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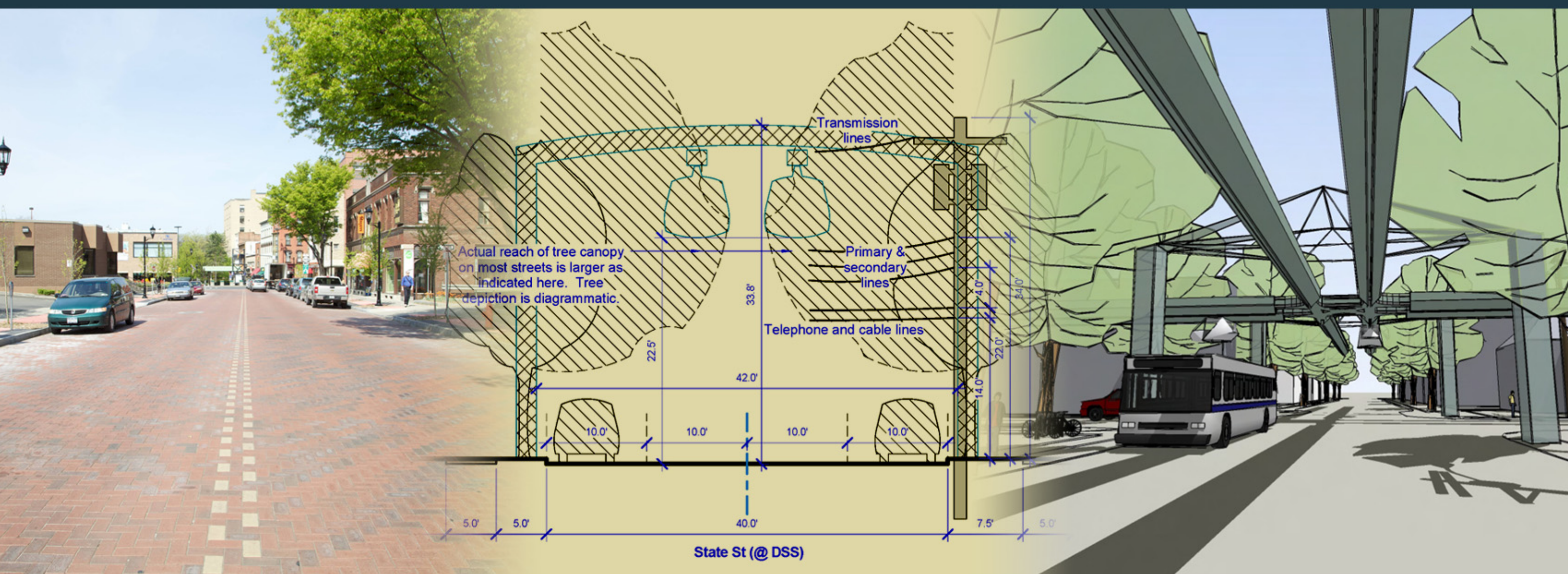

Feasibility of PRT in Ithaca, New York

Final Report

September 2010

FEASIBILITY OF
PERSONAL RAPID TRANSIT IN ITHACA, NEW YORK
Final Report

Prepared for

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Personal Rapid Transit (PRT) is an emerging technology that has the potential to reduce the emission of greenhouse gases and the consumption of petroleum products by reducing vehicle miles traveled (VMT). This research study funded by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT) evaluates the feasibility of implementing a PRT system and policies to promote transit oriented development (TOD) in Ithaca, NY. The report documents the history and current state of PRT development. It defines the various components of a PRT system and identifies the most appropriate components for application in Ithaca. Through economic and environmental assessments, the study documents how the PRT system together with TOD will reduce vehicle miles travelled, enhance the quality of life and promote economic development in New York’s small and mid-sized cities.</td></tr>
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ABSTRACT

Personal Rapid Transit (PRT) is an emerging technology that has the potential to reduce the emission of greenhouse gases and the consumption of petroleum products by reducing vehicle miles traveled (VMT). This research study funded by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT) evaluates the feasibility of implementing a PRT system and policies to promote transit oriented development (TOD) in Ithaca, NY. The report documents the history and current state of PRT development. It defines the various components of a PRT system and identifies the most appropriate components for application in Ithaca. Through economic and environmental assessments, the study documents how the PRT system together with TOD will reduce vehicle miles travelled, enhance the quality of life and promote economic development in New York's small and mid-sized cities.

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SUMMARY

Personal Rapid Transit (PRT) is an emerging technology that has the potential to reduce the emission of greenhouse gases and the consumption of petroleum products by reducing vehicle miles traveled (VMT). This research study funded by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT) evaluates the feasibility of implementing a PRT system and policies to promote transit oriented development (TOD) in Ithaca, NY. The study assesses how the PRT system together with TOD will enhance the quality of life and promote economic development in New York's small and mid-sized cities.

PRT (also known as *PodCar*) is a subset of a type of mechanized public transportation system known as an Automated Transportation System (ATS), Automated Group Transit (AGT), or Automated People Mover (APM). PRT has the following features that differentiate it from APMs and other forms of traditional transit:

1. 24-hour on demand service
2. Non-stop direct service
3. Fully automated vehicles
4. Small vehicles: one (1) to six (6) passengers
5. Small dedicated guideway

PRT Development

Even though some of the key concepts of PRT have been tinkered with for over a century, contemporary PRT discourse did not really begin until around 1953 when Donn Fichter, an American planner now retired from the NYSDOT, first sketched out a PRT system he called Veyar. Early PRT system development and implementation took place in the late 1960s through the 1970s. It was during this period that the Urban Mass Transportation Administration (UMTA) contracted with NASA's Jet Propulsion Laboratory to develop the Morgantown Personal Rapid Transit project, the first automated people mover in the U.S. at the University of West Virginia. The system is still in continuous operation with about 15,000 riders per day (as of 2003). Several other systems were also developed and tested in Europe and Asia. However, in the early 1980s there appears to have been a loss of interest in PRT. The General Accounting Office issued a report entitled *Better Justification Needed for Automated People Mover Demonstration Projects* and Congress withdrew support for the development program of automated transportation systems with three-second headways. Recent advances in PRT technology and the eminent commercial operation of a PRT system at London's Heathrow Airport and Masdar City, Abu Dhabi, have generated renewed interest and promotion of PRT.

While there are fourteen different systems in various stages of research, design, testing and implementation, only three systems are currently commercially viable.

1. BAA/ULTra : Bristol, United Kingdom, EU - The first modern PRT system is in place at London's Heathrow Airport. The system is carrying employees and is slated for full passenger service in the fall of 2010.
2. 2getthere: Utrecht, Netherlands, EU – Masdar City in United Arab Emirates (UAE) is being designed with a subterranean PRT system. The system provider, 2getthere, is undergoing operational testing and is expected to provide public service in late 2010.
3. VECTUS, LTD: Uppsala, Sweden and Seoul, Korea - VECTUS, a UK registered company, with branch offices in Korea and Sweden received passenger safety certification from the Swedish Rail Authority in early 2009 and is scheduled to deploy a PRT system in Suncheon, South Korea in 2013.

Description of PRT

Among PRT systems that are being implemented and planned, there is substantial diversity in the approach to design. This study reviews the following system components and characteristics:

System Components

1. Guideway

A primary system component is the dedicated guideway which can be at-grade, elevated or underground. The guideway is structured as a network, unlike the line haul system of traditional transit. The network configuration allows vehicles to select the most direct route between stations.

PRT guideways are smaller than traditional transit requiring less right-of-way and capital expenditure and reducing visual impacts. PRT guideways are generally classified as one of the following:

- *Open guideway* –The system consist of a flat surface that supports the vehicle. Vehicles typically have rubber wheels and steer themselves, sensing their position relative to side walls or other fixed objects.
- *Captive bogey.* In this system, the vehicle is supported by the chassis it rides on. The vehicles typically have horizontal wheels that run along and are held captive by side elements. The guideway steers the vehicle.
- *Suspended.* Vehicles in this system are suspended (hang) from the guideway.

2. Vehicle

The vehicle design is dependent on guideway type and will vary by vendor. The optimum vehicle size is in the range of two to six passengers to provide convenient, demand-based service with maximized energy efficiency.

3. Propulsion

The PRT industry has primarily worked with electric propulsion, although some have a gas powered option. Within electric propulsion there are two concepts to consider – power source and propulsion method. Power source can be provided by batteries within vehicles or a lineside conductor (power rail). The propulsion method is typically provided by traditional rotary motors that drive wheels or linear electric motors that propel the vehicle via electromagnetic resistance.

4. Switching

There are two general types of switching used in transportation systems- mechanical and electromagnetic. Mechanical systems require a moving physical component, while electromagnetic methods simply guide the vehicle via magnetic attraction and no moving parts. Mechanical switching is typically a vehicle-mounted mechanism that deploys well in advance of the diverging point on the guideway and maintains control specific to each vehicle. In the event that a vehicle-mounted mechanical switch fails the problem is isolated to the vehicle. The use of electromagnetic switching is becoming more popular as the PRT technology has matured. Some systems place the switch in the guideway but like mechanical switches, a vehicle mounted switch is preferable to avoid a system wide shutdown in the event of a switch failure.

5. Stations

A primary feature of PRT stations is that they are situated on off-line side tracks so that through-traffic can bypass vehicles picking up or dropping off passengers. This allows the system to provide direct, non-stop service to each vehicle. Unlike traditional heavy and light rail stations that need to accommodate the full length of the train, PRT stations are sized to meet the local demand at peak times.

6. Maintenance and Storage Facilities

A depot is needed to service vehicles to maintain reliability, clean vehicles, and store vehicles not used during off-peak periods. Depending on the overall configuration of the PRT system the number and dispersion of depots will vary. In general it seems practical to locate depots at the periphery of urban areas where the necessary land acquisitions is more feasible or place them in areas of high demand such as near a collegiate sporting arena.

System Characteristics

1. Headway

Headways refer to the spacing between vehicles and can be defined in terms of time or distance. From a safety standpoint headways are usually determined by the stopping distance required to prevent a lead vehicle that is stopped from being struck by the vehicle behind it. The spacing of pods on the guide-way influences the overall maximum passenger capacity of the entire network, so designers prefer to achieve smaller headway distances. Testing has shown that headways of one to two seconds are achievable. One system, VECTUS, has obtained safety approvals to operate at 3 seconds headways.

2. Travel Speed

PRT systems have been simulated to operate with a line speed in the range of 25 to 45 MPH, which often results in an average speed of 20 to 25 MPH. These simulations factor in the impacts of system congestion on switches and potential reduced speeds under times of heavy system loads. In comparison buses average 12 MPH and light rail averages 15 MPH.

3. Capacity

PRT systems vary their capacity by increasing the number of vehicles or pods in the system and reducing the headways between vehicles. Studies have estimated that the capacity of a PRT system can range from a capacity similar to the auto (1,800 passengers per hour) to a capacity comparable to light or commuter rail (14,400 passengers per hour).

Application of PRT in Ithaca

The City of Ithaca was selected as a case study to assess the feasibility of implementing a PRT system in New York. The city's population is 29,287 and the greater metropolitan area has a population of 100,135. The total number of jobs within Tompkins County, where Ithaca is located, is 57,032. The City is also home to two major college campuses: Cornell University and Ithaca College. These demographics are consistent with areas that have a growing demand for transit and where PRT is stated to be the most efficient. Several recent local studies have also documented the need for improved transit service and the desire to have increased development density that would rely on alternative transportation modes. The study documents the various considerations for implementation of PRT in Ithaca, NY.

Research and Data Collection

Existing relevant studies were compiled and reviewed to obtain background transportation and travel behavior information. Fully 40 percent of Tompkins County commuters currently use alternative modes of transportation, compared to only 25 percent nationwide. Several studies document the region's continued support of transit and increased density in urban areas and the Ithaca-Tompkins County Transportation Council Long Range Plan suggests that PRT as a transit option is worth further investigation.

Route Prioritization

A full PRT system for Ithaca would include an extensive network connecting West Hill, South Hill and East Hill/Cayuga Heights; serving as a circulator route between downtown and the major educational institutions, as a connector between park and ride facilities and these major employment centers and provide access to retail and medical facilities on the city's perimeter. However, the extent of the PRT system is limited by the funding for this study and therefore focuses on a Phase 1 section that will link Cornell University, Downtown and Ithaca College. These three destinations were selected because they offer the highest density of workplaces in the county, have a broad mix of uses, and have a significant amount of existing housing within a five-minute walk of the proposed system. In addition to serving the three major destinations, the following considerations were taken into account in the assessment of route prioritization:

1. The area served by the route must have sufficient capacity to support new mixed-use, transit-oriented development (TOD).
2. The route must provide access to storage parking location(s) to insure the near term market viability of new housing development, and ease existing parking problems in neighborhoods surrounding developed or developing areas like Collegetown.
3. The route must extend to or include a location suitable for a maintenance and operations facility (likely including pod storage tracks).

Another consideration in the development of the preferred route is the use of single versus double track configurations. PRT is best organized in looping configurations where a single track carries vehicles running in one direction along one street, and another single track carries traffic in the opposite direction on another street. This distributes the PRT service, allowing for the location of stations over a larger service area. It also distributes the infrastructure over a greater area, impacting more locations but with a smaller sky-print at each location. Double track, with both travel directions supported on one set of poles along a single street, concentrates the infrastructure impacts in one location; however, the sky-print of double track is greater than for single. Route prioritization minimizes the use of double track configurations. The proposed route is depicted in the following figure and summarized below:

Guideway Length: *Total equivalent double track length – 4.5 miles*

Single track – 4 miles/Double track – 2 miles/Station associated track – 1 mile

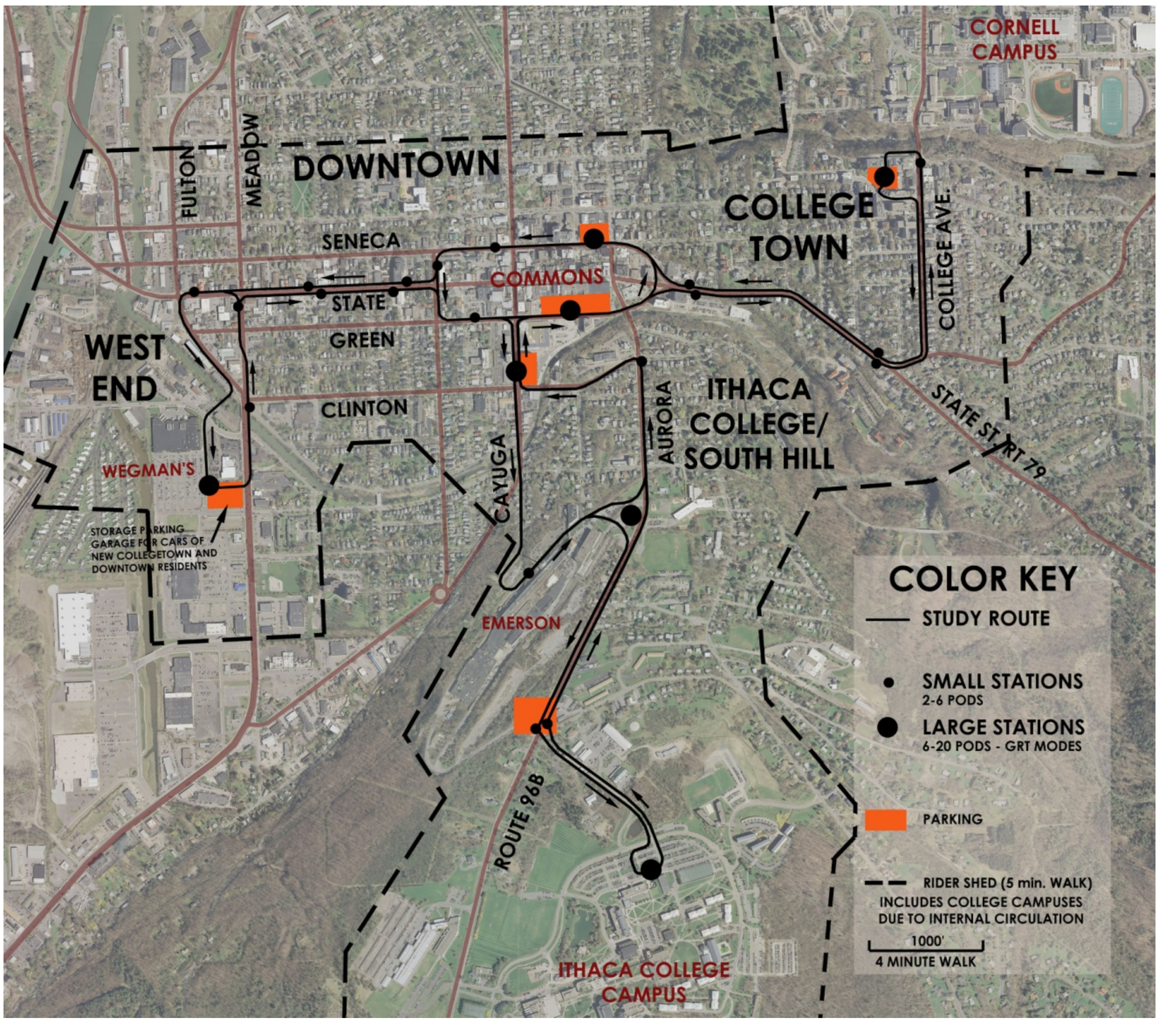
Total equivalent single track length – 9 miles

Stations: *26 Total Stations*

7 Large stations (4 berths each)/19 Small stations (2 berths each)

Vehicles: *350*

Storage Depots: *Total capacity for 500 vehicles* (provided in two facilities)



Proposed Route

Technical Feasibility

Optimum technical characteristics of a PRT system operating in Ithaca, New York were developed based on the scale and character of the existing built environment, the Upstate NY climate, and Ithaca's challenging topography. One of the largest factors regarding physical integration of a PRT system into an existing urban streetscape is the utility infrastructure. Not only would the guideway have to be kept above standard road clearance heights, but also it would have to negotiate the telephone, communication, and power lines that cross the right-of-ways (ROWs). The concept of integrating these utility lines into the PRT infrastructure is interesting and provocative but may be politically and fiscally difficult. Therefore, this study assumes that the PRT system will share the ROW with the existing utility line infrastructure. With the above factors in mind, the following system characteristics have been identified:

- Minimum turning radius must be 50' (15m) or less to keep track within public rights of way.
- System must exhibit quieter than automobile operation (<65db) because of inevitable proximity to buildings.
- System selected must have enough design flexibility to allow for track to be positioned over the center of streets, above the touching point of the tree canopy, so as to hide the infrastructure from the pedestrian level and to minimize impingement of natural tree shapes.
- Track underside should not exceed 24" (0.6m) to minimize the visual impacts of overhead tracks, especially where dual direction lines are located.
- Support pole spacing should be equal to or exceed utility pole spacing (60' – 80' average).
- Edge to edge visual intrusion of support structures must be minimal. (<24" dia.).
- In most areas opposing support poles would ideally be placed on the sides of the road, typically within the tree lawns, and connected with cross-beams to support the guideways running over the center of the streets.

Preferred Guideway for Ithaca System - Although this is an area that will require additional research, based on currently available data the preferred system for Ithaca, NY would include an elevated guideway with either a captive or suspended bogey.

Vehicle - A critical factor of the physical vehicle design in a PRT system is size. One of the differentiating factors that separate PRT from other transit modes is the small vehicle size and number of passengers. The optimum vehicle size is in the range of two to six passengers to provide convenient, demand-based service with maximized energy efficiency. The most notable difference between the vehicle concepts that currently exist is seat orientation. The vehicle side and seating orientation would be determined during the design of a system. Other considerations for vehicle design are the suspension and braking systems which will depend of the type of guideway and propulsion systems used.

Propulsion - Linear Induction Motor (LIM) driven systems appear to be the logical choice for smaller PRT networks that do not require high speeds. Ultimately the propulsion choice for a PRT system will have long term impacts in terms of energy efficiency, serviceability, and continued viability.

Policymakers will want to make the most effective choice with the inevitable public funding that will support PRT implementation, so additional study of this topic is recommended.

Switching - The clear advantages of magnetic switching over mechanical systems are speed, reliability (even more so with redundancy), less susceptibility to weather, and logical integration with propulsion systems using linear electric motors. The decision on the type of switching to utilize will fall on the manufacturers of the preferred PRT system and would ideally have the ability to upgrade or transition from one switching type to another. In vehicle switching is preferred for system reliability and maintenance.

Stations - A key characteristic of PRT is the off-line station configuration that allows for all trips to be non-stop from origin to destination by bypassing intermediate stations. Because of the above grade design a logical place for station locations is over small parking lots since the current land use would be minimally affected. Another location for easy and logical station locations is adjacent to large "big box" retailers where parking facilities and space are ample, the locations are typically peripheral to urban core areas and thus make good park-n-ride locations, and the environmental impacts of surface parking and predominant automobile access can be relieved by PRT trips. Within the urban core a logical placement of stations is to build them into parking garages since this provides parking as well as long building facades for the platforms. Since stations will be on private property, additional research and coordination with property owners is required to assess their willingness to cooperate and the feasibility of using existing structures.

Maintenance and Storage Facility - The maintenance of a transportation system plays a significant role in the long term viability of a system. To provide adequate space for service bays, cleaning and vehicle storage, it is anticipated that two 250 berth storage depots would be required, each with a building footprint of approximately 165' x 140' with two upper storage floors for a total square footage of 51,100 SF. Above the larger first story footprint would be ample space to construct offices and a system control center.

Headway - Headway is defined as the time or distance between moving vehicles. Headways of 3 to 5 seconds would provide an acceptable level of service in Ithaca.

Travel Speed - PRT systems have been simulated to operate with a line speed in the range of 25 to 40 mph, which often results in an average speed of 20 to 25 mph. These simulations factor in the impacts of system congestion on switches and potential reduced speeds under times of heavy system loads.

Capacity - In an effort to understand the impacts and performance of an initial Ithaca PRT system some simulations were performed utilizing Beamways' proprietary software BeamEd, which documented the feasibility of a design hour volume of approximately 3,000. This is consistent with the ridership projection assuming no new transit oriented development. If additional development were to occur along the PRT system, the system would need to add vehicles and/or be expanded into a network configuration.

Right-of-Way Assessment

A series of assumptions were developed to assess the potential ROW requirements for a PRT system in Ithaca. The majority of the system will be placed within the existing road ROW, owned by the City of Ithaca or State of New York. In some sections, curb extensions will be required to accommodate the poles. This will result in some loss of parking that would be determined during the design phase. The locations where the PRT system deviates beyond the existing public ROW are near the Collegetown station, Wegman's station and the Ithaca College station. It is anticipated easements will be required for seven tax parcels to accommodate track infrastructure.

Large stations identified in the study route are proposed to be integrated into existing parking garages. It is assumed that the larger stations utilize stairs and elevators in the existing parking garages. The Dryden Road Garage and Green Street Garage stations are planned to be on the roof of the garages. The height of the Seneca Street and Cayuga Street garages (8 stories), places the stations at the 3rd or 4th parking levels. The large station at Wegman's would be built into the storage parking garage, integrated with the building. New structures will need to be built in the Ithaca College and the manufacturing parcel to the west of Aurora St. A private negotiation with seven property/facility owner is necessary to determine the value of individual easements and acquisitions. These negotiations will also need to address the following issues:

- Access to privately-owned parking garages need to be obtained,
- The potential loss of parking needs to be addressed, and
- The structural feasibility of the overhanging station platforms need to be analyzed.

Several small stations are also planned along the PRT system. Fifteen tax parcels will be impacted by the construction of small stations.

Constructability Assessment

The construction of an elevated PRT system is comparable to an elevated light rail system although the low weight of small pods allows smaller guide-ways and support structures than light-rail. These smaller structures translate into lower construction cost and smaller easements. The primary issues associated with construction are associated with the construction of a new system in an already constrained urban environment. Key issues include site logistics and constraints:

- Maintain access to adjacent buildings,
- Utility clearances and potential relocation,
- Maintenance and protection of traffic,
- Potential disruption of the groundwater,
- Potential impacts to adjacent buildings,
- Crossing of six-mile creek, and
- Use of existing structures for stations.

Assessment of Transit Oriented Development

An analysis was conducted to determine the potential for transit oriented or transit supportive development (TOD or TSD) within the area served by the proposed PRT Phase 1 Route. The area within a 5-minute walk of the system contains approximately 10,400 residents and 300 to 400 businesses. With the inclusion of the 26,000 students and 11,000 workers at the college campuses, the proposed system area would likely provide the minimum population density, job concentration and destination characteristics necessary for viability as determined by the 2007 study *Viability of Personal Rapid Transit in New Jersey.* This suggests that density is not required to implement PRT. However, the development of a PRT system will provide the opportunity for additional higher density development with reduced on-site parking requirements thereby reducing vehicle miles traveled and associated greenhouse gas emissions. TOD will also support increased PRT system ridership providing financial support for operation and maintenance activities.

Four development scenarios were generated for comparison of land use and ridership forecasts:

- Scenario 1: Theoretical development potential per current zoning.
- Scenario 2: Actual development potential tempered by market demands for parking.
- Scenario 3: Development potential per current zoning with PRT.
- Scenario 4: Development potential of expanded zoning envelope.

Ridership Forecast

Ridership for the PRT system in Ithaca is assumed to occur from the following scenarios:

1. Shift from the existing Tompkins Consolidated Area Transit (TCAT) bus service
2. New demand resulting from shift in mode share
3. New demand from transit oriented development
4. New demand from proposed Park and Ride service

Ridership forecasts were developed for the four development scenarios. The base ridership without any TOD that includes the displacement from TCAT service, shift in mode share and proposed Park & Ride Service is first estimated. To highlight the importance of TOD to the total ridership, TOD scenarios 3 and 4 are added respectively to the base ridership.

PRT Ridership Sources	DHV	Weekday Daily	Weekend Daily	Annual
Total Ridership without TOD	3,110	12,660	4,160	3,734,500
Total Ridership - TOD Scenario 3	4,190	23,720	13,860	7,629,600
Total Ridership - TOD Scenario 4	5,790	40,550	28,460	13,540,000

In comparison, the average daily ridership for Morgantown GRT in 1995 was 14,000 with a record daily ridership of 30,175. The anticipated base ridership for Ithaca PRT (12,660) is close to the average daily ridership of Morgantown PRT. TOD Scenario 3 that has the development potential per current zoning with PRT brings the Ithaca PRT ridership (23,720) closer to the record Morgantown ridership. TOD Scenario 4 which includes the development potential of expanded zoning envelope makes the Ithaca PRT ridership exceed the Morgantown PRT record ridership.

Approval Requirements

The following approvals will be required to construct and operate a PRT system in Ithaca, New York.

- Federal – If federal money is used the project will need to go through the Metropolitan Transportation Planning Process, comply with the National Environmental Policy Act (NEPA) and be sponsored by a public entity.
- State – The development of the system will require:
  - approval from the New York State Department of Transportation (NYSDOT),
  - compliance with 6 NYCRR Part 617 State Environmental Quality Review (SEQR),
  - compliance with terms and conditions of a NYSDOT Highway Work Permit, in accordance with New York State Highway Law, Article 3, Section 52,
  - operating authority through the New York State Department of Transportation (NYSDOT) NYSDOT Registrating and Permitting Bureau,
  - development of a System Safety Program Plan (SSPP) approved by New York's Public Transportation Safety Board (PTSB),
- Regional - To receive federal funding, the development of a PRT system needs to receive approval from the Ithaca-Tompkins County Transportation Council (ITCTC) and be incorporated into the Transportation Long Range Plan and ultimately the Transportation Improvement Program (TIP)
- Local – The City of Ithaca would need to approve the development of a PRT system and transit-oriented development. If approved the following additional approvals and actions would be required by the City of Ithaca:

    - amendment to the City Zoning Code for transit-oriented/supportive development,
    - sub-division approval and site plan review through the City of Ithaca Planning and Development,
    - building permits through the City of Ithaca Building Department,
    - easements within the city owned road right-of-way and street permits through the City of Ithaca Department of Public Works.
- Other – The design and construction of the system may require relocation of some existing utilities that would require coordination and approval with individual companies. It is recommended that the PRT system comply with the voluntary standards established by the American Society of Civil Engineers (ASCE).

Capital and O&M Costs

Development of capital and operation and maintenance costs were developed based on data provided by seven PRT vendors who responded to a request for information (RFI). The following is a summary of the estimated capital costs per mile of double track:

Guideway & infrastructure:	$15 million per mile
Vehicles:	$3-6 million per mile
Stations:	$4 million per mile
Storage and Maintenance Facilities:	$4 million per mile
Total:	$26-29 M per mile

The Study Route is the equivalent of approximately 5.75 miles of double track so the total infrastructure cost of a PRT system similar to the Ithaca Study Route would be $150 to $168 million. It is anticipated that design will be 16% of the capital costs, adding $24-27 million. With the additional $1.5 million anticipated for ROW acquisition, the total estimated capital cost of a PRT system in Ithaca that can be used for planning purposes is $175 to $196 million. Based on the average of this cost range, $186 million, the per mile cost for a PRT system in Ithaca can be estimated at $32 million per mile of two-way track. This is consistent with estimates by Booz Allen Hamilton, in the Viability of Personal Rapid Transit in New Jersey Final Report, which indicated the capital cost of two-way PRT track ranges from $30-$50 million per mile.

Due to the many variables associated with the design of a region specific PRT system, the ability to forecast precise operating and maintenance (O&M) costs is too difficult at this time. Using the data provided by vendors and incorporating a 20% contingency factor, operating and maintenance costs are estimated to be approximately $1 million per year per mile or $5.75 million annually.

Additional costs are anticipated to address the need to relocate utilities, modify the tree canopy and potentially provide visual screening of the PRT system or refinement of the aesthetics to blend the system with the neighborhood character. Additional research will be required to fully understand the impact of these costs.

Financing

The vast majority of surface transportation funding in the U.S. is derived from public sources at the federal, state, and local levels. Additional funding may be available through private resources. The study identifies potential funding sources at the time of report preparation and is subject to change. As traditional sources of transportation revenue continue to decline in adequacy to fund transportation systems, new funding mechanisms will necessarily be implemented to meet the increasing demands on paying for future system operations, maintenance, and expansion.

Project Benefits

Energy and Environmental Benefits

Due to the inherent efficiencies of the extremely light-weight vehicles and non-stop travel, the energy use for PRT is generally more efficient than other modes of transit. The proposed Ithaca PRT Study route has the potential to reduce annual vehicle miles traveled (VMT) by 3,054,100 miles resulting in a reduction of 1,694 metric tons of CO_2e. Additional transit-oriented development (TOD), supported by the PRT system, could further reduce VMT and greenhouse gas emissions. PRT also produces less noise and vibration than other form of conventional transit.

Quality of Life Benefits

PRT has the potential to increase land availability by creating a PRT enabled mixed-use district which contains all essentials of daily life within a maximum combined transit/walk trip of approximately 10 to 15 minutes. By attracting more riders to the public transit system, facilitating a higher density of housing, and serving as a circulator within the district, the need for a vehicle for intra-district trips is eliminated, in effect reducing overall parking demand. Where there is still a demand for parking, the PRT system reduces the need for on-site parking by providing access to long-term vehicle storage on the perimeter.

By reducing parking and vehicle travel and supporting higher density, mixed-use developments, PRT supports the development of vibrant 24-hour street life with an improved pedestrian and bicycle environment. The result is an area with improved air quality, reduced ambient noise and increased physical activity. Shifting from car ownership to PRT will also reduce transportation costs for households.

Safety Benefits

Research and development have proven the safety and reliability of PRT. The Morgantown PRT, the only fully operational system in the world, has completed over 110 million injury-free passenger miles since 1974. Comparatively, in 2008 automobile travel in the US averaged 80 injuries and 1.27 fatalities per 100 million vehicle miles traveled. Specific PRT safety features include:

- Computer control to eliminate human error
- Grade separation to eliminate pedestrian/vehicular conflicts
- Lower maximum speed
- Private trips

Economic Benefits

Many of the economic benefits of PRT are associated with the potential for transit-oriented development that could be support by the system. If realized, the increased development opportunities would generate additional property tax revenue. The housing component of TOD would expand the affordable housing supply and attract new residents who would contribute to an increase in retail sales and an associated increase in sales tax revenue.

Because PRT reduces overall parking demand within the service area, the capital cost of new parking facilities, approximately $15,000 per space, would be significantly reduced. PRT also supports the development of remote facilities to accommodate the remaining parking demand at a reduced cost due to lower land values.

Facilitation of development inside the urban core will prevent development of the surrounding automobile dependent towns, and thus prevent an influx of daily commuter traffic into the city. This would reduce the cost associated with additional road infrastructure and maintenance, policing, and accidents. Finally, by providing the opportunity for increased development within the PRT service area, rural land can be preserved allowing agricultural uses to continue and support the tourism industry.

Benefits over Other Modes

There are many reasons why people are advocating for more intelligent mobility and why many U.S. cities have seen public transit use on the rise. Americans need options that are less expensive, faster, and more environmentally friendly. However, most people who live in small to mid-sized American cities are dependent on automobile technology and infrastructure for their daily mobility needs because transit alternatives are not available. The following PRT characteristics allow it to draw a greater percentage of riders out of the private automobile than other public transit modes:

- Private Automated Trips
- 24-hour On-demand Service
- Fast Non-Stop Service
- Coverage and Convenience
- Accessible
- Environmental Appeal

In addition to increased ridership attraction, PRT has smaller right-of-way requirements than other transit modes which contribute to its lower capital cost. The capital cost of a PRT system is estimated to be a third of Automated People Mover (APM) systems, half of light rail, and more than one fifth the cost of heavy or metro rail. The BRT busway is the only transit system that is cost competitive with PRT. However this type of system requires allocation of at-grade right-of-way which is not always available in mature cities. With regard to operating and maintenance (O&M) costs, PRT has the potential to compete with the low operating costs of heavy or metro rail and consistent with the costs of light rail. The O&M costs of a PRT system can also compete with the cost of small bus transit systems and personal automobile ownership.

Finally, as an emerging technology, PRT provides potential economic development opportunities through:

- research and development,
- manufacturing,
- planning and design, and
- support and operations industry.

Potential Challenges

The study documents that there are several potential challenges that will need to be overcome for successful PRT implementation.

- PRT is still an emerging technology. There is limited depth of experience in the industry and safety, security and technical standards, specific to PRT operation in the United States, have not been developed.
- PRT is best suited for low density travel. It may not be possible to achieve minimum headways which would make it difficult to meet peak hour demand.
- Perhaps the most politically contentious aspect of PRT, besides capital cost, is the visual impact. Visual impacts would apply to any system with a dedicated right-of-way or fixed guideway.

Next Steps

This study evaluated the feasibility of a PRT system in Ithaca, NY. In general the study has concluded that a PRT system can be physically accommodated within the existing built environment of a mature city like Ithaca and that a PRT system in conjunction with transit-oriented development would provide substantial environmental, quality of life and economic benefits to the region. However, the study has also identified several areas that will require additional research before the City and the region can make a decision to pursue the implementation of a PRT system in Ithaca. Once the decision is made to pursue a PRT system, the approval requirements identified in this memorandum will need to be obtained and a financing strategy finalized. It is recommended that the following planning steps be pursued in the next few years to determine if a PRT system should be pursued for the City.

Short-Term

- Technology Assessments – There is a need to continue to track the status of research and development of both guideway type and propulsion systems to determine which are most appropriate and commercially available for implementation in Ithaca.
- Master Plan – There is a need to conduct a more detailed planning study of PRT development in Ithaca.
- Benefit/Cost Analysis – There is a need to develop more detailed capital and O&M cost estimates and summarize the anticipated benefits in monetary terms so that a benefit-cost ratio can be calculated.
- Public Involvement Process –There is a need to both educate the community on the technology and solicit their input on its potential in Ithaca. This process should include renderings of how the system could be integrated within the existing infrastructure of Ithaca as well as animations showing how a PRT system operates to overcome the potential challenges associated with new technology and visual impacts.
- Identification of Ownership/Operation Structure – There is need to evaluate potential ownership and operating structures to determine which is the most appropriate for implementation in Ithaca.

Long-Term

Upon completion of the short-term tasks, if it is determined that a PRT System in Ithaca should be pursued, the next steps include procurement, engineering and system implementation and testing.

Application in NY Beyond Ithaca

Developing a PRT system in conjunction with implementing policies to promote transit oriented development (TOD) has the potential to reduce VMT and associated greenhouse gases while enhancing the quality of life and economic development. Urban areas with over 30,000 jobs, as well as college campuses and activity centers, are suitable locations for the introduction of PRT.

Issues Requiring Additional Research

The following were issues were identified as requiring additional research beyond the scope of this feasibility study:

- System Components/Vendor
  - Selection of guideway type
  - Selection of propulsion system
- Route/ROW
  - Feasibility of using private property and structures for stations
  - Feasibility of integrating utilities into the PRT infrastructure
  - Identification of locations for storage/maintenance facilities
- Constructability
  - Maintain access to adjacent buildings during construction,
  - Utility clearances and potential relocation,
  - Maintenance and protection of traffic,
  - Potential disruption of the groundwater,
  - Potential impacts to adjacent buildings,
  - Crossing of Six-Mile Creek, and
  - Use of existing structures for stations.
- Ridership Projections including perceived attractiveness of PRT by potential users
- Detailed Cost Estimate
  - Cost comparison of PRT to other modes particularly bus transit, private automobile use, and car share programs. In particular the capital and maintenance cost for the road infrastructure and how it contributes to the O&M cost per passenger mile for automobile or bus use.
  - Cost of expanded services, most notably schools and social services, needed to serve the transit-oriented development (TOD) supported by a PRT system and how this may reduce the potential economic benefits.
- GHG emission reductions associated with reduction in idling due to congestion

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SECTION 1
INTRODUCTION

1. INTRODUCTION

Personal Rapid Transit (PRT) is an emerging technology that has the potential to reduce the emission of greenhouse gases and the consumption of petroleum products by reducing vehicle miles traveled (VMT).

PRT (also known as *PodCar*) is a subset of a type of mechanized public transportation system known as an Automated Transportation System (ATS), Automated Group Transit (AGT), or Automated People Mover (APM). Traditional APMs, like a light-rail system or monorail, run on a fixed schedule along dedicated guideways in a line-haul configuration with vehicle capacities of 12 to 100 people. Increasingly, APM systems are being built at airports, hospitals, business and academic campuses, and amusement parks around the globe.

PRT, as depicted in **Figure 1-1,** has the following features that differentiate it from APMs and other forms of traditional transit:[i]

- 24-hour on demand service
- Non-stop direct service
- Fully automated vehicles
- Small vehicles: one (1) to six (6) passengers
- Small dedicated guideway

Figure 1-1. Examples of Proposed PRT Systems

ULTra PRT | Beamways | ULTra PRT | Unimodal/SkyTran

2Getthere | MIST-re PRT | Vectus PRT | Austrans

With increasing fuel prices, transit rider-ship is growing, particularly in communities with a population of less than 100,000. A recent study documented that urban and suburban areas with over 30,000 jobs, as well as college campuses and activity centers, are suitable locations for the introduction of PRT. Given these statistics, PRT technology could serve the growing demand for transit in New York's small and mid-sized cities. PRT infrastructure can also be accommodated within the existing built environment resulting from 19th and 20th Century industrialization. PRT can also be used strategically to supplement and enhance traditional bus and light-rail service, using each technology where it is most effective and efficient.

Ithaca, NY has been selected as a case study for the application of this technology. The city's population is 29,287 and the greater metropolitan area has a population of 100,135. The total number of jobs within Tompkins County, where Ithaca is located, is 57,032. The City is also home to two major college campuses: Cornell University and Ithaca College. These demographics are consistent with areas that have a growing demand for transit and where PRT is stated to be the most efficient. Several recent local studies have also documented the need for improved transit service and the desire to have increased development density that would rely on alternative transportation modes.

This research study funded by the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT) evaluates the feasibility of implementing a PRT system in Ithaca. In particular, it evaluates how developing a PRT system together with implementing policies to promote transit oriented development (TOD) will enhance the quality of life and promote economic development in New York's small and mid-sized cities. The study includes the following components:

- State of PRT development
- Application of PRT in Ithaca
- Project benefits
- Implementation
- Application in New York beyond Ithaca

SECTION 2
PRT DEVELOPMENT

2. PRT DEVELOPMENT

2.1. <u>Genesis and History of PRT</u>

The advance of Automated Transportation Systems (ATS), of which PRT is a sub-category, has been championed by an assortment of professionals, politicians, and dedicated citizens since the late 1800s. Many accounts indicate that the need for a viable public transit complement to the auto led early pioneers to attempt the development of an enhanced, automated, streetcar, the use of which had peaked around 1917. As streetcars disappeared off of American roads, many public transportation advocates felt that if the enhanced streetcar notion matured, the hopes they had for the return of traditional streetcars to city centers would quickly vanish. The conflict that emerged between the two factions became quite fierce and would come to foreshadow the difficulties experienced in subsequent PRT development in the latter part of the 20th century.

Even though some of the key concepts of PRT have been tinkered with for over a century, contemporary PRT discourse did not really begin until around 1953 when Donn Fichter, an American planner now retired from the NYSDOT, first sketched out a PRT system he called Veyar. He eventually developed a total system concept, including both system technology and a methodology for integrating it within existing cities, and published his findings in his paper: “Individualized Automated Transit in the City”.[ii]

Detailed in the body of this narrative, he stressed the necessity for the smallest and lightest-weight cars and correspondingly, the smallest and lowest cost guide-ways possible. To demonstrate, he designed his car for one person. Although Fichter did not initiate the development of a hardware system, his well-reasoned and thorough explanations had considerable influence on later developments.

The automated transit concept was widely accepted in Europe, and in 1967 the first PRT project was started in Paris, France. Shortly thereafter, additional PRT projects began to emerge in Europe and beyond. In 1965, the U.S. government asked the Department of Housing and Urban Development (HUD) to:

"undertake a project to study new systems of urban transportation that will carry people and goods…speedily, safely, without polluting the air, and in a manner that will contribute to sound city planning".[iii]

The $110,000 feasibility study completed by the Cornell Aeronautical Laboratory, concluded with the publication of the 1966 report entitled "Tomorrow's Transportation." The report strongly endorsed the development of electric Urbmobiles travelling on an automated tracked guideway. The study stimulated an enormous effort to create much of the mathematical framework we now utilize when analyzing these systems today.

Source: Science Service; ©Cornell Aeronautical Laboratory, Inc.; http://scienceservice.si.edu/pages/001035.htm

Figure 2-1. Urbmobile Concept Sketch

Throughout the '60's and early '70's, numerous PRT tests were conducted by a range of authorities and institutions in the USA, Europe and Japan. A major contributing factor to this effort in America was the success of the Apollo Moon Landing Program, a major scientific breakthrough. During President Richard Nixon's budget speech to Congress in January 1972, he announced a federal development program for automated transportation systems:

"If we can send three men to the moon 200,000 miles away, we should be able to move 200,000 people to work three miles away."[iv]

In 1975, just three years after that presidential proclamation, the first passenger certified PRT project in the world was built in Morgantown, at West Virginia University (WVU). The system is still in operation today and there are plans to expand the Morgantown/WVU PRT's size, service and overall capacity in the near future.

During the 1980s and 1990s, interest in PRT waned. The U.S. General Accounting Office stated that there was insufficient justification for research and funding was eventually withdrawn. However, the past decade has experienced renewed interest in PRT. There are currently 14 systems at various levels of availability and two systems are being progressed to implementation. The following table summarizes the history of PRT development:

Table 2-1. Brief History of PRT Projects and Studies[v]

Concept/Research	
1953	Donn Fichter began research on PRT and alternative transportation and began the sketch of a system he called Veyar. In 1964 he published his findings in a book, *Individualized Automatic Transit and the City* Development of Monocab, a 6-passenger monorail system on overhead guide-ways.
1960	Invention of Alden staRRcar, a dual-mode system of small electric vehicles. A 1/20th scale model was operated in 1968.
1961	Lloyd Berggen invented Uniflo, a system where vehicles operated in an enclosed tube.
1965	Cornell Aeronautic Laboratories developed a dual-mode concept called Urbmobile. Although the system was never built, it documented the feasibility of safely operating vehicles at short headways. The concept was presented in a December 1965 issue of LIFE and the October 1967 issue of Popular Science.
1966	The United States Department of Housing and Urban Development undertook a study of new systems of urban transportation. The resulting report, *Tomorrow's Transportation: New Systems for the Urban Future,* was published in 1968, and proposed the development of PRT, as well as other systems. Congress created the Urban Mass Transportation Administration (UMTA) and gave it responsibility for the development of new types of transit systems.
1967	French aerospace company, Matra, started the Aramis project in Paris. The project was canceled when it failed its qualification trials in November 1987. The Canadian Ministry of Transportation sponsored a comparative study of transport alternatives. The British Cabtrack System was initiated as a private venture by L.R. Blake. The Minister of Transport later funded the project which was further developed by the Royal Aircraft Establishment (RAE) and a comprehensive report was issued in 1968. Further studies and the testing of a model concluded in 1974.
1968	Massachusetts Institute of Technology published the report, *Project Metran*, which embodied most of the ideas of PRT and influenced its development.
Early Development/Implementation	
1969	Vero, Inc. built and operated a full-scale test track of Monocab using a new means of switching with no moving parts. Transportation Technology, Incorporated (TTI) conducted a full-scale testing of the air-cushion vehicle, Hovair, originally developed by General Motors Research Laboratory in the late 1950s and early 1960s. A team from Aerospace Corporation published the first widely distributed description

	of *PRT: Systems Analysis of Urban Transportation Systems*, Scientific American From 1969 to 1980, the Cabintaxi Joint Venture developed the Cabinentaxi urban transportation system in Germany. Their extensive PRT technology was considered fully developed by the German Government and its safety authorities. An installation was planned in Hamburg, but budget cuts stopped the proposed project before the start of construction.
1970	UMTA contracted with NASA's Jet Propulsion Laboratory as the system manager for the first automated people mover in the U.S. at the University of West Virginia in Morgantown. In 1975, the Morgantown Personal Rapid Transit project was completed. The system is still in continuous operation with about 16,000 riders per day (as of 2003). It successfully demonstrates automated control, but was not sold to other sites because the heated track has proven too expensive. U.S. Department of Transportation (DOT) funded studies for automated transportation systems with three-second headways.
1971	Vero sold Monocab to Rohr Corporation who developed and tested a system using magnetic suspension and linear induction propulsion. The May issue of Architect's Journal published a study by the British architectural firm, Robert Matthew, Johnson-Marshall & Partners, that examined the integration of the Cabtrack PRT system into a section of London and assessed the visual impacts of overhead guideway systems.
1972	Transpo72, the U.S. International Transportation Exposition sponsored by the newly created U.S. Department of Transportation, was held at Dulles International Airport. The Urban Mass Transit Administration (UMTA), predecessor of the Federal Transit Administration (FTA), funded four companies at $1.5 million each to set up a demonstration of their automated guide way transit (AGT) development results. Demonstration included Monocab, TTI's Hovair, Dashaveyor and Ford's Automatically Controlled Transportation (ACT). Jet Rail System was developed, built and operated at Love Field in Dallas, Texas. The system was automatically controlled and used a light-weight guideway to support vehicles.
1973	Monocab selected for installation in Las Vegas but the project was stopped in 1974 for a combination of reasons
1974	On September 10, 1974, the Transportation Subcommittee of the Senate Committee on Appropriations requested an assessment of Personal Rapid Transit and other new systems. In 1975, the United States Congress Office of Technology Assessment published a report titled *Automated Guideway Transit: Assessment of PRT and Other New Systems* that stated "No clear urban transportation need is apparent for the short three-second headway performance specified for the (DOT) program.
1975	A project called Computer-controlled Vehicle System (CVS) was in public operation in Japan from 1975-1976. The project was cancelled when Japan's Ministry of Land, Infrastructure and Transport declared it unsafe under existing rail safety regulations, specifically in respect of braking and headway distances. The UMTA announced its Downtown People Mover Program and sponsored a nationwide competition among the cities. Several cities were selected although some withdrew due to lack of constituent support.

1976	The Advanced Transit Association (ATRA) was formed. The non-profit organization promotes the investigation and development of advanced transit strategies and technologies.
1978	A team from Aerospace Corporation published a book on *PRT: Fundamentals of Personal Rapid Transit*
1979	UMTA developed a manual, *Planning for Downtown People Movers,* as part of the Transportation Systems Center's Urban and Regional Research Series.
Loss of Interest?	
1980	The General Accounting Office issued a report entitled *Better Justification Needed for Automated People Mover Demonstration Projects*. The GAO report stated that UMTA had not shown why each of the planning projects was needed to meet program objectives. In 1981, the people mover installation program was discontinued, however, installations started in Miami and Detroit were completed. DOT rescinded its request for funds for the development of automated transit systems with three-second headways, but Congress requested the program proceed.
1983	With the help of University of Minnesota, a company, later called Taxi2000 Corporation, was formed
1984	Congress withdrew support for the DOT development program of automated transportation systems with three-second headways.
1989	Advanced Transit Association publishes a report, *Personal Rapid Transit, another Option for Urban Transit*
1990 **1993** **1996**	The Chicago-Area Regional Transportation Authority (RTA) release a request for proposals for a pair of $1,500,000 Phase I PRT design studies. Twelve proposals were received, and for Phase I two teams, Taxi 2000 Corporation with Stone & Webster as prime contractor and Intamin, A.G., were selected to develop parallel PRT designs. The Northeastern Illinois Regional Transit Authority selected Raytheon Company and Taxi 2000 system to design, build and operate a PRT system. Raytheon constructed the PRT 2000 Test Facility in Massachusetts. The test facility proved the feasibility but there were issues with size and cost. The program was cancelled in 1999 due to changes in political leadership.
2003	Advanced Transit Association publishes a report, *Personal Automated Transportation, Status and Potential of Personal Rapid Transit*

Renewed Interest – Commercial Application	
2007	Construction initiated on the first commercial deployment of ULTra's PRT system serving London Heathrow's Terminal 5.
2008	Plans for the car-free Masdar City, Abu Dhabi, include the development of a PRT system.
2009	Commencement of system operation of Heathrow's PRT system anticipated in the fourth quarter.

2.2. State of PRT Development

Over the past 60 years, there have been innumerable PRT/APM/GRT designs that have been conceived, researched, developed and reported on. Although the technology has undergone significant research and development and is now advancing to a state of commercial readiness around the world, progress still continues to proceed with comparatively limited resources and with only partial public support and guidance in the U.S., in particular. The status of PRT development and its application in the U.S. is summarized in the conclusions of the report, *Viability of Personal Rapid Transit in New Jersey*, a copy of which is provided in **Appendix A.**

Since the Morgantown/WVUPRT broke ground as the first commercialized automated rapid transit system in the world, scores of driverless APM's have been commissioned, assembled and put to use at hospitals, airports, amusement parks, and in cities around the globe. Many full scale PRT testing facilities have also been built in Europe, Asia, and America, but only the Morgantown/WVU PRT system, and now the BAA/ULTra system at Heathrow can claim to offer legitimate passenger service. Both of these systems are detailed in **Appendix B, Case Studies.**

A listing of planned or proposed PRT Projects is provided in **Appendix C.** As of August 2010 three of the most viable planned PRT systems include:

1. BAA / ULTra Heathrow. The first modern PRT system is in place at London's Heathrow Airport. Featuring the ULTra product, the system is carrying employees and is slated for full passenger service in the fall of 2010. The construction and operating costs are being covered by BAA (British Airports Authority); a private-sector firm that owns and operates 7 airports including London Heathrow, the world's third largest. This transit system is not government-subsidized. Detail on this system is provided in **Appendix B, Case Studies.**

2. Masdar City, in United Arab Emirates (UAE). Masdar is a mega-development designed to emit zero carbon dioxide while housing up to 50,000 people and 1,500 businesses. In addition to being powered by solar energy, the City's streets will be "car-free". The urban grid is being constructed so that all of the buildings' ground floors are several meters above the ground, making room for a comprehensive subterranean PRT system. According to an article in Technology Review #9 (February 2009), the underground network will have 83 stations spaced at 400 meter intervals. It will operate 24 hours a day, 7 days a week. The vehicles will travel on pavement equipped with embedded magnets placed every five meters and will use the magnets, along with information about wheel angles and speed, to determine their location. Pods will be powered by lithium iron phosphate batteries and average about 25 mph. The system provider, 2getthere, will offer three vehicle types: 6-seat passenger vehicles, cargo vehicles, and vehicles for recyclables. The system is undergoing operational testing and is expected to provide public service in late 2010.

3. Suncheon, South Korea. Starting with a corporate venture in POSCO (the South Korean steel company), VECTUS was incorporated in February 2005 as a UK registered company. Two branch offices are in operation: one in Korea ("VECTUS Korea") and one in Sweden ("VECTUS Sweden"). VECTUS built a test track in Uppsala, Sweden, and received passenger safety certification from the Swedish Rail Authority in early 2009. VECTUS is scheduled to deploy a PRT system in Suncheon, South Korea in 2013.

Amid an expanding group of automated transit systems being installed, prototypes on the verge of production, and inspired engineering solutions being presented for further research and development, there is a remarkable diversity in scale, design, network performance and overall implementation strategy. In an effort to be inclusive while reviewing the current state of the industry, the following fourteen ventures are featured in **Appendix D, PRT System Availability and Status.**

1. BAA/ULTra (Advances Transport Systems Ltd.); Bristol, United Kingdom, EU
2. Beamways; Linkchoping, Sweden, EU
3. Innovia (Bombardier ART); Berlin, Germany, EU
4. Mist-ER Ltd; Poronin, Poland, EU
5. Taxi 2000 Corp; Minnesota, USA
6. SkyTran (Unimodal Systems, LLC); California, USA
7. VECTUS, LTD; Uppsala, Sweden and Seoul, Korea
8. 2getthere; Utrecht, Netherlands, EU
9. DCC: Doppelmayr Cable Car; Wolfforth, Austria, EU
10. SkyCabs; Aukland, New Zealand

11. AMT (American Maglev, Inc.); Georgia, USA
12. Cybertran International; California, USA
13. Austrans; North Ryde, Australia
14. SkyCab; Stockholm, Sweden, EU

These systems exhibit both (PRT) and Small Group Rapid Transit (SGRT) characteristics. System requirements for making the list are as follows:

- is available on demand
- goes non-stop from start to destination
- is easily accessible and offer a full choice of destinations
- is environmentally sustainable
- has a comparatively low cost to construct
- integrates well with other forms of transport.

Even though PRT is becoming available for implementation, the full-scale development and realization of its large-scale networked capabilities in America must be a part of a long-term strategic initiative that includes substantial policy consideration and financial investment to get established. It cannot be undertaken successfully without fully comprehending how the features of a new PRT network, the community and environment in which it serves, and the myriad other factors involved, are interrelated. According to J. Edward. Anderson, PhD, a well respected researcher, designer, historian, and advocate of PRT:

> "*A successful PRT development program requires leadership that understands the theory of PRT, its relationship to the transportation problem in quantitative detail, the history of other PRT development programs and their successes and failures, the concerns of citizens and planners, customer needs, and the institutional problems that have hindered development of PRT. In addition, other important factors include:*
>
> - *A strong, disciplined and continuous commitment to weight and cost control.*
> - *Use of proven components when such components are available, but willingness to develop new components when necessary.*
> - *Commercially realistic performance specifications.*
> - *Consideration of failure modes and effects analysis as fundamental to the design, for example, understanding of the consequences of reliance on braking through wheels.*
> - *A commitment to careful system optimization of components.*
> - *Willingness to consider unconventional guide-way designs to obtain maximum stiffness with minimum guide-way size and cost.*
> - *Willingness to support experiments that clarify uncertainties.*

- *Sufficient training at the beginning of the design process to enable engineers to avoid pitfalls by having thought about them in advance, when errors can be easily corrected and before they are committed."*[vi]

2.3. State of PRT Approvals for U.S. Implementation

Although many APM products are currently on the market working to serve airports, hospitals, campuses, theme parks, and communities across the country, only the Morgantown/WVU PRT has been given official certification to operate and maintain a PRT/GRT system in the U.S. To better understand the regulatory process for qualifying a modern PRT system in America including emergency procedures, vehicle and operational safety, headways, visual impact, cost, ownership and management, design, function, and accessibility, etc., a series of interviews were conducted with transit authorities. Based on these interviews, it was determined that for U.S. implementation:

- No Federal approvals (FTA, FRA) are required unless federal money is used;
- State transportation oversight may apply (State DOT);
- There are currently accepted standards for APM that could be adapted for PRT; and
- Prior to U.S. implementation, a full-scale, modern, PRT testing facility should be developed.

The interviews are summarized below:

Grady Cothen, Deputy Associate Administrator for Safety Standards of the Federal Rail Authority/USDOT:

> *"Assuming the system to be similar to Morgantown in terms of the population served, compactness within an urban area, etc., this kind of transit system would not be subject to FRA regulation…It is likely, however, that State oversight would apply."*

Dennis Manning, retired California Department of Transportation Civil Engineer; member of ATRA:

> *"APM's (Automated People Movers) were tested and studied in the U.S. for 10 year before gaining their certification, but the regulatory standards they are held to should be amended to include PRT, with some additional testing done on a modern PRT application. The problem is, however, there are no full scale PRT testing facilities currently operating in the U.S."*
>
> *"So far as I know a PRT system only needs State certification and I think there is some confusion over what agency would issue the certification. Not to sell anyone short but I doubt if any U.S. PRT supplier has applied for certification yet. In short, I don't believe that you need federal approval, if there are no federal funds involved".*

Lawrence Fabian, Treasurer of ATRA (The Advanced Transit Association), and principal of Trans.21:

> *"The simple (answer) is that there is neither market-ready product nor a certification process in place (in the U.S.), other than maybe with the APM Standards Committee."*

John Esslinger, Director of the APM Standards Committee (APMSC):

> *"The APMC has created a government recognized Standard of Safety and Operation for the Automated People Mover industry…We have just recently developed a PRT Task Force Sub-Committee to address, head-on, the growing issue of PRT certification in the U.S.…Frankly, the National APM Standard - ASCE-21 - already covers most, if not all, of the concerns related to modern PRT certification and it may already provide enough of a framework to evaluate a PRT technology for civic implementation...“Anyone who owns, operates, builds, maintains, designs, tests, insures, oversees, or certifies APMs or other innovative technology transit systems, such as magnetic levitation, air cushion, and monorail systems, will benefit from this Standard. It will also be useful to transportation engineers, safety engineers, and contractors of APM systems."*

The APM Standards Committee is a working group within the Transportation and Development Institute (T&DI) of ASCE (American Society of Civil Engineers) and is accredited by the American National Standards Institute (ANSI). Its mission is to develop the minimum set of requirements to achieve an acceptable level of safety and performance for an APM system. These requirements cover the planning, design, construction, and operations of an APM system in the U.S. A copy of the requirements is provided in **Appendix E: ASCE APM Standards.**

SECTION 3

GENERAL DESCRIPTION OF PRT

3. GENERAL DESCRIPTION OF PRT

Among the large number of systems that are being proposed world-wide, there is substantial diversity in the approach to design. The following sections identify the PRT system components and potential design variations as well as distinguishing systems characteristics.

3.1. System Components

3.1.1. Guideway

The guideway is the path, dedicated right-of-way or support structure of the PRT system. Guideways may be at-grade, elevated or underground (in a tunnel). The following is a brief description of the three general types of guideways used in the current PRT industry and depicted in **Figure 3-1**:

1. *Open guideway.* Open guideway systems consist of a flat surface that supports the vehicle. Vehicles typically have rubber wheels and steer themselves, sensing their position relative to side walls or other fixed objects. Examples include ULTra and 2getthere.

2. *Captive bogey.* In this system, the vehicle is supported by the chassis it rides on. The vehicles typically have horizontal wheels that run along and are held captive by side elements. The guideway steers the vehicle. These systems are commonly powered by linear induction motors. Examples include Vectus, ITNS and Skyweb Express.

3. *Suspended.* Vehicles in this system are suspended (hang) from the guideway. One company, MagneMotion, contends that a suspended system makes electromagnetic switching easier. Examples include J-Pods, Beamways, SkyTran and MISTER.

ULTra's Elevated Open Guideway

Vectus' Captive Bogey Guideway

Beamway's Suspended Guideway

Figure 3-1. Guideway Types

There is debate over what the best type of guide-way is, and whether a guide-way standard is necessary. Some support the construction of many proprietary, yet interconnected, guide-way systems that perform distinct tasks and serve specific purposes. They claim this will be the best way to ensure that many players are active in the PRT industry, while encouraging competition, and creating systems that are individual to the community, climate and terrain they will eventually work to serve. Others are interested in establishing international operating principles (like with air, rail or highway travel), so that they can normalize and synchronize distinct networks as the technology is implemented. To date, there is no consensus.

The charge of introducing a new form of transit service into an established U.S. city is a daunting task, however. Many older cities began with horse and buggy pathways and town greens, which eventually became trolley-car corridors and industrious downtowns, having now evolved into wide automobile boulevards featuring fast food chains and strip malls. Many newer U.S. cities have been designed, planned and built with the latter as an urban model.

One of the biggest challenges to the implementation of new transit, therefore, is to establish a dedicated “right of way” that is grade separated from the current street/car network, seamlessly integrated into it, or replaces it all together. When comparing modes of public transit, experts consider it advantageous for the system’s guide-way and infrastructure to have a small footprint, allowing it to penetrate the urban fabric, increase its level of door to door service, and therefore compete with the private auto for overall vehicle miles traveled. Proponents of PRT argue that its systems would require much less horizontal space than existing metro-rail systems, with individual cars being typically around 50% as wide for side-by-side seating configurations, and less than 33% as wide for single-file configurations (Refer to **Appendix F, Guideway Scale Comparison**). This is an important factor in considering implementation in densely-populated, high-traffic areas, because the light and slim framework of its guide-way would allow for it to operate at a separate, uninterrupted, grade other than on-street level traffic, as well as to help deliver passengers in close proximity to their end destination.[vii]

PRT plans also propose to utilize the guide-way as a conduit to distribute power and data communications to the vehicles, track and stations. The guideways can also serve as an aggregate right of way for use by public utilities like electricity, network and cable television, fiber optics, and other wire-based telecommunications technology. The integration of these right-of-ways will reduce the visual clutter along transportation corridors.

3.1.2. Vehicle

One of the differentiating factors that separate PRT from other transit modes is the small vehicle size and number of passengers. Most industrialized countries that boast significant automobile infrastructure average under two people per trip, and in the U.S., the average vehicle occupancy for work trips is only 1.14 persons (Summary of Travel Trends, 2001 National Household Travel Survey, U.S. Department of Transportation, December 2004). Based on these figures and trends, some designers have recommended that two passenger vehicles, or even single passenger vehicles, are optimum for PRT.

Other designers, however, choose to create larger vehicles, making it possible to accommodate families with small children, riders with bicycles, groceries or luggage, groups of friends, or passengers with wheelchairs. Larger vehicles, however, are more expensive to produce, use more energy to start and stop, and require bigger and more expensive guide-ways, a major capital cost of the system. In addition, if vehicles are too large, point-to-point routing becomes less dexterous because of important factors such as reduced aerodynamic efficiencies and a lesser capacity to maneuver swiftly and quietly. The size, weight and design of the vehicle fleet also influence the material, look and scale of the system's guide-way, critical issues related to the resultant visual impacts of the overall infrastructure.[viii]

The optimum vehicle size is in the range of two to six passengers to provide convenient, demand-based service with maximized energy efficiency. The ability to platoon vehicles through the control system will also allow PRT to dynamically operate in a train-like mode at times of high demand.

In general the features that PRT vehicles have in common are related to the comfort and conveniences of the modern world including:

- Heating and air conditioning.
- Radio, television, and personal video/ music interfaces.
- Internet connectivity.
- Automated fare collection systems
- Visitor information systems

The most notable difference between the vehicle concepts that currently exist is seat orientation. Systems such as Vectus, ULTra, Beamways, 2GetThere, and others feature walk-in vehicles with reasonable headroom, but not full height. Usually the seating is opposed with two (2) to three (3) seats per side. The doors are placed in the center of the vehicle and allow the passengers to choose a side to sit on. Beamways creates a slight variation with the primary seating at the back of the vehicle and facing the direction of travel. The opposing side has fold-away seats to allow for wheelchair users or storage of items such as bicycles or luggage.

Another aspect of vehicle design is the suspension system which includes the bogey that interfaces with the guideway. Variations in the bogey design will depend of the type of guideway and propulsion systems used. Examples of a captive bogey, suspended bogey and a bogey in an open guideway system are presented in **Figure 3-1**.

Aside from the purpose of connecting to the guideway the suspension system provides rider comfort by absorbing vibrations and articulating the vehicle to adjust for grades and banking in turns. With a track-based system the suspension components are less critical since there are fewer variations in the guideway when compared to a traditional road surface or when considering an open guideway system, i.e. a precast concrete running surface. Regardless of the guideway type there will always be "track" imperfections that would create occupant discomfort and must be mitigated. As previously suggested a suspended bogey has an advantage over captive bogeys in that they can articulate from fewer points to accommodate grade changes or banks. This grade change articulation can be initiated by gravity in a suspended system whereas a captive bogey would need to mechanically lift the vehicle. Yet another design variation within the suspension and bogey systems is magnetic levitation, or maglev, where the vehicle is suspended in the air on a magnetic field.

One other function of the vehicle bogey is to provide the braking system. While traditional drum and rotor brakes as found on cars could be employed by the industry and are found in open guideway vehicles, the predominant braking method is through linear electric motors because they are frictionless and more powerful. In contrast mechanical braking systems experience a great deal of wear and require more maintenance. Similarly the braking forces possible are limited by the mechanical nature of the system, as well as impacted by weather.

3.1.3. Propulsion

Various methods of propelling a PRT vehicle have been explored by the industry. Since the Internal Combustion Engine (ICE) is proving to be an antiquated method of propulsion powered by limited fossil fuel resources the PRT industry has primarily worked with electric propulsion, although some have a gas powered option. Within electric propulsion there are two concepts to consider:

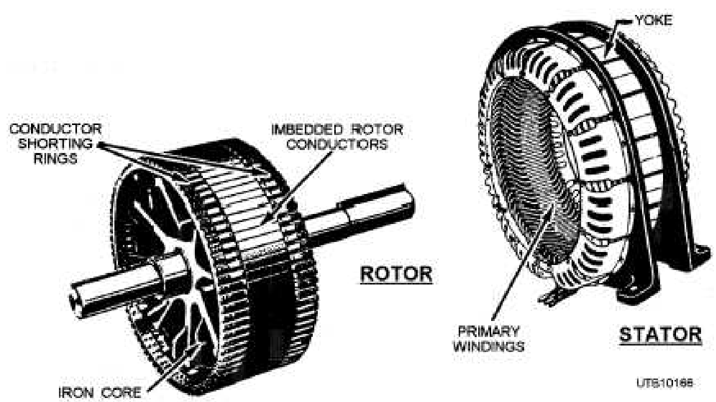
Power source:

- Batteries within vehicles
- Lineside conductor (power rail)

Propulsion method:

- Traditional rotary motors that drive wheels
- Linear electric motors that propel the vehicle via electromagnetic resistance.

The Morgantown system is powered by a rotary electric motor which is the most traditional type of electric propulsion. It consists of magnets and coils turning a shaft that is powered by DC, AC, or variable AC electric (See **Figure 3-2**). Application of this type of motor leads to a PRT vehicle that mimics a car.[ix] It has rubber wheels that produce friction which reduces energy efficiency, creates noise, and can be compromised by rain, snow and ice. Another characteristic of rotary motors is that they can be used for regenerative braking to recharge on-board batteries.[x] The ULTra system at Heathrow airport will utilize this type of system.



Source: http://www.tpub.com/content/construction/14625/css/14625_198.htm

Figure 3-2. Diagram of Components in a Rotary Electric Motor

An alternative propulsion found in the PRT industry is the linear electric motor which is an alternating current (AC) electric motor that has had its stator "unrolled" so that instead of producing a torque (rotation) it produces a linear force along its length. With linear electric motors the traction is direct and only limited by the power capacity of the motors, not the wheels. Similarly, the same forces used for acceleration and propulsion can be reversed to provide frictionless braking. Many designs have been put forward for linear motors, falling into two major categories, low-acceleration and high-acceleration linear motors. Low-acceleration linear motors, usually of the linear synchronous design (LSM), are suitable for maglev trains and other ground-based transportation applications. High-acceleration linear motors, usually of the linear induction design (LIM), are normally quite short, and are designed to accelerate an object up to a very high speed and then release it, like roller coasters.[xi]

The difference between LIM and LSM technology is important to understand. With LIMs the stationary windings, or "stators," are typically mounted on the vehicle. Then, an electric current is applied to generate a magnetic field in the windings which induce secondary magnetic fields in conductive aluminum or copper sheets embedded in the guideway to serve as a reaction plate, or the "rotor." These sheets are often laminated to an iron backing plate to increase rigidity and induce a larger magnetic field.[xii] The reaction of these magnetic fields results in propulsion. In contrast LSM systems replace the aluminum or copper sheets with permanent (or energized) magnets and place them on the vehicle to react with the magnetic field of stator windings now placed in the guideway. The vehicle then moves at the speed of and synchronously with the magnetic field as it changes polarity.

Described above were the short-stator (on vehicle) linear induction motor and the long-stator (on guideway) linear synchronous motor. These types of linear motors have been practically tested and applied. Conversely, the long-stator (on guideway) LIM creates an electromagnetic wave that reacts with a short on-vehicle plate but its performance is inferior to LSMs of similar configuration. Vectus, the leading PRT company utilizing a LIM-drive system, has employed a long-stator LIM configuration. Likewise, the short-stator (on vehicle) linear synchronous drive with primary windings on the vehicle and discrete field windings distributed along the guideway makes the track design too complicated to negotiate the route of a typical transportation system, and thus economically impractical. A hybrid technology, the inductor-type linear synchronous motor, has also been studied, but leads to increased vehicle weight and a complex guideway structure, precluding it from being commercially viable.[xiii] It is important to note that much research has been done on linear motor propulsion systems from the standpoint of light rail transport that uses large vehicles requiring heavier components and more significant power requirements. Vectus' decision to forgo the advantages of LSM but then commit their system to the cost and complications of stator windings embedded in the guideway suggests that PRT has a unique parameter set not directly comparable to light rail. Vectus reports that their decision to use a long-stator LIM drive was made to provide more reliability and better performance in severe conditions. This is because you do not need power collection and power electronics on the vehicle, which reduces vehicle weight, simplifies the vehicle, and reduces the risk of electrocution and other electrical issues resulting from the power collection system.

With LSMs the magnets potentially make the system heavier than a LIM system, but synchronous systems are more efficient because they create less heat. This is because the reactive force is with a magnetic whereas a LIM induces a magnetic field in a conductive plate thus generating heat. LIMs (of the long-stator, or on-track, variety) are now commonly found in roller coasters and there are several reported instances where the LIM fins have cracked from overheating.[xiv] One company, MagneMotion, contends that the magnet array in an LSM is comparable to the weight of the reaction plate in a LIM. The other half of the equation is that because LIMs must produce all of their drive current in the stator the windings are heavier and typically shorter in length (located on vehicle instead of guideway) to maintain a reasonable efficiency. MagneMotion also uses passive permanent magnets in lieu of energized magnets which require external excitation to generate a magnetic field in the moving element. A LIM with the stator windings moving with the vehicle, which is more practical than a long-stator (on guideway) LIM, requires electrical power to be transferred from a third rail to the vehicle with collectors (brushes or sliding contacts). MagneMotion contends that these additional components are a maintenance liability, a weight penalty, and a potential safety concern (inherent danger from a high-voltage third rail similar to subways).[xv]

Electric motors require precise control of the gap between the stator and winding. With the rotary induction motor the air gap between the stator winding and the rotor is much smaller (few millimeters) and does not vary which results in greater efficiency. Air gaps of 10 to 15 mm are used for LIM drives due to clearance requirements from the vehicle suspension system.[xvi] With linear motors the stator and rotor are separated with one component on either the vehicle or the guideway, which complicates the suspension system since the gap distance needs to be maintained within a set range.[xvii] However, Bombardier's Advanced Rapid Transit technology using a combination of linear induction motors and conventional wheel-based suspension proves this is feasible with systems operating in Malaysia, the US, Canada, and very soon in South Korea. Likewise, Transrapid International's system uses linear synchronous motors and magnetic levitation (maglev) that is commercially proven in the Shanghai MagLev Train system built in 2004 in China. The most mature drives presently being installed and implemented for transportation are the LIM-driven, Chubu HSST and LSM-driven Transrapid maglev systems. Both of these systems use iron-core propulsion motors with relatively small (10-15 mm) propulsion air gaps, and electromagnetic-type (EMS) levitation.

Comparison of LIM and LSM (information based on an analysis of maglev light rail systems)[xviii]

LIM Advantages:

- Power conditioning system and construction is similar to conventional electric railway vehicles.
- Significant database of practical experience and design with manufacturers and operators.
- All-weather capable.
- Can negotiate tight curves and steep grades.
- Precise stopping and high acceleration not possible with power-driven steel wheels.
- Public perception of improved service, ride quality, safety, and reliability.
- Passive guideway with hot third rail power pickup similar to conventional rail systems.
- Vehicle design and performance adaptable within guideway electrical and mechanical load limits.
- Flexible in response to variable or uncertain demand.

LIM Disadvantages:

- Lower theoretical energy efficiency compared to rotary induction motors and LSMs.
- Power conditioning equipment and wayside power systems are larger than LSM systems.
- Electrical-to-mechanical efficiency at the power pickup hot-rail is 70-80%.
- Less stable than LSM in maglev systems at high speeds (over 120 MPH).

LSM Advantages:

- Lighter vehicle due to drive power supplied from the guideway.
- Power-rating of the guideway motor can be tailored to specific route sections, i.e. steep grades.
- Same on-board magnets can also be used for maglev operation.
- Power generation and operation control can be integrated with drive system.
- Reduced vehicle weight results in high acceleration and deceleration capability. Ride comfort and safety are the limiting factors, so LSM has no significant advantage over LIM in this regard.
- Electrical-to-mechanical efficiencies of 87% have been demonstrated.

LSM Disadvantages:

- Reliable and precise vehicle position and velocity sensing is required.
- Many components complicate the guideway.
- Each guideway section can only drive one vehicle at a time with a dedicated converter.
- Reliable LSM motors are required on both sides of the vehicle for balanced thrust.
- Reliable on-board power system required to continuously operate field magnet.
- The initial investment in an LSM system must accommodate the highest demand anticipated over the life of the design since the active guideway is costly to change.

Some of the other propulsion systems that have been studied by the PRT industry include:

- Pneumatically supported LIMs (TTI's Hovair system at Duke Medical Center).
- Cable Propulsion (Doppelmayr Cable Car- http://www.dcc.at/. See MGM's CityCenter project in Las Vegas).
- Pneumatic Propulsion (Evacuated Tube Transport Technologies- http://www.et3.com/).

However, it appears that none of these technologies are currently proposed in any PRT systems.

3.1.4. <u>Switching</u>

With PRT the guideways are networked and would therefore typically include numerous switching points depending on the route the vehicle needs to take to reach its destination. Switching is similar to that of trains but PRT vehicles will often need to make many more directional changes to complete a trip, which will impact the speed of the trip if the switching is slow. There are two general types of switching used in transportation systems- mechanical and electromagnetic. Mechanical systems require a moving physical component, while electromagnetic methods simply guide the vehicle via magnetic attraction and no moving parts. Switches can be located in the vehicle or in the guideway. With electromagnetic switches there are a variety of methods to sense the electromagnetic cue that is being signaled. These include laser sensing, wire guidance, optical and radar sensing, and embedded track magnets.

The use of a mechanical switch in the guideway has been viewed to be problematic in that it is time consuming and would drastically reduce vehicle headways and system capacity.[xix] The practical approach to mechanical switching is a vehicle-mounted mechanism that deploys well in advance of the diverging point on the guideway and maintains control specific to each vehicle. In the event that a vehicle-mounted mechanical switch fails the problem is isolated to the vehicle. However, maintenance of mechanical switching would be more frequent and potentially more costly than an electromagnetic switch. PRT concepts that have vehicle-mounted mechanical switches include Taxi 2000's Skyweb Express, MISTER, and Vectus. The Vectus system utilizes a switch in the form of a drop-down roller on one side of the vehicle, so it is not "bi-stable." Edward J. Anderson contends that vehicle-mounted mechanical switches must be bi-stable, yet Vectus' test track has been operating successfully. It will be important to consider the long-term, in-service performance of mechanical switches, especially if they are not bi-stable.

The use of electromagnetic switching is becoming more popular with PRT concepts as the technology has matured. Interestingly the Aerospace Corporation's work in the early 1970's chose an electromagnetic switch placed in the guideway since it coupled naturally with the linear motor also used by the model concept. MagneMotion utilizes this type of switch as well in its M3 urban maglev transportation concept, but it is not a true PRT system since the vehicles can carry 24 passengers. Regardless their work has been carried over to their PRT concept with electromagnetic switching and it seems likely to place this technology at the top of the list for preferred switching systems. Assuming the reliability of magnetic switching can be proven for a high-use scenario, the lack of moving parts is a clear advantage. Some research efforts have concluded that magnetic switching is easier to implement in an overhead suspended system configuration. Similar to mechanical switching, the activation of the switching should come from the vehicle to prevent a system-wide shutdown in the event that a guideway switch fails.

For wheel-based systems the control is often provided with an electronic guidance system that steers the vehicle. The ATS ULTra system is on the verge of commercial operation and laser sensing for vehicle control and switching was chosen for the production vehicle. Inductive loops are placed in the guideways which interact with the sensing circuits on the vehicles. After extensive evaluation and testing laser sensing was selected over wire guidance, optical and radar sensing, and embedded track magnets.[xx]

3.1.5. Stations

Most PRT network proposals locate hub stations within short walking distance of one another and situated on off-line side tracks so that through-traffic can bypass vehicles picking up or dropping off passengers.

The off-line station configuration is a critical factor that allows PRT capacity to compete with or exceed light rail and bus rapid transit capacities. In order for the system to operate effectively the stations must be sized according to local demand at near peak times. The sizing includes the number of vehicle berths, the length of the deceleration and acceleration lanes, the entrance/exit queues and the switch lengths at the diverge points (see **Figure 3-3**).

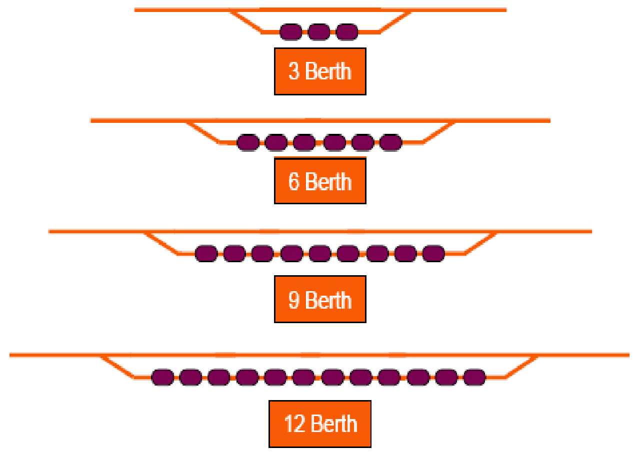


Figure 3-3. Elements of a PRT Station

The throughput capacity of a PRT station is directly proportional to the number of berths allocated to loading and unloading, the queue lengths that allow vehicles to dwell while keeping the main line open to traffic, and the main line operating speed that determines the track length needed for deceleration & acceleration. As a result the space allocation for PRT stations is quite high even for stations with only a few berths. A good estimate for platform length is approximately 15 feet per vehicle berth. The overall offline length including the platform is three (39 times the platform length, i.e. a four (4) berth platform would need to be approximately 60 feet long and the required off-line length would be approximately 180 feet. This total length can be reduced if system capacity is not adversely impacted by acceleration/ deceleration of vehicles exiting/entering the station being performed on the main line. The advantage of PRT, however, is that a three (3) berth station can provide significant throughput of riders as cited by many sources in relation to adequate system capacity. Also, as the number of berths increases for high demand stations the length is not required to grow proportionally if group dispatching of vehicles is performed during high volume conditions.

Currently systems like ULTra's PRT and the Morgantown GRT have been implemented in locations with more available land (college campus; airport) or with a limited impact on a dense urban environment (single route & station within city). Integrating a PRT network into an urban area represents a much greater challenge. As discussed earlier the existing road ROWs provide an obvious place for the guideways. The implementation of stations will result in a greater encroachment of the ROW since the off-line guideway portions leading to a station will increase the amount of guideway over the ROW by 50% (station on one side) to 100% (station on both sides). Due to spacing requirements the off-line track may also need to occupy space over private property, but generally speaking the typical ROW width of 50 feet to 60 feet is adequate to confine a dual direction main line with off-line sections on each side within the ROW airspace.

3.1.6. Maintenance and Storage Facilities

The maintenance of a transportation system plays a significant role in the long term viability of a system. With PRT, being a relatively unknown mode of transportation, the need to quantify and understand the maintenance impacts of operating the system will be of utmost importance when a system approaches the implementation phase. As a transit system PRT is intended to compete with the automobile for some of its mode share based on personal convenience, reliability and the operational speeds it can achieve when moving riders. This same set of factors will make PRT stand out among transit options such as light rail and buses. The key to providing the convenience and travel times that PRT systems can offer is reliability. With a rail-based transit system the track or guideway must remain operational along with the vehicles that travel on it. Therefore the design and maintenance strategy of a PRT system should include[xxi]:

- Careful part selection and minimization of moving parts to achieve high reliability in mechanical and electromagnetic systems.
- Use of system redundancy.
- Frequent inspection and preventative maintenance schedules (potentially daily).
- Replacement of system components before they wear out.

While it is important to reduce operational failures to ensure reliability the maintenance of a system should not be overly cumbersome and result in high operational costs. Even though some of the strategies above suggest a potential for high labor and parts costs through regular maintenance, the primary focus should be on part selection and minimization of moving parts to reduce the baseline amount of maintenance needed. Parts should be high quality with long service life while systems should be mechanically simple with a preference for advanced electromagnetic technologies, i.e. linear induction motors; maglev; electromagnetic switching.

Sanitation is another consideration with the maintenance of a PRT system. As a personal transit concept without user ownership there is the potential for vandalism and disregard for the cleanliness of the vehicles. Utilization of video monitoring and assignment of responsibility for vehicle conditions through electronic ticketing systems will curtail most issues. Additionally riders can decline a vehicle that is not clean upon arrival and send it to the maintenance facility. Another measure to regulate the use of a PRT system is through station managers and other employees to assist people with the system features and inspect the vehicle conditions. During off-peak hours and at small stations rider assistance and regulation can be provided with a video surveillance and communication system from a central control office. Although there is great potential for a PRT system to operate and maintain itself automatically for a vast majority of the time it will be important to have human over sight and presence to mitigate any public concerns of using an automated system. As such this will lead to job creation and alleviate concerns over losing jobs as less efficient transit systems are replaced by PRT systems.

Unlike transit systems like bus and light rail operations where all of the vehicles typically return to a service garage or depot during off hours a PRT system can store some of the vehicles at stations. This will also provide vehicles for the occasional overnight or off-hour rider. The remainder of the vehicles that are normally circulating on the system during peak hours will need to be stored at a depot. The number of vehicles in a PRT network will depend on ridership demand. The storage capacity of a depot(s) will be further impacted by the sizing and number of stations. Some of the early work with PRT systems set a conservative requirement that depot capacity should be 85% of the vehicle fleet.[xxii] Storage depots would be multifunctional facilities to provide vehicle cleaning, subsystem checks, and regular maintenance. Upon arrival at a depot a vehicle would be routed to the necessary service areas via track switching and/or vertical lifts. The cleaning and subsystem checkout processes would be semi-automatic with human monitors, while the maintenance tasks would require more extensive human resources. Approximate size references for the various elements of a depot are as follows:

- Vehicle storage space - 100 SF each.
- Service bays - 250 SF each; Potential number of bays would be 10% of storage capacity.
- Cleaning and subsystem checkout processes could be carried out in an assembly line method. This line would have to be approximately 12 feet wide and 15 feet long per function bay, i.e. wash bay; subsystem check bay; visual inspection bay. There may be other type of service bays as well as multiples of each to expedite the vehicle processing time.
- Additional track loops for moving vehicles through the depot.

Maintenance and storage depots require acquisition of land of adequate size and zoning to allow for their construction. Depending on the overall configuration of the PRT system the number and dispersion of depots will vary. A suggested rule of thumb is to place the storage depots at intervals of 2 miles[xxiii]. In general it seems practical to locate depots at the periphery of urban areas where the necessary land acquisitions is more feasible. This placement can also support park-n-ride scenarios where the peripheral depots provide the vehicle capacity to serve morning commuters when the commute pattern is more concentrated. An alternative to the peripheral depot concept is to place them in areas of high demand such as near a collegiate sporting arena.

3.2. System Characteristics

3.2.1. Headway

Headways refer to the spacing between vehicles and can be defined in terms of time or distance. From a safety standpoint headways are usually determined by the stopping distance required to prevent a lead vehicle that is stopped from being struck by the vehicle behind it. The spacing of pods on the guide-way influences the overall maximum passenger capacity of the entire network, so designers prefer to achieve smaller headway distances. Advocates of computerized controls assert that automated vehicles can achieve closer spacing than with human commanded cars, since multiple vehicles can automatically decelerate and brake in unison, and because driver fatigue and/or other human factors will not influence vehicle performance.

Through research, analysis and testing PRT systems can operate with headways that are fractions of a second. With a combination of linear motors that allow for frictionless electromagnetic braking and advanced computer monitoring with redundant controls operating headways of less than 1 second are not a technological issue but rather one of acceptance dependent upon reliable commercial performance at higher initial headway rates. Currently Vectus has safety approvals to operate at 3 seconds headways and the ULTra system at Heathrow Airport will begin operation at 6 second headways.[xxiv] Currently, no government or agency has endorsed headways below one second, yet PRT proponents believe that regulators may be willing to reduce headways as operational experience increases.

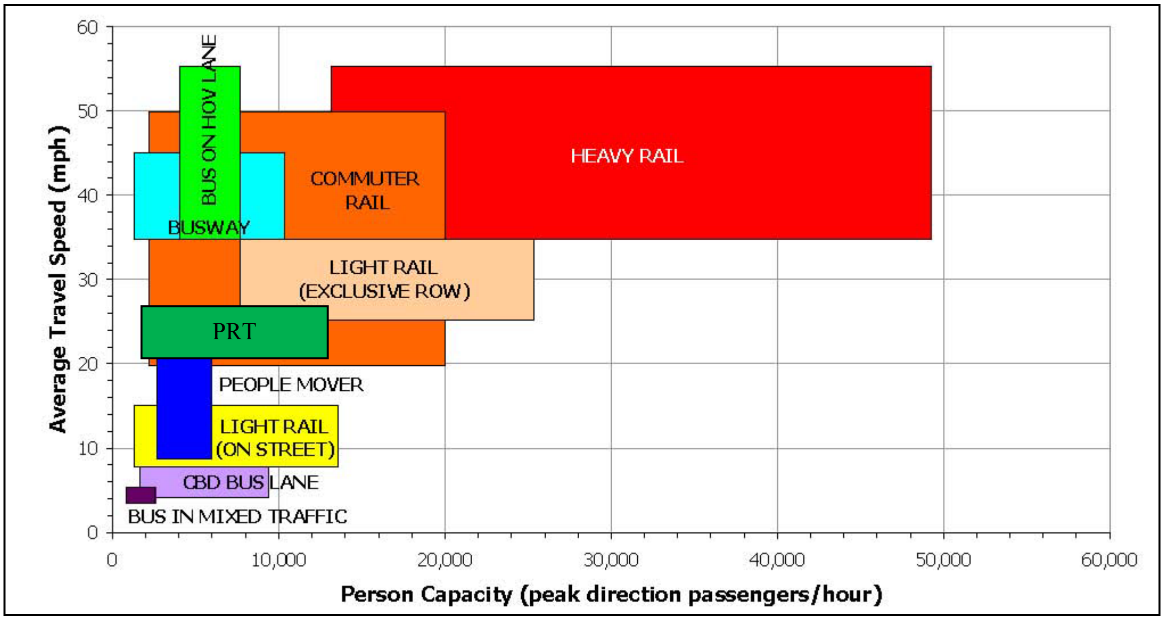
3.2.2. Travel Speed

PRT systems can operate within a large speed range due to the lightweight vehicles and extreme power achievable with linear motors. From a practical standpoint the travel speed is comprised of a combination of factors including time to reach a PRT station and board a vehicle, make the trip, and then complete the trip via walking or other means to reach a destination. Under the assumption that a PRT network exists with a large enough coverage the time traveling to and from a station is most likely synonymous with the time it takes to park a car and walk, so the travel time comparisons should be made between the actual vehicle trip times. Within an urban environment automobile travel is severely limited by congestion and traffic control mechanisms. Average speeds of approximately 15 MPH are typical when driving through neighborhoods using side streets or when arterial roads are congested. When arterial roads are moving freely speeds can increase to 25 MPH average and rarely reach 30 MPH. PRT systems have been simulated to operate with a line speed in the range of 25 to 45 MPH, which often results in an average speed of 20 to 25 MPH. These simulations factor in the impacts of system congestion on switches and potential reduced speeds under times of heavy system loads. In comparison buses average 12 MPH and light rail averages 15 MPH.[xxv]

Theoretically the line speeds can be significantly higher when there is less congestion. Conversely congestion can be mitigated with an expanded network to provide alternate routing options through lower demand areas. The benefits in this regard are two-fold in that systems speeds can increase while increasing the service area to lower demand areas that would not otherwise justify a system extension. Ultimately it has been thoroughly demonstrated that PRT systems can provide average travels speeds equal to or greater than automobile travel.

3.2.3. Capacity

An important litmus test for a viable transportation system is its capacity to move people. The interesting part about PRT is that it lies somewhere between a transit system and a private automobile conceptually, but when it comes to capacity it is documented to outperform conventional buses and automobiles, equal light rail and Bus Rapid Transit (BRT), and theoretically compete with heavy rail. A bus in mixed traffic in an urban environment can achieve a peak capacity of approximately 3,000 passengers per hour (pph), which is not significantly higher than the optimum auto capacity of approximately 1,800-2,000 pph (assuming single occupancy vehicles). PRT systems vary their capacity by increasing the number of vehicles or pods in the system and reducing the headways between vehicles. J. Edward Anderson has estimated that the capacity of a PRT system can range from a capacity similar to the auto (1,800 pph with a 2 second headway and 1 passenger per vehicle) to a capacity comparable to light or commuter rail (14,400 pph with a 1 second headway and 4 passengers per vehicle). **Figure 3-4** illustrates how the passenger capacity varies by transit system.[xxvi,xxvii,xxviii]



Sources: "Transit Capacity and Quality of Service Manual," 2nd Ed.- TCRP
PRT – J. Edward Anderson

Figure 3-4. Capacity Comparison by Transit System

When considering capacity the potential ridership becomes the essential factor. The ability of a system to move people in substantial quantities is irrelevant if people do not want to utilize that mode of transportation. Looking at the City of Ithaca, a small city, and the size of the PRT study route it becomes obvious that this initial PRT system should be viewed as a circulator. As such the modes of transportation that are most applicable for comparison are buses in mixed traffic moving through the central business district and automobiles. In this applied environment the capacity of a PRT system is dictated by three main factors:[xxix]

1. Physical attributes
    - Route layout and geometry
    - Number, size and location of stations
    - Number, size and location of storage/maintenance facilities

2. Control software that regulates
    - Minimum headway
    - Empty vehicle movement and storage
    - Maximum mainline speed
    - Vehicle availability
3. Spatial pattern of the service demand

The first two factors are related to technological and physical limitations. As a PRT system is designed the flexibility of the route layout and station/storage/maintenance locations become driven by external factors such as politics and land availability. Quickly physical limitations will no longer remain as variables in the assessment of a system's capacity. The present review of the technological limitations of PRT systems, which includes control software, indicates that technology will either not be the limiting factor (maximum speed capability) nor a variable that can be manipulated (headways much less than 0.5 seconds). This leaves ridership forecasting and spatial pattern of that demand as the true determinant of a PRT system's ability to meet capacity requirements. The impact of a special event such as a large sporting event cannot be taken lightly, but all stations and network geometries do not need to be designed for such a scenario.

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SECTION 4
APPLICATION OF PRT IN ITHACA

4. APPLICATION OF PRT IN ITHACA

The City of Ithaca was selected as a case study to assess the feasibility of implementing a PRT system in New York. The city's population is 29,287 and the greater metropolitan area has a population of 100,135. The total number of jobs within Tompkins County, where Ithaca is located, is 57,032. The City is also home to two major college campuses: Cornell University and Ithaca College. These demographics are consistent with areas that have a growing demand for transit and where PRT is stated to be the most efficient. Several recent local studies have also documented the need for improved transit service and the desire to have increased development density that would rely on alternative transportation modes. The following sections document the various considerations for implementation of PRT in Ithaca, NY:

- research and data collection on transportation issues and travel behavior,
- stakeholder outreach,
- route prioritization,
- technical feasibility,
- right-of-way assessment,
- constructability assessment,
- assessment of transit-oriented development,
- ridership forecasts,
- approval requirements,
- capital costs,
- operating and maintenance costs,
- potential financing strategy,
- project benefits,
- potential challenges, and
- next steps.

4.1. Research and Data Collection

The following existing relevant studies were compiled and reviewed to obtain background transportation and travel behavior information.

- Tompkins County Comprehensive Plan
- 2025 Long Range Transportation Plan
- 2030 Long Range Transportation Plan
- Northeast Subarea Transportation Study Transit Planning Project
- Park and Ride White Paper
- Tompkins County/Cornell Employees Survey
- Cornell Master Plan for the Ithaca Campus
- transportation-focused Generic Environmental Impact Statement (t-GEIS)
- Transportation Impact Mitigation Strategies
- Collegetown Urban Plan and Design Guidelines
- NY Route 13/366 Corridor Management Plan
- NY Route 96 Corridor Management Study
- Downtown Ithaca Alliance (DIA) Development Report
- DIA 2020 Strategic Plan

Appendix G, Relevant Studies provides excerpts from these studies. In general, the following characteristics of Tompkins County and the City of Ithaca support the development of additional transit infrastructure.

Non-auto/Transit Use

Fully 40 percent of Tompkins County commuters used alternative modes of transportation, compared to only 25 percent nationwide. Non-automobile use is higher in the City of Ithaca and other areas where development is compact. Tompkins Consolidated Area Transit (TCAT) TCAT ridership exceeded 3 million passengers every year since 2005 (approx. 3.3 million in 2008). At Cornell University, 1,800 employees receive countywide transit pass (1.4 million trips taken) and all faculty and staff ride free on weekdays in urban zone. The student option – Omniride – is used by 6,100 students. The Collegetown Urban Plan & Design Guidelines recommends expanding this universal pass program to all employees and residents of Collegetown.

The Ithaca-Tompkins County Transportation Council (ITCTC) 2025 Long Range Transportation Plan has several goals that continue to support non-auto and in particular transit use, including:

- Ensure that the transportation initiatives address air emissions issues in a comprehensive manner with the goal of improving or maintaining air quality.
- Encourage and implement the development of a transportation system, which uses energy efficiently and minimizes transportation related traditional fossil fuel consumption.
- Identify existing and emerging markets and provide a package of public transportation services capable of capturing those markets.
- Exceed customer expectations for transit system convenience.
- Develop infrastructure resources to support public transportation.

The 2030 Long Range Transportation Plan addresses parking and circulation. "In urban areas seeking increased densities in order to stimulate their local economies and the vibrancy of the community, parking requirements may need to be reconsidered in order to allow more land to be dedicated to productive uses (residential, office, commercial) instead of parking. The City of Ithaca can consider offering access to transit and car share as 'credits' to reduced parking requirements. The Plan also documents that the ITCTC supports efforts that will make public transportation easier to use by overcoming some of its associated penalties (time, inconvenience, etc.). The plan suggests that PRT as a transit option is worth further investigation.

The DIA 2020 Strategic Plan advocates a significant commitment to automobile and parking demand management and the use of alternative modes of transportation to handle both commuter movement into and out of Downtown, as well as for circulation between Downtown and the college campuses. The plan specifically recommends study of a fixed-rail trolley and/or Pod Car system between Downtown and the campuses. The Plan also suggests increased parking of cars outside the city center (park & ride) as a means of reducing traffic intrusion and thus enhancing the pedestrian environment of Downtown. Maintenance and enhancement of Downtown's pedestrian character was one of the foremost desires expressed by the community.

Nodal Development

The geography of the City of Ithaca – a valley surrounded by hills – encourages compact development. Well defined nodes include Downtown Ithaca, Collegetown, Cornell University and Ithaca College.

In addition, the Tompkins County Comprehensive Plan – Planning for Our Future encourages nodal development to promote livable communities, provide more transportation options and reduce vehicle miles travelled. The County's policy is to strengthen and enhance the City of Ithaca's downtown by increasing the amount and density of housing and business space in the central business district.

Consistent with the County Plan, the DIA 2020 Strategic Plan concludes that Downtown, the State Street Corridor and West End are the primary areas into which new mixed use development should be sited, given their current zoning, proximity to existing activity areas and their under-utilized land area. Based on community outreach, "there is strong community support for continued Downtown growth, within a framework that recognizes key issues of community character." The plan further states that the public's ability to provide adequate parking or enhanced public transit, as well as the constraints of current zoning will be a limit to growth, and that these issues need to be addressed in further detail.

Sustainability

It is the goal of Tompkins County to reduce green house gas emissions by 80% by 2050. It is the County's policy to consider energy usage and GHG emissions in transportation and infrastructure decisions. An action item in the Comprehensive Plan is to "Reduce Vehicle Miles Traveled through planning for park and rides, express regional commuter service, vanpool, bike/pedestrian ways and other transportation improvements."

Both Cornell University and Ithaca College are signatories to the American College & University Presidents' Climate Commitment and have released Climate Action Plans. As part of the Commitment, the institutions have pledged to reduce greenhouse gas emissions including those associated with transportation.

The Ithaca-Tompkins County Transportation Council 2030 Long Range Transportation Plan identifies a vision for Sustainable Accessibility that will integrate transportation with land use planning for nodal development to promote land use patterns that reduce dependency on the automobile as a sole source of transportation. With sustainable accessibility at its core the transportation network will integrate multiple modes of transportation so that traveling by transit, bike, car share, car pool, etc. becomes as attractive, convenient and cost effective as private car ownership and use were in the second half of the 20th century. By bringing all modes to bear, the transportation system becomes more efficient and more resilient. A vision of Sustainable Accessibility will also embrace new transportation options and technologies, which will emerge as more investments are made to address the challenges of energy descent and climate change.

4.2. Stakeholder Outreach

A Technical Advisory Committee was established to provide guidance through the course of the project. Individual participants are identified in **Appendix H.** The TAC consists of local stakeholders and includes representatives from:

- Tompkins County
- City of Ithaca
- Town of Ithaca
- Tompkins Consolidated Area Transit (TCAT)
- Ithaca-Tompkins County Transportation Council (ITCTC)
- Cornell University
- Ithaca College
- Downtown Ithaca Alliance (DIA)

TAC members were contacted individually to gather data and provide local insight and guidance. In addition a meeting of all TAC members was held on June 22, 2009. A copy of the full meeting minutes is provided in **Appendix I.** The purpose of the meeting was to:

- formally introduce the study and team of investigators to the TAC,
- request assistance in identifying and accessing existing relevant studies,
- review the findings of *Technical Memorandum 1 - Status of PRT Development,* and
- provide the TAC with a forum to identify issues to be addressed in the study.

In general, the study concept was well received by the TAC. TAC members expressed an overall understanding of how a PRT system works and why it is worth considering as a long range planning tool for the region, county and city. TAC members also expressed an interest in learning more about the following aspects of a PRT system:

- density needed to support a system,
- right-of-way requirements,
- best practices for operating agreements including public-private partnerships,
- potential financial models including revenue streams,
- documentation of the experience of other municipalities or transit agencies who have explored PRT, and
- potential barriers to implementation.

4.3. <u>Route Prioritization</u>

<u>Analysis</u>

A full PRT system for Ithaca would include an extensive network connecting West Hill, South Hill and East Hill/Cayuga Heights as depicted in the figure below. This larger system would serve as a circulator route between Downtown and the major educational institutions, as a connector between park and ride facilities and these major employment centers and provide access to retail and medical facilities on the city's perimeter. However, the extent of the PRT system is limited by the funding for this study and therefore focuses on a Phase 1 section that will link Cornell University, Downtown, Ithaca College and the West End. These four destinations were selected because they offer the highest density of workplaces in the county, have a broad mix of uses, and have a significant amount of existing housing within a five-minute walk of the proposed system.

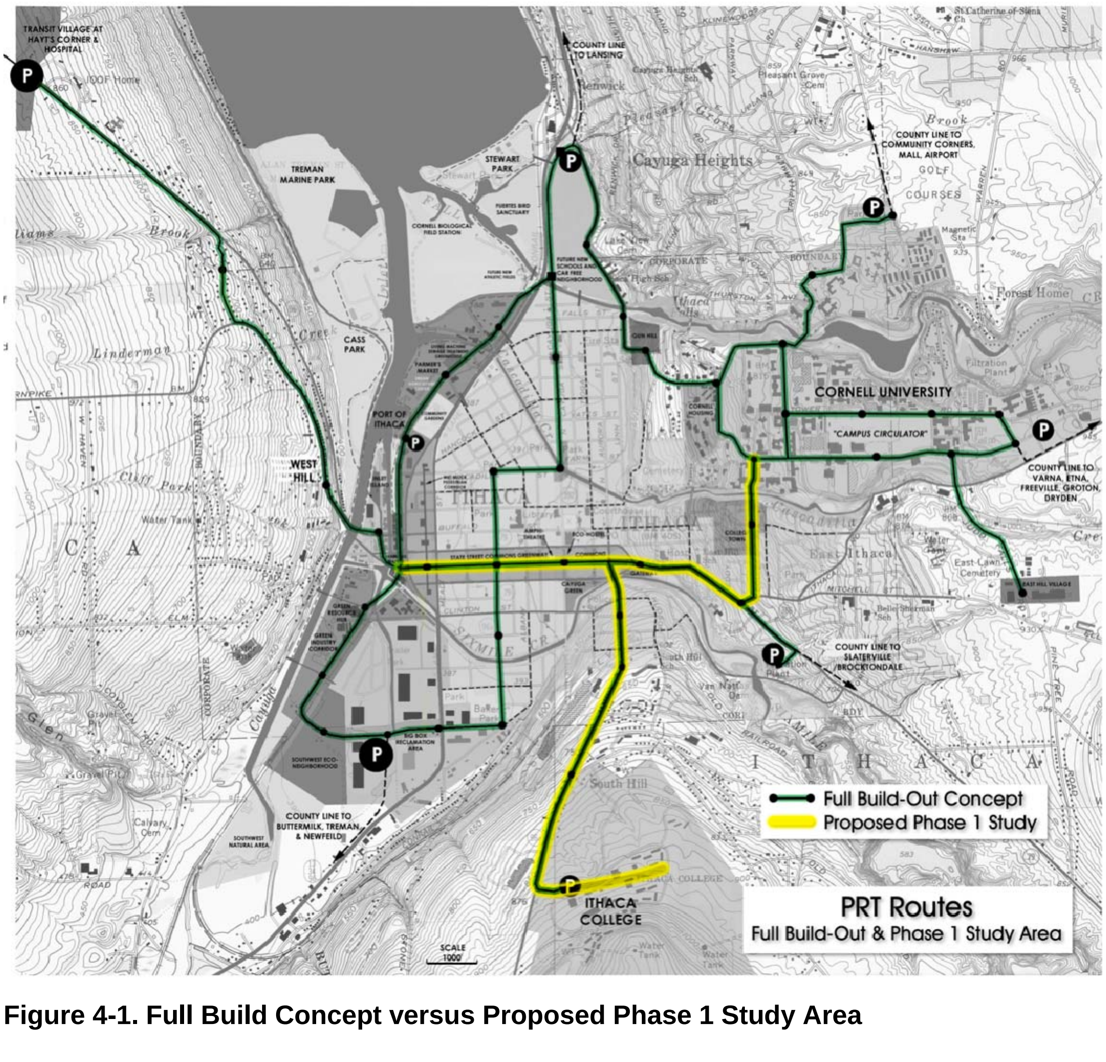


Figure 4-1. Full Build Concept versus Proposed Phase 1 Study Area

In addition to serving the three major destinations, the following considerations were taken into account in the assessment of route prioritization:

1. The area served by the route must have sufficient capacity to support new mixed-use, transit-oriented development (TOD).
2. The route must provide access to storage parking location(s) to insure the near term market viability of new housing development, and ease existing parking problems in neighborhoods surrounding developed or developing areas like Collegetown.
3. The route must extend to or include a location suitable for a maintenance and operations facility (likely including pod storage tracks).

The first consideration for route selection was the capacity of the surrounding area for transit-oriented development. It is anticipated that the largest reduction in vehicle miles traveled (VMT) will be achieved by reducing or eliminating the employee commute trips in single-occupant vehicles. By developing a sufficient supply of housing along the PRT system, commuters to the major employment centers can relocate and eliminate their automobile commute. Collegetown has reached a saturation point with regard to new development, and faces significant neighborhood resistance to new projects. The Downtown area can accommodate some new housing development, but is already significantly built-out. It was therefore determined that the route be extended southwest from the Commons to a terminus somewhere in the West End commercial area. This extension places the route within walking distance of underdeveloped areas of the city zoned for new mixed-use development, and a significant number or additional existing commercial destinations, including 2 major grocery stores.

The second consideration involves the need for "off-site" automobile storage with access provided by the PRT system. These parking areas are intended to serve new housing and commercial developments with limited on-site parking. Despite the availability of transit *within* Ithaca, transit access to the surrounding rural and village areas is limited. There is limited air and long distance bus service and no passenger rail service. The current market reality dictates that non-student oriented housing will require a minimum of one space per dwelling unit. Also considered was the cultural reluctance of people moving into the city to give up their cars. It is reasonable to assume that a formerly rural or sub-urban household will relinquish a second or third car, but always retain one vehicle, considering it a basic necessity. In addition, current retail business in the Downtown Business Improvement District (BID) is 90% visitor dependent (only 10% of sales being made to in-town residents)[xxx]. Although new commercial space within the TOD area is expected to be of a character that caters to resident's daily needs and may increase the percentage of sales by in-town residents, some parking will still be required for commercial uses. The intent of the TOD area is to minimize on-site parking and provide off-site parking, accessed by the PRT system. The West End and the Ithaca College areas provide potential for sites for park and ride facilities. These locations are also appropriate to accommodate the PRT system maintenance facility, the third consideration.

With the Downtown, Cornell University, Ithaca College and the West End commercial area defined as the key destinations, the next step for route prioritization was to consider the following potential visual impacts:

1. **Single versus Double track.**

PRT is best organized in looping configurations where a single track carries vehicles running in one direction along one street, and another single track carries traffic in the opposite direction on another street. This distributes the PRT service, allowing for the location of stations over a larger service area. It also distributes the infrastructure over a greater area, impacting more locations but with a smaller sky-print at each location. This does not increase the amount of track, though it does double the number of poles needed for a given system size.

Double track, with both travel directions supported on one set of poles along a single street, concentrates the infrastructure impacts in one location, however the sky-print of double track is greater than for single, and, unless stations are offset, a dual direction station would have a sky-print of 4 track widths.

Due to the potential visual impacts, route prioritization minimizes the amount of double track and stations that required a 4-track width.

2. **Effects at intersections**

The minimum turn radius for many PRT track systems is 50 feet. At intersections where multiple tracks cross, there is a combined visual impact of main line tracks, curved sections, extra support structures and switches.

Route prioritization focused on simplification of intersections to limit visual impact and support smoother vehicle movements. The following is the preferred order of intersection configurations:

- Intersection of two single tracks (2 tracks and 1 switch),
- Intersection of a single and double track (3 tracks and 2 switches)
- Intersection of two double tracks (4 tracks and 3 switches)

Using this criteria and maximizing connections with existing TCAT service and parking areas, **Figure 4-2, Draft Route and Options,** was developed for review by the TAC members.

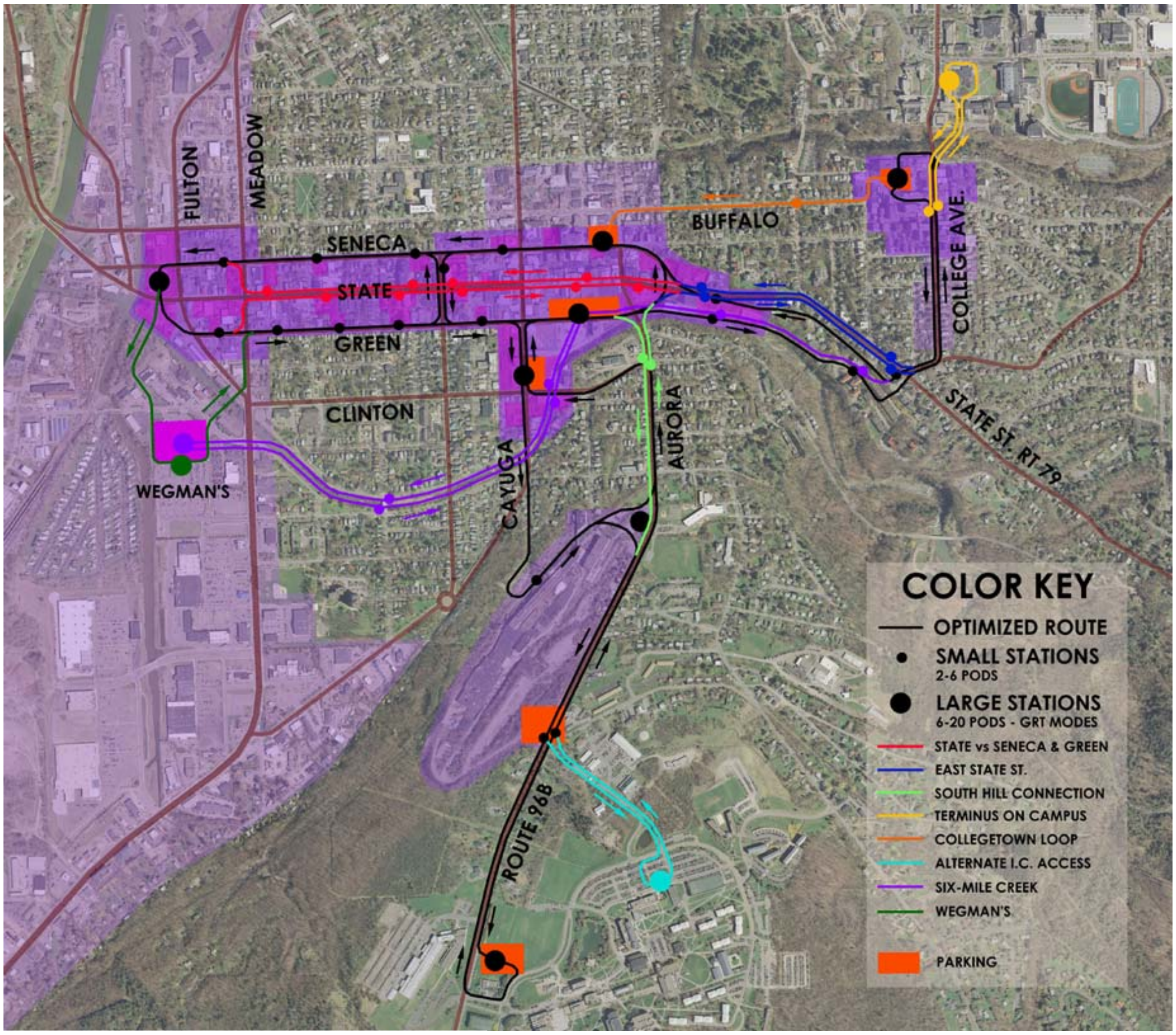


Figure 4-2. Draft Route and Options

<u>Description of Draft Route</u>

Cornell representatives preferred the terminus be located in Collegetown and not on campus. The Cornell Masterplan calls for the implementation of a "campus circulator." Connection to this circulator, would effectively give passengers arriving at Collegetown access to the entire campus. However, requiring a transfer between the PRT system and the "campus Circulator" would reduce the attractiveness of transit access to campus.

Within Collegetown, a large station is proposed to be located on top of the city-owned Dryden Road Garage (corner of Dryden Road and College Avenue). Providing access to the station would be a single track that forms a turnaround loop along the densest and narrowest part of College Avenue, around the Schwartz Center, along Cascadilla Gorge and up Dryden Road. At the intersection of Dryden and College Avenue, the loop returns to a double track running south down College Ave, and west along Mitchell Street to the intersection with East State Street. A double track is proposed for College Avenue to minimize impacts on the predominantly residential neighborhoods to the east and west, including the East Hill National Register Historic District. College Avenue was deemed suitable for more intense multi-story residential development by the Collegetown Urban Plan and Design Guidelines, so the choice was made to concentrate rather than distribute the impact of PRT in this area.

Dryden Road Garage

East State Street is a busy gateway to Downtown Ithaca and borders the aforementioned historic district. To minimize impacts to East State Street, the draft system includes two single tracks to the south. From the intersection of Mitchell Street with East State Street, the westbound single-track is proposed to cross onto private property (the Valentine Apartments) and through the surface parking areas behind rental properties on the south side of State Street. The westbound track would emerge at the intersection of State Street with East Green Street/Seneca Way ("tuning fork"). A parallel eastbound single-track is proposed to extend from East Green Street, skirt the Six-Mile Creek Gorge offering a scenic view of the natural area, and connect with the double-track on Mitchell Street at its intersection with East State Street.

Through the Downtown BID and extending to the West End, a single-track PRT line is proposed on Seneca and Green Streets, consistent with the existing one-way traffic flow. This avoids visual impact on the Commons while simultaneously allowing large stations to be located at the two existing city-owned parking garages:

- Seneca Street Parking Garage: corner of Seneca Street with Tioga Street, and
- Green Street Parking Garage: 100 block of East Green Street.

Station platforms would be located along the sides of the garages above the sidewalks. At ground level, both garages are adjacent to major TCAT bus stops, making these locations principal inter-modal transfer points. These stations would serve the Commons and majority of the BID.

To maximize circulation within the Downtown area, two loops are proposed to connect the single-tracks on Seneca and Green Street. One loop is proposed on Albany Street, the approximate mid-point of the single-track system. The second loop is proposed on the west end on Fulton Street and provides access to both TCAT, Greyhound and Shortline buses.

Small stations, along Green and Seneca streets, could be sited close to redevelopment sites and even incorporated in new buildings. The rationale for additional smaller stations is to reduce and distribute the impact of stations as the track network exits the BID and passes through residential areas. The distributed smaller stations would also create a higher level of convenience and access (reducing walk distance to station), increasing the likelihood of system use.

The West End the terminus is proposed at the bus station, which is in close proximity to the Greenstar cooperative grocery and a number of other West End businesses. The area also contains potential development sites. As noted in the potential full-build system (**Figure 4-1**), this terminus would be a connecting point for a Phase 2 PRT extending north to the Farmer's market and Stewart Park, south to shopping centers and west to residential areas and the hospital.

Due to the small size and pedestrian nature of the Ithaca College campus, the edge of campus is considered a reasonable location for the terminus. As with Cornell, circulation within the campus is left to the discretion of the institution.

The selection of a potential route to Ithaca College attempts to achieve the following goals:

- Simplify the track system at the intersection of State Street with East Green Street/Seneca Way ("tuning fork"), and
- Minimize the impacts of double-track through much of the South Hill residential neighborhood - a significant gateway into Downtown.

To achieve these goals, the draft system proposes a southbound single-track along Cayuga Street from its intersection with Green Street. This extends PRT service to the southern end of the BID, a viable development site. This track also provides the opportunity for a large station at the Cayuga Garage. The single-track would proceed up South Hill on Cayuga Street, route behind the Emerson facility, and emerge at the main entry to the plant

Cayuga Street Garage – far left

on New York State (NYS) Route 96B, where space exists for a station and broad radius high speed intersection. Northbound service is proposed to include a single-track on Aurora Street, connecting back to Cayuga Street with a westbound single-track on Prospect/Clinton streets. The northbound track is intended to serve the South Hill residential area, which is home to a large number of Ithaca College students. This configuration provides sufficient space between the intersection of Green and Cayuga streets, the proposed Green Street Garage station and the intersection of State Street with East Green Street/Seneca Way ("tuning fork") for acceleration and deceleration.

South of the Emerson facility, NYS Route 96B has sufficient right-of-way to provide a double-track line on one side of the road. This line is proposed to extend to a terminus at the main entrance to Ithaca College, near Alumni Hall. Though no current development is planned in this location, land area exists for a possible off site parking facility and Transit Oriented Development along this part of the PRT route.

Route Options

At the first TAC meeting, held on June 22, 2009, the draft system described above was presented. The following route options, depicted in **Figure 4-2,** were also presented for consideration by the TAC:

1. *State Street versus Seneca and Green streets*. This option replaces the single-track loop on Seneca and Green streets with a double track along State Street. This option allows passengers to see the retail and restaurant amenities along State Street and to make demand stops if there is something of interest. The loop on Green and Seneca streets relies on passengers knowing where they need to stop and walking one block to State Street. Advantages of the State Street option include:
    a. Direct access to amenities on State Street (reduced walking distance),
    b. Reduced impact on the edges of residential neighborhoods on Green and Seneca streets,
    c. Reduced support structure costs, and
    d. Potential for the double-track structure to support street covering infrastructure for festivals, etc.

    Disadvantages of this option include:
    a. Intrusion on The Commons pedestrian mall,
    b. Lack of direct connection to the parking garages and busses,
    c. Need for large (high capacity) stations on the Commons,
    d. Potential visual impact on historic buildings, and
    e. Connection to Ithaca College occurring at intersection of Cayuga and State streets – the start of the pedestrian mall, busy traffic intersection and a space considered to be the traditional heart of the city.

With the exception of the intrusion on The Commons, members of the TAC expressed support of both options (single-track loop on Green and Seneca streets and double-track on State Street). Protection of the Commons is imperative and the bus/parking garage connections are considered both logical and necessary. In a discussion on implementation with Thys van Cort, former Director of City Planning and Development, it was suggested that the route avoid the Commons, connect to the garages and jump from Seneca and Green streets to State Street at Albany. The vast majority of properties on West State Street are commercial, while 50-60% of the property on West Green and West Seneca streets west of Albany Street is residential. It is anticipated that the residential property owners would resist PRT placement on their streets, but that the developing commercial interests on W. State Street would welcome it. *The preferred route provides single-track on Seneca and Green streets between the Tuning Fork and Albany streets, merging to a double-track on West State Street.*

2. *East State Street versus private property*. Because of the difficulties presented by siting track on private property (despite potential benefits to the owner) and the potential conflicts with placing track along the edge of a natural area, the option of placing double track directly on East State Street was proposed. In the TAC meeting, stakeholders supported the notion of limiting the extent of impact, even if it meant that certain areas would bear a higher localized intensity of impact. In the conversation with Thys van Cort, it was revealed that the Valentine Apartments have already received approval for a very high-density project that would involve the demolition of all their residential property on the south side of East State Street. The project, currently in the planning stage, will substantially increase housing density and benefit from a station placed at the intersection of State and Mitchell streets. Additionally, the "historic" houses along East State are not owner occupied, and it is anticipated that owners would not resistance to PRT placement. *The preferred route places the double track on East State Street.*

East State Street

3. *South Hill Connection.* As an alternative to the single-track loop on Cayuga, Aurora and Prospect/Clinton streets, a double-track was proposed along Aurora Street. The advantages of this option include:
   a. Simplified route,
   b. Reduced infrastructure costs, and
   c. Impact on fewer streets.

The primary disadvantage would be the impact to the intersection of State Street with East Green Street/Seneca Way (“tuning fork”). The extension of a double track from this intersection would place it in close proximity to the Green Street Garage station potentially impacting the speed of the system. *This option was dismissed.*

4. *Terminus on the Cornell Campus.* To create a more direct connection to the campus, this option proposes to extend the Collegetown leg across Cascadilla Creek above the original trolley bridge (now a footbridge). This would place the high capacity terminal station at the Engineering Quad and eliminate the need for a Collegetown loop and large station at the Dryden Road Garage. *Cornell representatives on the TAC dismissed this option due to new plans for the Engineering Quad.*

5. *Collegetown Loop*. To reduce the impact of a double-track along College Avenue and East State Street, this option proposes to create a single-track loop. The loop would travel east on East State Street, then north on College Avenue, maintain the single track loop within Collegetown to the Dryden Road Garage, then extend west on Buffalo Street rejoining the Downtown track at the Seneca Street Garage. *This option was dismissed due to the sensitive architecture and character of Buffalo Street, part of the East Hill National Register Historic District.*

College Avenue

6. *Alternate access to Ithaca College.* To reduce track length and avoid the main gateway to the campus, this option proposes a double-track from the proposed off-site parking facility on NYS Route 96B, entering the campus in the vicinity of the Physical Plant and connecting to a station in the student parking area near Park Hall. This option does not provide access to the South Hill Business Park or potential development sites on NYS Route 96B. This option was favored by Ithaca College representative on the TAC because it protects the campus’ view-shed and places the PRT station closer to the pedestrian core of the campus. *This option is incorporated in the preferred route.*

7. *Six-Mile Creek.* This option, developed by Cornell graduate students as part of an independent study class project examining the planning and landscape design aspects of PRT, proposes a double-track along Six-Mile Creek from its intersection with Green Street west to the Wegman’s

supermarket. The students assessed that routing through a natural corridor would have minimal impact on neighborhoods and would facilitate implementation. However, local stakeholders on the TAC indicated that the intrusion on Ithaca's prized natural areas would meet with significant community resistance. It was also determined that this routing option failed to place transit near potential development sites. *This option was dismissed.*

8. *Wegman's*. Though outside the initial study area, the overwhelming opinion of stakeholders was to extend the western terminus past the bus station to Wegmans, the busiest grocery store in the county. This extension would benefit residential development along the PRT system and is considered a desirable destination by students. Thys van Cort, former Director of City Planning and Development, indicated that obtaining permission to cross the railroad (along the west side of Fulton Street) would be the single most difficult aspect of implementation and should be avoided if possible. Therefore, this option proposes a single-track loop along Fulton Street to the south, crossing Six-Mile Creek with a long-span segment of track and ending at a high capacity station in the Wegmans parking lot. This option also proposes the construction of an off-site parking facility, on the Wegman's expansion lot, to serve residential and commercial development Downtown. *This option is incorporated in the proposed route.*

Wegmans' Plaza

Proposed Ithaca Study Route

The proposed route for the purpose of this study is depicted in **Figure 4-3**. The route consists of approximately 4 miles of one-way track and another 2.0 miles of double track, and another mile of station associated track for a total equivalent of 9 miles of single-track length. There are also 7 large and 19 small stations for a total of 26 stations.

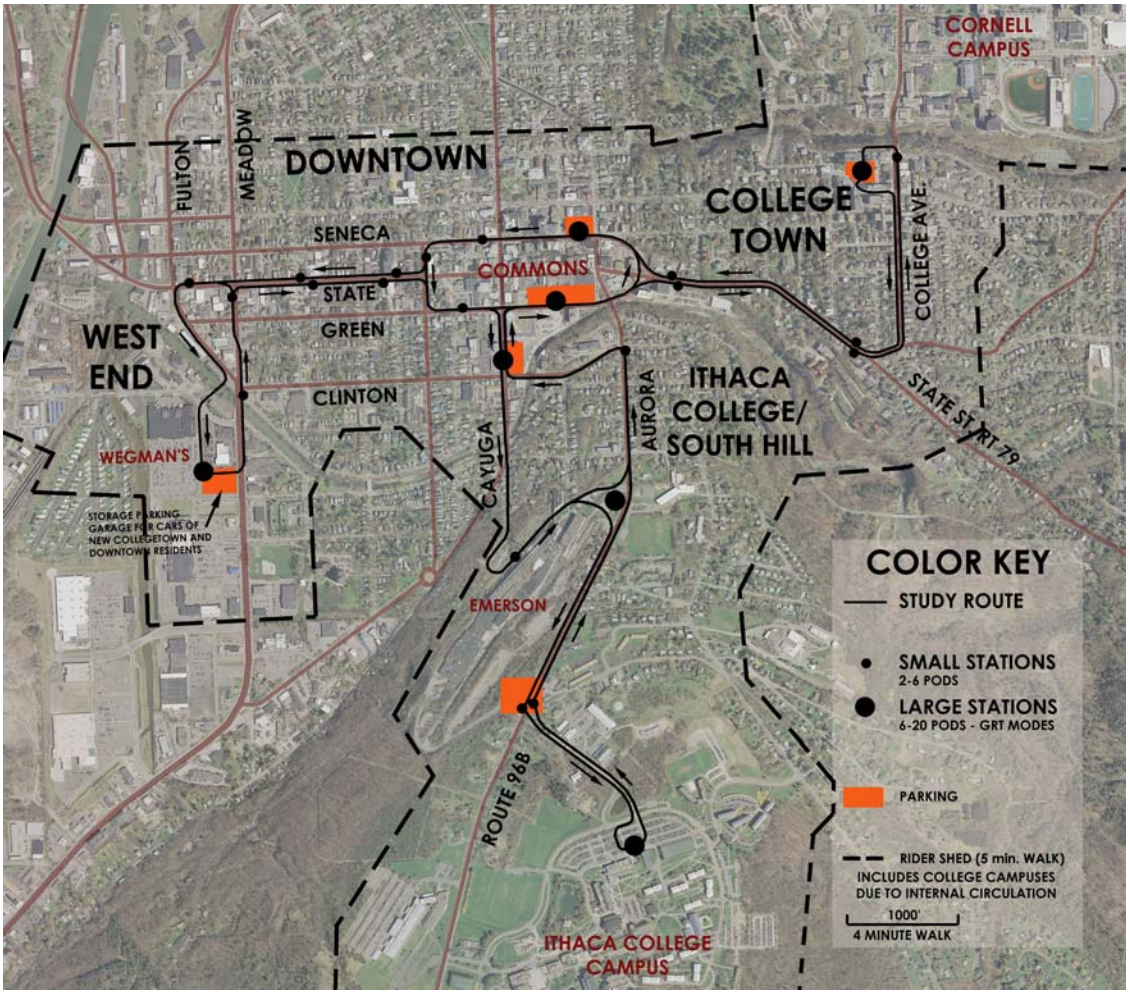


Figure 4-3. Proposed Ithaca Study Route

4.4. <u>Technical Feasibility</u>

4.4.1. <u>Local Conditions</u>

The following is an introduction to the optimum technical characteristics of a PRT system operating in Ithaca, New York. The primary limiting selection factors are scale and character of the existing built environment, the Upstate NY climate, and Ithaca's challenging topography.

Built Environment

Much of the Phase 1 study route (see **Figure 4.3**), and the majority of potential system extensions, pass through existing urban neighborhoods which were built during the late 19th and early 20th centuries. The typical publicly owned street rights-of-way vary from 40 feet to 60 feet, and building setbacks range from 0 feet to 20feet from the right-of-way boundaries. Significant street trees exist along approximately 55% of the proposed route, and there is a strong desire within the community to preserve their integrity as indicated by Ithaca's planning standards. Most of the architecture along the route is aesthetically traditional and local planning and design sentiments favor new construction which respects the existing character of the community.

One of the largest factors regarding physical integration of a PRT system into an existing urban streetscape is the utility infrastructure. Not only would the guideway have to be kept above standard road clearance heights (14 feet; 16 feet on state routes), but also it would have to negotiate the telephone, communication, and power lines that cross the right-of-ways (ROWs). The concept of integrating these utility lines into the PRT infrastructure is interesting and provocative but may be politically and fiscally difficult, at least in the short term. This is an area that will require additional research. *Therefore, this study assumes that the PRT system will share the ROW with the existing utility line infrastructure, not replace it.*

With the above factors in mind, we have identified the following system characteristics:

- Minimum turning radius must be 50' (15m) or less to keep track within public rights-of-way.
- System must exhibit quieter than automobile operation (<65db) because of inevitable proximity to buildings.
- System selected must have enough design flexibility to allow for track to be positioned over the center of streets, above the touching point of the tree canopy, so as to hide the infrastructure from the pedestrian level and to minimize impingement of natural tree shapes.
- Track underside should not exceed 24" (0.6m) to minimize the visual impacts of overhead tracks, especially where dual direction lines are located.
- Support pole spacing should be equal to or exceed utility pole spacing (60' – 80' average).
- Edge to edge visual intrusion of support structures must be minimal. (<24" dia.).
- In most areas opposing support poles would ideally be placed on the sides of the road, typically within the tree lawns, and connected with cross-beams to support the guideways running over the center of the streets.

Climate

The climate in Ithaca, NY exhibits four seasons with major extremes. The system selected will need to operate fully and provide passenger comfort under the following conditions:

- Winter temperatures down to –20 degrees Fahrenheit (°F)
- Summer temperatures up to 100°F
- Gusty wind conditions with a maximum design wind speed of 90 mph.
- Heavy snowfall (average of 70 inches per year with some snow events in excess of 18 inches at once, snowfall rates up to 2 inches per hour).
- Icing conditions.
- Over 150 days per year with precipitation.

Topography

The Phase 1 route will traverse elevation changes from Downtown up to the college campuses in excess of 500 feet. Some areas of the route have street slopes of approximately 15%. Though variation in track elevation above the streets can mitigate some slope concerns the aesthetic, passenger comfort (vertigo), and serviceability issues may dictate pole/track height above ground be kept within reasonable limits. System selected will therefore need to meet the following criteria:

- Operate effectively and preserve passenger comfort on slopes up to 10% (15% ideally for optimum design flexibility)
- Use motive power technology which can move vehicles up grades without excessive wear and tear or degradation of performance.
- Use a motive power technology which can make use of regenerative braking as vehicles move downhill.
- Have sufficient traction or track clearing technology to operate on steep slopes in snow and ice conditions.

4.4.2. Guideway

At-grade systems, like 2GetThere's FROG system follow dedicated road ROW's but also negotiate intersections and crossings of traditional vehicular and pedestrian environments with advanced sensor and control systems. This guideway approach as well as other at-grade concepts requires space for dedicated right-of-way (ROW) that would most likely come from already constrained roadways. The integration of an at-grade PRT solution into existing urban environments like the City of Ithaca would result in shared or significant loss of space. This implementation barrier is evidenced by the experience of trying to create bike lanes in the City of Ithaca for almost 35 years. Another disadvantage of at-grade guideway is delay incurred at intersections, which significantly reduces the potential time-saving benefits of non-stop service.

Masdar City, in United Arab Emirates (UAE), is a mega-development designed to emit zero carbon dioxide while housing up to 50,000 people and 1,500 businesses. The urban grid of this "car-free" city is being constructed so that all of the buildings' ground floors are several meters above the ground, making room for a comprehensive subterranean PRT system. While feasible in new construction, u*nderground systems* present significant implementation barriers in a built environment. Construction of any system will have temporary impacts to travel flow and access to adjacent properties, but an underground system, requiring tunnel construction, will also have the potential for the following impacts:

- Disruption of groundwater table
- Disruption to foundations of adjacent buildings
- Disruption to and potential relocation of underground utilities
- Require additional safety and security measures since the system is not visible from the street or adjacent properties

Elevated, open guideway systems like the ATS ULTra system at Heathrow Airport in London consist of a flat surface to support the vehicle. The ULTRa system is comprised of a steel superstructure with pre-cast concrete panels providing a running surface for the vehicles. This type of system is essentially a reduced-scale conventional road surface for rubber tire vehicles. The guideway provides very little protection from weather and the size is dictated by the width of the vehicles. Studies performed by ATRA[xxxi] looked at the "skyprint" of various PRT concepts and concluded that a guideway similar to ULTra's is the heaviest when compared to overhead, track-supported captive bogey or track-suspended PRT vehicle guideways. The form of elevated, open guideway systems presents the following disadvantages for a city environment in a cold climate:

- Winter weather conditions could result in compromised tire traction in snow and ice, particularly on steep grades, which would most likely require that the guideway be heated as was done with the Morgantown GRT system.
- Greater visual impact due to the required width of the guideway (vehicle width plus side barriers).
- Material efficiency is low because there is more guideway surface needed than required by the wheels.

Elevated captive bogey systems, like those proposed by Vectus, Taxi 2000, and PRT International, can minimize visual impacts since the track can be narrower than the vehicle width. However, adequate track width is required to provide even vehicle support and stability. The stability afforded by a two-rail track design would provide exceptional performance in windy conditions and minimizes the number of moving parts in the vehicle design since the track could be banked. However, at slower speeds a banked track could create occupant discomfort and would also increase the design and fabrication costs of the guideway due to the need for metal components with compound curves. A possible solution to this issue is to utilize an articulating vehicle bogey to offset high bank angles or grades but the mechanical complexity would be a drawback in terms of vehicle cost and maintenance. According to Vectus' website[xxxii] their system can negotiate grades up to a 100% gradient, or 45 degrees. In Ithaca there are road grades as steep as 14% and a PRT system route may experience grades of 15 to 20% to optimize a route when negotiating some of Ithaca's dramatic topography. Even so these grades are far from the technical limitations of a supported-vehicle guideway, which means other issues such as occupant comfort (15% maximum; 10% preferred) or construction feasibility would be the limiting factors in this regard. From a safety standpoint a supported vehicle would be restrained from falling by the track and the loads that would force a vehicle to detach by mechanical failure are very minimal since the guideway provides the necessary support against gravity and the largest proportion of moving loads.

Vectus' test track in Uppsala, Sweden has shown that a bottom-supported captive bogey guideway can operate successfully in snow and ice conditions. Vectus has verified that speed reduction is only in effect when using the "snow plough" and then normal speeds are restored. The track is not heated, but some testing has been done on short sections with heated track which could prove useful to avoid accumulation of ice. The heating would only need to be applied for short periods of time at specific conditions. As long as vehicles are operated reasonably frequently, there is very little build up of snow and ice. The form of elevated, captive bogey guideway systems presents the following disadvantages for a city environment in a cold climate:

- The exposure of the tracks must be eliminated to mitigate the effects of snow and ice, which could create problems climbing & braking on the steep grades in Ithaca.
- Greater visual impact due to the required width of the guideway.

Elevated suspended-vehicle guideways would provide the smallest "skyprint" or visual footprint with the width at least 50% smaller when compared to a captive bogey guideway. This configuration is represented in system concepts such as Beamways, Mister, and Skytran. With a suspended vehicle the track would only have to be built with two dimensional curves since the vehicle connection to the guideway could articulate to handle any required banking. This may simplify the guideway design and reduce cost. Conversely the vehicle or pod design would have a more complicated bogey with moving parts, but this is potentially comparable to captive bogey design with a different set of design complexities. Intuitively it seems likely that a suspended bogey is sufficient for the light weight of PRT vehicles (~1800lbs or less fully loaded) as long as the torsion forces can be mitigated, which may be as simple as using heavier gauges and thicknesses for the structural components. This strength increase may prove to have a two-fold benefit since the guideway load capacity would also increase thus allowing for some higher load freight traffic. In contrast with a supported-vehicle guideway where the structure has to be spread horizontally to support the vehicle a suspended-vehicle guideway can allocate the structure in a vertical configuration to optimize the span capacity of the guideway between poles. The form of elevated, suspended guideway systems presents the following advantages for a city environment in a cold climate:

- The configuration makes it much easier to ensure complete protection from snow and ice.
- The guideway size has the potential to be the smallest to minimize visual impact.

For all *elevated systems*, the guideway superstructure, comprised of the foundations, poles, and either support arms or cross-beams, needs to be incorporated in the existing built environment. The guideway must be woven between utility poles and wires, traffic signals, and street trees (see **Figure 4-4**). In Ithaca, as with many other upstate New York cities, there are utility poles lining one side of a street with wires spanning between them and crossing the street at varying intervals. In addition, trees often line both sides of the street. While there will be some instances where pole and support arm structures can line one side of the street to carry the guideway, the majority of the system will require the guideway to be placed over the center of the street. This factor will require that the primary superstructure supporting the guideway be in a two-pole and cross-beam configuration (see **Figure 4-5**).

Figure 4-4. Example of utility infrastructure in Ithaca, NY

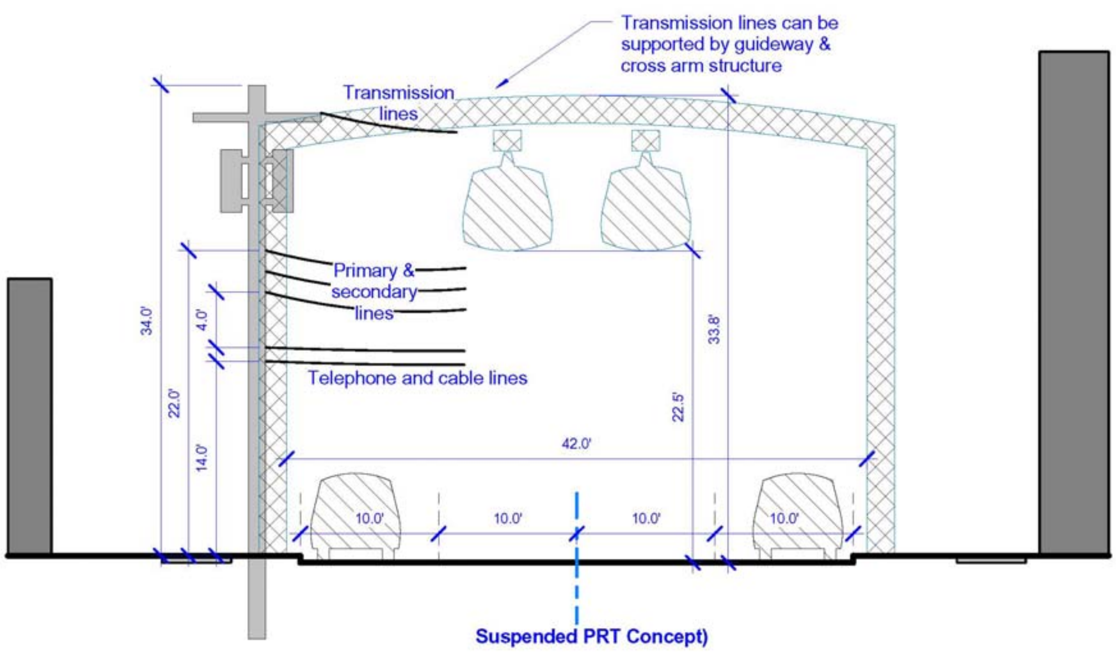
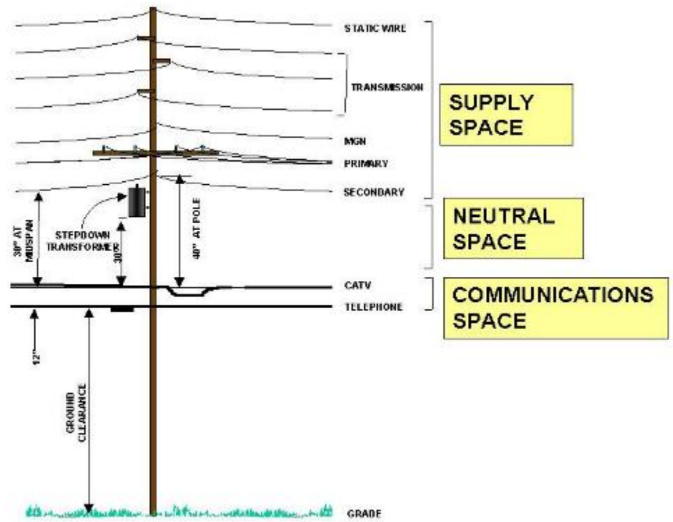


Figure 4-5. Example of a PRT right-of-way cross-section - Suspended Bogey

Integrating the PRT poles with the utility infrastructure on one side of the street may prove quite difficult since the wires spanning between utility poles will limit the height of that pole. Another critical factor of an elevated PRT network is that the lowest physical element of the system cannot be lower than 14 feet, and over state roads not lower than 16 feet. Typical utility infrastructure (see **Figure 4-6**) includes a communications space at 12 to16 feet, secondary electrical service lines approximately 4feet above that, primary service lines anywhere from approximately 2 to 4 feet above them, and then usually a gap before the main electrical transmission lines at the top of the pole which is typically approximately 34 feet (40 feet with 6 feet burial). Depending on utility line crossings the guideway will most likely need to be further elevated above the secondary and primary service lines. To clear these lines the clearance zone for a PRT system will begin at approximately 20 to 24 feet above grade and have a height of approximately 11 feet to fit the guideway and cross arm structure (approximately 4 feet) and the vehicle (approximately 6 feet plus 1 foot buffer). System integration may require that the transmission lines be adjusted upward slightly to create more space.



Source: http://annsgarden.com/poles/poles.htm

Figure 4-6. Typical Utility Infrastructure

Combining the utility line crossings and the road clearance requirements the physical space impacts of an elevated PRT system will vary depending on whether the vehicles are suspended or supported by the guideway. If an elevated supported guideway design is progressed, the height of the guideway plus the vehicle above the approximately 20 to 24 foot road and utility line clearance requirement is approximately 11 feet, which places the pole height and cross arms at 20 to 24 feet above the road, but also puts the top of the vehicle at approximately 31 to 35 feet above the road. This creates a potential conflict between the transmission lines and the top of the vehicle (See **Figure 4-7**).

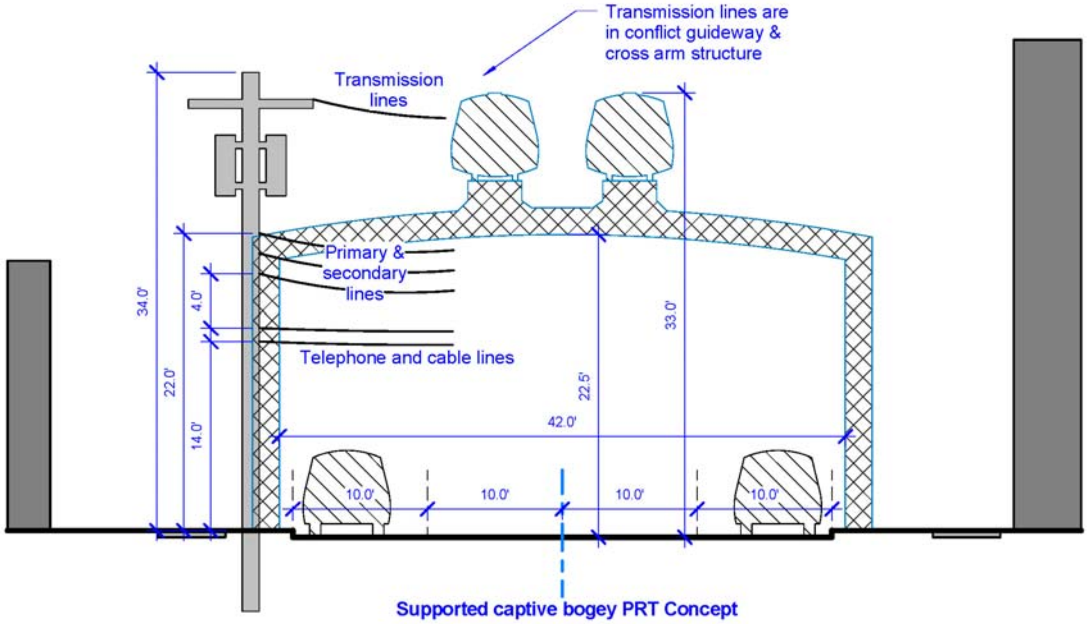


Figure 4-7. Example of a PRT right-of-way cross-section - Supported Captive Bogey

With a suspended system the track, which could act as an electrical transmission conduit in the future and also requires power, the existing transmission lines can be supported by the track itself, allowing the vehicles to operate below. This is an advantage of a suspended system over a supported system. The pole height and cross arms would then be located at approximately 31 to 35 feet above the road. Regardless of the guideway type the track will generally run parallel to the transmission lines that typical run along the sides of the road with very few crossings. For safety and service reasons the communications space needs to remain in the current height zone (12 to 16 feet). This leaves the secondary and primary electrical lines as the primary ROW obstruction with the most road crossings to provide electrical service to buildings. Under the assumption that a PRT network is more likely to be realized as an integrative solution rather than an infrastructure replacement solution, the logical placement of the PRT guideway is at least above the secondary lines which make the most crossings and above most of the primary crossings. This should limit the amount of work by the utility company to accommodate and make room for a PRT system. Of course a replacement scenario would be the ideal scenario but it seems prudent to assume that even if some utility ROW areas along a PRT route may secure funding and approval for a combined ROW upgrade there is likely to be multiple scenarios for how PRT will need to share the existing road and utility ROW.

Preferred Guideway for Ithaca System

Although this is an area that will require additional research, based on currently available data the preferred system for Ithaca, NY would be an elevated guideway. Due to the desire to minimize visual impacts associated with an elevated guideway, either a suspended or supported captive bogey system is preferred over an open guideway system. In general, an elevated guideway presents the following advantages and disadvantages:

Advantages:

- Operates in a dedicated right-of-way to ensure a predictable schedule.
- Does not require disruption for below-grade construction.

Disadvantages:

- Visual impacts, which may represent the greatest obstacle to overcome.
- Disruption to and potential relocation of overhead utilities.
- May require snow and ice removal during winter.

Of the PRT systems currently under development, only three companies are advanced enough to provide a passenger-ready PRT system. They are Vectus PRT, Ultra, and 2getthere. Each have demonstrated working prototypes, achieved safety certifications, and both Ultra and 2getthere have delivered working PRT systems and/or “PRT-like” automated mobility systems. These three systems all use bottom supported vehicles. The following disadvantages of a bottom-supported system as compared to a suspended system may be overcome through design:

- Track must be banked through turns to resolve centrifugal forces and passenger comfort. Though this can be calculated and engineered, the vehicles must pass through turns at design speed. System conditions may not always allow this, i.e. during peak periods, system congestions or emergency stops in turns.
- Vehicle speeds will slow through tight turns, resulting in overall system slowdown.
- Climbing angle is restricted by passenger comfort, even if sufficient power and traction is available.
- Track is more exposed to adverse weather conditions.

4.4.3. <u>Vehicle</u>

In an effort to understand the impacts and performance of an initial Ithaca PRT system some simulations were performed utilizing Beamways’ proprietary software BeamEd (see **Appendix J**). The main variable in each of the BeamEd simulation scenarios is the number of vehicles in the system which was increased to obtain simulation results within the operational limits of the software. This suggests that a high percentage of departure waits can be a result of too few vehicles in the system. The number of vehicles required is an area that requires additional research and will most likely be dependent on the final system selection. *For planning purposes, it is assumed that the system will include approximately 350 vehicles. The selection of a vehicle type for Ithaca, NY will be dependent on selection of a system type and supplier.*

4.4.4. Propulsion

Based on the above propulsion system characteristics, LIM-driven systems appear to be the logical choice for smaller PRT networks that do not require high speeds. This is because the technology is simpler and the next evolutionary step in propulsion systems with similar components, as well as a related research, design and operation background as found in the current rail industry. An assessment of various Transrapid LSM applications show that the costs of an LSM-driven system will be at least 2 to 2.5 times the cost of a LIM-driven system.[xxxiii] However, this assessment was based on a review of higher speed, multi-passenger trains, not PRT. The LSM technology has some significant performance advantages, especially energy efficiency, and a specific analysis of LSM use in smaller PRT networks may reverse this initial conclusion that LIM is the preferred technological choice for PRT. This is evidenced by the work of MagneMotion with LSM technology preferred in their PRT concept. Similarly Vectus' system that utilizes a long stator LIM configuration that begins to emulate the configuration of a LSM system. *Ultimately the propulsion choice for a PRT system will have long term impacts in terms of energy efficiency, serviceability, and continued viability, so additional research on propulsion systems is recommended.*

4.4.5. Switching

Intuitively, the preferred method of switching in a PRT system would be an electromagnetic system. This is because there are no moving parts and therefore less prone to wear out or require maintenance. Another advantage is that electromagnetic switches tend to either fail immediately or operate for a long time. *Ultimately the decision on the type of switching to utilize will fall on the manufacturers of PRT systems.* Through operational testing it may be shown that a mechanical switch may overcome the inherent shortcomings, but seems unlikely. Therefore an optimized PRT system would ideally have the ability to upgrade or transition from one switching type to another. The clear advantages of magnetic switching over mechanical systems are speed, reliability (even more so with redundancy), less susceptibility to weather, and logical integration with propulsion systems using linear electric motors.

4.4.6. Stations

Since PRT system optimally run on elevated guideways to avoid street level traffic the station platforms need to be elevated as well. Depending on the guideway configuration (vehicle-supported or vehicle-suspended) the platform elevation will vary. A simple station will require stairs and an elevator, basic weather protection, and a service interface component for ticketing. All that is needed to build the station/platform are land parcels that are +/- 60 feet wide, which is a common lot width in the City of Ithaca. Parcel assemblage to create station would require one (1) or two (2) lots per station. Because of the above grade design a logical place for station locations is over small parking lots since the current land use would be minimally affected. Another location for easy and logical station locations is adjacent to large "big box" retailers where parking facilities and space are ample, the locations are typically peripheral to urban core areas and thus make good park-n-ride locations, and the environmental impacts of surface parking and predominant automobile access can be relieved by PRT trips. Within the urban core a logical placement of stations is to build them into parking garages since this provides parking as well as long building facades for the platforms. The parking becomes a critical means to encourage users (residents, commuters, tourists) to carry out their daily errands on the PRT system, but also provides storage parking to promote a shift to urban living in parking-reduced new housing developments. Other candidates for future PRT stations include hotels, campus centers, housing complexes, airport terminals, train stations, malls, casinos, or office buildings/complexes.

As identified in Section 4.3, Route Prioritization, the preferred system for Ithaca would include 26 stations. The following seven large stations would serve major destinations:

1. Dryden Road Parking Garage - Collegetown/Cornell University
2. Seneca Street Parking Garage - Commons/BID
3. Green Street Parking Garage - Commons/BID
4. South Hill
5. Wegmans
6. Emerson
7. Ithaca College – Alumni Hall

Nineteen small stations would be distributed throughout the network.

4.4.7. Maintenance and Storage Facilities

Early research of PRT systems has indicated that the storage capacity should be 85% of the total vehicle fleet and maintenance bays should equal 10% of the storage capacity. *The Ithaca Study Route would require 350 vehicles and therefore a storage capacity of 300 vehicles and 30 service bays.*

Based on the need for 100 SF for vehicle storage and 250 SF for service bays, the storage and service depot would require the following:

- 30,000 SF of storage space which could be a 10,000 SF footprint 3 stories tall.
- Thirty service bays at 250 SF each would be 7,500 SF located on one floor.
- Assembly line tracks with three function bays and triple redundancy would require approximately 2,000 SF of space including track switching space and accessory spaces.
- The size of the main track running the length of the building and a circulating loop around the storage area would depend on the building configuration.

Therefore a 300 berth depot could have an approximately 100 foot x 120 foot storage area with a 30 foot x 120 foot service bay on one side and a multi-function assembly line 15 foot x 120 foot on the other. The circulation tracks would add two more building areas approximately 10 foot wide x 120 foot long plus return tracks on each end of the building to create a loop. *This would result in a building footprint of approximately 160 feet x 140 feet (23,000 SF) with two upper storage floors for a total square footage of 51,100 SF. Above the larger first story footprint would be ample space to construct offices and a system control center.*

Although the system is small the daily maintenance of the PRT vehicles would be a significant task. The daily service tasks (cleaning and subsystem checks) would be performed in an assembly line approach. Assuming a service cycle of 10 minutes/vehicle on three lines in the hypothetical 300 berth depot described above would allow for the servicing of 18 vehicles per hour or 432 vehicles in a 24 hour period. This also assumes that some vehicles are serviced throughout the day during times of low system usage. This maintenance capacity (432 vehicles) is greater than the total vehicle count in a system. However, it may not be possible to perform daily service tasks during the day when vehicles are in use, which means the timeframe for servicing may be realistically reduced to 12 hours, requiring additional maintenance area to accommodate all vehicles.

Locating maintenance and storage depots of this size requires acquisition of land of adequate size and zoning to allow for their construction. The property must be developable in terms of topography and zoning regulations. The depot operations would be similar to a motor vehicle repair facility so the zoning must allow this type of commercial use. Likewise the most efficient use of the property would be to build up and the zoning must allow for three stories or more in height.

Depending on the overall configuration of the PRT system the number and dispersion of depots will vary. Limited land availability may preclude construction of one large depot to provide complete storage, daily servicing, and long term maintenance. In addition the movement of vehicles through the core of the system to reach a single service depot would potentially add congestion to the system. Another factor to consider when locating the maintenance and storage depot(s) is that the large storage capacity of the depot(s) should be ideally located near areas that generate high peak demand scenarios. For obvious reasons the use of multiple storage depots provides for an even distribution of capacity to respond to various high demand situations. A suggested rule of thumb is to place the storage depots at intervals of 2 miles[xxxiv].

The radial configuration of the Study Route with three lines extending from the city center would dictate that a depot be located near the periphery of the PRT system. This placement is consistent with the land availability in the Ithaca area since larger parcels become more possible for acquisition the further you get from the downtown. *Potential locations for a system depot(s) in close proximity to the Study Route are adjacent to Wegmans or on the former Emerson Power Transmission site in the Town of Ithaca.*

In relation to the Study Route it seemed practical to plan for two storage depots of 250 vehicles each. An Emerson depot, in close proximity to Ithaca College, could accommodate the high demand at this end of the system. This location also accounts for the additional travel distance created by the PRT system having to navigate the topography of South Hill to reach the IC campus. Unfortunately with land availability being scare in the downtown city core and in "Collegetown" the logical place for another depot is in the vicinity of Wegmans. This depot would be larger than the Emerson depot since it would need to respond to large demand scenarios created in Collegetown and from the adjacent Cornell campus. The Wegmans depot also suggests the concept of a park-n-ride scenario where commuters traveling to work via Route 13 in the morning could consider the Wegmans location an ideal place to park before riding the PRT system to work at one of the primary employment centers consisting of downtown, Cornell University, or Ithaca College.

4.4.8. <u>Headway</u>

A good reference to begin to understand the relationship between headway, travel speed and capacity is Edward J. Anderson's paper titled "The Capacity of PRT Systems." To do this we must first examine ridership potential with some theoretical figures as follows:[xxxv]

- In the US a typical assumption is that there are three vehicle trips per person per day with 10% of daily trips occurring in the peak hour. Thus, the peak-hour trips per square mile equal 0.3 times population density.
- Assume a PRT network consisting of a grid of guideway spaced ½ mile in each direction. This yields an average station density of 8 stations per square mile at the nodes of this grid. Note: The Ithaca Study Route is a linear system so network load reductions are not possible through alternate routing. This means the Study Route will not follow this hypothetical scenario due to higher congestion and will require lower headways.
- Population density of at least 6,000 people per square mile (City of Ithaca density per US Census Bureau): Peak-hour trips/square mile = 0.3 x population density= 1,800; PRT mode share of 30% would equate to 504 peak-hour trips.

In a network configuration with eight stations per square mile the average peak-hour station flow would be 68 trips. The headway required to handle those trips would be 53 seconds (3,600 seconds per hour divided by the 68 trips). However, this assumes an equal distribution of trips. The Study Route might polarize this distribution in the peak hour and load the stations virtually at the same time. As such it could be argued that the more conservative estimate is to calculate the necessary headway based on all 504 peak-hour trips requiring a headway of approximately 7 seconds (3,600/504). If we assume an extreme scenario where the transient student population doubles the population density the required headway needed to handle the peak-hour flow would be 3.5 seconds. Therefore, the theoretical capacity requirement of the Study Route is consistent with the current safety approval of 3 seconds for the Vectus PRT concept. *Headways of 3 to 5 seconds would provide an acceptable level of service in Ithaca.*

4.4.9. Travel Speed

Most PRT systems operate in the range of 25-45 mph, with an average of 25-30 mph. The speed for a system in Ithaca will be dependent on the final system selected.

4.4.10. Capacity

Before a PRT system is to be considered for actual implementation a realistic model of its performance needs to be made. For it to be interwoven into an existing urban environment an accurate computer simulation becomes critical if policymakers and regulatory authorities are to allow its construction. Just as important are the testing scenarios and results from actual test tracks that can justify the software parameters.

In an effort to understand the impacts and performance of an initial Ithaca PRT system some simulations were performed utilizing Beamways' proprietary software BeamEd (see **Figure 4-8**). It should be noted that this software is based on one PRT vendor's attempt to incorporate the necessary parameters to produce an accurate guide for PRT feasibility. While an argument could be made that such software could be self-serving it would not be beneficial for a PRT system designer to fabricate results that cannot be replicated in an actual system. In order to use the simulator the following assumptions were made:

- **Demand** - as defined by the BeamEd software is "the percentage of the population which makes a PRT trip in one hour." For this analysis, the population was assumed to be 55,000 people (City of Ithaca population is ~29,000; Cornell & Ithaca College population is ~26,000). Several scenarios were analyzed varying the demand to equate to the ridership projections developed for the study route.
    - 10% of the population equates to a DHV of 5,500, which is reasonably consistent with the ridership forecast assuming TOD Scenario 4 with a DHV of 5,790.
    - 5% of the population equates to a DHV of approximately 3,000, which is reasonably consistent with the ridership forecast without TOD with a DHV of 3,110.
- **Velocity** – most PRT systems operate in the range of 25-45 mph, with an average of 25-30 mph. Several scenarios were analyzed varying the speed as follows:

- o 15 meters per second (33.5 MPH)
- o 12.5 meters per second (28 MPH)

- **Headway** – scenarios were analyzed with headways of 1 to 3 seconds.
- **Depot capacity** – assumed up to 500 vehicles could be accommodated in two depots.

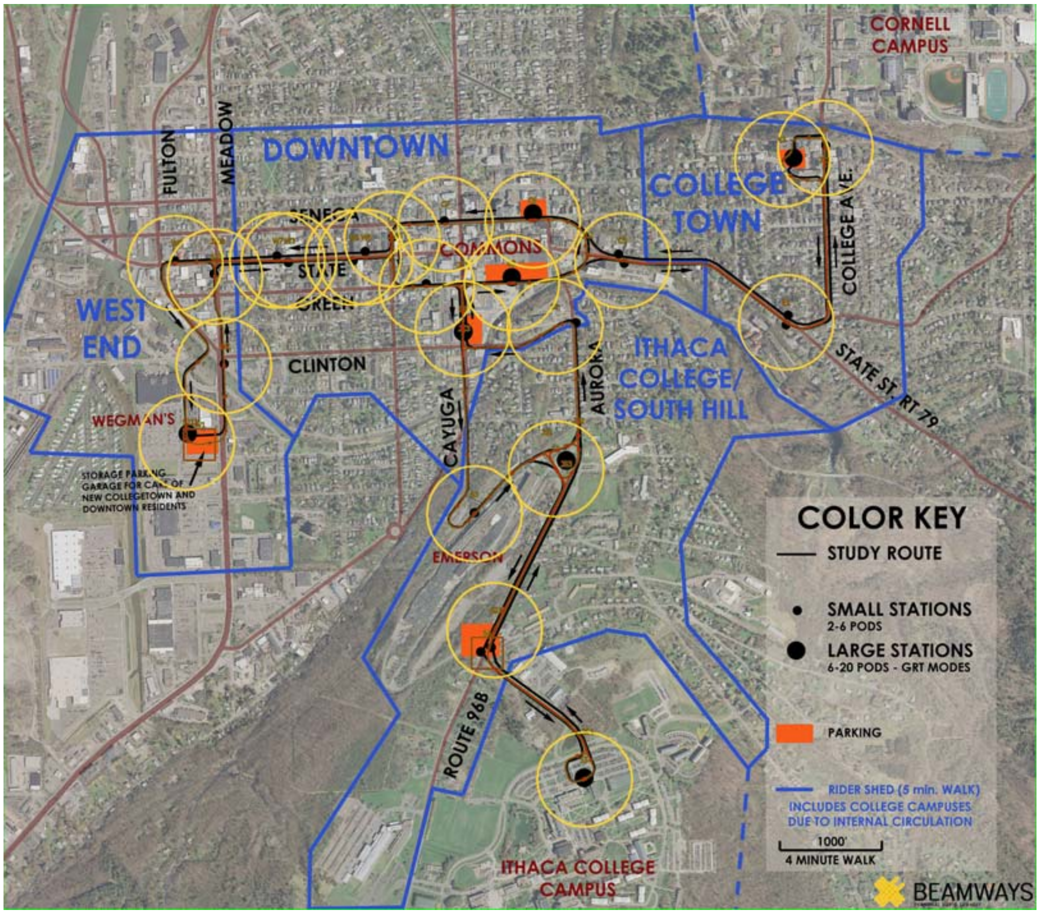


Figure 4-8. Study Route Map from BeamEd Software

Each of the scenarios was simulated for a period of one (1) hour. The software evaluates the system based on the following operational limits:

- Maximum track crossing (xing) delay should not exceed 10 seconds.
- Percentage of departure waits should not exceed 25%.

The results are shown in **Appendix J**. The Study Route can accommodate a DHV of 3,000 at an average speed of 33.5 MPH and three (3) second headways. Therefore, if the system were built today it would operate successfully within operational limits. However, if TOD were to occur around the system increasing the DHV, the system begins to experience peak period delay that exceeds the software's operational limits. The conclusion from the simulation results is that the physical configuration of the Study Route is the limiting factor in terms of feasibility. The Study Route modeled in the simulation is essentially a line haul configuration with a one-way loop around The Commons to create an exchange at the core to feed the three end-of-line destination points. There are also one-way loops near Wegmans and in the South Hill/Emerson area. To accommodate the additional ridership that would result from TOD, the system would need to be expanded into a network configuration.

4.5. Right-of-Way Assessment

4.5.1. Assumptions

Based on the proposed route and system recommendations, the following assumptions were developed to assess the potential ROW requirements for a PRT system in Ithaca. The PRT system structure is assumed to be supported by columns placed on both sides of the road, joined by a horizontal beam that supports the track(s) over the center of the road. This layout will be used for both single and double-track segments. The only difference will be the number of tracks placed on the horizontal beam. The placement of the tracks over the center of the road is intended to preserve the existing tree canopy in the City of Ithaca. The suggested PRT concept for Ithaca is visualized in **Figure 4-9**.

Figure 4-9. Support Poles

- Poles on the sides of the road will be black painted steel tubes 12 to 18 inches in diameter (not to exceed 2 feet) consistent with the city's choices for new street light and traffic signal poles.
- Poles must have a clearance of at least 5 feet from parked or traveling vehicles. Plan details for a PRT pole are shown in the **Figure 4-10**.

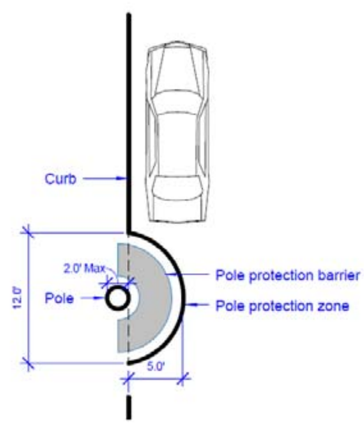


Figure 4-10. Plan Detail of PRT Pole in Curb Extension

- An aggregate right-of-way integrating utilities and PRT is assumed, which would enable PRT poles to support utility cables thus eliminating the utility poles along PRT routes An example of State Street is shown in **Figure 4-11**.

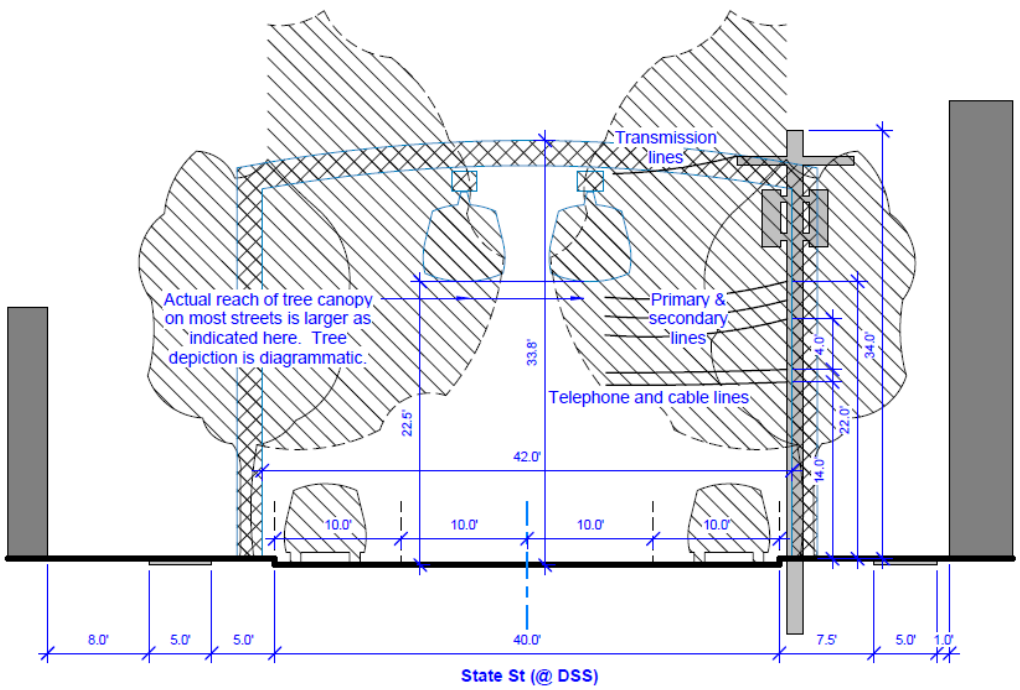


Figure 4-11. State Street Example of Integration of Utilities and PRT

- It is assumed that the track or suspended vehicle will be approximately 20.5 feet – 22.5 feet in height to clear primary and secondary lines and align below transmission lines.
- Support pole spacing is approximately 100 feet on straight sections and 80 feet on curves.

Track:

- Track to track centerline distance is 10 feet.
- Desirable track width is 12 to 18 inches wide.
- Minimum turning radius is 33 feet for pods that slow and approach a station. On curves where the pod passes through, a minimum radius of 100 feet is desirable to maintain reasonable speed

Station:

- Pod size 11'-6" long x 4'-10" wide x 6'-6" high
- All stations are assumed above grade.
- Small stations are assumed to have a 2 pod capacity. A switchback stair 8'x16', a single elevator 8'x8' and a "lobby" 8'x8' at ground level between them are needed. A total base of 30’x16’ feet is assumed. Poles around this footprint would be needed to support the main line, deceleration track, berthing track and station platform above.
- Large Stations are assumed to have 4 berths, an area of 16’x60’ as shown in **Figure 4-12**. These stations utilize stairs and elevators in existing parking garages. The Dryden Road and Green Street garage stations are on top of the garages. The Seneca St and Cayuga St garages are 8 stories tall, so stations would "kiss" the sides of the buildings at the 3rd or 4th parking levels with the boarding platform assumed to be in the building. The large station at Wegman's would be built into the storage parking garage, integrated with the building.

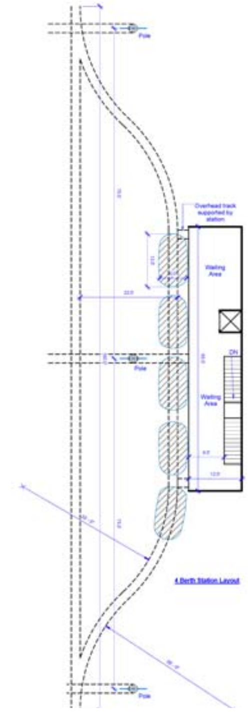


Figure 4-12. Layout of a Large Station

4.5.2. <u>Right-of-Way Impacts</u>

Guideway Infrastructure

Cross sections of city streets where PRT is planned are presented in **Appendix K**. The cross section of College Ave is presented in **Figure 4-13**. As depicted in this figure, the poles on the east side of College Ave will be placed in the grass median between the curb and the sidewalk in line with trees and utility poles. As there is no grass median on the west side of College Ave, poles on the west side of College Ave will have to be placed in the parking lane which amounts to loss of some parking spaces. Curb extensions with pole protection zones as shown in **Figure 4-10** will need to be placed approximately every 100 feet. The actual number of parking spaces that will be lost would be determined during the preliminary design.

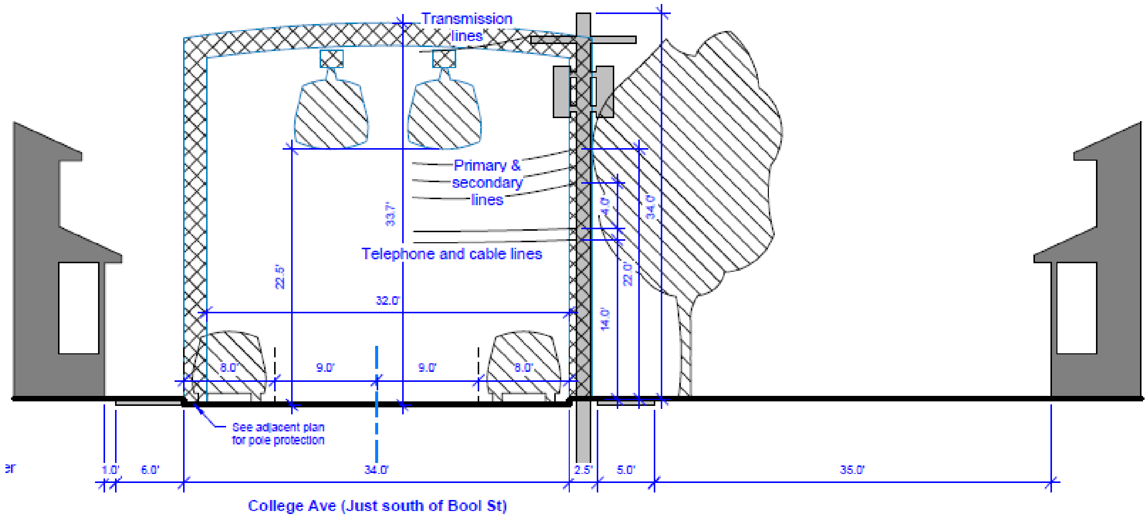


Figure 4-13. Proposed Section of College Ave.

On Seneca, State and Green Streets, the PRT poles will be placed on grass medians between the curb and sidewalk when available. When the grass median is unavailable, the poles will be placed on the edges of the sidewalks as shown in **Appendix K**. The sidewalks on these streets are generally wider and will be able to accommodate these poles.

Figure 4-14. Row Corridor – identifying acquisition required

As shown in **Figure 4-14**, the PRT system is generally within the existing roadway ROW. The following table identifies the roads that are affected and the owner of these roads:

Table 4-1. Roads Segments Affected by Proposed PRT Route

Road	From	To	ROW Owner
College Ave	Mitchell St	Cascadilla Pl	City of Ithaca
Cascadilla Pl	Eddy St	College Ave	City of Ithaca
Dryden Rd	Eddy St	College Ave	City of Ithaca
Mitchell St	East State St	College Ave	New York State
East State St	Seneca Way	Mitchell St	New York State
West State St	Albany St	Fulton St	New York State
Seneca St	Seneca Way	Albany St	New York State
Green St	East State St	Albany St	New York State
Meadow St	West State St	South St	New York State
Fulton St	West State St	West Clinton St	New York State
South Cayuga St	Green St	End	City of Ithaca
Clinton St	Cayuga St	Aurora St	New York State
Aurora St	Prospect St	Coddington Rd	New York State

The locations where the PRT system deviates beyond the existing public ROW are near the Collegetown station, Wegman's station and the Ithaca College station. The tax parcels that will be impacted at these three locations are identified in the table below:

Table 4-2. Private Property Impacted by Proposed PRT Route

Tax ID	Roll Section	Address	Property Class	Area (Acres)
63.-5-1 Wholly	Exempt	Cascadilla Pl	College / Univ	1.30
63.-5-8	Wholly Exempt	Dryden Rd	College / Univ	0.19
79.-2-1.2	Taxable	220-28 Fulton St S	> 1 use sm bld	0.59
79.-10-1	Taxable	400 Meadow St S	Motel	1.41
95.-1-1.2	Taxable	500 Meadow St S	Supermarket	17.54
106.-1-8	Wholly Exempt	620-40 Aurora St S	Manufacture	31.0
41.-1-30.2	Wholly Exempt	953 Danby Rd	College / Univ	585.89

Easements to provide infrastructure that supports the PRT system will be needed for the tax parcels 63.-5-1 and 63.-5-8. Full acquisition will not be needed, but easements that enable the PRT system to turn around the buildings and access the Collegetown PRT station on top of the Dryden road garage will be needed in these parcels. Aerial ROW will also need to be acquired as the PRT system crosses the public ROW into these tax parcels.

Tax parcels 79.-2-1.2 and 79.-10-1 are impacted when the PRT system deviates from the public ROW on Fulton St to access the Wegmans parking garage station. In addition to crossing these two tax parcels, the PRT system crosses the creek that flows between these two parcels. The creek is around 120 feet wide and the support poles across the creek that support the PRT infrastructure could be more than 120 feet apart. The support pole spacing for straight sections is only assumed as 100 feet. The infrastructure around the creek will probably need to be specially designed. Also, an engineering study will need to be conducted to see if easements and partial acquisition is feasible or if full acquisition will be needed for Tax parcels 79.-2-1.2 and 79.-10-1.

Easements will also be needed to support the PRT infrastructure in the Wegmans area (Tax parcel 95.-1-1.2), Aurora St industrial area (Tax parcel 106.-1-8) and Ithaca College (Tax parcel 41.-1-30.2). It is assumed that these owners will co-ordinate with the PRT construction.

Station Infrastructure

Large stations identified in the study route are proposed to be integrated into existing parking garages. It is assumed that the larger stations utilize stairs and elevators in the existing parking garages. The Dryden Road Garage and Green Street Garage stations are planned to be on the roof of the garages.

The height of the Seneca Street and Cayuga Street garages (8 stories), places the stations at the 3rd or 4th parking levels. The large station at Wegman's would be built into the storage parking garage, integrated with the building. New structures will need to be built in the Ithaca College and the manufacturing parcel to the west of Aurora St. The tax parcels that are impacted to construct these large stations are presented in the table below:

Table 4-3. Large Stations

Tax ID	Roll Section	Address	Property Class	Area (Acres)
61.-4-5	Wholly Exempt	202 Seneca St E	Parking Garage	0.76
70.-4-5.2	Wholly Exempt	120 Green St E	Parking Garage	1.45
63.-5-7	Wholly Exempt	118 Dryden Rd	Parking Garage	0.51
95.-1-1.2	Taxable	500 Meadow St S	Supermarket	17.54
81.-2-1	Wholly Exempt	235 Cayuga St S	Parking Garage	1.63
106.-1-8	Wholly Exempt	620-40 Aurora St S	Manufacture	31.0
41.-1-30.2	Wholly Exempt	953 Danby Rd	College / Univ	585.89

A private negotiation with each property/facility owner is necessary to determine the value of individual easements and acquisitions. These negotiations will also need to address the following issues:

- Access to privately-owned parking garages need to be obtained,
- The potential loss of parking needs to be addressed, and
- The structural feasibility of the overhanging station platforms need to be analyzed.

Several small stations are also planned along the PRT system. The tax parcels identified to construct these small stations are presented in the table below:

Table 4-4. Small Stations

Tax ID	Roll Section	Address	Property Class	Area (Acres)	2009 Full Market Value
83.-3.8	Taxable	808 State St E	Parking Lot	0.10	50,000
83.-2-11	Taxable	807 State St E	Vac w/imprv (Res)	0.16	145,000
69.-2-19	Wholly Exempt	408-10 State St E	Converted Res	0.55	700,000
69.-6-3	Wholly Exempt	401 State St E	Office bldg	3.92	5,180,000
61.-6.9	Wholly Exempt	100-08 Seneca St W	Benevolent	0.43	1,300,000
70.-6-20	Wholly Exempt	124 Green St W	Parking Lot	0.15	110,000
71.-3-1	Wholly Exempt	201 Seneca St W	Parking Lot	0.31	200,000
71.-2-5	Wholly Exempt	320 State St W	Govt Bldgs	1.13	7,300,000
71.-5-5	Taxable	323 State St W	Parking Lot	0.10	20,000
71.-1-3	Taxable	430-44 State St W	Det row bldg	0.75	1,000,000
71.-6-1	Taxable	429-39 State St W	Gas Station	0.54	375,000
72.-4-23	Taxable	107 Meadow St S	Parking Lot	0.08	30,000
72.-2-1	Wholly Exempt	125 Fulton St N	Bank	0.69	1,875,000
81.-5-1	Taxable	201 Prospect St	Apartment	0.24	320,000
40.-3-3	Wholly Exempt	810 Danby Rd	Manufacture	63.30	1,996,000

An area of approximately 30 feet by 16 feet will be required to construct small stations. A conceptual layout plan for the small stations is needed to determine if full or partial acquisition is required.

Two other smaller stations are planned within the road ROW. These stations are proposed to be located on islands at the intersections of College Avenue with Oak Avenue and Clinton Street with Meadow Street. These stations will require an area of approximately 30 feet by 16 feet. A detailed conceptual plan and traffic study are needed to verify the feasibility of these stations and pedestrian access to them.

Maintenance and Storage Facility

As identified in Section 4.4, a 300 berth depot would serve the PRT system in Ithaca. A large parcel of land that would accommodate a building footprint of around 23,000 SF will be needed. The City and Town zoning requirements allow maximum lot coverage by buildings of 50% and 30% respectively. With a 23,000 SF building, the minimum lot size will need to be around 50,000 SF in the city and 80,000 SF in the town. These requirements will supersede the space requirements for parking and other site requirements such as storm-water controls. Therefore the lot size for the maintenance and storage facility has to be a minimum of 1.5 acres in the city and 2 acres in the town. Since it is logical to build new parking garages (assuming a building footprint of 50,000 SF) on these same lots, the minimum acreage considered for selecting sites for the maintenance and storage facility are 3 acres in the city and 4 acres in the town.

Since it may not be possible to construct one large depot to provide complete storage, daily servicing, and long term maintenance, two depots are assumed. The two potential locations for system depots in close proximity to the study route are adjacent to the Wegmans (Tax Parcel 95.-1-1.2) or on the former Emerson Power Transmission site (Tax Parcel 40.-3-3) in the Town of Ithaca.

Since the two locations identified are in close proximity to the study area, two alternative locations further from the study area for each of the two depots are also identified. The alternative sites for the Wegmans depot are identified as the Cherry Street Industrial Park (Tax Parcel 100.-2-1.2) and the Southwest Park (Tax Parcel 119.-1-2). The two alternative sites identified are city-owned. The alternatives for the Emerson depot are the South Hill Business Park (Tax Parcel 39.-1-1.1) and the Ithaca College owned land (Tax Parcel 39.-1-1.32). The South Hill Business Park is privately owned.

The potential locations identified above are presented in **Table 4-5**.

Table 4-5. Potential Locations of Maintenance and Storage Facilities

Tax ID	Roll Section	Address	Property Class	Area (Acres)
Wegmans Depot Alternatives				
95.-1-1.2	Taxable	500 Meadow St S	Supermarket	17.54
100.-2-1.2	Wholly Exempt	Cherry St	Vacant Comm	8.25
119.-1-2	Wholly Exempt	Elmira Rd	Vacant Comm	55.21
Emerson Depot Alternatives				
40.-3-3	Wholly Exempt	810 Danby Rd	Manufacture	63.3
39.-1-1.1	Wholly Exempt	950 Danby Rd	Office bldg	10.77
39.-1-1.32	Wholly Exempt	Danby Rd	College / Univ	50.87

Full or partial acquisition of one of the three alternatives for the two depots will be required. Additional research will determine the best alternatives for the two depots.

4.5.3. Utility Conflicts

PRT plans to integrate utilities and PRT track as an aggregate right-of-way, which would enable PRT poles to support utility cables thus eliminating the utility poles along PRT routes. This will also help de-fuse some of the resistance to adding visual clutter to the streetscapes.

It is recommended that a detailed study be conducted to evaluate the feasibility of bundling utilities with the PRT track. This study should obtain the types of utility poles, heights of the cables and poles from the ground and evaluate if those can be integrated with the PRT system. The study will have to coordinate with all the utility companies and incorporate their concerns.

4.6. Constructability Assessment

The construction of an elevated PRT system is comparable to an elevated light rail system or automated people mover (APM), although the low weight of small pods allows smaller guide-ways and support structures than light-rail. These smaller structures translate into lower construction cost and smaller easements. The primary issues associated with construction are associated with the construction of a new system in an already constrained urban environment. Key issues include site logistics and constraints:

- Maintain access to adjacent buildings,
- Utility clearances and potential relocation,
- Maintenance and protection of traffic,
- Potential disruption of the groundwater,
- Potential impacts to adjacent buildings,
- Crossing of Six-Mile Creek, and
- Use of existing structures for stations.

These issues are beyond the scope of this research effort but will need to be addressed during the planning and design phase for a new system. The most critical issue is the use of existing structures for stations. This should be addressed in the early planning stages and will require a full structural assessment and negotiation with the owners. The cost of structural reinforcement or potential impacts to the existing structure, such as loss of parking, could impact the feasibility of using existing structure for stations. The use of these existing parking garages is critical assumption in the feasibility of the PRT system in Ithaca.

4.7. Assessment of Transit Oriented Development (TOD)

4.7.1. Purpose

The purpose of this analysis task is to determine the potential for transit oriented or transit supportive development (TOD or TSD) within the area served by the proposed PRT Phase 1 Route. This area, shown with a dashed line, is based on a 5 minute walk to the system and contains approximately 10,400 residents and 300 - 400 businesses. With the inclusion of the 26,000 students and 11,000 workers at the IC and Cornell campuses, the proposed system area would likely provide the minimum population density, job concentration and destination characteristics necessary for viability as determined by the 2007 study *Viability of Personal Rapid Transit in New Jersey.*[xxxvi] This suggests that higher residential density is not required to implement PRT. However, the development of a PRT system will provide the opportunity for additional higher density development with reduced on-site parking requirements thereby reducing vehicle miles traveled and associated greenhouse gas emissions. TOD will also support increased PRT system ridership providing financial support for operation and maintenance activities.

Within the context of this analysis, the PRT Phase 1 Route serves as a circulator system between major employment centers (colleges and Downtown), areas which offer significant housing and/or housing development opportunities (Downtown, West End and Collegetown), and areas offering essential services (Wegman's, Downtown). The intent of the circulator system is to reduce vehicle trips by creating a "PRT enabled mixed-use district" which contains all the essentials of daily life (work, education, services, recreation, food procurement, housing) within a maximum combined transit/walk trip of approximately 10 to 15 minutes. PRT is being studied as a tool to unite into an easily accessible whole, parts of town which are now remote from each other as measured by walking or biking. It is the perceived remoteness, exacerbated by the topography, which causes many students and residents to rely on automobiles for local trips.

New housing within the "PRT enabled mixed-use district" is anticipated to appeal to employees now in-commuting because of the lack of affordable housing available in Ithaca. The Tompkins County/Cornell Employee Commuter Survey documented that among non-Tompkins County employees

- 54% lived outside Tompkins County because of housing costs
- 30% would consider moving to Tompkins County if housing was more affordable
- 25% would consider moving to Tompkins County if housing was more available

However, the survey also documented that 80% or respondents would want a single-family home if they moved to Tompkins County. A dense mixed-use district with multi-unit housing developments may appeal to a small percentage of Tompkins county employees but should also be desirable by students.

It is also anticipated that the PRT system will allow for increased density within the "PRT enabled mixed-use district." Although many areas in Ithaca do not have parking requirements defined in the zoning code, the real estate market reflects the auto dependent culture and typically includes parking for both housing and commercial developments. The demand for parking increases development costs and limits the density potential. The development of a PRT system reduces the demand for on-site parking and provides the opportunity to meet parking demand with off-site facilities located in areas with adequate developable area and reduced acquisition costs. The PRT system provides access to long-term vehicle storage on the perimeter and serves as a circulator within the district to eliminate the need for a vehicle for intra-district trips. For example the need for Collegetown parking can be met by potential parking facilities in the vicinity of Wegmans or Ithaca College which have land available, and the need for more housing in the already saturated Collegetown could be met by developing the West End.

4.7.2. <u>Assumptions and Methodology</u>

This study will assume a 20 year development horizon which allows time for large redevelopment projects involving significant parcel assemblages to occur. Such projects generally prove to be more economically viable than smaller infill projects and typically provide greater housing density and more useable commercial floor plates. Much of the allowable zoning envelope outside the current Central Business District is under-utilized.

It is assumed that new housing in these areas will be supported by certain factors:

- The already established demand for housing within Tompkins County (see *projected demand for housing* in **Appendix L**)
- The increasing popularity of Ithaca as a retirement and quality-of-life destination.
- The increasing affordability of transit-served housing in contrast to car-dependent housing, as peak oil and climate concerns drive up the cost of fossil energy.
- The emerging attractiveness of a convenient, pedestrian focused, urban quality of life within the PRT served district.
- The City's need to enhance Downtown business viability and increase tax base, motivating government support for new development.
- Demands from neighborhoods surrounding the PRT service area to reduce parking and traffic problems and the desire to deflect development pressure away from those same residential neighborhoods.

Given these demand drivers, it is assumed that 25% of the Transit Oriented Development (TOD) area, as described below, will be redeveloped by 2030.

4.7.3. <u>Determination of TOD Area</u>

The following criteria define the land area considered to be the potential development area:

- *2-3 minute walk + commercial zoning:* The PRT route was selected so as to run predominantly through parts of the city which are already zoned for commercial or mixed-use development. Within these zoning areas, we are considering land area within a 2-3 minute walk (750') of the PRT track as having potential for transit oriented development. With the 2-3 minute walk added to the PRT trip itself, doorstep to doorstep travel time within the service area would be close to or under 12 minutes[xxxvii]. Thus the TOD development area corresponds to an area where users will feel the highest sense of convenient accessibility to amenities and workplaces, a feeling which will add to the market viability of TOD projects. **Figure 4-15, TOD Area** shows this approximately 160 acre area outlined in dashed line.

- *Residential neighborhoods:* The PRT route runs by necessity through areas with residential zoning in which urban-scaled mixed-use development is inappropriate. Though served by stations and benefiting from access to PRT (especially with regard to neighborhood parking issues), no new development is assumed in these areas, even if they fall within a 2-3 minute walk of a PRT station.
- *Subtracted buildings:* Subtracted from the potential development area are buildings with historic or institutional value, buildings which would be expected to be preserved because they define local urban character, buildings which sufficiently fill out their potential within the zoning envelope, and newer buildings including parking structures, put into service within the past 15 years. (shown in red on TOD area map)
- *South Hill and Ithaca College:* Note that because of the predominantly suburban nature of the Town of Ithaca and areas surrounding Ithaca College, no locations along the route extending to Ithaca College were deemed acceptable for urban mixed-use or high density residential development. The Emerson industrial site is anticipated to be a significant transit-oriented *commercial* location on the PRT route, but given the environmental conditions associated with the facility it is unlikely to host residential development within the next 20 years. As a result, the TOD area map excludes the Ithaca College leg of the route.

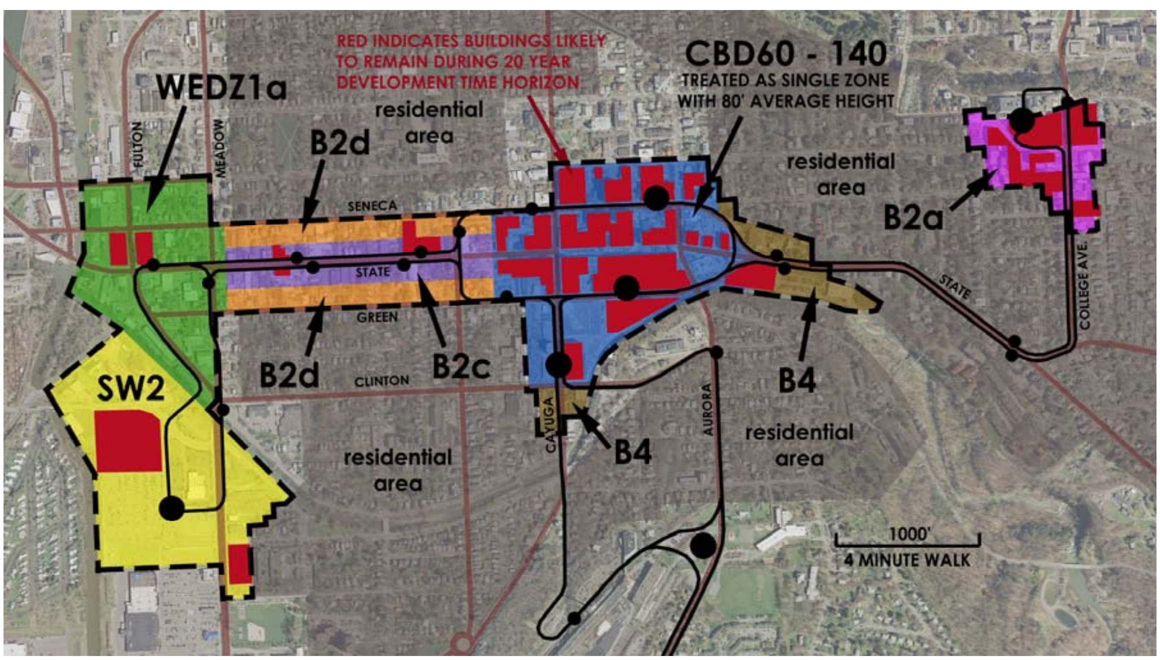


Figure 4-15. TOD Area

Based on census block group data, aerial photo confirmation of the extent of actual residential areas within block groups and on-site observation of housing density, it is estimated that the +/- 160 acre TOD area currently contains roughly 3,300 residents, with a population density of about 20 people per acre (ppl/acre). The population however is unevenly distributed, with the majority, about 2,000, in the Collegetown section (upper right corner, population density 167ppl/acre), about 1,100 Downtown (from Meadow Street east, pop density 14ppl/acre) and only about 200 in the West End section (from Meadow Street west, pop density only 3ppl/acre).

The following existing commercial zones (refer to TOD area map) were deemed appropriate for mixed-use re-development and included in TOD analysis:

- WEDZ1a
- SW2
- B2a, B2c, B2d and B4
- CBD60, CBD85, CBD100, CBD120 and CBD140. Numerical designations refer to the height limitation within each zone which is the only variation between the different CBD zones. Because of the fluid nature of Central Business District zoning and the tendency to modify height restrictions on a project by project basis, an average height of 80' for all CBD zones was assumed for analysis purposes.

The following existing commercial zones are within the distance criteria for inclusion in the TOD area, but not included in the analysis:

- WEDZ1b, along the east side of Meadow Street, was considered un-conducive to TOD redevelopment because of its nature as a very specific ½ block deep transitional zone between commercial and residential areas. The small lot sizes available in the zone, 2 story height limit and proximity to residential areas did not lend the zone to mixed use re-development.

- B1a, along the north side of Seneca Street and much of Buffalo Street, was considered un-conducive to TOD redevelopment because much of the zone is within the Dewitt Park Historic District and is a buffer between the CBD zones and residential areas.

4.7.4. <u>Development Scenarios</u>

Based on a reasonable assumption of the allowable development footprint within each zone, the following four development scenarios were generated for comparison. It is assumed that the provision of housing for current in-commuters that will produce the most significant reduction in VMT, therefore each scenario was assessed for its potential to meet projected housing demand. The analysis does not make aggressive assumptions about the demand for additional retail or office space beyond the need to support daily life activities of new residents (i.e. neighborhood groceries, cafes, news-stands, gyms, medical offices, etc). Assumptions used in the development of the scenarios are provided in **Appendix L.**

1. *Scenario 1: Theoretical development potential per current zoning.* A calculation of development potential was made within the current zoning envelope restrictions, and providing parking per the regulations. In 4 of the 7 zones (WEDZ-1a, B2c, B2d, and CBD-60) regulations allow zero parking, therefore development area and residential unit count was calculated accordingly. However, market reality and the existing car culture demand that parking be accommodated, thus scenario 1 proceeds to assume provision of parking in city owned garages in each zone. A further calculation of the required garage space and the number of residential units displaced was made. It is assumed that garages will fill the zoning height envelope and that their ground floors will be commercial space. Totals for development potential in the **Appendix M** summary reflect the garage parking and reduced unit count, presenting a realistic scenario. For analysis purposes, it was assumed that 25% of the development potential would be realized in the 20-year study period.

2. Scenario 2: Actual development potential tempered by market demands for parking. Scenario 2 examines development potential in the absence of a city investment in garages such that zones which had no parking requirement must provide on-site parking to meet market demands. This scenario is the same as scenario 1 in the zones which have an on-site parking requirement (B2a, B4, SW2). Parking assumptions can be found in **Appendix L**.

3. *Scenario 3: Development potential per current zoning with PRT.* A calculation of development potential within the existing zoning envelope was made, but with the assumption that parking requirements for some residents and regular office employees within the PRT service zone will be accommodated off-site in storage parking facilities. This will quantify the direct benefit to development offered by PRT's level of access, with all other variables remaining the same. Also assumed within this analysis will be a reduction in the amount of on-site parking needed for commercial uses because of an increase in resident population, outlined in **Appendix L.**

4. *Scenario 4: Development potential of expanded zoning envelope.* A calculation of additional residential stories required, and/or additional percentage of TOD area to be developed within the time horizon was made, to demonstrate the measures which need to be taken to meet housing demand and demonstrate the magnitude of discrepancy between development potential per current zoning restrictions and housing demand.

4.7.5. TOD Analysis

A development analysis was conducted for each of the scenarios and the following results are documented in **Appendix M.**

- Existing zoning requirements
- Area of developable land.
- Assumed average redevelopment lot size
- Development potential: SF of commercial space and number of residential units
- Population potential: number of employees and residents
- Parking requirements: on-site and off-site parking spaces
- Expresses development potential as a percentage of utilization of legally developable site area (not total site area).

Scenario 1: Theoretical development potential per current zoning.

Appendix M documents that current zoning would accommodate a total of 2,045,456 SF ground floor commercial space, 5,504 dwelling units and a resident population of 12,344. Within the 20 year development horizon, it is assumed that 25% of this potential will be realized, the TOD area can accommodate 511,364 SF ground floor commercial space with 767 office workers, and 1,444 dwelling units with a resident population of 3,239. Under this scenario the TOD area can theoretically accommodate 25.9% of projected housing demand, however the market demand for parking would necessitate the city provide 2,516 garage parking spaces in the WEDZ1a, B2c, B2a, and CBD zones, despite the lack of an official parking requirement in those zones. An additional 1,082 ground level spaces would be provided per zoning in the remaining 3 zones (B2a, B4, and SW2) for a total of 3,598 spaces. The construction of garages with parking decks above ground floor commercial space would result in a loss of 403 housing units and 904 residents, and the TOD area would accommodate 1,041 units, 2,336 residents and meet only 18.7% of housing demand.

- Resulting population density within TOD area: 35.2 people/acre
- Resulting population density in Ithaca mixed-use core (same as PRT service district): 12.1 people/acre
- Garage + on-site Parking Demand and additional traffic intrusion : 3,598 vehicles

Scenario 2: Probable development potential tempered by market demands for parking.

As documented in **Appendix M,** market demands for parking reduce the development potential of the TOD area to 1,099,728 SF ground floor commercial space, 2,958 dwelling units and a population of 6,620. Within the 20 year development horizon, assuming 25% of this potential is realized, the TOD area can accommodate 274,932 SF ground floor commercial space with 412 office workers, 738 dwelling units with a population of 1,655, and an onsite parking requirement of 2,113 spaces. Under this scenario the TOD area can accommodate 13.3% of projected housing demand.

- Resulting population density within TOD area: 30.9 people/acre
- Resulting population density in Ithaca mixed-use core (same as PRT service district): 11.5 people/acre
- On-Site Parking Demand and additional traffic intrusion: 2,113 vehicles

It is apparent from Scenario 2 that in the absence of a competitive mobility alternative to the automobile or a significant investment in public parking garages, the market demand for residential parking limits the potential for Downtown development to meet housing demand.

Scenario 3: Development potential per current zoning with PRT.

Appendix M documents that maintaining existing zoning but providing a PRT system to reduce on-site parking demand increases the TOD area development potential to 1,682,032 SF ground floor commercial space, 5,776 dwelling units and a population of 12,956. Within the 20 year development horizon, assuming 25% of this potential is realized, the TOD area can accommodate 420,508 SF ground floor commercial space with 631 office workers, 1,444 dwelling units with a population of 3,239, an onsite parking requirement of 1,621 spaces and an off-site parking requirement of 1,085 spaces. Under this scenario the TOD area can accommodate 25.9% of projected housing demand.

- Resulting population density within TOD area: 40.8 people/acre
- Resulting population density in Ithaca mixed-use core (same as PRT service district): 13 people/acre
- On-Site Parking Demand and additional traffic intrusion: 1,621 vehicles.
- Off-Site Parking Demand: 1,085 spaces

Note that PRT has reduced the overall parking demand in the TOD area by 24% over Scenario 1, while accommodating 38% more residents and allowing the theoretical zoning potential to be fulfilled with regard to housing. However, it is apparent from Scenario 3 that the current zoning envelope is insufficient to accommodate projected housing demand, falling short by 4,120 units.

Scenario 4: Development potential of expanded zoning envelope.

As documented in **Appendix M**, the TOD area development potential in Scenario 4 includes 1,815,148 SF ground floor commercial space, 11,006 dwelling units and a population of 24,688. This scenario assumes larger redevelopment sites. The DIA report for the Business Improvement District made an assumption that within its 10 year development horizon, potential infill projects would have a 50% success rate[xxxviii], and that larger re-development projects would have a 33% success rate[xxxix]. It further suggested that a 50% success rate for re-development projects could be attained[xl]. Given that our time horizon is double that of the DIA report, a 50% success rate over the entire developable area is assumed reasonable.

Within the 20 year development horizon, assuming 50% of the full potential is realized, and the number of allowable residential stories is doubled in each zone, the TOD area can accommodate 907,574 SF ground floor commercial space with 1,361 office workers, 5,503 dwelling units with a population of 12,344, an onsite parking requirement of 2,993 spaces and an off-site parking requirement of 4,346 spaces. Under this scenario the TOD area can accommodate 99% of projected housing demand.

- Resulting population density within TOD area: 98 ppl/acre
- Resulting population density in Ithaca mixed-use core (same as PRT service district): 22 ppl/acre
- On-Site Parking Demand and additional traffic intrusion: 2,993 vehicles
- Off-Site Parking Demand: 4,346 spaces

Note that PRT has reduced the car intrusion into the TOD area by 13.8% over Scenario 1, while accommodating the entire projected housing demand, over 5 times the amount of housing provided in Scenario 1.

Policy changes recommended to achieve scenario 4 include the following:

- Modify height restrictions as follows:
  WEDZ1a – from 5 stories to 9 stories
  B2c – from 5 stories to 9 stories
  B2d – from 4 stories to 7 stories
  CBD – from an average of 8 stories (80') to an average of 11 stories (110')
  SW2 – from 5 stories to 9 stories
  B2a – from 6 stories to 11 stories
  B4 – from 4 stories to 7 stories
- Reduce on-site parking requirements to conform to scenario 4 parking assumptions in **Appendix L.** Unbundle parking.
- Increase cost of parking as driver nears the center of the city to encourage parking at the perimeter off-site facilities and using transit to move to final destinations within the city.
- Construct off-site parking facilities at ends of PRT system.

- Adopt strict priorities with regard to infrastructure enhancement and expansion which favors accommodation of the pedestrian first, followed by transit, bikes, then the private auto.
- Adopt a form based zoning code and pedestrian focused design standards.

Table 4-6 provides a comparison of the development potential of each scenario.

Table 4-6. Scenario Comparison

Development Potential	Scenario #1	Scenario #2	Scenario #3	Scenario #4
Retail	127,841 SF	68,733 SF	105,127 SF	226,893 SF
Restaurant/Assembly 127,84	1 SF	68,733 SF	105,127 SF	226,893 SF
Office	255,682 SF	137,465 SF	210,254 SF	453,787 SF
Office workers	767 412	631	1,361	
Dwelling Units	1,041 738		1,444 5,503	
Residents	2,336 1,655	3,239	12,344	
On-site Parking	1,082 2,113	1,621	2,993	
Off-site Parking	NA NA 1,085			4,346
Public garage parking	2,516	NA	NA	NA

Note: Dwelling Unit and resident totals assume Scenario #1 with public garage parking

4.8. Ridership Forecast

Ridership for the PRT system in Ithaca is assumed to occur from the following scenarios:

1. Shift from the existing TCAT service
2. New demand resulting from shift in mode share
3. New demand from transit oriented development
4. New demand from proposed Park and Ride service

The calculation of PRT ridership is based on average weekday peak period and daily ridership since the reduction in employee commute trips is assumed to have the greatest potential to reduce VMT. According to the American Public Transit Association (APTA), the majority of people using public transportation take two trips per day (one to a destination in the morning and one home in late afternoon or evening). At most agencies (10% to 30%) of riders transfer to a second transit vehicle to reach their final destination. APTA's best estimate is that the number of people using public transportation on any day is about 45% of the number of trips reported. Saturday ridership is often about 50% of weekday ridership, and Sunday ridership may be only 25%.[xli]

4.8.1. Shift from the Existing TCAT Service

The introduction of PRT in Ithaca will complement the existing TCAT bus system, encouraging more people to shift to transit and freeing up existing bus resources to serve new routes. However, due to overlap with the proposed PRT network, it is anticipated that the PRT service will replace several TCAT routes and potential reduce some demand on other routes. **Figure 4-16** shows the overlap between the two systems. The following TCAT bus routes will be impacted:

- Route 10: Cornell University - Ithaca Commons
- Route 11: Ithaca College – Ithaca Commons
- Route 12: Ithaca College – Ithaca Commons – Cornell University (Night Service)
- Route 28: Wegmans – WalMart – Ithaca Commons – Cornell Campus – Hasbrouck Apts (Weekend only)
- Route 30: Ithaca Mall – Cornell University – Ithaca Commons
- Route 31: Airport – Cornell University – Ithaca Commons

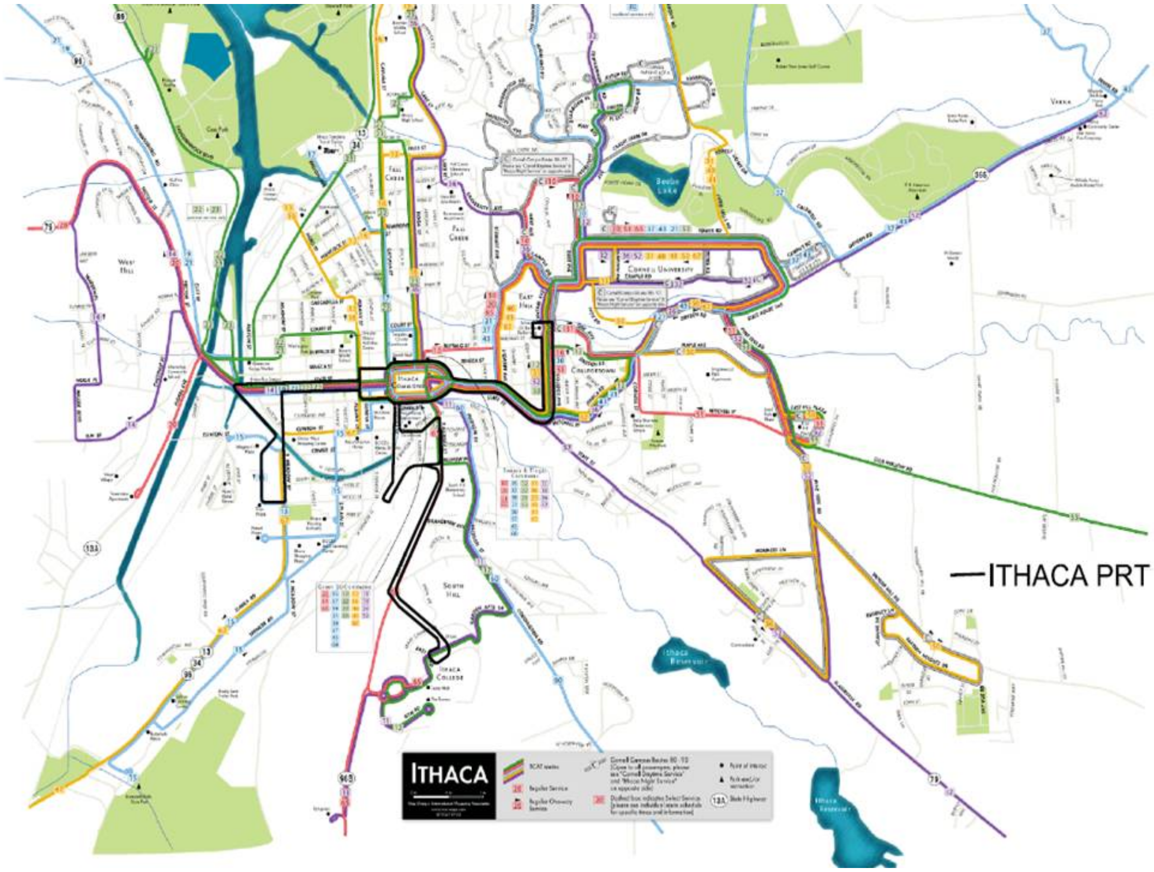


Figure 4-16. PRT Overlap Existing TCAT Service Routes

Weekday and weekend (Saturday and Sunday separately) ridership for these routes were obtained from TCAT for the month of April 2009. TCAT uses two systems known as Blackbox ETM and Wayfarer to capture ridership data. TCAT provided monthly ridership data for all the routes for April 2009 separated by weekday and weekend from these two systems. In addition, detailed ridership data captured by the Blackbox ETM for the first two weeks of April separated by weekday and weekend, date, and route were provided for routes 10, 11, 12, 28, 30 and 31. Route numbers were followed by two more numbers, usually 00 and 10 that stand for outbound and inbound respectively. The outbound and inbound ridership numbers were added to obtain the total ridership per route.

Average weekday daily, weekday AM peak, weekday PM peak and weekend daily ridership for these routes were calculated as presented in **Table 4-7**.

Table 4-7. Existing TCAT Ridership

	Average Ridership – April 2009			
Route	**Weekday**			**Weekend**
	Daily	**AM Peak**	**PM Peak**	**Daily**
10 1941		362	371	0
11	433 115		102 203	
12 198		0	0	187
28	0 0		0 123	
30 2684		391	615	1717
31	546 150		145 0	

* Weekend includes Saturday and Sunday except for Route 12 which does not run on Sundays

Due to its limited network, the PRT system will only replace riders that travel within the PRT network. There is limited information available on passenger boarding at specific stops so potential shifts in passengers from TCAT to a PRT system were based on the percentage of overlap between the two routes and the bus service provided beyond the PRT network. These displacement percentages were applied to the average ridership calculated in Table 9-1 to estimate PRT ridership displaced from TCAT, presented in **Table 4-8**.

Table 4-8. PRT Ridership based on shift from TCAT

Route	**Displacement %**	**Projected PRT Ridership**			
		Weekday Daily	**Weekday AM Peak**	**Weekday PM Peak**	**Weekend Daily**
10	50%	971	181 186	0	
11	100%	433	115 102	203	
12	100%	198	0 0 184		
28	100%	0	0 0 123		
30 25%		671	98	154	429
31	25%	136	37 36	0	
	Total	**2409**	**431**	**478**	**939**

Route 10 currently operates on weekdays from Monday to Friday between the Cornell Campus and Ithaca Commons from 7:30 AM to 7 PM with 14 runs in the AM peak, 18 runs in the PM peak and 51 runs during the off-peak. It is assumed that 50% of Route 10 riders will shift from using TCAT to PRT. The primary limitation of the PRT network as compared to Route 10 is that Route 10 enters and circulates through the Cornell University campus.

Route 11 currently operates from Monday to Saturday between Ithaca College and Ithaca Commons from 6 AM to 7 PM with 6 runs in the AM peak, 6 runs in the PM peak and 15 runs during the off-peak. This route has reduced service on Sundays with 9 runs from 9 AM to 5 PM. It is assumed that 100% of Route 11 riders will shift from using TCAT to PRT.

Route 12 currently operates only from Monday to Saturday and serves Cornell University, Ithaca College and Ithaca Commons with a night-only service from 7:30 PM to 1:44 AM. It is assumed that 100% of Route 12 riders will shift from using TCAT to PRT.

Route 28 operates only in the weekends with 5 runs from 1:40 PM to 6:08 PM and serves Cornell University, Ithaca Commons, Wegman's and Wal-Mart. It is assumed that 100% of Route 28 riders will shift from using TCAT to PRT.

Route 30 serves the Shops at Ithaca mall, Cornell University and Ithaca Commons from 6 AM to 9 PM on weekdays with 10 runs in the AM peak, 12 runs in the PM peak and 24 runs during the off-peak. This route has different schedules on Saturdays and Sundays. As this route primarily serves communities north of Cornell University, it is assumed that 25% of Route 30 riders will shift from using TCAT to PRT.

Route 31 serves the Airport, Cornell University and Ithaca Commons from 7:20 AM to 7:40 PM only on weekdays with 3 runs in the AM peak, 5 runs in the PM peak and 9 runs during the off-peak. As this route primarily serves communities north of Cornell University, it is assumed that 25% of Route 31 riders will shift from using TCAT to PRT.

Over the four year period from 1998 to 2001 total TCAT ridership grew at 4.7% annualized rate, with a less than average increase of 2.5% from 2000 to 2001[xlii]. To estimate the PRT ridership shifted from TCAT service in 2030, a conservative annualized growth rate of 0.5% is used. The projected 2030 PRT ridership shifted from TCAT service is presented in **Table 4-9**.

Table 4-9. Project PRT Ridership Shifted from TCAT Service

	Design Hourly Volume (DHV)	Weekday Daily	Weekend Daily	Annual
2030 Projection	530	2670 1040	804,60	0

4.8.2. New Demand Resulting from Shift in Mode Share

Fully 40% of Tompkins County commuters use alternative modes of transportation, compared to only 25% nationwide. Non-automobile use is higher in the City of Ithaca and other areas where development is compact. However, the Tompkins County/Cornell Employee Commuter Survey documented that commuters currently do not use transit for the following reasons:

- Personal
  - 44% needed car for errands
  - 35% liked independence
  - 25% needed car for business
- Service
  - 27% bus not available when needed
  - 21% bus takes too much time

Commuters also indicated that if their concerns were addressed:

- 27% would take transit most of the time
- 40% would take transit some of the time

These findings are further supported by the 2008 Cornell Master Plan, which documented the need to optimize transit ridership through improving the network, including a campus circulator, and simplifying service.

PRT addresses the two service related concerns. The on-demand direct service makes the service available all the time and reducing the travel time for point to point service. However, the PRT service area, particularly the proposed Phase I section is limited. Although it does provide access to the major employment centers, it does not provide connections to all existing residential areas, particularly those outside of the City of Ithaca. Therefore, PRT will only encourage greater transit use within its service area. In addition, the current non-auto mode share in the PRT system area is already high at over 40% compared to a nationwide share of 25%. Of the non-auto share, approximately 5% is transit ridership. For these reasons, it is assumed that the implementation of PRT could increase transit ridership in the PRT area by 15% (20% total). The 2030 PRT ridership from shift in mode share is presented in **Table 4-10**.

Table 4-10. Project PRT Ridership From Shift in Mode Share

	Design Hourly Volume (DHV)	Weekday Daily	Weekend Daily	Annual
2030 Projection	1590	8010	3120	2,413,700

4.8.3. New Demand from Transit Oriented Development

A study of TOD has documented that this type of development typically has an auto share that is 50% less than traditional development.[xliii] This is consistent with the assumptions above that the PRT system would increase the transit share from 5% to 20% thereby increasing the non-auto mode share in the system area to 55%.

Ridership estimates are developed for two TOD Scenarios 3 and 4. As documented in Section 4.7, Scenario 3 calculates the development potential within the existing zoning envelope but with the assumption that parking requirements for some residents and regular office employees within the PRT service zone will be accommodated off-site in storage parking facilities. Within the 20 year development horizon, the TOD area can accommodate 420,508 SF ground floor commercial space and 1,444 dwelling units. The commercial space is assumed to consist of:

- 25% restaurant, bar, theatre, and performance venue
- 25% retail
- 50% office or professional service

The residential units are assumed to consist of 1014 owner occupied units (639 for relocation of in-commuters and 375 to meet projected housing demand) and 430 rental units (337 to meet projected housing demand and 93 units for student housing).

Trip generation for the TOD Scenario 3 is based on the Institute of Transportation Engineers, Trip Generation and is detailed in **Appendix N**.

Table 4-11. Project PRT Ridership From TOD Scenario 3

	Design Hourly Volume (DHV)	Weekday Daily	Weekend Daily	Annual
2030 Projection	1080	11,060	9,700	3,895,100

As documented in Section 4.7, Scenario 4 expands the zoning envelope to allow sufficient density to support TOD. Within the 20 year development horizon, the TOD area can accommodate 907,572 SF ground floor commercial space and 5,503 dwelling units. The commercial space is assumed to consist of:

- 25% restaurant, bar, theatre, and performance venue
- 25% retail
- 50% office or professional service

The residential units are assumed to consist of 3,862 owner occupied units (2,437 for relocation of in-commuters and 1,425 to meet projected housing demand) and 1,641 rental units (1,285 to meet projected housing demand and 356 units for student housing).

Trip generation for the TOD Scenario 4 is based on the Institute of Transportation Engineers, Trip Generation and is also detailed in **Appendix N**.

Table 4-12. Project PRT Ridership from TOD Scenario 4

	Design Hourly Volume (DHV)	Weekday Daily	Weekend Daily	Annual
2030 Projection	2,680	27,890	24,300	9,805,500

4.8.4. New Demand from Proposed Park and Ride Service

Mode share for employees working in traffic analysis zones around the PRT system in Ithaca were obtained from the Census 2000 data. The TAZs that were analyzed are shown in **Figure 4-17**.

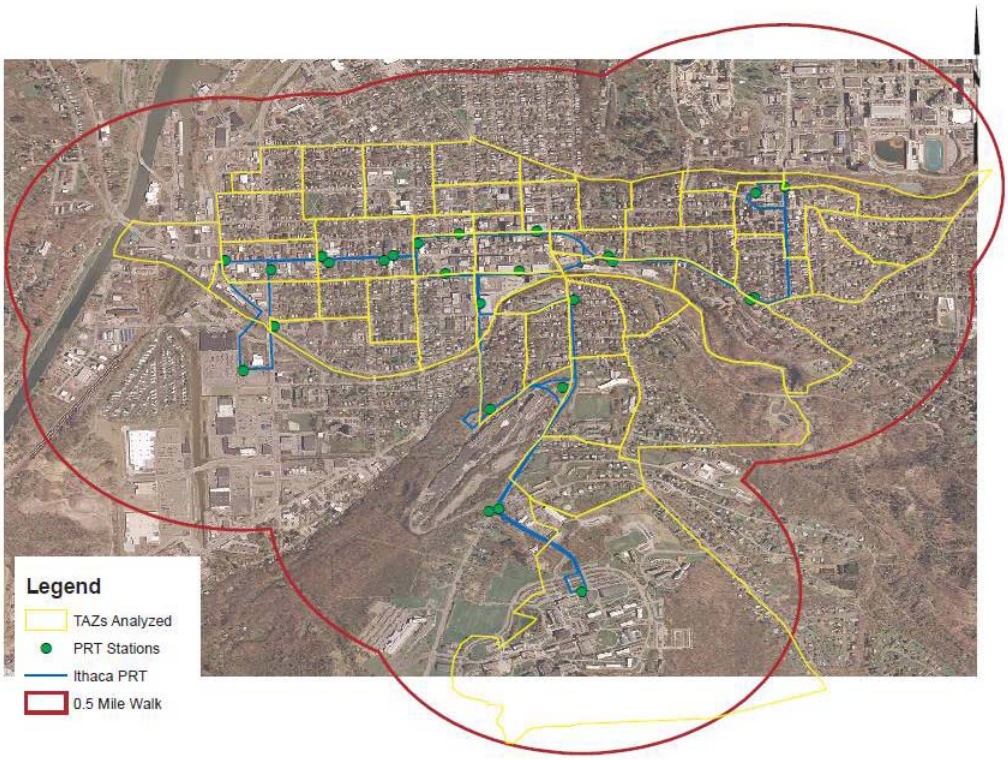


Figure 4-17. TAZs Analyzed for Park and Ride

As can be seen from the figure, only those TAZs that were well within 0.5 mile (10 min walk) from the PRT stations were included. It was assumed that employees commuting from farther distances will park at the Park-n-Ride lots and use the PRT system to exit at any station along the system and walk to their place of employment within 10 min. TAZs that had ample parking available were not included since employees in those TAZs will not utilize the Park-n-Ride and then the PRT. The TAZs that were analyzed mainly included Downtown and TAZs immediately in the vicinity of PRT stations in Cornell University and Ithaca College. It is to be noted that the entire Ithaca College is one TAZ. The following table presents the mode share information for the 10,252 employees in the TAZs identified in **Figure 4-17**.

Table 4-13. Employees in TAZs around Ithaca PRT

Means of Transportation		
Drive Alone	6,590	64%
Car Pool	1,372	13%
Transit 283		3%
Walk/Bike 1,729		17%
Other 278		3%
Total	**10,252**	**100%**

It is assumed that the PRT system attracts 15% of the above employees driving alone to utilize the Park & Ride facilities provided by the PRT. Thus the PRT ridership utilizing the Park & Ride facilities is estimated as 989 riders during both the AM and PM peak periods and 1,978 riders daily. As noted in **Table 4-14**, this equates to 516,200 annual riders.

Table 4-14. Project PRT Ridership From Proposed Park and Ride Service

	DHV	Weekday Daily	Weekend Daily	Annual
2030 Projection	990	1,980	0	516,200

4.8.5. Summary of Projected PRT Ridership

As discussed in the previous sections, ridership for the PRT system in Ithaca is assumed to occur from the following sources:

1. Shift from the existing TCAT service
2. New demand resulting from shift in mode share
3. New demand from transit oriented development
4. New demand from proposed Park and Ride service

The total ridership resulting from the above sources is summarized in **Table 4-15**. The base ridership without any TOD that includes the displacement from TCAT service, shift in mode share and proposed Park & Ride Service is first estimated. To highlight the importance of TOD to the total ridership, TOD Scenarios 3 and 4 are added respectively to the base ridership.

Table 4-15. Total PRT Ridership

PRT Ridership Sources	DHV	Weekday Daily	Weekend Daily	Annual
Displacement from TCAT	530	2,670	1,040	804,600
Shift in Mode Share	1,590	8,010	3,120	2,413,700
Park & Ride Service	990	1,980	0	516,200
Total Ridership without TOD	**3,110**	**12,660**	**4,160**	**3,734,500**
TOD - Scenario 3	1,080	11,060	9,700	3,895,100
Total Ridership - TOD Scenario 3	**4,190**	**23,720**	**13,860**	**7,629,600**
TOD - Scenario 4	2,680	27,890	24,300	9,805,500
Total Ridership - TOD Scenario 4	**5,790**	**40,550**	**28,460**	**13,540,000**

The base PRT ridership on a weekday without any TOD is 12,660. TOD Scenario 3 adds about 11,060 to make the total ridership around 23,720. TOD Scenario 4 adds about 27,890 to make the total ridership around 40,550. In comparison, the average daily ridership for Morgantown GRT in 1995 was 14,000 with a record daily ridership of 30,175[xliv]. The anticipated base ridership for Ithaca PRT (12,660) is close to the average daily ridership of Morgantown PRT. TOD Scenario 3 that has the development potential per current zoning with PRT brings the Ithaca PRT ridership (23,720) closer to the record Morgantown ridership. TOD Scenario 4 which includes the development potential of expanded zoning envelope makes the Ithaca PRT ridership exceed the Morgantown PRT record ridership.

4.9. Approval Requirements

Although many Automated People Movers (APM) products are currently on the market working to serve airports, hospitals, campuses, theme parks, and communities across the country, only the Morgantown/WVU PRT has been given official certification to operate and maintain a PRT/GRT system in the U.S. To better understand the regulatory process for qualifying a modern PRT system in the U.S. interviews were conducted with the following representatives:

- Grady Cothen, Deputy Associate Administrator for Safety Standards of the Federal Rail Authority/USDOT
- Lawrence Fabian, Treasurer of ATRA (The Advanced Transit Association); Principal of Trans.21
- Dennis Manning, retired California Department of Transportation Civil Engineer; member of ATRA
- John Esslinger, Director of the APM Standards Committee (APMSC), a working group within the Transportation and Development Institute (T&DI) of ASCE (American Society of Civil Engineers) and accredited by the American National Standards Institute (ANSI).

Based on these interviews, it was determined that for U.S. implementation:

a) No Federal approvals (FTA, FRA) are required unless federal money is used;
b) State transportation oversight may apply (State DOT);
c) There are currently accepted standards for APM that could be adapted for PRT; and
d) Prior to U.S. implementation, a full-scale, modern, PRT testing facility should be developed.

Based on this data and regional and local knowledge, the following approval requirements were identified for a PRT system in Ithaca, NY:

Federal

No federal approvals are required unless federal money is used. If federal money is used the project will need to:

- Go through the Metropolitan Transportation Planning Process including the completion of a corridor study to evaluate alternatives.
- Comply with the National Environmental Policy Act (NEPA).
- Require a public entity as the project sponsor.

State

The development of the system will require approval from the New York State Department of Transportation (NYSDOT) to obtain easements within the road right-of-way of state owned roads.

The development of a PRT system will require an environmental impact assessment as prescribed by 6 NYCRR Part 617 State Environmental Quality Review (SEQR).

If a private company will operate the system, they will need to receive operating authority through the New York State Department of Transportation (NYSDOT) NYSDOT Registrating and Permitting Bureau.

It is anticipated that New York's Public Transportation Safety Board (PTSB) will have oversight over a PRT system, particularly if the system will receive State Transit Operating Assistance (STOA). The PTSB, within the NYSDOT Office of Modal Safety and Security State requires the development of a System Safety Program Plan (SSPP). Guidelines for developing an SSPP are available for Commuter Rail, Heavy Rail and Light Rail. Guidelines for a PRT SSPP will have to be developed.

The use of New York State highway right of way must be carried out and completed in accordance with terms and conditions of a NYSDOT Highway Work Permit, in accordance with New York State Highway Law, Article 3, Section 52.

Regional

To receive federal funding, the development of a PRT system needs to comply with the metropolitan planning process. The Ithaca-Tompkins County Transportation Council (ITCTC) is the Metropolitan Planning Organization (MPO) for Tompkins County. The ITCTC would need to approve the project and incorporate it into the Transportation Long Range Plan and ultimately the Transportation Improvement Program **(**TIP**)**, a five year program of federally funded transportation projects. The Transportation Policy Committee is the final MPO decision-making authority, its members include:

1. Chair, Tompkins County Legislature
2. Mayor, City of Ithaca
3. Supervisor, Town of Ithaca
4. Supervisor, Town of Dryden
5. Mayor, Village of Lansing
6. Mayor, Village of Cayuga Heights
7. Regional Director, NYSDOT
8. Cornell University
9. Federal Highway Administration (FHWA)
10. Federal Transit Administration (FTA)
11. TCAT, Board Chair
12. One representative from each of the following groupings, selected jointly on a biennial and rotating basis: 1) Towns of Ulysses, Enfield, and Newfield; 2) Towns of Danby and Caroline; 3) Towns of Lansing and Groton.

Local

The City of Ithaca would need to approve the development of a PRT system and transit-oriented development. If approved the following additional approvals and actions would be required by the City of Ithaca:

- The development of transit-oriented development will require an amendment to the City Zoning Code.
- The right-of-way acquisition and development of the PRT system's stations and maintenance and storage areas will require sub-division approval and site plan review through the City of Ithaca Planning and Development.
- The stations and maintenance and storage facility will require a building permit through the City of Ithaca Building Department.
- The construction of the system will require easements within the city owned road right-of-way and street permits through the City of Ithaca Department of Public Works.

Other

The design and construction of the system may require relocation of some existing utilities that would require coordination and approval with individual companies.

It is recommended that the PRT system comply with the voluntary standards established by the American Society of Civil Engineers (ASCE), an American National Standards Institute (ANSI) accredited Standards Development Organization (SDO). The ASCE Automated People Movers (APM) Standards Committee develops and maintains APM Standards that should be used as a framework for a PRT system until the PRT Task Force Subcommittee determines if modified standards are needed for a PRT system.

4.10. Capital Costs

4.10.1. Request For Information

A request for information was circulated to various PRT companies to solicit preliminary information and an assessment of the Ithaca PRT Study Route. Specifically the request for information (RFI) asked for information regarding capital costs as well as the costs for operations and maintenance (see **Appendix O** for a copy of the RFI). The information provided included a map of the Study Route and approximate quantities for the length of guideway, number and size of stations and number of switches. Also included were preliminary ridership figures that were estimated before the completion of Section 4.8. This includes a demand hourly volume (DHV) of 5,830 riders and an annual ridership figure of 13,644,000. The following is a list of specific information that was requested:

- Number of vehicles required to meet anticipated ridership demand
- Size and estimated cost of the maintenance/storage facility for that number of vehicles
- Size of staff required to operate the PRT (mechanics, control monitors, administrators & other personnel)
- Electricity required to operate the basic system
- Cost of the equipment
- Cost to engineer the system
- Cost of training, technical support and commissioning
- Control software licensing (cost per year)
- Any other equipment/services/factors provided by your company that we should include in a preliminary cost analysis

In general, the goal was to ascertain the unitized costs for each element of a PRT system so that a preliminary assessment could be made for the Ithaca study system. The responses we received varied in the amount of comprehensive data provided and should be considered estimates only since an in-depth analysis was not performed by the vendors. A summary table of the information received is shown below in **Table 4-16**.

Data for Ithaca Study Route System:							
On-Line Miles of guideway:	5.75						
Number of Passenger Stations per mile:	3.65						
Number of Passenger Stations:	21						
Number of Storage Stations:	2						
Total Number of Vehicles:	325						
Average berths per passenger station:	7						
		Shaded numbers are default values matched to similar system types					
	Capital Costs (Millions per mile)						
	Vendor A	**Vendor B**	**Vendor C**	**Vendor D**	**Vendor E**	**Vendor F**	**Vendor G**
Guideway & Support Structures:	17.2	Inc. below	na	Inc. below	Inc. below	na	na
Guideway (Dual-direction)	Inc. above	na	14.7	na	na	7.8	4.1
Support structure & installation	Inc. above	na	Inc. above	na	na	Inc. above	7.2
Vehicles	14.3	Inc. below	4.5	Inc. below	Inc. below	Inc. above	2.7
Stations (3.65 per mile)	Inc. below	Inc. below	4.2	Inc. below	Inc. below	3.8	1.7
Storage, Maintenance, & Control Facility	8.3	Inc. below	4.4	Inc. below	Inc. below	1.2	4.4
Total:	**39.8**	**21.0**	**27.8**	**15**	**13.0**	**12.8**	**20.1**
Soft Costs:	12.50%	16%	16%	16%	Inc. below	16%	16%
Design & engineering	Inc. above	Inc. above	Inc. above	Inc. above	In system $	Inc. above	Inc. above
Permitting & Legal	Inc. above	Inc. above	Inc. above	Inc. above	Not included	Inc. above	Inc. above
Training, tech support, commissioning	Inc. above	Inc. above	Inc. above	Inc. above	20%	Inc. above	Inc. above
Total:	**5.0**	**3.4**	**4.4**	**2.4**	**2.6**	**2.0**	**3.2**
Complete Capital System Cost:	**44.8**	**24.4**	**32.2**	**17.4**	**15.6**	**14.8**	**23.3**
	Operating Costs (Millions per year)						
	Vendor A	**Vendor B**	**Vendor C**	**Vendor D**	**Vendor E**	**Vendor F**	**Vendor G**
Operations & maintenance	na	6.5	na	4	1.3	30% of capital	na
Control software licensing	na	Inc. above	na	Inc. above	Inc. above	Inc. above	na
Complete Operations & Maintenance Cost:	6.5	6.5	6.5	4	1.3	4.4	6.5
	Miscellaneous Information						
	Vendor A	**Vendor B**	**Vendor C**	**Vendor D**	**Vendor E**	**Vendor F**	**Vendor G**
Number of vehicles		175-200	580-600	300	1000-1200*	230	238
Size of maintenance and storage facility		10-25 KSF					
Maintenance only							
Storage only				22 KSF			
Size of staff to operate system (people)		40			90		
Administration							
Operations				3			
Maintenance							
Headway required (Based on DHV of 5,830)			1				
Energy required				0.24 kwh/ vehicle mile @ 25 mph		286 kwh/ vehicle mile (approx)	0.2-0.25 kwh/ vehicle mile
*	Vehicle Surplus Factor of 4						

Table 4-16. Vendor Cost Information

4.10.2. Guideway and Infrastructure

For the purposes of this study, the guideway costs include the actual track sections, support structures, and foundations, as well as any power, guidance and control systems. Depending on the type of PRT system these costs will vary. For example, simple guideways like ULTra's do not require power and are essentially a running surface for the vehicles to drive on, which could be dedicated portions of existing roads. However, the preferred guideway for an Ithaca PRT system is an elevated one and the costs to build this type of infrastructure are significantly more. In Section 4.4, the simulation results led to the conclusion that there is a substantial advantage to building dual-direction guideways. In fact the benefit has been reported by various sources to have a cost factor of 1.5 to 1.85 of the cost of a single-direction guideway because of the shared support structures. As such, all guideway costs stated here shall refer to dual-direction configurations.

From the RFI responses, only three PRT companies provided specific costs for guideways. The types of guideways represented by the cost information covered the three different types discussed in Section 4.4. The estimates ranged from $7.8 million per mile for an open elevated guideway per Vendor F to $17.2 million per mile for a suspended guideway per Vendor A. Vendor G provided the most detailed cost information for a captive-bogey guideway with each component of the structure, power, and guidance systems itemized. These costs were very compelling, considering the itemized analysis provided, and suggested a higher level of resolution than the other cost figures acquired. The cost per mile for this system is only $11.3 million. Since the preferred guideway for Ithaca has been assumed to be a captive bogey or a suspended system we can dismiss the lower cost figure for the open guideway system and forecast that an average guideway cost is approximately $15 million per mile.

4.10.3. Vehicles

With PRT vehicles the cost variability is similar to the guideway and depends on the type of system. Since the size of the vehicles are relatively consistent with a capacity range of two to six passengers, the expense to build the physical cabin and service features such as the navigation interface, air conditioning, and other electronic amenities will be similar. One PRT company, Vendor A, has a system intended to be a more generalized transportation solution to compete with road-based systems. Their decision to design a system capable of both personal mobility and freight transportation increases both their guideway costs ($17.2 million per mile) and their vehicle cost, which is $14.3 million per mile. This is obviously due to heavier infrastructure to handle increased loads. Another factor is that their system forgoes true station platforms and adds the cost of a hoist mechanism to raise and lower the vehicle.

The methods of propulsion, braking, and navigation will further increase the cost differentials across system types. On-board propulsion systems such as electric rotary motors will increase the vehicle cost but it is usually offset by simpler guideways. Separate braking systems will add cost over linear motor systems that are used for both propulsion and braking. Vehicle navigation systems will also increase vehicle costs since a switch mechanism has to be integrated. Again, these costs shift out of the vehicle and into the guideway depending on the design choices of the PRT vendor.

Aside from the cost per mile for the heavier system mentioned above, there were only two other responses regarding specific vehicle costs, which were for linear motor systems. The first was for a suspended system from Vendor C and their reported cost was $80,000 per vehicle. The number of vehicles in a system therefore becomes very important. For example a six mile, dual-direction system will have 12 miles of guideway. Assuming an average speed of 33.5 MPH (15 mps) and 3 second headways the safe operational spacing of the vehicles on the system is 148 feet (45 m). Spread out over the 12 miles of guideway there is room for 428 vehicles to safely move about on the system. Accounting for vehicles in the station berths the total vehicle count would easily reach 450, which is the vehicle count that Vendor C reported after they completed a basic system simulation with dual-direction guideway throughout. This would result in a vehicle cost of $36 million or $6 million per mile for a 6 mile system. However, it should be noted that ridership demand determines the vehicle count so the system above may only require 325 vehicles (vehicle count per the final alternate BeamEd analysis) at a cost of $4.5 million per mile. The second cost figure provided was for a captive bogey system by Vendor G. Their vehicle cost is $2.7 million per mile. This lower value could be attributed to greater engineering optimization or more advanced research and analysis of vehicle costs. This level of resolution is beyond the scope of this study but it seems reasonable to assume a vehicle cost range of $3 to $6 million per mile.

4.10.4. Stations

There are many possibilities for PRT stations from simple ground level shelters similar to a conventional bus shelter to large transit hubs. Since the preferred Ithaca system is elevated, the base cost will be increased by the additional structure, stairs, and conveying systems to ensure handicap accessibility. Optional features include enclosing walls, air conditioning, and retail service areas. However, it is reasonable to assume that the majority of PRT stations will resemble simple train platforms. In this study a size range of two to six berths has been considered. With many other costs to a PRT system it is prudent to look at station designs that serve their necessary functions as well as provide attractive and comfortable spaces for patrons.

With the promise of on-demand service the stations need only be wind shelters with greater complexity increasing as funding allows. Depending on the location of the stations in relation to ridership demand some of the larger stations will become part of mixed-use facilities. These stations are likely to be developed as real estate ventures with partnership from private developers. Station integration into buildings can reduce cost by spreading the financial burden of the stairs and wheelchairs lift and potentially some of the structural elements. A good example is a parking garage with some of the street-side spaces converted to waiting areas and a covered platform attached to it. Therefore the cost difference between small and large stations has the potential to be reduced since the larger stations are more likely to secure funding from external sources or benefit from building integration.

In general the cost data that was received through the RFI was for simple, elevated stations that satisfy the functional requirements and provide the necessary service amenities to ensure a comfortable, safe, reliable, and enjoyable experience. Only three of the seven responders provided specific cost information for stations. Vendor G's information was substantially lower than the other two by a factor of almost two and a half. This information was based on the most detailed & itemized cost data provided and reported a per mile station cost of just $1.7 million when applied to the Ithaca Study Route, which has a station density of 3.65 stations per mile. The other station costs reported by Vendor F and Vendor C respectively were $3.8 and $4.2 million per mile in comparison. This anomaly could be a result of the greater level of resolution and analysis that substantiated Vendor G's low cost figure or it could relate to geographic cost variations, i.e. Europe versus the US (Vendor G is from the US; Vendors C and F are European companies). Regardless, a station cost of approximately $4 million per mile is a reasonable station cost to apply to the Ithaca system since it is consistent with two of the reported values and conservatively greater than the third value reported by a US based company. However, there is potential to reduce this cost on the order of 50% or more to $2 million per mile or less based on Vendor G's scientific assessment.

4.10.5. <u>Storage, Maintenance and Control Facility</u>

The information gathered regarding the costs for the combined storage, maintenance, and control facility needed with a PRT system was very limited. Many of the companies considered this facility less essential in terms of storage capacity since the ideal scenario is to store most of the vehicles on the network. Our preliminary peak ridership figure was also considered high and this drives the number of vehicles required to operate the system effectively. However, it should be noted that the DHV noted in the RFI is projected for twenty years into the future, and a resultant of dense Transit Oriented Development (TOD). High ridership, especially on a small system, will require many more vehicles than can be stored at the stations, but 20 years into the future the system will potentially be larger than the Study Route. Therefore, the ability to accurately size a storage facility is limited to more detailed project analysis and requires further study.

Three companies reported costs for storage facilities but the first, Vendor A, lumped the maintenance facility in with stations and their PRT philosophy does not consider storage necessary so this cost information was not useable. The second company, Vendor F, provide facility cost information for a 230 vehicle system, with 150 storage bays (the rest are stored at stations), a maintenance facility for 25 vehicles, and an approximate 900 SF control room. The cost of the storage, maintenance and control facility worked out to be approximately $1.2 million per mile. The third company, Vendor G and again the one providing a detailed breakdown did not include any storage capacity costs. The facility is purely for maintenance and service, along with the system control center and administrative offices. Another factor to note is that the service throughput is not known so the size of the service and maintenance equipment cannot be assessed to be adequate or not.

In Section 4.4 the potential of automated daily servicing of the vehicles was discussed. These types of assembly line functions could dramatically reduce the size of the service facility if automated. In Vendor G's detailed breakdown of the maintenance facility costs, the number of vehicle cleaning bays described in Section 4.4 was inputted into the spreadsheet and these bays were assumed to be part of an assembly line process. The resulting cost of this facility is approximately $1.5 million, but since there are two storage and service facilities planned with the Study Route it is reasonable to use $3 million as a cost figure for the service, control, and administrative facility. This cost can also be described on a per mile basis as approximately $0.5 million per mile.

The storage depot depends on the capacity but a minimum of 300 storage berths could be assumed for a PRT system similar to the Study Route. In Section 4.4, the space allocation for storing one vehicle was 100 SF. Another way to look at this is to consider storing vehicles on the guideway which would require 15 feet per vehicle (300 vehicles would need almost 1 mile of guideway). Once again it was possible to extract pertinent elements from the detailed cost breakdown provided by Vendor G to determine a per mile track only cost of $4.9 million. A basic storage structure would require approximately 30,000 SF of space and with a conservative construction cost assumption of $200 per SF, another $6 million would have to be added to conclude that each storage depot would cost approximately $10.9 million. The Ithaca Study Route is assumed to potentially require two 300 berth storage depots for optimization and when combined with the cost of the service, control, and administrative facility at each storage depot location, the total cost for this component of an Ithaca PRT System would be about $25 million, which is approximately $4.4 million per mile. When compared to Vendor F's figure of $1.2 million per mile, this cost is significantly more, but the stored vehicle count is also much higher. On a stored vehicle basis Vendor F's cost results in $8,000 per vehicle (150) whereas Vendor G's cost is $7,334 per vehicle (600). As such, a general rule of thumb value of $8,000 per stored vehicle appears to be a reasonable cost figure for the Ithaca Study Route system.

4.10.6. Total Capital Cost

From the above analysis of the vendor supplied data in relation to the Study Route, the following is a summary of the estimated capital costs:

Guideway & infrastructure:	$15 million per mile
Vehicles:	$3-6 million per mile
Stations:	$4 million per mile
Storage and Maintenance Facilities:	$4 million per mile
Total:	$26-29 M per mile

The Study Route is 5.75 miles so the total infrastructure cost of a PRT system similar to the Ithaca Study Route would be $150 to $168 million.

There are additional costs for the design and engineering of a specific PRT system for each application as well as other soft costs such as permitting and legal work. Once built, the system will also require training, technical support, and commissioning to become operational. These expenses have been reported by three vendors as a percentage of the capital costs and ranged from 12.5% (Vendor A) to 20% (Vendor E). The 20% value was an anomaly though because the design and engineering were not included, which increases the net difference between the other percentages and reduces the confidence in this percentage since logically it should have been lower than the others. The only other value was reported at 16% by Vendor G and in an effort to remain conservative this percentage shall be applied to the Ithaca Study Route system. This figure would be $24 to $27 million.

It should be noted that the integration of a PRT system into an existing urban environment will have costs related to the Right-of-Way (ROW) acquisition. A preliminary estimate of ROW acquisition costs is presented in **Appendix O.** Several assumptions were used in estimating these preliminary ROW acquisition costs. It was mainly assumed that the tax parcels whose roll section is "wholly exempt" will not involve any acquisition costs. The ROW acquisition costs for wholly exempt parcels involve political decisions which are complicated and are beyond the scope of this study. For the taxable parcels, ROW acquisition costs include permanent easement costs which include PRT infrastructure, stations and aerial ROW. Full acquisition may be needed in some cases. Temporary easements during construction are not included in the ROW costs. In addition to the easement costs, negotiation/project management costs (15%), engineering mapping/survey costs (15%) and legal costs (10%) are added to the full acquisition costs. It is anticipated that costs associated with ROW acquisition will be approximately $1.5 million.

Therefore, the total estimated capital cost of a PRT system in Ithaca that can be used for planning purposes is $175 to $197 million. Based on the average of this cost range, approximately $186 million, the per mile cost for a PRT system in Ithaca can be estimated at $32 million per mile of two-way track. This is consistent with estimates by Booz Allen Hamilton, in the Viability of Personal Rapid Transit in New Jersey Final Report, which indicated the capital cost of two-way PRT track ranges from $30-$50million per mile.

Additional costs are anticipated to address the need to relocate utilities, modify the tree canopy and potentially provide visual screening of the PRT system or refinement of the aesthetics to blend the system with the neighborhood character. Additional research will be required to fully understand the impact of these costs.

4.11. Operating and Maintenance Costs

4.11.1. Request for Information

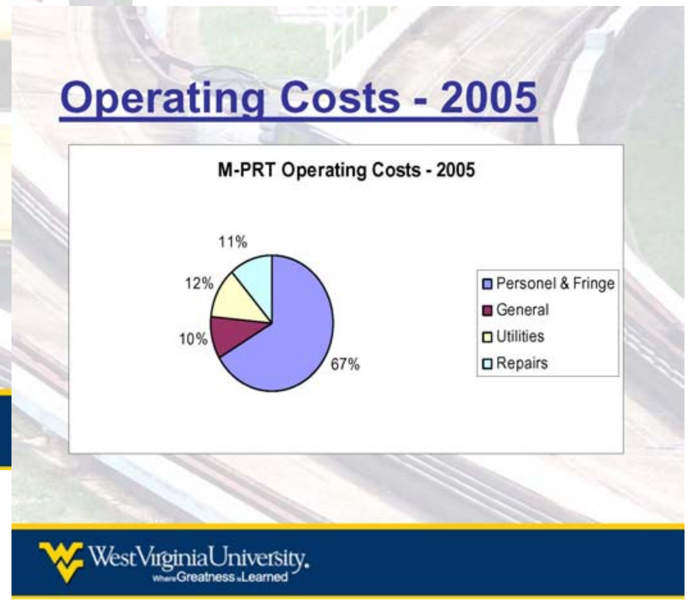
The cost of operating and maintaining a PRT system is probably the most speculative since a true PRT system does not exist. The ULTra system at Heathrow airport is very close to commercial operation and real data will soon be available. However, modern engineering and the similarity of PRT to rail transit, automated people movers, and the closely matched Morgantown, WV group rapid transit (GRT) system has provided the industry with plenty of historical information to draw upon. The range of costs reported by four vendors was $1.3 to $6.8 million with an average cost of $4.7 million per year. Due to the many variables associated with the design of a region specific PRT system, the ability to forecast precise operating and maintenance (O&M) costs is too difficult at this time.
Another consideration is that the O&M costs will also depend on the business model created by the system operator. This will be affected by the ownership model chosen, i.e. public, private, or a partnership between the two. Other factors include the cost of electricity and market forces such as ridership. Intuitively the system variables will all tie back to the number of miles of guideway since this determines the amount of infrastructure that needs to be maintained, which implies a range for the number of vehicles that can safely operate on the system. The O&M costs for the number of stations and storage/service depots will also be proportional to the vehicle quantity, which again relates back to the miles of guideway.

The average annual O&M cost above, including a 20% contingency factor, is roughly equal to the number of guideway miles in the Ithaca Study Route, so a reasonable rule of thumb is to suggest that O&M costs are equal to $1 million per year per mile of guideway in the system.

4.11.2. Review of Industry Data

A great point of reference for O&M costs is to look at the Morgantown, WV GRT system. The system has 8.7 lane miles or when compared to a dual-direction PRT guideway the system would be classified as a 4.35 mile system. Ridership is 30,000 passengers each day. Compared to the Ithaca Study Route system with 5.75 miles of dual-direction guideway and a peak daily ridership of 40,860 the Morgantown system is proportionally 75% smaller. Its annual operating costs for 2004/2005 were $3.4 million.[xlv] The majority of the operating costs, 67%, go to personnel and fringe benefits. **Figure 4-18** shows a summary of the Morgantown O&M costs. Historically this percentage has increased approximately 10% per year since 1980 which was 44%.[xlvi] From 2000 to 2005, the personnel costs have only increased 2% to the current total of 67%, which suggests a theoretical limit may be close to being reached. The staff size for the Morgantown system is currently at 49 with three in administration, nine in operations, thirty two in maintenance, and five in engineering.

The rule of thumb estimate for annual operating costs seems accurate when applied to the Morgantown system, i.e. 4.35 miles of dual-direction guideway would require an annual O&M budget of $4.35 million. While approximately 20% higher than the actual $3.4 million figure, it could be argued that Morgantown has achieved an optimization of its operational costs. Therefore, if the Morgantown PRT system were built today, a $4.35 million annual O&M budget estimate, which includes a 20% contingency, seems prudent and begins to substantiate the rule of thumb figure presented in this study.



Source: Hendershot-Overview PowerPoint, The William L. Alden Morgantown O&M Seminar, October 2005, Robert Hendershot of WVU

Figure 4-18. Morgantown O&M Costs

4.12. Potential Financing Strategy

The vast majority of surface transportation funding in the U.S. is derived from public sources at the federal, state, and local levels. Additional funding may be available through private resources. The following section identifies potential funding sources at the time of report preparation and is subject to change. As traditional sources of transportation revenue continue to decline in adequacy to fund transportation systems, new funding mechanisms will necessarily be implemented to meet the increasing demands on paying for future system operations, maintenance, and expansion. Funding and financing of a PRT system in Ithaca is an area that will require additional research as the project concept progresses.[xlvii]

4.12.1. Federal Funding

The United States government offers a variety of financial assistance programs, grants, loans, and tax incentives to individuals and business that meet certain criteria when making public improvements. A list of the programs that may support PRT development includes:

F-1. SAFETEA-LU (Safe, Accountable, Flexible, Efficient Transportation Equity Act)

Each year Congress provides an annual appropriation which funds the programs specified in SAFETEA-LU. Upon receiving this appropriation, Federal Transit Administration (FTA) apportions and allocates these funds according to formulas and earmarks. SAFETEA-LU is currently under a series of extensions.

F-2. Transportation Investment Generating Economic Recovery (TIGER)

TIGER is a supplementary discretionary grant program included in the American Recovery and Reinvestment Act of 2009 (ARRA). The legislation provides $1.5 billion for a National Surface Transportation System through September 30, 2011, "to be awarded on a competitive basis for capital investments in surface transportation projects that will have a significant impact on the Nation, a metropolitan area or a region."

F-3. The Transportation Infrastructure Finance and Innovation Act (TIFIA)

The TIFIA program provides Federal credit assistance in the form of direct loans, loan guarantees, and standby lines of credit to finance surface transportation projects of national and regional significance. TIFIA credit assistance provides improved access to capital markets, flexible repayment terms, and potentially more favorable interest rates than can be found in private capital markets for similar instruments. TIFIA can help advance qualified, large-scale projects that otherwise might be delayed or deferred because of size, complexity, or uncertainty over the timing of revenues. Many surface transportation projects - highway, transit, railroad, intermodal freight, and port access - are eligible for assistance. Each dollar of Federal funds can provide up to $10 in TIFIA credit assistance - and leverage $30 in transportation infrastructure investment.

F-4. Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) Program

Managed by FTA's Office of Research, Demonstration and Innovation in coordination with the Office of Program Management and Regional Offices, the TIGGER Program works directly with public transit agencies to implement new strategies for reducing greenhouse gas emissions or reduce energy usage from their operations. Initiated within the American Recovery & Reinvestment Act of 2009, the TIGGER Program has been continued through the Transportation, Housing and Urban Development, and Related Agencies Appropriations Act 2010. $75 million was appropriated for FTA to providing direct funding to public transit agencies for "capital investments that will assist in reducing the energy consumption or greenhouse gas emissions of their public transportation systems...." These strategies can be implemented through operational or technological enhancements or innovations.

F-5. Transit Capital Investment Program

The transit capital investment program provides capital assistance for 3 primary activities: new and replacement buses and facilities (Bus and Bus Related Facilities program), modernization of existing rail systems (Fixed Guideway Modernization Program) and new fixed guideway systems (New Starts program and Small Starts). The New Starts program, which would apply to a new PRT system, provides funds for construction of new fixed guideway systems or extensions to existing fixed guideway systems. The Small Starts program provides funds to capital projects that either (a) meet the definition of a fixed guideway for at least 50 percent of the project length in the peak period or (b) are corridor-based bus projects with 10 minute peak/15 minute off-peak headways or better while operating at least 14 hours per weekday. The Federal assistance provided must be less than $75 million and the project must have a total capital cost of less than $250 million, both in year of expenditure dollars.

Eligible applicants under the New Starts program are public bodies and agencies (transit authorities and other state and local public) including states, municipalities, other political subdivisions of states; public agencies and instrumentalities of one or more states; and certain public corporations, boards, and commissions established under state law. Eligible activities are light rail, rapid rail (heavy rail), commuter rail, monorail, automated fixed guideway system (such as a "people mover"), or a bus-way/high occupancy vehicle (HOV) facility, or an extension of any of these.

Projects become candidates for funding under this program by successfully completing the appropriate steps in the major capital investment planning and project development process. Major new fixed guideway projects, or extension to existing systems financed with New Starts funds, typically receive these funds through a full funding grant agreement that defines the scope of the project and specifies the total multi-year Federal commitment to the project.

F-6. Advanced Technology Vehicles Manufacturing Loan Program

Created by Congress to help automakers get the financing needed to retool older plants and equipment to produce energy-efficient vehicles, this program authorized up to $25 billion in direct loans to eligible applicants for the costs of reequipping, expanding, and establishing manufacturing facilities in the U.S. to produce advanced technology vehicles, and components for vehicles providing meaningful improvements in fuel economy performance.

F-7. Rural and Small Urban Areas

This program provides formula funding to states for the purpose of supporting public transportation in areas of less than 50,000 populations. Eighty percent of the statutory formula is based on the non-urbanized population of the States. Twenty percent of the formula is based on land area. Funds may be used for capital, operating, and administrative assistance to state agencies, local public bodies, Indian tribes, and nonprofit organizations, and operators of public transportation services. The state must use 15 percent of its annual apportionment to support intercity bus service, unless the Governor certifies, after consultation with affected intercity bus providers that these needs of the state are adequately met. Projects to meet the requirements of the Americans with Disabilities Act, the Clean Air Act, or bicycle access projects, may be funded at 90 percent Federal match. The maximum FTA share for operating assistance is 50 percent of the net operating costs.

F-8. The Livable Communities Act

The Livable Communities Act, *Creating Better and More Affordable Places to Live, Work and Raise Families,* will help communities foster sustainable development by cutting traffic congestion; reducing greenhouse gas emissions and gas consumption; protecting rural areas and green spaces; revitalizing existing Main Streets and urban centers; and by creating more accessible and affordable housing. The purposes of the Act include: improving the coordination of housing, community development, transportation, energy, and environmental policy in the United States; coordinating Federal policies and investments to promote sustainable development; and encouraging comprehensive regional planning for livable communities and the adoption of sustainable development. Included in the Livable Communities Act is a Challenge Grant Program that authorizes $3.75 billion over three years for competitive grants to assist communities in carrying out sustainable development projects outlined in their comprehensive regional plans. Eligible activities include: investment in transit-oriented development; affordable housing; public transportation infrastructure and facilities; pedestrian and bicycle thoroughfares; redevelopment of brown-fields; and projects to spur economic development. The last major action on this legislation was in February 2010 when it was referred to House subcommittee on Water Resources and Environment.[xlviii]

F-9. National Research & Technology Program

The National Research and Technology Program seeks to improve public transportation for America's communities by delivering products and services that are valued by customers and by assisting transit agencies in better meeting the needs of their customers. To accomplish these goals, FTA partners with the transportation industry to undertake research, development and demonstrations that will improve the quality, reliability, safety and cost-effectiveness of transit in America and lead to increases in transit ridership. Projects include research, development, demonstration and deployment projects, and evaluation of technology of national significance to the public transportation.

F-10. University Transportation Centers Program

Grants for University Transportation Research are awarded to non-profit institutions of higher learning by the Research and Innovative Technology Administration (RITA) using funds appropriated to FTA. This program focuses on the transfer of knowledge relevant to national, state, and local issues, and builds professional capacity of the transportation workforce. Research and education activities address transportation planning, analysis and management, with special emphasis on increasing the number of highly skilled individuals entering the field of transportation. Under the program participating universities conduct basic and applied research, education programs that include multidisciplinary course work and participation in research, and ongoing programs of technology transfer that make research results available to potential users.

F-11. Transit Cooperative Research Program (TCRP)

The TCRP, administered by the Transportation Research Board (TRB), promotes operating effectiveness and efficiency in the public transportation industry by conducting practical, near-term research designed to solve operational problems, adopt useful technologies from related industries and introduce innovation that provides better customer service. TCRP products, such as transit security guidelines, new transit paradigms, transit industry best practices, and new planning and management tools, as well as forums for the exchange of ideas, are being used to develop and equip a quality transit workforce with the resources necessary to meet new challenges and opportunities.

TCRP is sponsored and funded by FTA and carried out under a three-way agreement among the National Academy of Sciences, acting through the Transportation Research Board; the Transit Development Corporation, the educational and research component of the American Public Transportation Association; and FTA. Funds for projects are allocated by transit industry consensus through TRB. Research problem statements are solicited annually from the transit community. TRB awards competitive contracts for research and synthesis studies of current best practices. The TCRP Oversight and Project Selection Committee select the highest priority problems to be addressed and designate funds for conducting the research.

4.12.2. <u>State Funding</u>

States collect taxes and fees from motor vehicle users and use the revenues to support a variety of transportation expenditures. Other significant sources of state revenue include tolls, general fund appropriations, and bond proceeds. The following is a list of state programs that may be applicable to a PRT system:

S-1. New York State Department of Transportation (NYSDOT) State Transit Operating Assistance NYSDOT distributes about $3.0 billion annually in Statewide Mass Transportation Operating Assistance (STOA), and other transportation assistance, to approximately 130 transit operators. In State Fiscal Year (SFY) 1975-76, the NYS Legislature enacted a permanent, ongoing STOA Program with appropriations from the State's General Fund and administered by the state Commissioner of Transportation (this is the Section 18-b Program). In SFY 1981-82, in response to anticipated continuing operating deficits of state mass transportation systems, the Legislature enacted a series of taxes; portions of these proceeds are deposited within the Mass Transit Operating Assistance (MTOA) fund. This fund is subdivided into upstate and downstate dedicated tax fund accounts.

The Mass Transit Operating Assistance fund was created by Section 88-a of State Finance Law. The downstate account provides funding to transit systems in the 12-county New York metropolitan transportation commuter district and consists of revenues from the following sources: a portion of the Petroleum Business Tax (PBT); the MTA Corporate Tax Surcharge; a 1/4 Percent Sales Tax in the MTA region; and the Long Lines Tax. The upstate account provides funding to all transit systems outside the 12-county metropolitan transportation commuter district. A portion of the PBT is the sole dedicated revenue source for the upstate account.

S-2. New York State Energy Research and Development Authority (NYSERDA)

New York State Energy Research and Development Authority (NYSERDA) is a public benefit corporation created in 1975 under Article 8, Title 9 of the State Public Authorities Law. Currently, NYSERDA is primarily funded by state rate payers through the System Benefits Charge (SBC). NYSERDA's aim is to help New York meet its energy goals: reducing energy consumption, promoting the use of renewable energy sources, and protecting the environment. NYSERDA strives to facilitate change through the widespread development and use of innovative technologies. NYSERDA's transportation programs are designed to provide funding opportunities for projects, and innovative research and development initiatives that reduce emissions, improve air-quality, and reduce our dependency on imported oil. NYSERDA funds its projects through competitive solicitations.

4.12.3. Local Funding

The FTA share of a federally-aided capital project is typically 80%. The State provides 50% of the non-federal share (10%) and the locals provide the remaining portion of the non-federal; share (10%). The following is a partial list of programs used by local governments to fund the local share of transit projects.

L-1. Bond Financing

A bond is a contract to repay borrowed money with interest at fixed intervals. In finance, a bond is a debt security, in which the authorized issuer owes the holders a debt and, depending on the terms of the bond, is obliged to pay interest and/or to repay the principal at a later date, termed maturity. Many communities explore the use of bond financing for capital projects, such as public transit improvements, as a way to reduce the need for increasing taxes.

L-2. Tax Increment Financing (TIF)

Used for redevelopment and community improvement projects in the United States for more than 50 years, TIF has become an often-used financing mechanism for municipalities designed to leverage private investment for economic development projects in a manner that enhances the benefits accrued to the public interest. TIF uses future gains in taxes to finance current improvements (which theoretically will create the conditions for those future gains). When public projects such as a road, school, or mass transit improvements are carried out, there is often an increase in the value of surrounding real estate, and often spur additional new investment in the areas affected. This increased site value and investment typically generates increased tax revenues, thus the "tax increment."

4.12.4. Other Funding/Financing Sources

The following is a list of potential funding sources, many of which are still in the development stages. The potential use of these funding sources for a future PRT system is an area that requires additional research beyond the scope of this study.

O-1. User Fees - Fare Box Receipts

PRT suppliers claim that the convenience, reliability and efficiency of its product will increase ridership and overall fare box collections. These user fees can be used to payback capital financing or finance operations and maintenance costs.

O-2. Sale of Promotional, Advertising and Marketing Rights

The sale of promotional, advertising, marketing and educational campaigns in, or on, PodCars and at PRT Stations can support operations and maintenance costs.

O-3. Private Finance Initiatives (PFI)/Public-Private Partnerships (PPPs)

A Private Finance Initiative is a way of creating "public–private partnerships" (PPPs) through a procurement method which secures private funding for public institutions. PFI is also an operational framework which transfers responsibility, but not accountability, for the delivery of public services to private companies. PFI projects aim to deliver infrastructure on behalf of the public sector, together with the provision of associated services such as maintenance. Typically, a public sector authority signs a contract with a private sector consortium that has been formed for the specific purpose of providing the PFI. The consortium's funding will be used to build the facility and to undertake maintenance and capital replacement during the life-cycle of the usually long term contract. During the period of the contract the consortium will provide certain services, which were previously provided by the public sector. The consortium is paid for the work over the course of the contract on a "no service no fee" performance basis.

The public authority will, however, design an "output specification" which is a document setting out what the consortium is expected to achieve. If the consortium fails to meet any of the agreed standards it should lose an element of its payment until standards improve. If standards do not improve after an agreed period, the public sector authority is usually entitled to terminate the contract, compensate the consortium where appropriate, and take ownership of the project. Public-Private Partnerships are becoming an increasingly popular way of financing public transit projects. PPP's allow transportation agencies to leverage private technical, management and financial resources to achieve public objectives, such as greater cost and schedule certainty, supplementing in-house staff, innovative technology applications, specialized expertise or access to private capital.

O-4. Managing an Aggregate Utility Right of Way (ROW)

Typically overseen by a State, County, Town or City, a Utility Right of Way is a public resource that is often "franchised" over a period of time (i.e. 10-50 years) to allow a private entity to occupy the public right-of-way in order to distribute various utility services to the community. It is the responsibility of the franchisee to act as stewards of the right-of-way and insure that appropriate care and maintenance of the right-of-way occurs in accordance with all applicable local, state and federal laws. There is an opportunity for the PRT above-grade guideway infrastructure to act as a combined conduit for other suspended utilities, such as telephone, fiber optics, gas and electric, which increasingly congest urban areas and add visual clutter as new assets are installed. Service providers could conceivably establish franchise agreements and the uniform rights to install PRT guideway to provide transit service and also coordinate right-of-way with other utility providers.

O-5. Renewable Energy Service

Due to PRT's inherent light weight efficiencies, many specialists agree that sufficient renewable energy could be generated on site to operate a local PodCar network. It is therefore presumed that a major subdivision of the PRT industry would be made responsible for developing the most energy-efficient product possible, including ways to capture and utilize renewable energy at stations and on the guideway itself, that contribute to powering the overall transit system. In addition to reducing energy consumption within the transit service, and building renewable energy production at the point of use, the opportunity also exists to identify comprehensive green building practices which could be integrated into the design and construction of PRT stations and facilities. As a result, advanced PRT development projects should not only be evaluated to show how they could operate on renewable energy sources, but they should also work demonstrate the ability to generate a level of energy production *beyond the needs* of powering the PodCar vehicles in order to create a net energy surplus that could also work to feed the grid for stations and surrounding properties to utilize. Renewable Energy Certificates, also called Tradable Renewable Certificates (TRCs) or "green tags", are tradable certificates representing the attributes of energy derived from a qualified renewable energy source. In the U.S., voluntary markets are actively emerging while formal ones are being developed.

O-6. Carbon Offset Credits

Carbon Credits are key components of a national and international attempt to mitigate the growth in concentrations of greenhouse gases (GHGs) around the world. This fairly new undertaking is designed to place a "cap" on emissions and allow market mechanisms and financial incentives drive industrial and commercial processes in the direction of less carbon intensive approaches. Since GHG mitigation projects, such as exceedingly low emission PRT systems, can actively produce carbon credits, they can then be sold, or traded, to commercial and individual customers who are interested in lowering their carbon footprint. The value of the credit is based on the validation process and sophistication of the fund or development company that acted as the sponsor to the carbon project.

O-7. Commuter Tax

A commuter tax is a tax levied upon persons who work in a jurisdiction, but who do not live in that jurisdiction. For example, Philadelphia has a 3.98% wage tax on residents and a 3.5392% tax on non-residents for wages earned in the city as of July 2008. The argument for a commuter tax is that it pays for public services, such as mass transit, received by and beneficial to people who work within the jurisdiction levying the commuter tax. Arguments against such a tax are that it acts as an incentive for businesses to relocate outside of the jurisdiction, along with their residents.

4.13. Project Benefits

4.13.1. Energy Efficiency

Due to the inherent efficiencies of the extremely light-weight vehicles and non-stop travel, the energy use for PRT is generally more efficient than other modes of transit. Numerous studies conclude that traditional PRT uses less than one-fourth the btu's per passenger mile than an average automobile. Studies also estimate that PRT systems will consume "50 to over 300 percent less energy than conventional public transportation systems and could achieve an automotive use of 70 to 90 miles per gallon". [xlix] For further detail, refer to **Appendix P: Comparison of Energy Use by Mode**.

The PRT network itself is a fixed and congruent structure, allowing it to easily connect to a single source of electricity for power or potentially use the elevated PRT guideway itself as a support brace for an all inclusive solar power supply. Additionally, PRT systems produce no pollution at the point of use.

Ron Swenson, a mechanical engineer in Santa Cruz, California who has achieved numerous accomplishments in solar energy, has suggested that an umbrella-like canopy could protect pods and the guide-way from the elements and collect clean sun rays to produce energy for the network and the stations. Mr. Swenson estimates in his report, "*How Can We Turn Sun Radiation into Automotion?",* that "compared against gasoline at $2.50 per gallon…a solar system like this will pay for itself in 4 years…" Mr. Swenson's calculations are provided in **Appendix Q: Solar PRT.**

4.13.2. VMT/GHG Emissions Reduction

PRT systems have the potential to reduce the emission of greenhouse gases (GHG) and the consumption of petroleum products by reducing vehicle miles traveled (VMT). The assumptions used to calculate the estimate of GSG emissions is provided in **Appendix R**. A PRT system in Ithaca is anticipated to reduce VMT and GHG in the following ways:

Associated with Shift in Mode Share

Auto to PRT

PRT ridership from shift in auto to PRT mode share is estimated in Section 4.8. The estimate assumes that the implementation of PRT could increase transit ridership in the PRT area from the existing 5% to 20% resulting in weekday and weekend PRT ridership of 8,010 and 3,120 respectively. Since the Phase 1 study route mainly serves Cornell University, Ithaca Commons, Ithaca College and Wegmans, it is conservatively assumed that the average VMT reduced per trip is 1 mile. Thus, the weekday and weekend VMT reductions are estimated at 8,010 and 3,120 respectively. The VMT and GHG emissions reductions associated with shift in mode share from auto to PRT are summarized in **Table 4-17.**

Table 4-17. VMT and GHG Emissions Reductions From Shift in Mode Share from Auto to PRT

	Weekday Daily VMT Reduction	Weekend Daily VMT Reduction	Annual VMT Reduction	Annual CO2e Emissions Reduced (metric ton)
2030 Projection	8,010	3,120	2,413,700	1,101

Bus to PRT

The introduction of PRT in Ithaca will complement the existing TCAT bus system, encouraging more people to shift to transit and freeing up existing bus resources to serve new routes. It is anticipated that the PRT service will replace several TCAT routes and potentially reduce some demand on other routes.

As discussed in Section 4.8, it is assumed that TCAT Route 10 service is reduced by 50% and TCAT Routes 11, 12 and 28 are eliminated. Even though ridership on other TCAT routes including 30 and 31 may be impacted, no change in TCAT service is expected. The anticipated reduction in TCAT service and the corresponding VMT reductions are estimated in **Table 4-18.**

Table 4-18. Anticipated Reduction in TCAT Service and the Corresponding VMT Reduction

Time Period	Existing Runs	Future Runs	VMT Reduction
Route 10: Cornell University - Ithaca Commons			
		Length (miles)	3
AM Peak	14	7	21
PM Peak	18	9	27
Off-Peak	51	26	75
Weekend	0	0	0
		Total	123
Route 11: Ithaca College - Ithaca Commons			
		Length (miles)	5.5
AM Peak	6	0	33
PM Peak	6	0	33
Off-Peak	15	0	82.5
Weekend	33	0	181.5
		Total	330
Route 12: Ithaca College - Ithaca Commons - Cornell University (Night Service)			
		Length (miles)	11.5
Off-Peak	7	0	80.5
Weekend	7	0	80.5
		Total	161
Route 28: Wegmans – WalMart – Ithaca Commons – Cornell Campus – Hasbrouck Apts			
		Length (miles)	9.8
Weekend	5	0	49
		Total	49

The VMT and GHG emissions reductions associated with reduction in TCAT service are summarized in Table **4-19.** The annual GHG emissions reduction is estimated assuming the use of a diesel bus.

Table 4-19. VMT and GHG Emissions Reductions with Reduction in TCAT Service

	Weekday Daily VMT Reduction	Weekend Daily VMT Reduction	Annual VMT Reduction	Annual CO2e Emissions Reduced (metric ton)
2030 Projection	352	311	124,200	357

Associated with Transit Oriented Development

PRT Phase 1 route serves as a circulator system between major employment centers (colleges and Downtown), areas which offer significant housing and/or housing development opportunities

(Downtown, WestEnd and Collegetown) and areas offering essential services (Wegmans, Downtown). PRT in conjunction with Transit Oriented Development (TOD) has the potential to reduce vehicle trips by creating a PRT enabled mixed-use district which contains all essentials of daily life within a maximum combined transit/walk trip of approximately 10 to 15 minutes. The PRT system within the TOD area reduces the demand for on-site parking and provides the opportunity to meet parking demand with long-term vehicle storage on the perimeter. It also serves as a circulator within the district to eliminate the need for a vehicle for intra-district trips.

Associated with Housing to Accommodate Current In-commuters

The biggest reduction in VMT associated with TOD will result from new housing which is anticipated to appeal to employees now in-commuting because of the lack of affordable housing. The Tompkins County/Cornell University Employee Commuter Survey Report documented that more than one-third (37%) of those surveyed worked 5 or fewer miles from home. About one-fifth (21%) had a 6-10 mile commute and roughly the same proportion (24%) traveled 11-20 miles to work. About one out of ten (12%) commuted 21-30 miles and 6% travel 31 miles or more. Based on the above data, the average commute length is estimated at 10 miles one-way (20 miles round trip).

Section 4.7 estimates that TOD Scenario 3 can accommodate 1,444 dwelling units of which 639 will accommodate relocating in-commuters. The remaining units will meet the area's anticipated growth in housing demand which includes owned occupied and rented units as well as student housing. The estimate of VMT reduction is based on the relocation of current in-commuters. Even though there is some potential VMT reduction associated with the rest of the housing, it is not accounted for in this study. Using a reduction of an average 20 mile two-way commute for the 639 relocating in-commuters, the VMT and GHG emissions reductions associated with TOD Scenario 3 are summarized in **Table 4-20.**

Table 4-20. VMT and GHG Emissions Reductions with TOD Scenario 3

	Weekday Daily VMT Reduction	**Weekend Daily VMT Reduction**	**Annual VMT Reduction**	**Annual CO2e Emissions Reduced (metric ton)**
2030 Projection	12,789	0	3,334,400	1,521

Section 4.7 estimates that TOD Scenario 4 can accommodate 5,503 dwelling units, of which 2,437 will accommodate relocating in-commuters resulting in the VMT and GHG emissions reductions summarized in **Table 4-21.**

Table 4-21. VMT and GHG Emissions Reductions with TOD Scenario 4

	Weekday Daily VMT Reduction	Weekend Daily VMT Reduction	Annual VMT Reduction	Annual CO2e Emissions Reduced (metric ton)
2030 Projection	48,740	0	12,707,100	5,798

Associated with Park and Ride

It is estimated in Section 4.8, that approximately 990 commuters will park at the Park-n-Ride lots and use the PRT system to exit at any station along the system and walk to their place of employment within 10 min. It is conservatively assumed that the average VMT reduction for a Park-n-Ride user is one mile for one-way commute trip (two miles round trip). The VMT and GHG emissions reductions associated with Park-n-Ride are summarized in **Table 4-22.**

Table 4-22. VMT and GHG Emissions Reductions with Park-n-Ride

	Weekday Daily VMT Reduction	Weekend Daily VMT Reduction	Annual VMT Reduction	Annual CO2e Emissions Reduced (metric ton)
2030 Projection	1,980	0	516,200	236

Associated with Reduced Traffic Congestion

The above sections identify various ways in which VMT is reduced, removing vehicles from the road system. The indirect benefit of these factors is the ease of congestion in the Ithaca area which reduces GHG emissions significantly. The estimation of GHG emissions reduction due to reduced traffic congestion/idling is beyond the scope of this study and requires additional research.

Associated VMT/GHG Emissions Reduction Summary

As discussed in Sections 2.2., VMT and GHG emissions reduction are assumed to occur from the shift in mode share and transit oriented development and are summarized in **Table 4-23.** The importance of TOD in reducing VMT and GHG emissions is demonstrated by the significant reductions associated with TOD Scenarios 3 and 4.

Table 4-23. Total VMT and GHG Emissions Reductions

Estimated VMT and CO2 Reduction				
VMT Reduction Sources	**Weekday Daily VMT Reduction**	**Weekend Daily VMT Reduction**	**Annual VMT Reduction**	**Annual CO2e Emissions Reduced (metric ton)**
Reduction in Bus Service (Bus miles)	352	311	124,200	357
Shift in Mode Share	8,010	3,120	2,413,700	1,101
Park & Ride Service	1,980	0	516,200	236
Total without TOD	**10,342**	**3,431**	**3,054,100**	**1,694**
TOD - Scenario 3	12,789	0	3,334,400	1,521
Total - TOD Scenario 3	**23,131**	**3,431**	**6,388,500**	**3,216**
TOD - Scenario 4	48,740	0	12,707,100	5,798
Total - TOD Scenario 4	**59,082**	**3,431**	**15,761,200**	**7,492**

4.13.3. Quality of Life Benefits

4.13.3.1. Less Noise

The combined use of the following PRT design elements is expected to produce less noise and vibration as compared with automobiles, buses and trains:

- Rubber tires on steel rails or concrete roadways,
- Electric motors,
- Small light-weight vehicles, and
- Low maximum vehicle speed.

4.13.3.2. Increased Land Availability/Development Opportunities

Crucial to evolving the core urban area of the City of Ithaca into a vibrant, walkable district with a high quality of life for residents and visitors alike will be maximizing the amount of land available for mixed use development projects, especially housing. Consistent with the Downtown Ithaca 2020 Strategic Plan, the Central Business District (CBD), West State Street Corridor and the West End are areas where ground floor commercial, upper story office and upper story residential uses must be prioritized, and where uses such as parking lots and garages, which detract from the pedestrian experience, need to be minimized.

PRT has the potential to increase land availability by creating a PRT enabled mixed-use district which contains all essentials of daily life within a maximum combined transit/walk trip of approximately 10 to 15 minutes. By attracting more riders to the public transit system, facilitating a higher density of housing, and serving as a circulator within the district, the need for a vehicle for intra-district trips is eliminated, in effect reducing overall parking demand. Where there is still a demand for parking, the PRT system reduces the need for on-site parking by providing access to long-term vehicle storage on the perimeter.

The capacity of a PRT system to move people without cars allows for increased density and frees up land currently dedicated to parking facilities. Increased land availability and an expanded zoning envelope, coupled with reduced on-site parking requirements, will improve the financial viability of projects to include workforce housing.

Because of its service characteristics, PRT has the unique ability to connect areas, typically perceived by the pedestrian as remote, into a synergistic single destination with mutually reinforcing uses. In Ithaca, the Downtown, West End, State Street Corridor, and to some extent the Southwest area, would coalesce into single district because of the ease of movement offered by PRT. This shift would expand the public's perception of where mixed-use development could and should be located. The access offered by PRT could open up locations for mixed-use projects which would be otherwise viewed by developers as being too far from an existing center of activity. An example of this phenomenon might be the opening up of land on the West End for student housing which cannot be accommodated in Collegetown.

4.13.3.3. <u>Improved Pedestrian and Bicycling Environment</u>

By reducing parking demand and vehicle travel within the district, PRT would support the following improvements to the pedestrian and bicycle environment.

<u>Reallocating Space from the Car</u>

The reduction in VMT enabled by PRT would reduce congestion and the need to allocate roadway capacity for auto travel. As a result, more of the road right-of-way could be allocated to other uses including PRT, sidewalks and bike lanes. This would support the streetscape improvements advocated in the Downtown Ithaca 2020 Strategic Plan. Such improvements include curb extensions to shorten crossing distances, expansions of sidewalk into parking lanes to accommodate outdoor dining and landscaping, the temporary closure of streets for festivals and the possible permanent expansion of The Commons pedestrian area.

Pedestrian activity is routinely thwarted by the existence of "dead zones" along the path of movement. Parking lots, gasoline stations and parking garages are the least desirable types of spaces to walk past, and pedestrians actively avoid them. Typically, parking facilities must be located within a 5 to 7 minute walk of destinations, implying the need for large garages spaced no more than 1,200 to 1,500 feet apart within an urban district. PRT allows these garages to be moved to the perimeter of an urban district while still providing residents and users of the district access to their cars within a 5 to 7 minute timeframe. By contributing to the reduction or elimination of auto-oriented land uses, PRT contributes to the walkability of the districts it serves.

24-hour Activity

By playing a key role in making land available for higher density, mixed-use developments, PRT supports the development of vibrant 24 hour street life which makes a district attractive to pedestrians. The high volume of people, and the businesses which emerge to serve them, keep pedestrians socially and visually engaged, and multiply the diversity of services available within the district. With PRT stations spaced about every ¼ mile, some amount of walking will be needed to use the system. These short walks within the district will serve to activate the street and enliven the district and generate foot traffic for business. The number of "eyes on the street" also helps people feel safe, further encouraging walking as a mobility mode during all hours.

Consolidation of Visual Clutter

Consolidation of power and telecommunication lines into the track structure (as opposed to burial) is a likely possibility that deserves further study. Contrary to the view that PRT would add to the visual clutter, consolidation would remove many existing unsightly poles and wires from view. Their relocation to the center of the PRT track conduit would allow trees to assume a more natural shape than is currently possible with power lines running along the tree belt. Traffic signals and signage could also be integrated with the PRT overhead support system. The enclosure of these stretches of power and telecommunications infrastructure would also protect it from ice and wind damage.

Service and Amenities Armature

Far from being an imposition on the streetscape, PRT infrastructure could be designed as a service armature used to enhance the usefulness of the street as an outdoor room. Such street use will become increasingly desirable as pedestrian activity increases. The resulting visual impact would be such that streets with PRT would have a very special character and enhanced amenity. For example, shading or covering canopies can be suspended from the underside of track (assuming a bottom supported vehicle). These street coverings would make PRT streets ideal for rain-or-shine outdoor events, and station locations ideal for street vendors, musicians, etc. Poles could act as support for trash receptacles, drinking fountains, information kiosks, benches, etc, and also provide regular electricity hookup points for street vendors, holiday lighting and equipment used during street festivals. Beams supporting track could also support way-finding signage, traffic signals and LED street lighting. Given the benefits afforded to Downtown merchants by special events, having specialized street spaces to host those events would be a positive addition to the urban environment.

Safety

By reducing vehicle travel, the potential for vehicle conflicts with pedestrians and bicyclists will be reduced. In addition, there is the potential to dedicate more right-of-way to increase sidewalks and provide dedicated bicycle lanes. These improvements will increase safety for these modes.

Hill Climbing

PRT can be used by bicyclists as an inexpensive and convenient means to climb Ithaca's notoriously steep hills, without investing in and maintaining an electric bike. Even though horizontal distances are fairly short in Ithaca, hill climbing is an obstacle which prevents all but the most able bodied people from engaging in regular bike commuting. PRT would function to "negate" the hills, and thus expand the viability of bicycles as a mobility option, especially for the elderly. PRT vehicles can typically carry two bikes with their riders, and larger groups can readily summon additional pods as needed, in contrast to the current bus system's bicycle accommodation which forces bicyclists to wait anywhere from 10 to 60 minutes for the next bus if the two bike rack slots are full.

4.13.3.4. Health Benefits

Improved Air Quality

The reduction in GHG emissions will reduce particulate matter and ozone ambient concentrations that have a negative impact on public health. [1]

Reduced Ambient Noise

Because PRT systems are electrically powered, pods will generate less noise than a passing car. Streets on which PRT is the primary transit mode will benefit from a reduction or elimination of bus engine noise, which is especially disturbing on more densely built urban streets where building facades reflect and amplify sound. These areas are also the primary pedestrian zones, where noise impacts the ability to enjoy conversation. PRT's low operating noise characteristics will thus improve the quality of the Downtown pedestrian experience.

Increased Physical Activity

The health benefits of regular physical activity include reduced risk of coronary heart disease, stroke, diabetes, and other chronic diseases; lower health care costs; and improved quality of life for people of all ages. A PRT system encourages physical activity through, walking and bicycling, both to the system and in the district in general.

4.13.3.5. Reduced Transportation Costs

Taking into account license and registration fees, depreciation, insurance, finance charges, fuel, maintenance and other costs, AAA found that "owning and operating a typical sedan" climbed to about 56.60 cents per mile, or $8,487 per year, in 2009, based on 15,000 miles of driving in the year and gas priced at $2.60 per gallon. That's a jump of more than $390 over AAA's cost estimates in last year's report. Owners of mini-vans and SUVs have even higher costs. [li] The cost to own and operate the average sedan equates to approximately $23 per day, far in excess of the cost of a transit pass. By shifting from vehicle ownership to PRT, or other alternative modes, the average household can significantly reduce their transportation costs, saving close to $8,000 per year for each car they can do without. This savings amounts to 16.6% of median household income in Tompkins County ($48,537 per 2008 US Census data).

4.13.4. Safety Benefits

Several billion dollars worth of work has been done on the research, development and application of automated forms of rail or guide-way mobility over the past three decades, including PRT. This work has been necessary to prove the safety and reliability of PRT and has shown in many applications over the past quarter century that automated transit works in daily practice and has been regularly accepted by the public.

There is ample illustration of exceptionally safe automated transportation operations, such as the Morgantown/WVU PRT, the Lindenwold/Philadelphia line, the Tampa Bay, Las Vegas, and SeaTac systems, the Duke University Medical Center Patient Rapid Transit System, the Clarion People Mover in Indiana, and many others that have run routinely for decades with no significant events to report; considered by many a sign of technical success. The Morgantown PRT, the only fully operational system in the world, has completed over 110 million injury-free[lii] passenger miles since 1974. Comparatively, in 2008 automobile travel in the US averaged 80 injuries and 1.27 fatalities per 100 million vehicle miles traveled.[liii]

Specific PRT safety features include:

4.13.4.1. Computer control to eliminate human error

Unlike transit driven by humans who have limited awareness of the conditions around them, an automated system like PRT is constantly re-calculating system-wide information, reading a myriad of inputs of important data about what is happening in and around the entire network, not just what is happening in front of the traveler. As a result, computer controlled vehicles, utilizing proven technologies, weave together in traffic seamlessly and reduce stop times, eliminating the possibility of chain reaction collisions as every vehicle in the system is aware of every other, and will react and brake in time.

4.13.4.2. Grade separation to eliminate pedestrian/vehicular conflicts

In systems with grade separated guide-ways there are no intersections that cross other roads or guideways, therefore eliminating the potential for head-on collisions with other vehicles, objects or people. When Pods need to change direction, they merge or diverge with a guideway in the desired direction. At these locations, the potential for rear-end or side-swipe accidents are reduced due to the computer control referenced above.

4.13.4.3. Lower maximum speed

Since Pod Cars bypass all but the destination station, the trip is non-stop and the maximum speed is close to the average speed, which is not the case for other forms of transit that have to stop at each station. For example, light rail with stations a mile apart must get up to a top speed of 55mph in order to average 25mph. A PRT system needs to only have a top speed of approximately 30mph to average 25mph.[liv] The lower maximum speed makes PRT inherently safer.

4.13.4.4. Private trips

In contrast to conventional transit which carries large numbers of passengers, PodCar vehicles are typically designed to accommodate up to 6 passengers, and can be used by a single individual if desired. Independent travel reduces the potential for crime or terrorist target. In addition, PRT vehicles and stations can be monitored by video, passengers can communicate via intercom with staff at the control center, and an Emergency Stop button will divert the Pod to the closest station in the event of an emergency.

4.13.5. Economic Benefits

Aside from any direct benefits associated with the PRT system itself, additional indirect economic benefits are as follows:

4.13.5.1. Tax Base

It is presumed that a PRT system would be built in conjunction with a strategy for transit oriented development as presented in Technical Memo #2. The value of development in Scenario 3 is approximately $518M, generating yearly property tax revenue of about $18.1M. In Scenario 4, which assumes an expanded zoning envelope and more aggressive rate of redevelopment, the value of new development is approximately $1.8B, generating yearly property tax revenue of about $64M.[lv]

A significant area for more detailed study would be to ascertain the cost of expanded services needed to serve the additional city population, most notably schools and social services. Because the new development would be in the form of sprinklered buildings, the need for expansion of fire protection service may be minimal. Sewer and water system capacity would also need to be assessed, and development would need to absorb the direct costs of improving these systems (or provide alternative on-site sewage treatment, and/or water conservation to reduce the extent to which these public systems need to be expanded).

4.13.5.2. Retail Sales

Based on Downtown Ithaca Alliance figures, each new Downtown resident would spend an average of $5,778 per year on food and entertainment, retail goods and convenience merchandise within the Downtown district. Scenario 3 estimates 3,239 new residents, producing $18.7M in sales and $1.5M in sales tax revenue. Scenario 4 estimates 12,344 new residents, producing $71.3M in sales and $5.7M in sales tax revenue.

4.13.5.3. Reduced Cost of Parking Facilities

Because PRT offers the previously mentioned benefits of reduced overall parking demand and the option for remote parking, there would likely be a savings in the cost of providing parking facilities in two respects:

1. The first is with regard to the reduced number of spaces needed. As mentioned in Section 3 part 3 above, 18,400 cars would need to be accommodated in parking facilities estimated to cost $270M. The cost for parking under Scenario 4, serving the same population, would require facilities, either public or private, for 2,993 cars on site, and public facilities for 4,346 cars off-site, a total of 7,339 cars. At a construction cost of $15,000[lvi] per space, this amounts to approximately $110M, a savings of $160M in capital costs, which could be used to offset the cost of PRT.

2. The second is savings in the cost of land for remote parking versus parking on prime land in the heart of the urban district. The PRT proposal suggests locating remote parking facilities at an existing parking lot near Wegmans, and possibly on suburban land along the route in the Town of Ithaca near Ithaca College. Land in Collegetown is currently valued at $1.7M per acre, in Downtown Business district at $1M per acre, along the West State Street corridor at $350,000 per acre, for an average cost of $911,000 per acre. By contrast in the Southwest area land is currently valued at $210,000 per acre, and in proximity to Ithaca College at $33,000 per acre, for an

average cost of only $121,000 per acre.[lvii] If remote parking facilities were 6 stories high, approximately 5 acres of land would be needed. Thus, compared to providing new parking facilities in core pedestrian areas, remote parking facilities located in the Southwest and near Ithaca College could save up to $3.9M on raw land costs.

4.13.5.4. Enhanced Project Feasibility

The reduced on-site parking demand will make mixed use development easier to achieve, possibly without subsidy through tax abatements. Marketing such projects with little or no on-site parking will be easier given the availability of readily accessible off-site storage parking.

Energy cost stability. The possibility of running the core component of Ithaca's transit system on locally producible alternative energy will make public transit less susceptible to the inevitable increases or unexpected fluctuations in the cost of fuel, which was demonstrated in 2008 when the TCAT fuel budget was exceeded by some $500,000. Creating a locally owned and controlled power source dedicated to supplying electricity to the PRT system will insure that affordable mobility can be sustained in a changing energy marketplace.

4.13.5.5. Avoided Expense of Accommodating Traffic

Facilitation of development inside the urban core will reduce development in the surrounding automobile dependent towns, and the associated vehicle traffic. Costs associated with accommodating this additional vehicle traffic include policing, road maintenance, road and bridge widening, the cost of accidents and emergencies, the slowing of public transit vehicles and corresponding diminishment of service quality, as well as the cost of commuter parking. If the projected 20 year housing demand for 5,500 homes was developed outside the city and the major employment centers remained in the city, at least 5,500 employees would enter the city each day, requiring an investment of up to $80M in parking infrastructure at workplaces, primarily Downtown and at the colleges. The city would need to absorb the costs associated with this automotive influx, while receiving no additional tax revenue from development outside its jurisdiction.

4.13.5.6. Rural Land Preservation

The economic benefit of rural land preservation will increase in value as fossil fuels increase in cost. Local land preserved for food and biomass fuel production will insure that Tompkins County residents are more resistant to future economic shocks and energy shortages. Rural land preservation also enhances the local tourism industry, a significant revenue generator. If 5,500 homes were developed on one-acre rural lots, at least 6,000 acres would be lost, representing lost food and fuel production capability. The value of this loss, which will likely increase with rising food and energy prices, is estimated at approximately $3.7M per year , based on 2009 agricultural production data for New York State by US Department of Agriculture.

4.13.5.7. Meeting Affordable Housing Demand

Besides avoiding the un-compensated public costs of accommodating suburban commuter traffic, facilitating the construction of 5,500 units of housing in the PRT served core of the city could have a significant impact on household cost of living, effectively expanding the affordable housing supply, and freeing household incomes for other spending. Reducing upward pressure on Tompkins County and City of Ithaca home prices by filling unmet demand will have a positive impact on affordability.

4.13.6. Benefits Over Other Modes

4.13.6.1. Ridership Attraction

There are many reasons why people are advocating for more intelligent mobility and why many U.S. cities have seen public transit use on the rise, including:

- The average 2009 cost of driving a passenger vehicle in the U.S. was 56.6 cents per mile.
- Roads and bridges are in disrepair.
- Cities are experiencing increased traffic congestion.
- The climate is being threatened by GHG.
- The nation's auto fleet is increasingly dependent on foreign fuel for its energy needs
- 40,000 people die from automobile accidents every year in the U.S. [lviii]

Americans need options that are less expensive, faster, and more environmentally friendly. However, most people who live in small to mid-sized American cities are dependent on automobile technology and infrastructure for their daily mobility needs because transit alternatives are not available. Standard simulations predict that 2% of auto drivers will switch to conventional trains if they were available. These same methods predict that more than 25% of auto drivers would switch to PRT if the systems can fulfill the following stated benefits:

- move people substantially faster than their cars,
- be more accessible, affordable, and convenient to a larger range of people,
- be a fun, safe and enjoyable transit experience, and
- be environmentally sensitive, highly efficient, and carbon neutral

PRT has several characteristics which may allow it to draw a greater percentage of riders out of the private automobile than other public transit modes. These characteristics include:

Private Automated Trips

Unlike other forms of mass transit, such as train, plane, and bus, where coach configurations are aligned in an open seat manner, accommodating 20 to 100 people per trip, PRT features a more intimate travel experience. The Pods are built to accommodate an individual and their belongings, light cargo, or a small group of people. PodCar vehicles are typically designed to accommodate up to 6 passengers, and can be used by a single individual if desired. Pods do not have to be shared unless by choice. Once en route, automation allows for the passengers to experience the liberty of private, hands-free, comfortable, and safe transit. PRT shares the smooth ride characteristic typical of rail transit, and pods are quieter than cars both from inside and outside.

24-hour On-demand Service

Due to its use of fully automated vehicles, PRT is designed to be available 24 hours a day. It is also designed to be demand-responsive. A PRT network offers more Pods than stations, adding more vehicles to meet increased ridership demand. Conversely, most forms of local/regional public transit have more stops on their routes than vehicles in service, employing a pre-scheduled loop, forcing riders to be on its schedule. The only exception to a near zero wait time with PRT is during peak demand times, or after the large public events, when the majority of Pods will be in service at once. Computer management of the system insures that as riders are dropped at their destinations, that pods are efficiently deployed to the nearest waiting riders, thus minimizing wait times system-wide.

Fast Non-Stop Service

PRT is envisioned as a grade separated network that does not share its guideway with other forms of automotive transit (public or private), pedestrians, or bicyclists, and which has a level of service not impacted by poor surface conditions and most weather conditions. PRT stations, or "stops", are located off-line, allowing passengers to go from pick-up location to end destination without their vehicle stopping at additional stations for other commuters, red lights, school crossings, or other activity from competing traffic sharing a right-of-way. Due to the on-demand, non-stop service, a PRT system is able to deliver the fastest average travel speed and overall trip time.

Coverage and Convenience

A well designed PRT network will connect major destinations, including schools, shopping and conference centers, employment centers, and entertainment districts, all within walking distance of a transit station. Ideally PRT systems are to be developed as a series of loops, or in a grid, so that an entire region served by the same network would offer single trip access to any station from any other station, without the rider leaving the vehicle and without transfers, in contrast to line-haul busses or trains.

Imageability

The presence of overhead track will make it absolutely clear "where the transit is and goes". Visitors especially will be able to immediately grasp the PRT portion of Ithaca's transit system. "Imageability", the ability of the human mind to visualize where transit is and where it goes, is helpful to building ridership. Similar to PRT, trolley systems have this characteristic because of the presence of track, in contrast to busses which can conceptually go anywhere with their routes not apparent by visual means.

Accessible

Like other forms of public transit, all Pods and stations will be fully ADA compliant. Pod interiors are designed to be flexible and utilitarian, featuring folding seats, automated doors, and flat floor surfaces, allowing wheelchair users to easily roll on and off the vehicle. Boarding would not inconvenience or delay other passengers, as is often the case with busses. Such inconvenience in boarding negatively impacts not only the wait time at stops, but also the public's attitude toward the physically challenged. Access would also be improved for bicycle commuters who face similar boarding delays as wheelchair bound transit users. Bikes could roll onto pods rather than having to be strapped to bike racks on busses or taking up seating space on trains. In addition, bike commuters would not be forced to wait for another bus if bike rack space is unavailable. Elevated stations would include all necessary elevators or lifts to insure full access by bicyclists, the physically challenged, wheelchair bound and elderly.

Beyond aiding those with physical disability to move about for more freely, PRT would also allow many people increased freedom of mobility. Children can travel directly to and from school in a secure vehicle; the elderly can maintain their mobility when no longer able to drive safely; people who cannot afford to own and maintain a private auto, yet lack the availability of frequent and reliable public transit, could participate in daily life like most others with cars on an equally flexible schedule.

Environmental Appeal

Because it is highly energy efficient, can use alternative energy sources and has low noise impacts on its surroundings, PRT may potentially draw ridership from environmentally aware commuters who choose this mode based on their personal convictions about sustainability and climate change.

4.13.6.2. Right-of-Way Requirements

Due to its use of small, light-weight vehicles, a PRT system has smaller guideway or infrastructure requirements as compared to other modes. The width of a single PRT track varies depending on the guideway type, but can range from as small as 1.5-2 feet for an elevated suspended system to 6-7 feet for an elevated open or at-grade guideway. By comparison, a single track for a light rail or bus rapid transit (BRT) system is typically 12-14 feet wide, twice the width of the PRT guideway. Refer to **Appendix F, Guide-way Scale Comparison** for a diagram of different guide-way sizes.

The smaller vehicles also reduce the required station size. A typical PRT station is approximately 30-feet in length. A BRT station would need to be 40-feet to accommodate a single vehicle and approximately 85-feet to accommodate a double articulated vehicle. Similarly a light rail station typically ranges from 50-120 feet depending on the vehicle used.

4.13.6.3. Capital and Operating Costs

The most similar transit modes to PRT include Bus Rapid Transit (BRT), light rail, and heavy or metro rail. Automated People Movers (APM) are a unique system type that has a close resemblance to PRT but from a cost standpoint is essentially on par with light rail. Conventional bus transit is also worth comparing but it is more difficult to draw direct correlations since the infrastructure costs are nonexistent due to the use of existing roads. However, this infrastructure benefit also severely compromises the efficiency of bus transit due to road congestion and increased travel times. From an operational standpoint bus transit is also markedly inconvenient when compared to on-demand PRT systems, so any O&M comparison should acknowledge the considerable variation in service convenience. The private automobile is also worth comparing since PRT can compete with the convenience factor, speed, and reliability of this predominant transportation choice in the US, but a direct comparison is more complicated because of the existing infrastructure and other hidden costs such as parking.

According to the 2007 report "Viability of Personal Rapid Transit in New Jersey" the following capital between PRT and conventional transit was reported:

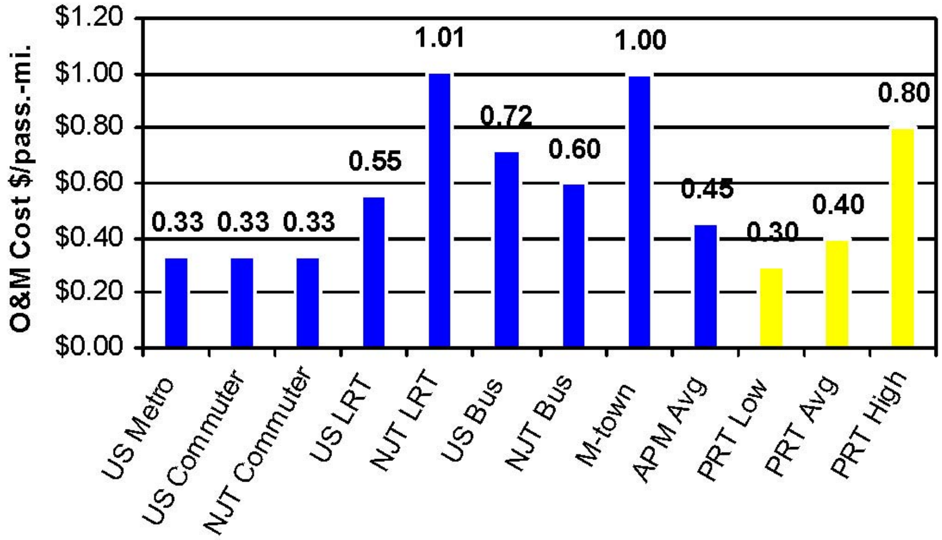
Mode	Capital Cost/Mile ($M) Low	Average	High
Observed Construction Costs			
Heavy Rail	$110	$175- $250	$2,000*
Light Rail	$25	$50-$70	$195
APM – Urban	$30	$100-$120	$145
APM – Airport	$50	$100-$150	$237
BRT Busway	$7	$14-$25	$50
BRT Tunnel	$150	$200 - $250	$300
Theoretical Engineering Cost Estimates			
PRT One Way	$15	$20-$35	$50
PRT Two Way	$25	$30- $50	$75

Source: Viability of Personal Rapid Transit in New Jersey, Booz Allen Hamilton, February 2007

Figure 4-19_ Comparison of Transit Capital Costs

From the average costs in the table above a theoretical two-way (dual-direction guideway) PRT system is estimated to cost between $30 and $50 million per mile. In Section 4.10 it was concluded that a PRT system in Ithaca, NY that was similar to the Study Route would cost approximately $32 million per mile, which is consistent with the low end of the theoretical average cost range reported here. As shown in **Figure 4-19**, the capital cost of a PRT system is estimated to be a third of APM systems, half of light rail, and more than one fifth the cost of heavy or metro rail. The BRT busway is the only transit system that is competitive with PRT. However, a BRT busway is an at-grade solution that competes with roadway traffic thus requiring the necessary space allocation. While this is a very cost-effective way to resolve transit demands in large metropolitan areas, it does not seem to be an easy or appropriate fit in small cities to utilize dedicated right-of-ways. This is especially true in Ithaca, NY with narrow street right-of-ways that wind up steep grades. If a BRT system is built as a grade-separated solution the capital costs quickly fall in line with light rail and even heavy rail.

When comparing O&M costs the analysis needs to use an equalized unit of measure, which is often cost per passenger mile. In **Figure 4-20** below, also from the report "Viability of Personal Rapid Transit in New Jersey," the O&M costs of various transit systems have been compared.



Source: Viability of Personal Rapid Transit in New Jersey, Booz Allen Hamilton, February 2007

Figure 4-20 O&M Costs of Transit Systems per Passenger Mile

As shown, PRT seems to have the potential to compete with the low operating costs of heavy or metro rail and consistent with the costs of light rail. In Section 4.11 the annual O&M costs for the proposed Ithaca Study Route was concluded to be approximately$1 million per mile of guideway. In the case of the Ithaca Study Route this total cost was estimated to be $5.75 million. In order to convert this figure to a cost per passenger mile for comparative analysis the simulation results from the BeamEd analysis in Section 4.4 can be used. The results suggest that the average PRT trip would be 2.5 km or 1.6 miles. Assuming each trip has an average of 1.2 passengers, which is the same for automobile use in the US, and multiplying these values by the annual ridership without TOD (3,734,500), results in a conservative estimate of 7,170,240 passenger miles. Based on the $5.75 million estimated annual O&M cost, a PRT system similar to the Ithaca Study Route would have an O&M cost per passenger mile of $0.80, which is consistent with the high end of the PRT costs in **Figure 4-20.** As PRT technology improves with reduced headways and capacity increases with network optimization the operational costs should be reduced to be more consistent with the average $0.40 per passenger mile presented in **Figure 4-20.**

It is also desirable to compare PRT to conventional bus transit despite the differences in service and its use of existing infrastructure. Assuming capital costs have been resolved and a PRT system exists, the O&M costs become a straight comparison. The most obvious bus service to use for this analysis is the local transit provider in Ithaca, Tompkins Consolidated Area Transit (TCAT). From the Federal Transit Administration's National Transit Database the 2008 report from TCAT shows an O&M cost of $1.25 per passenger mile, which is 50%

more than PRT's high end cost. Clearly PRT has the potential for tremendous operational savings over conventional bus transit.

The cost of car ownership is also an interesting comparison to PRT O&M costs. AAA's 2010 edition of *Your Driving Costs* estimates the average cost per mile for car ownership as shown in **Table 4-24.**

Table 4-24. Average Car Ownership Cost per Mile

	Miles per Year		
Vehicle Size	**10,000**	**15,000**	**20,000**
Small Sedan	56.4 cents	43.3 cents	36.6 cents
Median Sedan	72.9 cents	56.2 cents	47.6 cents
Large Sedan	92.6 cents	70.2 cents	58.6 cents
Sedan: Composite Average	**73.9 cents**	**56.6 cents**	**47.6 cents**
Minivan	**80.6 cents**	**62.0 cents**	**52.4 cents**
4WD Sport Utility Vehicle	**96.9 cents**	**73.9 cents**	**62.1 cents**

Source: *Your Driving Costs-How Much are You Really Paying to Drive*, 2010 Edition, AAA[lix]

AAA's methodology to calculate average driving cost assumes the vehicle is used for personal transportation over five years and 75,000 miles of ownership. This data suggests that operation and maintenance costs of PRT would be competitive with automobile ownership and operation, but with improved energy and environmental efficiency, and safety benefits.

Not accounted for in this analysis is the capital and maintenance cost for the road infrastructure that allows automobiles to operate. These expenditures would obviously drive the O&M cost per passenger mile for automobile use even higher. This is an area that requires additional research to truly make a comparative analysis. Another area of study that should also be considered is the cost of car share programs and how they compare to PRT, but this is beyond the extent of this study.

4.13.6.4. Economic Development Opportunities

Automobiles and transit are mature industries while PRT is still an emerging technology. As an emerging technology, PRT provides economic development opportunities through:

- research and development,
- manufacturing,
- planning and design, and
- support and operations industry.

4.13.7. Potential Challenges

The following is a summary of the potential challenges that will need to be overcome for successful PRT implementation:

New technology

Since PRT is still an emerging technology there is limited depth of experience in the industry. Safety, security and technical standards, specific to PRT operation in the United States, have not been developed. There is also a need to develop open technology standards to avoid proprietary designs and vendor exclusivity. The public outreach for a PRT system will also be more challenging as there is a need to educate the public on the technology, its benefits and limitations.

Capacity limitations

PRT is best suited for low density travel. It may not be possible to achieve minimum headways which would make it difficult to meet peak hour demand, requiring the system to be supplemented with peak hour or special event bus service.

Visual Impacts

Perhaps the most politically contentious aspect of PRT, besides capital cost, is the visual impact. Visual impacts would apply to any system with a dedicated right-of-way or fixed guideway. The smaller infrastructure requirements for a PRT System reduce the potential visual impacts as compared to traditional light or heavy rail systems; however, mitigation measures may still be necessary. This needs to be studied in greater detail, specific to the locations where PRT infrastructure is to be sited.

4.13.8. Next Steps

This study evaluated the feasibility of a PRT system in Ithaca, NY. In general the study has concluded that a PRT system can be physically accommodated within the existing built environment of a mature city like Ithaca and that a PRT system in conjunction with transit-oriented development would provide substantial environmental, quality of life and economic benefits to the region. However, the study has also identified several areas that will require additional research before the City and the region can make a decision to pursue the implementation of a PRT system in Ithaca.

4.13.8.1. Short-term

It is recommended that the following planning steps be pursued in the next few years to determine if a PRT system should be pursued for the City of Ithaca:

Technology Assessments

There is need to continue to track the status of research and development of both suspended and supported systems to determine which guideway type is the most appropriate and commercially available for implementation in Ithaca. Similarly, there is a need to conduct additional research on the most appropriate propulsion system.

Master Plan

There is a need to conduct a more detailed planning study of potential PRT development in Ithaca. This study should include the following:

- *PRT route alternatives analysis and station planning* – including an assessment of the feasibility of using private property and existing structures for stations and identification of locations for storage/maintenance facilities.
- *Alternatives analysis* – including a comparison of how a PRT system would compare to bus transit, Bus Rapid Transit (BRT) and car share programs. The cost comparison should address the capital and maintenance cost for the road infrastructure and how it contributes to the O&M cost per passenger mile for automobile or bus use.
- *Ridership Demand* – evaluation of the perceived attractiveness of PRT by potential users and more detailed analysis of ridership projections through a local travel survey.
- *Simulation Modeling* – detailed modeling of the proposed Phase 1 system and its potential future scalability. Modeling should independent of proprietary software or the proposed system should be modeled using at least three different company's proprietary software for comparison.
- *Environmental assessment* – assessment of the possible impact—positive or negative—that a PRT system may have on the environment, including natural, social and economic aspects. This assessment should include the following areas that were identified in this study as needing additional research:
    - Constructability
    - Cost of expanded services, most notably schools and social services, needed to serve the transit-oriented development (TOD) supported by a PRT system
    - VMT reductions associated with reduction in idling due to congestion
    - Infrastructure consolidation – evaluate the ability to consolidate telecommunications, energy, traffic and signage infrastructure into the PRT guideway.

Benefit/Cost Analysis

There is a need to develop more detailed capital and O&M cost estimates and summarize the anticipated PRT system benefits in monetary terms so that a benefit-cost ratio can be calculated.

Public Involvement Process

Since PRT is an emerging technology there is a need to both educate the community on the technology and solicit their input on its potential in Ithaca. This process should include renderings of how the system could be integrated within the existing infrastructure of Ithaca as well as animations showing how a PRT system operates.

Identification of Ownership/Operation Structure

There is need to evaluate potential ownership and operating structures to determine which is the most appropriate for implementation in Ithaca. This assessment should consider a variety of procurement strategies from a PRT vendor providing design/build/operate and maintain (DBOM) services to a local transit authority planning, designing, building and operating his own system It is important to identify the approach in the early planning stage since it will impact potential funding opportunities.

4.13.8.2. Long-Term

Upon completion of the short-term tasks, if it is determined that a PRT System in Ithaca should be pursued the next steps include:

- Procurement
- Engineering
- System Implementation and Testing

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SECTION 5

APPLICATION IN NY BEYOND ITHACA

New York State's extensive support for public transportation contributes to the lowest per capita transportation energy consumption in the nation. However, the high share of public transportation use in New York is skewed by the disproportionately large participation in public transportation in the New York metropolitan area. As summarized in the following table, smaller urban areas, particularly those in central and western New York have a much lower participation in public transportation.

Table 5-1. 2000 Census Percent Mode Share Comparison

	National	New York State	Ithaca, Tompkins County	Syracuse, Onondaga County	Rochester, Monroe County	Buffalo, Erie County
Drive-alone	75.7	56.3	59.8	80.1	82.7	80.9
Car-pool[1]	12.2	10.5	12.5	10.4	9.4	9.7
Transit	4.7	23.6	4.8	2.5	2.3	4.5
Walk/Bike	4.1	7.0	18.3	4.2	3.2	2.9
Telecommute	3.3	3.0	5.1	2.8	2.4	2.1

Sources: Bureau of Transportation Statistics State Transportation Statistics, 2004; Genesee Transportation Council; Ithaca-Tompkins County Transportation Council, 2000 Census Transportation Planning Package

[1] – includes taxi/other means

To further reduce the footprint of New York State's transportation system on the environment and improve energy efficiency, there is a need to reduce vehicle miles travelled (VMT) in these smaller urban areas. As shown in this report, developing a PRT system in conjunction with implementing policies to promote transit oriented development (TOD) has the potential to reduce VMT and associated greenhouse gases while enhancing the quality of life and economic development. Urban and suburban areas with over 30,000 jobs, as well as college campuses and activity centers, are suitable locations for the introduction of PRT.

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C. Interviews

This report was informed by the following interviews conducted by Connect Ithaca in April 2009:

1. Ron Swensen, President, Solar Quest & Solar Evolution
2. Grady Cothen, Deputy Associate Administrator for Safety Standards, Federal Rail Authority/USDOT
3. Dennis Manning, Civil Engineer, retired from California Department of Transportation, Member of Advanced Transit Association (ATRA)
4. Lawrence Fabian, President of Trans21, Treasurer of ATRA
5. John Esslinger, Director, APM Standards Committee

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