Alternative Route Design for the WRTA

A Major Qualifying Project Report:

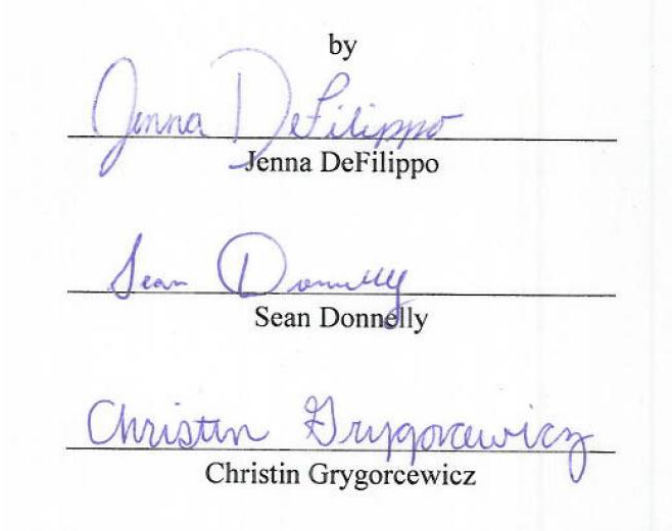
Submitted to Faculty of

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by



Jenna DeFilippo

Sean Donnelly

Christin Grygorcewicz

Date: March 3, 2011

Approved:

_____

Suzanne LePage, Advisor

ABSTRACT

The Worcester Regional Transit Authority (WRTA) desires for more students to use its services. Students do not feel the need to leave campus or find public transit inconvenient. This project designed bus routes with more appealing destinations that are time efficient for students. The route design software, HASTUS, was utilized when scheduling the routes. Utility functions were used to project ridership and a cost analysis was prepared regarding potential alternatives. Two route designs with alternatives were proposed to the WRTA.

AUTHORSHIP

Throughout this project, each member of the team contributed to presenting ideas, performing essential calculations, and editing the work. Below is a list of the primary author(s) of each section.

Key:

Jenna DeFilippo= JD
Sean Donnelly= SD
Christin Grygorcewicz= CG
Equal Contribution= ALL

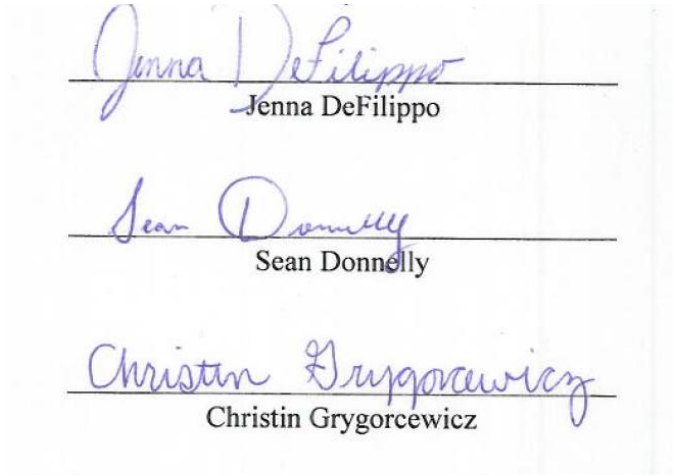


TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

CAPSTONE DESIGN STATEMENT

In order to meet the constraints set forth by the Accreditation Board for Engineering and Technology (ABET) this project needed to meet the requirements of the capstone design experience for Major Qualifying Projects. According to ABET General Criterion 4, "students must be prepared for engineering practice through the curriculum culminating in a major design experience based on knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political." (Criteria for Accrediting Engineering Programs, 2008).A portion of this Major Qualifying Project applied an economical approach to the design of alternative route designs for the Worcester Regional Transit Authority (WRTA) that is more accessible to college students. Other areas that are heavily populated by students, such as Boston, Chicago and Rhode Island have had success with student ridership. The project analyzed these systems, Worcester's current transit system and multiple design factors to produce alternative route systems that better fit student needs. The project also incorporated the following topics covered in the capstone design statement: sustainability, economic, environmental, ethical, political, manufacturability, health and safety and social.

Sustainability

Properly developed transit routes are designed to be sustainable. The alternative routes for this project were designed in order to save fuel and decrease the amount of privately operated, or family, vehicles on the road. Each of these concepts reduced the impact of automobiles on the environment so that fuel and the environment may be preserved for future generations.

Economic

Transit systems must take revenue generated from fare boxes as well as fuel costs into consideration when creating route systems. The redesign or addition of alternative routes to

Worcester's transit system is expected to increase revenue. Alternative designs may boost revenue through increased ridership as well as be more efficient and therefore save money in fuel costs. A larger amount of college student riders could bring in revenue that is absent in the current system. This project conducted a cost analysis based on projected new ridership and fuel cost.

Environmental

The WRTA is currently reducing their impact on the environment with the purchase of four hybrid buses. These hybrid buses result in a 30% - 40% reduction in emissions (WRTA, 2010). However, this project was more focused on transit design and the amount of emissions that could be reduced with the design of more efficient routes. The decrease in the amount of vehicles on the road and the pollutants they emit with more students choosing public transportation over private transportation was also taken into consideration.

Ethical

All transportation projects follow the code of ethics for civil engineers. This project used technology and knowledge to better the transit system for society while having as little impact on the environment as possible. All work was done honestly and in compliance with all rules in order to enhance knowledge.

Political

Input from the WRTA Advisory Board will be used when designing the alternative routes. Although this project did not directly address the political effects of alternative route designs some collaboration between colleges and the WRTA may be necessary for the funding of the proposed routes. Issues between the WRTA, college community and city of Worcester regarding funding may arise as well.

Manufacturability

This project produced realistic route designs that fit student needs. The alternative routes were designed to be feasible for the WRTA to implement. As a result of the proposed designs the availability of the transit system should have increased student ridership.

Health and Safety

When designing a transit system bus stop safety is priority. This project considered the design of a hub for students placed at a central location in-between several colleges. The hub and any additional stops for the alternative routes were located in an area that is safe from oncoming traffic, near crosswalks or an area with safe traffic control devices and adequate lighting.

Public transportation decreases the number of vehicles on the road, increasing road safety as well as public health. According to the American Public Transportation Association (APTA) emissions from road vehicles are the largest contributors to smog. The goal of the project was to increase the amount of student riders, resulting in a decreased amount of vehicles on the road allowing for a reduction in smog and a healthier Worcester.

Social

The goal of the project was to successfully increase student ridership and promote interaction between students of different colleges in the city of Worcester. The routes design included more of the student population and as a result encouraged students to be more involved in Worcester's community. An increase in the number of student friendly routes increased the amount of students utilizing retail areas, restaurants and cafes in the Worcester area.

LIST OF ACRONYMS

ARRA- American Reinvestment and Recovery Act

APTA- American Public Transit Authority

AVA- Automatic Voice Annunciation

AVL- Automated Vehicle Locator

CBD- Central Business District

CMMPO- Central Massachusetts Metropolitan Planning Organization

CMRPC- Central Massachusetts Regional Planning Commission

CTA-Chicago Transit Authority

FTA- Federal Transit Administration

FY- Fiscal Year (ending on June 30 for the WRTA)

IQP- Interactive Qualifying Project

MBTA–Massachusetts Bay Transportation Authority

MQP- Major Qualifying Project

RIPTA- Rhode Island Public Transit Authority

RTP- Regional Transportation Plan

TIP- Transportation Improvement Program

UPT-Unlinked Passenger Trips

WRTA- Worcester Regional Transit Authority

BASIC DEFINITIONS

Block- The term used for each driver whose hours worked on a route are manually inputted into the software program HASTUS.

Captive transit rider- A person without access to private transportation.

Cross-town route- A route going from the CBD of one town or city to another that has many stops in between.

Express route- A cross-town route that uses the highway and has no stops.

Headway- Time between vehicles on the same route and traveling in the same direction.

Hub - Area where all routes run and allow riders to transfer to other routes.

Major Activity Center- A place characterized by a large transient population and heavy traffic.

Modal Split- The ratio of trips made by a single mode of transportation to total trips made by all modes of transportation.

Parameter- The term used for the rules and regulations inputted into the software program HASTUS.

Shuttle system-Short routes that transfer riders from one location to another transportation system such as a rail station or airport.

Span of service- The time allotted between the first and last trip on any given route.

Trip end density- Number of transit patrons in an area.

Trunk Route- A route that runs from one hub to another.

1. INTRODUCTION

Transit systems are essential to communities, especially cities with large populations. They reduce the number of cars in the streets, resulting in less traffic, and a less polluted environment. Furthermore, they provide a means of transportation for people who do not have cars or just prefer an alternative way of getting places. Worcester, Massachusetts has a population of approximately 182,000, over 16% being college students who may not be able to have a car at their campus (City of Worcester, 2010). Therefore, it is essential to provide such a large population with a reliable way of getting to their most popular destinations.

Worcester is home to a large community of college students. There are a total of 13 campuses with a total student population of over 30,000. Last year, two students from WPI approached the WRTA with a project because they were from other parts of the world where transit service was more heavily utilized and wanted to explore why so few college students in Worcester took advantage of the service. That project included researching the reasons behind students not using the transit system. Surveys and focus groups that the project team conducted showed that students were either unaware of the transit system or found it inconvenient. Several issues that students expressed are:

- Perceived lack of safety
- Inconvenience with student schedules and classes
- Time inefficiency
- Lack of bus stops or routes
- Overall unawareness of the system

Of the reasons listed above, inconvenience with student schedules and classes, time efficiency, and lack of bus stops or routes are the driving factors of our in-depth analysis of the bus system and

how to improve service to students. This Major Qualifying Project (MQP) developed alternative route designs in an attempt to attract more college students by addressing the needs and concerns that they have previously expressed. We conducted a cost analysis, evaluated effects on time and scheduling, predicted new ridership and considered sustainability.

2. BACKGROUND

2.1 THE WORCESTER REGIONAL TRANSIT AUTHORITY (WRTA)

The Worcester Regional Transit Authority (WRTA) was created in 1974 and given the responsibility to develop, finance and contract the operation of transportation facilities and services within the Worcester area (WRTA, 2010). Its goal is to provide convenient, comfortable, safe, reliable and cost efficient mobility services. The WRTA's fleet is comprised of 48, 35-foot and 40-foot buses, four of which are clean diesel-electric hybrid. In an effort to be more environmentally conscious all new buses purchased by the WRTA are either newer Gilligs that get 4-5 miles per gallon (mpg) or hybrid buses that get 6-7 mpg (WRTA, 2010). Compared to the older fleet, which received only 3-4 mpg and considering the amount of mileage each bus gets, the newer buses are much more energy efficient.

2.1.1 FINANCING

The WRTA's $20-million operating budget is funded by federal, state and local monies and revenue. Revenue is generated by fare box proceeds as well as money received for advertisements on the buses. Each year state funding accounts for up to 75% of the total cost of service, fare box proceeds account for 15%-30% of operating costs and Federal funds can be used only for tangible objects, (buses, new fare boxes, etc.) (WRTA, 2010). Expected funding sources for the Fiscal Year (FY) 2010 are shown in Figure 1 below.

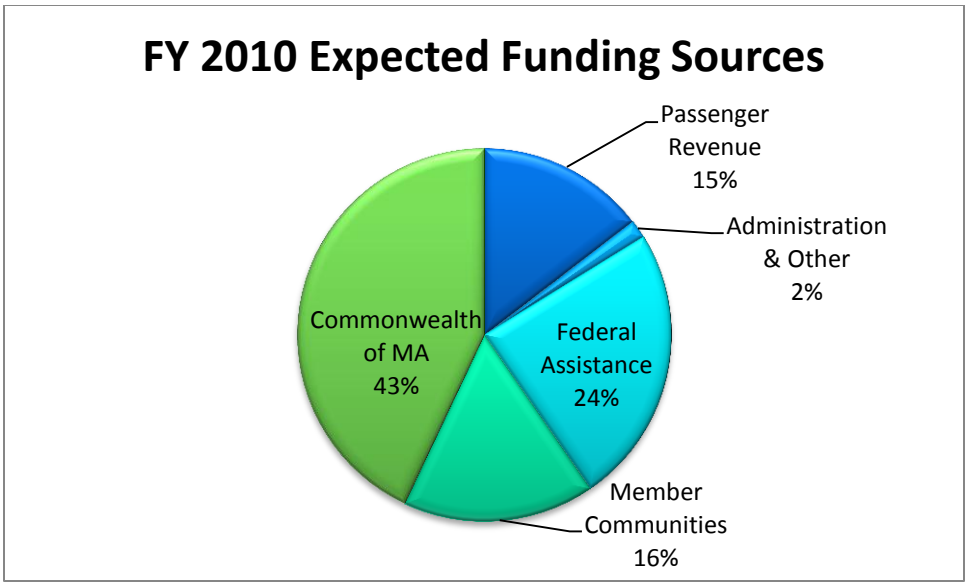


FIGURE 1: EXPECTED FUNDING

Day to day business at the WRTA is managed by Stephen O'Neil, the Administrator, as well as the WRTA Advisory Board. The Advisory Board consists of the City Manager of Worcester (currently Michael O'Brien) as well as representatives from the 35 member communities of the WRTA. Representatives of the 35 member communities are the City Manager or Mayor of each city, Chairman from the Board of Selectman, or the Town Manager or Town Administrator of the town. There are currently representatives from Auburn, Barre, Brookfield, Charlton, Clinton, Douglas, Holden, Leicester, Millbury, Northborough, Oxford, Rutland, Shrewsbury, Spencer and West Boylston on the Advisory Board.

In FY 2009 the WRTA was forced to cut services and raise fare prices for the first time in 5 years due to the rise in fuel costs and health insurance. Although they received $12.4 million from the American Recovery and Reinvestment Act (ARRA) through the Federal Transit Administration (FTA) (WRTA Advisory Board, 2009), the money was used to buy 15 new Gillig buses because Federal funds can only be used for capital expenditures (i.e. the purchase of tangible objects). The Advisory Board reported total revenue of $20,069,879 and net expenses of $19,282,793 for FY

2009 (WRTA Advisory Board, 2009). Tables 1 and 2 below break down the net revenue and expenses, respectively.

Revenue	
Source	**Amount**
Federal Government	$ 4,661,770.00
Commonwealth of MA	$ 8,814,942.00
Member Municipalities	$ 3,313,819.00
Passenger Revenues	$ 2,914,852.00
Advertising and other	$ 364,496.00
NET	$ 20,069,879.00

TABLE 1: REVENUE

Expenses	
Source	**Amount**
Fixed Route Transit Services	$ 13,455,818.00
Demand Response	$ 4,106,310.00
Administrative Expenses	$ 1,321,409.00
Management Fee	$ 399,256.00
NET	$ 19,282,793.00

TABLE 2: EXPENSES

The major costs of the WRTA include labor, fuel, services, material and supplies, maintenance and insurance. Although most of the WRTA's employees are bus drivers, or operators, they must also employ foremen, mechanics, janitors and office personnel. The total labor expense for FY 2009 was about $1.8 million and it costs the WRTA $81 thousand (on average) to employ each operator (WRTA, 2009). Services to maintain the WRTA facilities in FY 2009 were $61 thousand, materials and supplies for buses cost $756 thousand and insurance cost $454 thousand (WRTA, 2009). The WRTA used an average of 34,253 gallons of diesel fuel at $3.28/gallon and 2,974 gallons of gasoline at $2.08/ gallon for a total of $118,536 per month in the FY2009 (WRTA, 2009).

2.1.2 SERVICE AREA AND RIDERSHIP

Having a service area of over a half million customers residing in 35 communities makes the WRTA the second largest transit system in Massachusetts. The bus fleet covers 23 fixed routes throughout Worcester as well as to towns outside of Worcester including Auburn, Brookfield, Holden, Leicester, Millbury, Oxford, Spencer, Webster and West Boylston. On a typical weekday the WRTA has about 14,000 passengers (Mejia & Horvath, 2009). According to data gathered by the WRTA, 57% of their passengers ride 5 times or more per week, 53% for work, 17% for school and 30% for medical appointments, shopping and other day to day activities (WRTA, 2010).

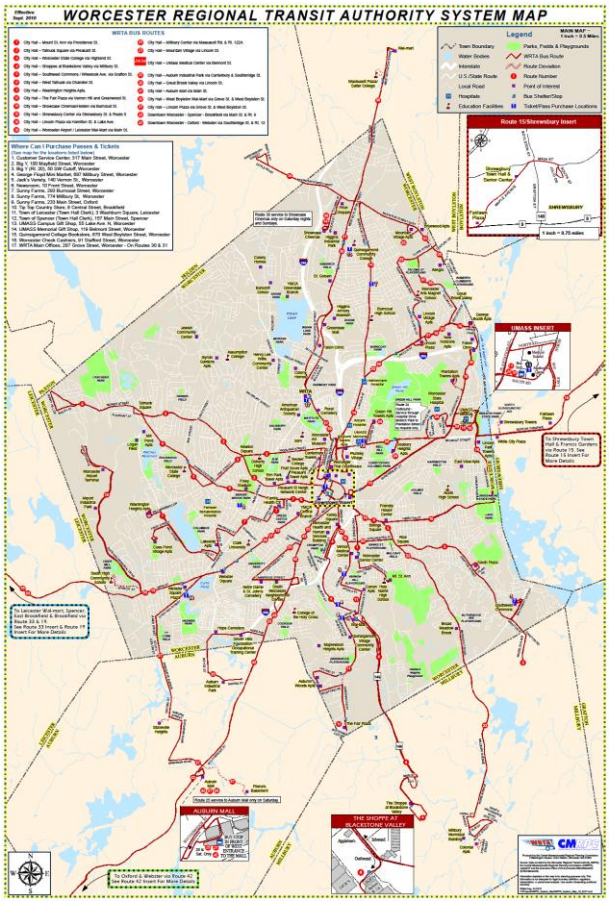


FIGURE 2: WORCESTER BUS ROUTES

In the FY 2009 the WRTA feared that ridership would decrease due to the fare increases. Contrary to what most believed, ridership actually increased 2.3% to 3,176,036 Unlinked Passenger Trips (UPT). UPTs are the number of passengers who board public transit vehicles, not taking into consideration whether or not the boarding was a transfer from another route. On the other hand, due to the loss of serving two communities that joined another RTA the amount of paratransit trips dropped 10.8% to 231,912 UPT.

2.1.3 ATTRACTING COLLEGE STUDENTS

A recent trend of the WRTA is to attract more of the college student population of Worcester. Students are currently an untapped market and if they were to fill buses it could increase the WRTA's fare box revenue and generate the ridership numbers to justify additional federal and state financial assistance. One approach taken to increase student ridership was to more heavily advertise to colleges. The WRTA has supplied freshmen at select universities in the area with free bus passes for their first semester because they believe that students decide what mode of travel they will use within their first 6 months of college attendance. Additionally, they have created a brochure that lists some attractions including stores and restaurants around Worcester that may be appealing to college students, along with the routes to get there. The sections of the pamphlet include route numbers to get to the library, Union Station, theatres and museums, parks/activities, malls, shopping centers and grocery, nightlife and dining. The WRTA is working with campus bookstores to devote a section to the bus system that will include these brochures, route maps, schedules, and passes for purchase. They have also partnered with Wachusett Mountain in offering a route to the ski area for $1.50 to students with monthly or semester passes as well as discounts off of their lift tickets with the possession of any bus pass. Furthermore, the WRTA would like to investigate new service ideas and route designs in an attempt to better adapt to the needs of college students.

The WRTA is also investing in new technologies that make riding the bus easier and more convenient for all riders and therefore expected to increase student ridership. These technologies are anticipated to take at least one year (Farley, 2010) to institute and include Automated Vehicle Locator (AVL), transit signal priority, message boards with real-time bus location, electronic bus pass dispensers, new fare boxes and Automatic Voice Annunciation (AVA). AVL will be a program on the WRTA website that shows where any particular bus of interest is en route, saving time waited at bus stops for riders. Transit signal priority keeps traffic signals green longer for buses,

saving fuel and travel time. Electronic message boards with bus locations at each major bus stop will be installed that will show riders when their bus will arrive. AVA will be a system on the bus that automatically shows and tells riders what stop is approaching, making it less confusing for inexperienced riders. The WRTA also wishes to invest in electronic bus pass dispensers that will be situated throughout Worcester as well as new fare boxes that can be tapped by a bus pass instead swiping the bus pass.

2.2 TRENDS OF COLLEGE STUDENTS

College students have different needs than the typical captive transit rider. They operate on completely different schedules, want and need to go to different places and due to their inexperience have different concerns with public transit. An evaluation of the WRTA service from a student's perspective was recently conducted by WPI students Adrian Mejia and Nathan Horvath. Their project analyzed why public transit student ridership in Worcester is low and its findings provided the WRTA with valuable information.

The evaluation found time efficiency and scheduling to be a major reason why college students choose other modes of transportation over public transit. A college student's life is based around classes, homework, studying and sometimes even a part time job. Time waiting for a bus, transferring and arriving early is valuable time lost that could have been spent finishing assignments or preparing for tests. Students are also concerned that there is not enough time in between classes to take a bus somewhere due to headway, transferring and delays. Often a college student's day runs later than the services the WRTA offers, which creates concern that they will go somewhere using their bus pass and have no way back home.

To many college students public transit can be an unattractive and scary thing. Especially in Worcester, students are aware of how dangerous it can be when venturing off campus. They do not have enough information about the public transit system needed to trust it and feel safe using it.

Their concerns might include feeling unsafe while waiting at a stop, on the actual bus or getting lost in an unfamiliar territory. Routes can be confusing especially when transfers are needed. This is another major reason students would rather travel privately than using public transit.

2.3 OTHER COLLEGE CITIES

There are some areas in the United States with very successful programs to enhance college student ridership. Specifically, Chicago, Boston and Rhode Island each have distinct systems that can be analyzed to improve Worcester's transit system. Although they may not be appropriate solutions on their own, ideas can be drawn from each to create a unique service plan for Worcester.

2.3.1 CHICAGO PUBLIC TRANSIT

In Chicago, it is mandatory for all of the 140,000 full-time students at the 45 participating colleges and universities to have a U-Pass. In most cases, the cost of the pass is built in to their tuition. The schools are charged 81 cents per student per day for unlimited rides on the buses and subways. This strategy produced $20 million in proceeds for the Chicago Transit Authority (CTA) last year. The CTA says that signing up college students boosts ridership and revenues while also helping the environment. This was originally introduced as a pilot program in 1998. The CTA started small by getting a few schools interested to weigh the pros and cons and get all of the glitches out. They found that it was much easier to gain interest than expected (Gurley, 2010).

2.3.2 BOSTON PUBLIC TRANSIT

Boston takes a different approach in which the MBTA semester pass program is voluntary. However, only 20,000 of approximately 383,000 undergraduate and graduate students buy the passes. This generates roughly $5 million a year in revenue. They have looked at the program that Chicago uses, but do not think that it would be attractive to Boston students because most prefer to walk or ride bikes, and it is the commuters that make the most use of the transit system. The

program is not considered flexible and the schools fear that it would turn students away. Conversely, a Boston University senior thinks that the pass is a good idea, and that students and parents would be wary at first but eventually see the benefits (Gurley, 2010).

2.3.3 RHODE ISLAND PUBLIC TRANSIT

Rhode Island's transit (RIPTA) works with participating colleges and universities to boost student ridership with the Providence U-Pass since 2001. Students get free or reduced fair transit depending upon which college or university they attend. For example, all students from Brown University and Providence College can ride the bus for free and simply have to show their student ID when boarding. Alternatively, students at Roger Williams University can purchase 15-ride passes at 50% off in the school bookstore (UPASS). This is possible because the colleges and universities subsidize the program.

2.4 DESIGN CRITERIA

When designing a transit system several factors must be taken into consideration. Different aspects that go into a transit system's design including schedule design, service design and operational design are essential to its successful operation. Factors that are taken into consideration when designing a transit system are demographics such as population of the city, employment and transit dependency. Much of the Worcester population is dependent on the use of the transit system to get to and from work along with their other desired destinations throughout the city (WRTA, 2010).

2.4.1 SCHEDULE DESIGN

Schedule design is based upon three main factors; span of service, frequency of service and loading guidelines. The span of service is the time allotted between the first and last trip on any given route. Routes may be needed specifically for weekends, weekdays, throughout the entire day

or specifically only one interval of time during the day. Frequency of the service is determined by the demand of the riders and should be designed to meet those demands in order to make their travel patterns more convenient and successful (Transit Design Manual, 2004). Scheduling is important to the operation of a transit system because the schedule determines which buses run which routes throughout the day, assuring that riders get to their desired destinations reasonably on time. One goal of the WRTA is to have buses running routes in 15 minute intervals so that riders have access to several buses throughout the day and the schedule runs smooth (Farley, 2010).

2.4.2 SERVICE DESIGN

Service design consists mostly of the types of routes offered to riders. Routes can be designated as trunk, cross-town, circular shuttle or express routes depending upon its purpose. The type of route should be chosen according to what is needed by the riders. Trunk design is used for a rider to get from one central hub to another in order to transfer to other routes that may become cross-town or express routes. Cross-town routes allow for a rider to get from one end of the central business district to the other with several stops in between while express routes run on highway systems and allow for riders to get from one area, such as an urban area, to the CBD. Shuttle systems are often short routes that transfer riders from one location to another transportation system such as a rail station or airport (Transit Design Manual, 2004).

2.4.3 OPERATIONAL DESIGN

Operational design often consists of bus design and maintenance, roadway or route design and bus stops. Bus design begins with the selection of the vehicles used in the transit system, which are typically 30-foot, 35-foot or 40-foot buses. Buses are selected based on their ability to travel the terrain or roadways along their route. A smaller bus would be used on a route that has a lower number of riders but may also travel roadways with heavy traffic flow, on-street parking, or narrow travel lanes. The larger buses are often used on routes that are in high demand by riders and travel

on roadways that are wider and consist of fewer conflicts with other vehicles. The capability of the bus to travel the roadways already existing in the city is essential to the infrastructure of the transit system. However, transit providers will often also work with city planning officials to improve roadway geometrics and enhance transit-friendly infrastructure.

Routes are to be designed to maximize the operating speed and minimize the travel time of riders. Route spacing is crucial to the success of a transit system (Transit Design Manual, 2004). For example, vehicles that travel on the same routes in opposite directions allow for a high level of accessibility throughout the city and enhance the attractiveness of the transit system. Routes should also be as direct as possible to make them more convenient for riders. In order to achieve these direct routes, transit providers must design the routes based on the roadways that reach each destination. It is essential to reach each destination in a timely manner while also allowing for the ease of travel for the operators. The more access riders have to desired destinations throughout the city and the more convenient it is for them to ride the more likely they are to use the city's transit system.

Bus stops are designed based on three major factors: safe operation of the bus, safety of the rider and rider convenience. Safe operation pertains to the ability of the bus to safely exit and reenter the flow of traffic with minimum interference with other vehicles on the roadway. The position of the bus, while stopped, should not interfere with the sight or view of the other motorists on the road. The safety of the rider pertains to the surface of the bus stops, which should be even and allow for safe and even footing for the rider. The bus stop location should also insure that the riders are able to wait at the stop without being subject to any danger of moving traffic along the roadway. Bus stops are to be located, as often as possible, near crosswalks or safe traffic control devices that allow for the riders to easily cross roadways in order to transfer from one location to a convenient bus stop. They should also have adequate lighting for riders to be able to locate the stop as well as allow the driver to locate the riders waiting at existing stops. The final key element

allowing for rider convenience is the location and identification of the bus stops. Bus stop signs should be posted in locations that are often traveled by pedestrians and should stand out to riders so that they know where the buses may stop and which routes run through that specific stop (Transit Design Manual, 2004).

2.4.4 BUS AND RAIL TRANSIT SYSTEMS

One major aspect of scheduling is the relationship between bus and rail transit systems. Many riders may take the bus to a train station and then travel by train to their desired locations. In order for this to run smoothly bus schedules must run somewhat in line with train schedules. Local transit bus systems may also link with larger bus systems in the area such as companies like Peter Pan or Greyhound. These larger bus systems do not run local routes; instead they run from city to city. For example, this may cater to an individual from a suburb working in a major city area.

2.4.5 DESIGN CRITERIA FOR THE WRTA

The WRTA routes are designed based on a radial traffic system used mainly in central business districts (CBD) such as downtown Worcester (Basic Design Controls, 2006). Located within Worcester's CBD, City Hall acts as a hub or area where all routes run and allow riders to transfer to other routes. Routes act as a web coming into the central hub, City Hall, and then continue in the same direction out of City Hall. Several buses may run the same routes at the same time but in different directions. The hub allows for riders to switch to another route or to stay on the same bus while it waits for other riders transferring from a different route to the one the bus is traveling. In Worcester every bus runs through the center of the city and passes by Union Station or locations near Union Station making it convenient for riders to take the bus to or near Union Station where they can then take a train to their desired destination. It has also become apparent that the WRTA may be planning on moving their central hub to Union Station in order to increase the ease of transferring between bus and train systems in the city.

2.4.6 SOFTWARE USED BY THE WRTA

The software used by the WRTA to design and control their route system is known as HASTUS. This program uses a list of rules and regulations called "parameters" to make sure the route system is designed correctly taking into consideration all the rules that the WRTA must follow. Parameters include driver break times, how long a driver's shift may be, where each bus stop is located, and the amount of time it takes to travel between bus stops. The rules that regulate how the program runs consist of two main groups, "General" and "Network", and can be found under the definitions category of the program. The "General" category consists mainly of parameters or rules that determine the scheduling of operators based on specific events, weekdays or weekends as well as the information on the vehicles being used for the week. The second category, "Network", consists of rules regulating specific stops, places, zones and routes. Each of these categories is used to actually program the schedule of the buses and operators. No stop or vehicle can be used in the program unless it is located in these sections. If a new stop that is not currently in the system was to be desired for use in a new route it would need to be added in this area of the HASTUS program. A figure of the parameters and their location in the HASTUS program can be seen below:

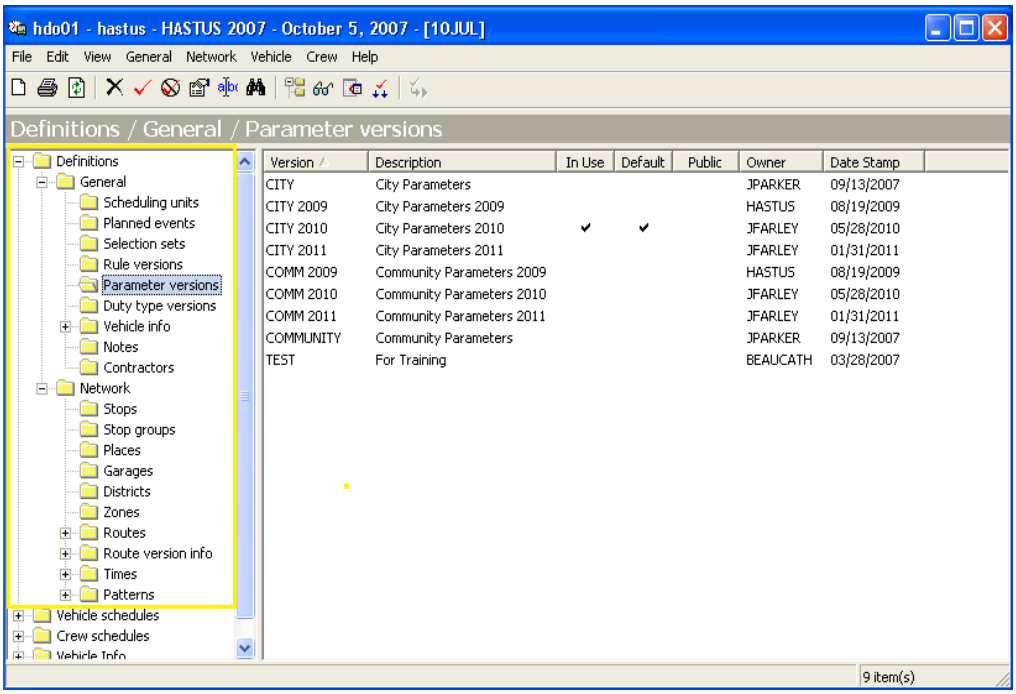


FIGURE 3: HASTUS PARAMETERS

The program allows the user to manually enter routes to be driven by a certain operator for their assigned shift; each driver in the program is called a "block". Should the route design submitted break one of the parameters an error message will be displayed saying that the route must change, but will not give a reason why the route does not work. The problem with the route must be determined solely by the person operating the program. HASTUS is not necessarily a program that is used to design a route. The program focuses more on how to schedule the desired route by which operator will be traveling the route at what time, which routes can be broken up by operator or when and where an operator will be located while traveling the route. The program is most useful for breaking routes up between two different operators and having them travel two different routes in an hour window. For example, operator 1 may travel route A for 40 minutes and route B for 20 minutes while operator 2 travels route B for 20 minutes and then route A for 40. This allows for each operator to have equal traveling hours as well as allowing them to travel along different routes throughout the work week rather than repeating the same routine daily.

2.4.7 ADAPTING DESIGN TO COLLEGE LIFE

The WRTA is attempting to reach out to college students in order to increase the number of students understanding and utilizing the transit system in the area. In order to increase the number of college riders, many design aspects need to be addressed. Route designs may need to be changed in order to make the system easier for students to ride. Such adjustments may include bus stops located closer to college campuses in the area, changes in the existing routes and the addition of routes or another hub. Alternative routes may need to run through or close to college campuses if they do not currently while also taking into consideration the destinations students may wish to reach. An extension in service hours and a weekend route to destinations frequently traveled to by college students is another way the WRTA may increase student ridership.

Scheduling may be one of the toughest problems when attempting to attract more college students. Many students may wish to use the bus system to get to the train, go visit other colleges and universities or go into cities like Boston or Providence. The bus schedule currently runs smoothly with the train schedules, but many routes operate on approximately one-hour headways. College students have busy schedules packed with classes and extracurricular activities. If the bus schedule can be managed in order to provide the 15-minute intervals that the WRTA desires, the number of conflicts between the bus and college schedules should be minimized.

Route and bus design and scheduling are very important aspects of any transit system that are critical to its success. Although much planning has already gone into the design of the current transit system in the Worcester area, the WRTA needs more design options to attract more college students. Adjustment of route designs, bus stops and or scheduling changes would make Worcester's transit system more adaptable and understandable to college students.

3. METHODOLOGY

The goal of this project was to assist the Worcester Regional Transit Authority in designing a new service that will boost student ridership in Worcester, Ma. To reach this goal, the following objectives were identified:

1. Utilize research and field observations to begin formulating potential design options.
2. Propose preliminary designs to the WRTA and continuously develop alternatives.
3. Perform cost analysis, new ridership projections, and time savings calculations for all alternatives.

The following sections will describe the approach used to complete these objectives.

3.1 PRELIMINARY RESEARCH

A significant amount of research needed to be done in the first few weeks of the project before the design process could begin. This research had multiple areas of focus including background research, learning the HASTUS software, and our own personal research by taking bus trips. The team conducted extensive research on the current system, other college city transits, and design criteria. Additionally, bus rides were taken by the team to determine what college students felt needed to be improved upon or changed. Each of these areas played an important role in the designs that were developed.

3.1.1 ACQUIRING BACKGROUND INFORMATION

Informational background research was primarily conducted in three areas including the WRTA, other college city transit systems, and design methods and criteria. It was extremely important that the team became familiarized with the background and operational procedures of the WRTA to ensure that they are taken into consideration. Looking at other college city transits played a crucial role in providing ideas as to how to make the system appeal to students and how to

advertise it. Though they were not directly applicable, the individual elements of each enabled the team to generate new ideas more applicable to Worcester. Finally, learning about design criteria was a fundamental step to ensure that all of the work that is done complies with standards. Ideas were drawn from each of these sources and areas to formulate unique ideas for the WRTA.

3.1.2 LEARNING HASTUS

Learning to use the design software, HASTUS, was a very important step. The team met with John Farley at the WRTA for software training and each member was given remote access to the program. With this, the team was able to get as familiar with the program as possible in order to proceed to input design ideas in the most efficient manner possible. The system will say when there are errors resulting from design changes, but it will not say what the errors are, so the programmer must also be aware of all rules relating to the various lengths of time for the operators' breaks. All of these rules were explained by John Farley and other staff members of the WRTA. These rules can also be seen in Figure 3 of Section 2.4.6. The team was then able to enter design ideas and changes into the system to see if they work and how they may affect times of the current routes.

To accomplish all modifications to routes in HASTUS multiple changes and additions needed to be made. First of all, the additional stops needed to be entered into the program. For each modified route, these stops were manually added where needed. Stops for modified routes were also manually deleted when necessary.

Secondly, the amount of time it takes between stops, for both inbound and outbound, needed to be entered for each route changed or added. This number was estimated using a Google maps travel time to HASTUS travel time ratio. A ratio was used because it takes longer for a bus to travel than a regular vehicle due to the size of the bus and the duration of the stops. Therefore, the travel time given by Google maps would be inaccurate to use in HASTUS. To find the ratio, multiple

routes already entered into HASTUS were drawn into Google maps which gave the amount of time it takes for a regular vehicle to travel them. The two travel times were then compared in a ratio form. A ratio of 2:1 was consistently used for the late night routes. When traveling south on the Park Ave routes, a ratio of 2:1 was used, however when traveling north a ratio of 2.5:1 was used. These were determined from looking at Routes 30 and 27 in HASTUS which demonstrated a longer rate when traveling north.

New routes were added by creating a new trip, adding the necessary stops and then manually entering the time it takes to travel between them. However, the team was never able to determine how to make the HASTUS program understand or accept the times that were entered into the program for each stop. The team was able to enter new, or change existing stops, but could not make the program accept the times for when the bus would arrive at each of the new desired stops. When this was attempted the program would enter the same time into each of the time blocks for each stop rather than allowing the team to manually enter what time each bus would arrive at each stop. As a result, the program would return an error message. The team was never able to determine whether or not the new or alternative route designs would be accepted by the HASTUS program.

After routes were modified, the routes that they affected would have needed to be changed to work with the system. For example, if one route turned into another route at City Hall the times would have been changed so that there were no overlaps or idle times at the switch of the route. Stops after the switch at City Hall then needed to be changed accordingly.

3.1.3 BUS RIDES

Initially, the team was unfamiliar with how a transit system works, so it was imperative to begin utilizing the bus around Worcester in order to understand and become comfortable with the system. Aspects of the system that would be beneficial for college students and aspects that needed

improvement were noted. Specifically, ease of use and convenience were observed. These attributes provided a better understanding of useful stop locations and destinations for students, and also what kind of schedule would best fit the students' needs. Riding various routes to destinations popular with college students enabled the team to better comprehend how routes and their timing should be changed. The group traveled to the Auburn Mall, Greendale Mall and Super Walmart. Specific details and observations from the trip can be found in Appendix A. The most important discovery, however, was the large amount of time it took to make these trips. The group used this observation to formulate routes that would more easily fit into the busy schedule of a college student.

3.2 DESIGN ALTERNATIVES

Design alternatives were developed based on all of the research performed by the group. The team took into consideration all aspects of service discussed in the previous sections including all of our background research for developing ideas and all of the rules within the WRTA. Designs were entered into the HASTUS software to ensure that there were no errors. A variety of designs from conservative to radical changes were sampled. Conservative changes included slight route and scheduling modifications, while radical changes consisted of the addition of a hub and other routes to the system. As the ideas were added to the software we were able to make adjustments as needed. From there we performed all calculations necessary to determine whether or not the design would be a useful and practical alternative for college students as well as the WRTA. The wide range of designs helped to determine which changes will be the most successful.

3.3 ANALYSIS AND CALCULATIONS

The final step included performing calculations which were used in proposing recommendations to the WRTA. Necessary calculations included a cost analysis, projected new ridership and time savings. All of these factors were considered when evaluating alternatives.

Ideas were proposed to the WRTA to guarantee that all of their input was received and as many edits as necessary were performed in order to arrive at the best possible alternatives.

3.3.1 PROJECTED RIDERSHIP

The WRTA does not currently use a model or formula to calculate projected ridership. For this project, ridership for each modified or additional route was calculated using a utility function taken from the text Traffic and Highway Engineering by Garber and Hoel (Hoel, 2008):

$$\text{Utility}_i = b(\text{IVTT}) + c(\text{OVTT}) + d(\text{COST})$$

IVTT = in-vehicle travel time (min)

OVTT = out-of-vehicle travel time (min)

COST = out-of-pocket cost (cents)

These values varied for each route and are shown in Appendices B, C, D and E for all of the proposed alternatives. While the cost to ride a bus was easy to calculate using the $1.50 fare that is charged for each ride, many assumptions were made to calculate the cost to take a private vehicle. It was first assumed that college students pay their own car insurance, maintenance and operational costs. Next it was assumed that the average vehicle gets 25 mpg with gas being priced at $3.00 per gallon. From personal experience and doing many online quotes the cost to insure a vehicle for a college student per year was assumed to be about $1,000, average maintenance and operational costs to be $500 and the average miles traveled per year to be 10,000 miles. This makes the cost of traveling in a private vehicle $.27/mile. The text used methods published in NCHRP Report 365 for values of coefficients *b, c and d*:

b = -.025

c = -.050

$$d = \frac{(b)(1248)}{(TVP)(\text{AI})}$$

TVP= (value of one hour travel time)/(hourly employment rate)=0.30

AI= the average income of college students

AI is usually the average annual regional household income; however this project was more concerned with student riders. Therefore it was assumed that the average student works over the summer and breaks, receives money from grants or their parents and maybe has a part time job during the school year as well. Values of $5,000 and $10,000 were used.

Once the utility function was solved for both transit use and private auto a Logit Model taken from the same text was used to calculate the percentage of students that would ride the bus:

$$P(T)=\frac{e^{Ut}}{e^{Ut}+e^{Ua}}$$

Ut=Utility function for transit

Ua=Utility function for private auto

Lastly, the total student populations of WPI, Assumption College, Holy Cross, Becker College, Worcester State University, Clark University and Quinsigamond Community College when applicable were multiplied by the percent of projected riders to get the number of forecasted student riders. For the weekend route, the percent of riders was multiplied by one third of the student population since it is predicted that only people of drinking age would use the route. Appendix B shows these calculations.

3.3.2 COST ANALYSIS

A cost analysis was prepared for the additional routes made which includes the weekend routes and new Park Ave. route. The analysis took into account the number of buses that would be driving the route, the gas consumed and payment of the operators. The most recent data available provided by the WRTA's financial reports was used in our calculations. The average cost of diesel fuel for the WRTA in 2010 was $1.95 per gallon (WRTA, 2010), and the newer Gillig buses get 4-5mpg while the hybrids get 6-7 mpg (WRTA, 2010), Doing the math out gives the costs of diesel per bus per mile of $.43/mile for the newer Gilligs and $.30/mile for the hybrids. In 2010, the total hourly cost of an operator including wages and fringes was $38.94/hour.

3.4 SUMMARY

Several steps were involved in our methodology including background research, developing design alternatives, and calculations. After all of these steps were taken, this project's objectives were completed and recommendations for the WRTA were formed. The following chart summarizes the time spent on each step over the course of three academic terms, approximately 21 weeks, at WPI.

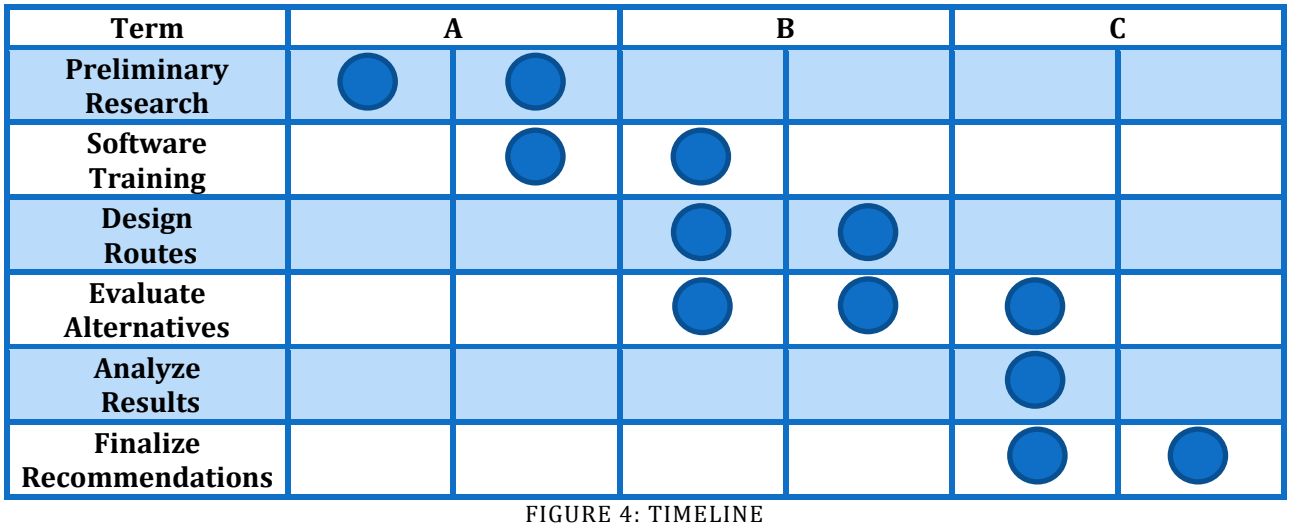


FIGURE 4: TIMELINE

4. ANALYSIS AND CALCULATIONS

4.1 CHOOSING ROUTES TO MODIFY

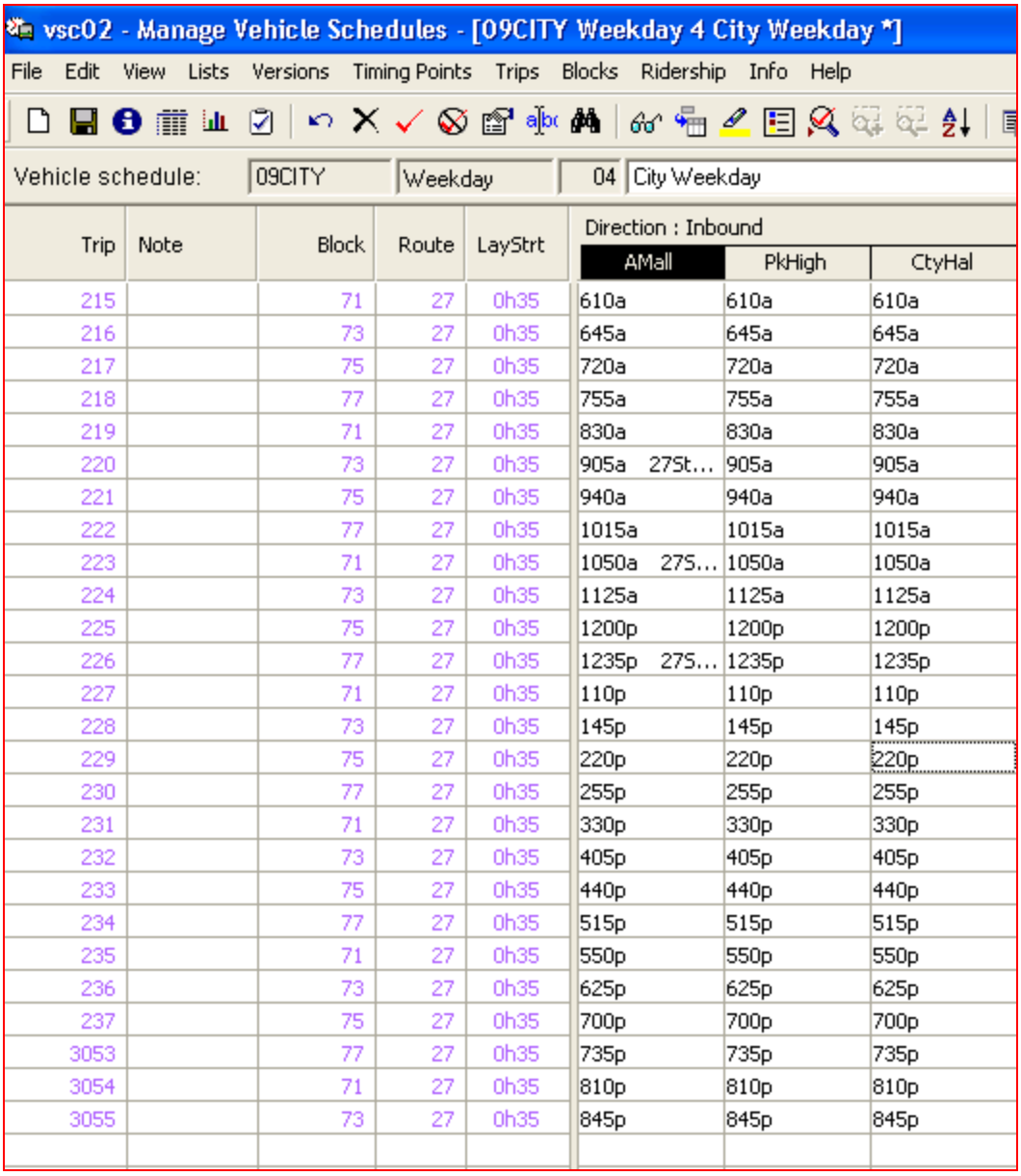
Routes that reach popular destinations of college students were the primary focus of this project. These routes were specifically chosen to provide convenient and time effective options. Some preliminary objectives included:

1. Having a late night route for students wishing to experience Worcester's night life.
2. Modifying a route or routes to utilize Park Avenue and provide a more direct route to the Auburn and Greendale Malls.
3. Providing a more direct service to the colleges and universities.

The routes chosen to modify to accomplish these goals were the 27 and 30. Three late night routes running from 8:30 p.m. to 2:30 a.m. three nights per week were designed to pick up students from multiple colleges and reach popular late night destinations.

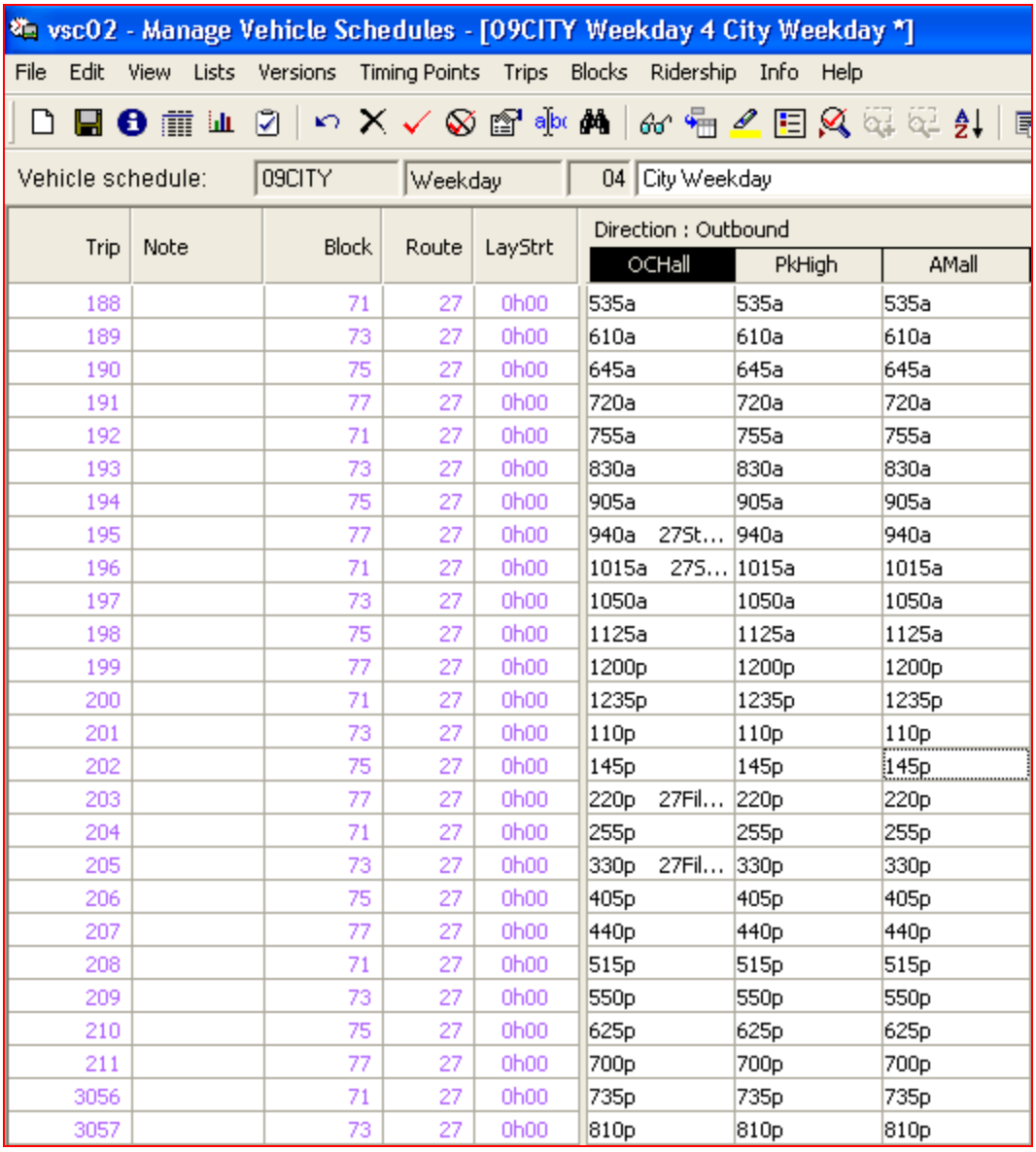
4.1.1 USING HASTUS

Route 27 was modified and uploaded into HASTUS, changing a few stops. The travel design was modified in order to run from the Auburn Mall to Highland Street and then to City Hall for the inbound. The outbound route travels from City Hall to Highland Street and then to the Auburn Mall. Although the stops along the route were modified the time was unable to be properly modified in order for the HASTUS program to accept the time tables entered. The travel designs can be seen below:



Trip	Note	Block	Route	LayStrt	Direction : Inbound		
					AMall	PkHigh	CtyHal
215		71	27	0h35	610a	610a	610a
216		73	27	0h35	645a	645a	645a
217		75	27	0h35	720a	720a	720a
218		77	27	0h35	755a	755a	755a
219		71	27	0h35	830a	830a	830a
220		73	27	0h35	905a 27St...	905a	905a
221		75	27	0h35	940a	940a	940a
222		77	27	0h35	1015a	1015a	1015a
223		71	27	0h35	1050a 27S...	1050a	1050a
224		73	27	0h35	1125a	1125a	1125a
225		75	27	0h35	1200p	1200p	1200p
226		77	27	0h35	1235p 27S...	1235p	1235p
227		71	27	0h35	110p	110p	110p
228		73	27	0h35	145p	145p	145p
229		75	27	0h35	220p	220p	220p
230		77	27	0h35	255p	255p	255p
231		71	27	0h35	330p	330p	330p
232		73	27	0h35	405p	405p	405p
233		75	27	0h35	440p	440p	440p
234		77	27	0h35	515p	515p	515p
235		71	27	0h35	550p	550p	550p
236		73	27	0h35	625p	625p	625p
237		75	27	0h35	700p	700p	700p
3053		77	27	0h35	735p	735p	735p
3054		71	27	0h35	810p	810p	810p
3055		73	27	0h35	845p	845p	845p

FIGURE 5: INBOUND TRAVEL DESIGN



Trip	Note	Block	Route	LayStrt	Direction : Outbound		
					OCHall	PkHigh	AMall
188		71	27	0h00	535a	535a	535a
189		73	27	0h00	610a	610a	610a
190		75	27	0h00	645a	645a	645a
191		77	27	0h00	720a	720a	720a
192		71	27	0h00	755a	755a	755a
193		73	27	0h00	830a	830a	830a
194		75	27	0h00	905a	905a	905a
195		77	27	0h00	940a 27St...	940a	940a
196		71	27	0h00	1015a 27S...	1015a	1015a
197		73	27	0h00	1050a	1050a	1050a
198		75	27	0h00	1125a	1125a	1125a
199		77	27	0h00	1200p	1200p	1200p
200		71	27	0h00	1235p	1235p	1235p
201		73	27	0h00	110p	110p	110p
202		75	27	0h00	145p	145p	145p
203		77	27	0h00	220p 27Fil...	220p	220p
204		71	27	0h00	255p	255p	255p
205		73	27	0h00	330p 27Fil...	330p	330p
206		75	27	0h00	405p	405p	405p
207		77	27	0h00	440p	440p	440p
208		71	27	0h00	515p	515p	515p
209		73	27	0h00	550p	550p	550p
210		75	27	0h00	625p	625p	625p
211		77	27	0h00	700p	700p	700p
3056		71	27	0h00	735p	735p	735p
3057		73	27	0h00	810p	810p	810p

FIGURE 6: OUTBOUND TRAVEL DESIGN

Route 30 was also modified from the original travel pattern. The current route 30 travels from City Hall to the Lincoln Plaza. However, it was determined that the route would be more useful if it ran from City Hall to the Wachusett Plaza, running down Highland Street as well. Although the variants and stops were changed in the HASTUS program, the program would not

show the new travel pattern. If the HASTUS program were to accept the manually entered time tables they would run through the stops shown below from 5:20am to 7:20pm:

Inbound	City Hall	Park Ave/Highland	West Grove St	Greendale Mall	Quinsigamond CC	Wachusett Plaza
Outbound	Wachusett Plaza	Quinsigamond CC	Greendale Mall	West Grove St	Park Ave/Highland	City Hall

FIGURE 7: ROUTE 30 TRAVEL PATTERN

The "New Park Ave" route along with the Late Night Weekend routes were designed from start to finish in the HASTUS program. These routes are much more time consuming to program due to the fact that they have to be designed from scratch and the time tables for the late night routes are slightly more complicated to complete due to the time of night they will be running. Since HASTUS is programmed for eight hour windows for operators, the Late Night Weekend routes will be running from 630pm-230am, allowing for students to reach downtown locations with restaurants, clubs or bars.

In order to successfully add the new routes that are desired into the HASTUS program, the routes that were modified had to be manually changed based on the travel pattern and the stops that run along the desired path of travel. The time tables must also be manually changed in order to follow the HASTUS travel time to Google maps travel time ratio. Once this is completed the program will either accept the new route designed or return feedback stating that the route was not accepted.

4.1.2 LATE NIGHT ROUTES

Three separate options for a late night route were developed in order to appeal to college students. These late night routes are being considered and proposed for multiple reasons. First is safety; students who plan to consume alcohol should not be driving, and the buses provide a safe alternative. Secondly, students do have the option of taking a cab, but the bus would be less

expensive. Thirdly, it would be convenient and easier to travel in larger groups. If buses are constantly running from different hot spots throughout the night, students will be more likely to take the bus to travel from one location to another, and still have a reliable ride home at the end of the night.

OPTION 1: TWO ROUTES

Option 1 contains two separate routes that would run simultaneously. The first route would begin at Assumption College, travel down Highland Street passing both WPI and Becker College, down Park Ave toward Clark University, and ending at Kelley Square. This route would provide service to students from four colleges or universities directly to desired night life locations. The second route would begin at Worcester State University, travel on a short segment of Park Ave, travel via Pleasant Street and Main Street to Kelley Square, and end at Holy Cross. This route would service two colleges, while also creating the option to switch routes from the other weekend bus at both Park Ave and Kelley Square.

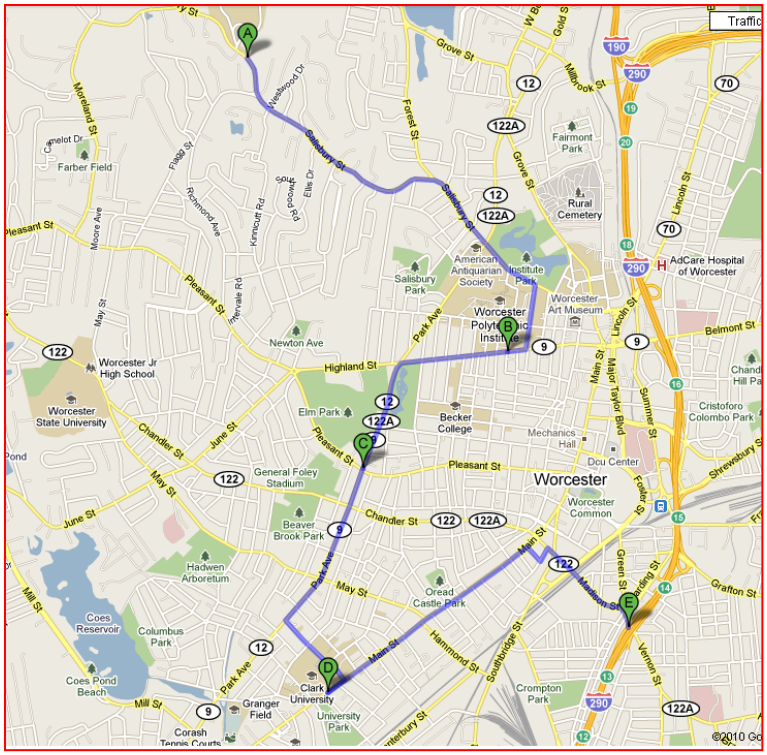


FIGURE 8: OPTION 1- LATE NIGHT ROUTE 1

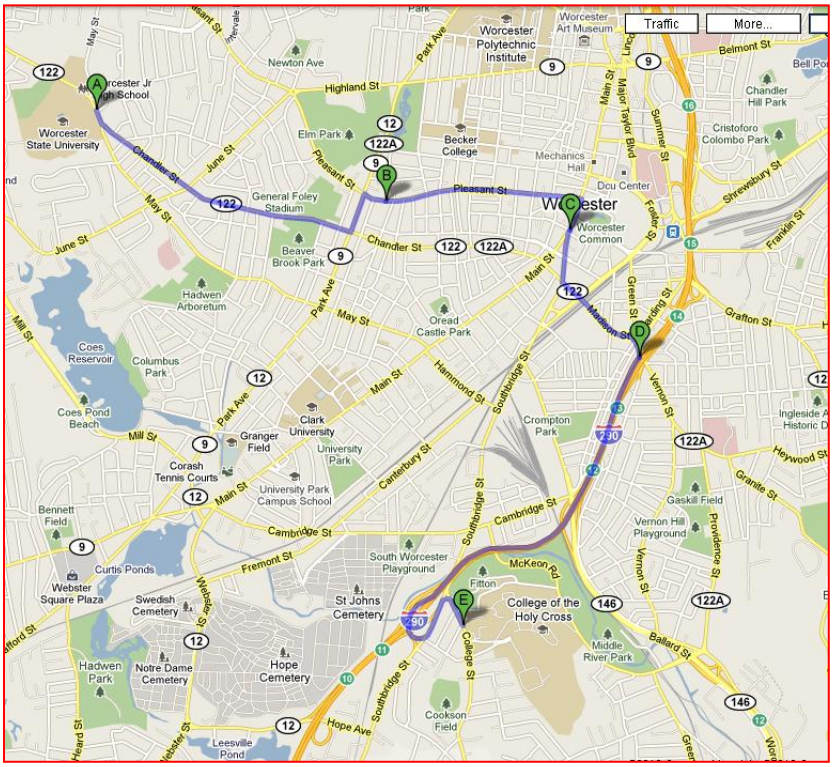


FIGURE 9: OPTION 1- LATE NIGHT ROUTE 2

Travel times associated with each of the routes efficiently utilize the 8 hour time period from 6:30pm-2:30am. Assumptions of a 2:1 minute ratio as explained in Section 3.1.2 were made based off of a bus to car ratio for Route 3. It is also recommended that two buses are traveling on each of the routes in order to minimize headway. Using these assumptions, route 1 results in a 1 hour and 20 minute loop with 40 minute headway, while route 2 will operate in a 1 hour loop with 30 minute headway. Car travel times were based off of GoogleMaps. The information and times for each of the two routes within Option 1 can be seen in the following tables.

Late Night Route 1	
Car Travel Time- one way	18 minutes
Assumed Bus Travel Time one way	36 minutes
Break	3 minutes
Total Loop (approximately)	1 hour 20 minutes
Number of buses running	2 buses
Headway	40 minutes

TABLE 3: OPTION 1- LATE NIGHT ROUTE 1 INFORMATION

Time	Assumption (bus)	Kelley Square (bus)
6:30	1	2
7:10	2	1
7:50	1	2
8:30	2	1
9:10	1	2
9:50	2	1
10:30	1	2
11:10	2	1
11:50	1	2
12:30	2	1
1:10	1	2
1:50	2	1
2:30	1	2

TABLE 4: OPTION 1- LATE NIGHT ROUTE TIMES

Late Night **Route 2**	
Car Travel Time- one way	13 minutes
Assumed Bus Travel time one way	26 minutes
Break	3 minutes
Total Loop (approximately)	1 hour
Number of buses running	2 buses
Headway	30 minutes

TABLE 5: OPTION 1- LATE NIGHT ROUTE 2 INFORMATION

Time	Worcester State (bus)	Holy Cross (bus)
6:30	1	2
7:00	2	1
7:30	1	2
8:00	2	1
8:30	1	2
9:00	2	1
9:30	1	2
10:00	2	1
10:30	1	2
11:00	2	1
11:30	1	2
12:00	2	1
12:30	1	2
1:00	2	1
1:30	1	2
2:00	2	1
2:30	1	2

TABLE 6: OPTION 1- LATE NIGHT ROUTE 2 TIMES

Below is a matrix that shows the amount of time it would take to get from any one point to any other point by riding the late night bus Option 1.

Option 1: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	20	n/a	*32	*22	*26	26
Assumption	18	36	*32	n/a	14	26	*56
WPI/Becker	5	26	*23	14	n/a	12	*37
Clark U	8	14	*26	26	23	n/a	*34
Holy Cross	22	10	26	*56	*37	*34	n/a
*** Transferring, 10 minutes added**							

TABLE 7: OPTION 1- TRAVEL TIMES MATRIX

Based on the average gas costs from 2010, the following table displays the projected gas cost ranging from one night to one year for each of the proposed routes. If the Hybrid buses are used for each of the routes, it would require approximately an additional $17,000 per year. However, since these numbers are based off of the average gas prices of 2010, this number would probably be higher for 2011.

	Gillig	**Hybrid**
	$.43/mile	$.30/mile
Route 1 loop: 12 miles	5.16	3.60
Route 1 per night	41.28	28.80
Route 1 per night, 2 buses	82.56	57.60
Route 1 per 3 nights, 2 buses	247.68	172.80
Route 1 per year, 2 buses	**12,879.36**	**8,985.60**
Route 2 loop: 10.4 miles	4.47	3.12
Route 2 per night	35.78	24.96
Route 2 per night, 2 buses	71.55	49.92
Route 2 per 3 nights, 2 buses	214.66	149.76
Route 2 per year, 2 buses	**11,162.27**	**7,787.52**
Yearly total	**24,041.63**	**16,773.12**

TABLE 8: OPTION 1- LATE NIGHT ROUTE GAS COST

Each of the late night routes are being proposed in eight hour blocks, thus creating a full shift for each of the drivers. The numbers in the following chart are based on the total hourly cost of an operator including wages and fringes of $38.94/hour in 2010.

Operator Pay Information	
Operator pay per night	311.52
Operator pay per 3 nights	934.56
Operator pay per year	48,597.12
Per year sum of both routes	97,194.24
Per year, both routes, 2 buses	194,388.48

TABLE 9: OPERATOR PAY

Finally, the team has come up with multiple results regarding projected ridership and the income that can be expected from it. The highest level of expectation represents the total number of students from each college or university that are of age to go to the popular late night destinations. The lowest level represents one third of that population. The income is based on the assumption that each rider will take one inbound and one outbound ride on the bus in one night, costing $3 in total. These projections were used to develop the scenarios for high, medium, and low expectations for multiple travel frequencies. The worst possible situation would be with the lowest number of riders making use of the routes every third week, resulting in $36,822 income per year. The best case scenario with all eligible students riding the bus once per week would result in a profit of $337,896 per year.

Expectation Level	Projected Riders	1 Night Income
High	2,166	$6,498
Medium	1,444	$4,332
Low	722	$2,166

TABLE 10: OPTION 1- NIGHTLY INCOME EXPECTATIONS

Per Year			
Expectation Level	**Once per week ($)**	**Every Other Week ($)**	**Every Third Week ($)**
High	337,896	168,948	110,466
Medium	225,264	112,632	73,644
Low	112,632	216,626	36,822

TABLE 11: OPTION 1- YEARLY INCOME EXPECTATIONS

The sum of gas usage and driver pay for two buses traveling each of the 2 routes, 3 nights per year costs approximately $220,000. If high expectations are met, this will still result in a high recovery rate for the WRTA. However, if low expectations are met, the WRTA will obtain approximately 17% recovery from the addition of these routes. A possible solution to this would be to not run these routes over the summer when students are not at school. Ridership will be at a low over those months so it may not be necessary to have the routes running. Also, an advantage of the addition of these routes is the exposure the WRTA will be getting. Students will realize how easy it is to ride the bus, and then may consider riding it for other purposes. The charts below contain numbers that were found via the same calculations, but based off of a 40 week year to account for the months of September through May, and not running the buses during the summer.

	Gillig	**Hybrid**
	$.43/mile	$.30/mile
Route 1 loop: 12 miles	5.16	3.60
Route 1 per night	41.28	28.80
Route 1 per night, 2 buses	82.56	57.60
Route 1 per 3 nights, 2 buses	247.68	172.80
Route 1 per year, 2 buses	**9,907.20**	**6,912.00**
Route 2 loop: 10.4 miles	4.47	3.12
Route 2 per night	35.78	24.96
Route 2 per night, 2 buses	71.55	49.92
Route 2 per 3 nights, 2 buses	214.66	149.76
Route 2 per year, 2 buses	**8,586.40**	**5,990.4**
Yearly total	**18,493.60**	**12,902.40**

TABLE 12: OPTION 1- LATE NIGHT ROUTE GAS COST (40 WEEKS)

Operator Pay Information	
Operator pay per night	311.52
Operator pay per 3 nights	934.56
Operator pay per year (~ 40weeks)	37,382.40
Per year sum of both routes	74,764.80
Per year, both routes, 2 buses	149,529.60

TABLE 13: OPERATOR PAY (40 WEEKS)

Per Year			
Expectation Level	**Once per week ($)**	**Every Other Week ($)**	**Every Third Week ($)**
High	259,920	129,960	86,640
Medium	173,280	86,640	57,760
Low	86,640	43,320	28,880

TABLE 14: YEARLY INCOME EXPECTATIONS (40 WEEKS)

By reducing the route to only running for 40 weeks out of the year and using the Hybrid buses, the sum of gas usage and driver pay would cost approximately $162,432, which is significantly less expensive than running the buses for the entire year. 24% recovery can be achieved within the low expectation range.

OPTION 2: LOOP ROUTE

Another alternative would be keeping the same destinations, but creating a loop out of the two routes mentioned in Option 1. This loop would have endpoints at Assumption College and Worcester State University, and would still pass all of the late night hot spots.

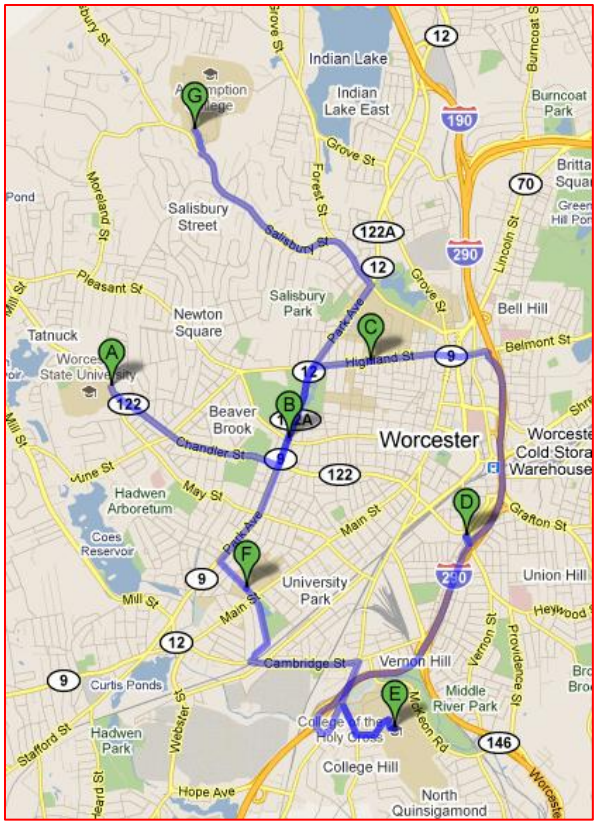


FIGURE 10: OPTION 2 ROUTE

The loop would still require 4 buses in order to keep the headway comparative. All of the same calculations that were completed for Option 1 were performed for Option 2 and can be seen in the following charts. Operator pay would be the same as in Table 9 and Table 10 because all options are based on the same hours per year. Projected ridership will also remain constant. This was determined after performing the calculation multiple times for various scenarios. Below the general information regarding Option 2 can be seen.

Late Night Route Option 2	
Car travel time one way	36 minutes
Assumed Bus Travel time one way	1 hour 12 minutes
Break	3 minutes
Total Loop (approximately)	1 hour 20 minutes
Number of buses running	4 buses
Headway	40 minutes

TABLE 15: OPTION 2- LATE NIGHT ROUTE INFORMATION

This next table shows the times that the Option 2 bus will be departing from each of the loop endpoints, Worcester State University and Assumption College. This was based on headway of 40 minutes. More specifically, a matrix of all times to get to and from every location along the route can be seen in Table 17.

Time	Worcester State (bus)	Assumption (bus)
5:50	4	3
6:30	1	2
7:10	3	4
7:50	2	1
8:30	4	3
9:10	1	2
9:50	3	4
10:30	2	1
11:10	4	3
11:50	1	2
12:30	3	4
1:10	2	1
1:50	4	3
2:30	1	2

TABLE 16: OPTION 2- TIMES

Option 2: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	22	n/a	80	12	55	38
Assumption	14	60	80	n/a	64	24	40
WPI/Becker	5	10	10	12	n/a	10	26
Clark U	7	32	58	20	12	n/a	16
Holy Cross	21	16	42	34	32	14	n/a
*** WPI/Becker to Assumption and Clark walks to Park Ave**							
***Clark takes bus to Park Ave for WPI/Becker**							

TABLE 17: OPTION 2- TRAVEL TIMES MATRIX

Gas cost was calculated using averages from 2010 and can be seen below. Option 2 proves to be significantly less expensive than Option 1.

	Gillig	Hybrid
	$.43/mile	$.30/mile
Circle Route: 12.7 miles	5.46	3.81
Circle Route per night per bus	16.38	11.43
Circle Route per night, 4 buses	65.52	45.72
Circle Route per 3 nights, 4 buses	196.56	137.16
Cirlcle Route per year (40 weeks), 4 buses	**7,862.40**	**5,486.40**

TABLE 18: OPTION 2- GAS COST

Overall, Option 2 proves to be a worthy option. It is cost effective, has a competitive headway, and provides service to all of the colleges and universities in the area without the need to transfer.

OPTION 3

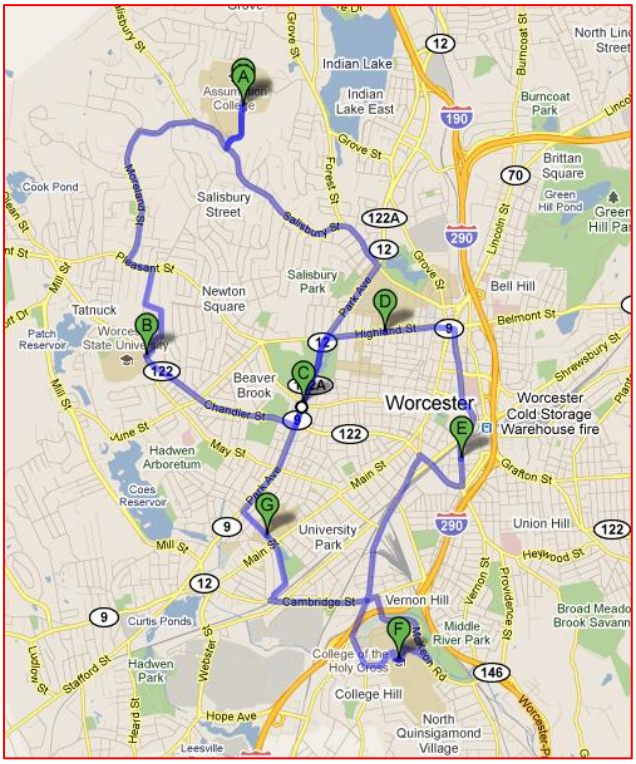


FIGURE 11: OPTION 3 ROUTE

The final option is extremely similar to Option 2 because it is also a loop that connects all points with one route. The main difference, however, is that is connects Assumption College and Worcester State University by continuing the loop on Moreland Street. General information regarding the route can be seen below in Table 19.

Late Night Route Option 3	
Car travel time one way	44 minutes
Assumed Bus Travel time one way	1 hour 28 minutes
Break	3 minutes
Total Loop (approximately)	1 hour 31 minutes
Number of buses running	4 buses
Headway	45 minutes
*** Say 1 hour 31 minutes = 1 hour 30 minutes**	

TABLE 19: OPTION 3- LATE NIGHT ROUTE INFORMATION

The route runs with 45 minute headway, and a breakdown of when the buses leave Assumption College headed in opposite directions can be seen below. Four buses would be on the route and each bus would travel the loop twice per night.

Time	Assumption Left(bus)	Assumption Right (bus)
5:45	1	2
6:30	3	4
7:15	2	1
8:00	4	3
8:45	1	2
9:30	3	4
10:15	2	1
11:00	4	3
11:45	1	2
12:30	3	4
1:15	2	1
2:00	4	3
*** only 7.5 hour long shift**		

TABLE 20: OPTION 3- TIMES

As can be seen in the following matrix, the Option 3 route greatly reduces the travel time between Assumption College and Worcester State University. The times to the other destinations remain similar to those of Option 2.

Option 3: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	22	n/a	16	12	55	38
Assumption	14	60	16	n/a	14	24	40
WPI/Becker	5	10	10	12	n/a	10	26
Clark U	7	32	58	20	12	n/a	16
Holy Cross	21	16	42	34	32	14	n/a
***Assumption takes bus to Park Ave for WPI/Becker**							
***Clark takes bus to Park Ave for WPI/Becker**							

TABLE 21: OPTION 3- TRAVEL TIMES MATRIX

Gas cost was calculated using averages from 2010, so this number will probably increase in upcoming years. The calculation breakdown can be seen in the following table.

	Gillig	Hybrid
	$.43/mile	$.30/mile
Option 3 Route: 15.6 miles	6.71	4.68
Circle Route per night per bus	13.42	9.36
Circle Route per night, 4 buses	53.66	37.44
Circle Route per 3 nights, 4 buses	160.99	112.32
Circle Route per year (40 weeks), 4 buses	6,439.68	4,492.8

TABLE 22: OPTION 3- GAS COST

While Option 3 does have the least expensive gas cost, this route includes a road that may not be travelable for buses. Option 3 utilizes Moreland Street to reduce the travel time between Assumption College and Worcester State University; however, due to a steep grade and a narrow width this may not be a realistic option.

4.1.3 PARK AVENUE

Many of the establishments located on Park Ave. are popular destinations of college students. These include restaurants, bars, convenience stores, Price Chopper and pharmacies. However, there are currently no bus routes that service Park Ave. in its entirety. Modifying routes to run down Park Ave. is therefore a possible way to increase student ridership.

ROUTE 27

Route 27 currently runs from City Hall to the Auburn Mall and back via Main Street. Once the inbound 27 reaches City Hall, it turns into Route 26 and runs to Allegro Microsystems via Lincoln Street. The 26 passes Lincoln Plaza and is a popular route so the least amount of effect on it was desired. However, the following reasons made Route 27 a prime candidate to modify:

- It could be easily switched to run down Park Ave. instead of Main St. with a minimum effect on its timing
- There are multiple routes that go to the Auburn Mall from City Hall including the 25 and 42 that regular non-student riders may take
- A more direct and convenient route to the Auburn Mall may be more heavily used by college students because it avoids the very busy Main Street
- Saves time by not having to go to City Hall to transfer

The modification to route 27 from the Auburn Mall includes removing it from the Main Street service and instead having it use the same path as route 3 to Park Ave. from City Hall. The route would then run south down Park Ave. to Stafford Street and onto its current path to the Auburn Mall. Stops would be added along Park Ave. at popular and convenient destinations. The inbound route 27 would switch into route 26, as it does now, at City Hall. Once the 26 inbound reached City Hall, it would switch back into the proposed 27 outbound to Auburn Mall as it currently does already. Therefore, the only major affect to Route 26 is the timing of its stops.

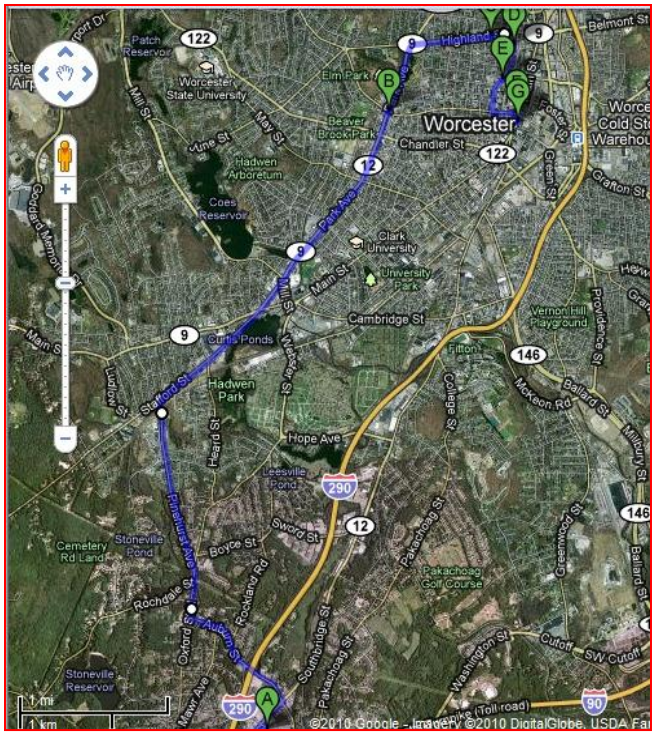


FIGURE 12: ROUTE 27 OUTBOUND

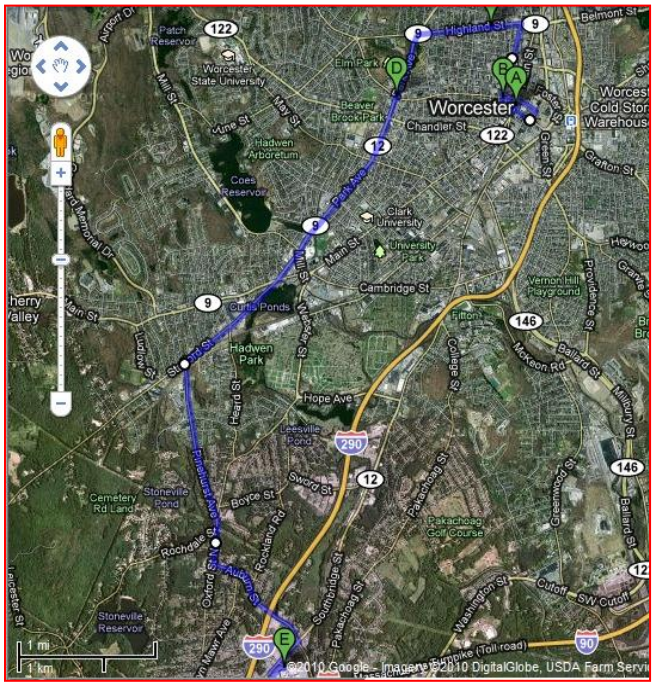


Figure 13: Route 27 Inbound

According to GoogleMaps, the proposed route 27 would take 20 minutes inbound 23 minutes outbound with the use of a private vehicle. The HASTUS travel times to Google travel times

ratios as stated in Section 3.1.2 were used to determine the travel times of the modified routes. The estimated amount of time it would take to travel the entire proposed route 27 would be 40 minutes inbound, 46 minutes outbound compared to its original time of 32 minutes inbound, 35 minutes outbound. However, for students transferring at Highland Street, their estimated times of travel accounting for any transferring to and from the Auburn Mall are as follows:

College	Original Travel Time	Modified Travel Time
WPI/Becker College	1 hour 7 minutes*	32 minutes
Worcester State University	1 hour 19 minutes*	54 minutes
Clark University	30 minutes	30 minutes
*The original travel times are all based partially or wholly on firsthand experience.		

TABLE 23: TRAVEL TIMES TO AUBURN MALL

EFFECT ON MAIN STREET SERVICE

Switching the 27 to run down Park Ave. has a negative impact on the Main St. service. Main Street is currently the most popular route and has an average headway of about 15 minutes when routes 19, 27 and 33 are combined. This average headway is mostly a result of the 15 and 20 minute headways created by routes 27 and 19. Eliminating route 27 from Main Street increases the average headway to about 25 minutes. However, without route 27 there is no distinct pattern of time between buses and there are many occurrences where buses are 35 minutes apart.

ROUTE 30

There were two options for covering the section of Park Ave. North of Highland St. including route 30 and route 31. The section of the routes that would be modified are currently identical, so both were viable options. Route 30 was first chosen because the 31 goes to Lincoln Plaza and the other route that goes to Lincoln Plaza, the 26, was already affected by modifying the 27. Other reasons to adjust route 30 to run down Park are as follows:

- To run past Price Chopper, a popular grocery store

- Any destinations wished to be reached on Grove Street could still be attained by route 31
- The small modification would create a more direct route to the Greendale Mall, West Boylston Walmart, and Wachusett Plaza for multiple colleges without cutting out any important stops prior to the adjustment

The proposed Route 30 outbound would run down Highland and Park instead of Grove Street, following Rt. 3 for the section between Highland and City Hall to ensure bus maneuverability. The proposed inbound and outbound routes are shown below.

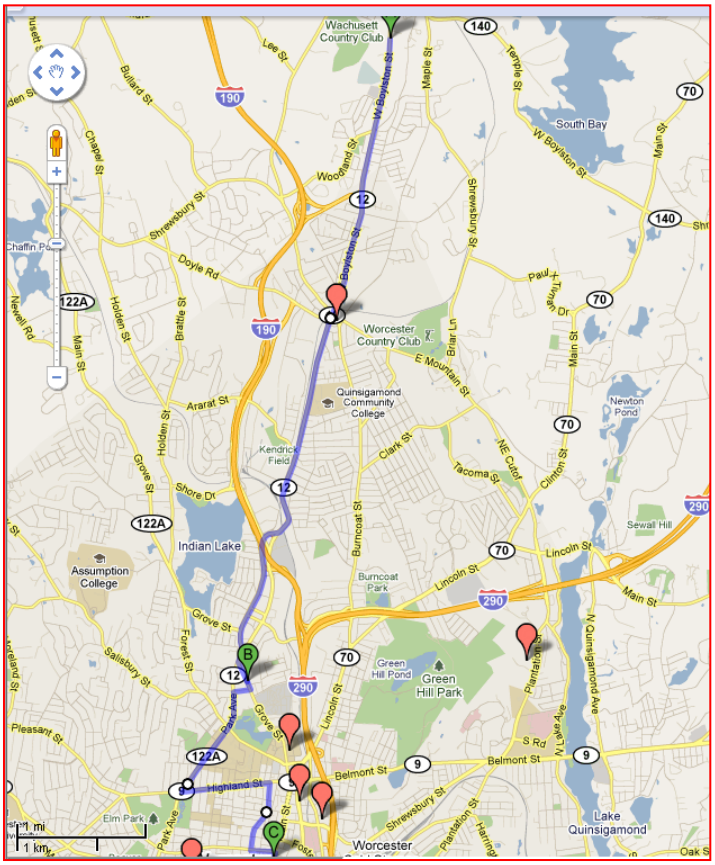


FIGURE 14: ROUTE 30 INBOUND

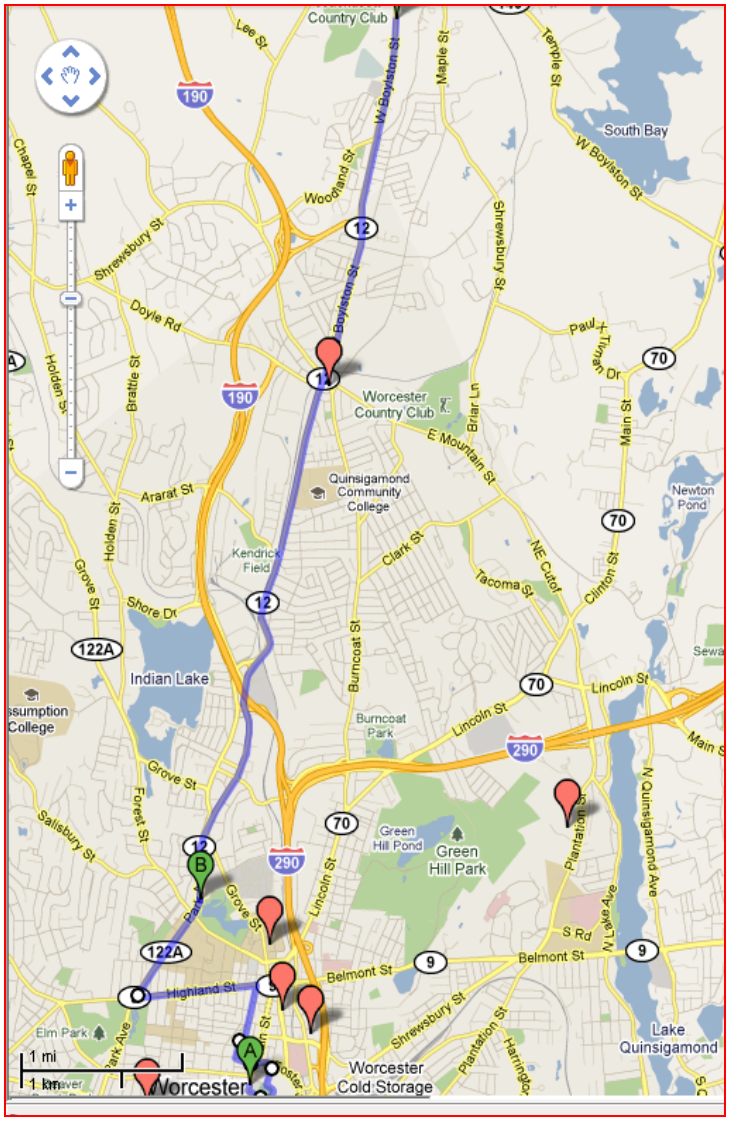


FIGURE 15: ROUTE 30 OUTBOUND

Using Route 30 to attain a HASTUS to Google ratio of 2.5:1 minutes for its section, the following table shows the time saved by modifying Routes 30 and 27:

College	Destination	Original Travel Time	Modified Travel Time
WPI/Becker College	Greendale Mall	12 minutes*	10.2 minutes
	West Boylston Walmart	28.1 minutes	27.2 minutes
Worcester State University	Greendale Mall	41.1 minutes	18.2 minutes
	West Boylston Walmart	50 minutes	35.2 minutes
Clark University	Greendale Mall	10 minutes	31.1 minutes
	West Boylston Walmart	40 minutes	33.2 minutes
*Based partially or wholly on firsthand experience			

TABLE 24: TIME SAVINGS

NEW PARK AVE. ROUTE

Since changing Route 27 to run down Park Avenue had such an extreme effect on the Main Street service an additional route to run down Park was created. Three options with different ending destinations along the New Park Ave Route were considered. Adding a route instead of modifying existing routes to run down Park Ave. is ideal because it has no negative effects on the existing routes. The route would be desirable to college students because it reaches popular destinations on Park Ave. and West Boylston Street without the need to transfer at City Hall.

There are several options to be considered when adding a route to run along Park Ave. Option 1 runs from two stops already in the WRTA's service, the Auburn Mall and Wachusett Plaza. Option 2 has the route run past the Wachusett Plaza to the West Boylston Walmart as Route 30 does. The route length on the southern end is then decreased to Webster Square Plaza resulting in a decreased headway. Option 3 considers having the bus stop at the Greendale Mall on the northern end of the route and turn around in its driveway which decreases the total length of the trip from the Auburn Mall by about 30 minutes, in turn decreasing the headway between buses. Since the biggest expense of adding a new route is operator wages the cost of adding the route would be about the same no matter which option is chosen, but one may be more attractive to riders because of its destinations or decreased headways.

OPTION 1: AUBURN MALL TO WACHUSETT PLAZA

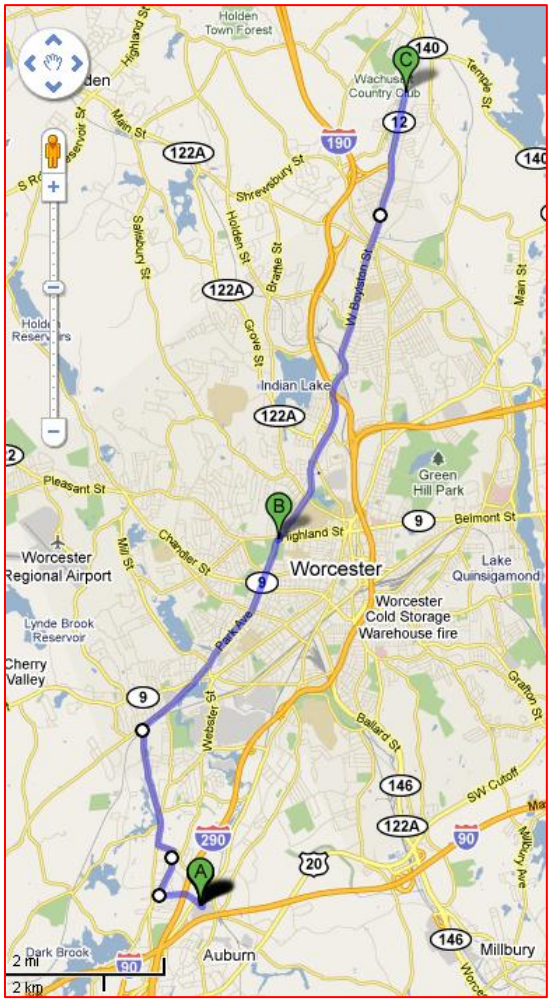


FIGURE 16: PARK AVE ROUTE OPTION 1

Wachusett Plaza was first chosen as the northern ending destination because it is currently only a "by request" stop for the outbound route 30. It consists of Salter College, Planet Fitness, Jazzercise, a few restaurants and a tanning salon. This route also offers a valuable service to the students of Quinsigamond Community College (QCC), who already use the transit system heavily, by adding a direct route from QCC all the way down W. Boylston and Park to the Auburn Mall. This saves the QCC students time by omitting the need to transfer to reach any of the stores, pharmacies or restaurants they may need to reach along Park Ave. The new route would also make traveling down Park Ave. and West Boylston St. much easier, time and cost efficient for students of WPI and

Becker College. There would no longer be a need to travel into City Hall to take the correct outbound bus depending on where on Park Ave. they want to go.

The amount of time to travel for students of different colleges to the Auburn mall would be the same as in Table 23. A Google to HASTUS ratio of 2.5 northbound, 2 southbound was calculated using Routes 30 and 31, making the amount of riding time to reach Wachusett Plaza for multiple colleges as follows:

College	Original Travel Time	Modified Travel Time
WPI/Becker College	40 minutes*	27.5 minutes
Worcester State University	58 minutes	37.5 minutes
Clark University	43 minutes	40 minutes
* Based partially or wholly on firsthand experience with waiting and walking time		

TABLE 25: TIME TO WACHUSETT PLAZA

The Option 1 Park Avenue route would have a round trip of 85 minutes, meaning each bus could travel the full route north and south about 5.7 times a day. If four buses were to be used a 32.5 minute headway would be created. Using methods described in Section 3.3.1, the route is expected to attract about 33% of the population of the colleges it is designed to serve. These schools include WPI, Becker College, Worcester State University, Clark University and Quinsigamond Community College. This totals to about 6,900 student riders. However, one must take into account that the desirability of the transit system to students is low due to the fact that many don't feel the need to leave campus, do not know how to use the transit system or feel that it is unsafe. One must also take into account that the projected riders may only need to reach destinations along Park once or twice a week.

Adding this route to the weekend service would cost the WRTA $108,069.12 if four hybrid buses were to be running. At $38.94/hour, four operators alone cost $99,686.40 and a breakdown of the cost of gas is shown in Table 26 below. If this route were to truly attract 6,900 new student

riders (as calculations show) and they were to take the bus only once a month for the school year (accounting for vacations=9 months) they would account for 62,100 one way trips, or 124,200 trips all together. If four buses were to be used, their fares would pay for all expenses as well as create $264,530.88 in revenue.

	Gillig	Hybrid
Headway: 32.5 minutes (3.7 trips/bus)	$.43/mile	$.30/mile
Option 1 Park Ave Route: 23.6 miles (round trip)	10.15	7.08
Option 1 per day per bus	37.56	26.2
Option 1 per day, 4 buses	150.22	104.78
Option 1 for 2, 8 hour days, 4 buses	300.44	209.57
Option 1 per year (40 weeks), 4 buses	12,017.60	8,382.72

TABLE 26: NEW PARK AVE OPTION 1 GAS COST

Although this would be ideal, because of the low desirability of students to use the public transit system these values are most likely inaccurate. However, one driver count taken in 2010 shows that on a typical day Routes 30, 31 and 27 have a ridership of 1,065 and 589 and 1,155 respectively. These routes have some of the same destinations as a Park Ave route would have. If there is a high enough need in regular riders for a route to run along Park Ave along with any extra ridership from college students the potential revenue recovery could be the same as any of the current routes.

OPTION 2: WEBSTER SQUARE PLAZA TO W. BOYLSTON WALMART

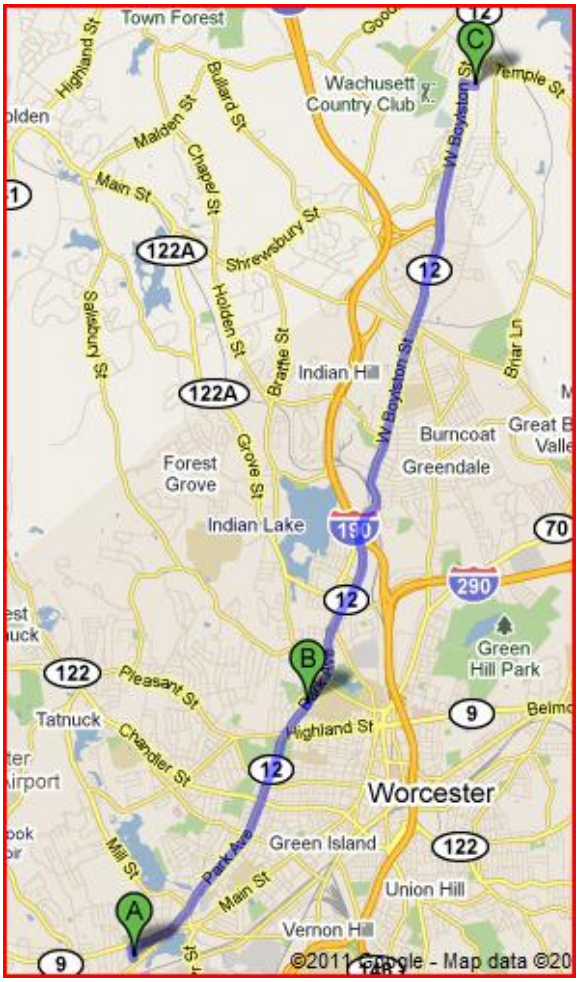


FIGURE 17: NEW PARK AVE. ROUTE RUNNING FROM WEST BOYLSTON WALMART TO WEBSTER SQUARE PLAZA

Having Webster Square Plaza and the W. Boylston Walmart as ending destinations to the new Park Ave. Route would reduce the headway to 21.25 minutes. Travel times to these destinations from colleges served are shown in Table 27 below. The W. Boylston Walmart is a mere 5 minutes north from Wachusett Plaza and could potentially bring in more ridership.

Travel Times from Colleges to W. Boylston Walmart		
College	Original Travel Time	Modified Travel Time
WPI/Becker College	56 minutes*	46 minutes
Worcester State University	1 hour 14 minutes	56 minutes
Clark University	59 minutes	54 minutes
Travel Times from Colleges to Webster Square Plaza		
College	Original Travel Time	Modified Travel Time
WPI/Becker College	30 minutes*	14 minutes
WorcesterStateUniversity	40 minutes*	30 minutes
ClarkUniversity	10 minutes	10 minutes

TABLE 27: TIME TO W. BOYLSTON WALMART AND WEBSTER SQUARE PLAZA

Using the utility function described in Section 3.3.1, about 36% of students this route is intended to serve would utilize the route, totaling 7,805 riders. Calculations are shown in Appendix D. Again, this is unrealistic due to the low desirability or students to use public transit. The gas cost to implement the route on the weekend over the school year using 4 buses is shown in Table 28 below and the cost of operators would again be $99,686.40. If the calculated 7,805 student riders were to use the bus once a month for the school year it would create $101,587.00 in revenue for the WRTA.

	Gillig	Hybrid
Headway: 21.25 minutes (5.7 trips/bus)	$.43/mile	$.30/mile
Option 2 Park Ave Route: 17.6 miles (round trip)	7.57	5.28
Option 2 per day per bus	42.39	29.56
Option 2 per day, 4 buses	169.56	118.27
Option 2 for 2, 8 hour days, 4 buses	339.12	236.54
Option 2 per year (40 weeks), 4 buses	13,564.80	9,461.60

TABLE 28: NEW PARK AVE OPTION 2 GAS COST

OPTION 3: AUBURN MALL TO GREENDALE MALL

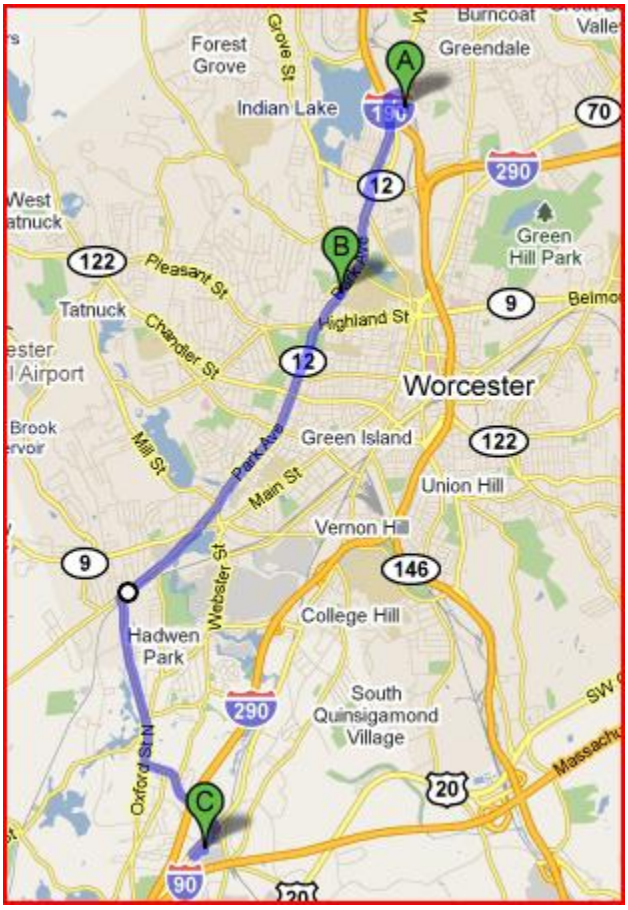


FIGURE 18: NEW PARK AVE OPTION 2

Option 3 considers the new Park Ave. route running from the Auburn Mall to the Greendale Mall as shown in Figure 19 above. This results in headway of 25.5 minutes, allowing for 4.8 round trips/day/bus. The travel times from multiple colleges to the Greendale Mall and Auburn Mall using this route are shown in Table 29 below.

Travel Times from Colleges to Greendale Mall		
College	Original Travel Time	Modified Travel Time
WPI/Becker College	40 minutes*	10 minutes
Worcester State University	41 minutes	18 minutes
Clark University	31 minutes	16 minutes
Travel Times from Colleges to Auburn Mall		
College	Original Travel Time	Modified Travel Time
WPI/Becker College	1 hour 7 minutes*	32 minutes
WorcesterStateUniversity	1 hour 19 minutes*	54 minutes
ClarkUniversity	30 minutes	30 minutes

TABLE 29: TIME TO GREENDALE MALL AND AUBURN MALL

Calculations shown in Appendix E resulted in a projected ridership of 35% of the students serviced for a total of 4,465 students. This number is low compared to the others because the route does not serve QCC. Again, this is unrealistic due to the low desirability or students to use public transit. The gas cost to implement the route on the weekend over the school year using 4 buses is shown in Table 30 below and the cost of operators would again be $99,686.40. If the 4,465 projected student riders were to use this route only once per month for the 9 month school year it would bring a revenue of $13,494.80 to the WRTA.

	Gillig	Hybrid
Headway: 25.5 minutes (4.8 trips/day)	$.43/mile	$.30/mile
Option 3 Park Ave Route: 16 miles (round trip)	6.88	4.8
Option 3 per day per bus	33.02	23.04
Option 3 per day, 4 buses	132.1	92.16
Option 3 for 2, 8 hour days, 4 buses	264.19	184.32
Option 3 per year (40 weeks), 4 buses	10,567.68	7,372.80

TABLE 30: NEW PARK AVE OPTION 3 GAS COST

5. CONCLUSIONS AND RECOMMENDATIONS

After analyzing multiple route changes and alternatives for the WRTA, two routes are being proposed. The first will run down Park Ave. and the second will be a late night route running to popular night time destinations. Both routes were analyzed by the following rubric:

Route Evaluation Rubric	
Category	Criteria
Road Geometry	• Need for a snow route • Ease of turning • Road grade • Width of road
Headway	• Headway with use of 4 buses • Smaller headway is better
Potential Recovery/ Ridership Expectations	• Calculated projected ridership
Destinations	• Popularity of stops
Cost	• Cost of gas • Operator payment is constant for all routes

TABLE 31: ROUTE EVALUATION RUBRIC

This rubric lists the criteria by descending importance. Road geometry was considered most important because the buses must be able to drive down the routes. Headway was next important due to the fact that a decrease in headway provides more convenience to riders. In turn, people who were previously hesitant to ride the bus due to time constraints are now more likely to make use of the WRTA's services. Ridership is important not only because it produces revenue but also because as more people become comfortable riding the bus it will provide advertisement for the WRTA through word of mouth. This project's purpose was to increase student ridership as well as awareness of the transit system. Cost is a major concern of the WRTA's due to the fact that they are given a strict budget each year. However, it is ranked lowest on the rubric because all proposed routes will have similar costs.

The first route that the team will be recommending is the Park Ave. route Option 3 – Auburn Mall to Greendale Mall. This route was decided upon after researching the major travel roads and destinations, and then further narrowing down the end points based on the rubric in Table 32. Although projected ridership is lowest for Option 3, it does not take into account the desirability of the ending destinations. The initial endpoints were the Auburn Mall and Wachusett Plaza because there is a popular gym there for students. However, WPI is constructing a new fitness center which will deter some students from traveling to Wachusett Plaza. Therefore, the Greendale Mall would be a more appropriate end point and it would also decrease headway. The Auburn Mall was chosen as the other endpoint because Webster Square Plaza is not well known by college students and does not have as many stores that appeal to college students.

Park Ave. Route Evaluation Rubric	
Category	Evaluation
Road Geometry	For all alternatives: • No need for snow route • Route includes all major roads • Alternatives travel down same path of current routes when permissible
Headway	• Option 1: 32.5 minutes • Option 2: 21.25 minutes • Option 3: 25.5 minutes
Potential Recovery/ Ridership Expectations	• Option 1: 33% (6,900 students) • Option 2: 36% (7,805 students) • Option 3: 35% (4,465 students)

Destinations	• Option 1:
	  ○ No outside factors affecting desire to go to the mall
	  ○ The desirability of Wachusett Plaza will decrease as a destination when WPI's fitness center is built because Planet Fitness is the biggest draw in Wachusett Plaza
	• Option 2:
	  ○ Many students are unaware of Webster Square Plaza and W. Boylston Walmart
	  ○ Most students would prefer the Walmart Supercenter in Worcester
	• Option 3:
	  ○ No outside factors affecting desire to go to the mall

Cost	• Operator payment is constant for all routes
	• Cost of Gas:
	  ○ Option 1: $8,382.72
	  ○ Option 2: $9,461.60
	  ○ Option 3: $7,372.80

TABLE 32: PARK AVE EVALUATION

The group also recommends piloting the proposed Park Ave. route. The route should only be run one day on the weekend to determine the interest on the route. Running the route for only one day instead of two would cut costs by 50%. Eventually, if there is enough demand the route can be expanded to run the entire weekend or be made into a weekday route.

The second route that is being proposed is the Late Night Route. It was initially considered for three main reasons, with the first being safety. Students who plan to consume alcohol should not be driving, and the buses will provide a safe alternative. Secondly, it would be cost effective. While students do have the option of taking a cab, the bus would be less expensive. Finally, it would provide convenience and ease for traveling in larger groups. Students would know what time to expect the bus to show up, and would not have to split up into smaller groups. If the buses are constantly running to and from all of the different hot spots throughout the night, students will be more likely to utilize the bus in traveling from one location to another, and be comfortable in knowing that they have a reliable ride home at the end of the night. Table 33 shows the evaluation of the three options for the Late Night Route.

Late Night Route Evaluation Rubric	
Category	Evaluation

Road Geometry	• Option 1
	  ○ Travels down same path of current routes when permissible
	• Option 2
	  ○ Travels down same path of current routes when permissible
	• Option 3
	  ○ Moreland Street was determined too narrow and steep for a bus to travel year round
	  ○ Travels down same path of current routes when permissible

Headway	• Option 1
	  ○ Route 1: 40 Minute Headway
	  ○ Route 2: 30 Minute Headway
	• Option 2
	  ○ 40 Minute Headway
	• Option 3
	  ○ 45 Minute Headway

Potential Recovery/ Ridership Expectations	For all alternatives: ○ There is a range of 18% - 160% recovery depending upon what level expectations are met
Destinations	For all alternatives: • Stops at Lietrim's Pub, The Loft and Kelley Square • Stops at all local colleges and universities

Cost	• For all alternatives:
	  ○ Operator pay is constant
	• Option 1 Gas
	  ○ $12, 902.40
	• Option 2 Gas
	  ○ $5,486.40
	• Option 3 Gas
	  ○ $4,492.80

TABLE 33: LATE NIGHT ROUTE EVALUATION

Option 2 is the Late Night Route the team will be recommending to the WRTA based on the evaluation rubric. It does not require transferring to reach any of the stops as Option 1 does and

would not require a snow route as Option 3. While it is not the most inexpensive option, it is only slightly more expensive than Option 3 and more practical based on road geometry. The travel times between stops on Option 2 was also deemed the best of the options, which can be seen below in Tables 34, 35 and 36.

Option 1: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	20	n/a	*32	*22	*26	26
Assumption	18	36	*32	n/a	14	26	*56
WPI/Becker	5	26	*23	14	n/a	12	*37
Clark U	8	14	*26	26	23	n/a	*34
Holy Cross	22	10	26	*56	*37	*34	n/a
*** Transferring, 10 minutes added**							

TABLE 34: LATE NIGHT OPTION 1 MATRIX

Option 2: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	22	n/a	80	12	55	38
Assumption	14	60	80	n/a	64	24	40
WPI/Becker	5	10	10	12	n/a	10	26
Clark U	7	32	58	20	12	n/a	16
Holy Cross	21	16	42	34	32	14	n/a
*** WPI/Becker to Assumption and Clark walks to Park Ave**							
***Clark takes bus to Park Ave for WPI/Becker**							

TABLE 35: LATE NIGHT OPTION 2 MATRIX

Option 3: Travel Time from Colleges to Destinations (minutes)							
College	Lietrim's Pub	Kelly Square	Worcester State	Assumption	WPI/Becker	Clark U	Holy Cross
Worcester State	8	22	n/a	16	12	55	38
Assumption	14	60	16	n/a	14	24	40
WPI/Becker	5	10	10	12	n/a	10	26
Clark U	7	32	58	20	12	n/a	16
Holy Cross	21	16	42	34	32	14	n/a
***Assumption takes bus to Park Ave for WPI/Becker**							
***Clark takes bus to Park Ave for WPI/Becker**							

TABLE 36: LATE NIGHT OPTION 3 MATRIX

The Late Night Route should be run only during the school year from September to early May. The route will attain the most ridership during this time because school is in session and students who may not live in the area over the summer will be around. By reducing the route to only running for 40 weeks out of the year and using the Hybrid buses, the sum of gas usage and driver pay would cost approximately $155,016.00, which is significantly less expensive than running the buses for the entire year. If the ridership falls within the low expectation range (found in Table 14), 24% recovery will still be met.

To increase ridership the group also recommends that a variety of passes should be available to college students. Passes should be made readily available to students in their book stores. These passes should include:

- A $3.00 night pass allowing the student to make as many trips as necessary throughout one night
- A $5.00 week pass allowing the student to make as many trips as necessary throughout one week
- A $15.00 month pass allowing the student to make as many trips as necessary throughout one month

Although these prices may seem cheap, they need to be competitive with Worcester cab services. Also, with low prices students are more likely to purchase a pass even if they are unsure of often they will be riding that particular week or month. The team is not recommending semester or yearly passes because students are not likely to plan that far in advance and would be hesitant to make such a large investment, especially when they do not know what to expect of the services.

While this project will be leading the way for the implementation of new routes there are still further details that could be worked out in future projects. One possible MQP would be analyzing the routes this project proposed to ensure that they are travelable by large buses. The MQP would evaluate the width and grade of the roads utilized along with any other factors they deemed necessary. Another part of this project could be to assess the possibility of the buses entering the campuses as well as the affect it would have on ridership. With the help of the suggested MQP along with some further research the proposed routes could be implemented and successful.

WORKS CITED

(2007). Retrieved September 2010, from CMRPC: http://www.cmrpc.org/document_display.aspx?page_id=34&cat_id=10&cat_type=CAT

(2010). Retrieved September 2010, from APTA: http://apta.com/searchcenter/pages/results.aspx?k=riding%20bus%20is%20safer

Transit Planning. In Anderson, *Planning the Built Environment.*

Basic Design Controls. (2006). Retrieved October 4, 2010, from MassHighway: http://www.mhd.state.ma.us/downloads/designGuide/CH_3_a.pdf

City of Worcester, D. o. (2010). *Demographics & Census Information*. Retrieved September 20, 2010, from City of Worcester, MA: http://www.worcestermass.org/home/about-worcester/special-events/demographics-census-information

Council, N. S. (2010, 10 2). *National Safety Council*. Retrieved 10 2, 2010, from National Safety Council: http://www.nsc.org/Pages/Home.aspx

Criteria for Accrediting Engineering Programs. (2008, November 1). Retrieved February 28, 2011, from http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2009-10%20EAC%20Criteria%2012-01-08.pdf

Farley, J. (2010). MQP. (J. DeFilippo, S. Donnelly, & C. Grygorcewicz, Interviewers)

Gurley, G. (2010). Transit authority's student pass may hold lessons for MBTA. *CommonWealth* .

Hoel, N. G. (2008). *Traffic & Highway Engineering.* Toronto: Cengage Learning.

Mejia, A., & Horvath, N. (2009). *Evaluation of WRTA Service.* Worcester.

Transit Design Manual. (2004, August). Retrieved October 4, 2010, from PalmTran: http://www.pbcgov.com/palmtran/marketing/pdf/library/transit-design-manual.pdf

UPASS. (n.d.). Retrieved September 17, 2010, from Rhode Island Public Transit Authority: http://www.ripta.com/programs/upass.php

WRTA. (2010). Retrieved September 2, 2010, from Worcester Regional Transit Authority: http://therta.com/

WRTA Advisory Board. (2009). *WRTA Annual Report 2009.* Worcester: WRTA.

WRTA. (2010). *Financial Report.* Worcester.

WRTA. (2009). *Fiscal Year 2009 Fuel Usage.* Worcester: WRTA.

WRTA. (2009). *Income Statement.* Worcester: WRTA.

APPENDICES

APPENDIX A: BUS TRIP DETAILS AND OBSERVATIONS

Bus Trip to Greendale Mall 9/29/2010

Bus Routes	Departure Time	Arrival Time	Number of People	Size of Bus	Notes
30 from Ralph's to Greendale Mall	1:32	1:39	Full, had to stand	30'(bus 9307)	Mostly adults, few young people

- 1:17 – 1:32 walk to stop at Ralphs
- Once we got to Greendale Mall were unsure of which stop to go to
    - Walked around to W. Boylston Street crossed highway to Goldstar Blvd. and waited at bus stop near Shell.
        - 1:39 – 1:54 to get to bus stop at Shell
        - Waited until 2:14 then friend picked us up

Bus Trip to Auburn Mall 10/6/2010

Bus Routes	Departure Time	Arrival Time	Number of People	Size of Bus	Notes
3 from Honey Farms to City Hall	2:23	2:31	Half full	40'	Mostly adults, few young people
27 From City Hall to Auburn Mall	2:55	3:30	21 people	40'	
27 From Auburn Mall to City Hall	4:40	5:09			
31 From City Hall to Ralph's	5:20	5:28			

- 5 minute walk from home to honey farms bus stop
- 10 minute walk from Ralphs to home
- Round trip: 3 hours ten minutes including 1 hour ten minute mall trip

Bus Trip to Walmart

Bus Routes	Departure Time	Arrival Time	Number of People	Size of Bus	Notes
30 from WRTA office to City Hall	6:49	6:57	10 w/ us	30’	All old people
11 from City Hall through Kelly Square to Walmart	7:20	7:38	5 w/ us	35’	2 young people and 1 older man

- 6:30-6:45 to walk to bus stop

APPENDIX B: WEEKEND ROUTE PROJECTED RIDERSHIP

Weekend Route		Private Auto			Transit		
School	Miles traveled	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	12	18	2	3.24	36	5	3
Becker	12	18	2	3.24	36	5	3
Assumption	12	18	2	3.24	36	5	3
Worcester State	10.4	13	2	2.808	26	5	3
Holy Cross	10.4	13	2	2.808	26	5	3
Clark	12	18	2	3.24	36	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-1.2124	-0.61739	0.355487	397.7895204
-0.025	-0.05	-0.0208	-1.2124	-0.61739	0.355487	205.4712625
-0.025	-0.05	-0.0208	-1.2124	-0.61739	0.355487	252.3954955
-0.025	-0.05	-0.0208	-0.9624	-0.48341	0.38249	690.7765789
-0.025	-0.05	-0.0208	-0.9624	-0.48341	0.38249	361.4528611
-0.025	-0.05	-0.0208	-1.2124	-0.61739	0.355487	258.4387679

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-1.1812	-0.5837	0.354915	397.1498253
-0.025	-0.05	-0.0104	-1.1812	-0.5837	0.354915	205.1408391
-0.025	-0.05	-0.0104	-1.1812	-0.5837	0.354915	251.9896121
-0.025	-0.05	-0.0104	-0.9312	-0.4542	0.382962	691.6285367
-0.025	-0.05	-0.0104	-0.9312	-0.4542	0.382962	361.8986529
-0.025	-0.05	-0.0104	-1.1812	-0.5837	0.354915	258.0231662

APPENDIX C: NEW PARK AVE OPTION 1 PROJECTED RIDERSHIP

Option 1- Auburn Mall	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	7	14	2	1.89	32	5	3
Becker	7	14	2	1.89	32	5	3
Worcester State	6.4	15	2	1.728	54	10	3
Clark	5	13	2	1.35	30	5	3
Quinsigamond Community College	9.5	17	2	2.565	50	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-1.1124	-0.48931	0.349079	1183.72845
-0.025	-0.05	-0.0208	-1.1124	-0.48931	0.349079	611.5872143
-0.025	-0.05	-0.0208	-1.9124	-0.51094	0.197585	1081.382235
-0.025	-0.05	-0.0208	-1.0624	-0.45308	0.352214	775.9281706
-0.025	-0.05	-0.0208	-1.5624	-0.57835	0.272089	2271.673656

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-1.0812	-0.46966	0.351707	1192.638678
-0.025	-0.05	-0.0104	-1.0812	-0.46966	0.351707	616.1907887
-0.025	-0.05	-0.0104	-1.8812	-0.49297	0.199691	1092.907034
-0.025	-0.05	-0.0104	-1.0312	-0.43904	0.356139	784.5751062
-0.025	-0.05	-0.0104	-1.5312	-0.55168	0.272986	2279.16214

Option 1- Wachusett Plaza	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	6	12	2	1.62	27.5	5	3
Becker	6	12	2	1.62	27.5	5	3
Worcester State	7.5	16	2	2.025	37.5	10	3
Clark	7.5	16	2	2.025	40	5	3
Quinsigamond Community College	2.7	6	2	0.729	10	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-0.9999	-0.4337	0.362113	1227.925836
-0.025	-0.05	-0.0208	-0.9999	-0.4337	0.362113	634.4223135
-0.025	-0.05	-0.0208	-1.4999	-0.54212	0.277323	1517.78821
-0.025	-0.05	-0.0208	-1.3124	-0.54212	0.316419	697.0700431
-0.025	-0.05	-0.0208	-0.5624	-0.26516	0.426233	3558.620227

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-0.9687	-0.41685	0.365435	1239.189535
-0.025	-0.05	-0.0104	-0.9687	-0.41685	0.365435	640.2418356
-0.025	-0.05	-0.0104	-1.4687	-0.52106	0.27936	1528.935554
-0.025	-0.05	-0.0104	-1.2812	-0.52106	0.318616	701.9107648
-0.025	-0.05	-0.0104	-0.5312	-0.25758	0.432019	3606.926628

APPENDIX D: NEW PARK AVE OPTION 2 PROJECTED RIDERSHIP

Option 2-Webster Square	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	3.1	9	2	0.837	14	5	3
Becker	2.8	9	2	0.756	14	5	3
Worcester State	2.9	7	2	0.783	24	10	3
Clark	1.3	5	2	0.351	10	5	3
Quinsigamond Community College	6.2	15	2	1.674	26	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-0.6624	-0.34241	0.420678	1426.519395
-0.025	-0.05	-0.0208	-0.6624	-0.34072	0.420268	736.3087355
-0.025	-0.05	-0.0208	-1.1624	-0.29129	0.295023	1614.658897
-0.025	-0.05	-0.0208	-0.5624	-0.2323	0.418216	921.3309197
-0.025	-0.05	-0.0208	-0.9624	-0.50982	0.388747	3245.651485

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-0.6312	-0.3337	0.42617	1445.142186
-0.025	-0.05	-0.0104	-0.6312	-0.33286	0.425964	746.2887894
-0.025	-0.05	-0.0104	-1.1312	-0.28314	0.299841	1641.02786
-0.025	-0.05	-0.0104	-0.5312	-0.22865	0.424934	936.1303309
-0.025	-0.05	-0.0104	-0.9312	-0.49241	0.392029	3273.052045

Option 2 - W. Boylston Walmart	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	6.4	13	2	1.728	30	5	3
Becker	6.8	15	2	1.836	30	5	3
Worcester State	7.9	17	2	2.133	40	10	3
Clark	8	17	2	2.16	37.5	5	3
Quinsigamond Community College	3.2	7	2	0.864	12.5	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-1.0624	-0.46094	0.35401	1200.448889
-0.025	-0.05	-0.0208	-1.0624	-0.51319	0.366047	641.3151078
-0.025	-0.05	-0.0208	-1.5624	-0.56937	0.270313	1479.424699
-0.025	-0.05	-0.0208	-1.2499	-0.56993	0.336268	740.7974169
-0.025	-0.05	-0.0208	-0.6249	-0.29297	0.417771	3487.97334

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-1.0312	-0.44297	0.357041	1210.727228
-0.025	-0.05	-0.0104	-1.0312	-0.49409	0.368861	646.2447348
-0.025	-0.05	-0.0104	-1.5312	-0.54718	0.272095	1489.178618
-0.025	-0.05	-0.0104	-1.2187	-0.54746	0.33822	745.0989574
-0.025	-0.05	-0.0104	-0.5937	-0.28399	0.423184	3533.166991

APPENDIX E: NEW PARK AVE OPTION 3 PROJECTED RIDERSHIP

Option 3 - Auburn Mall	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	7	14	2	1.89	32	5	3
Becker	7	14	2	1.89	32	5	3
Worcester State	6.4	15	2	1.728	54	10	3
Clark	5	13	2	1.35	30	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-1.1124	-0.48931	0.349079	1183.72845
-0.025	-0.05	-0.0208	-1.1124	-0.48931	0.349079	611.5872143
-0.025	-0.05	-0.0208	-1.9124	-0.51094	0.197585	1081.382235
-0.025	-0.05	-0.0208	-1.0624	-0.45308	0.352214	775.9281706

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-1.0812	-0.46966	0.351707	1192.638678
-0.025	-0.05	-0.0104	-1.0812	-0.46966	0.351707	616.1907887
-0.025	-0.05	-0.0104	-1.8812	-0.49297	0.199691	1092.907034
-0.025	-0.05	-0.0104	-1.0312	-0.43904	0.356139	784.5751062

Option 3 Greendale	Private Auto				Transit		
School	Miles	IVTT	OVTT	COST	IVTT	OVTT	COST
WPI	2.2	6	2	0.594	12.5	5	3
Becker	2.6	7	2	0.702	12.5	5	3
Worcester State	3.7	10	2	0.999	22.5	10	3
Clark	3.8	10	2	1.026	20	5	3

$5,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0208	-0.6249	-0.26236	0.410344	1391.475424
-0.025	-0.05	-0.0208	-0.6249	-0.2896	0.416952	730.4999076
-0.025	-0.05	-0.0208	-1.1249	-0.37078	0.319924	1750.944396
-0.025	-0.05	-0.0208	-0.8124	-0.37134	0.391489	862.4494124

$10,000 income						
b	*c*	*d*	*Ut*	*Ua*	*P(t)*	Projected riders
-0.025	-0.05	-0.0104	-0.5937	-0.25618	0.416411	1412.051196
-0.025	-0.05	-0.0104	-0.5937	-0.2823	0.422773	740.6987284
-0.025	-0.05	-0.0104	-1.0937	-0.36039	0.324469	1775.817215
-0.025	-0.05	-0.0104	-0.7812	-0.36067	0.39639	873.2472327