.17	8.19	85	11
8	0.29	0	3	3.01	95	2
9	1.28	0.83	4.17	4.28	91	3

11	2.29	2.17	6.83	6.89	72	8
12	2.25	2.33	5.33	5.38	66	13
13	0.76	0.17	5	5	90	11
14	3.09	2.5	8	8.07	59	66
15	0.68	0	5	5	92	5
16	0.37	0	2.67	2.8	100	7
17	1.02	0.83	3	3	99	12
18	2.63	2.33	6.67	6.76	57	11
23	0.75	0.5	3.17	3.23	99	5
Averages	1.33	0.93	4.87	4.93	1.4	

Appendix, Figure XVII. Boarding and Deboarding Report (Ash-5-bigger2.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-5-bigger stat.trk
05/21/06 20:02:22 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8
1|	0	338	240	204	173	151			
2|	0	176	90	74	63	54	58	52	
3|	0	133	17	2					
4|	6	231	221	182					
5|	0	124	36	13					
6|	0	24	8	14					
7|	0	121	21	4	5	5			
8|	0	26	6	6	10	4			
9|	0	95	17	3					
11|	0	183	65	12					
12|	0	180	58	23					
13|	0	179	63	27					
14|	0	336	224	179	146	129	104	86	75
15|	0	103	20	18	15				
16|	0	56	8	1	8				
17|	22	266	271	245	235	203	185	165	137
18|	0	180	54	7					
23|	0	194	86	51					

Appendix, Figure XVIII. Summary Report (Ash-6a-2nd switchback.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6a-2nd switchback.trk
05/21/06 21:40:11 SUMMARY

Minimum line headway, seconds 0.5
Number of vehicles in system 400
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 4417
Number of completed passenger-trips 4417
Total passenger-km traveled 11979.1
Total vehicle-km traveled 18540.7
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.65
Average riding time, min 6.03
Average trip time counting station wait, min 7.18
Average trip length, km 2.70
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.5
Average trip speed counting station wait, m/s 6.3
Number of station-entry denials 16
Number of second station-entry denials 2
Number of resolved merge conflicts 1776
Largest Slip, m 26.41
Peak kilowatts 6136
Total propulsion energy use, kWhr 4422
Average watt-hours per vehicle-km 238

Appendix, Figure XIX. Wait Time Report (Ash-6a-2nd swtichback.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6a-2nd switchback.trk
05/21/06 21:40:11 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.4	0.83	5.33	5.43	85	54
2	0.15	0	2.17	2.21	100	3
3	1.08	0	6.33	6.43	86	15
4	0.29	0.17	1.5	1.62	100	4
5	0.84	0	4.17	4.32	90	7
6	0.32	0	2.17	2.24	100	1
7	1.91	1.5	6.83	6.86	77	18
8	0.1	0	1.17	1.23	100	1

9	1.78	0.83	6.83	6.89	77	7
11	2.25	2.17	5.33	5.46	65	11
12	1.88	1.67	4.67	4.71	71	18
13	1.55	0.5	7.67	7.82	78	20
14	3.66	3.17	8.5	8.62	42	82
15	0.71	0	5.67	5.71	85	11
16	0.44	0	4.33	4.42	96	5
17	1.06	0.83	3.33	3.48	98	19
18	0.83	0.17	3.33	3.44	98	7
23	0.42	0	3.17	3.32	98	4
Averages	1.15	0.66	4.58	4.68	1.4	

Appendix, Figure XX. Boarding and Deboarding Report (Ash-6a-2nd swtichback.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6a-2nd switchback.trk
05/21/06 21:40:11 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1|	0	307	208	192	166	140	110	91	86			
2|	0	172	115	81	79	91	78	48				
3|	0	133	40	13								
4|	1	198	194	166	119	60						
5|	0	127	33	9								
6|	0	36	15	7								
7|	0	139	42	10	2	4						
8|	0	41	13	10	4	3						
9|	0	110	31	12								
11|	0	176	61	26								
12|	0	204	73	23	9	2	5					
13|	0	195	72	31								
14|	0	328	209	209	171	130	113	95	77	69	53	47
15|	0	113	28	12	9							
16|	0	94	23	7	6							
17|	15	232	225	216	198	192	193	184	166	149	123	94
18|	0	146	73	57								
23|	0	158	119	104								

Appendix, Figure XXI. Summary Report (ash-6b-larger.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6b-larger.trk
05/21/06 23:00:08 SUMMARY

Minimum line headway, seconds 0.5
Number of vehicles in system 418
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 4535
Number of completed passenger-trips 4534
Total passenger-km traveled 12180.9
Total vehicle-km traveled 18559.6
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.66
Average riding time, min 5.75
Average trip time counting station wait, min 6.72
Average trip length, km 2.69
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.8
Average trip speed counting station wait, m/s 6.7
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 1754
Largest Slip, m 30.37
Peak kilowatts 6250
Total propulsion energy use, kWhr 4531
Average watt-hours per vehicle-km 244

Appendix, Figure XXII. Wait Time Report (ash-6b-larger.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6b-larger.trk
05/21/06 23:00:08 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.97	0.5	4.67	4.78	90	46
2	0.16	0	1.67	1.83	100	5
3	0.84	0	5.17	5.32	90	12
4	0.19	0	1.33	1.37	100	5
5	0.84	0	5.5	5.52	87	12
6	0	0	0	0	100	1
7	1.73	1	8	8.1	78	13
8	0.62	0	4.33	4.47	96	4
9	2.05	1.67	7.5	7.63	70	7

11	1.72	1.5	5.17	5.28	77	9
12	1.83	1.67	4.33	4.35	71	17
13	1.44	0.5	9.83	9.84	84	24
14	3.02	2.67	7	7.11	62	63
15	0.92	0	7.5	7.58	86	10
16	0.09	0	1.83	1.85	100	3
17	0.44	0.17	1.83	1.89	100	12
18	0.46	0	4.67	4.78	94	10
23	0.15	0	1.33	1.48	100	3
Averages	0.97	0.54	4.54	4.62	1.5	

Appendix, Figure XXIII. Boarding and Deboarding Report (ash-6b-larger.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-6b-larger.trk
05/21/06 23:00:08 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1|	0	295	219	189	158	135	108	87	70	47	31	21			
2|	0	165	90	58	61	66	89	84	60	37					
3|	0	130	39	9											
4|	0	149	114	114	123	114	84	48							
5|	0	129	47	17											
6|	0	19	11	10											
7|	0	148	41	11	2	0									
8|	0	39	9	5	8	6									
9|	0	123	25	6											
11|	0	175	76	36											
12|	0	206	75	28	10	7	8								
13|	0	200	98	30											
14|	0	321	215	188	168	134	116	79	59	48	38	32	23	21	
15|	0	113	33	13	8										
16|	0	89	13	3	7										
17|	0	235	211	173	155	160	165	172	180	161	148	122	92	62	37
18|	0	112	43	26	36	27	26								
23|	0	143	58	62	45	44	54								

Appendix, Figure XXIV. Summary Report (ash-7a-2s headway.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-7a-2s headway.trk
05/21/06 23:39:19 SUMMARY

Minimum line headway, seconds	2.0
Number of vehicles in system	418
Number of extra waiting berths in passenger stations	3
Duration of demand, minutes	120
Total number of passengers arriving at stations	2656
Number of completed passenger-trips	2656
Total passenger-km traveled	7180.8
Total vehicle-km traveled	11532.6
Mean loading time, sec	6.0
Standard deviation in loading time, sec	2.5
Maximum loading time, sec	18.0
Minimum loading time, sec	2.0
Average passengers per occupied vehicle	1.00
Average passengers per vehicle including empties.	0.62
Average riding time, min	6.66
Average trip time counting station wait, min	7.48
Average trip length, km	2.68
Maximum line speed, m/s	9.0
Average passenger speed of travel, m/s	6.7
Average trip speed counting station wait, m/s	6.0
Number of station-entry denials	53
Number of second station-entry denials	14
Number of resolved merge conflicts	4527
Largest Slip, m	1171.61
Peak kilowatts	6697
Total propulsion energy use, kWhr	3891
Average watt-hours per vehicle-km	337

Appendix, Figure XXV. Wait Time Report (ash-7a-2s headway.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-7a-2s headway.trk
05/21/06 23:39:19 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.5	0.17	1.83	1.96	100	13
2	0.12	0	1.5	1.5	100	5
3	0.25	0	2.33	2.41	100	4
4	1.41	0.17	10.17	10.3	81	10
5	0.44	0	2.5	2.61	100	4
6	0.27	0	3.83	3.84	93	1
7	0.55	0	4.5	4.58	93	8

8	0	0	0	0	100	1
9	2.49	2.17	6.83	6.99	63	4
11	1.03	0	5	5.08	87	6
12	0.58	0	2.67	2.81	100	7
13	2.67	2.67	6.17	6.23	54	16
14	3.08	3.5	5.67	5.77	35	46
15	0.28	0	2.67	2.8	100	5
16	0.65	0	4	4.11	91	8
17	0.17	0	2	2.13	100	7
18	0.26	0	2.5	2.59	100	6
23	0.04	0	0.83	0.94	100	1
Averages	0.82	0.48	3.61	3.7	1.5	

Appendix, Figure XXVI. Boarding and Deboarding Report (ash-7a-2s headway.trk)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-7a-2s headway.trk
05/21/06 23:39:19 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1|	0	180	151	134	108	62	53	31	35	19	14	10			
2|	0	123	41	19	21	23	29	41	56	39					
3|	0	75	18	11											
4|	48	37	44	40	40	61	92	124							
5|	0	78	19	4											
6|	0	18	5	4											
7|	0	81	11	2	2	3									
8|	0	18	4	5	9	3									
9|	0	64	14	3											
11|	0	102	40	21											
12|	0	126	40	13	7	5	4								
13|	0	139	51	19											
14|	0	275	191	142	109	86	48	26	18	10	8	5	5	6	
15|	0	73	9	8	7										
16|	0	36	6	2	6										
17|	5	143	101	69	54	52	66	85	92	102	111	109	97	69	47
18|	0	47	34	19	16	15	21								
23|	0	69	25	18	21	36	73								

Appendix, Figure XXVII. Summary Report (ash-8-revdemand-50)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:11:41 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 381
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2162
Number of completed passenger-trips 2162
Total passenger-km traveled 6041.2
Total vehicle-km traveled 8265.6
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.73
Average riding time, min 6.07
Average trip time counting station wait, min 6.57
Average trip length, km 2.80
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.7
Average trip speed counting station wait, m/s 7.1
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 1802
Largest Slip, m 61.83
Peak kilowatts 5624
Total propulsion energy use, kWhr 2295
Average watt-hours per vehicle-km 278

Appendix, Figure XXVIII. Wait Time Report (ash-8-revdemand-50)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:11:41 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.15	0	1.67	1.67	100	11
2	0	0	0	0.02	100	1
3	0.12	0	2.17	2.28	100	3
4	0.06	0	0.83	0.85	100	3
5	0.83	0.67	2.83	2.98	100	9
6	0.15	0	3.67	3.75	96	1
7	0.96	0	4	4.1	87	10

8	0.45	0	3.67	3.8	99	6
9	0.92	0	5.67	5.72	88	7
11	3.27	3.17	7.83	7.99	46	11
12	1.3	1.17	4.5	4.51	89	13
13	0.58	0.33	2	2.11	100	9
14	0	0	0	0.04	100	1
15	0.01	0	0.5	0.52	100	2
16	0.16	0	2	2.02	100	5
17	0.01	0	0.17	0.22	100	2
18	0.13	0	1.33	1.33	100	4
23	0.04	0	0.33	0.44	100	2
Averages	0.51	0.3	2.4	2.46	1.6	

Appendix, Figure XXIX. Boarding and Deboarding Report (ash-8-revdemand-50)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:11:41 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	195	117	72	43	31	17	17	15	15	14	7			
2|	0	35	5	0	0	5	11	8	36	70					
3|	0	94	26	10											
4|	0	42	20	19	24	32	50	58	66	74	53				
5|	0	184	76	39											
6|	0	27	10	22											
7|	0	113	21	11	4	3									
8|	0	154	57	29	26	34									
9|	0	66	47	26											
11|	0	194	54	6											
12|	0	173	52	26	11	5	6								
13|	0	151	68	24											
14|	0	68	7	1	0	0	0	0	2	5	7	6	7	30	
15|	0	75	16	6	2										
16|	0	126	36	11	8										
17|	0	68	13	1	0	1	3	5	5	9	11	22	57	61	65
18|	0	96	38	30	24	26	22								
23|	0	70	27	32	51	79	95								

Appendix, Figure XXX. Summary Report (ash-8-revdemand-60A)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:13:44 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 381
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2422
Number of completed passenger-trips 2422
Total passenger-km traveled 6879.1
Total vehicle-km traveled 9552.3
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.72
Average riding time, min 6.18
Average trip time counting station wait, min 6.84
Average trip length, km 2.84
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.7
Average trip speed counting station wait, m/s 6.9
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 2236
Largest Slip, m 101.40
Peak kilowatts 5108
Total propulsion energy use, kWhr 2566
Average watt-hours per vehicle-km 269

Appendix, Figure XXXI. Wait Time Report (ash-8-revdemand-60A)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:13:44 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.33	0	1.67	1.77	100	13
2	0.01	0	0.33	0.37	100	2
3	0.28	0	2	2.03	100	5
4	0.05	0	0.67	0.82	100	2
5	1.07	1	2.5	2.66	100	8
6	0.24	0	2.17	2.27	100	2
7	1.36	1	5.67	5.67	83	8

8	0.59	0	2.5	2.63	100	9
9	0.68	0	5	5.09	97	3
11	2.13	1.33	6.5	6.57	68	11
12	2.2	2.17	6	6.16	61	13
13	1.09	0.83	3.5	3.53	95	14
14	0	0	0	0.13	100	1
15	0.38	0	2.83	2.99	100	6
16	1.01	0.33	3.83	3.92	96	16
17	0.01	0	0	0.13	100	2
18	0.43	0	3	3.02	98	5
23	0.02	0	0.33	0.34	100	2
Averages	0.66	0.37	2.69	2.78	1.6	

Appendix, Figure XXXII. Boarding and Deboarding (ash-8-revdemand-60A)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:13:44 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	206	121	79	62	44	39	22	18	13	6	11			
2|	0	44	6	3	2	2	15	29	51	60					
3|	0	111	34	14											
4|	0	68	39	38	45	53	59	56	54	43	30				
5|	0	183	76	31											
6|	0	32	13	16											
7|	0	117	31	11	3	1									
8|	0	113	84	62	38	39									
9|	0	81	34	21											
11|	0	180	77	17											
12|	0	192	73	25	11	8	9								
13|	0	187	61	25											
14|	0	63	11	1	0	2	1	1	6	6	6	10	11	18	
15|	0	92	12	5	4										
16|	0	152	57	29	18										
17|	0	66	13	0	0	2	4	7	12	11	22	38	54	60	61
18|	0	87	54	31	29	25	20								
23|	0	83	28	38	55	89	122								

Appendix, Figure XXXIII. Summary Report (ash-8-revdemand-70)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:16:24 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 381
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2638
Number of completed passenger-trips 2638
Total passenger-km traveled 7519.9
Total vehicle-km traveled 10955.4
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.69
Average riding time, min 6.25
Average trip time counting station wait, min 7.18
Average trip length, km 2.85
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.6
Average trip speed counting station wait, m/s 6.6
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 3643
Largest Slip, m 198.00
Peak kilowatts 5922
Total propulsion energy use, kWhr 2918
Average watt-hours per vehicle-km 266

Appendix, Figure XXXIV. Wait Time Report (ash-8-revdemand-70)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:16:24 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.16	1.17	3.33	3.49	96	21
2	0.02	0	0.33	0.33	100	1
3	0.69	0	3.17	3.33	99	10
4	0.08	0	0.67	0.69	100	4
5	1.58	1.5	4.17	4.22	85	20
6	0.88	0.17	3.67	3.69	90	4
7	2.02	2	5	5.01	67	11
8	0.41	0	2.83	2.89	100	6
9	0.96	0.33	4.5	4.6	92	5

11	2.92	3.17	7.5	7.6	45	13
12	3.11	3.67	6.67	6.79	42	24
13	1.67	1.5	4.17	4.33	78	16
14	0	0	0	0.1	100	1
15	0.3	0	2.5	2.61	100	5
16	0.56	0	3	3.12	99	10
17	0.04	0	0.83	0.86	100	3
18	0.19	0	1.67	1.71	100	3
23	0.14	0	1.5	1.58	100	5
Averages	0.93	0.75	3.08	3.16	1.5	

Appendix, Figure XXXV. Boarding and Deboarding Report (ash-8-revdemand-70)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:16:24 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1|	0	188	127	102	73	52	42	30	26	24	19	21			
2|	0	43	14	8	10	13	18	20	33	55					
3|	0	114	47	18											
4|	0	83	42	33	40	55	66	70	52	58	36				
5|	0	180	95	60											
6|	0	58	16	10											
7|	0	147	38	3	2	2									
8|	0	144	81	67	52	25									
9|	0	94	37	22											
11|	0	161	75	31											
12|	0	215	84	35	21	10	6								
13|	0	190	70	29											
14|	0	61	13	1	1	0	2	1	7	4	2	6	11	26	
15|	0	96	29	6	6										
16|	0	133	49	16	15										
17|	0	73	21	8	9	6	10	8	9	14	28	36	57	60	56
18|	0	95	54	34	25	35	50								
23|	0	70	33	48	65	93	102								

Appendix, Figure XXXVI. Summary Report (ash-8-revdemand-80)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:24:13 SUMMARY
Minimum line headway, seconds 2.0
Number of vehicles in system 381
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 3075
Number of completed passenger-trips 3075
Total passenger-km traveled 8673.9
Total vehicle-km traveled 12711.4
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.68
Average riding time, min 6.32
Average trip time counting station wait, min 7.41
Average trip length, km 2.82
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.4
Average trip speed counting station wait, m/s 6.3
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 5245
Largest Slip, m 469.58
Peak kilowatts 5337
Total propulsion energy use, kWhr 3494
Average watt-hours per vehicle-km 275

Appendix, Figure XXXVII. Wait Time Report (ash-8-revdemand-80)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:24:13 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.44	1.5	3.67	3.83	95	24
2	0.18	0	2.17	2.2	100	5
3	0.63	0.17	2.5	2.63	100	7
4	0.05	0	0.83	0.88	100	2
5	1.96	2.33	4.5	4.5	72	26
6	0.36	0	3.5	3.6	96	2
7	2.41	2.33	5.67	5.8	66	16
8	0.7	0.17	3.33	3.48	94	10

9	1.54	1.17	5.17	5.33	80	7
11	3.71	3.83	7.83	7.88	32	17
12	3.23	3.83	6.5	6.57	33	24
13	1.38	1.5	3.67	3.82	94	18
14	0.01	0	0	0.14	100	2
15	0.4	0	2.17	2.3	100	6
16	0.91	0.17	3.33	3.44	94	16
17	0.04	0	0.67	0.79	100	2
18	0.59	0	4	4.03	96	7
23	0.07	0	0.83	0.84	100	3
Averages	1.09	0.94	3.35	3.45	1.4	

Appendix, Figure XXXVIII. Boarding and Deboarding Report (ash-8-revdemand-80)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-8-final.trk
05/25/06 13:24:13 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	163	116	96	92	79	83	76	43	39	26	19			
2|	0	68	24	17	14	14	24	32	30	52					
3|	0	102	58	18											
4|	0	74	45	38	47	59	82	93	75	65	46				
5|	0	193	116	62											
6|	0	49	18	24											
7|	0	151	49	10	2	6									
8|	0	162	116	68	40	35									
9|	0	115	38	23											
11|	0	203	98	49											
12|	0	204	90	52	24	8	5								
13|	0	188	91	41											
14|	0	79	27	2	1	2	3	3	5	4	5	14	21	12	
15|	0	95	30	13	8										
16|	0	156	73	43	25										
17|	0	93	43	31	16	15	10	8	13	19	25	40	46	57	50
18|	0	107	77	39	32	41	35								
23|	0	82	63	70	83	99	96								

Appendix, Figure XXXIX. Summary Report (ash-9c-larger 11 12-A-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:41:09 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 393
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2922
Number of completed passenger-trips 2922
Total passenger-km traveled 8226.3
Total vehicle-km traveled 11851.0
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.69
Average riding time, min 6.18
Average trip time counting station wait, min 6.97
Average trip length, km 0.00
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 0.0
Average trip speed counting station wait, m/s 0.0
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 4138
Largest Slip, m 140.37
Peak kilowatts 5737
Total propulsion energy use, kWhr 3184
Average watt-hours per vehicle-km 269

Appendix, Figure XL. Wait Time Report (ash-9c-larger 11 12-A-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:41:09 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.83	0.5	3	3.01	99	16
2	0.04	0	0.67	0.67	100	1
3	0.63	0.17	2.5	2.64	100	7
4	0.12	0	1.33	1.42	100	3
5	1.5	1.33	3.5	3.66	84	20
6	0.43	0	3	3.06	96	3
7	1.6	1.67	4.83	4.99	88	12
8	0.15	0	1.33	1.41	100	4

9	1.13	0.33	6.33	6.34	88	6
11	3.45	3.67	7	7.15	32	16
12	1.42	1.33	4.17	4.28	90	14
13	1.43	1.17	4	4.02	90	16
14	0.01	0	0.17	0.32	100	2
15	0.21	0	2.5	2.64	100	4
16	1.09	0.83	3.5	3.58	96	14
17	0.02	0	0.17	0.32	100	3
18	0.13	0	1.17	1.28	100	3
23	0.04	0	0.67	0.77	100	2
Averages	0.79	0.61	2.77	2.86	1.5	

Appendix, Figure XLI. Boarding and Deboarding Report (ash-9c-larger 11 12-A-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:41:09 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	173	116	91	84	68	53	40	35	22	6	7			
2|	0	62	15	3	10	15	20	32	42	41					
3|	0	109	48	36											
4|	0	74	43	33	38	61	68	66	79	61	50				
5|	0	196	95	51											
6|	0	45	19	28											
7|	0	148	42	14	1	0									
8|	0	113	99	74	72	54									
9|	0	113	51	25											
11|	0	176	79	35	2	3	5	3	2	14					
12|	0	201	91	47	17	9	5	5	2	2	1	4	7		
13|	0	194	94	36											
14|	0	79	27	7	1	7	4	7	5	8	11	7	8	11	
15|	0	98	20	5	9										
16|	0	158	73	37	30										
17|	0	75	29	3	4	7	5	10	14	29	43	56	56	67	41
18|	0	97	62	36	31	42	50								
23|	0	103	60	51	88	107	91								

Appendix, Figure XLII. Summary Report (ash-9c-larger 11 12-B-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:43:17 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 393
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2827
Number of completed passenger-trips 2827
Total passenger-km traveled 8075.1
Total vehicle-km traveled 11666.2
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.69
Average riding time, min 6.28
Average trip time counting station wait, min 7.10
Average trip length, km 2.86
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.6
Average trip speed counting station wait, m/s 6.7
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 3991
Largest Slip, m 235.90
Peak kilowatts 5421
Total propulsion energy use, kWhr 3111
Average watt-hours per vehicle-km 267

Appendix, Figure XLIII. Wait Time Report (ash-9c-larger 11 12-B-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:43:17 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.24	1.17	3.33	3.46	98	20
2	0.02	0	0.33	0.38	100	1
3	0.79	0.33	3	3.02	99	9
4	0.07	0	0.67	0.72	100	2
5	1.52	1.5	4.33	4.35	91	17
6	0.69	0	3.33	3.37	96	3
7	2.1	1.83	5.5	5.58	65	13
8	0.86	0.67	3.33	3.36	98	9

9	0.77	0	7	7.06	94	5
11	1.13	0.67	4.83	4.83	90	10
12	1.65	1.5	4.5	4.66	72	15
13	1.71	1.33	4.83	4.91	70	22
14	0.01	0	0	0.14	100	2
15	0.32	0	3.33	3.44	99	7
16	0.88	0	3.83	3.91	97	13
17	0.05	0	1.17	1.33	100	2
18	0.85	0.17	3.67	3.77	95	7
23	0.06	0	0.5	0.58	100	3
Averages	0.82	0.51	3.19	3.27	1.5	

Appendix, Figure XLIV. Boarding and Deboarding Report (ash-9c-larger 11 12-B-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:43:17 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	161	129	103	86	59	42	31	20	17	11	18			
2|	0	43	20	7	9	9	9	25	43	51					
3|	0	100	55	21											
4|	0	75	38	33	41	55	63	81	72	55	47				
5|	0	196	114	44											
6|	0	54	19	17											
7|	0	135	45	14	4	1									
8|	0	166	105	59	47	38									
9|	0	82	29	22											
11|	0	183	65	25	19	6	11	9	8	9					
12|	0	186	86	35	26	13	8	7	3	4	1	6	3		
13|	0	197	93	49											
14|	0	79	16	3	0	0	0	3	9	6	13	12	13	22	
15|	0	112	19	5	6										
16|	0	152	62	26	20										
17|	0	90	26	13	14	17	11	12	11	17	22	32	44	58	50
18|	0	107	73	40	24	32	33								
23|	0	76	58	60	75	106	103								

Appendix, Figure XLV. Summary Report (ash-9c-larger 11 12-C-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:45:21 SUMMARY
Minimum line headway, seconds 2.0
Number of vehicles in system 393
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2748
Number of completed passenger-trips 2748
Total passenger-km traveled 7685.8
Total vehicle-km traveled 10842.6
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.71
Average riding time, min 6.08
Average trip time counting station wait, min 6.77
Average trip length, km 2.80
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.7
Average trip speed counting station wait, m/s 6.9
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 3533
Largest Slip, m 107.32
Peak kilowatts 5813
Total propulsion energy use, kWhr 3143
Average watt-hours per vehicle-km 290

Appendix, Figure XLVI. Wait Time Report (ash-9c-larger 11 12-C-WaitTimes)

TAXI2000 Corporation						
TRANSPORTATION NETWORK SIMULATOR						
System Simulated: ash-9c-larger 11 12.trk						
05/25/06 14:45:21 WAIT TIMES IN MINUTES						
Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	0.71	0.5	2.33	2.4	100	12
2	0	0	0	0.08	100	1
3	0.6	0.17	2.33	2.48	100	6
4	0.1	0	1.17	1.31	100	2
5	1.61	1.67	3.83	3.91	87	19
6	1.64	0.83	5.83	5.89	76	6
7	1.68	1.33	4.67	4.73	71	14

8	0.34	0	3.83	3.98	98	5
9	1.12	0.5	5.17	5.18	86	4
11	1.04	0	4.83	4.96	89	9
12	0.63	0	3.83	3.88	95	9
13	1.74	1.83	3.83	3.93	83	19
14	0	0	0	0.11	100	2
15	0.16	0	1.5	1.58	100	3
16	0.71	0	4	4.03	97	12
17	0.02	0	0.17	0.23	100	2
18	0.27	0	1.83	1.83	100	4
23	0.03	0	0.33	0.39	100	2
Averages	0.69	0.38	2.75	2.83		

Appendix, Figure XLVII. Boarding and Deboarding Report (ash-9c-larger 11 12-C-WaitTimes)

TAXI2000 Corporation															
TRANSPORTATION NETWORK SIMULATOR															
System Simulated: ash-9c-larger 11 12.trk															
05/25/06 14:45:21 BOARDINGS & DEBOARDINGS															
Number of boardings and deboardings at each berth:															
	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	171	148	107	81	50	30	21	16	20	15	3			
2|	0	48	6	0	1	6	21	31	43	50					
3|	0	109	38	28											
4|	0	80	57	50	48	40	54	60	66	54	33				
5|	0	187	104	62											
6|	0	71	19	25											
7|	0	139	33	12	1	1									
8|	0	168	106	66	50	40									
9|	0	106	32	21											
11|	0	140	55	35	25	12	10	11	4	1					
12|	0	166	74	26	6	6	5	4	8	8	4	5	4		
13|	0	209	94	47											
14|	0	88	17	2	4	3	2	2	1	6	11	10	15	14	
15|	0	92	17	4	5										
16|	0	136	63	25	11										
17|	0	70	27	10	7	8	9	13	12	17	22	41	51	58	35
18|	0	108	75	42	34	30	34								
23|	0	81	52	57	84	109	95								

Appendix, Figure XLVIII. Summary Report (ash-9c-larger 11 12-D-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:49:45 SUMMARY

Minimum line headway, seconds 2.0
Number of vehicles in system 393
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 2811
Number of completed passenger-trips 2811
Total passenger-km traveled 7936.8
Total vehicle-km traveled 11334.7
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.70
Average riding time, min 6.23
Average trip time counting station wait, min 6.92
Average trip length, km 2.82
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 7.6
Average trip speed counting station wait, m/s 6.8
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 3683
Largest Slip, m 166.46
Peak kilowatts 5113
Total propulsion energy use, kWhr 3112
Average watt-hours per vehicle-km 275

Appendix, Figure XLIX. Wait Time Report (ash-9c-larger 11 12-D-WaitTimes)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-9c-larger 11 12.trk
05/25/06 14:49:45 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.05	0.67	3.5	3.53	97	23
2	0	0	0	0.09	100	2
3	0.51	0	2.67	2.71	100	7
4	0.1	0	0.67	0.81	100	2
5	1.77	2	3.67	3.79	83	19
6	0.5	0	2.83	2.88	100	2
7	1.7	1.83	4.67	4.7	82	9
8	0.21	0	1.83	1.86	100	4
9	0.94	0.33	4	4.05	92	5

11	1.72	0.5	8	8.04	77	15
12	0.7	0.33	3.33	3.36	96	13
13	1.29	1.17	4	4.11	89	19
14	0	0	0	0.12	100	2
15	0.51	0	3.83	3.98	97	7
16	0.85	0.33	3.83	3.94	98	11
17	0.02	0	0.5	0.53	100	1
18	0.54	0	2.67	2.82	100	9
23	0.03	0	0.33	0.43	100	2
Averages	0.69	0.4	2.8	2.87	1.6	

Appendix, Figure L. Boarding and Deboarding Report (ash-9c-larger 11 12-D-WaitTimes)

TAXI2000 Corporation TRANSPORTATION NETWORK SIMULATOR System Simulated: ash-9c-larger 11 12.trk 05/25/06 14:49:45 BOARDINGS & DEBOARDINGS Number of boardings and deboardings at each berth:															
	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	169	130	86	66	52	38	39	35	29	29	34			
2|	0	60	11	2	6	10	22	33	49	62					
3|	0	102	40	18											
4|	0	78	49	39	36	46	44	57	58	71	48				
5|	0	191	106	68											
6|	0	42	6	32											
7|	0	132	40	9	1	3									
8|	0	142	106	68	42	44									
9|	0	108	38	30											
11|	0	153	55	30	25	20	6	5	8	9					
12|	0	195	92	32	12	6	2	1	2	3	3	6	9		
13|	0	184	77	34											
14|	0	73	19	5	2	3	0	1	3	6	9	12	13	12	
15|	0	95	21	5	11										
16|	0	146	61	34	27										
17|	0	78	27	13	9	15	18	15	20	17	23	38	48	60	41
18|	0	113	88	49	33	26	31								
23|	0	92	50	47	85	101	102								

Appendix, Figure LI. Summary Report (ash-10d-90)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-10d-altered Zoo bypass.trk
05/26/06 22:39:28 SUMMARY
Minimum line headway, seconds 2.0
Number of vehicles in system 384
Number of extra waiting berths in passenger stations 3
Duration of demand, minutes 120
Total number of passengers arriving at stations 3697
Number of completed passenger-trips 3697
Total passenger-km traveled 9762.3
Total vehicle-km traveled 14746.9
Mean loading time, sec 6.0
Standard deviation in loading time, sec 2.5
Maximum loading time, sec 18.0
Minimum loading time, sec 2.0
Average passengers per occupied vehicle 1.00
Average passengers per vehicle including empties. 0.66
Average riding time, min 5.85
Average trip time counting station wait, min 7.15
Average trip length, km 0.00
Maximum line speed, m/s 9.0
Average passenger speed of travel, m/s 0.0
Average trip speed counting station wait, m/s 0.0
Number of station-entry denials 0
Number of second station-entry denials 0
Number of resolved merge conflicts 8862
Largest Slip, m 228.82
Peak kilowatts 6171
Total propulsion energy use, kWhr 3786
Average watt-hours per vehicle-km 257

Appendix, Figure LII. Wait Time Report (ash-10d-90)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-10d-altered Zoo bypass.trk
05/26/06 22:39:28 WAIT TIMES IN MINUTES

Station	Average	Median	3 Sigma	Maximum	%< 3 min	Max # Waiting
1	1.78	1.83	3.83	3.99	82	31
2	0.13	0	1.17	1.27	100	2
3	1.98	2	4.67	4.74	68	18
4	0.14	0	1.17	1.23	100	3
5	2.02	2	5	5.03	76	24
6	1.38	0.67	5.83	5.97	80	6
7	3.13	3.33	6.5	6.53	37	25

8	0.4	0	2.17	2.2	100	7
9	1.12	0.83	3.33	3.39	94	5
11	1.31	1	3.67	3.81	90	15
12	3.58	3.5	7.67	7.82	35	25
13	2.63	3.17	6.17	6.28	47	26
14	0	0	0	0.14	100	2
15	0.52	0	3.67	3.73	97	7
16	1.79	1.33	5.5	5.6	69	20
17	0.22	0	1.83	1.98	100	4
18	0.87	0.5	3.33	3.46	97	10
23	0.25	0	1.5	1.5	100	6
Averages	1.29	1.12	3.72	3.81	1.4	

Appendix, Figure LIII. Boarding and Deboarding Report (ash-10d-90)

TAXI2000 Corporation
TRANSPORTATION NETWORK SIMULATOR
System Simulated: ash-10d-altered Zoo bypass.trk
05/26/06 22:39:28 BOARDINGS & DEBOARDINGS
Number of boardings and deboardings at each berth:

	WO	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1|	0	294	186	126	93	71	41	28	19	14	8	8			
2|	0	97	48	23	19	11	14	14	34	36					
3|	0	162	72	21											
4|	0	117	98	72	72	63	64	61	56	50	35				
5|	0	247	146	79											
6|	0	76	32	25											
7|	0	181	62	26	10	4									
8|	0	135	142	101	94	58									
9|	0	151	51	21											
11|	0	222	144	83											
12|	0	248	126	58	22	7	3								
13|	0	225	119	50											
14|	0	88	28	5	2	2	3	5	12	10	8	19	16	18	
15|	0	115	30	7	11										
16|	0	167	96	40	23										
17|	0	112	102	59	33	18	24	21	27	29	17	27	31	36	36
18|	0	201	101	41	20	11	10	7	8	15					
23|	0	111	100	98	109	117	93								