A Concept for a Personal Rapid Transit System in the State of New Jersey

Final Course Project for ORF 467 Transportation Systems Analysis, Fall 2007-08
Princeton University
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Chapter 1

Executive Summary

1.1 Personal Rapid Transit

Personal Rapid Transit (PRT) is a design for a system that provides individual transportation service with consistent service. PRT would compete with the personal automobile as a mode of transportation, and in order to do so, would have to provide service comparable to that of the personal automobile. The expectations of a PRT system are small cars running along a one-way stretch of guideway and periodic, off-line stations for users to enter and leave the PRT network. An image of a potential car is included in Figure 1.1, which is a design of a vehicle done by Vectus, a PRT company.

Figure 1.1: Vectus' Concept Design of a PRT Vehicle, Source: Vectus. http://www.vectus.se/eng_press.html

There is a substantial cost to building a guideway (estimated to be $5 million per mile) for PRT vehicles as well as PRT stations ($2.5 million) and PRT vehicles ($150,000). We assumed that no one would walk more than a quarter mile to a station, so in order to ensure coverage, stations would need to be fairly close to the trip productions and attractions. In less busy areas, where the cost of building guideway and a station is hard to justify, stations could be placed within biking distance or within a short drive for a dual-mode trip.

1.2 Project Overview

This fall, Professor Alain Kornhauser led Princeton University's ORF 467 Transportation class to an in-depth analysis of the feasibility of a PRT network for the state of New Jersey. The goal of this network was to cover approximately 95% of the trip productions and attractions in the State, while providing benefits to the user somewhat comparable to the personal automobile.

Students were paired and assigned to one, two, or three counties based on the size and perceived complexity of the counties. Students then researched the county, looking for major points of interest. Concurrently, several students were commissioned with the task of building software tools to help generate and manipulate the network. These students began working with Google Maps to create an interface to enter, update, and delete data about a PRT network and Google Earth to conveniently show the static results of the project. These tools dramati-

cally contributed to the success of this project and would serve as excellent tools to do some degree of network optimization.

One focus of this project was to begin to generate numbers about trip productions and attractions for points of interest in the state of New Jersey. In order to develop a transportation network, one must have a good idea of how and where it will be used. At each station location, understanding what the productions and attractions were enables a far deeper analysis of how a PRT system could be used. Our software tools enabled us to type our stations based on the kind of production or attraction found at the station location.

1.3 Future Research

The idea of a PRT network in New Jersey merits study in addition to the contents of this report. As as state with many public transportation networks but still a heavy reliance on the personal automobile, New Jersey would be a prime state in which to test a PRT network. The Commissioner of Transportation was asked, in 2004, to look at the possibility of a PRT system in New Jersey.[1] This report has a comprehensive outline of what a PRT system entails and what details are important when selecting a PRT network. (Similar demands of a PRT network may be found in various county reports, like Section 8.14 which refers specifically to PRT use in Cumberland County.) Instead of focusing on this aspect of a PRT network, we dedicated our efforts to placement of stations and guideway in New Jersey.

Future research in this area should have a primary focus on trip productions and attractions. A detailed study of trip productions and attractions is a substantial undertaking—even when done independently of a transportation systems analysis. From this analysis, stations can be placed with the guidance of clustering algorithms to produce optimal station locations. In addition, the formal creation of a trip matrix, where estimates of daily trips from productions to attractions are found. For a state-wide network, this would require major amounts of computing power as the number of stations is in the hundreds or over a thousand. The problem grows tremendously as the number of stations increases. At the same time, however, doing the problem in this way would likely reduce the number of stations needed, as clustered points of interest would only become one station.

In terms of the project organization, only in some ways is a county-by-county analysis relevant. In the denser areas, where the conties are interconnected in many places, the county-line division seems somewhat arbitrary. The assumption that most of the trips beginning in one county end in the same county does not really hold. In this way, the resulting network would be more efficient if the sub-networks were designed around high-density locations rather than counties. For most of New Jersey, the county approximation works fine, but the high-density approach would be more natural after clustering stations together.

[1] Carnegie, Jon A., and Hoffman, Paul S. *Viability of Personal Rapid Transit in New Jersey.* Report. Feb 2007. http://faculty.washington.edu/jbs/itrans/big/PRTfinalreport.pdf. Page 1

Chapter 2

Summary of Findings

2.1 Overview

New Jersey has 21 counties, each with distinct characteristics. Most of the counties have provided estimates of trip production and attraction data based on their own methodology. A good example of this takes place in Section 4.4 on page 28, where the methodology around Bergen county is discussed. Because several counties did not provide estimates, and because the aggregate total needs to be realistic in terms of state-wide statistics, we can check that our results are reasonable relative to some key statistics. Table 2.1 provides a few relevant facts from the U.S. Census Bureau about New Jersey. Based on the information in Table 2.1, we can calculate that there are about 5.5 million million people between the ages of 18 and 65. We also see 3.6 million non-farm jobs, but recognize that there are many jobs in New York and Philadelphia to which New Jersey residents may commute, and a number of farm jobs that are not included in that number. 2000 Census data indicates that there were about 4 million employed people in 2000,[1] which leads us to believe that the current num

Table 2.1: Census Summary for New Jersey,
Source: U.S. Census Bureau http://quickfacts.census.gov/qfd/states/34000.html

Census Data	**NJ**	**US**
Population, 2006 estimate	8,724,560	299,398,484
Population, percent change, April 1, 2000 to July 1, 2006	3.70%	6.40%
Population, 2000	8,414,350	281,421,906
Persons under 5 years old, percent, 2006	6.40%	6.80%
Persons under 18 years old, percent, 2006	23.90%	24.60%
Persons 65 years old and over, percent, 2006	12.90%	12.40%
Private nonfarm employment, 2005	3,594,862	116,317,003

The Federal Highway Administration, part of the U.S. Department of Tranportation, cites a survey conducted in 2001 for average trips:[2]

> The 2001 National Household Travel Survey show that daily travel in the United States totaled about 4 trillion miles, an average of 14,500 miles per person annually. On a daily basis, Americans averaged 4 trips per day, totaling on average 40 miles of travel - most of it (35 miles) in a personal vehicle.

With an estimate of four trips per day, per person, and with population estimates in Table 2.1, this causes us to estimate nearly 35 million trips taking place each day in New Jersey. In meeting 95% of the productions and attractions, we expect to be able to capture roughly 95% of the trips, or about 33 million trips daily. This is just over 12 billion trips a year.

[1] U.S. Census Bureau: American FactFinder. "Economic Characteristics - New Jersey." http://quickfacts.census.gov/qfd/states/34000lk.html

[2] U.S. Department of Transportation: Federal Highway Administration. "Operations - Did you know? - Archive." http://ops.fhwa.dot.gov/resources/didyouknow/didyouknow_archive.asp

2.2 Land Use

Land use is the foundation for building a transportation network. Knowing how spaces are used helps to understand what sorts of transportation will be needed between those locations. This was the primary factor in determining how a network should be built.

Land use varies widely from county to county, and in some cases, even within the county. In the Northern part of the state, housing tends to be fairly dense. The closer to New York City, the more dense the population. Counties like Hudson, Essex, and Union have tremendous densities, while Salem and Cumberland are much less dense. Density also increases along the coastline, which creates an interesting problem for designers of a transportation network.

2.3 Methods and Approaches

Given the wide variety of land use characteristics that face New Jersey, students used a variety of methods to place stations to optimize the utility of the PRT service relative to the cost of building the network. In highly-dense areas, grid patterns were often an effective way to get coverage. These grids were formed by overlaying two sets of parallel guideways perpendicular to one another and connecting them with interchanges. Each set of parallel guideways has one-way lines that alternate direction. When overlayed on one another, these sets of guideways form a grid-like pattern of one-way roads. The road system on the island of Manhattan approximates this idea nicely.

From a local perspective, some of the squares of the grid are actually a small loop that has a direction to it. Generalizing this form, a loops served as a resonably way of serving somewhat less dense areas. It was often effective to place a series of stations on a small loop of guideway whose origin and destination is one interchange. Loops could have one or more interchanges where they might connect to other loops or other network designs.

Another design that was used was the hub-and-spoke method. Used often where there were pockets of densely populated areas among sparser areas, the hub-and-spoke arrangement provided a cost-effective way to handle the vast majority of trips in the area.

Aside from using estimates of trip productions and attractions, students looked to pre-existing transportation networks to understand what the current infrastructure says about transportation needs. Roadways were of primary interest to the students, especially in counties where commuters used cars in greater numbers. Roads—like the New Jersey Turnpike, the Garden State Parkway, and other interstates—signal significant transportation flows in the direction of the roadway. At the most abstract level, roadways are the physical result of an earlier attempt to solve a transportation network problem.

Train networks, too, help demonstrate trips. NJTransit provides rail service in many places throughout the state. In these places, the direction of the rail lines and frequency of train service gives us a good idea of what the demand for PRT would be in these locations. Train stations also provided locations for PRT stations because a PRT network would have to be fully cointegrated with the pre-existing networks. In the same way, airports, bus terminals, Park & Ride lots, and other current systems of mass transit provided productions and attractions for trips.

2.4 PRT Design Results

Each of the 21 counties in New Jersey has been analyzed, and a PRT network has been designed for each one. The number of stations and miles of guideway generally reflect the population density.

As seen in Figure 2.2, the total base cost of our PRT system is estimated to be $89 billion. This would cover the stations and guideway for our PRT nework. In addition, this network would need a sufficient number of cars to cover 33 million trips per day estimated in Section 2.1. In addition to these costs, we need the costs of PRT vehicles, which are outlined in many of the following chapters.

Most of the subsequent chapters have provided an in-depth analysis of the stations in each county, as well as a justification for the placement of stations that may not have many trip ends per day. These chapters have a histogram for the trips by station, which helps determine how well the network will be utilized. Furthermore, these trip ends have lead each county to a total number of trips, which was then used to compute the number of vehicles used in the network. In order to calculate this figure, we made some assumptions about the peak load of the network and worked to have enough vehicles to satisfy that peak load.

Table 2.2: PRT Network Summary

County	**# Stations**	**Miles Guideway**	**# Arcs**	**Avg Arc Length (miles)**	**Est. Cost $ million**
Atlantic	191	525.72	253	2.08	3,124
Bergen	1,117	878.37	1,640	0.54	7,184
Burlington	597	487.93	688	0.71	3,935
Cape May	976	496.67	1,255	0.40	4,923
Cumberland	437	1,008.76	924	1.09	6,136
Essex	595	295.35	755	0.39	2,964
Gloucester	412	435.13	514	0.85	3,206
Hudson	467	122.39	545	0.22	1,779
Hunterdon	405	482.77	474	1.02	3,426
Mercer	413	403.06	534	0.75	3,048
Middlesex	444	678.88	765	0.89	4,504
Monmouth	335	565.08	448	1.26	3,663
Morris	858	693.88	973	0.71	5,619
Ocean	540	1,166.46	739	1.58	7,182
Passaic	1,185	1,360.49	2,152	0.63	9,765
Salem	285	772.48	595	1.30	4,575
Somerset	568	432.51	675	0.64	3,590
Sussex	409	764.33	542	1.41	4,844
Union	577	254.24	692	0.37	2,714
Warren	484	436.62	524	0.83	3,393
Total	11,295	12,261.12	15,687	0.78	89,576

Chapter 3

Atlantic County

Atlantic is a county situated in the US state of New Jersey. As of 2000 census, the population is 252,552. Its county seat is Mays Landing. This county is part of the Delaware Valley area.

Figure 3.1: Atlantic County, NJ

As of the census of 2000, there were 252,552 people, 95,024 households, and 63,190 families residing in the county. The population density was 174/km^2 (450/sq mi). The racial makeup of the county was 68.36% White, 17.63% Black or African American, 0.26% Native American, 5.06% Asian, 0.05% Pacific Islander, 6.06% from other races, and 2.58% from two or more races. 12.17% of the population were Hispanic or Latino of any race. 18.6% were of Italian, 13.0% Irish, 9.5% German and 5.2% English ancestry according to Census 2000.The average household size was 2.59 and the average family size was 3.16.In the county the population was spread out with 25.30% under the age of 18, 8.10% from 18 to 24, 30.60% from 25 to 44, 22.40% from 45 to 64, and 13.60% who were 65 years of age or older. The median income for a household in the county was $43,933, and the median income for a family was $51,710. The per capita income for the county was $21,034. About 7.60% of families and 10.50% of the population were below the poverty line, including 12.80% of those under age 18 and 10.50% of those age 65 or over. Atlantic County encompasses 561 square miles has a diverse mix of industries. Employing 119,759 in a variety of industries, most notably casino and resort services, but also in manufacturing and agricultural sectors.

Atlantic County's economy and population continue to grow led by a continued expansion of the casino gaming industry. This growth has in turn resulted in the diversification and strengthening of the County's economy to include a broad array of residential development (single and multifamily, assisted living, and age restricted), retail centers, first class golf courses, and other industries which cater not only to the needs of the casino industry but to all of those people drawn to Atlantic County in search of employment opportunities.

In determining the network on which the most efficient and convenient PRT system will run, it is necessary to consider how PRT's creation will serve Atlantic County's population and how it will further promote multimodal transportation through integration with current transportation infrastructure.

Atlantic County encompasses 561 square miles has a diverse mix of industries.

Realistically, there are few alternatives to the use of the car within Atlantic County. The train systems that run through Atlantic County are primarily for freight. Additionally, there are no local bus routes serving the Atlantic County community, only regional bus systems for travel between outlying Cumberland and Atlantic County. The clear solution for this lack of efficient and local and regional travel is the State of New Jersey Transit system.

3.1 Road Mileage

State: 6,671 miles County: 373.23 miles Garden State Parkway (toll road): 31 miles Atlantic City Expressway (toll road): 29 miles Atlantic County has over 7,000 miles of road, with two major toll roads. 791 miles of PRT track would provide access to the same area, a considerable decrease in miles needed. With over 97,004 households, a very large number of home-school, home-work, and home-shopping trips will occur everyday, most likely around a million a day.

In determining the network on which the most efficient and convenient PRT system will run, it is necessary to consider how the PRT creation will serve Atlantic County's dynamic population and how it will further promote multi-modal transportation through integration with current transportation infrastructure.

Our PRT network in Atlantic County had two main focuses in design. The first is our residential areas, with a concentric connected circle layout for tracks. The concentric circles connect to others through in going and outgoing links joining different sized circles and the networks that connect to other circular networks.

Stations are placed with an emphasis on destinations needed by those who are either very young or very old, with an emphasis on schools, hospitals, and shopping areas.

In dense areas, there is always a station $\frac{1}{4}$ of a mile away. In less dense areas, the station placement can be as far as $\frac{1}{2}$ mile. This network design helps facilitate the movement in a particular township, and between townships.

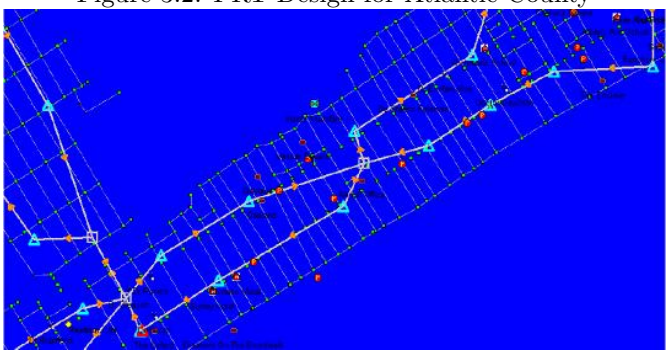
The second was for Atlantic City itself. Atlantic City is connected through a two pearl necklace strands that are interlinked every few blocks. The PRT network runs in Parallel paths that move in different directions. These paths come together at transfer points where the PRT vehicle can either continue on its path or turn around and go back on the other way. It operates rather like a freeway or expressway that you may have to turn around if your destination is on the other side of the road.

Our selection of stops in Atlantic City included all of the normal desitnations that would be necessary in a residential setting, but also including stops along the boardwalk at the various Casinos and Resorts. Wherever possible, the PRT network is placed on the inland side of a resort to preserve ocean views.

Because of the large number of vacationers coming into Atlantic City, the demand for PRT vehicles will be no higher than in other counties. The extra needed cars that will be needed come from outlying counties, and stay in the city as long as the vacationer does, which is often only for the day. The system works perfectly for Atlantic County, because the county does not need extra vehicle even though it benefits from an incredible increase in accessibility. As Atlantic County, and Atlantic City tries to reinvent itself as a premiere vacation place, providing an alternative mode of transportation is so important. To increase the number of guests without having to install additional parking, accommodate more day trippers, and make Atlantic City a more easily accessible location for all of New Jersey, PRT is a necessity. In the face of no available public transportation available aside from traveling to Philadelphia, it is difficult to imagine the number of visitors to Atlantic City to increase by a large percentage. Anyone who has been caught in the traffic on the Atlantic City Expressway knows the dire need of Alternative transportation other than a crowded in and outgoing road. PRT in Atlantic County, when used in conjunction with other county PRT networks, promises to be a boom for the county and a boom for New Jersey as a whole.

A multitude of historic, environmental, economic and regulatory factors have influenced current land use patterns and contributed to the development of the County's 561 square miles. Notably today, the natural environment contributes both opportunities and constraints to the intensity of land development in the County. The proximity to wetlands and requirements of maintaining wetland buffers, as well as, soil suitability all have a profound affect on the ability of the land to support new development. This is particularly critical in Atlantic County due to

Figure 3.2: PRT Design for Atlantic County



three major river systems and associated inland and coastal wetlands limiting development potential. In fact, approximately 40 percent of the County's land mass is inundated with wetlands soils, as noted by the Atlantic County Soil Survey. The past land use patterns of agricultural, manufacturing, and tourism industries that portrayed many older communities are now being replaced by service industries, as well as residential development. Also, sophisticated transportation networks and legislative actions have forever left their impact on the County's landscape.

3.2 The PRT Network: Land Use and Design

The Atlantic County Personal Rapid Transit network was designed to address the lack of transportation between mainland and coastal communities within Atlantic County and provide connectivity to 82% of New Jersey's points of interest. The final design contains 623 station locations and requires nearly 500 miles of guide way with the average distance between stations being around 0.4 miles.

The land use considered in determining the structure of the PRT network are housing, employment, shopping, religious, education, and transportation. Population: 271,015 (86% urban, 14% rural). Considering correlation between the type of land use and population density, it is necessary to distinguish between lower and higher population densities when designing the PRT network. In general, in low density areas, ridership will have lower congestion per unit time under typical conditions, so stations can be placed farther away from each other. In contrast, high density areas will have higher ridership per unit time under typical conditions, so it is necessary to place stations in closer proximity to alleviate any congestion that might arise.

The highest density communities are all predominately located around the biggest cities of the county. In general, around each of these cities we have build a sub-PRT network to allow a fluidity of movements around those congested areas making it very easy to provide robust multidirectional transportation throughout each respective community for maximum connectivity. Those sub-networks are concentric rings with nodes along major avenues and roads are integrated into the current automobile transportation infrastructure to make multi modal trips utilizing the PRT network within each respective coastal township as convenient and efficient as possible. Additionally, land use in these areas is predominately saturated with hotels, casinos, recreational facilities, and office buildings, catering to the needs of the seasonal influx of vacationers attracted to Atlantic.

Less urbanized Atlantic County communities, with smaller population densities, are not as spatially structured as the shoreline communities. For the most the most part, non-urban communities are not clearly distinguishable as independent physical entities. Land use in Atlantic is largely shopping, housing, and recreation (gambling mostly, et cetera).

3.3 The PRT Network: Service and Trip Generation

3.3.1 Service to Education

One of the largest volume destination locations on the PRT network will be areas zoned for primary, middle, secondary, and undergraduate education. In primary, middle, and secondary education, there are currently 84960 students enrolled in 118 schools throughout Atlantic County, averaging about 720 students per educational facility.

There are two university level establishments:

1. Richard Stockton College, Pomona and

2. Atlantic Cape Community College, Mays Landing

And they both together totalize about 13,200 students. Unlike other points of interest, it is essential that the location be as close to each respective campus as necessary to ensure that the ridership (primarily children under 18) is able to seamlessly transition from the network to the point of interest without hindrance.

Trip Generation

When generating trips for education, the enrollment at each respective school was taken into account as trips to and from the educational facilities. The school faculty was also added to the trip generation by multiplying the enrolled student numbers at each educational facility by the student to faculty ratio. It was assumed in building the network that those in permanent housing would be the sole source of trips provided to the educational locations. Additionally, despite the low volumes to some educational facilities, accommodations were made to insure a station at every location. The station was placed near to the school, while all other attractions and productions within a quarter mile radius were aggregated to represent the total volume for the school centric station.

3.3.2 Service to Housing

Considering the housing in Atlantic needs to support permanent as well as temporary/vacationing populations, we must assess the use of the PRT network by both constituent.

Permanent Residents

There are a total of 124,047 housing units in Atlantic County. The average number of residents per unit in Atlantic County is about 2.6.

The permanent residents of Atlantic County will use the network predominantly for educational, employment and public space trips. Of course regular shopping and religious trips are being made by the permanent population, but the proportion of total trips to employment, education and public space destinations generated by the permanent population is vastly larger than proportion of temporary resident trip generation to those points of interest.

The 124,047 residents who comprise the permanent population of Atlantic County will use the network predominantly for educational, employment and public space trips. Of course regular shopping and religious trips are being made by the permanent population, but the proportion of total trips to employment, education and public space destinations generated by the permanent population is vastly larger than proportion of temporary resident trip generation to those points of interest.

Figure 3.3: Atlantic County Households by Household Type: 1990 and 2000

Household Type	1990 Number	1990 Percent	2000 Number (Estimate)
Total Households	85,123	100	102,147
Married Couple Family	41,202	48.4	49,439
Female Householder	11,647	13.7	13,994
Male Householder	3,727	4.4	4,494
Non-Family Households	28,547	33.5	34,219

Source: U.S. Bureau of the Census, STF 1 (1990)
Year 2000 household estimates created by Atlantic County Department of Regional Planning and Economic Development

Trip Generation

When considering the trip generation of the permanent residents we operated under the assumption that in each living unit, there were three residents each making a round trip from home to another destination and then returning back to home. Using the population density for each of the municipalities and by utilizing the graphic power of Google Earth, housing areas were assigned estimates as to the number or units and therefore the number of trips generating from the surrounding housing units.

Seasonal Residents

In addition to the permanent residents, housing in Atlantic County needs to be able to support an additional population of seasonal residents. Primary housing for the vacationing population will include single family units that are vacant during non-summer periods, apartments, motels, hotels, inns, and any other sort of temporary residence. Atlantic County provides 47,244 units of single family residence and apartments, so under the assumption that each vacationer's family is around four people, this takes up 188,976 of the vacationing population, leaving the remaining vacationers and temporary residents to find housing in resorts, hotels, motels and other temporary residence.

In contrast to the permanent population, the trips along the network for the seasonal residents are predominantly for recreational, gambling and shopping purposes. Also, the seasonal population will account for small proportion of the generated trips to religious, educational, employment, and public space.

Trip Generation

Building a network robust enough to serve a population inflation requires not only forecasting trip generation for the general population, but also for the seasonal residents. However, due to the fact that both populations would be able to operate on the same network because of overlapping points of interest throughout both populations, the only major operational concern in this case would be congestion. Also, considering that the temporary influx of population into Atlantic is primarily exhibited in Atlantic City and to a much lesser extent mainland Atlantic county, it is reasonable to assume that vacationers will have little need to travel throughout mainland Atlantic meaning that infrastructure for mainland Atlantic can be built to serve solely the permanent population.

3.3.3 Service to Employment/Public Administration

Considering that 73% of commuters in Atlantic County use a car to get to work, the appeal of the PRT system must be towards the working population. In order to provide a superior mode of transportation or add the PRT component to the multimodal commute to work, the service to employment locations must be close enough to provide for a brisk walk from the station to the point of interest, but not allocated to the point of having a station at every employment location.

As of 1996, Atlantic County's total non-farm employment stood at 138,150 jobs. As indicated below in Figure, Atlantic County's economy is dominated by the service sector accounting for 53.5 percent of the total non-farm jobs, then retail trade with 15.2 percent of the jobs, followed by the public service sector which includes education with 14.2 percent of the total nonfarm employment. Other sectors such as manufacturing, transportation, communication, utilities; construction; finance, insurance, real estate and wholesale trade account for the remaining 17.1 percent of non-farm employment.

Trip Generation

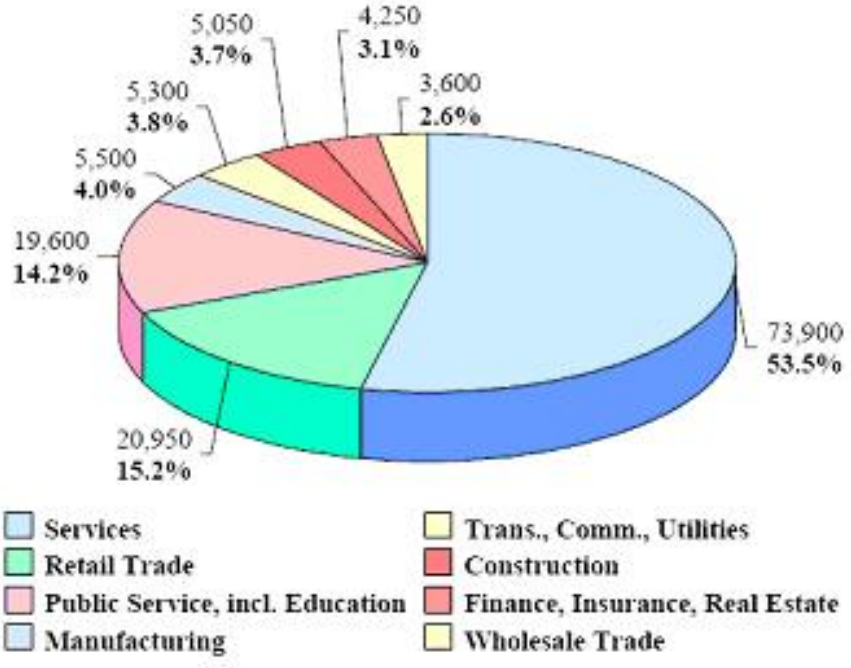
Starting out with the population of Atlantic County in the workforce and operating under the assumption that the labor force of Atlantic County serves solely locally and does not travel outside the County for employment, we then took out the percentage of unemployed people within the work force to generate the total number of employed people within Atlantic County. Then, we distributed this population of employees throughout the county to each respective municipality, based on the population percentage of each respective municipality as a proportion of the total population. Now with figures for number of employees per municipality, each municipality working population was separated into specific industry jobs based on average employment industry statistics for Atlantic County. Although not the most precise method of employment trip generation, considering the general homogeneity of occupations across Atlantic County, determining the exact number and type of each employee within an entire municipality is a worthless enterprise, considering the dynamic nature of employment trends over time.

3.3.4 Service to Shopping and Recreation

The Atlantic PRT system will provide service to all casinos, major shopping centers, paying attention to building stations at every frequented shopping location, rather than focusing on creating a network on which there is a station near high volume shopping areas.

As Atlantic is an ocean oriented community, there are many fishing, marina, boat-for-hire, camping, and observatory locations that are easily accessible from stations along the network. Similar to shopping, the aim is to

Figure 3.4: Atlantic County Total Non-Farm Employment: 1996



Source: N.J. Department of Labor, Division of Labor Market & Demographic Research

serve every recreational point of interest in Atlantic County, not to address areas of high volume, with emphasis of providing stations for every golf courses, casinos and marinas.

Trip Generation

Each member of a household was assumed to take two shopping or recreational trips per day. Given the data collected for shopping and recreation, divided total number of municipal specific shopping or recreational trips per day by the number of collected shopping and recreation points of interest within that municipality, number of trips per location was determined.

3.4 PRT Design Analysis

Keeping in mind the key purposes of Atlantic PRT are to bridge the mainland and coastline populations and provide access to 90% of New Jersey's points of interest, we are able to make assertions about station location and volume throughout the county.

It is key in the analysis to note that although mainland communities, in general, have lower population densities than coastal communities, during non-summer months, the total population in mainland communities is systemically higher than the total population in coastal communities. Furthermore, population growth in the mainland communities has been consistently as opposed to that in the coastal communities since 1970. This can be accounted for by the relative size and attractiveness of mainland and coastal communities. Considering that coastal communities span over. So, given that mainland communities are more populated, span more square miles, have lower population density, and have land use significantly less saturated than coastal communities, design of the PRT network for Atlantic County will need to provide proportionately more stations to mainland communities. As a result, a significant proportion of the stations on the PRT network will serve relatively fewer trips per station (as an artifact of lower population density in mainland communities) than others. In the designed PRT network for Atlantic County, this is exactly the case.

On aggregate the design of the PRT system for Atlantic County is consistent with the population demographic assumptions and transportation needs based on the population density of each respective township.

3.5 Cost of PRT

For all the convenience that the Atlantic County PRT will provide to its ridership, there is still the topic of cost to address. The creation of this network will require significant initial investment into building the physical capital needed for this project. At the base level, funding for the creation of stations, interchanges, guide way, and the PRT vehicles themselves is needed. In addition to physical capital expenditures, we must also take into consideration the need for human capital, such as station attendants at some of the higher volume stations and operations employees. Presented is a breakout of the costs used to create an estimate of the Atlantic County PRT system budget, which totals $5.67 billion.

Table 3.1: PRT Costs in Atlantic County

Expense Type	**Amount**
Physical Capital Expenditures	
Guide way	$3,483,350,000
Stations	$212,500,000
Interchanges	$83,100,000
Vehicles	$3,018,900,000
Human Capital Expenditures	
Stations Attendants	$19,805,714
Operations Technicians	$85,714,285

3.5.1 Budget Calculations

Guideway

The cost per mile of guideway was assumed to be $5 million.

Stations

The network requires 425 stations. Each station has a projected cost of about $0.5 million.

Interchanges

At this stage, interchanges are viewed as increment costs added to the cost of guideway. Not as capital intensive as the construction of a station, an interchange provides a landed cost of $150,000 for each of the 554 interchanges on the Atlantic County PRT network.

Vehicles

The network for Atlantic County requires 20,126 PRT vehicles at a cost of $150,000 per vehicle.

Station Attendants

Assuming that stations with volumes above 3,000 trips per day would require two attendants to direct ridership efficiently, salaries based on hourly wages of $15.00 and 40 hour weeks, an infinite annuity was calculated based on the yearly salary cost of attendants and a discount rate of 7%.

Operations Technicians

Different from attendants, operations technicians are assumed to be employed on a yearly salary rather than hourly. The average yearly salary was assumed to be $120,000 and with 497 miles of guideway, there would need to be 50 technicians, or one technician for every ten miles of guideway. An infinite annuity for the cost of 50 technicians was also calculated with a discount rate of 7%.

3.6 The Benefit of PRT

In joining the fifteen other counties in New Jersey, upon adoption and creation of the State-wide Public Rapid Transit system, Atlantic County will have access to within a quarter mile of virtually every point of interest in Atlantic County and New Jersey. Providing an environmentally friendly and safe transportation system such as this will alleviate most of the State's current concerns with automobile emissions while at the same time, providing a solution to the plague of congestion throughout the State.

In addition to provided State-wide benefits, Atlantic County locals will also reap great benefits from the construction of this transportation system; considering that during the summer months in Atlantic County the population balloons to more than 600% of the permanent population, this transportation system will serve the needs of vacationers to and from Atlantic County, cutting down the need for them to contribute to the automobile emissions and congestion by the frequent use of automobiles for transportation within Atlantic County and to adjacent Atlantic County. Additionally, more than 89% of all commuters in Atlantic County are traveling to work by car, which provides the perfect opportunity for PRT market penetration as commuter after commuter will choose either a fully PRT mode or multi-modal PRT trip to get to their place of employment. Additionally, through the ease of transportation between points of interest in Atlantic County, more and more vacationers will flock to Atlantic County, furthering the development of the area.

Chapter 4

Bergen County

Overview and Assessment for Personal Rapid Transit (PRT)

4.1 General Description of County

Owing to the extensive shared border of Bergen County and Passaic County, and serving for an introduction, a joint analysis and preliminary comparison of the two counties is in order, so as better to understand the one, from the other: Located in the northeastern tip of New Jersey, both part of the New York Metropolitan Area, Bergen and Passaic Counties together comprise a total area of 444 square miles, of which ninety-four percent, or 419 square miles, is land and the remaining six-percent is water, accounting for 25 square miles. The two counties, Bergen and Passaic, are contiguous, as may be seen on the map in Figure 4.1, with Passaic enveloping most of Bergen from below and to the west. Founded in 1837, much later than Bergen County, incorporated since 1683, Passaic County was in fact created from a partition of Bergen and Essex Counties, hence its present position today between those two counties. However, despite their shared border, Bergen and Passaic counties differ markedly in their population demographics and topography. Bergen County, notably, is the most populous county in present-day New Jersey and has been for some time: of the 8,724,560 total residents of New Jersey estimated for 2006, 904,037 of those are Bergen County residents, more than ten percent. Passaic County, slightly smaller than Bergen in total area by about twenty percent, has approximately half the residents, with a 2006-estimated population of 497,093. Bergen County is also growing at a faster rate than its neighbor, with a 2.3% population increase since 2000, versus 1.4% for Passaic. Though the working age populations (taken between ages eighteen and sixty-five) of Bergen and Passaic Counties are close in proportion, fifty-three percent and fifty-six percent respectively, Passaic County is characterized by younger and larger families than those which live in Bergen. Bergen County, in this respect, with an average resident age of 39 and 2.64 persons per household overall, contrasts with statistics from Passaic, for which the average age is 34 and the average household size is 2.92. Twenty-nine percent of Bergen County residents are under 18 years old, but in Passaic County, this figure is thirty-five percent. The disparity in residential realty between the two counties explains this difference: The median home value for Bergen County, at $250,300, is much pricier than that of $190,600 for Passaic. At a macroscopic level, Bergen County therefore appeals to mature families and working-individuals with a history of saving and high aggregate income commensurate with being able to afford such (comparatively) expensive real estate. Substantiating this conclusion, median household income for 2004 for Bergen County was $65,637, significantly above the figure of $47,861 for Passaic County, which fell below the state average household income of $57,338. Bergen County, indeed, has the twenty-first highest per-capita income of counties in the United States. The geographic, commercial, and transportation landscapes of the two counties reflect these population demographics, to which we now turn.

4.2 Bergen Land Use and Existing Transit

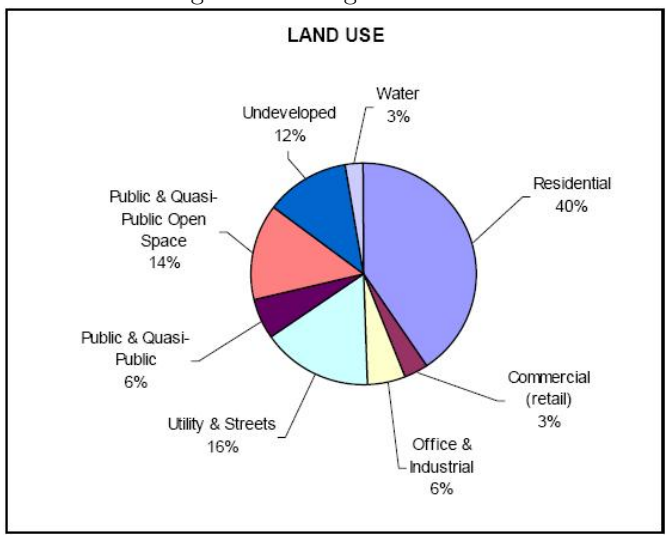
4.2.1 Employment

As demonstrated by the pie chart in Figure 4.2, the primary land use in Bergen County is residential, accounting for forty percent of the total land area. Another twenty-six percent is undeveloped or designated as public and quasi-public open space. Though only six percent of land is devoted to office and industrial complexes, the 101,335 firms incorporated in Bergen County as of 2002, with manufacturers' shipments topping $12.7 billion, point to

Figure 4.1: Map of NJ Counties

the strength of the job sector. Bergen County, in fact, has 14.7% of New Jersey's jobs, over 487,000, more than any other county in New Jersey. Furthermore, boasting the lowest county tax rate in New Jersey since 1990, Bergen County attracts a wide variety of working professionals and business retailers. 14.8% of all New Jersey's manufacturing jobs are located just in Bergen County, surpassing other New Jersey counties.

Figure 4.2: Bergen Land Use



Referencing the tables in Figures 4.3 and 4.4, we see that most persons residing in Bergen County in fact work in Bergen, or 57.59% of the Bergen working population; however, nearly twenty percent work in New York City, making transportation a paramount concern for the many long-distance commuters in search of safe, reliable, and efficient means of travel to work each day. More than 450,000 Bergen residents belong to the metropolitan area workforce, nearly equaling the total population of neighboring Passaic County.

In fitting with this impressive worker productivity, and supplementing earlier analysis of the county's general affluence, the private sector payroll in Bergen—over $15 billion—is the highest in New Jersey. The county's top

Figure 4.3: Bergen Work

	PLACE OF WORK FOR BERGEN COUNTY RESIDENTS					
	1980	Percent	1990	Percent	2000	Percent
New York City	64,541	15.65	71,537	16.87	74,966	17.54
Dutchess Co, NY	92	0.02	78	0.02	71	0.02
Nassau Co, NY	560	0.14	1,354	0.32	1,468	0.34
Orange Co, NY	327	0.08	234	0.06	486	0.11
Rockland Co, NY	3,871	0.94	5,475	1.29	5,858	1.37
Suffolk Co, NY	107	0.03	214	0.05	302	0.07
Westchester Co, NY	2,599	0.63	5,005	1.18	3,689	0.86
Bergen Co	237,948	57.71	256,562	60.49	246,163	57.59
Essex Co	15,890	3.85	16,959	4	17,733	4.15
Hudson Co	21,051	5.11	24,385	5.75	25,444	5.95
Middlesex Co	1,835	0.45	2,842	0.67	4,149	0.97
Monmouth Co	113	0.03	510	0.12	952	0.22
Morris Co	3,501	0.85	6,014	1.42	9,631	2.25
Passaic Co	24,029	5.83	24,659	5.81	24,081	5.63
Somerset Co	304	0.07	982	0.23	1,492	0.35
Union Co	3,220	0.78	4,029	0.95	5,124	1.20
Other Areas/ Not Reported	32,241	7.82	3,263	0.78	5,853	1.37
Total Employed	**412,329**	**100.00%**	**424,102**	**100.00%**	**427,462**	**100.00%**

Source: U.S. Bureau of the Census, Census 2000. (STF S-5, 1980, 1990)

Figure 4.4: Bergen Residence

	PLACE OF RESIDENCE FOR PERSONS EMPLOYED IN BERGEN COUNTY					
	1980	Percent	1990	Percent	2000	Percent
New York City	15,888	4.47	31,572	7.14	20,325	1.67
Dutchess Co, NY	167	0.05	208	0.05	245	0.06
Nassau Co, NY	1,309	0.38	2,330	0.53	1,337	0.31
Orange Co, NY	3,314	0.93	8,175	1.85	7,310	1.68
Putnam Co, NY	93	0.03	305	0.07	157	0.04
Rockland Co, NY	10,166	2.86	14,808	3.35	12,687	2.92
Suffolk Co, NY	522	0.15	1,041	0.24	564	0.13
Westchester Co, NY	1,904	0.54	5,253	1.19	3,221	0.74
Bergen Co	237,948	66.99	256,562	58.00	246,163	56.64
Essex Co	9,997	2.81	14,453	3.27	18,158	4.18
Hudson Co	17,553	4.93	22,176	5.01	26,458	6.09
Middlesex Co	2,219	0.62	4,595	1.04	5,826	1.34
Morris Co	6,163	1.73	9,614	2.17	12,094	2.78
Passaic Co	37,697	10.60	47,954	10.84	53,138	12.23
Somerset Co	459	0.13	1,576	0.36	2,327	0.54
Union Co	2,378	0.67	4,335	0.98	5,419	1.25
Other Areas/Not Reported	8,004	2.25	17,360	3.92	19,169	4.41
TOTAL	**355,781**	**100.00%**	**442,317**	**100.00%**	**434,598**	**100.00%**

Source: U.S. Bureau of the Census, Census 2000. (STF S-5, 1980, 1990)

three employers are: the Hackensack University Medical Center, with 6,200 employees; the Valley Hospital System, with 2,700 employees; and the New Jersey Sport and Exposition Authority, with 2,5000 employees; many of the highest-paying local jobs are concentrated in health care. A complete listing of the most popular employers in Bergen County is shown in Table 4.1:

Table 4.1: Major Employers in Bergen County

# Employees	Employer
6200	Hackensack University Medical Center
2700	Professional Employer Group Service
2700	County of Bergen, NJ
2700	The Society of the Valley Hospital
2500	NJ Sports & Expo Authority
2200	Merck-Medco Managed Care LLC.
2200	Quest Diagnostics Inc.
2100	AT&T Wireless Services, Inc.
2000	Englewood Hospital and Medical Center
2000	Aramark Svcs Management of NJ Inc.
2000	Holy Name Hospital

When planning the layout of our Personal Rapid Transit stations for employees, we took care to ensure the connectivity of these and other major employment centers, relative not only to the dense residential communities in their vicinity, but to nearby commercial areas as well.

One must also recognize here the county's considerable economic symbiosis with neighboring Passaic County, for nearly fifteen percent of the total workforce in Bergen resides in Passaic, a significant figure. To be successful, a network of personal rapid transit stations must reflect in its distribution between the two counties the interrelationships connecting them, buttressing both employment and commercial and recreational linkages.

4.2.2 Shopping

The robust job market in Bergen, in turn, translates to high shopping demand and frequent visitation of recreational parks and facilities. There are two primary commercial and entertainment zones in Bergen, which we took into consideration in planning our distribution of personal rapid transit stations: East Rutherford and Paramus. In East Rutherford, one finds the Izod Center and Meadowlands Racetrack. Paramus alone is home to the Garden State Plaza Shopping Mall, the Paramus Park Mall, Bergen Town Center, and Fashion Center. The Garden State Plaza, notably, is the eighteenth largest mall in America, providing in excess of two million square feet of shopping space, and, interestingly, the second-largest mall in the New York metropolitan area of which Bergen County constitutes a considerable part. As one of the most popular (and therefore, frequently visited) destinations in Bergen County (not to mention New Jersey), the Garden State Plaza, among other popular shopping plazas, attracted our close attention in planning our PRT layout for Bergen County. A well-connected and flexible PRT system is essential for effectively serving the trip needs of a destination hub such as Garden State Plaza, as well as those in its vicinity. To this end, while building our PRT system, we made sure to integrate these busy areas of interest into the overall network. Figure 4.5 presents a screenshot of Garden State Plaza and its surrounding community.

Our overarching design goal, as exemplified here, was to ensure the "connectivity" of a central hub (e.g., Garden State Plaza) to those locales likely for originating trips ending there: surrounding residential areas, neighboring transportation centers, and other nearby commercial zones. As might be expected, Garden State Plaza is a major bus transfer point for New Jersey Transit, as the 162 and 163 to the Port Authority Bus Terminal, the 171 and 175 to the George Washington Bridge Bus Station, the 770 to Paterson and Hackensack, the 709 to Bloomfield, and Bergen County Academy Express-contracted local routes 751, 753, 755, 756 and 758, all of which stop there. Fittingly, Garden State Plaza accounts for 20,652 daily trips in our current system design, or $20{,}652(2) = 41{,}304$ trip ends (estimated) daily. Outside East Rutherford and Paramus, other areas of interest for shopping in Bergen County also include Hackensack, with The Shops at Riverside, and Edgewater Commons, all of which have been made easily accessible to patrons (as well as employees) through our planned PRT system. Other areas of interest for shopping include Hackensack, with The Shops at Riverside, and Edgewater Commons. We have collected in Table 4.2 the complete listing of major shopping areas for Bergen County.

Figure 4.5: Aerial View of Garden State Plaza

Table 4.2: Shopping Attractions

Largest Malls and Shopping Centers
Bergen Mall
City Place at the Promenade
Closter Plaza
Edgewater Commons
Elmwood Park Shopping Center
Emerson Shopping Plaza
Fashion Center
Garden State Plaza
Hackensack Shopping Center
Interstate Shopping Center
Linwood Plaza
Lyndhurst Shopping Center
Mall at IV
Market Street Complex
Paramus Park Mall
Paramus Towne Square
Ramsey Square
Riverside Square Mall
Route 17 Shopping Center
Saddle Brook Mall
Washington Bridge Plaza
Yoahan Plaza

4.2.3 Recreation

Exemplified in a map of the population density of Bergen County by geographic area a few pages below, the northwest quadrant of Bergen County is sparsely populated: most residential areas are concentrated in the southeast. It is therefore in the northern section of Bergen that we find an abundance of open space. Bergen County contains in this region two large state parks: the Ramapo Mountain State Forest, located in Mahwah, and the Palisades Interstate Park, overlooking the Hudson River. A number of county parks are also scattered throughout northern Bergen, with two in Garfield, Belmont Hill County Park and Dahnert's Lake County Park, and another three in Mahweh. Sixteen county parks in total may be found in Bergen. Besides leisurely recreation, sports facilities are also popular, including not only the Giants Stadium in East Rutherford, but also the Sportsworld Indoor Amusement Park and Meadowlands Sport Complex. We summarize some of the notable parks, sports, and recreation possibilities in Bergen County in Table 4.3. All of these parks were included in our PRT network as major stopping points, in particular the Meadowlands Sports Complex and the Giants Stadium because of their size and popularity. Both of these complexes will be greatly served by the PRT system we designed, cutting down on significant traffic during game days. For some of the forest parks in Bergen County, we placed stations only near the main point of entry. Though visitors here likely will spend most of their time further inside the parks, the (relatively modest) number of visitors in these areas on any given day does not justify the cost of additional stations, cost being a major consideration for us in planning our layout of stations.

Table 4.3: Bergen Recreation

Major Parks, Sports, and Recreation
Bergen County Zoological Park
Ramapo Valley County Reservation
Palisades Amusement Park Historical Society
Sportsworld Indoor Amusement Park
Meadowlands Sports Complex
Continental Airlines Arena
Giants Stadium

4.2.4 Schooling

Reflecting its status as the most populated county of New Jersey, Bergen has no fewer than three hundred public schools serving primary and secondary educational needs: sixty-one high schools, fifty-five middle schools, and one-hundred eighty-six elementary schools in total. The most populated high school in Bergen County is Hackensack High School, with 1,854 students, a logical consequence of the fact that Hackensack serves as the county seat of Bergen County. Next to Hackensack High School in population is nearby Ridgewood High School, with 1,665 students currently enrolled. When deciding on our productions for school PRT stations, we took the following district numbers and historical enrollment data, summarized in Tables 4.4 - 4.7, into account.

Table 4.4: Bergen Public School Statistics

# High Schools	**# Middle Schools**	**# Elementary Schools**
61	55	186

Historically, we found that non-public enrollments accounted for approximately 10.5% of total school enrollments, and thus represent a minority of the school data overall. Exact enrollment numbers for private schools were not always available, so trip estimates here we based on available public school numbers, adjusted to account for the fact that private schools are normally smaller.

We should mention that the above data was paramount to us for devising a PRT system that would effectively serve current—as well as future—school needs by elucidating two areas of fundamental interest: growth of student body and trip demand. From the provided data, a trend may be discerned from historical public school enrollment figures, which have steadily increased by an average of two thousand students, or about 1.7%, per academic year, supported by the fact that current public school total enrollment (as of 2007) in Bergen County stands at approximately 137,766, an increase of 7.1% from the 2002-03 academic year and an adjusted annual increase of 1.8% since 2003. Non-public school enrollment has historically fluctuated around twenty-seven thousand students; it has remained largely steady from year-to-year. Note that we have only listed high schools in our above tabulation of

Table 4.5: Bergen County's Most Populated Schools

School	**# Students**
Hackensack High School	1,854
Ridgewood High School	1,665
Fair Lawn High School	1,476
Teaneck Sr High School	1,460
Northern Highlands Regional High School	1,309
Ramapo High School	1,293
Bergenfield High School	1,287
N Valley Regional Old Tappan High School	1,280
Paramus High School	1,279
Garfield High School	1,205

Table 4.6: Bergen County's Public School Enrollment

	1997-98	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**
Pre-Kindergarten	890	784	1,135	1,526	1,527	1,695
Kindergarten	8,239	8,461	8,467	8,143	8,518	8,522
Grades 1-8	69,402	70,841	73,401	74,830	76,137	77,697
Grades 9-12	30,268	30,8725	30,952	31,258	32,213	33,769
Special Ed	5,256	5,129	5,490	5,583	5,765	4,813
Vocational	1,365	830	1,593	1,894	1,961	2,113
Total	115,420	116,918	121,387	123,309	126,123	128,610

Table 4.7: Bergen County's Non-Public School Enrollment

	1997-98	**1998-99**	**1999-00**	**2000-01**	**2001-02**	**2002-03**
Grades K-8	20,059	19,771	20,036	20,522	19,739	18,715
Grades 9-12	6,493	6,410	6,541	6,833	6,972	7,059
Special	860	1,011	1,087	1,136	1,252	1,246
Total	27,412	27,192	27,664	28,491	27,963	27,020

most populated schools. Although the enrollment figures tabulated there sum to 14,108, accounting by themselves for approximately 28,216 trip ends, these numbers only shadow the much larger demand, supported by the steady yearly increase we have mentioned in public school matriculation, for school-based trips in total across Bergen County.

To explain, with about 164,766 cumulative primary or secondary-school students currently (=137,766 for public schools + 27,000 estimated for private schools), and expecting our PRT network to serve ninety-percent of daily trip demand (most likely an underestimate, given our extensive and highly connected distribution of planned stations), Bergen County can expect at a minimum approximately 296,579 (=167,766 primary/secondary students total * 90% * 2) trip ends for schools alone. Nevertheless, even this figure ignores, first, figures for nursery school and school day-care, and more importantly, the trip demand for schools originating from non-students but with a connected interest: parents, teachers, and supporting members of the school community. To reflect the added influx of these population segments on popular community events such as game days, sport meets, and student productions (explained in greater detail in the Section 4.4), and realizing the reality that at least one parent usually accompanies his or her child to school through second grade, we have added to the trip demand for schools, trips per day per housing station within a given school's municipality. The 879,792 daily trips (estimated) that we expect to serve just for schools in Bergen County, shown in our proposal for personal rapid transit stations in Table 4.8, corroborates the significant patron numbers outlined above that Bergen County may expect to draw now and in the coming years.

Beyond primary and secondary education, Bergen County also supports a number of higher education institutions, including Bergen Community College, Berkeley College, Fairleigh Dickinson University, Felician College, and Ramapo College, as well as the professional school, Dover Business College. Most of the students matriculating at these colleges are local, residing in Bergen County, although a sizable proportion of the student body for higher education in Bergen draws from Passaic County as well.

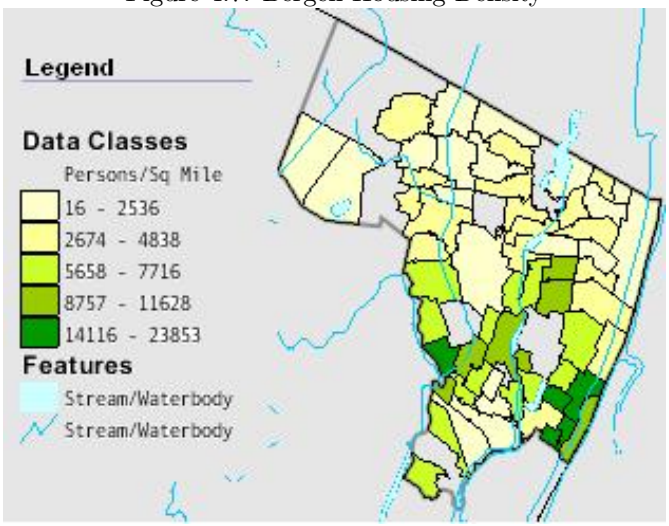
Overall, the 217 school PRT stations planned for Bergen have been well chosen to distribute school trip demand according not only to location, with one or two PRT stations strategically placed for serving closely clustered schools, reducing congestion, but also with reference to school type and overall enrollment. Regarding the latter, we took care to ensure the connectivity of the most populated schools to nearby commercial and work zones, not to mention residential locales, easing the burden of daily commutes. In the representative picture shown in Figure 4.6, for Teaneck High School, with a student body of 1,460, thirty-five hundred trips are actually generated daily, or seven-thousand trip ends, which accounts for the residential area closely bordering the school and visible here in the aerial view of the school and its station.

Figure 4.6: Aerial View of Teaneck High School

4.2.5 Housing

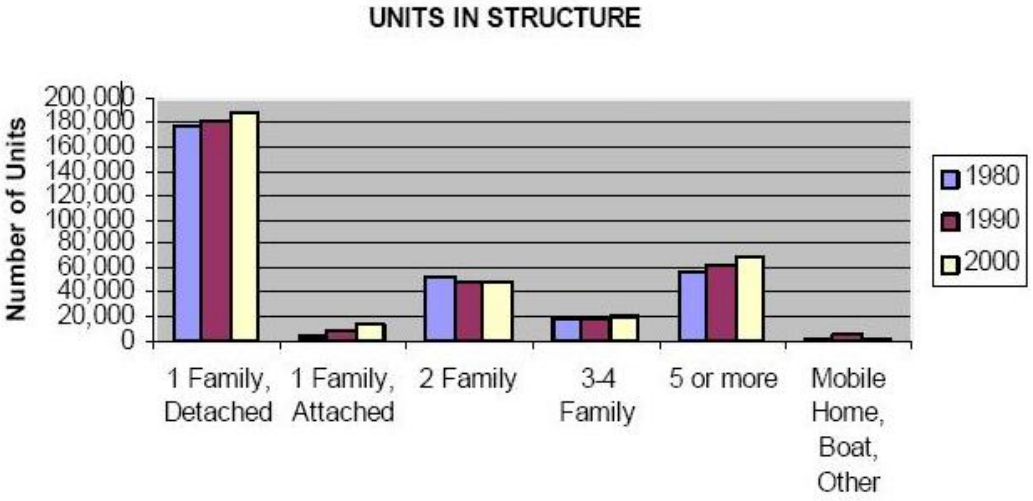
As previously mentioned, the most densely populated residential areas in Bergen County are located in the south region of Bergen, as shown in Figure 4.7. Although the composite population density for Bergen County is 3,788 persons per square mile, focusing just on those regions of highest population concentration, the average density per square mile is closer to ten thousand persons. Placing a PRT station every half mile here immediately serves five thousand patrons, and we acknowledge in this instance only home-based trips. Because commercial areas, school buildings, and religious centers are interspersed throughout these dense residential communities, the daily trip total per station is necessarily higher than what might be estimated focusing on housing statistics only.

Figure 4.7: Bergen Housing Density



Supporting earlier analyses, the bar graph in Figure 4.8 shows the breakdown in household size in Bergen by the number of housing units per size category. Since 1980, the majority of housing units in Bergen County is comprised of single-family homes. Of the 346,033 housing units recorded in 2005, around 185,000, or fifty-three percent approximately, were one family, detached residences. Together, housing units in multi-unit structures, as of 2005, accounted for 40.4% of all housing units.

Figure 4.8: Bergen Home Size



Our PRT network is consistent with Figure 4.7 showing housing density. In areas such as Garfield, Fort Lee, and Palisades Park, where population density is extremely high, the PRT stations there serve a very large number of trip ends. In areas further in the northwest of the county, where population density is rather low, the PRT stations

accordingly serve a much lower number of trips ends, in conjunction with reduced total demand from patrons. The figure accompanying housing density, showing average housing size for Bergen County, justifies our simplification in calculating housing trip ends for our finished PRT system, for which we assumed mostly single-family residences. The predominance of multi-unit structures, on the other hand, would have required a further upward estimate of trips served because of the greater concentration it would imply of working families in a smaller-than-typical area.

4.2.6 Transportation

Bergen County residents currently enjoy a highly connected road network, which encompasses the north end of the New Jersey Turnpike (including part of Interstate 95) and Garden State Parkway, as well as the east end of Interstate 80 and part of Interstate 287. Also running through Bergen County are US Highways 46, 202, 9, 9W, and New Jersey State Highways 4, 17, 3, 120, 208, and the Palisades Interstate Parkway.

For commuting to New York City, motorists typically frequent the George Washington Bridge, located in Fort Lee, and the Lincoln Tunnel in Hudson County. Three lines of the New Jersey Transit, the Bergen County, Erie Main, and Pascack Valley Lines, all offer train service. Each line follows a north-south route terminating in Hoboken Terminal, and from there additionally allows riders to connect to PATH trains as well. One-stop service to New York Penn Station is available through New Jersey Transit at the Secaucus Junction transfer station. Besides rail, bus service may be found through both New Jersey Transit and the private companies Red and Tan Lines and DeCamp Bus Lines, each serving Bergen County in addition to other New Jersey locations, and the Port Authority Bus Terminal and George Washington Bridge Bus Terminal in New York City. Between 62,000 and 72,000 Bergen County residents commute to New York City every day, either by bus or rail, a considerable proportion of the total workforce. A representative example of a PRT transport station for Bergen County is reproduced in Figure 4.9, located directly adjacent to the existing Garfield station on the main Bergen County line and accounting for 3,127 daily trips in our proposed network.

Figure 4.9: Aerial View of Garfield Station

Even with a well-developed network of PRT stations, such as we have planned, existing rapid transit serving out-of-county commutes, particularly for New York, would continue in popularity because of the fast, direct service already provided. The PRT stations we placed were designed, accordingly, to ease travel to the major transportation centers enumerated here from the densest residential zones, where traffic is high, and from the less connected communities also, our goal being to keep total expected time spent reaching work at a minimum.

Less represented, local air transportation consists solely in Teterboro Airport in Teterboro, under the control of The Port Authority of New York and New Jersey. As could be expected, the much larger Newark Liberty International Airport in neighboring Essex County serves most commercial air traffic, not just for Bergen County, but also for most New Jersey.

As displayed in Figure 4.10 organized by district, in the densely populated areas of Bergen County, near twenty percent of workers use some form of public transportation to get to work. Typical commute time, seen in the next diagram, is approximately thirty minutes, but could be as high as an hour for those employed in Manhattan

for example. A well-connected network of PRT stations would help especially in mitigating local congestion and reducing these travel times.

Figure 4.10: Proportion of residents utilizing transportation for work commutes

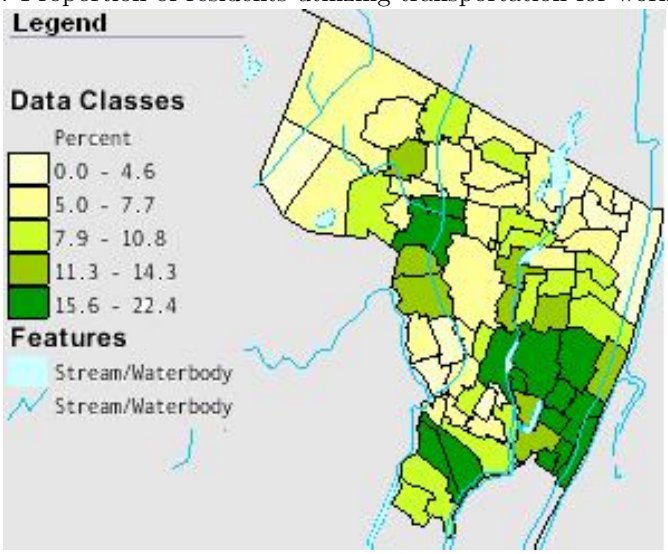
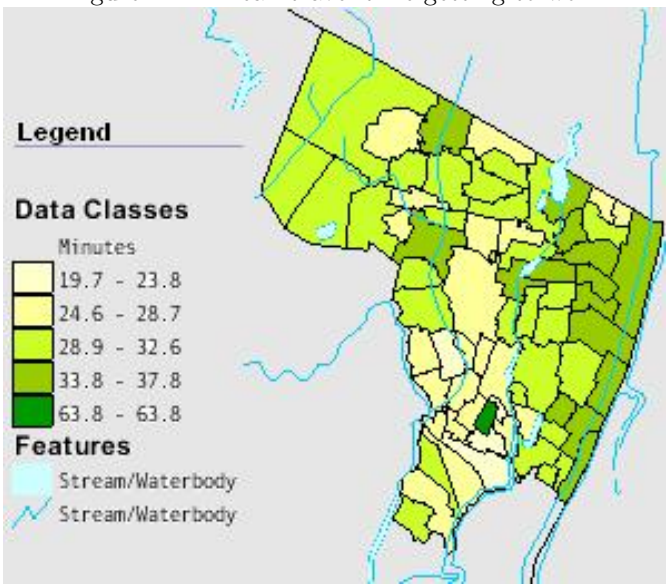


Figure 4.11: Mean travel time getting to work



4.3 Proposal for Network of Personal Rapid Transit Stations

The design of Bergen County's PRT network is similar to that of a grid. For an example, see the representative picture in Figure 4.12.

Modeled after New York City's street design, one system of arcs travels north, with an adjacent system of arcs traveling south. Interchanges connect these, creating a new set of arcs traveling east and west. Figure 4.13 clearly shows the east/west paths created by interchanges.

For summary purposes, please find in Table 4.8 tabulated results for the Bergen PRT network, showing node count and daily trips served by station type, as well as the total number of stations and interchanges, and average arc length. Calculating trips per mile of guide-way, taking 878.37 miles into 4,164,984 total trips served daily, gives 4741.719 trips on average per mile of guide-way for the Bergen County network.

Figure 4.12: Grid Layout of PRT in Bergen County

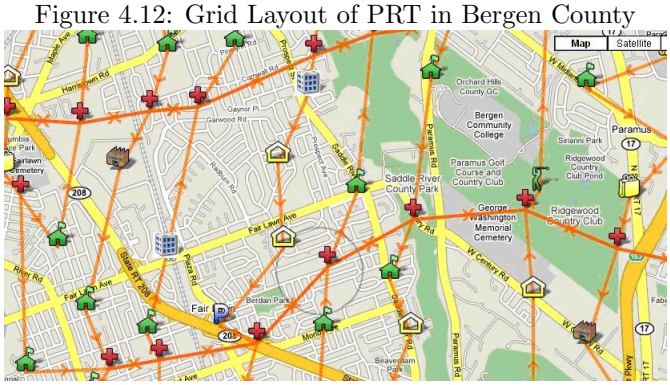


Figure 4.13: East-West Interchange Positioning in Bergen County

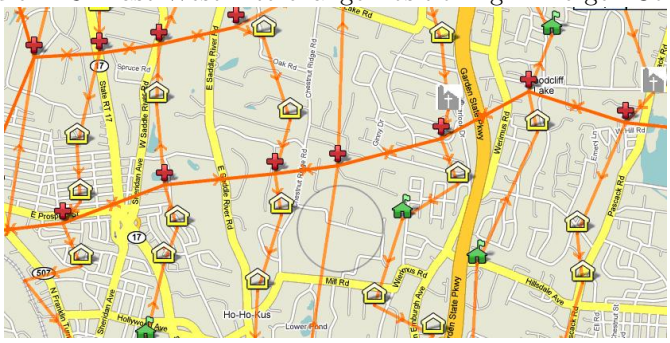


Table 4.8: Bergen County PRT Summary

Node Type	**Count**	**Daily Trips Served**
Housing	394	1,256,724
School	217	879,792
Office	87	1,172,724
Industry	37	369,399
Public	15	215,803
Recreation	48	15,756
Shopping	26	78,495
Religious	17	61,216
Transport	27	115,074
Other	0	0
Total Stations	868	4,164,984
Interchanges	249	
Total Length of Guide-ways	878.37 mi	
Average Arc Length	0.54 mi	

From first glance, a projection of 1.2 million housing trips per day appears high in the context of some of the less densely populated municipalities. In a municipality like Allendale, where the population density is only 2,143 people per square mile, each station naturally serves only about 850 trips per day, but these trip numbers importantly are not representative of the county as a whole. Bergen County, as the most densely populated in the state, necessarily supports many municipalities that are much more crowded. For instance, Cliffside Park boasts over twenty-three thousand people per square mile, and each housing station in that municipality accordingly will serve approximately ten-thousand trips per day. Because the population density across Bergen County is not uniformly distributed, 1.2 million housing trips per day is not only reasonable, it is necessary. Just the largest station in the Bergen County network alone, the Garden State Shopping Plaza, will serve over twenty-thousand trips per day.

4.3.1 Economic Considerations

Given our Project Integrator's calculations for the required number of vehicles, the projected cost for building the proposed PRT system in Bergen County is as follows:

Table 4.9: Bergen County PRT Costs

	Number (miles)	**Cost per unit (mile)**	**Total Cost**
Guideway (miles)	878.37	$5,000,000.00	$4,391,850,000
Stations (inc. Interchanges)	1,117.00	$2,500,000.00	$2,792,500,000
Vehicles	281,342.00	$150,000.00	$42,201,300,000
Total Cost			$49,385,650,000

Clearly, these figures represent monumental costs. It would cost Bergen County $54,000 per person to build a PRT system. In order to afford the cost of building the proposed system within five years (ignoring operating costs), Bergen would have to charge at least the following per one-way trip:

Table 4.10: Bergen County PRT Trip Costs

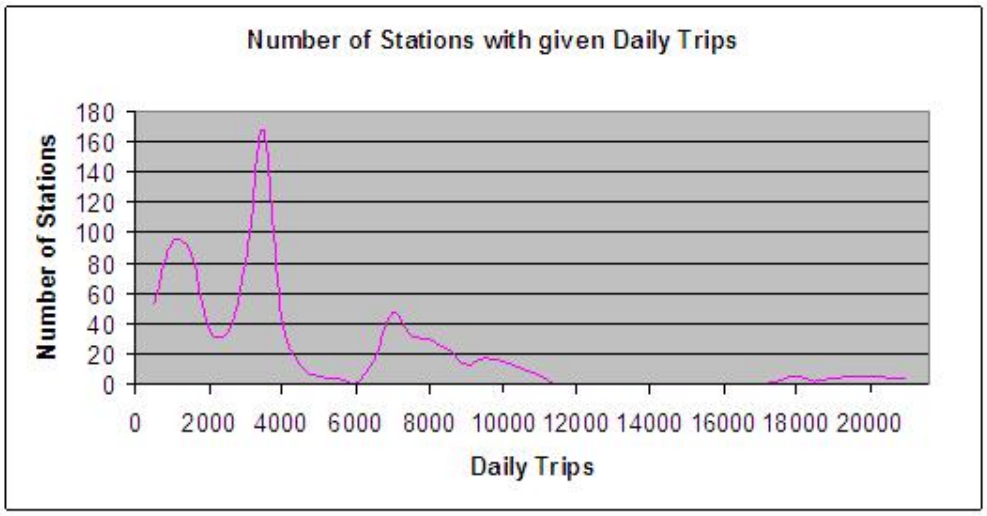
Recoup Costs	**Bergen**
Total Cost	$49,385,650,000
Trip Ends per Day	7,278,806.26
Trip Ends in 5 years	13,283,821,415.85
Cost per One-way Trip	$3.72

Surprisingly, an estimated fare of $3.72 per trip is reasonable expensive—but many may still not find it worth paying. This estimate, of course, only gives a rough approximation of what on average would need to be charged, and could be adjusted further to account for trip length as well. At the same time, Bergen County has a vested motivation for implementing a PRT system as proposed. As Bergen County has nearly fifteen percent of New Jersey's jobs, there is no doubt of its need for an integrated PRT system. Moreover, the entire state of New Jersey would benefit from the easy access provided to the county.

4.3.2 Distribution of Trips per Day

The graph in Figure 4.14 shows the distribution of daily trips for Bergen County under the planned PRT network. As may be seen, the majority of stations serve just fewer than four thousand trips per day. The outlying figures interestingly, near twenty-thousand trips per day, are all for shopping centers, for Bergen County has some of the country's largest malls, with one notable behemoth, the Garden State Plaza, mentioned earlier.

Figure 4.14: Bergen County Trip Distribution



4.4 Methodology for Daily Trip Calculations

The methodology that follows was used for both Bergen and Passaic Counties.

4.4.1 Office, Industry, and Public Stations

To determine the number of trips per office, industrial, and public station, we first determined the total work force. In Bergen County, 3.6% of people are unemployed, 5% are under the age of five, 18% are school-aged children, and 15% are elderly. This means that the working force is approximately 58% of the population. In Passaic County, 5.1% are unemployed, 19% are in school, 8% are under the age of five, and 12% are elderly, leaving a working force population of approximately 56%. After much research on the nature of employment in Bergen and Passaic Counties, we estimated that 55% of jobs were office jobs, 35% were industrial, and 10% were public. Using these facts, we determined the total number of office, industrial, and public workers per county. The number of trips per station in these categories is equal to:

$$\text{Trips per office station} = 2 \times \left[55\%(\text{office workers}) \times 58\%(\text{workforce}) \times \frac{\text{total Bergen population}}{\text{number of office stations}} \right] + \varepsilon \quad (4.1)$$

The trips per public and industrial stations in both counties are similar. The ε term here accounts for people that visit office, industrial, and public locations each day that are not employed there, and varies per municipality and individual station.

4.4.2 Shopping, Religious, and Recreation Stations

It was difficult to determine the number of people who visit each shopping, religious, and recreation sites each day, so we made many assumptions. On average, 5% of the population attends a religious service per day; because each church is usually surrounded by a housing area, we determined the trips per religious station per day to equal:

$$\begin{aligned} \text{Trips per religious station per day} = 2 \times & \frac{5\% \times \text{population of municipality}}{\text{number of religious stations in municipality}} \\ & + \text{trips per day per housing station in church's municipality} \end{aligned} \quad (4.2)$$

To determine the number of trips per shopping and recreation station, we assumed the following about demographic activities:

Using these percentages, populations per county, and number of stations per county, we determined the number of trips per shopping and recreation station per day.

4.4.3 School Stations

To determine the number of trips per school station per day, we found the number of students per school at PublicSchoolReview.com. Unfortunately, this site did not provide any information on private schools, so we assigned the number of students per private school equal to the average number of students per school in the particular municipality, minus 100, as private schools are generally smaller than public schools. Most schools in Passaic and Bergen Counties are surrounded by residential areas. Because of this fact, we added the number of trips per day per housing station in the municipality in which the school was located to the trips per day per school. The number of trips per school station per days equals:

$$\begin{aligned}\text{Trips per day per school station} &= 2 \times \text{students per school} + \\ &\quad \text{trips per day per housing station in school's municipality}\end{aligned} \tag{4.3}$$

It is very important to note here that we include housing station trips in each school's range. Because most schools are surrounded by residential areas, we assumed that residents in nearby neighborhoods would use the school station to access other parts of the county. In addition, we acknowledge in this calculation the fact that many parents take their children to school, increasing the number of trips per school station. Moreover, large public events, such as plays and football games, often take place at schools, in turn boosting the number of trips per school station.

4.4.4 Housing Stations

Each residential station provides service to everyone within a quarter-mile circular radius, with the station located at the center. To determine the housing trips per station per day, we first classified every residential station according to its municipality. We then found the population density per municipality. The number of people each station serves is equal to:

$$\text{People per station} = \text{population density (people/mi}^2) \times (0.25(\text{mi})^2) \times \pi \tag{4.4}$$

To determine the trips per station per day, we multiplied the number of people per station times the expected trips per day. The US Department of Transportation states that each person takes 4.1 trips per day on average. However, because we assumed many people would be making non-home based production trips, we multiplied the people per station by a smaller number. For Bergen County, we used 2.3 trips per day, and for Passaic County, we used 2.0 trips per day. The determination of these numbers is discussed later.

Figure 4.15 shows a screenshot of the largest housing station in Bergen County, located in Cliffside Park. As can be seen, the area includes major apartment complexes, surrounded by dense housing, and is expected to serve 11,640 trips per day.

Figure 4.16 was taken at the same altitude as the one above. It is for a housing station in the municipality of Alpine, and is only expected to serve 144 trips per day. As may be observed, this area is extremely sparsely populated. One of the wealthiest areas in the nation, Alpine has low residential density, with each house set on an enormous tract of land. One might add here the fact that the extremely wealthy, typified by the residents of Alpine municipality, are the least likely to use the PRT system, supporting the lack of daily trips here.

4.4.5 Transport Stations

The US Census provides very detailed information on the percentage of people per municipality who use public transportation. We used these numbers to determine how many people would be using each transport station. On

Table 4.11: Bergen County Demographics

Demographic	**% Go Shopping + Dining/day**	**% Visit Recreation/day**
Working Force	30%	20%
Unemployed	35%	15%
Young Children	10%	30%
School-Aged Children	20%	40%
Elderly	70%	15%

Figure 4.15: Cliffside Park, Bergen County

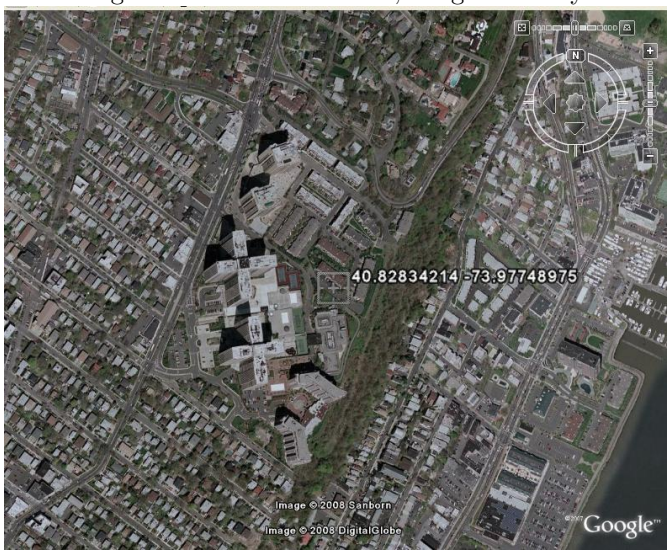


Figure 4.16: Alpine, Bergen County

average, 4.5% of people in Bergen County use public transportation daily, while only 2.3% of people in Passaic County use public transportation. The number of trips per transport station per day is equal to:

$$\text{Trips per transport station} = 2 \times \%\text{pop. using public transportation} \times \text{pop. of transport station's municipality} \tag{4.5}$$

4.4.6 Additional Information

These calculations left us with a matrix of station type (by municipality) and number of trips per day. However, this configuration means that many stations would have the same number of trips per day. By this method, every housing station in Allendale (a municipality of Bergen County) has 968 expected trips per day. Realizing that actual trips per station per day are never going to be equal for two stations, we let the number of trips vary at random by ten percent. In other words, all housing stations in Allendale have between 871 and 1065 trips per day.

At the end of the process, we summed the total trips across all stations in each county per day, and divided by the population, to find the total number of trips per person per day on average. By changing the number of trips per housing unit per day, as discussed in the Housing Stations section, the total number of trips per person per day changes. In Bergen, assuming that each person per housing station area takes 2.3 trips a day, the total number of trips per person across all stations is approximately 4.1 trips per day, as we had expected.

Chapter 5

Burlington County

5.1 Land Use

Burlington County, located in west-central New Jersey just beneath Mercer County is New Jersey's largest County, by size, with a square mile area of 827 square miles (529,351 acres) and about 15 square miles of water (5,191 acres).[1] This County extends from the Delaware River to the east coast where a small piece of the County touches the Great Bay of the Atlantic Ocean.[2] Its neighboring counties are Mercer County to its north, Monmouth County to its northwest, Ocean County to its east, and Camden and Atlantic Counties to its South.[3] Within this New Jersey's largest county there are 40 municipalities. There are 3 cities (Beverly, Bordentown, and Burlington), 6 boroughs (Fieldsboro, Medford Lakes, Palmyra, Pemberton, Riverton, and Wrightstown), and 31 townships. Much of the land of these municipalities is rural with parks, golf courses, Pineland forests, lakes, streams, plains of "scrub-oak", plains of laurel, and farmland. In fact, "Burlington County has always been one of the leading agricultural counties in the country" and has the considerable industry in blueberry and cranberry agriculture—"Burlington County is the 2nd largest cranberry producing county in the United States ... as it has always been one of the leading agriculture counties in the country." [4] Therefore, much of the County is rural, making the population concentrated in the urban west of the County along the Delaware River where there is considerable manufacturing.[5]

According to U.S. Census Bureau estimates, Burlington County's population in 2006 was 450,627 and its population density was 526 persons per square mile.[6] Further Census Bureau (2000 Census) Demographics state that of this population about 34% are children under the age of 18, and 58% are married couples living together making the number of households in the County approximately 154,371.[7] The mean family size in the county is 3.14 and the mean household size is approximately 2.65.[8]

5.2 Current Transit Service

Burlington County's public transportation services consist of the BCTS (Burlington County Transportation Service), Burlink bus service, the BC Xpress bus service, and the NJT (New Jersey Transit) bus/rail services. The BCTS is a free bus service offered to the county's senior citizens (60 years old and older) and adult disabled (21-59 year-old citizens who are physically impaired) Mondays through Fridays from 8am to 5pm. This service is sponsored by the Board of Chosen Freeholders, the county's 5-member, partisan elected administrative and policy-making governing body, and subsidized by the County funds, State and Federal Grants, and Casino Revenue.[9] The Burlink bus service connects with the NJT bus and rail stops and basically exists to provide public transportation for south-jersey locations not service by NJT.[10] The BC XPress is an express BurLink bus service that operates between The Willingboro Town Center and Burlington County College's Willingboro and Pemberton campuses; providing

[1] http://www.co.burlington.nj.us/info/index.htm
[2] http://www.co.burlington.nj.us/
[3] http://www.co.burlington.nj.us/
[4] http://www.co.burlington.nj.us/info/index.htm
[5] http://www.co.burlington.nj.us/info/index.htm
[6] http://quickfacts.census.gov/qfd/states/34/34005.html
[7] http://en.wikipedia.org/wiki/Burlington_County,_New_Jersey
[8] http://en.wikipedia.org/wiki/Burlington_County,_New_Jersey
[9] http://www.co.burlington.nj.us/
[10] http://www.co.burlington.nj.us/

Figure 5.1: Burlington County, NJ

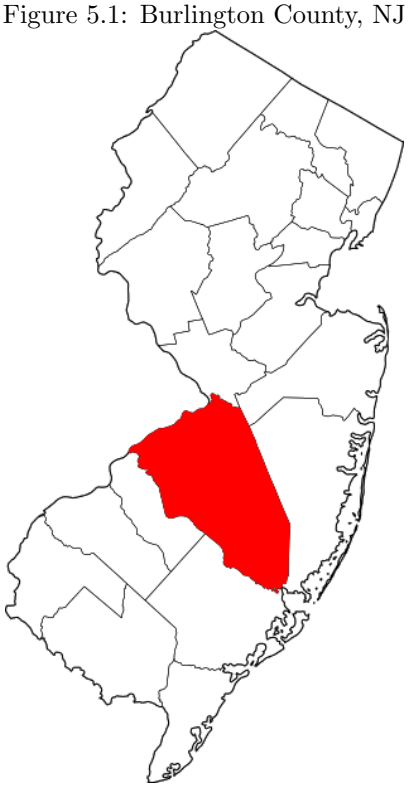
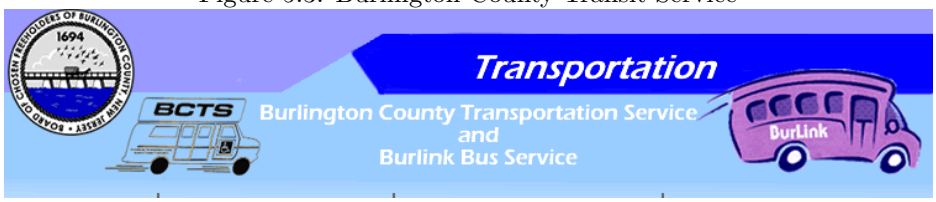


Figure 5.2: Burlington County Geography

several connections to NJT (at NJ Transit Bus Route 317 and NJ Transit Bus Route 409).[11] The predominant means of transportation in Burlington County is personal transportation by means of home-owned private vehicles. This leads to congestion such highways as Hwy 130, I-295, and the New Jersey Turnpike in the western densely populated region of Burlington County. A Personal Rapid Transit (PRT) would do a great deal of service to the efficiency of traffic throughout Burlington County. In fact, the PRT could have one-way direction, fewer than 30 interchanges, and only be throughout just one-third of Burlington County (western BC near the Delaware River), and it would still do a great deal in ameliorating traffic congestion. In fact, a PRT would eliminate the need for all 3 of these services—BCTS, BC Xpress, and Burlink. A PRT could be made free of charge to Senior Citizens and it would provide Burlington County with interconnected transportation to the rest of New Jersey.

Figure 5.3: Burlington County Transit Service



5.3 PRT Network Design

The first step to designing a Personal Rapid Transit network for Burlington County was researching the extent and way in which land was occupied by Burlington citizens all throughout the county. Through the aid of GoogleEarth, satellite imaging, Geocoding Latitude & Longitude tools, and addresses of 10 different types of residences/locations—transportation, schools, housing/hotel, recreation, office complex, industry, public building, commercial/shopping, religious building, other—my teammate and I found over 5,000 latitudes and longitudes (Lats & Longs) of these various kinds of locations all throughout Burlington County. After perusing these residences, a diverse (diversity of the 10 "types" of locations) selection of 1,200 locations was filtered down from the original 5,000 and were imported in to a GoogleMaps "PRT Designer" created by a fellow Princeton student (Aaron Linsky)—in the PRT Designer these residences were Personal Rapid Transit Station locations. Next, the PRT Designer was used to further filter the 1,200 locations (or PRT stations) down to a few hundred by deleting locations that were not in optimal locations for the PRT design, consolidating clusters of locations so that single stations were servicing residential or highly populated urban/commercial/employment areas that were within a quarter-mile radius of them, and basically, minimizing the number of stations to what was necessary to service quarter-mile-radius areas. Then, after the diverse stations/locations (stations were "typed" by where they were they were mainly servicing) were reduced to the couple of hundred stations that were deemed adequate for servicing Burlington County, they were connected by arcs and interchanges to create the PRT Network. The PRT Network was decided to be constructed in a concentrically circular, Paris-like manner. Essentially, in this network design, there are circular/elliptical-shaped networks of stations connected to one another (stations-to-arc-to-station) and these circular networks are connected to other circular networks via interchanges. Some of these circular networks are adjacent or parallel to one another, while others are concentric—either way, the means by which these circular networks are connected is interchanges. Also, these concentric networks were designed to often move counter clockwise to one another while many of the adjacent (adjacent from east-to-west/west-to-east) networks move in the same clockwise motion! Therefore, the PRT network is Cyclical in nature and services many of the western urban locations where there is a high amount of attraction.

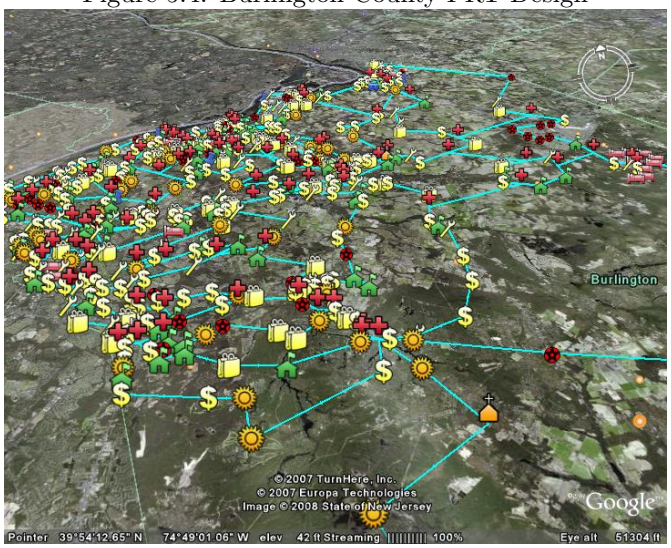
Furthermore, the network's total number of nodes and total number of arcs came to be 598 and 688, respectively, while the total miles of guideway for the entire network came to be 487.93 miles.

5.4 Station Types

As stated before, the PRT network was thought about in terms of servicing 10 different types of residences and was thereby constructed in the google-based PRT Designer with different icons for each of these different "types". And though there's a diversity of station types for quite a few of the locations (mainly all of the types except for 3, transportation, religious, and other), many of the stations service more types than what their icon conveys. For

[11] http://www.co.burlington.nj.us/

Figure 5.4: Burlington County PRT Design



a considerable number of the station locations there were 5 to 10 locations/stations of various "types" within a quarter-mile area (and less than a .25 mile area) of one another; these were high-attracting quarter-mile radiuses that have just about every type of location. Thus, in these situations, the highest-attracting location (and sometimes just a random location) was chosen to be the station for a particular area and its trips were decided by taking into account the productions and attractions (P & A) of all of the other nearby locations—locations that were deleted because they were unneeded for servicing the particular area. In conclusion, most of the stations were separated by at least 0.5 miles.

Also, it should be noted that in the PRT design there were stations "Iconized" as one thing and servicing multiple other "types" of locations. For instance, there were stations that serviced residential areas—hence the Housing type of location—that weren't shown as Housing stations (with the House Icon). This was because there were stations within a quarter-mile of a residential area that were also within a quarter mile of an industrial site, recreation center, or a shopping, and hence were sometimes given an Industry, Recreation, or Shopping Icon instead of a Housing one. Furthermore, since this PRT Design was constructed by filtering over 1,200 locations/icons down to 500 locations/icons that have been strategically placed as stations, all of the Productions & Attractions (P/A) from the 700 or so locations that were deleted were incorporated into P/A numbers of the 500 stations. It was from these P/A numbers for areas all throughout the municipalities of Burlington County that the Trip-ends for all of the stations were calculated. Thus, many stations have much more representation than what their Icon portrays. Some stations service just about all of the different types of locations, while others service mainly one type of location. Also, there are good stations that have really high traffic because of their service to particular addresses or regions, and there are others that have low amounts of traffic due to their serviceability. And therefore, there are good stations and bad stations; stations that barely pay for themselves and others that are crucial to daily commutes and travel.

The best stations in the PRT Design with high utility for Burlington County are those that service large numbers of daily residents and are those that have the most accurate P/A and Trip-ends. The Lockheed Martin station along with other Industry stations servicing top-ten largest employing Companies (Industry "type") in Burlington are examples of stations with accurate volume estimates. Furthermore, the stations servicing Burlington County College are other examples stations with accurate volume estimates, estimates that were accomplishable given the fact that attendance data for the institution was readily available. Some of the stations that weren't as accurately gauged are many of the shopping/commercial stations that are servicing numerous stores; data on the arrivals of customers in many of these stores was hard to access.

5.4.1 Education

There are over 160 parochial, private, and public schools in Burlington County. Of these, there are just over 60 whose names have been taken as the name of a nearby station—these are the stations that are iconized as a school. However, though there are only 60 school-type stations, there are many other types of stations who service nearby schools. Thus, just about all of these schools are serviced by a station within a quarter-mile radius. In total, the

stations with school icons have a total volume of 362,800 trip-ends, and the total volume for every station servicing a BC school would likely be about double this number since the county's number of schools is well over 160. Some of the major schools serviced are Burlington County College, Bordentown Regional High School, and Burlington Technical College.

5.4.2 Shopping

There are many locations (many of the original 5,000 locations/addresses that this PRT Network design started off with) that could fell under the "shopping" and/or "commercial" type; in fact, I would say the majority of locations within the County would fall under this category. However, despite the large number of these locations the network's placement of stations is more densely aligned—with shorter station separation—in BC's more densely populated regions; regions with municipalities like Beverly, Burlington, and Bordentown. The concentric-circular design of the entire Burlington County PRT Network is most evident in these densely populated and urban areas. The Thus, the total volume of trip-ends in these regions is higher than less dense locations and shopping/commercial related trip-ends is one of the higher volumes. More specifically, the total volume of trip ends for stations with shopping icons is 404,800. Again, like in the prior section (PRT Service to Education), the volume of trip-ends for all travelers going to a shopping center or commercial store would be considerably higher than this number.

5.4.3 Housing

There are a total of 23 stations with housing icons, and many more that are in a quarter-mile proximity to residential communities. The Browns Mill stations, Chateau Apartments station, and the Country Lake Residential stations are a few examples of the stations that are of the housing "type" and directly service a housing community. These stations surround the respective neighborhoods for which they are named and provide to and fro travel to employment, shopping, and recreational endeavors for residents. They respectively have 16000, 64000, and 28800 trip-ends.

5.4.4 Recreation

Burlington County has a considerable number of recreation locations—from fitness centers, golf courses and country clubs, to parks, creeks, and forests. Wharton Forrest, the largest Forrest in Burlington County and home to large amounts of outdoor recreation, is surrounded, on the outskirts, by over 6 different stations. All of them are makeup the outer-most circle for the county's concentrically elliptical PRT network design. The Wharton Forrest Stations (A-F, there's 6 of them) drop off tourists, environmentalists, and visitors of the forest at locations on the perimeter of the woodland, and connect with inner-circles via interchanges. A list of other recreational locations that are directly serviced is: Burlington County Country Club, County of Burlington YMCA, Bally Total Fitness, Golden Pheasant Golf Club, Indian Springs Golf Club. Lake State Forrest, Little Mill Country Club, Mill Creek Park, Regal Cinemas Inc., Scooters Family Skating Center, and Spencer Memorial Park, just to name a few.

5.4.5 Employment

Table 5.1 shows the top 10 employers in Burlington County and gives the number of employees each of those companies employ. This data was invaluable to increasing accuracy in employment trip-end numbers and overall volume numbers of the BC PRT network. *Each of these 10 companies received stations that directly served them, meaning employees of these companies could ride a PRT straight into stations with names that corresponded to their workplace destinations, get out and walk less than a quarter-mile to get to work.* The corresponding trip-end volumes for the top three employment locations (Lockheed Martin, PHH Mortgage, and Virtua Memorial Hospital of Burlington County) were 22000, 20000, and 40000, respectively. The thought behind these estimates is that there is, on average, 4 trip-ends generated by each employee and customer/patient (patient, in the case of Virtua) for these 3 companies and all of the major companies that were directly serviced by stations in this PRT Design.

5.5 Distance Between Stations

The initial station selection in the PRT Designer was an optimization problem of maximizing the number of people that could be serviced (maximizing the number of population-dense residential/industrial/office/commercial that could be serviced) while minimizing the number of stations throughout the network. Essentially, this network design decision is a maximizing service, while minimizing cost problem/effort. My partner and I considered that

though ideal to service every community in our counties, this is endeavor is simply not realistic. We figured that, in real-life terms, it wouldn't be cost effective to service within .25 miles of every "nook and cranny" of our counties. So, some residential areas that are isolated didn't receive as much proximity to a station as others because in this situation it's likely that such an effort would be more costly than profitable. Furthermore, station locations were less prevalent in unpopulated places, and highly concentrated in populated areas; thus, densely populated areas have the greatest likely-hood of having a station within a quarter-mile radius of every major residential/housing community (residential station types are denoted by the house-shaped icon in the PRT Designer). Overall though, there was an average arc length of 0.71 miles, meaning that the stations and interchanges of the network were on average 0.71 miles away from one another.

5.6 Trip Estimation

Most of the estimates of numbers of Trips taken for the stations of the PRT Designer were "guestimates" on the productions and attractions (P & A) of residences in the areas of the station. These guestimates (estimates) were on occasion compounded with known numbers of attractions for areas/locations. For example, a list of the top Full Time employees in Burlington County was utilized in station locating by making sure that (1) all of these office/industry locations were in the original 1,200 locations imported into the PRT Designer, (2) were made into stations for the areas in which they resided, and (3) were factored in to Trip number of those stations by adding the known /concrete number of employees to the P & A estimates for surrounding locations. The estimate for the total number of daily PRT trips in my County was approximately just under 700,000. This is comparable to the usual estimates of car daily trip numbers in Burlington County; a county with a population of over 450,000.

Table 5.1: Major Employers in Burlington County

Company	**Municipality**	**# Employees**
Lockheed Martin	Moorestown, NJ	5,000
PHH Mortgage	Mount Laurel, NJ	4,500
Virtua Memorial Hospital of Burlington County	Mount Holly, NJ	3,794
Commerce Bank	Burlington County, NJ	2,664
Deborah Heart and Lung Center	Browns Mills, NJ	1,405
Viking Yacht Co. Corp.	New Gretna, NJ	1,350
Burlington Coat Factory	Burlington, NJ	1,103
Lourdes Medical Center of Burlington County	Willingboro, NJ	1,100
CVS Corporation	Lumberton, NJ	1,010
Medco	Willingboro, NJ	1,000

5.7 Conclusion

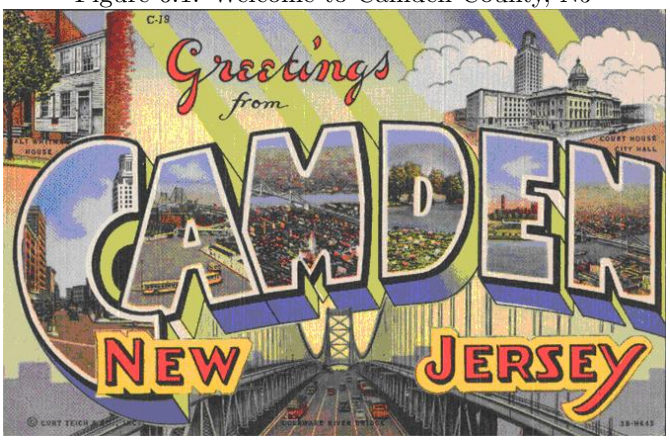
This PRT Network requires 141,212 vehicles that would cost $150,000 each. Therefore, the total vehicle cost for the Burlington County PRT design would be $21,181,777,826; a number that is seemingly unaffordable. However, a cost of this magnitude would simply be an investment whose returns would profit transportation efficiency within Burlington County for decades to come. Under this network there would be an average of 3,653,400 daily trips in vehicle with an average occupancy of 1.64, and an average trip time during peak hour of 18.14 minutes!

This kind of Personal Rapid Transit system would be highly beneficial in Burlington County; especially densely populated western Burlington County which has a weigh higher density than the county as a whole (county's density is 526 per sq.ml.). In fact, eastern Burlington County which is comprised of open space, agriculture, forests, lakes, and parks could utilize a PRT network for tourist reasons - connecting the PRT to the outdoor tourist attractions, recreational locations, and "outdoorsy" commercial locations like the Viking Yacht Company. This PRT would easily replace and fulfill the services of Burlink, BC Xpress, and BCTS and would eliminate the majority (safe to say over 75%) of car/personal-vehicle traffic. Thereby, not only increasing the efficiency of transportation throughout the city, but also reducing the "road-rage", stress of traffic gridlocks, and car accidents!

Chapter 6

Camden County

Figure 6.1: Welcome to Camden County, NJ



Camden County spans 222.3 square miles in southwestern New Jersey directly across the Delaware River from Philadelphia. It has 508,932 people living in 185,744 households. The City of Camden in the northwestern most section of the county is urban, but as one moves to the southwest, the population density steadily decreases as one moves through suburbs and eventually reaches the rural southwest portion of the county. The farther one is from Philadelphia, the more rural Camden County becomes.

6.1 Existing Transit Service

6.1.1 PATCO High Speed Line

The PATCO High Speed Line is a high-speed rail line that runs from the center of Camden County through Camden, over the Ben Franklin Bridge, and into Philadelphia.

There are nine stops total in Camden County. The line starts in Lindenwold, where one access Atlantic City via a NJ Transit train. Then the line goes towards Philadelphia with stations in Voorhees, Cherry Hill, Haddonfield, Haddon Township, Collingswood, and three stops in Camden. The stops in Camden are at Ferry Avenue, Broadway, and City Hall. The Broadway stop provides access to the Walter Rand Transportation Center, which is somewhat of an unofficial transit hub for the county (described in detail below).

Once the high-speed line passes over the Delaware River, it makes four stops in Philadelphia. The first is at 8th & Market near the shopping districts, the Pennsylvania Convention Center, the downtown business district, and the SEPTA Market East Station - one of the central subway stations in Philadelphia with links all over the city, including University City. The second station is 9th - 10th & Locust close to three major city hospitals. The third is 12th - 3th & Locust, which has a connection to the SEPTA Broad Street Line, which provides access to the Philadelphia professional sports stadiums. The last station is 15th - 16th & Locust, which is in the heart of the Theatre District.

The PATCO high-speed line is mainly used by commuters who go from Camden County into Philadelphia. The other twenty percent of riders are shoppers, sports fans, and students.

6.1.2 River LINE

The River LINE is a light rail line that starts in Camden and ends in Trenton, traveling along the Delaware River through Camden, Burlington, and Mercer Counties.

The River LINE has six stations in Camden County. There are four in downtown Camden: the River LINE starts at the Camden Waterfront at the Entertainment complex, then stops at the NJ State Aquarium, then goes to the Camden campus of Rutgers University, and finally stops at the Walter Rand Transportation Center. Once the River LINE leaves downtown Camden, it makes a final stop within the city lines of Camden at 36th St. Then, there is one last station in Camden County on Route 73 in Pennsauken.

The River LINE goes on to make 11 stops in Burlington County in townships along the Delaware River, none of which have connections to any other transportation systems. The line then enters Mercer County and makes

Figure 6.2: Municipalities of Camden County

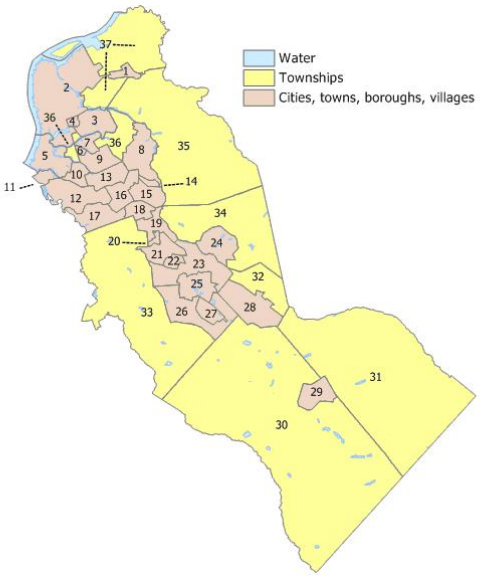


Figure 6.3: Camden County PATCO Train

three stops in downtown Trenton. The final station is Trenton, which links to Trenton Rail Station where the NJ Transit, SEPTA, and AMTRAK all provide train service along the Northeast Corridor toward both New York and Philadelphia.

Commuters are not the focus of the River LINE, unlike the PATCO high-speed line. Most River LINE users are traveling to the end stations (Camden and Trenton) in order to see events such as concerts or sports matches. However, Trenton is usually not a final destination as many people continue on trains north towards the New York metropolitan area from the adjacent Trenton Rail Station.

Figure 6.4: River LINE Train

6.1.3 RiverLink Ferry

The RiverLink Ferry travels from the Camden waterfront area to Penn's Landing in Philadelphia. Many do not use this travel option as it takes the slow but "scenic" route across the Delaware River. The vast majority of RiverLink Ferry clients make use of the ferry before and after events at the Camden waterfront—especially when there are concerts at the Tweeter Center.

Figure 6.5: Roadway Map of Camden County

6.1.4 Walter Rand Transportation Center

The Walter Rand Transportation Center is a transportation hub located in the heart of downtown Camden. As mentioned previously, the transit center features stations for both the PATCO high-speed line and the River LINE. The Walter Rand Transportation Center also serves as a bus station for twenty-two NJ Transit buses.

6.2 Employment & Shopping

There are over 3600 places of business in Camden County including retail stores, offices, and industrial centers. Almost all of the heavy industry in Camden County is located in the City of Camden along the Delaware River. Otherwise, the bulk of businesses in Camden County are offices and retail stores located in almost every municipality.

6.2.1 Malls

Cherry Hill Mall Located in Cherry Hill. This is the largest mall in South Jersey. It currently holds 165 stores and is expanding. There are many adjoining restaurants and strip malls that are not officially part of the mall that make the area is high-traffic retail and recreation destination in the heart of Camden County.

Voorhees Town Center Located in Voorhees. This is the third largest mall in South Jersey. Formerly known as the Echelon Mall, it has been downsized and completely renovated. As with the Cherry Hill Mall, there are many successful strip plazas surrounding the mall.

6.3 Recreation

The main recreations in Camden County are movie theaters, museums, and the Camden Waterfront area. There are also other entertainment attractions such as the Clementon Water Park, Flyers Skate Zone, and Perkins Center for the Arts. Many Camden County residents travel to Philadelphia in search of recreational endeavors.

Figure 6.6: Walter Rand Transportation Center

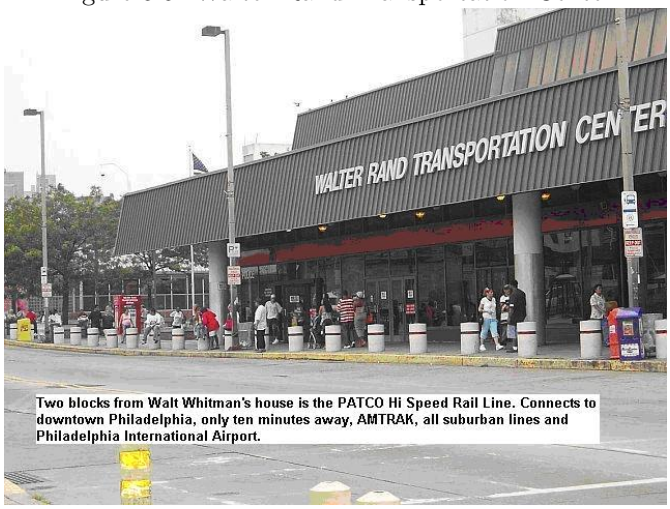


Figure 6.7: Loews Cinema Camden

6.4 Education

6.4.1 Primary and Secondary Education

There are about 250 primary and secondary schools in Camden County. These include those in public school districts as well as both non-secular and religiously affiliated schools. The townships with the most schools in the county include Blackwood, Camden, Cherry Hill, Haddonfield, Pennsauken, Sicklerville, and Voorhees.

6.4.2 Camden County Community College

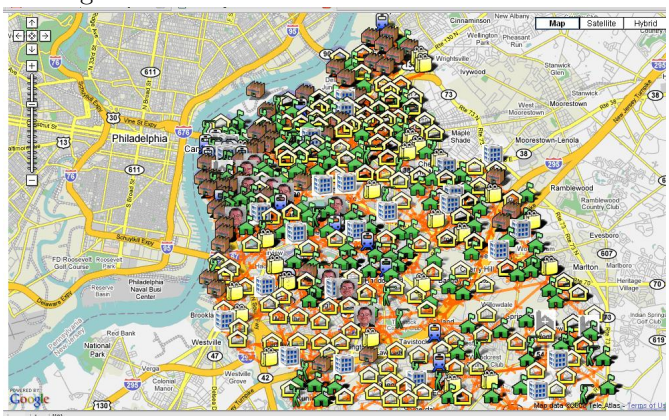
Camden Community College (Camden County CC) is a New Jersey Public Community College with three different campuses in Camden County. The main campus is located in Blackwood, NJ while there are two smaller campuses located in downtown Camden near Rutgers Camden as well as in Cherry Hill.

6.4.3 Rutgers University, Camden

Rutgers - Camden is a Division III school located in downtown Camden next to the Waterfront area. It has over 5000 undergraduate and graduate students.

Figure 6.8: Rutgers - Camden

Figure 6.9: PRT Network for Northern Camden



6.5 Personal Rapid Transit Network

The very first design stage after determining the overall land use of Camden County involved determining exact locations of probable high traffic areas throughout the county. The first batch of these were simply all the RiverLine

Figure 6.10: PRT Network near Philadelphia

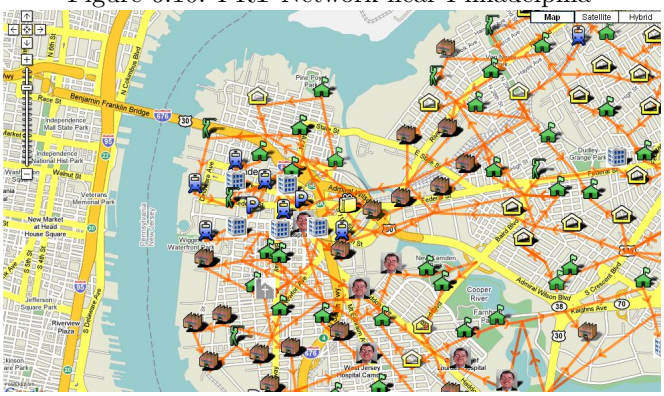


Figure 6.11: Loop Design in Camden PRT Network

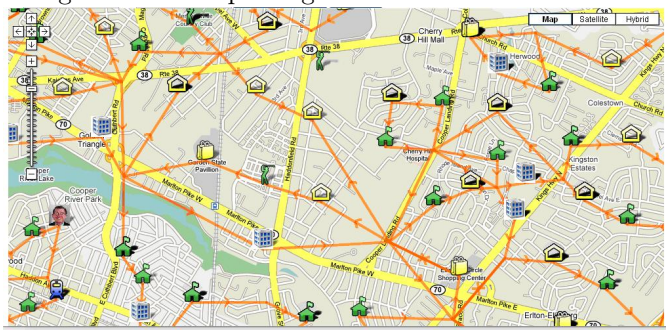


Figure 6.12: South-East Camden County PRT

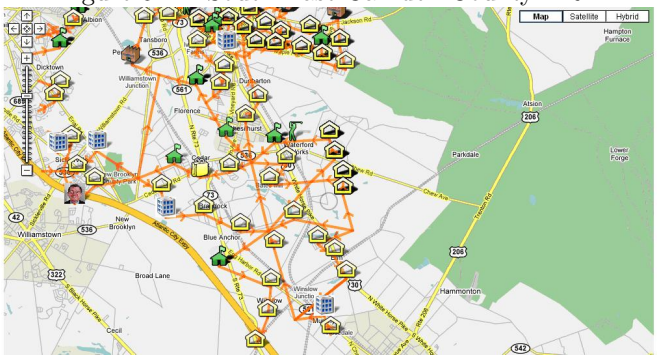


Table 6.1: Schools in Camden County

School	Address	Zip	Town
Gibbsboro School	37 Kirkwood Rd	08026	Gibbsboro
Glendora School	201 Station Ave	08029	Glendora
Cold Springs School	1194 Market St	08030	Gloucester City
Gloucester Catholic High School (Religious)	333 Ridgeway St	08030	Gloucester City
Gloucester City Junior Senior High School	1300 Market St	08030	Gloucester City
Mary E Costello School	520 Cumberland St	08030	Gloucester City
St Mary School (Religious)	Cumberland Sussex St	08030	Gloucester City
Atlantic Ave School	Atlantic Ave & Green St	08035	Haddon Heights
Baptist High School (Religious)	Third Station Ave	08035	Haddon Heights
Glenview Ave School	Glenview & Sycamore Sts	08035	Haddon Heights
Haddon Heights Junior Senior High School	301 Second Ave	08035	Haddon Heights
Seventh Ave School	Seventh Ave & High St	08035	Haddon Heights
St Rose of Lima Elementary School (Religious)	300 Kings Highway	08035	Haddon Heights
Kings Christian School (Religious)	800 W Kings Highway	08035	Haddon Heights
Avon School	Mercer Dr	08033	Haddonfield
Bancroft School (Private)	Hopkins Lane	08033	Haddonfield
Beechwood School (Private)	441 Beechwood Ave	08033	Haddonfield
Central School	3 Lincoln Ave	08033	Haddonfield
Christ the King Regional School (Religious)	164 Hopkins Ave	08033	Haddonfield
Elizabeth Haddon School	501 West Redman Ave	08033	Haddonfield
Haddonfield Friends School (Private)	47 N Haddon Ave	08033	Haddonfield
Haddonfield Memorial High School	401 Kings Highway East	08033	Haddonfield

and PATCO stations. After this, the task turned to businesses—both retail and office-based. This was done using a master Excel spreadsheet that accounted for every business in the county; only ones with sizeable workforces of at least 100 employees were deemed important (especially in the case of office complexes where there are no extra trips coming from customers) enough to be accounted for. This process also revealed important recreational and shopping attractions throughout the county.

The next step required pinpointing the distribution of residents throughout the county. Positional housing data is hard to come by, so the method used here focused on primary and secondary schools (mostly public ones). The idea behind this was that schools would be located rather close to the bulk of the residential population. Also, schools attract a sizeable amount of daily trips that would have to be served by any successful PRT system. Table 6.1 shows a sample of schools in Camden County.

After all these types of stations were placed, the obvious gaps were filled in by looking on hybrid mode on Google Maps. With a satellite image available, it was rather easy to spot suburban residential areas not within range of the current PRT stations. Thus housing stations are at the bottom of the totem pole and almost exclusively serve residences, unlike most other stations which usually serve a mixture of needs.

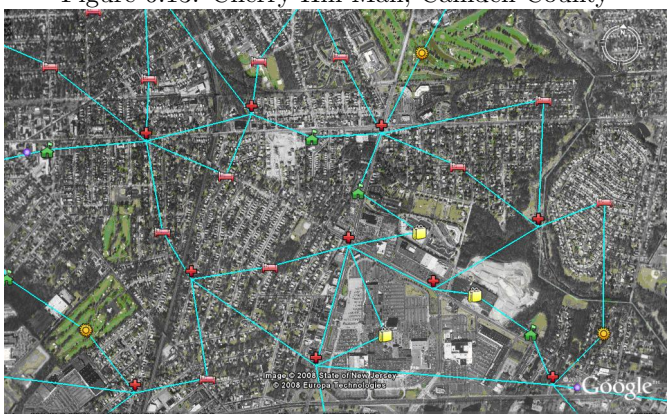
6.5.1 Arc Design

The Camden County PRT network serves the needs of Camden County residents based upon the land use in the county. The design makes use of relatively extensive transportation systems already available in the county—with a special emphasis on the PATCO high-speed line running through the heart of Camden County. With this in mind, the PRT network provides a grid-like structure within the urban and heavily suburban northwest half of the county that interconnects with the PATCO and RiverLine stations. Thus, passengers making longer trips can transition onto more direct forms of transportation while local trip passengers are offered quicker service.

The network is not a complete grid. Rather, it applies a design where every vicinity holds two or three intersections that account for anywhere between 5 and 10 stations. The intersections in each area interconnect with those intersections in other areas. Figure 6.13 is an example of this design around the Cherry Hill Mall area.

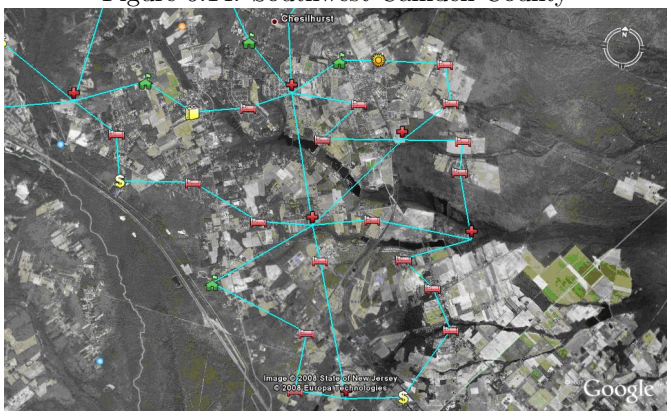
As one travels to the less suburban and rural areas of Camden County, the design of the network slowly morphs into one that resembles beads on a necklace. In these less populated localities, there is no economic rationale for more track distance, stations, or interchanges. Below is an example of the "beads on a necklace" approach near Chesilhurst in southwestern Camden County - it should be noted that the map below encompasses a much larger area that the previous one in order to better demonstrate the extent of the PRT network in this less densely

Figure 6.13: Cherry Hill Mall, Camden County



populated area:

Figure 6.14: Southwest Camden County



6.5.2 Network Details

All in all, there are 768 nodes in Camden County. 192 of these are interchanges with the other 576 being stations. These nodes are connected by 1052 arcs which measure up to a tad over 300 miles of guide way. This gives an average of .29 miles per arc, which is a rather low number but makes sense considering the high population density—especially in the northwest portion of Camden County where the majority of the stations are located.

In order to estimate trip ends for each station, much of the same data that was used to determine the locations of the stations was reused to estimate trip ends for those stations. In general that meant between 3 or 4 daily trip ends at businesses for each employee, 2 trip ends at schools for students and faculty as well as for recreation, and 4 daily trip ends for housing. Exact numbers would be infeasible to calculate, but housing numbers for each station were calculated by spreading them out by eye over all the stations in a zip code giving access to residences. The population by zip code in Camden County is shown below (data from 2006 US census estimates):

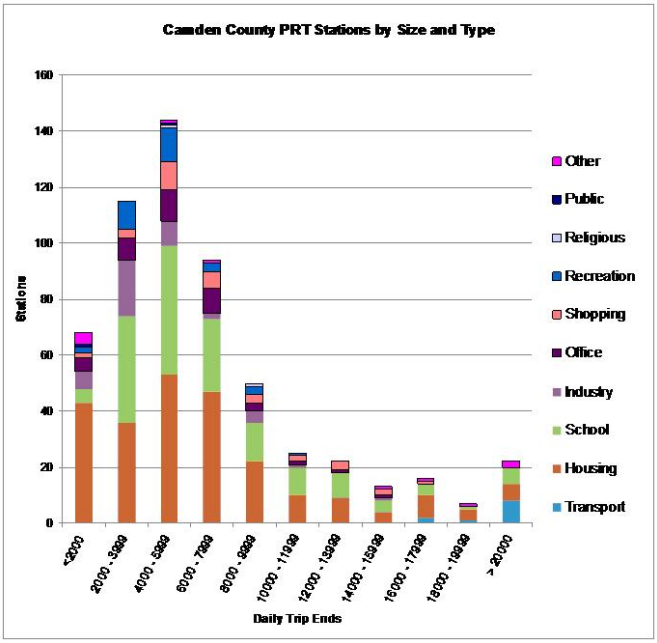
In the end, 3,954,550 trip ends were estimated for the County of Camden. With a total of 516,806 residents living in the county, this came in at about 7.65 daily trip ends per person, which seems to be a rational figure. A graph of the distribution of trip ends per station based on trip type is shown on the next page:

As one can see, the majority of stations serve between about 2000 and 8000 trips per day. The stations that serve less than this generally are not economically practical and a great deal of effort was put in to avoid having such stations. On the other end of the scale, there are less and less stations in each bucket until one reaches the last sector which contains all those stations that serve more than 20,000 trips per day. These are the major hospitals, universities, urban high-rises, and transportation hubs of Camden County that predict to hold large amounts of traffic.

Table 6.2: Population by Zip Code in Camden County

Zip	**Population**
08002	20800
08003	30714
08004	14299
08007	5378
08009	11869
08012	39208
08021	45848
08030	13461
08031	11639
08033	16531
08034	18402
08035	7547
08043	28126
08045	2671
08049	5427
08059	5402
08078	8379
08081	42891
08083	9874
08084	7271
08089	3979
08091	5237
08102	9866
08103	15566
08104	24602
08105	30762
08106	10284
08107	13500
08108	18557
08109	22710
08110	16006
	516806

Figure 6.15: Trip Distribution for Camden County



6.5.3 Economics

Given there are an estimated 4 million daily trip ends—and thus about 2 million trips per day—in the County of Camden, the estimated amount of vehicles needed to serve the network would be about 76,500, which at a cost of $150,000 each figure to cost the County a bit less than $11.5 billion. With one mile of track costing about $5 million and each station at about $25 million, the total for both the tracks and stations comes in at $15.9 billion. With a total cost approaching $27.5 billion for a single county, the PRT system is no small investment. Nonetheless, it is not worth doing at all if not done well because the system needs to be ubiquitous to be successful.

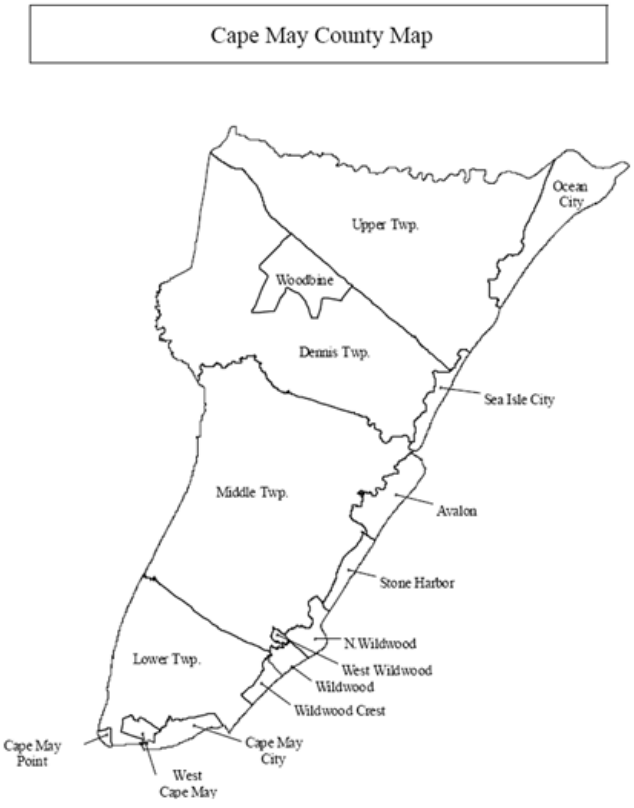
The most expensive part of the Personal Rapid Transit system is the stations. In an effort to control costs, one could make fewer stations by simply not building those which are not serve a sufficient amount of travelers. However, small rural areas must be served in order to provide full coverage. In a more extensive look at the possibilities of a PRT network in Camden County, one would attempt to find a suitable middle ground between system exposure to the county and cost. Nevertheless, the Personal Rapid Transit network would have to reach at least 90% of the trip ends in the county in order to thrive.

Chapter 7

Cape May County

Cape May County is a prominent seashore community of townships located at the southern-most tip of New Jersey. Cape May offers myriad activities to its residents and vacationers during the summer time, from camping and fishing to surfing and bar culture. However, transportation to and within Cape May is largely done by car. 89% of commuters in Cape May County for 2005 used a car (80% alone, 9% carpooled), while only 2% used public transportation. [1] Route 9 and the Garden State Parkway, running north to south down the eastern corridor of Cape May County in tandem, form the backbone of the County's highway network. Highway 47 represents a secondary north to south artery, running along the sparsely population western tract of Cape May County. These three highway systems provide support to the commuters throughout mainland Cape May, but a series of complicated interchanges and a lack of highway speed roads make it very difficult to traverse the densely populated and highly frequented cities along Cape May County's eastern coast; this essentially divides the Cape May population, limiting travel between mainland and coastal communities.

Figure 7.1: Cape May County, New Jersey



[1] Cape May County Planning Department. Cape May County Data Book. Cape May Court House: Cape May County Planning Department, January 2003 (p. 30).

Route 9 and the Garden State Parkway, running north to south down the eastern corridor of Cape May County in tandem, form the backbone of the County's highway network. Highway 47 represents a secondary north to south artery, running along the sparsely population western tract of Cape May County. These three highway systems provide excellent support to the commuters throughout mainland Cape May, but a series of complicated interchanges and a lack of highway speed roads make it very difficult to traverse the densely populated and highly frequented cities along Cape May County's eastern coast. Development of a Public Rapid Transit system for Cape May County will create a much more efficient transportation method to interconnect mainland Cape May County with the coast in addition to providing a speedy alternative within coastal cities to seasonally congested roads and avenues.

Development of a Public Rapid Transit system for Cape May County will create a much more efficient transportation method to interconnect mainland Cape May County with the coast in addition to providing a speedy alternative within coastal cities to seasonally congested roads and avenues.

Realistically, there are few alternatives to the use of the car within Cape May County. The train systems that run through Cape May County are primarily for freight and the only private consumer oriented rail transportation is the Cape May Seashore Line, a tourist line with service from Cumberland County to Tuckahoe and Cape May Court House to Cape May City.

Table 7.1: Population Statistics in Cape May

Townships in Cape May County	**Summer Population (2005)**	**Permanent Population (2005)**	**Population Density per sq. mile (2000)**
Avalon	30229	2204	465
Cape May City	35213	4363	1753
Cape May Point	3745	261	602
Dennis Township	33477	6807	104
Lower Township	88626	23881	837
Middle Township	60338	17274	233
North Wildwood	51173	5086	2902
Ocean City	114678	15828	2196
Sea Isle City	37002	2951	1232
Stone Harbor	18106	1174	705
Upper Township	39881	12669	186
West Cape May	6477	1160	912
West Wildwood	5170	467	1493
Wildwood	62510	5608	4181
Wildwood Crest	40083	4132	3618
Woodbine	7823	2827	348
TOTAL	604302	106692	

Additionally, there are no local bus routes serving the Cape May County community, only regional bus systems for travel between outlying Cumberland and Atlantic County. The clear solution for this lack of efficient and local and regional travel is the integration of Cape May County into the State of New Jersey's new Public Rapid Transit system.

Addressing the dynamic nature of Cape May County, we will consider how the population changes on a seasonal basis. While the population in Cape May County was about 100,000 in winter of 2005, Cape May County's population ballooned to over 600,000 in the summer of that year. This marked seasonality of Cape May County can be explained by its heightened attractiveness to beach vacationers during the summer months. [2] The five largest townships in Cape May County—Wildwood Crest, Cape May, Ocean City, Wildwood, and Avalon - all represent a significant portion of the resort or beach facing community in Cape May County. Interestingly, accounting for 40% of Cape May County's population during non-summer months, resort communities have a population density of about 1700 people per square mile, whereas the mainland only exhibits a population density of 260 people per square mile. [3] In the summer months however, the growth in population is predominately within the resort communities on the coast. As a result, during the summer, the proportion of population within the resort community increases from 40% to 65%.

In determining the network on which the most efficient and convenient PRT system will run, it is necessary to

[2]Ibid, (p. 10).
[3]Ibid, (p. 18).

consider how PRT's creation will serve Cape May County's dynamic population and how it will further promote multi-modal transportation through integration with current transportation infrastructure.

7.1 The PRT Network: Land Use and Design

The Cape May County Personal Rapid Transit network was designed to address the lack of transportation between mainland and coastal communities within Cape May County and provide connectivity to 90% of New Jersey's points of interest. The final design contains 623 station locations and requires nearly 500 miles of guide way with the average distance between stations being around 0.4 miles. To address the dynamic nature of Cape May County's population, the implemented design was made robust enough to sustain the 600% population increase during the summer months with little to no congestion in highly trafficked areas. Physical network design characteristics were considered in two distinct groups: low population density design and high population density design.

Figure 7.2: Wildwood PRT

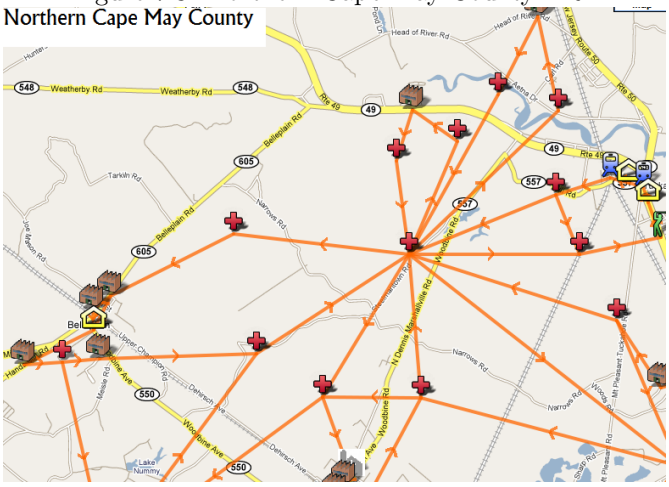
Throughout Cape May County, the population density of each respective township varies widely from around 4181 people per square mile in Wildwood City to just 104 people per square mile within the Township of Dennis. [4] The land use considered in determining the structure of the PRT network are housing developments, employment locations, shopping points of interest, religious buildings, educational facilities, and transportation hubs. In general, in low density areas, ridership will have lower congestion per unit time under typical conditions, so stations can be placed farther away from each other. In contrast, high density areas will have higher ridership per unit time under typical conditions, so it is necessary to place stations in closer proximity to alleviate any congestion that might arise with seasonal population increases.

The highest density communities are all predominately located along the eastern New Jersey coast-line in the Ocean City, Wildwood, Cape May, Sea Isle City, Avalon, and Stone Harbor townships. In general, each of these townships is built on a roughly rectangular grid, making it very easy to provide robust unidirectional transportation throughout each respective community for maximum connectivity. Provided is a cut of the PRT Wildwood network. Concentric rings with nodes along major avenues and roads are integrated into the current automobile transportation infrastructure to make multi modal trips utilizing the PRT network within each respective coastal township as convenient and efficient as possible. Additionally, land use in these areas is predominately saturated with hotels, recreational facilities, and office buildings, catering to the needs of the seasonal influx of vacationers attracted to Cape May.

Mainland Cape May County communities, with smaller population densities, are not as spatially structured as the shoreline communities. Northern Cape May County, in the areas of Marmora, Woodbine, and Dennis Township are rural and contain the lowest density of interest points. For the most part, mainland communities are not clearly distinguishable as independent physical entities. The relatively low density in land use introduces chaos in assessing physical distinction between and creating boundaries for each respective community; in these cases, concentric rings of unidirectional track were established to provide the most convenient travel services,

[4] Ibid, (p. 18).

Figure 7.3: Northern Cape May County PRT



considering the sparsely located points of interest. These concentric rings, in some cases, encapsulate and provide local transportation for more than one township. Land use in mainland Cape May is largely shopping, housing, and recreation (fishing, camping, boat touring, et cetera) centric.

7.2 The PRT Network: Service and Trip Generation

7.2.1 Service to Education

One of the largest volume destination locations on the PRT network will be areas zoned for primary, middle, secondary, and undergraduate education. In primary, middle, and secondary education, there are currently 16,121 students enrolled in 38 schools throughout Cape May County, averaging about 460 students per educational facility.

Table 7.2: School Enrollment in Cape May

Townships in Cape May County	School Enrollment	Serving Station #
Avalon	82	7960
Cape May City	2677	7971, 7972, 7987
Dennis Township	1179	7986, 7975
Lower Township	176	7964, 7965, 7966, 7967
Middle Township	5432	7977, 7978, 7979, 7991, 7993, 7994
North Wildwood	661	7969, 7990
Ocean City	2236	7983, 7993
Stone Harbor	85	7968
Upper Township	1644	7980, 7981, 7982
West Cape May	97	7962
Wildwood	1205	7963, 7974, 7988, 7990
Woodbine	216	7970

The sole university level establishment, the Cape May County location of the Atlantic-Cape Community College has a student enrollment of about 3,200 in Cape May Court House. Unlike other points of interest, it is essential that the location be as close to each respective campus as necessary to ensure that the ridership (primarily children under 18) is able to seamlessly transition from the network to the point of interest without hindrance.

Trip Generation When generating trips for education, the enrollment at each respective school was taken into account as trips to and from the educational facilities. The school faculty was also added to the trip generation by multiplying the enrolled student numbers at each educational facility by the student to faculty ratio. It was assumed in building the network that those in permanent housing would be the sole source of trips provided to the educational locations. Additionally, despite the low volumes to some educational facilities, accommodations were made to insure a station at every location. In the case of Stone Harbor, for instance, the station was placed near

to the school, while all other attractions and productions within a quarter mile radius were aggregated to represent the total volume for the school centric station.

7.2.2 Service to Housing

Considering the housing in Cape May needs to support permanent as well as temporary/vacationing populations, we must assess the use of the PRT network by both constituent.

Permanent Residents

Primary housing for the permanent population will be considered strictly single family units and apartment. There are a total of 91,047 housing units in Cape May County; 42,148 are occupied and 48,899 are vacant. Out of the occupied housing 31,294 units are owner owned and occupied, while 10,854 units are renter occupied. [5] Out of the vacant housing 43,124, or 89% are for seasonal and vacation use, while the remaining units are either on the market, reserved for migratory workers, or for rent; the average number of residents per unit in Cape May County is about 3.

The 106,692 residents who comprise the permanent population of Cape May County will use the network predominantly for educational, employment and public space trips. Of course regular shopping and religious trips are being made by the permanent population, but the proportion of total trips to employment, education and public space destinations generated by the permanent population is vastly larger than proportion of temporary resident trip generation to those points of interest.

Table 7.3: Housing in Cape May

	Number	Percent
Occupancy Status		
Total housing units	91,047	100%
Occupied housing units	42,148	46%
Vacant housing units	48,899	54%
Tenure		
Occupied housing units	42,148	100%
Owner-occupied housing units	31,294	74%
Renter-occupied housing units	10,854	26%
Vacancy Status		
Vacant housing units	48,899	100%
For rent	3,148	6%
For sale only	808	2%
Rented or sold, not occupied	589	1%
For seasonal, recreational, or occasional use	43,124	88%
For migratory workers	8	0%
Other vacant	1,222	3%

Trip Generation When considering the trip generation of the permanent residents we operated under the assumption that in each living unit, there were three residents each making a round trip from home to another destination and then returning back to home. Using the population density for each of the municipalities and by utilizing the graphic power of Google Earth, housing areas were assigned estimates as to the number or units and therefore the number of trips generating from the surrounding housing units.

Seasonal Residents

In addition to the permanent residents, housing in Cape May County needs to be able to support an additional population of 497,610 seasonal residents. Primary housing for the vacationing population will include single family units that are vacant during non-summer periods, apartments, motels, hotels, inns, and any other sort of temporary residence. Cape May County provides 43,124 units of single family residence and apartments, so under the assumption that each vacationer's family is around four people, this takes up 172,496 of the vacationing population,

[5] Ibid, (p. 42).

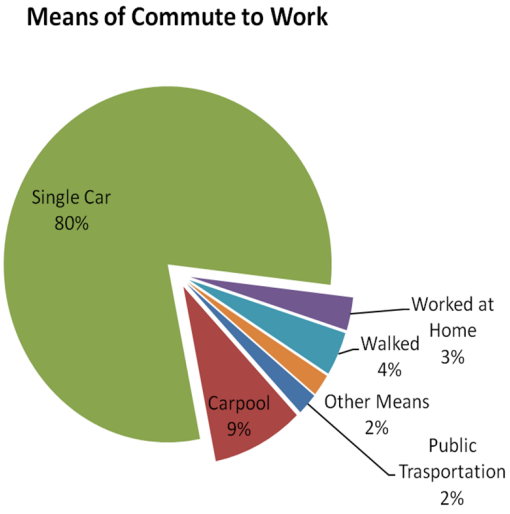
leaving the remaining 325,114 vacationers to find temporary housing in resorts, hotels, motels and other temporary residence. [6]

In contrast to the permanent population, the trips along the network for the seasonal residents are predominantly for recreational and shopping purposes. Again, the seasonal population will account for some proportion of the generated trips to religious, educational, employment, and public space.

Trip Generation Building a network robust enough to serve a population inflation of 600% for the summer months requires not only forecasting trip generation for the general population, but also for the seasonal residents. However, due to the fact that both populations would be able to operate on the same network because of overlapping points of interest throughout both populations, the only major operational concern in this case would be congestion. Also, considering that the summer influx of population into Cape May is primarily exhibited along the eastern coast and to a much lesser extent mainland Cape May, it is reasonable to assume that vacationers will have little need to travel throughout mainland Cape May during the summer months, meaning that infrastructure for mainland Cape May can be built to serve solely the permanent population. However, since the population along the eastern coast rises so significantly, to combat the congestion it is possible to assume only permanent residents in the trip generation and accommodate a rising population through pushing points of interest closer together on local networks.

7.2.3 Service to Employment/Public Administration

Figure 7.4: Means of Commute in Cape May



Considering that 80% of commuters in Cape May County use a car to get to work, the appeal of the PRT system must be towards the working population. [7] In order to provide a superior mode of transportation or add the PRT component to the multimodal commute to work, the service to employment locations must be close enough to provide for a brisk walk from the station to the point of interest, but not allocated to the point of having a station at every employment location.

Demographically, Cape May County has a labor force of 48,482 and an unemployment rate of 8.2%.[8] Eighty percent of the labor force or 35,573 people hold professional, service, and sales occupations. [9] Additionally, the most commonly employed industries in Cape May County are construction, management, retail trade, education, public administration, and accommodation, creating 33,685 jobs for the population of Cape May County. [10]

Trip Generation Starting out with the population of Cape May County in the workforce and operating under the assumption that the labor force of Cape May County serves solely locally and does not travel outside the County

[6] Ibid, (p. 42).
[7] Ibid, (p. 30).
[8] Ibid, (p. 37).
[9] Ibid, (p. 34).
[10] Ibid, (p. 34).

Table 7.4: Employment in Cape May

Occupations	**Numbers**
Management, professional, and related	14,006
Service	9,403
Sales and Office	12,164
Farming, fishing, and forestry	378
Construction, extraction, and maintenance	4,988
Production, transportation, and material moving	3,564
Industry	**Numbers**
Agriculture, forestry, fishing, hunting, and mining	497
Construction	4,041
Manufacturing	1,595
Wholesale trade	933
Retail trade	5,869
Transportation, warehousing and utilities information	1,911
Information	927
Finance, insurance, real estate, rental and leasing	2,834
Professional, scientific, management, administrative and waste	3,334
Educational, health and social, services	9,491
Arts, entertainment, recreation, accommodation and food	7,590
Other services (except public administration)	2,121
Public administration	3,360

for employment, we then took out the percentage of unemployed people within the work force to generate the total number of employed people within Cape May County. Then, we distributed this population of employees throughout the county to each respective municipality, based on the population percentage of each respective municipality as a proportion of the total population. Now with figures for number of employees per municipality, each municipality working population was separated into specific industry jobs based on average employment industry statistics for Cape May County. Although not the most precise method of employment trip generation, considering the general homogeneity of occupations across Cape May County (recall 88% of employees hold professional, services, or sales type occupations), determining the exact number and type of each employee within an entire municipality is a worthless enterprise, considering the dynamic nature of employment trends over time.

7.2.4 Service to Shopping and Recreation

The Cape May PRT system will provide service to major shopping centers, paying attention to building stations near high volume shopping areas, rather than focusing on creating a network on which there is a station at every frequented shopping location.

As Cape May is an ocean oriented community, there are many fishing, marina, boat-for-hire, camping, and observatory locations that are easily accessible from stations along the network. Similar to shopping, the aim is not to serve every recreational point of interest in Cape May County, but to address areas of high volume, with the exception of providing stations for nearby golf courses and marinas.

Trip Generation Each member of a household was assumed to take two shopping or recreational trips per day. Given the data collected for shopping and recreation, divided total number of municipal specific shopping or recreational trips per day by the number of collected shopping and recreation points of interest within that municipality, number of trips per location was determined.

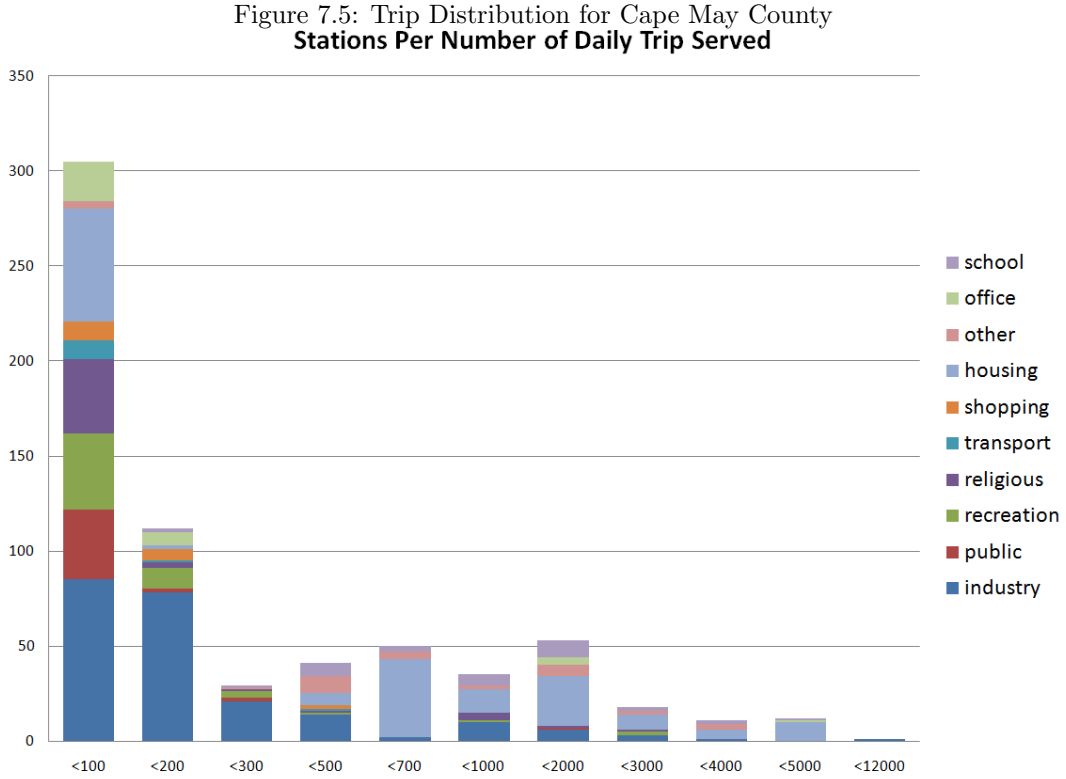
7.3 The PRT Network: Design Analysis

Keeping in mind the key purposes of Cape May PRT are to bridge the mainland and coastline populations and provide access to 90% of New Jersey's points of interest, we are able to make assertions about station location and volume throughout the county.

Is it key in the analysis to note that although mainland communities, in general, have lower population densities than coastal communities, during non-summer months, the total population in mainland communities (60,673 in

2000) is systemically higher than the total population in coastal communities (41,653 in 2000). Furthermore, population growth in the mainland communities has been consistently higher with an average yearly growth rate of 3.0% as opposed to 1.6% in the coastal communities since 1970. This can be accounted for by the relative size and attractiveness of mainland and coastal communities. Considering that coastal communities span over 23.8 square miles and mainland communities span over 232.7 square miles,[11] land use in the densely populated coastal communities is already near full saturation, whereas evident in higher population growth rates, land use in mainland communities is not. So, given that mainland communities are more populated, span more square miles, have lower population density, and have land use significantly less saturated than coastal communities, design of the PRT network for Cape May County will need to provide proportionately more stations to mainland communities. As a result, a significant proportion of the stations on the PRT network will serve relatively fewer trips per station (as an artifact of lower population density in mainland communities) than others.

Figure 7.5: Trip Distribution for Cape May County



In the designed PRT network for Cape May County, this is exactly the case. As the stacked bar chart "Stations per Number of Daily Trips Served" indicates, 73% of stations on the network serve fewer than 500 trips per day. Also, housing and employment trips make up for more than half of these 73% of stations on the network, consistent with population demographics of the mainland communities.

The remaining 27% of stations represent all other stations on the network serving more than 500 trips per day. The largest trip serving station will serve around 11,000 housing, employment, shopping, and recreation trips and is located in the heart of Sea Isle City. The next four largest trip serving stations are all located within Wildwood City (highest population density in Cape May County, 4181 people per square mile), serving over 6,000 daily trips to and from employment, education, shopping, and recreational locations. Special considerations were given to these high volume stations; to reduce potential congestion, some of these high volume locations required stations to be within less than $\frac{1}{2}$ mile of each other to avoid bottleneck service during the summer months. On aggregate the design of the PRT system for Cape May County is consistent with the population demographic assumptions and transportation needs based on the population density of each respective township.

[11] Ibid, (p. 18).

7.4 The Cost of PRT

For all the convenience that the Cape May County PRT will provide to its ridership, there is still the topic of cost to address. The creation of this network will require significant initial investment into building the physical capital needed for this project. At the base level, funding for the creation of stations, interchanges, guide way, and the PRT vehicles themselves is needed. In addition to physical capital expenditures, we must also take into consideration the need for human capital, such as station attendants at some of the higher volume stations and operations employees. Presented is a breakout of the costs used to create an estimate of the Cape May County PRT system budget, which totals $5.67 billion.

Table 7.5: Physical Capital Expenditures for PRT in Cape May

Expense Type	**Amount**
Guide way	$2,483,350,000
Stations	$312,500,000
Interchanges	$52,650,000
Vehicles	$2,718,954,605
Total	$5,567,454,605

Table 7.6: Human Capital Expenditures for PRT in Cape May

Expense Type	**Amount**
Stations Attendants	$19,805,714
Operations Technicians	$85,714,285
Total Human Capital Expenditures	$95,520,000
Total Expenditures	$5,672,974,605

7.4.1 Budget Calculations

Guideway The cost per mile of guideway was assumed to be $5 million and the Cape May County PRT network requires 497 miles of guideway.

Stations The network requires 625 stations. Each station has a projected cost of about $0.5 million.

Interchanges At this stage, interchanges are viewed as increment costs added to the cost of guideway. Not as capital intensive as the construction of a station, an interchange provides a landed cost of $150,000 for each of the 351 interchanges on the Cape May County PRT network.

Vehicles The network for Cape May County requires 18,126 PRT vehicles at a cost of $150,000 per vehicle.

Station Attendants Assuming that stations with volumes above 3,000 trips per day would require two attendants to direct ridership efficiently, salaries based on hourly wages of $15.00 and 40 hour weeks, an infinite annuity was calculated based on the yearly salary cost of attendants and a discount rate of 7%.

Operations Technicians Different from attendants, operations technicians are assumed to be employed on a yearly salary rather than hourly. The average yearly salary was assumed to be $120,000 and with 497 miles of guideway, there would need to be 50 technicians, or one technician for every ten miles of guideway. An infinite annuity for the cost of 50 technicians was also calculated with a discount rate of 7%.

7.5 The Benefit of PRT

In joining the fifteen other counties in New Jersey, upon adoption and creation of the State-wide Public Rapid Transit system, Cape May County will have access to within a quarter mile of virtually every point of interest in Cape May County and New Jersey. Providing an environmentally friendly and safe transportation system such as

this will alleviate most of the State's current concerns with automobile emissions while at the same time, providing a solution to the plague of congestion throughout the State.

In addition to provided State-wide benefits, Cape May County locals will also reap great benefits from the construction of this transportation system; considering that during the summer months in Cape May County the population balloons to more than 600% of the permanent population, this transportation system will serve the needs of vacationers to and from Cape May County, cutting down the need for them to contribute to the automobile emissions and congestion by the frequent use of automobiles for transportation within Cape May County and to adjacent Atlantic County. Additionally, more than 89% of all commuters in Cape May County are traveling to work by car, which provides the perfect opportunity for PRT market penetration as commuter after commuter will choose either a fully PRT mode or multi-modal PRT trip to get to their place of employment. Additionally, through the ease of transportation between points of interest in Cape May County, more and more vacationers will flock to Cape May County, furthering the development of the area.

Chapter 8

Cumberland County

Figure 8.1: Cumberland County

8.1 Overview

Cumberland County is a low-lying coastal county in south central New Jersey near the Delaware Bay and is known primarily for its noteworthy agricultural production and scenic countryside regions. Located approximately 40 miles southeast of Philadelphia and almost 60 miles south of Trenton, this isolated country covers a total area of 489.3 square miles and has a total population of 146,438 according to census data collected in 2000. It is bordered by Salem and Gloucester Counties to the northwest, Atlantic County to the northeast, and Cape May County to the east. This county has 18 distinct municipalities, the largest of which are Vineland, Millville, and Bridgeton. Named for Prince William, Duke of Cumberland, this country encompasses the main metropolitan districts of Vineland, Millville, and Bridgeton.

8.2 Population Data

An examination of demographic factors is fundamental to the development of an appropriate transportation system, as population density, size, age, and income all influence travel needs and characteristics. According to the 2000 U.S Census, 56,271 people, or 38.4 percent of county population, live in Vineland, the largest metropolitan district. Another 26,47 people, or 18.3 percent, live in Millville and 22,771, or 15.5 percent, live in the municipality of Bridgeton. These three major urban centers contain 72.3 percent of the overall county population. The total population is projected to increase by roughly 8 percent by 2010, reflecting the need for an improved transportation network. Much of the southeast region is sparsely population low-lying marshland, making transportation development in this region challenging. A table of the population distribution in all districts as found on the US 2000 Census website is reproduced below.

As one might expect, population density is a critical variable in the creation of an optimal public transportation network. The overall population density is 299 people per square mile as calculated from the 2000 census data. Denser regions require greater public transportation infrastructures given the elevated level of use.

Figure 8.2: Map of Cumberland County

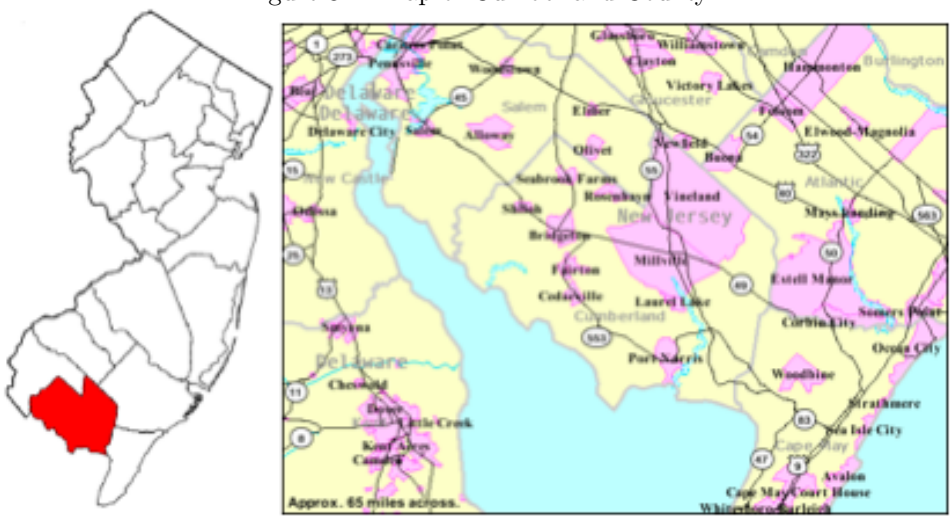


Figure 8.3: 2000 Census Data for Cumberland County

1990 – 2000 Population Trend by Municipality

Municipality	1990 Population	2000 Population	Population Change 1990-2000	Percent Change 1990-2000
Bridgeton	18,492*	22,771*	3,829	20.2
Commercial Township	5,026	5,259	233	4.6
Deerfield Township	2,933	2,927	(6)	(0.2)
Downe Township	1,702	1,631	(71)	(4.2)
Fairfield Township	5,699*	6,283*	584	10.3
Greenwich Township	911	847	(64)	(7.0)
Hopewell Township	4,215	4,434	219	5.2
Lawrence Township	2,433	2,721	288	11.8
Maurice River Township	6,648*	6,928*	280	4.2
Millville	25,992	26,847	855	3.3
Shiloh Borough	408	534	126	30.9
Stow Creek Township	1,437	1,429	(8)	(0.6)
Upper Deerfield Township	6,927	7,556	629	9.1
Vineland	54,780	56,271	1,491	2.7
Total	**138,053**	**146,438**	**8,385**	**6.1**

Source: US Census

* Includes prison population

8.3 Disabled Persons

It also seems relevant to analyze statistics in Cumberland County on the distribution personal with physical disabilities. Studies show that these individuals are more reliant on public transportation as many are unable to operate personal automobiles. The 2000 Census shows that there are 13,044 disabled persons in Cumberland County, or 8.9 percent of the population. They reside primarily in Upper Deerfield, Bridgeton, Millville, and Vineland. The figure below, albeit a bit grainy, illustrates the distribution effectively.

8.4 Housing Data

Cumberland County has over 52,000 housing units and an average of 2.73 people per residence. A full 40 percent of homeowners moved into the houses in the five years before the 2000 Census. Reflecting the economic hardships in the county, 24.8 percent of homeowners had housing costs that were 30% or more of their household income; for renters, the figure was 43 percent. 50 percent of occupied housing units had 2 or more vehicles available for use, while the average home owns 1.6 automobiles. Home values are represented graphically in the following figure.

Figure 8.4: Cumberland County Population Density Map

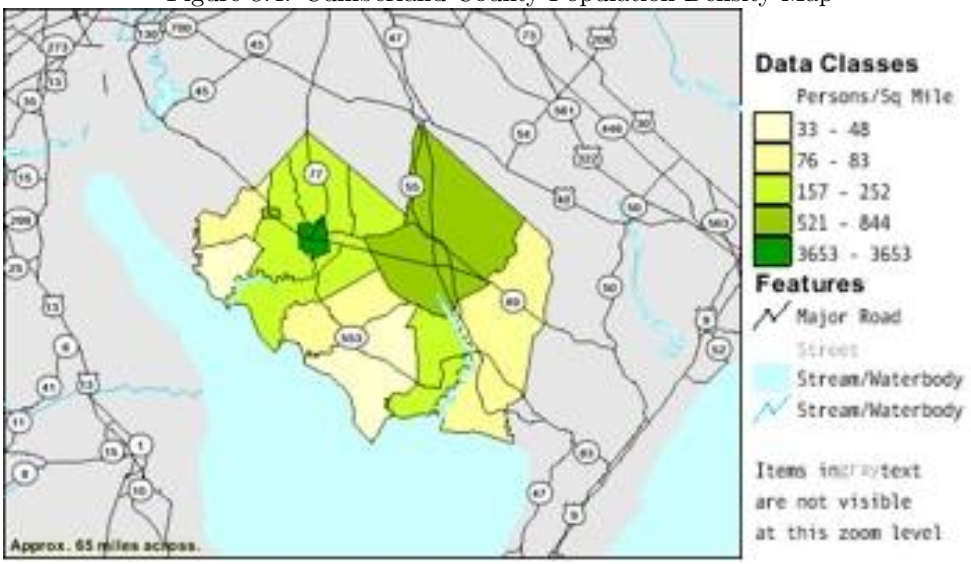
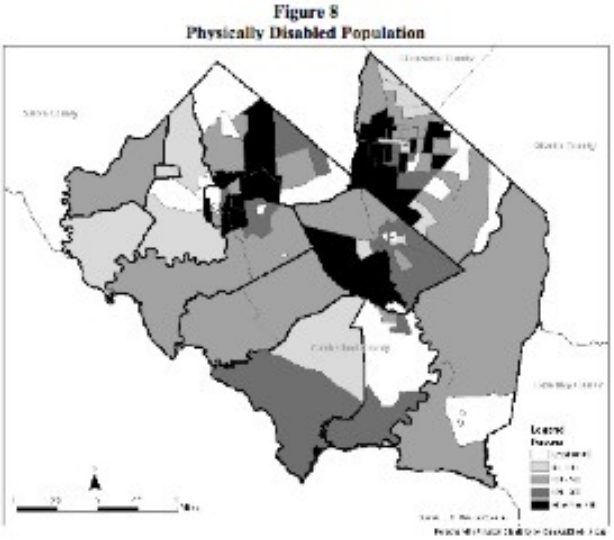


Figure 8.5: Map of Physically Disabled Population in Cumberland County



8.5 Economic Analysis

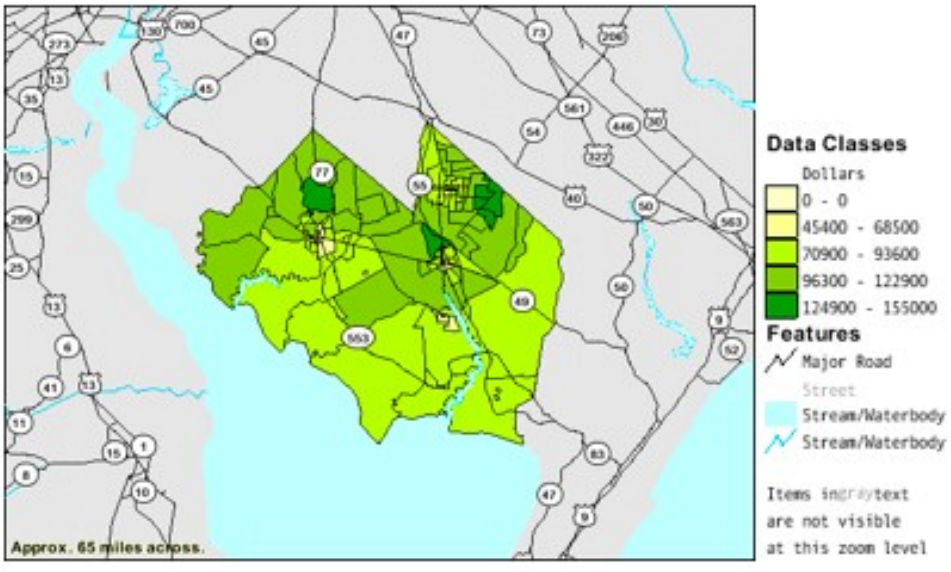
Cumberland County has a median per-capita income of $17,376 and a median household income of $39,150, making it the poorest county in all of New Jersey. The state average per capita income of $27,006 and median household income of $55,146 are both significant above the level of earnings realized by Cumberland County residents. Nationally, Cumberland County is ranked 1353 out of 3086 total counties in per capita income. Roughly 14 percent of residents are living in poverty. Lower income persons tend to exhibit a heavier reliance on public transportation services, as many are unable to afford the substantial cost of a personal automobile. The development, building, and implementation of a large-scale Personal Rapid Transit would provide a much-needed boost to the local economy while leading to substantial increases in available jobs.

8.6 Work-Related Travel

The need for and scope of public transportation such as a PRT network is also heavily dependent on the size and density of the labor force living in an area in addition to the amount of employment available in a particular region. These metrics help determine the level of production and attraction necessary in calibrating a transportation model. It is essential to develop intuition on the commuting patterns of residents in order to properly plan for work-related travel. In Cumberland County, the heaviest densities of both labor force and population exist in the downtown areas of the municipalities of Bridgeton, Millville, and Vineland. Labor statistics show that 58 percent of those aged 16 or over are in the labor force, with 20 percent of total workers holding government jobs. According to 2000 Census data, the total number of commuters on any given workday is approximately 43,645 people. However, only 565 get to work via public transportation, less than 2 percent of the work force! Only 14 percent of workers carpooled on their way to work. The majority of commuters, roughly 78 percent, drove to work alone in a personal vehicle. A total of 81 percent of commuters stay within the county, with the remainder travel to work locations in Atlantic and Gloucester Counties. Although there are many reasons for this skew, most obviously the lower population density across the county, a more comprehensive public transportation system would surely lead to environmental benefits associated with reduced automobile traffic. A Department of Labor survey implemented by ratings agency Moody's showed that the implementation of widespread transportation projects in Cumberland County will add 10,428 jobs between 2000 and 2010, a 17.3 percent increase. The study projects that 9,243 of these jobs, or 88.6 percent, will be created in the municipalities of Bridgeton, Millville, or Vineland.

The main areas of employment are concentrated in Bridgeton and Millville, with roughly 11,000 people working in these municipalities. Upper Deerfield employs roughly 2,500 individuals, and all other municipalities show employment of less than 1,225 persons. Bridgeton, Vineland and Millville had the highest number of employees commuting by public transportation, ach having more than 60 members of the workforce taking advantage of these

Figure 8.6: Cumberland County Home Values



services. Once again, these values are extremely important in the calculating of the production and attraction parameters essential to the development of our transportation model. Due to the fact that a large percentage of travel consists of trips to and from the workplace, it is essential to have accurate data on both the locations of employment and the residence locations of the workers. Tables of this data for Cumberland County are included in the Appendix (See Tables 1 and 2).

8.7 Commercial and Recreational Travel

The modeling of a personal rapid transit network in Cumberland County should also take into account the propensity of individuals to visit major attractions such as shopping centers, health care or senior citizen facilities, and educational centers such as schools and colleges. Together with major employment destinations, we collectively refer to these locations as major trip generators. To ensure the convenience and optimality of a public and human service transportation system we need to incorporated analysis of these trends into our model. Table 3 in the Appendix lists the major trip generators identified in Cumberland County. In the development of our own PRT model, we implemented an approach based around the identification of major trip generators, determining over 500 major destinations in the county to designate as stations or nodes in the network.

8.8 Education

In Cumberland County, the education sector accounts for roughly 15% of total private employment. More importantly, schools and colleges are significant destinations for travel and must be recognized in the development of a PRT system. A viable PRT system would transport students, teachers, and other employees to and from school. The county has 21 private schools, 37 elementary schools, 7 middle schools, and 7 public high schools. The total enrollment in Cumberland County Public Schools is in excess of 26,000 students. Cumberland County Community College, located in Vineland, is the only higher education institution in the county with a population of 3,000 commuter students. The college employs roughly 400 people.

8.9 Medical Facilities

Cumberland County has only one hospital, located in Vineland. This hospital, employing over 1,200 and of necessary service to the sick and injured, would most certainly be a node in our PRT network. This hospital features a cancer care center, a women's health center, and basic clinic facilities. Trauma patients are sent to more comprehensive centers in either Atlantic City or Philadelphia, a forty-five minute drive by car.

8.10 Existing Transportation Network

The current transportation network is heavily dependent on individual car travel. A transportation study presented by the South Jersey Transportation Planning Organization in June 2007 concluded that there is significant lack of transportation services; other than fixed routes operated by NJ Transit, there are no services available to the general public after 6:00 PM Monday through Friday and no services available on the weekends. The major corridors for vehicular travel in the country are State Highway 49 running east-west, State Highways 77 and 553 running north-south in the western districts of the county and State Highways 55 and 47 running north-south in eastern regions. Highway 55 is the county's major artery, connecting to the New Jersey Turnpike and providing access to Delaware and the rest of the state.

The road network in Cumberland County consists of 5,108 miles of paved roadway. 90 miles are under the jurisdiction of the New Jersey Department of Transportation, 542 miles are under county jurisdiction, and the remaining 637 miles are under municipal jurisdiction. The total daily vehicle miles traveled in the county is approximately 4,120,800 miles, or about 2 percent of the total for New Jersey. The average commuting time to work is about 23.1 minutes, reflecting the relatively low population density of only 489.3 persons per square mile. Transportation infrastructure remains basic—prior to the completion of Highway 55, there was no main artery connecting the county to the rest of the state. The limited public transportation infrastructure in Cumberland County consists of fixed bus routes operated by NJ Transit and the Cumberland County Office of Employment and Training and a flexible fixed route service operated by the Cumberland Area Transit System (CATS). The total public and human service transportation network consists of 63 vehicles that offer roughly 82,000 vehicle hours per year, transporting over 158,000 passengers. A table of fixed route services available in Cumberland County is

shown below. Notice that these routes are mainly connectors between major urban centers in Cumberland County and surrounding attractions like Philadelphia. These routes employ major highways 47, 49, 56, and 77.

Figure 8.7: Transportation Services in Cumberland County

Fixed Route Services

NJ Transit			
Route #	**From**	**To**	**Communities Served**
313	Philadelphia	Cape May	Maurice River Township, Millville, Vineland
408	Philadelphia	Millville	Millville, Vineland
410	Philadelphia	Bridgeton	Upper Deerfield Township, Bridgeton
553	Upper Deerfield	Atlantic City	Bridgeton, Fairfield Township, Millville, Upper Deerfield Township, Vineland

Cumberland County Public Transit System		
From	**To**	**Communities Served**
Downtown Vineland	Vineland Industrial Park	Vineland
Vineland Transit Center	One Stop Center - Vineland	Vineland
Vineland	Bridgeton	Bridgeton, Vineland
Bridgeton	Seabrook	Bridgeton, Seabrook, Upper Deerfield

The flexible or demand responsive services are characterized by having no scheduled origins, destinations, or stops. Instead, flexible service providers take reservations and allocate resources accordingly. CATS also provides a service for transporting elderly citizens and the disabled through the Cumberland County Department on Aging and Disables. Other flexible service providers maintain certain eligibility criteria in order to access their networks. These criteria are shown in the following figure.

Figure 8.8: Cumberland Transportation Services for the Disabled

Service Availability and Eligibility Criteria

Service	Type	Span	Coverage/Purposes	Eligibility
Access Link (NJ Transit)	Demand Response	At same times as applicable fixed route service	Within ¾ mile of a NJ Transit fixed route service	Disability which prohibits person from accessing fixed route service
Cumberland Area Transit System (CATS)	Demand Response	M-F – 5:30AM-6:00PM	Various trip purposes depending on eligibility, capacity. Locations in Cumberland County with select trips to Philadelphia and Wilmington	Seniors, Disabled, Veterans, JARC participants, General Public
Easter Seals of New Jersey	Demand Response	M-F – 6:30AM – 3:30PM	Employment, education and training in service area	Agency clients only
Elwyn New Jersey	Demand Response	M-F – 8:00AM-5:00PM	Any trip purpose in Cumberland, Gloucester, Atlantic Counties	Agency clients and family members of clients
Kessler Memorial Hospital	Demand Response	M,W,F 6:30AM - 6:30PM T,Th,Sat 6:30AM – 2:30PM	Medical trips	Agency clients
Pearl Transit Corp.	Demand Response	M-Sun. 6:00AM-12:00AM	Education and employment trips	Low income, disabled residents
Puerto Rican Action Committee of Southern New Jersey (PRAC)	Demand Response	M-F - 9:00AM - 4:00PM	To employment/job training, medical facilities, social service offices in Atlantic, Cape May, Cumberland and Salem Counties	Agency clients and DFYS referred clients

8.11 Proposed PRT Network for Cumberland County

The PRT network we created for Cumberland County has approximately 432 stations and well over 200 interchanges. Our PRT network addresses the major shortcomings of the current model by increasing mobility and access to the major trip generators (i.e. schools, employment districts, shopping centers) and increases handicapped accessibility to these destinations. Current inadequacies such the lack of coordinated access to the Jersey shore are addressed as well. The core of the system is a network of interchanges which provide efficient, “one-way” flows across the county in both the North-South and East-West directions. Branching out from these interchanges, two-way tracks connect each station to the network via the nearest interchange. Reflecting the rural nature of the county, the majority of stations are focuses around more urban areas, specifically the municipalities of Bridgeton, Millville, and Vineland.

Though two-way tracks may create a logistical concern, they are favorable given increased functionality, speed, and simplicity of transport.

The core of our transportation system is a network of interchanges connected using a grid-like network of one-way flows across the county in both north-south and east west directions. The network utilizes "hub and spoke" configurations as well as two-way tracks to connect stations to the nearest interchange. We believe that the two way tracks in conjunction with the hub and spoke configuration will improve the speed and efficiency of the network as travelers will not be required to stop at each station along their journey will instead benefit from high-flow travel between interchanges. A major challenge of implementation is managing the size and complexity of the infrastructure. In addition, given the rural nature of Cumberland County, a truly feasible network will most likely consist of far fewer stations and nodes, relying instead on local hubs in rural regions drawing travelers from a region much larger than the quarter-mile recommendation, necessitating a Park and Ride System.

8.12 Images of Cumberland County PRT Design

Figure 8.9: A Close Look at the Cumberland PRT Network

Figure 8.10: PRT in Cumberland County

8.13 Trip Matrix Calculation

We generated our productions-attractions trip matrix for Cumberland County by analyzing data from a variety of sources. Home based trips were based not only on population density estimates but also work and industry data compiled from employment data and empirical data gathered during a recent study of the transportation network in southern New Jersey conducted by a private consulting agency. The empirical data detailed the number of commuter trips to and from each region of the county, providing a valuable check for our estimated figures.

Figure 8.11: Hub-and-Spoke Structure in PRT Network

Recreation, religious, and shopping trip numbers were determined through analysis of population statistics and utilization of the Google Maps hybrid floor space calculator functionality. In total, we estimated that in Cumberland County there would be an average of 590,950 trips per day on our PRT network, an average of 4.04 trips per person. This figure makes sense in accordance with national trip per day averages, validating our model.

8.14 Service

The PRT system proposed for Cumberland County services all major offices, schools, recreation facilities, shopping locations, religious facilities, housing, mass transport facilities, industrial locations, and public buildings. Stations are designed to be within 0.25 miles (a reasonable walking distance) from any regularly accessed location in the county. In addition, the PRT network we created for Cumberland County has both rural and urban stations. Because agriculture and farming are fundamental aspects to the Cumberland lifestyle and economy, we wanted to make sure to offer rural stations to increase connectivity between all regions. Local hubs and a Park-and-Ride system or some variation of a similar model would work well to link rural travelers to the main Cumberland County Personal Rapid Transit network.

The key contributions of a PRT network in Cumberland County are myriad—such a system would revolutionize the way citizens go about their daily lives. The key characteristics and benefits are:

- On-demand, origin-to-destination service - Travelers would board a waiting PRT vehicle at an originating station and be transported quickly and efficiently to a station conveniently located near their destination.
- Compact, comfortable, and automated vehicles - The PRT vehicles require no driver or conductor and would provide exceptional comfort and safety relative to current transportation options.
- Exclusive-Use Tracks - The elevated systems supporting the PRT vehicles must be designed to avoid intersection with pedestrians or other forms of vehicular transport. Traffic is a distant memory!
- Integrated switching - The PRT system would incorporate an intelligent operating engine that would bypass stations that are not current destinations of passengers, increasing speed and efficiency.

Although PRT systems on this scale are state-of-the-art and relatively untested, the benefits to Cumberland County stemming from the implementation of such a system are clear. Advanced travel, enhanced safety, on-board switching and navigation, and high speed all contribute to make PRT systems a next-generation paradigm for mass transit.

8.15 Final Recommendations

The data presented supports the conclusion that the majority of public transportation improvement in Cumberland County should take place in Bridgeton, Millville, and Vineland. These three municipalities exhibit the highest density of employees and places of employment while also containing the highest numbers of youths, senior citizens, and disabled persons, groups that tend to utilize public transportation options most frequently. In addition, employment projections show that 88.6 percent of new jobs will be created in these municipalities between 2000 and 2010, making transportation development even more attractive. The low density of work-force populations in the rest of the county lead us to the conclusion that there is not enough demand in regions other than the municipalities named above to support widespread implementation of fixed route public transportation service. However, a rational

form of a comprehensive PRT system would lead to significant improvements in the transportation infrastructure of Cumberland County.

8.16 Additional Information

Note in Figures 8.14 and 8.15 that the number of individuals who commute by transit includes those who take a taxi to work. This is significant because these people are most likely to take advantage of any new public transportation improvements.

Figure 8.12: Cumberland Residence by Employment (1 of 2)

Top Five Municipalities of Residence Location by Municipality of Employment

Employment Location	Residence Location		Total Workers	Commute by Transit
	Municipality	County		
Bridgeton	Bridgeton	Cumberland	1,955	55
	Vineland	Cumberland	790	4
	Upper Deerfield Twp.	Cumberland	625	10
	Millville	Cumberland	500	20
	Hopewell Twp.	Cumberland	460	0
Commercial Twp.	Commercial Twp.	Cumberland	330	0
	Millville	Cumberland	55	0
	Bridgeton	Cumberland	40	0
	Vineland	Cumberland	40	0
	Downe Twp.	Cumberland	25	0
Deerfield Twp.	Bridgeton	Cumberland	255	0
	Upper Deerfield Twp.	Cumberland	250	0
	Vineland	Cumberland	245	4
	Deerfield Twp.	Cumberland	240	0
	Pittsgrove Twp.	Salem	175	0
Downe Twp.	Downe Twp.	Cumberland	90	0
	Vineland	Cumberland	60	0
	Millville	Cumberland	45	0
	Fairfield Twp.	Cumberland	40	0
	Lawrence Twp.	Cumberland	25	0
	Commercial Twp.	Cumberland	25	0
Fairfield Twp.	Fairfield Twp.	Cumberland	250	0
	Millville	Cumberland	200	30
	Vineland	Cumberland	160	4
	Bridgeton	Cumberland	125	0
	Upper Deerfield Twp.	Cumberland	95	0
Greenwich Twp.	Greenwich Twp.	Cumberland	55	0
	Pittsgrove Twp.	Salem	10	0
	Alloway Twp.	Salem	4	0
	Stow Creek Twp.	Cumberland	4	0
	Upper Deerfield Twp.	Cumberland	4	0
	Vineland	Cumberland	4	0
Hopewell Twp.	Hopewell Twp.	Cumberland	230	0
	Bridgeton	Cumberland	190	0
	Millville	Cumberland	140	0
	Upper Deerfield Twp.	Cumberland	115	0
	Vineland	Cumberland	95	30
Lawrence Twp.	Lawrence Twp.	Cumberland	145	0
	Vineland	Cumberland	65	0
	Bridgeton	Cumberland	50	0
	Fairfield Twp.	Cumberland	30	0

Figure 8.13: Cumberland Residence by Employment (2 of 2)

Employment Location	Residence Location		Total Workers	Commute by Transit
	Municipality	County		
	Commercial Twp.	Cumberland	25	0
Maurice River Twp.	Maurice River Twp.	Cumberland	105	0
	Vineland	Cumberland	55	0
	Millville	Cumberland	50	0
	Lawrence Twp.	Cumberland	30	0
	Pemberton Township	Burlington	15	0
Millville	Millville	Cumberland	4,335	45
	Vineland	Cumberland	2,035	40
	Bridgeton	Cumberland	600	4
	Commercial Twp.	Cumberland	545	0
	Fairfield Twp.	Cumberland	330	0
Shiloh Borough	Lawrence Twp.	Cumberland	4	0
	Woodstown Borough	Salem	4	0
Stow Creek Twp.	Stow Creek Twp.	Cumberland	85	0
	Hopewell Twp.	Cumberland	35	0
	Vineland	Cumberland	30	0
	Greenwich Twp.	Cumberland	25	0
	Upper Deerfield Twp.	Cumberland	20	0
	Clayton Borough	Gloucester	20	0
	Pittsgrove Twp.	Salem	20	0
Upper Deerfield Twp.	Upper Deerfield Twp.	Cumberland	685	0
	Bridgeton	Cumberland	565	15
	Vineland	Cumberland	380	25
	Hopewell Twp.	Cumberland	230	0
	Millville	Cumberland	185	0
Vineland	Vineland	Cumberland	13,310	4
	Millville	Cumberland	3,450	125
	Bridgeton	Cumberland	1,345	65
	Pittsgrove Twp.	Salem	935	0
	Franklin Twp.	Gloucester	710	0

Source: Bureau of Transportation Statistics, CTP Package 2000 Part 3 – Journey to Work Tables

Figure 8.14: Cumberland Employment by Residence (1 of 2)

Top Five Municipalities of Work Location by Municipality of Residence

Residence Location	Employment Location		Total Workers	Commute by Transit
	Municipality	County		
Bridgeton	Bridgeton	Cumberland	1,955	55
	Vineland	Cumberland	1,345	65
	Millville	Cumberland	600	4
	Upper Deerfield Twp.	Cumberland	565	15
	Deerfield Twp.	Cumberland	255	0
Commercial Twp.	Millville	Cumberland	545	0
	Vineland	Cumberland	515	4
	Commercial Twp.	Cumberland	330	0
	Bridgeton	Cumberland	130	0
	Woodbine Borough	Cumberland	60	0
Deerfield Twp.	Vineland	Cumberland	310	0
	Deerfield Twp.	Cumberland	240	0
	Millville	Cumberland	155	4
	Bridgeton	Cumberland	135	0
	Woodbine Borough	Cumberland	65	0
Downe Twp.	Millville	Cumberland	130	0
	Vineland	Cumberland	130	0
	Downe Twp.	Cumberland	90	0
	Bridgeton	Cumberland	35	0
	Deerfield Twp.	Cumberland	30	0
	Hopewell Twp.	Cumberland	30	0
Fairfield Twp.	Vineland	Cumberland	400	0
	Bridgeton	Cumberland	330	0
	Millville	Cumberland	330	0
	Fairfield Twp.	Cumberland	250	0
	Hopewell Twp.	Cumberland	90	4
Greenwich Twp.	Bridgeton	Cumberland	70	0
	Greenwich Twp.	Cumberland	55	0
	Vineland	Cumberland	50	0
	Millville	Cumberland	40	0
	Upper Deerfield Twp.	Cumberland	40	0
Hopewell Twp.	Bridgeton	Cumberland	460	0
	Vineland	Cumberland	340	0
	Hopewell Twp.	Cumberland	230	0
	Upper Deerfield Twp.	Cumberland	230	0
	Millville	Cumberland	175	0
Lawrence Twp.	Vineland	Cumberland	285	0
	Millville	Cumberland	230	0
	Lawrence Twp.	Cumberland	145	0
	Upper Deerfield Twp.	Cumberland	70	0
	Bridgeton	Cumberland	65	0

Figure 8.15: Cumberland Employment by Residence (2 of 2)

Residence Location	Employment Location		Total Workers	Commute by Transit
	Municipality	County		
Maurice River Twp.	Vineland	Cumberland	490	0
	Millville	Cumberland	315	4
	Maurice River Twp.	Cumberland	105	0
	Woodbine Borough	Cape May	60	0
	Fairfield Twp.	Cumberland	60	4
Millville	Millville	Cumberland	4,335	45
	Vineland	Cumberland	3,450	125
	Bridgeton	Cumberland	500	20
	Fairfield Twp.	Cumberland	200	30
	Atlantic City	Atlantic	195	35
Shiloh Borough	Upper Deerfield Twp.	Cumberland	65	0
	Bridgeton	Cumberland	40	0
	Vineland	Cumberland	35	0
	Hopewell Twp.	Cumberland	25	0
	Deerfield Twp.	Cumberland	20	0
Stow Creek Twp.	Bridgeton	Cumberland	110	0
	Stow Creek Twp.	Cumberland	85	0
	Vineland	Cumberland	70	0
	Upper Deerfield Twp.	Cumberland	55	0
	Deerfield Twp.	Cumberland	50	0
	Hopewell Twp.	Cumberland	50	0
Upper Deerfield Twp.	Upper Deerfield Twp.	Cumberland	685	0
	Bridgeton	Cumberland	625	10
	Vineland	Cumberland	450	4
	Millville	Cumberland	305	0
	Deerfield Twp.	Cumberland	250	0
Vineland	Vineland	Cumberland	13,310	4
	Millville	Cumberland	2,035	40
	Atlantic City	Atlantic	885	195
	Bridgeton	Cumberland	790	4
	Upper Deerfield Twp.	Cumberland	380	25

Figure 8.16: Major Trip Attractions in Cumberland County (1 of 3)

Major Trip Generators

Site	Location	Category
Durand Glass Manufacturing	Millville	Major Employer
Alcan	Millville	Major Employer
Wheaton Science Products	Millville	Major Employer
General Mills/Progresso	Vineland	Major Employer
Kimble Glass	Vineland	Major Employer
Seabrook Brothers & Sons	Upper Deerfield Twp.	Major Employer
Silverton Marine Corp.	Millville	Major Employer
Kimble/Gerresheimer	Millville	Major Employer
Elwyn New Jersey	Vineland	Major Employer
Millville Industrial Park	Millville	Major Employer/Indus. Park
Vineland Industrial Park	Vineland	Major Employer/Indus. Park
Millville Airport	Millville	Major Employer/Indus. Park
Cumberland County Mall	Vineland	Retail Center
Landis Avenue	Vineland	Retail Center
Target Shopping Center	Millville	Retail Center
WalMart Shopping Center	Millville	Retail Center
WalMart	Upper Deerfield	Retail Center
High Street	Millville	Retail Center

Figure 8.17: Major Trip Attractions in Cumberland County (2 of 3)

Site	Location	Category
Carll's Corner (77 & 56)	Bridgeton	Retail Center
Intersection of 49 & 77	Bridgeton	Retail Center
OE&T One Stop Center	Vineland	Job Counseling/Training
OE&T Administrative Office	Bridgeton	Job Counseling/Training
Tri-County Community Action	Bridgeton	Job Counseling/Training
State Office Building	Bridgeton	Job Counseling/Training
Kintock Halfway House	Bridgeton	Halfway House
South Jersey Regional Medical Center	Vineland	Major Employer/Hospital
SJH Bridgeton Health Center	Bridgeton	Hospital
Seabrook House	Seabrook	Treatment Center
Cumberland County College	Vineland	College/Vocational School
CC Technical Education Center	Bridgeton	College/Vocational School
Bishop McCarthy Residence	Vineland	Nursing/Assisted Living
NJ Veterans Memorial Home	Vineland	Nursing/Assisted Living
Cumberland County Medical Center (Manor)	Hopewell	Nursing/Assisted Living
Millville Center-Genesis Elder Care	Millville	Nursing/Assisted Living
Lincoln Specialty Care	Vineland	Nursing/Assisted Living
Renaissance Nursing Center	Bridgeton	Nursing/Assisted Living
Baker House	Vineland	Nursing/Assisted Living
Maurice House	Millville	Nursing/Assisted Living
Goldfinch House	Bridgeton	Nursing/Assisted Living
Spring Oak Assisted Living	Vineland	Nursing/Assisted Living
Millville Housing Authority	Millville	Nursing/Assisted Living
South Jersey Extended Care	Bridgeton	Nursing/Assisted Living
Alzheimer's Daycare Center	Vineland	Nursing/Assisted Living
Senior Care of Vineland	Vineland	Nursing/Assisted Living
Bridgeton Senior Center	Bridgeton	Senior Center

Figure 8.18: Major Trip Attractions in Cumberland County (3 of 3)

Site	Location	Category
Commercial Township Senior Center	Port Norris	Senior Center
Deerfield Township Senior Center	Rosenhayn	Senior Center
Downe Township Senior Center	Newport	Senior Center
Fairfield Township Senior Center	Fairton	Senior Center
Fiorilli Senior Center	Vineland	Senior Center
Lawrence Township Senior Center	Cedarville	Senior Center
Upper Deerfield Senior Center	Seabrook	Senior Center
Maurice River Township Senior Center	Leesburg	Senior Center
Millville Senior Center	Millville	Senior Center

Source: Cumberland County Improvement Authority

Chapter 9

Essex County

Established in 1682, Essex has evolved into an industrial and financial center of New Jersey. Its extensive networks of rail lines and highways connecting to Newark Liberty International Airport, Penn Station and to Port Newark are certainly assets for its economic growth and attraction of major national firms. In point of fact, there has been an economic shift from a manufacturing-based economy to more of corporate/service oriented economy, which would perhaps increase commuter traffic through the county (Corporations such as Prudential now have headquarters in Essex). Indeed the already robust rail transportation network in place as well as a high volume of commuters would make Essex an excellent location for a PRT network. The PRT network would carefully work in conjunction with existing mass transit to allow for more fluid connections between transportation modes and reduce highway traffic to whatever degree possible. Unlike other counties in New Jersey, Essex does not have a dire mass transit system in place; yet the system in place must be reachable from all over the county in order to be truly effective, something a PRT network could facilitate.[1]

Essex County has a total population of 793,633 people. Its total area is 130 square miles, of which 126 square miles are land. Essex's population density is 6,286 people per square mile and is comprised of 21 counties, with Newark as the county seat. The following is a quoted summary of statistics based on recent census data: "Essex County is the second most densely populated county in the state after Hudson County, and has the second largest total population after Bergen County. Newark, with a population density of 11,400 people/square mile, is the largest municipality in the county both in terms of area (24.14 square miles) and population (280,000). Meanwhile, Caldwell is the smallest in terms of land area (1.2 square miles) and Roseland has the smallest population (5,298); nevertheless, even these small towns have population densities (6,396 people/square mile and 1,464 people/square mile, respectively) that rival many big cities, and are well above the state's average, which in turn is the highest in the nation."[2]

Socioeconomically, Essex can be characterized by a noticeable discrepancy between its more affluent, suburban western section and its poor, inner-city eastern section. As one might expect, the eastern section is significantly more urbanized than the western section, accounting for the eastern section's higher building density. "In the 2000's, Newark [one of east Essex's most prominent cities] led the state in the issuance of building permits. Many reasons were cited: city-wide incentives to encourage construction development, an improving local economy, the rising demand of low-cost housing so close to Manhattan. Newark has since then become one of the fastest growing cities in the entire Northeast."[3] Hence, in recent years, poverty and crime have subsided a bit, although both continue to be a problem for the city. West Essex has a quainter, more spread-out, residential flair, which is reflected in the design of the PRT system for this county.

Essex's primary attractions, as measured by our trip number projections, are Rutgers University, Seton Hall, Newark Liberty International Airport, Essex County Airport, and Port Newark-Elizabeth Marine Terminal.

For our PRT projections, we anchored our assumptions in the data found in Essex's 2000 Census data, shows in Tables 9.1, 9.2, and 9.3.

As we can see from Table 9.4, Essex saw tremendous population growth during the beginning of the twentieth century. The population growth has recently tapered off due to a gentrification effect in increasingly wealthy West Essex. The steadying population size indicates that our trip generation numbers will not become obsolete solely due to continued population growth.

As for existing transportation rubrics in Essex County, there are very active rail lines, such as the Morristown

[1] http://www.co.essex.nj.us/
[2] http://en.wikipedia.org/wiki/Essex_County%2C_New_Jersey
[3] http://en.wikipedia.org/wiki/Essex_County%2C_New_Jersey

Figure 9.1: Map of Essex RoadwaysSource: http://en.wikipedia.org/wiki/Essex_County%2C_New_Jersey

Table 9.1: People QuickFacts for Essex CountySource: http://quickfacts.census.gov/qfd/states/34/34013.html

People QuickFacts	**Essex County**	**New Jersey**
Population, 2006 estimate	786,147	8,724,560
Population, percent change, April 1, 2000 to July 1, 2006	-0.8%	3.7%
Population, 2000	793,633	8,414,350
Persons under 5 years old, percent, 2006	7.3%	6.4%
Persons under 18 years old, percent, 2006	26.0%	23.9%
Persons 65 years old and over, percent, 2006	11.5%	12.9%
High school graduates, percent of persons age 25+, 2000	75.6%	82.1%
Bachelor's degree or higher, pct of persons age 25+, 2000	27.5%	29.8%
Persons with a disability, age 5+, 2000	158,244	1,389,811
Mean travel time to work (minutes), workers age 16+, 2000	31.2	30.0
Housing units, 2006	308,723	3,472,643
Homeownership rate, 2000	45.6%	65.6%
Housing units in multi-unit structures, percent, 2000	61.7%	36.1%
Median value of owner-occupied housing units, 2000	$208,400	$170,800
Households, 2000	283,736	3,064,645
Persons per household, 2000	2.72	2.68

Table 9.2: Business QuickFacts for Essex CountySource: http://quickfacts.census.gov/qfd/states/34/34013.html

Business QuickFacts	**Essex County**	**New Jersey**
Private nonfarm establishments, 2005	20,369	242,128
Private nonfarm employment, 2005	311,491	3,594,862
Private nonfarm employment, percent change 2000-2005	-4.7%	1.3%
Nonemployer establishments, 2005	49,425	573,134
Total number of firms, 2002	62,660	708,837
Manufacturers shipments, 2002 ($1000)	8,764,447	96,599,807
Wholesale trade sales, 2002 ($1000)	18,657,856	256,925,492
Retail sales, 2002 ($1000)	6,213,743	102,153,833
Retail sales per capita, 2002	$7,802	$11,910
Accommodation and foodservices sales, 2002 ($1000)	1,000,271	15,715,595
Building permits, 2006	3,284	34,323
Federal spending, 2004 ($1000)	5,727,450	55,264,350

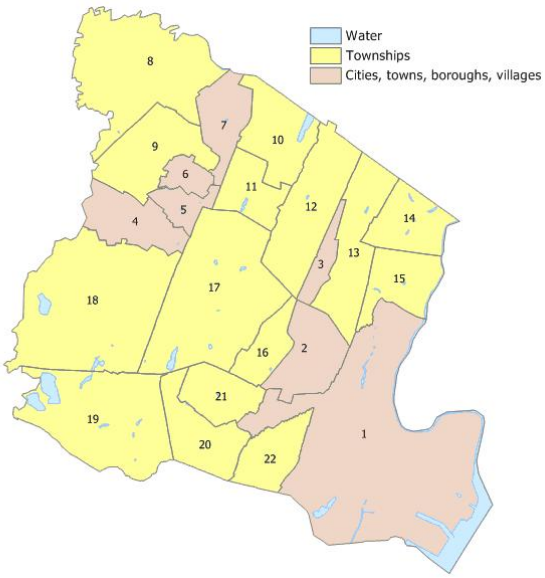
Table 9.3: Geography QuickFacts for Essex County
Source: http://quickfacts.census.gov/qfd/states/34/34013.html

Geography QuickFacts	**Essex County**	**New Jersey**
Land area, 2000 (square miles)	126.27	7,417.34
Persons per square mile, 2000	6,298.7	1,134.5
FIPS Code	013	34
Metropolitan or Micropolitan Statistical Area	New York-Northern New Jersey-Long Island NY-NJ-PA Metro Area	

Table 9.4: Essex County Population Growth
Source: http://en.wikipedia.org/wiki/Essex_County%2C_New_Jersey

Census	**Population**	**% ±**
1800	22,269	25.20%
1810	25,984	16.70%
1820	30,793	18.50%
1830	41,911	36.10%
1840	44,621	6.50%
1850	73,950	65.70%
1860	98,877	33.70%
1870	143,839	45.50%
1880	189,929	32.00%
1890	256,098	34.80%
1900	359,053	40.20%
1910	512,886	42.80%
1920	652,089	27.10%
1930	833,513	27.80%
1940	837,340	0.50%
1950	905,949	8.20%
1960	923,545	1.90%
1970	932,526	1.00%
1980	851,304	-8.70%
1990	778,206	-8.60%
2000	793,633	2.00%
Est. 2006	786,147	-0.90%

Figure 9.2: Map of Essex Municipalities



Line and Newark's subway system. Newark Penn Station is an extremely active rail pivot point, through which many NJ Transit lines run. Such rail lines also see tremendous through-traffic induced by Newark International Airport, some of whose statistics are listed in Table 9.6.

Essex has 1,673 miles of public road, much of which is obviously consumed with traffic. The breakdown of mileage is as follows (in miles): Municipal road: 1,330, County road: 233, State Highway: 59, Interstate: 27. The PRT network is designed to reach the innermost points of Essex County and account for all 21 municipalities and thus reduce traffic on the Municipal and County roads, those of which make up the bulk of the public roads in Essex. Individuals who wish to travel on these roads for any multitude of reasons may now find it more convenient to reach destinations within the county via PRT. We also suspect that traffic will somewhat be alleviated on the state highway and interstate since commuters living within Essex may opt to use PRT to connect to mass transit (obviously other users of the state highway or interstate may just be passing through and would not consider using PRT).[4]

Our proposed PRT system for Essex would greatly help reduce the current mean travel time to work of 31.2

[4] http://www.co.essex.nj.us/

Table 9.5: Map of Essex Municipalities, Key

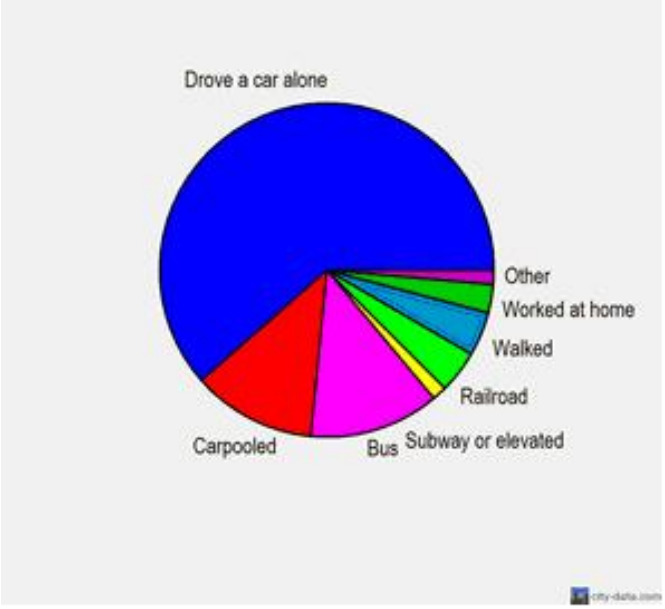
Index	Name
1	Newark
2	East Orange
3	Glen Ridge
4	Roseland
5	Essex Fells
6	Caldwell
7	North Caldwell
8	Fairfield Township
9	West Caldwell Township
10	Cedar Grove Township
11	Verona Township
12	Montclair Township
13	Bloomfield Township
14	Nutley Township
15	Belleville Township
16	City of Orange Township
17	West Orange Township
18	Livingston Township
19	Millburn Township
20	Maplewood Township
21	South Orange Village Township
22	Irvington Township

Table 9.6: Newark Liberty Airport StatisticsSource: http://panynj.gov/aviation/ehisfram.htm

Year	Passengers	Air Cargo (tons)	Air Mail (tons)	Plane Movements
1949	834,916	40,574	2,891	93,463
1960	2,935,613	58,313	10,557	163,378
1970	6,460,489	157,301	37,401	204,595
1980	9,223,260	107,167	38,227	196,781
1990	22,255,002	495,407	61,351	379,653
1995	26,623,803	958,419	84,818	420,520
1997	30,915,857	1,068,590	120,026	462,348
1998	32,620,671	1,086,460	120,134	455,685
1999	33,297,136	1,060,492	123,079	455,552
2000	34,188,702	1,070,379	123,013	450,288
2001	30,500,000	786,660	90,500	436,420

minutes, measured as a weighted sum of the distribution of the various transportation modes used for commuting.[5] As we can clearly see from the pie chart below, 73% of commuters opt to travel by car to work, with 61% of commuters opting to drive a car alone. Hence, personal automobiles are by far the most predominant means of transportation in Essex. "While many residents commute to New York City, Organon, Anheuser-Busch, Automatic Data Processing, Inc., CIT Group, Hoffmann-LaRoche, Grainger, Dun & Bradstreet and Prudential have large facilities in Essex County or are headquartered there, and there are numerous factories and large office parks scattered throughout."[6] PRT should expedite the commuting process, especially if implemented in such a way that favors those employment destinations with the largest number of employees. For example, PRT might make more trips to a large factory than to a startup consulting firm. According to the 2000 census above, Essex has 62,660 firms. 62,660 such priority gradations may be an excessive feature to program into PRT routings; however, 20 to 30 priority buckets seems like a practical implementation to effectively slash down commuting time and associated congestion. As it stands, public transportation is particularly underutilized in Essex County. Hence, a well-designed PRT system would be ripe to convince commuters to switch out of economically, environmentally, and temporally taxing personal transportation means. The routings of such a PRT would be designed to most heavily weight the schedules of commuters and students, who have less flexibility in avoiding the rush hour gridlock than do recreation-seekers and shoppers.

Figure 9.3: Mode of Transportation to Work in Essex County, NJ



PRT would also benefit the travel experience of students. Essex has 95,660 enrolled in schools in grades 1 to 8, 14.7% of which attend private schools. Essex has 47,396 enrolled in schools in schools grades 9 to 12, 14.9% of which attend private schools. Essex has 38,361 enrolled in schools in undergraduate colleges, 35.2% of which attend private schools.[7] Hence, a significant percentage of Essex's population makes a daily round trip to get to and from an academic venue. As it stands, elementary through high school students usually are driven by car or school bus to and from school. PRT has the potential to improve upon these modes of student transportation. Fewer trips would be needed, ameliorating congestion and decreasing polluting gas emissions. These factors make PRT preferable to existing transportation modes. However, to further convince worrisome parents, PRT will be equipped with supplementary safety features and will not make extraneous stops that may put young children at risk in unsafe environments.[8] And, as for college-age students, PRT prevents the possibility of drunk driving, a prospect both parents and undergraduate administrators would appreciate. In fact, administrators may appreciate this notion so much as to provide university-granted funding for further research/design/construction of a PRT system.

In Essex County, it is clear from our analysis and relevant statistics that many citizens commute out of the county into New York City. Therefore, our conception of PRT for these commuters could help facilitate their

[5] http://www.city-data.com/county/Essex_County-NJ.html
[6] http://en.wikipedia.org/wiki/Essex_County%2C_New_Jersey
[7] http://www.city-data.com/county/Essex_County-NJ.html
[8] This idea was partially inspired by the work done by the folks from Professor Kornhauser's 2005 transportation class.

out-of-county commute. For example, PRT may take a worker from his/her home to the nearest subway system or railroad transporting commuters to their ultimate destination.

As for other attractions in the county, the PRT system would be particularly well-suited for shoppers and recreation-seekers. Into our PRT system, we built in a variety of restaurant attractions, and perhaps certain PRT routes could be biased towards a tour of Chinese restaurants, for example. Additionally, Hudson County has two enormous shopping hubs: Livingston Mall and Short Hills Mall. According to our output for expected trip number, these two attractions draw tremendous numbers of shoppers. The PRT system would be well-suited to handle such shoppers. One idea is to have a maximum number of passengers on PRT's *to* the mall which exceeds the maximum number of passengers on PRT's *from* the mall. The idea here is that when traveling to the mall, a passenger has no cargo. However, after a healthy dose of shopping, a passenger might have many bags. In any case, we made an effort to ensure that there are PRT stations serving many of the aforementioned POI locations.

It should be noted that there are some areas in Essex where PRT stations appear to be clustered together and thus may be perceived as a design flaw. While it is obviously not economical to have seemingly independent stations right next to each other, we must realize that any of these PRT stations is likely to see a tremendous amount of commuter traffic through the station and simply putting one station down may be wholly insufficient in dealing with potential PRT demand. While our maps currently propose having certain stations right next to each other, we could instead use the POIs that make up the stations' locations to be a proxy for where we would put a very large station. Hence the cluster of PRT stations currently shown could instead be interpreted as a magnitude calculation for the size of the station needed in that vicinity. In addition, the choice of certain points of interest may seem somewhat bizarre for a station location; for instance, a local Italian restaurant may not appear to be the best location to have a station, yet it demarcates an area likely filled with other businesses, who in aggregate, would be a fine candidate for a PRT station.

That said, since we already account for the surrounding POIs within a quarter mile radius when we derive our attraction numbers (which is why they may seem a bit high in areas), some efforts could be put forth to remove clustered stations. The issue is that we describe the process of getting attraction numbers as being one that accounts for the surrounding areas; this assumes no other stations within the immediate area, which is inaccurate for these clusters. We attempted to create an excel function to measure distances between stations to determine whether or not some were excessive; we ran into issues dealing with the different possible geometric configurations of the stations and the resulting logic decisions. We believe that such a function that could aggregate POIs that are within a certain distance of each other would be an extremely useful tool in consolidating station locations. As we mentioned before, the cluster of stations indicates that this is an area of high traffic—we could, however, just keep one of the stations and utilize the average trip attraction numbers of the stations since all are within a quarter mile radius of each other. This, we believe, may help reduce the excess number of PRT stations in some areas and give more realistic numbers for the total number of trip attractions since we will no longer have the issue of overlapping station coverage areas. That said, we stand by our numbers as our POIs were geographically selected at random, and due to the fairly consistent land use patterns within the county, the numbers associated with a station in a cluster may be preserved if this station were moved out sufficiently. Thus as described below, we do not believe this will impact the economics of the PRT systems, it just may make them look a little more polished.

We have also put forth a significant effort to try to ensure that there are stations in every municipality in Essex

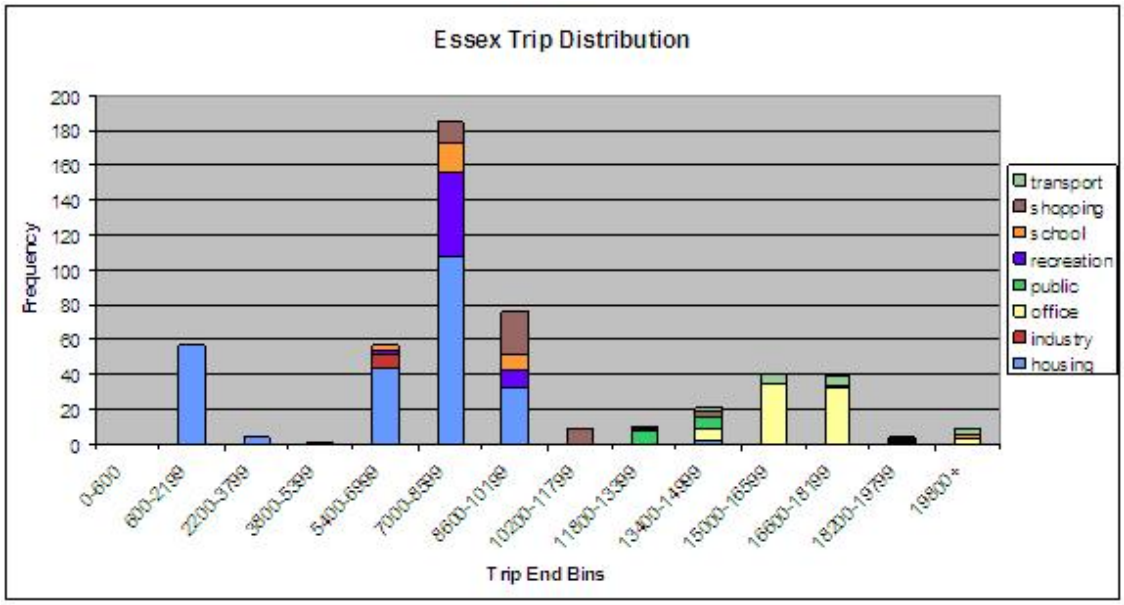
Table 9.7: Means of Transportation to Work

Means	**Number (Percent)**
Drove a car alone	201,772 (61%)
Carpooled	39,295 (12%)
Bus or trolley bus	41,473 (13%)
Streetcar or trolley car	76 (0%)
Subway or elevated	4,544 (1%)
Railroad	13,651 (4%)
Ferryboat	49 (0%)
Taxi	1,292 (0%)
Motorcycle	37 (0%)
Bicycle	498 (0%)
Walked	13,922 (4%)
Other means	2,399 (1%)
Worked at home	9,106 (3%)

to ensure maximum mobility. The nature of our search for POIs had lead us to have clusters of areas where we perceive for there to be significant demand, although it is quite possible demand may be slightly more uniform across the county. Efforts to improve our PRT network design would certainly begin with an effective means of getting dispersed POIs that would serve as proxies for station locations. This would most easily be accomplished by individuals with a clearer sense of major and relevant locations within the county. We were able to find additional station locations by analyzing the Google Map in hybrid mode to find what appeared to be relevant locations in areas within Essex that did not appear to be properly served by the PRT network.

9.1 Histogram Analysis

Figure 9.4: Trip Distribution in Essex County



The following is a description of the distribution of PRT stations by attraction size in Essex (please see Figure 9.4). In Essex, most stations were placed in areas with multiple attractions within a quarter of mile, which would result in nice size attraction numbers for the respective stations. If we analyze the bar graphs specifically, we see that our most "low volume" stations are housing POIs in the more diffuse Western Essex region. Several of these low volume stations cover the more luxurious housing areas, but housing areas that are still relatively close to other possible attractions. We feel that the PRT network should obviously not leave any particular demographic completely out of the picture and thus, we stand by these relatively low volume stations.

Towards the middle of the graph, we see a spike in PRT stations where attraction levels are between 5,600 and about 10,000 trip ends per day. These are composed primarily of more dense housing (think Newark), shopping, recreational and school POIs that get many attractions for the spillover from other attractions within the quarter mile radius. As discussed earlier, when we find recreation POIs, we analyze them on Google Earth to determine, based on the parking lot infrastructure and other factors, the relative attraction size. The denser housing may be found in more urbanized areas as well as housing areas surrounded by other establishment types (determined using Google Earth Hybrid Mode). Our goal was to get PRT stations in fairly attraction dense areas which is why there is a preponderance of PRT stations in this attraction range—we would like to get our money's worth for our network.

Finally, we have one last spike in PRT stations with attractions between 15,000 and 18,000 trip ends per day. As we see from the graph, these are primarily office facilities (hospitals and large office spaces determined via Google Earth). These office spaces also may also directly come into direct contact with consumers (shopping centers) and thus have their numbers around 15,000 attractions per day. Again many of these office areas are around urbanized areas, which contribute to their high volume of traffic since they are in such dense areas. As expected, our right tail tapers off substantially for stations with trip end attraction levels above 18,200. Our highest volume stations in terms of daily attractions (we see as 19,800+) are several universities and the major existing transportation infrastructures associated with Newark and its airport (these hover and exceed 20,000 attractions per day). Rutgers

and Seton Hall are two universities with well over 10,000 students and staff who would undeniably make great use of the PRT network—we have already described why students would find it so useful—university staff, meanwhile, will also look for a more efficient means of mass transportation to get back and forth to work. The largest PRT stations by attraction numbers are NJTransit Newark Penn Station and NJTransit Newark International Airport (cover roughly 25,000 trip ends a day). These PRT stations would likely serve many other New Jersey residents in other counties who will use their PRT network to go to the airport or to connect to go to Penn Station (since the PRT network is in fact in place for the entire state of New Jersey). The daily traffic through these transportation stations is staggering and the ease of PRT may make travelers consider using them as an efficient means to connect to their airport shuttles.

Now looking at the histogram on a macro scale, we see a fairly nice "bell curve" with the exception of the last mini-spike which is noticable due to high office trip ends. We see the bump of the bell is around stations with about 8,000 in daily trip ends served per day—this indicates that a lot of our stations are getting good use!

9.1.1 Snapshots of Major Stations

Figure 9.5: NJ Transit—Newark Penn Station
Right Adjacent to the PATH Train as well (the icon in the sent of the screen shot)

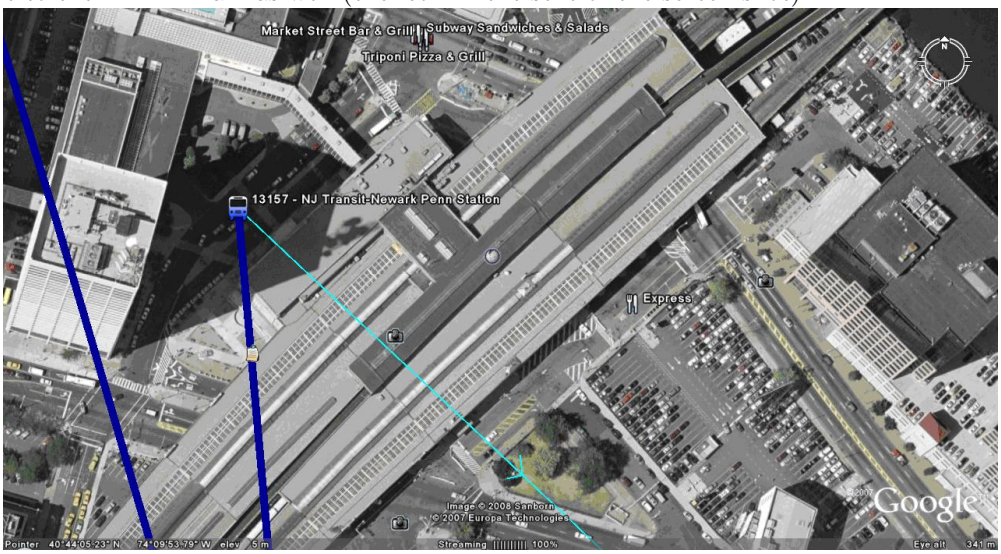


Figure 9.6: NJ Transit—Newark International Airport

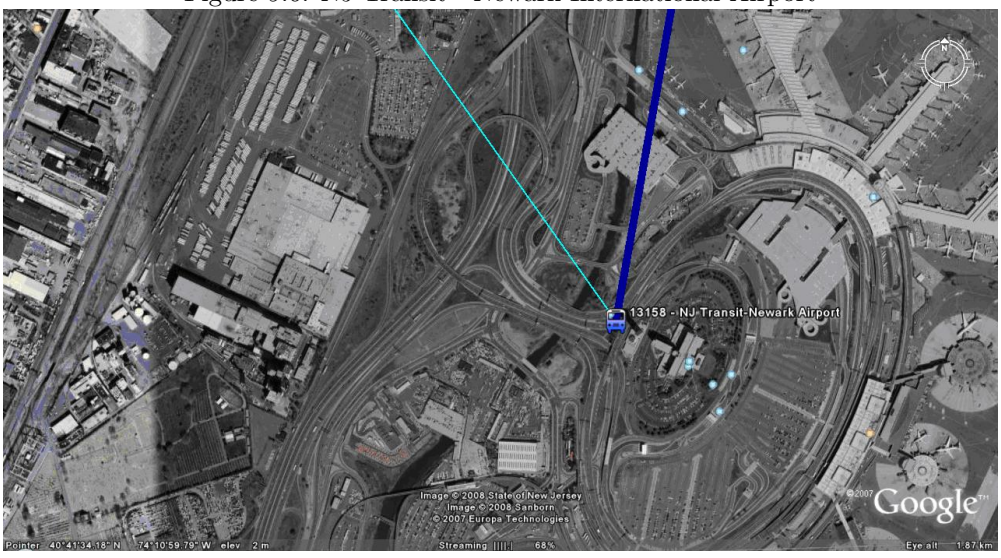


Figure 9.7: Seton Hall University

Figure 9.8: Livingston Mall

9.1.2 Snapshots of Network

Figure 9.9: South-East Essex (Newark)

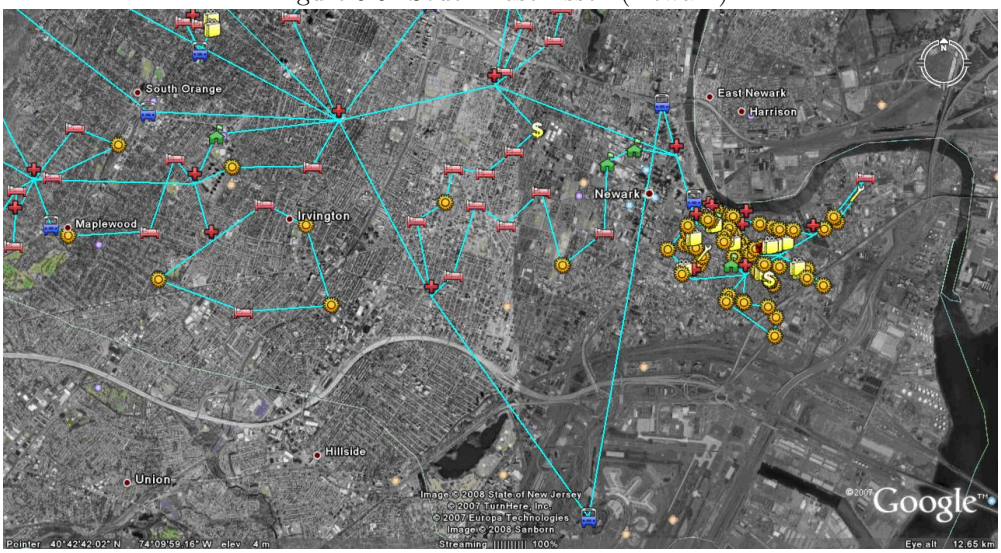
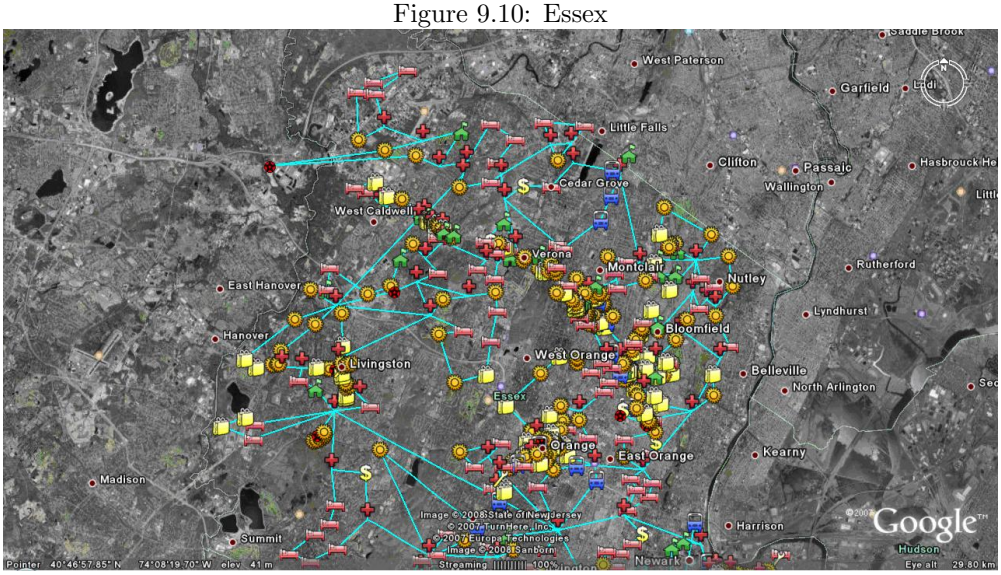


Figure 9.10: Essex



9.1.3 Cost Projections

One of the keys of getting any PRT network off the ground is to have a sound understanding on the likely costs. As of now, we will consider the costs of the guideway stations, and cars and explain any changes that may minimize these costs. As of now, all of our counties have guideway that extends to every area within the county—thus we feel that even with a modified network, our amount of guideway should already give an excellent prediction of what is needed to fully serve the county. As for stations, as described earlier, we do have some clusters of stations which may on the surface appear wasteful but can be thought of in several ways: One way to think of a cluster of stations is that they indicate the need for a superstation and hence the cost would likely be several multiples of a single station cost (perhaps similar to the number in the cluster). A second way to consider this is to imagine that since the POIs were selected geographically at random, since many of the counties have areas with consistent land use patterns, a station placed in a cluster could well serve the same number of trip attractions if it were indeed moved somewhere else. Thus using this logic, we will also use the number of stations currently down as a proxy for the total number of needed stations for cost purposes (even if the network gets modified at some point). As for cars,

we utilized a special formula not discussed here to get the cost of cars (we assume average trip length, though to be 7.5 miles rather than 10 miles):

Cost of Guideway: 295.35 Miles * $5 million/mile = $1,476 million

Cost of Stations: 512 Stations * $2.5 million/station = $1,280 million

Cost of Cars (ascertained using an excel file described in our leader's report): $10,484 million

Total Cost: $1,476 million + $1,280 million + $10,484 million = $13,241 million

9.2 Overview of Trip Number Generation

In order to get a feel for the county, we first scavenged the website www.yellowbook.com for a broad array of the county's points of interest (POIs). This website breaks down the county's attractions in a fairly granular fashion. For the purposes of designing our proposed PRT System for the county, we limited our categorizations to the following: 1) housing; 2) industry; 3) recreation; 4) school; 5) shopping; 6) public; 7) office; 8) transport. We wrote a Microsoft Excel 2003 macro to sweep out entire attraction entries into a spreadsheet appropriately formatted for the geocoding process in which we labeled each attraction as one of these 8 location types. Constructing this tool allowed us to efficiently harvest over 500 POIs.

There were various keywords we elected to use when searching for our POIs. Of note, when searching the yellowbook, we searched for housing under "apartments," "housing," and "hotels." To help beef up our housing POIs, we also used recreational POIs found in yellow book as proxy for medium dense housing locations (only to be reclassified once examined on Google Earth) since it would be more reliable than just picking home addresses at random. For office, we chose the indirect route of searching "wholesalers and distributers" under shopping, since these POIs would not necessarily be in direct contact with the consumer. In addition, facilities that sounded more like plants or production facilities were labeled as industry. We would use general department stores as shopping attractions, despite also doubling as an office. Lastly, the majority of our transportation POIs were found directly on NJTransit and PATH train websites (AMTRAK is not explicitly accounted for but since the stations may overlap, we do try to account for the trip attraction). We very much keep these overlaps in POI types in mind when we come up with our trip attraction numbers.

In truth, one's success with harvesting quality, relevant and disperse POIs is essential for creating a quality PRT network. Our yellowbook searches were somewhat successful in identifying POIs but did not necessarily give us the most relevant or popular locations. Moreover, there was no real way to ensure a proper distribution of the POIs across each of the counties. What we wound up doing is: once we had our POIs plotted on the map, we would literally look at the map to find additional POIs that would enable our PRT network to service more of the county and keep a vast majority of individuals within a fair walking distance from a station. As mentioned earlier, a revised PRT design would require careful choosing of POIs as proxies for stations by unbiased individuals who understand the respective counties.

In any case, after undergoing the geocoding process to get latitude/longitude coordinates, we decided to employ a homemade algorithm to estimate approximate trip numbers for each of these attractions. As a rough rule, we figured that trip magnitude by location would occur in the following ascending order: [housing, industry, recreation, school, shopping, public, office, transport]. Hence, this ordering gave us relative logic about the expected trip number for the elements of location type. Below, we will describe the exact methodology for formulating these absolute expectation levels.[9]

Before getting to the detailed, idiosyncratic reasons behind each expectation for this county, we provide a few further notes on the trip number generation algorithm. Hence, for the time being, we assume expectation values for each location type. Surrounding each expectation, we wanted to simulate a reasonable level of variance. Using our intuition and actual findings of the relative orderings, we selected the following variance bound levels in brackets for each location type, for example: housing [8%]; industry [9%]; recreation [10%]; school [11%]; 5) shopping [12%]; public [13%]; office [14%]; transport [15%] These increasing percentages of variance represented our desire to somewhat amplify the magnitude of variance for the higher trip-number attractions, as we believed higher numbers in this context should bear higher variances on both an absolute and a percentage basis.

We then crafted our variance randomizer. The rand() function in Excel takes on values from 0 to 1. Hence, to randomize the absolute value of variance up to the respective bounds specified above, we multiplied the maximum absolute value of variance bound by 2 * (rand() - .5), to ensure a uniformly sampled variance within the specified bounds. In the end, our lookup algorithm spat out randomized trip numbers for each attraction by going through

[9]Please note that many of these heroic assumptions in our analysis are open for discussion; however, we felt that taking a stab and formulating a robust suite of assumptions would yield the more earnest analysis and be the most useful exercise in PRT design.

the processes described above.[10]

Although we stand by the theoretical framework we imposed in order to come up with our randomized trip numbers, we also realized the need to temper computing/simulation powers with human intuition. Therefore, after the algorithm spit out suggested trip numbers, we then reviewed each of them to look for obvious outliers. Although we were comfortable accepting the majority of the simulated trip numbers, there were obvious exceptions that we corrected. For example, K-Mart and the local garment boutique both squarely fall under the "shopping" category. However, K-Mart undoubtedly attracts multiples more shoppers and therefore needs to be assigned a much higher trip number than the local garment boutique. The heterogeneity of POIs within a given category type thus necessitates extensive human oversight to ensure that very different POIs within a certain category get treated differently. In summary, trip numbers for every attraction underwent technological simulation and then human correction.

9.3 Overview of Absolute Expectation Levels

The actual expected value for the trip attractions is based on a bit of intuition and the US Census data (updated as recently as 2006). We must also note a few of our underlying assumptions that would make the calculation of some of these numbers tractable. While we were certainly able to nail down many of the NJ Transit POIs, the gathering of our shopping/recreation/housing/office/industry are but a small sample for each county. Since there is no real means of knowing what precise fraction of each type we have, relative to the total number of the aforementioned POI types, dividing the total demand for a given POI type by the total population size of each county would not give an accurate trip attraction value for just that POI. Rather, we assume that certain POI types are often aggregated in certain areas; meaning that one shop may be in a quarter mile range of other stores and different POI types and we therefore use what may appear to be inflated trip attraction numbers. This also goes back to the notion of the overlapping POI types—an office can be a store and so forth. Thus to be precise, when we speak of the number of POI trip attractions, we speak of the number of attractions that specific POI and the entire surrounding areas provide (again we do not have every POI in every county!)

Our natural starting place for getting our trip attraction numbers was to first establish a baseline for *housing* attractions numbers. While intra-county density may vary, our housing POIs appeared similar in style (mostly dense collection of houses or condos) and thus we used the county-wide density numbers as a proxy for how many people we would have per square mile. We then multiplied this by a quarter mile radius circle area to get the total number of people living in an area that would be serviced by a housing attraction. Again in many instances, housing is surrounded by housing and thus an assumption of homogeneity in some cases is not too far off (we deal with housing in cities on a more case by case basis). We assume each person living in a house makes about 4 one way trips a day (slightly more in more urban area) and from that, we are able to extract one way trip demands (what we use as attraction numbers). For housing areas seen around recreational POIs (another means of how we found housing areas), we accounted for the increased density as seen on the Google Earth maps.

We next tackle the questions of *schools* by using a similar logic to what we used in a city design assignment. We use census data to determine the number of people under the age of 18 and use that as a means of calculating the number of students, which we subsequently multiply by the number of one way trips to these school facilities (note: 1 trip relates to 2 trips ends). We must note that many of our categorized school are indeed specialty schools (music, hair-design, ect.) and we therefore look up the number of students specifically for larger high schools (http://schooltree.org/). While universities are also categorized as schools, their trip attraction values are significantly higher than all other schools. We looked up the total enrollment at nearly each major community college and university to get our trip attractions. We believe colleges to be a real hot bed for PRT demand; not only are they comprised of many facilities with many workers, but they also have many students who need a means of transport, and administrations who might look very favorably upon a PRT system.

The issue of finding attractions for *offices* was at first a bit challenging to us. Unfortunately, finding offices in the yellow book by searching just that did not produce a lot of results and thus many "office" POI labeling were somewhat discretionary (with exceptions of course). Since we did not have proper data for the total number of offices in each county to go along with the total number of workers, we did not take the number of workers divided by the number of office POI to be a proxy for the number of workers in an office. Instead we sought to find the density of offices and assumed that these offices are like dense housing units—people at work leave to get lunch

[10]The rand() function in Excel samples from a pseudo-random distribution. Although the degree of randomness of Excel's sampling process is not perfect, we genuinely believe it was sufficient for our purposes. However, it is not clear to us when our variance randomizer should have sampled from a uniform distribution, a Gaussian distribution, or some kind of fat-tailed distribution. Nonetheless, we opted for a uniform distribution to ensure that we had a healthy level of sampling even towards the bounds of each attraction's variance tolerance.

just as people at home leave to do errands. From US Census "Quickfacts", we were able to find the number of private non-farm establishments and employees to get a rough estimate of the number of workers in an office. This works out well because public institutions will be considered under the POI type of public and therefore not be considered an office. We also assume that office workers make roughly the same number of trips as people at home. Lastly we assumed that offices were mostly surrounded by homes (again with some major exceptions) and thus we would consider the office trip attractions to be

$$\alpha_{\text{office}} = (.75) \times \alpha_{\text{home}} + (0.25) \times \left(\frac{\rho_{\text{office}}}{\rho_{\text{home}}} \right) \times \alpha_{\text{home}} \tag{9.1}$$

where ρ_{office} is the office density described, ρ_{home} is the number of persons per household (census value) and α_{home} is the expected housing trip attraction value. We use similar formulas in other calculations and wanted to give the reader a taste here. In areas where this formula produced poor looking numbers, we did an estimation based on the Google Earth Hybrid view (parking lot size, building size).

We next dealt with *recreation* and *shopping* which we considered to be similar attraction types. Both recreation and shopping POIs were mostly small to medium sized establishments (restaurant boutiques etc) with a few very large exceptions (malls, parks, stadiums). Since we found that our distribution of the sizes of the POIs was similar across both recreation and shopping (and for good measure, considering some people find shopping recreation), we employed similar techniques for coming up with the number of attractions. As was the case with offices, we also realize that most store and recreation establishments are surrounded by more stores/recreational establishments and housing. We also were careful to assume that different people types (children, elderly, workers, non-workers) had different average trips numbers to these establishments (as we did in a city design project). We then made an estimate of the number of recreation/shopping establishments in each of the counties that we thought would be visited and then made an assumption of how many would be within a quarter mile based on Google Earth imagery. This gave us an order of magnitude number that we used as a baseline for daily trip ends. We then looked at a sample of recreation/shopping facilities on Google Earth to get a better idea of how many people seemed to be in and around the attraction area (see also the different POI types that make up the rest of the quarter mile radius). We noticed on the whole that many shopping/recreation POIs were surrounded by more shopping/recreational POIs and by housing. We then got our final attraction numbers by taking a weighted average of the attraction for a quarter mile circle by saying 75% of the area comprised of housing (with exceptions) and 25% of the area comprised of recreation/shopping POIs. The housing attraction numbers we had from earlier in the process. From this we were able to get ourselves some reasonable numbers for the attractions at these stations.

The case of *industrial* POIs is decidedly different than our other cases. We take a step back for a moment to realize that industrial plants are mostly segregated from other POI types and have a specific trip attraction numbers (these we actually found in a trip generation guide for San Diego—somewhere around 10 trips per 1000 square feet—see http://www.sandiego.gov/planning/pdf/tripmanual.pdf). We then examined on the map to literally get an approximation for the size of these facilities and looked at the parking lots to ultimately get an idea of how many trips we are including. Since we did not have that many industry POI, doing this on a case by case basis was doable. It turns out that in more diffuse counties, such as Essex and Union, that the industry locations had a higher "trips per day" value than housing locations. Yet in Hudson, where the majority of the county is urbanized, industry locations have a lower "trips per day" value relative to housing locations.

The trip attraction numbers for *public* facilities was ascertained in a similar way to the means by which we got them for our city design. Again we assumed that these public facilities are surrounded by other public facilities and a bunch of housing and thus these POIs got some spillage. In most situations (post office, courts etc.) we have that a small percentage of the population actually makes it to one of these facilities on a daily basis (exceptions do apply). We did, however, consider libraries as somewhat separate entities that get a few more attractions.

Our last and, on average, predictably biggest trip attraction numbers came from *transport* stations. While transport stations are not terribly close to houses, we were able to get a general feel for the number of commuters per day and we assume that all trains (AMTRAK and NJTransit) and mass transit buses depart from these areas (most do arrive in these areas). We note that the current ridership will likely boost substantially with the creation of the PRT network as people will not have to drive to stations (and then decide to drive to work instead). Many of our numbers were derived roughly from the total ridership per day on certain lines in the PATH and NJTransit found online.

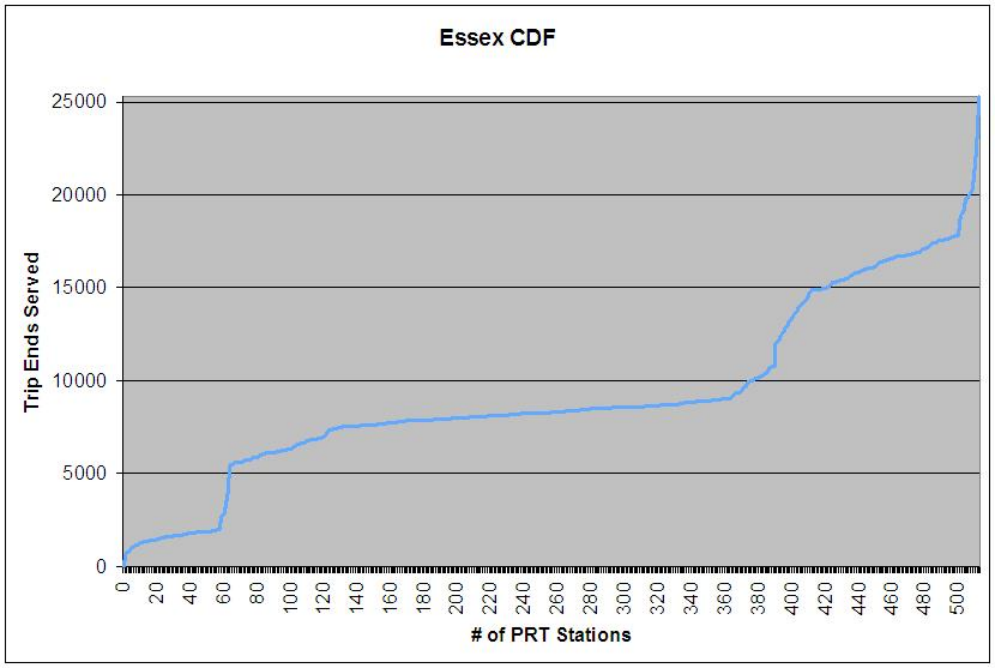
Thus some of our approximations for trip attraction values are rougher than others. Regardless of the POI type, however, all values were checked over to ensure a degree of consistency and of relative size (housing the smallest, transportation the largest). Our discussion above was merely a means of getting some starting values that we would subsequently tweak until we found them reasonable. We do note that the exact trip attraction numbers are

not listed here since they vary both within and between the counties—to get an idea for the attraction numbers for the various POI types, please refer to our histograms.

9.4 PRT Network

Summary statistics can be obtained on total number of stations and interchanges (including bidirectional interchanges), length (in miles) of guide way, total network arcs, and top 5 attractions by trip number. Essex County had 295.35 total miles of guide way, 755 total arcs, and 0.39 miles average arc length. Trip end statistics were the following: min = 671; max = 25,276; mean = 9,248; median = 8,328; 10% level → 51 PRT stations; 90% level → 461 PRT stations.

Figure 9.11: Station Usage in Essex County



After going through all the aforementioned steps of the methodology, our attractions with their relevant trip numbers were finally plotted on the map. We initially flirted with the idea of creating PRT stations in parking lots we located through the Hybrid view of Google Maps, ideally creating enough stations to cover upwards of 90% of all attractions within a reasonable circular radius (this was done over break successfully but recently scrapped when we realized that the means by which the networks were checked would give us problems—the POIs would not actually be PRT stations but would be proxies for PRT stations and thus would be linkless) . Although this idea sounded good on a cost-efficiency basis and a minimal urban interference basis, it ultimately proved highly impractical and less direct. Hence, we opted to assign a PRT station individually to each attraction plotted on the map. Although this greatly elevated the total number of PRT stations and, hence, network arcs and total guide way needed, from our previous idea, we found compensation in our confidence that each attraction would be dealt with in a direct manner (i.e. each attraction would definitely be directly incorporated into the network).

With these PRT stations now established, we were now ready to connect the system into one giant direct arc system. We generally employed a strategy of creating mini-circular networks to which we attached interchanges. This technique allowed us to carefully monitor and frequently back-test the network requirement of having one arc go into and one arc go out of each node. The interchanges associated with the previously described mini-circles created some breathing room in our design, as they can accept multiple arcs coming in and they can support multiple arcs going out. Also somewhat commonly, we opted to connect two interchanges to one another bidirectionally (i.e. arc going from interchange X to interchange Y *and* another arc going from interchange Y to interchange X). These bidirectionally supported particularly well the revising/re-routing/de-bugging process needed in response to the feedback provided by the ultimate network testing software. In general, throughout the network creation process, we kept up a consciousness about the relative travel distance between nodes.

As a general note about cost/budget, we were significantly more concerned about the fluidity of the network

than potentially comprising designs that might have been more cost-effective. For example, our network is full of bidirectional interchanges. In the real world, urban planners may frown on such an abundance of these as not being cost-efficient. However, in our case, we believe they were justified for the following two primary reasons: 1) ease of revision/redesign of network; 2) decreased travel time / decreased congestion / increased transportation efficiency. While the first reason was more a coup for our purposes in designing the PRT system, the second reason presents a very compelling argument as to how increased marginal costs, in this regard, may be more than offset by efficiency factors. While we did not formulate a generalized mathematical justification of this notion, we believe strongly in its plausibility. Such a mathematical model might include an objective function feature a trade-off between efficiency and cost. One must consider how big the coefficient in front of cost should be. While it would be irresponsible to make it zero, the coefficient should be relatively smaller when compared to the efficiency coefficient.

On a more practical level, many of our loops are relatively small with more disperse regions having larger loops. The idea behind the smaller loops is that we feel that PRT will be extremely effective for short trips and that it allows people to easily move throughout their neighborhood. The smaller loops though are connected bidirectionally such that it is still possible to travel relatively large distances without having to traverse too many nodes as may be the case in a large loop. This comes in very handy when potential train riders live far from stations—the PRT will connect to these trains rather than having these commuters park and ride (when they might feel they can just drive to work). We do mention that bidirectional guideways are handy for the actual assignment but they also make a bit of practical sense in that they will prevent longer roundabout paths. We do notice that we do have some very concentrated PRT stations in some areas—ideally, we would like some more dispersion, but the cluster of stations may help alleviate tremendous traffic at one station. Thus it may seem financially impractical to have several stations (in our case mostly shopping/recreation POIs) within a quarter mile radius, but at the same time, we must acknowledge a certain bottleneck on capacity at any given station and may need several stations to cover one area. We also imagine that the PRT stations will have one pass-through lane and a pick up lane such that the PRT vehicles will be able to zip through stations it is not stopping in.

The PRT system would also cater to a broad spectrum of individuals of all social classes and physical conditions. We especially like PRT systems around universities where a lot of the undergraduates live off campus and likely depend on some campus shuttle or personal car to get around. The PRT system will allow them to reach all sorts of attractions directly and conveniently without undo financial or environmental stress. The PRT system may also help lower highway accident rates with fewer young drivers on the road. The PRT system also has a natural appeal to rail/bus commuters who in the past needed to drive to connect to their means of mass transit and had to pay for a parking spot in the park and go area. The PRT system would come equipped with almost futuristic amenities catering to the physically disabled, such as handicap accessibility and unprecedented ease of entrance and exit. The PRT system would work nicely for school children (provided they are accompanied by an adult) to get to and from school as the network directly connects housing with schools with recreational attractions (for afterschool activities). On the whole, the PRT system will boost mobility for those living further from the centers of town or cities and may result in a mini-economic boom as shopping and recreational attractions become "closer to home." Even the rich and retired may appreciate being able to save the environment while using the PRT system to get to their country clubs.

Efforts to revisit and revise our PRT network designs for all of these counties would essentially require one to carefully select more disperse POIs and have a better idea of the total number of the various POI types that exist throughout the county (though obviously we would not use all of them as stations). Finding the total number of attractions may be greatly simplified if we could have a more precise means of understanding the average number of visitors to the various POIs. In addition, having a better idea of the distribution of different POI types within a quarter mile radius of a given POI type may better help determine the total trip attractions serviced within a quarter mile of a station due to spillover. Considering more specific POI types may also allow one to spend less time reviewing individual POIs which appear to be outliers in a certain broad class of POIs currently (maybe turn shopping into food shopping, malls, boutiques etc.). The creators of the network would also benefit from the tool discussed earlier on helping aggregate POIs that cover essentially the same area to prevent double counting of attractions and creating potentially unnecessary stations.

Chapter 10

Gloucester County

Figure 10.1: Gloucester County, NJ

10.1 Quick Facts

Located in southwest New Jersey, Gloucester County was founded in 1686 and used to contain the current Atlantic and Camden counties. It currently contains 24 townships and cities/boroughs. In size (337 square miles) it is somewhat bigger than its northern neighbor Camden, yet it is much less populated (282,031 people); Camden is nearly twice as populated (517,001 people). Gloucester County has less population per mile than the average number in New Jersey. Only around 20% of the land is developed, which is why population density is low as a whole (and also very low in certain municipalities). It is also the 14th most populated county in the state, out of 21 counties. The picture on the following page has the general layout of the land use in the county. As one can see, the northeast corridor is primarily zoned for metropolitan areas, which would make sense because of its proximity to the Philadelphia metropolitan area. Also, these areas are some of the more dense areas in the county. The western and southern municipalities are mostly zoned as rural and suburban areas (these areas are also less populated).

The employment statistics for the county are quite interesting. The mean travel time to work was 27.6 minutes, which is slightly above the national average of around 25. Also, 85% of people drive alone to work, with only 7.5%

carpooling. Overall, around 93% of people are travelling to work using private transportation of some sort, a fairly high number. A significant amount of people work outside the state of New Jersey, with about 18% of people working outside of the state. To go along with those 18% of people that work outside of the state, about 36% work outside of the county. The following picture shows the breakdown of townships and cities:

Gloucester County has access to the I-95, I-295, and I-76, so other parts of the state and other states as well (Pennsylvania) are easily accessible by highway. But for the other 46% of residents that work in the county, we can try to create a PRT network that optimizes their travel time.

As we can see by the following map, a few of the county subdivisions have mean travel times that are over 30 minutes (the county average is 27.6). Specifically, Franklin Township, Monroe Township, Washington Township, Logan Township, Woolwich Township, and South Harrison Township all had mean travel times over 30 minutes, which is at least 5 minutes above the national average. A possible cause for the long travel times in the southeastern part of the county is workers commuting to Philadelphia to work. If that reason is the prevailing reason for long travel times, there may not be as much improvement using a PRT model. In the meantime, we can try to figure out ways to alleviate long travel times within the county.

In general, population density for most of Gloucester County is quite low, with an average of 876 people per square mile. And with the exception of a few cities which bump up that average, namely Pitman borough, Westville

Figure 10.2: Gloucester County Land Use Map

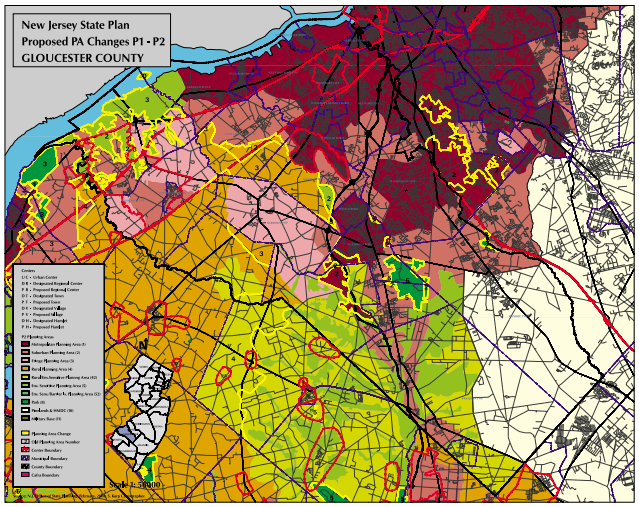
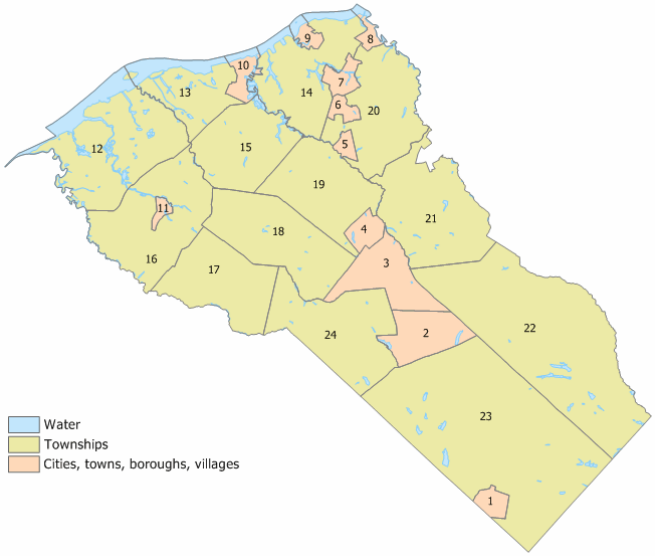


Figure 10.3: Gloucester County Municipalities



borough, and Woodbury city, around 50% of the county land has a population density below 700 people per square mile. Interestingly enough, the areas that have the least population density have the longer travel times. All of the townships which lie along the south border of the county have low population densities, due to the amount of farmland in each township. Unfortunately, because of the undeveloped land that separates many residents from their jobs (unless they work on their own farm), those residents will still have fairly long trips to their respective jobs. That is one of the possible explanations for the higher mean travel time for the townships with the least population density.

Only 2.5% of people use public transportation to get to work, which is a very low number in comparison to most

Figure 10.4: Gloucester County Travel Times

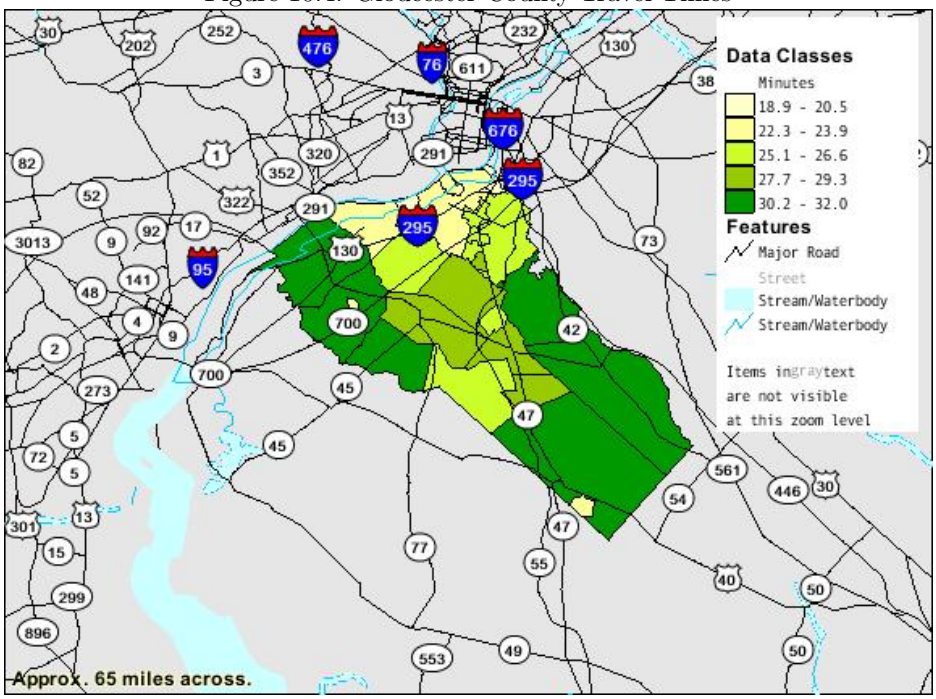
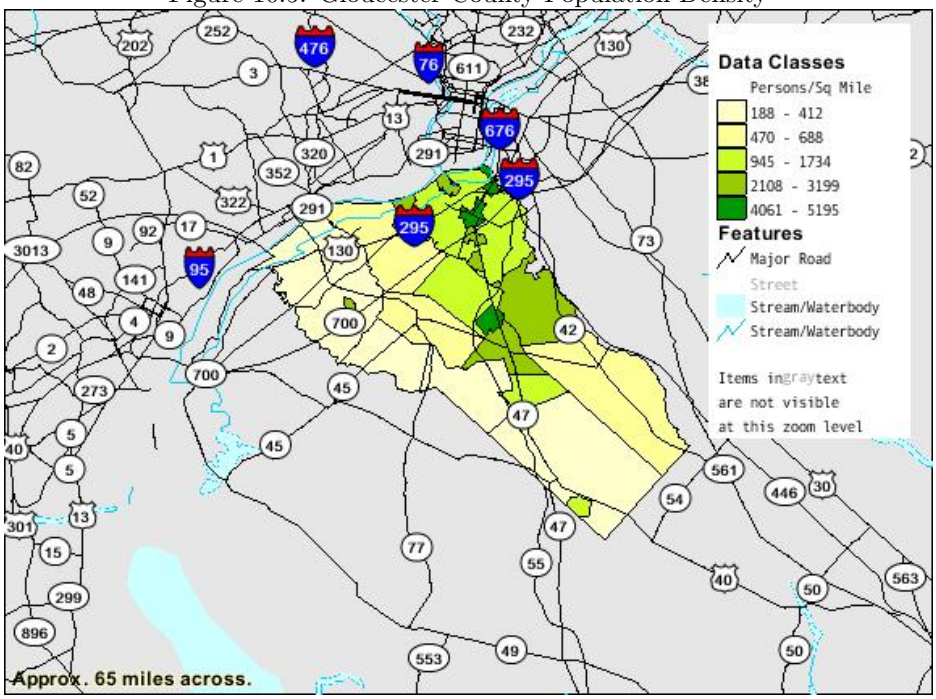


Figure 10.5: Gloucester County Population Density

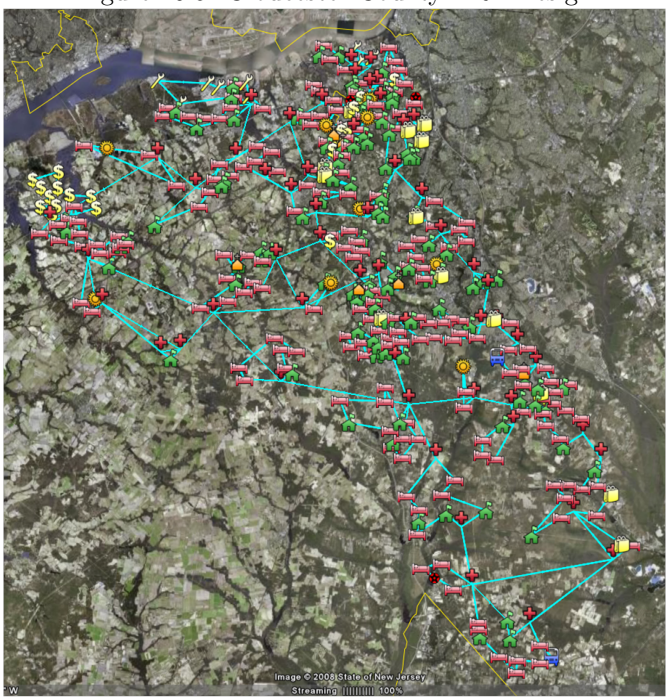


places. The bus systems are not connected well throughout the county, with one publication saying that the east to west bus service was strong, but going the opposite direction it was nearly nonexistent. One of the databases said the following about the current NJ Transit bus route situation in Gloucester:

> NJ Transit operates 11 regular bus routes in Gloucester County. The 11 routes consist of: Nine regional interstate routes providing service through Gloucester and Camden Counties to Philadelphia: 313, 315, 400, 401, 402, 403, 408, 410, 412; two intrastate routes: one regional (455) and one local (463). All routes except the 412 and 463 operate seven days a week. The 313 and 315 are shore routes (Cape May to Philadelphia) with limited schedules. Other routes, such as the 401, 402, and the 410, operate limited service during the midday. This limited service may prove a hardship to riders relying on buses to get to employment centers, especially if the jobs require shift work during off peak hours.

10.2 PRT Design

Figure 10.6: Gloucester County PRT Design



For the design, I tried to give the cities and most populated municipalities the most stations. The layout of the network follows fairly closer to the population densities of each sub county. Large areas that were undeveloped did not have stations but just arcs that ran through them.

My PRT design will offer public transportation options in areas that were previously unreachable by public transportation (or very inconvenient times). This will hopefully save on gas and purchase costs of using a car to travel to work.

My general method for placing stations was making loops around small areas and connecting them via interchange. Below you can see how this general design idea was implemented for a section in Woodbury.

10.2.1 PRT Service to Education

Gloucester County has one university (Rowan University) and one community college (Gloucester County College). Rowan University, a 4-year co-educational public university, has a suburban 200-acre campus located in Glassboro. Gloucester County College is a 2-year co-educational public community college that is located in West Deptford. In the PRT network, both of these universities have stations right on their campuses to service students and employees. Rowan University has 8,120 undergraduates and 1,218 graduate students, with around 3000 students living on campus, so quite a few people have to commute. The PRT system makes sure that these commuters are able to get to campus.

Out of the school stations, both of these colleges have some of the highest volumes in the county, with Rowan University's expected volume of around 35,000 trips and GCC with two stations that combine for around 21,000 trips.

In Gloucester County, there are around 140 private, public, parochial schools of every level. With around 78,000 school-aged children from nursery school to graduate school, our system has stations within walking distance of most of the houses and most of the campuses. If a station is not right next to the school, there is a station within a half mile of the campus.

10.2.2 PRT Service to Shopping

Gloucester County has a few major shopping centers, namely the Deptford Mall. There is ample service (about 3 stations) to each part of that mall to make sure that people do not have to make excessively long walks to reach some of the department stores. All of the other strip malls that populate some of the city centers have stations either on site or within a mile or so. About 75,000 trip ends are served, with about 11,000 going to each of the 3 stations in Deptford Mall.

10.2.3 PRT Service to Housing

The household population is 276,644 with around 100,000 total households. This comes up to an average household size of 2.76. In the townships with the more dense neighborhoods (Pitman, Westville, and Woodbury), there are quite a few more housing stations to accommodate them. But since Gloucester County is such a rural county on a whole, some of the remote areas are not serviced as well because of the amount of undeveloped land around them. Also, I did not place stations in certain residential areas because those specific areas contained a lot of undeveloped land or farmland, containing areas having very low population density. Most of the residents in these areas are within a mile or so of a station, so at the very least they can drive to the PRT station and possibly park in the general area. Because of the amount of housing stations, some of those stations serviced other types of places as well, such as businesses, schools, recreation, etc.

10.2.4 PRT Service to Recreation

Table 10.1 summarizes the recreational opportunities in Gloucester County.

The PRT network has stations are nearly all of these facilities, or at least a station within a mile of each one. A few of the state parks in the middle of undeveloped land may not be directly serviced, but they are not too far from any station.

Figure 10.7: Loop Structure in Gloucester County PRT Design

Each of the golf courses has stations with expected trip volumes around 15,000, since most of them will service housing as well as visitors/members of each golf course.

10.2.5 PRT Service to Employment

Some of the major private sector employers in the area are Underwood-Memorial Hospital (1776 employees), Rowan University (1637 employees), Kennedy Memorial Hospital (1035 employees), and Sony Music (located in Pitman with 582 employees). There are about 140,000 currently employed citizens who reside in the county, with around 64,000 of them working in the county. Most of these people have either "sales and office occupations" or management/professional and related occupations (combine to have 93,000 employees). The two industries with the most employees in Gloucester are retail trade (19,116 employees) and educational, health, and social services (27,605 employees).

Also, Gloucester County is home to the Pureland Industrial Complex, a 3000 acre industrial park with many different offices and warehouses for companies such as Mitsubishi, Home Depot, Nextel, etc. It happens to be one of the largest industrial parks in the world, and is already well connected with the major thoroughfares in the area (I-295, US highway 322, and US Highway 130). Our PRT network has quite a few stations in the industrial park, even though the complex is well connected via car and public transportation with buses and shuttles.

There are 3 oil refineries in Gloucester County as well; the Eagle Point Refinery, the Paulsboro Asphalt Refinery, and the Paulsboro Refinery, which all are used by Sunoco, Citgo, and Valero, respectively. Each of these 3 refineries has quite a few stations running through them, making them easily accessible.

Otherwise, most of the other major employers are accounted for at retail shops and even big megastores like Wal-Mart or ShopRite. Since there are quite a few stops in each townships business/town center, all of the businesses in the middle of the towns are accounted for.

Taking into visitors and employees into account, the station volume for the Underwood-Memorial Hospital was quite large, with a volume of 28,500 people. With the station for Rowan University, they are the two busiest stations in the network on a daily basis.

10.3 Trip Estimations

Most of the trip estimations were based on using population density numbers, enrollment numbers, and employment numbers for specific businesses. The municipalities along the southern border don't have many stations since the small communities cannot support a station, due to the fact that there would be a low amount of trips. Otherwise, most of the dense cities had stations within about a mile of each other, with schools, golf courses, and some shopping centers having stops of their own.

Table 10.1: Gloucester County Recreational Opportunities

Recreation Type	**Count**	**Recreation Opportunity/Venue**
Arts Organizations (in Gloucester County)	2	Rowan University Center for the Arts, Cultural & Heritage Commission
AC Casino Oceanfront Resorts	Several	Trump Taj Mahal, Bally's, Tropicana, Sands, AC Hilton, etc.
Beaches (riverfront only)	1	Red Bank Battlefield (no public swimming permitted)
Lakes	5	County Park System (public swimming permitted)
Boating (riverfront)	2	Private Marinas (lake boating at county parks)
City/State Parks	9	County Department of Parks and Recreation
Golf Courses (9, 18 & 27 Hole)	10	Pitman Golf Course (county owned and operated)
Movie Theaters	5	United Artist, Regal Cinemas, AMC, GCC, Pitman Theater
Museums	5	County Park System
Public Swimming Pools	3	Rowan University, Gloucester County Institute of Technology, YMCA
Symphony (in Camden County)	1	Haddonfield Symphony
Tennis Courts	17	Available at Public Schools and various County/City Parks

10.4 Value of PRT to Future Evolution of the County

These costs come out to a grand total of $11,059,451,822 for the entire system. This cost may seem high right now, but the convenience that this system will provide for the whole county is priceless.

Because of the gaps between the undeveloped land and the developed land, a PRT system will help to keep the county properly connected. Instead of having to drive out of the way to get around farms, the PRT system can be a more direct path to the destination. Since the bus system is only functional for certain parts of the county and only works during certain periods, a PRT system can give service to areas that were slighted by the bus/shuttle services and it can work at any time convenient for the user.

10.5 Statistics on PRT Network

Figure 10.8: Gloucester County PRT Station Volumes

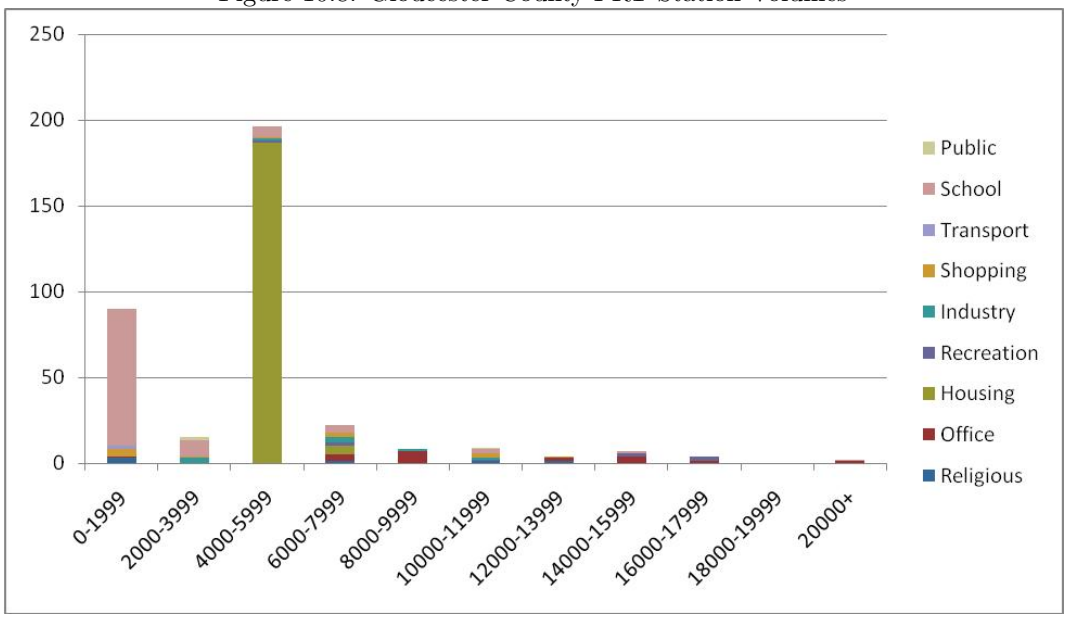


Table 10.2: Gloucester County Trip Data

Type	**# Trips**	**# Stations**
school	219,008	103
office	221,580	20
industry	56,412	9
transport	2,700	2
housing	1,024,652	192
interchanges	N/A	55
recreation	108,100	9
shopping	75,240	13
religious	34,438	6
public	14,000	3
total	1,756,130	412

Chapter 11

Hudson County

Figure 11.1: Major Roadways in Hudson County
Source: http://www.buyersadvisors.com/CountyMaps/hudson_county_map_files/image_map3.gif

Hudson County was created in 1840 and was named after the Hudson River and English explorer Henry Hudson, who landed his vessel in what is now Hoboken in 1609. Hudson County is referred to as the "Gateway to America" as it was typically the first stop for many immigrants who were processed at Ellis Island. Hudson County was also home to one of the first settlements in America, as the Village of Bergen, part of modern day Jersey City, was established as an European Settlement in 1661 (indeed it was New Jersey's first settlement as well). Hudson County is comprised of 12 municipalities, the most prominent of which is the City of Jersey City (also the County Seat). Hudson County, despite its small size, is host to 7 parks and 4 colleges. Formerly an industrial, shipping and manufacturing hub, Hudson has grown to become a home to many financial corporations—certainly attributable to its very close proximity and various transportation options to New York City.[1]

The following is a quoted summary of statistics based on US Census data: "As of the United States 2000 Census, the population was 608,975. It is part of the New York Metropolitan Area. There were 230,546 households and 143,630 families residing in the county. The population density was 13,044 people per square mile (5,036/km^2). There were 240,618 housing units at an average density of 5,154 per square mile (1,990/km^2). There were 230,546 households out of which 29.60% had children under the age of 18 living with them, 39.80% were married couples living together, 16.60% had a female householder with no husband present, and 37.70% were non-families. 29.50%

[1] http://www.jerseycityonline.com/hudson_county/facts.htm

of all households were made up of individuals and 9.60% had someone living alone who was 65 years of age or older. The average household size was 2.60 and the average family size was 3.27. In the county the population was spread out with 22.60% under the age of 18, 10.40% from 18 to 24, 35.60% from 25 to 44, 20.00% from 45 to 64, and 11.40% who were 65 years of age or older. The median age was 34 years. For every 100 females there were 96.50 males. For every 100 females age 18 and over, there were 94.20 males. The median income for a household in the county was $40,293, and the median income for a family was $44,053. Males had a median income of $36,174 versus $31,037 for females. The per capita income for the county was $21,154. About 13.30% of families and 15.50% of the population were below the poverty line, including 22.00% of those under age 18 and 15.70% of those age 65 or over. Hudson County is the most densely populated county in the state. Union City, within the county, is the most densely populated city in the country."[2]

For our PRT projections, we anchored our assumptions in the data found in Hudson's 2000 Census seen in Tables 11.1, 11.2, and 11.3. Please note that the steadying population size indicates that our trip generation numbers will not become obsolete solely due to continued population growth

Table 11.1: People QuickFacts for Hudson County
Source: http://quickfacts.census.gov/qfd/states/34/34017.html

People QuickFacts	**Hudson County**	**New Jersey**
Population, 2006 estimate	601,146	8,724,560
Population, percent change, April 1, 2000 to July 1, 2006	-1.3%	3.7%
Population, 2000	608,975	8,414,350
Persons under 5 years old, percent, 2006	6.9%	6.4%
Persons under 18 years old, percent, 2006	22.5%	23.9%
Persons 65 years old and over, percent, 2006	10.9%	12.9%
Living in same house in 1995 and 2000, pct 5 yrs old & over	53.8%	59.8%
High school graduates, percent of persons age 25+, 2000	70.5%	82.1%
Mean travel time to work (minutes), workers age 16+, 2000	32.6	30.0
Housing units, 2006	251,228	3,472,643
Homeownership rate, 2000	30.7%	65.6%
Housing units in multi-unit structures, percent, 2000	84.2%	36.1%
Median value of owner-occupied housing units, 2000	$150,300	$170,800
Households, 2000	230,546	3,064,645
Persons per household, 2000	2.60	2.68
Median household income, 2004	$40,311	$57,338
Per capita money income, 1999	$21,154	$27,006

Table 11.2: Business QuickFacts for Hudson County
Source: http://quickfacts.census.gov/qfd/states/34/34017.html

Business QuickFacts	**Hudson County**	**New Jersey**
Private nonfarm establishments, 2005	13,390	242,128
Private nonfarm employment, 2005	214,681	3,594,862
Private nonfarm employment, percent change 2000-2005	-1.5%	1.3%
Nonemployer establishments, 2005	39,593	573,134
Total number of firms, 2002	46,277	708,837
Manufacturers shipments, 2002 ($1000)	3,122,200	96,599,807
Wholesale trade sales, 2002 ($1000)	13,366,713	256,925,492
Retail sales, 2002 ($1000)	4,090,693	102,153,833
Retail sales per capita, 2002	$6,710	$11,910
Accommodation and foodservices sales, 2002 ($1000)	612,792	15,715,595
Building permits, 2006	4,275	34,323
Federal spending, 2004 ($1000)	3,499,556	55,264,350

Hudson County boasts a very deep array of attractions for its visitors. Hence, it is not surprising that such a plethora of transportation conduits would run through Hudson County and have hubs there. To name just a

[2] http://en.wikipedia.org/wiki/Hudson_County

Table 11.3: Geography QuickFacts for Hudson County
Source: http://quickfacts.census.gov/qfd/states/34/34017.html

Geography QuickFacts	**Hudson County**	**New Jersey**
Land area, 2000 (square miles)	46.69	7,417.34
Persons per square mile, 2000	9,999.9	1,134.5
FIPS Code	017	34
Metropolitan or Micropolitan Statistical Area	New York-Northern New Jersey-Long Island NY-NJ-PA Metro Area	

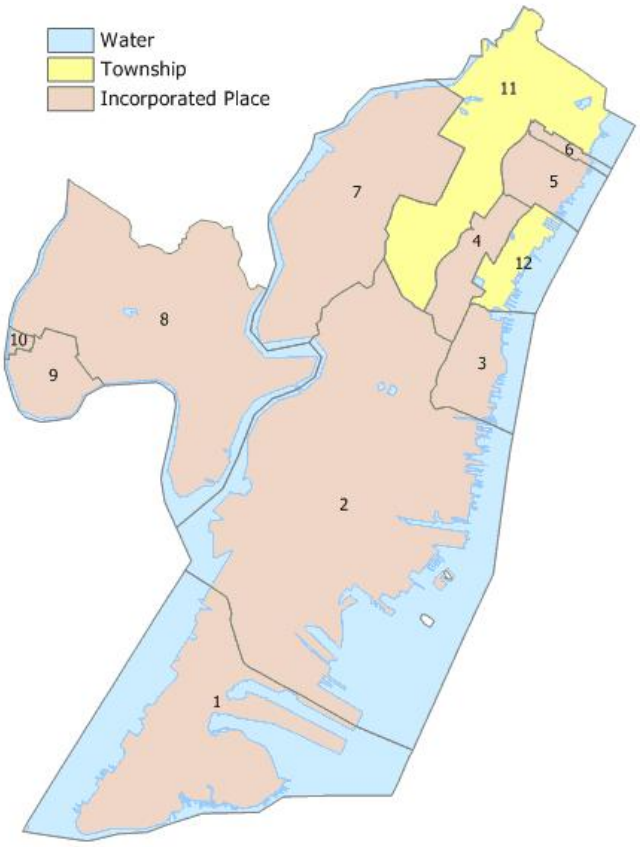
Table 11.4: Hudson County Population Growth

Census	**Population**	**% ±**
1850	21,822	130.10%
1860	62,717	187.40%
1870	129,067	105.80%
1880	187,944	45.60%
1890	275,126	46.40%
1900	386,048	40.30%
1910	537,231	39.20%
1920	629,154	17.10%
1930	690,730	9.80%
1940	652,040	-5.60%
1950	647,437	-0.70%
1960	610,734	-5.70%
1970	607,839	-0.50%
1980	556,972	-8.40%
1990	553,099	-0.70%
2000	608,975	10.10%
Est. 2006	601,146	-1.30%

Table 11.5: Map of Hudson Municipalities, Key

Index	**Name**
1	Bayonne
2	Jersey City
3	Hoboken
4	Union City
5	West New York
6	Guttenberg
7	Secaucus
8	Kearny
9	Harrison
10	East Newark
11	North Bergen Township
12	Weehawken Township

Figure 11.2: Hudson County Municipalities



few, Hudson is know for its metropolis Jersey City, the Liberty Science Center, the Circle Liner Tour Ferry, and Newark Liberty International Airport. Hudson County also bumps up against the Hudson River, which is one of New Jersey's most immediate buffers to New York City.

Hence, in terms of existing transportation systems, Hudson County is one of the focal points for all transportation in the northeast of the United States: "The confluence of roads and railways of the BosWash megalopolis and Northeast Corridor passing through Hudson County make it one of the Northeast's major transportation crossroads and provide access to an extensive network of interstate highways, state freeways and toll roads, and vehicular water crossings. Many long distance trains and buses pass through the county, though Amtrak and the major national bus companies—Greyhound Lines and Trailways—do not provide service within it. There many local, intra-state, and Manhattan-bound bus routes, an expanding light rail system, ferries traversing the Hudson, and commuter trains to North Jersey, the Jersey Shore, and Trenton. Much of the rail, surface transit, and ferry system is oriented to commuters traveling to Newark, lower and midtown Manhattan, and the Hudson Waterfront. Public transportation is operated by a variety of public and private corporations, notably New Jersey Transit, The Port Authority of New York and New Jersey, and NY Waterway, each of which charge customers separately for their service."[3]

During the McGreevey administration in 2002, Hudson made a significant push to build out its transportation infrastructure for the former Bayonne Military Ocean Terminal.[4] Quoted in the press release: "The City of Bayonne and the Bayonne Local Redevelopment Authority (LRA) welcome the state's interest in finding additional ways to link the property by land and water to the existing transportation systems in the North Jersey-New York metropolitan area. This initiative provide an unprecedented opportunity for economic growth for Bayonne, our state, and the entire region, said Mayor Doria."[5] Hence, the governance of the state of New Jersey, but especially Hudson County, has verbally acknowledged that transportation improvements may well bear economic benefits. If this is how Hudson residents/politicians think, then there is no question they will take the idea of a well-planned PRT system seriously. From decreasing commuting time to making intra-county travel more efficient, PRT has potential to bring economic improvements to Hudson County.

[3] http://en.wikipedia.org/wiki/Hudson_County
[4] http://www.state.nj.us/transportation/about/press/2002/051302a.shtm
[5] http://www.state.nj.us/transportation/about/press/2002/051302a.shtm

Hoboken Terminal, Bergenline Avenue at 32nd, 48th, and 91st Streets in North Hudson, Journal Square Transportation Center and Exchange Place in Jersey City are major public transportation hubs. The Port Authority Bus Terminal and Penn Station in midtown Manhattan, the World Trade Center in lower Manhattan, and Newark Penn Station also play important roles within the county's transportation network. Secaucus Junction provides access to eight commuter rail lines. The following represent existing transportation options in Hudson County:[6]

- Hudson-Bergen Light Rail (HBLR) serves Bayonne, Jersey City, Hoboken, and North Hudson at the Weehawken waterfront, Bergenline (Union City/West New York) and Tonnele Ave (North Bergen)
- New Jersey Transit Hoboken Division: Main Line (to Suffern, and in partnership with MTA/Metro-North, express service to Port Jervis), Bergen County Line, and jointly with MTA/Metro-North, Pascack Valley Line, all via Secaucus Junction; Montclair-Boonton Line and Morris and Essex Lines; North Jersey Coast Line (limited service as Waterfront Connection); Raritan Valley Line (limited service)

Exchange Place

- New Jersey Transit Newark Division: Northeast Corridor Line and North Jersey Coast Line can be reached via Secaucus Junction or PATH
- PATH is a 24-hour subway mass transit system serving Newark Penn Station (NWK), Harrison, Journal Square (JSQ), downtown Jersey City, Hoboken Terminal (HOB), midtown Manhattan (33rd) (along 6th Ave to Herald Square/Pennsylvania Station), and World Trade Center (WTC)

For Hudson, we were able to get exact number for the PATH train lines and use those accordingly (we also got some figures from Newark International on the Northeast Corridor line and used those in Essex as well).

CRRNJ Terminal in Liberty State Park, Ellis Island and Statue of Liberty ferry slips in foreground.

- NY Waterway ferry service, from Jersey City, Hoboken and Weehawken to World Financial Center and Pier 11/Wall Street in lower Manhattan, and to West 39th in midtown Manhattan, where free transfer is available to a variety of "loop" buses.
- Circle Line Downtown operates ferries to the Statue of Liberty and Ellis Island from Liberty State Park.
- Cape Liberty Cruise Port in Bayonne is one of three passenger terminals in New York Harbor.

Major highways include New Jersey Routes 3, 7, 139, 185, 440, 495, Interstates 78, 95, and 280, and U.S. Routes 1 and 9, as well as the New Jersey Turnpike and The Pulaski Skyway. Automobile access to New York City is available through the Lincoln Tunnel (via Weehawken to midtown Manhattan) and the Holland Tunnel (via Jersey City to lower Manhattan), and over the Bayonne Bridge to Staten Island.

As far as air transportation is concerned, Newark airport plays the most predominant role in the context of this county's transportation to and from airports. However, the other airports, including Laguardia, JFK, and Teterboro, are all within a reasonable range for Hudson as well.

See Table 9.6 on page 74 for Information about Newark Liberty Airport.

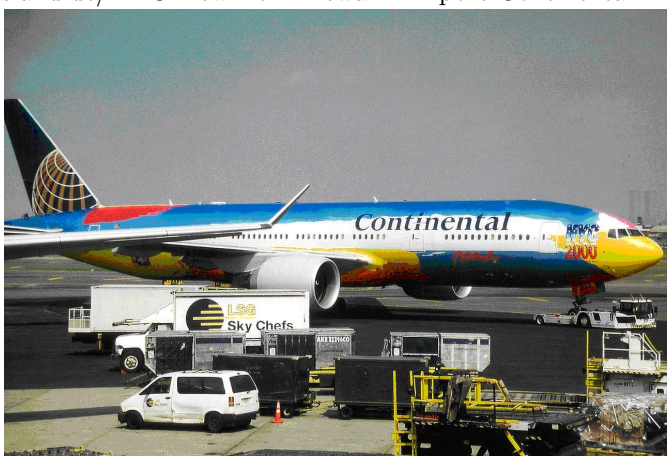
These grids make a strong case for the need for improved access and creation of public transportation options, such as commuter rail and shuttle services. However, we believe a PRT system would be superior in mitigating congestion and travel time issues. As a direct concequence, we have placed PRT stations at many of the aforementioned transportation POIs.

Additionally, Hudson County's legislature has always been interested in better avenues for improving its county's economic vitality. Having a number of nodes (PRT stations) integrated into the transportation landscape can only help in this endeavor, promoting cross-fertilization of industry inter- and intra-county, especially as Hudson has such a dense downtown region.

It should be noted that there are some areas in Hudson where PRT stations appear to be clustered together and thus may be perceived as a design flaw. This is perhaps more so apparent in Hudson, where we still strive to get the same number of POIs as in the more diffuse counties despite Hudson being much smaller in size. While it is obviously not economical to have seemingly independent stations right next to each other, we must realize that any of these PRT stations is likely to see a tremendous amount of commuter traffic through the station and simply putting one station down may be wholly insufficient in dealing with potential PRT demand. While our maps currently propose having certain stations right next to each other, we could instead use the POIs that make up the stations locations to be a proxy for where we would put a very large station. Hence the cluster of PRT

[6] http://en.wikipedia.org/wiki/Hudson

Figure 11.3: Jet at Newark Liberty Airport
Source:http://www.tropicalisland.de/NYC_New_York_Newark_Airport_Continental_Airlines_Boeing_B777_with_special_painting_b.jp



stations currently shown could instead be interpreted as a magnitude calculation for the size of station needed in that vicinity. In addition, the choice of certain points of interest may seem somewhat bizarre for a station location; for instance, a Chinese Restaurant may not appear to be the best location to have a station, yet it demarcates an area likely filled with other businesses, who in aggregate, would be a fine candidate for a PRT station.

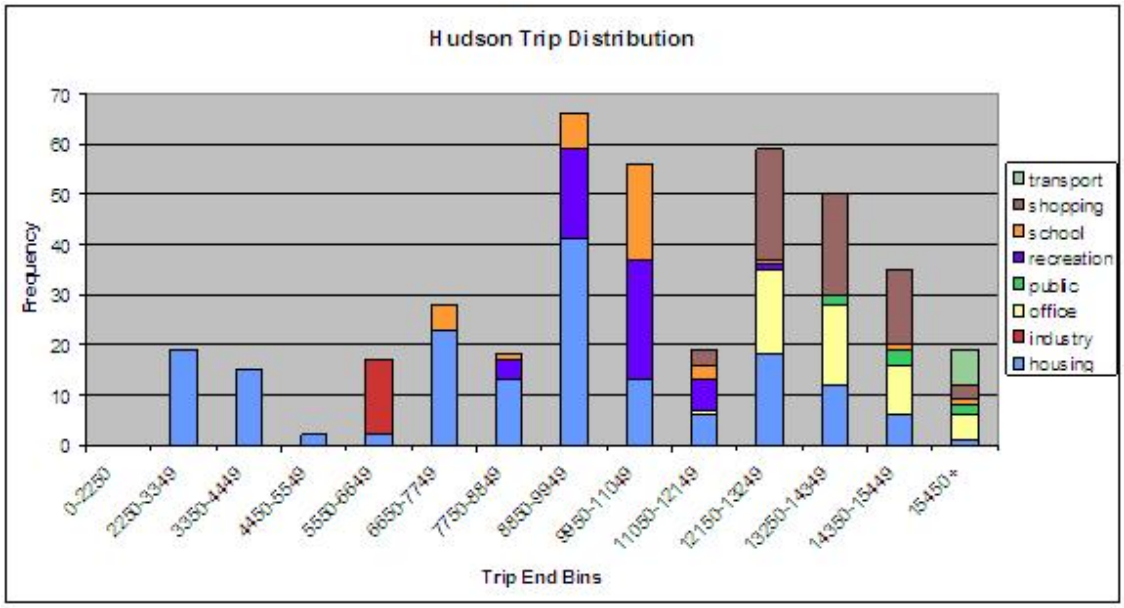
That said, since we already account for the surrounding POIs within a quarter mile radius when we derive our attraction numbers (which is why they may seem a bit high in areas), some efforts could be put forth to remove clustered stations. The issue is that we describe the process of getting attraction numbers as being one that accounts for the surrounding areas; this assumes no other stations within the immediate area, which is inaccurate for these clusters. We attempted to create an excel function to measure distances between stations to determine whether or not some were excessive; we ran into issues dealing with the different possible geometric configurations of the stations and the resulting logic decisions. We believe that such a function that could aggregate POIs that are within a certain distance of each other would be an extremely useful tool in consolidating station locations. As we mentioned before, the cluster of stations indicates that this is an area of high traffic—we could, however, just keep one of the stations and utilize the average trip attraction numbers of the stations since all are within a quarter mile radius of each other. This, we believe, may help reduce the excess number of PRT stations in some areas and give more realistic numbers for the total number of trip attractions since we will no longer have the issue of overlapping station coverage areas. That said, we stand by our numbers as our POIs were geographically selected at random, and due to the fairly consistent land use patterns within the county, the numbers associated with a station in a cluster may be preserved if this station were moved out sufficiently. Thus as described below, we do not believe this will impact the economics of the PRT systems, it just may make them look a little more polished.

We have also put forth a significant effort is trying to ensure that there are stations in every municipality in Hudson to ensure maximum mobility. The nature of our search for POIs had lead us to have clusters of areas where we perceive for there to be significant demand, although it is quite possible demand may be slightly more uniform across the county. Efforts to improve our PRT network design would certainly begin with an effective means of getting disperse POIs that would serve as proxies for station locations. This would most easily be accomplished by individuals with a clearer sense of major and relevant locations within the county. Our searches for POIs in the yellowbook mostly left us with three POI intense areas: Hoboken, Bayonne, and East Newark—conspicuously missing is Jersey City, for which we had to revisit the map to add in additional attractions. We were able to find additional station locations by analyzing the Google Map in hybrid mode to find what appeared to be relevant locations in areas within Hudson that did not appear to be properly served by the PRT network. Indeed, in our final product, Jersey City became a hub of sorts for the PRT network in that all PRT vehicles that wished to go from any of the three aforementioned POI concentrated areas would pass through Jersey City.

11.1 Histogram Analysis

The following is a description of the distribution of the range of PRT stations by attraction size in Hudson (please see Figure 11.4). In Hudson, most stations were placed in areas with multiple attractions within a quarter of mile, which would result in nice size attraction numbers for the respective stations. The leftmost part of the bar graph

Figure 11.4: Trip Distribution in Hudson County



(relatively low volume stations) demarcates stations in areas of housing that appear less dense (based on Google Earth imagery)—getting on average 3,500 trip ends per day. There aren't really any diffuse areas in Hudson (the most dense county in the US) but our Google Map helped spot a few housing areas with not too much going on or where there are other stations to suck up the traffic. The overwhelming majority of housing PRT stations, as seen on the graph, attracts many more one end trips due to the overall high density of Jersey City, Bayonne, Hoboken and East Newark.

We can then see what pretty much looks like a huge hump in the distribution of PRT stations that attracts between 5,000 and 15,450 trip ends per day, with the average of the hump appearing around 11,000 trip ends per day. On our bar graph, it almost appears as two humps (one for stations with attractions between 8,000 and 11,000 trip ends and another with attraction numbers between 12,000 and 15,450 trip ends) but this is merely an artifact of the the buckets—had we aggregated certain buckets, there would not be any dip in between these two humps. On the lower end of the hump, we see both medium density housing as well as smaller specialty schools and industrial areas. Industrial areas, as discussed, may be relatively large on a physical scale, but per square foot, do not get a lot of trip attractions. Moving to higher attraction PRT stations (8,000 to 12,000), we see some recreational facilities in the heart of the dense cities as well as dense housing in these areas as well. We also get some more popular schools in these urban areas.

Moving to the rightmost portion of the hump (or what appears to be the second hump), we find very dense shopping and transportation areas, offices, as well as more super-dense housing and public offices. The rightmost bucket, does not appear to taper off as much as it does in other counties—this should not mislead you. If we were to breakdown the final bucket, we would see most PRT stations have attractions close to 15,450, and a few with a bit more. The biggest PRT stations by number of attractions are generally those connecting to the PATH trains, which have a daily ridership of over 227,000![7] These would include PATH Exchange Place Jersey City and PATH Journal Square Jersey City, which we approximate as both getting 23,131 and 21,392 one way trip ends per day respectively. Another huge PRT station is Hudson Mall (the largest), which we expect to net 23,432 one way trip ends between both customers and workers. New Jersey City University is also among the top attraction PRT stations with over 9,000 in staff and students—both students and staff, as well as visitors to the University, would benefit from the PRT network in place.

11.1.1 Snapshots of Major Stations

[7] http://www.panynj.gov/CommutingTravel/path/html/index.html

Figure 11.5: PATH Station, Exchange Place Jersey City

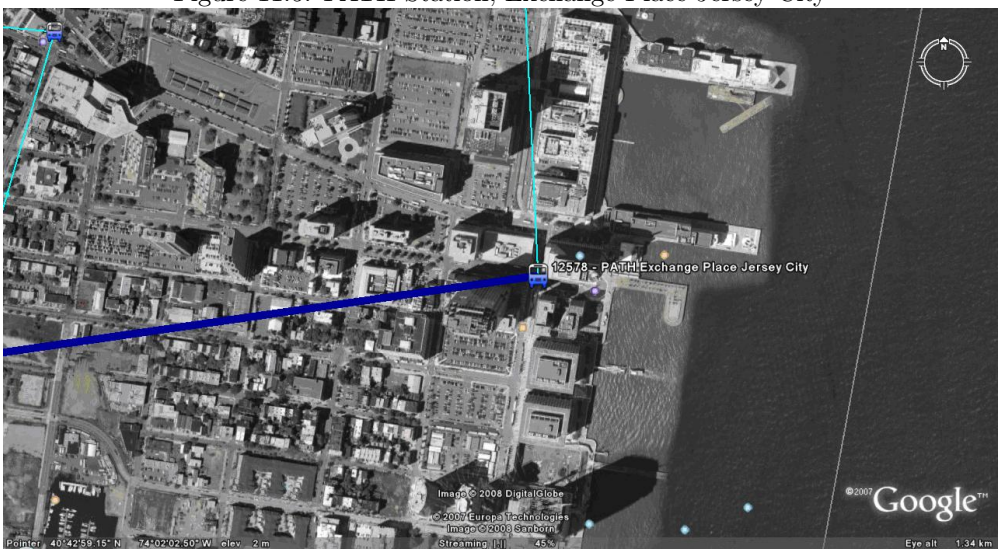


Figure 11.6: PATH Station, Journal Square Jersey City

Figure 11.7: Hudson Mall

Figure 11.8: New Jersey City University

11.1.2 Snapshots of Network

Figure 11.9: Macro View of Hudson PRT Network

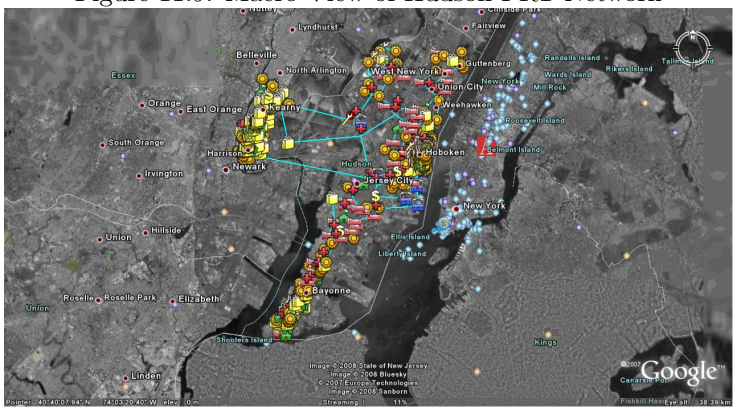


Figure 11.10: Southern Hudson County

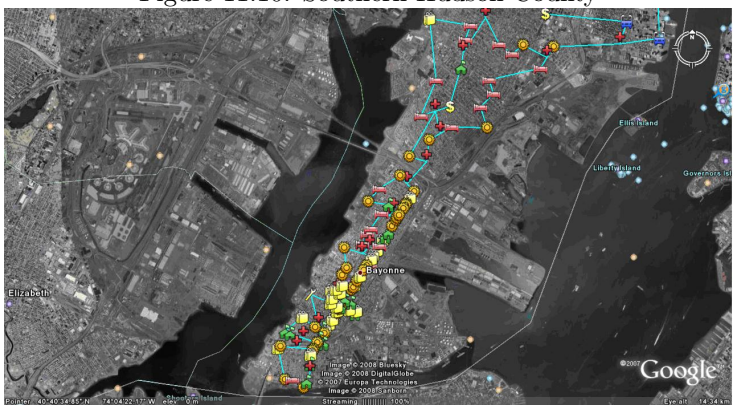
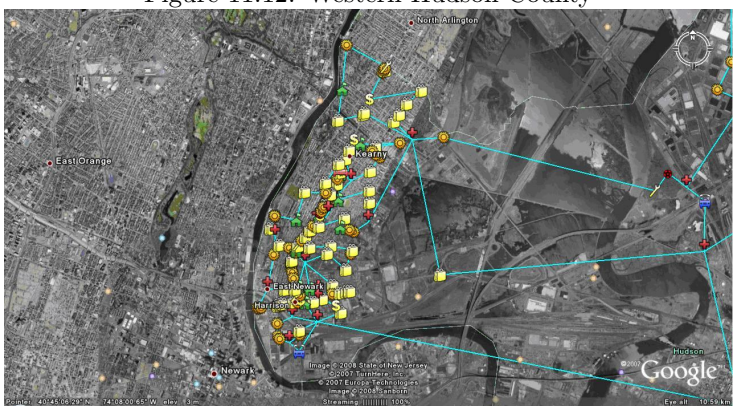


Figure 11.11: Northeast Hudson County

11.1.3 Cost Projections

One of the keys of getting any PRT network off the ground is to have a sound understanding on the likely costs. As of now, we will consider the costs of the guideway stations, and cars and explain any changes that may minimize these costs. As of now, all of our counties have guideway that extends to every area within the county—thus we feel that even with a modified network, our amount of guideway should already give an excellent prediction of what is needed to fully serve the county. As for stations, as described earlier, we do have some clusters of stations which

Figure 11.12: Western Hudson County



may on the surface appear wasteful but can be thought of in several ways: One way to think of a cluster of stations is that they indicate the need for a superstation and hence the cost would likely be several multiples of a single station cost (perhaps similar to the number in the cluster). A second way to consider this is to imagine that since the POIs were selected geographically at random, since many of the counties have areas with consistent land use patterns, a station placed in a cluster could well serve the same number of trip attractions if it were indeed moved somewhere else. Thus using this logic, we will also use the number of stations currently down as a proxy for the total number of needed stations for cost purposes (even if the network gets modified at some point). As for cars, we utilized a special formula not discussed here to get the cost of cars ((we assume average trip length, though to be 5 miles rather than 10 miles—this is partially based on the fact that Hudson is the smallest county in size and has the largest percentage of workers walking to work (over 10%), an indication that average trip length in Hudson should be shorter relative to other counties[8]):

Cost of Guideway: 122.39 Miles * $5 million/mile = $611 million

Cost of Stations: 403 Stations * $2.5 million/station = $1,007 million

Cost of Cars (ascertained using an excel file described in our leader's report): $6,615 million

Total Cost: $611 million + $1,007 million + $6,615 million = $8,235 million

Special Note on Hudson: What is great about PRT in Hudson is that relatively little guideway is needed when compared to other counties because it is so dense—at the same time, there is a potentially tremendous user base for it.

11.2 Overview of Trip Number Generation

See Section 9.2 on page 81 for information.

11.3 Overview of Absolute Expectation Levels

See Section 9.3 on page 82 for information.

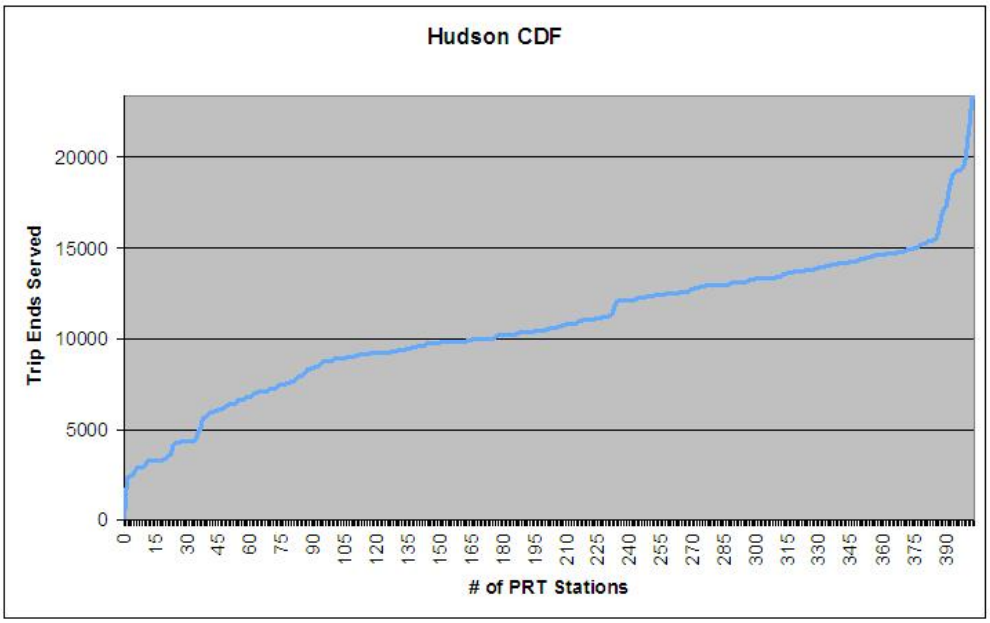
11.4 PRT Network

Summary statistics can be obtained on total number of stations and interchanges (including bidirectional interchanges), length (in miles) of guide way, total network arcs, and top 5 attractions by trip number. Hudson County had 122.39 total miles of guide way, 545 total arcs, and 0.22 miles average arc length. Trip end statistics were the following: min = 2,312; max = 23,432; mean = 10,733; median = 10,557; 10% level → 41 PRT stations; 90% level → 363 PRT stations.

After going through all the aforementioned steps of the methodology, our attractions with their relevant trip numbers were finally plotted on the map. We initially flirted with the idea of creating PRT stations in parking lots we located through the Hybrid view of Google Maps, ideally creating enough stations to cover upwards of 90% of all attractions within a reasonable circular radius (this was done over break successfully but recently scrapped

[8] http://www.state.nj.us/transportation/publicat/pdf/PedComp/pedintro.pdf

Figure 11.13: Station Usage in Hudson County



when we realized that the means by which the networks were checked would give us problems—the POIs would not actually be PRT stations but would be proxies for PRT stations and thus would be linkless) . Although this idea sounded good on a cost-efficiency basis and a minimal urban interference basis, it ultimately proved highly impractical and less direct. Hence, we opted to assign a PRT station individually to each attraction plotted on the map. Although this greatly elevated the total number of PRT stations and, hence, network arcs and total guide way needed, from our previous idea, we found compensation in our confidence that each attraction would be dealt with in a direct manner (i.e. each attraction would definitely be directly incorporated into the network).

With these PRT stations now established, we were now ready to connect the system into one giant direct arc system. We generally employed a strategy of creating mini-circular networks to which we attached interchanges. This technique allowed us to carefully monitor and frequently back-test the network requirement of having one arc go into and one arc go out of each node. The interchanges associated with the previously described mini-circles created some breathing room in our design, as they can accept multiple arcs coming in and they can support multiple arcs going out. Also somewhat commonly, we opted to connect two interchanges to one another bidirectionally (i.e. arc going from interchange X to interchange Y and another arc going from interchange Y to interchange X). These bidirectionally supported particularly well the revising/re-routing/de-bugging process needed in response to the feedback provided by the ultimate network testing software. In general, throughout the network creation process, we kept up a consciousness about the relative travel distance between nodes.

As a general note about cost/budget, we were significantly more concerned about the fluidity of the network than potentially comprising designs that might have been more cost-effective. For example, our network is full of bidirectional interchanges. In the real world, urban planners may frown on such an abundance of these as not being cost-efficient. However, in our case, we believe they were justified for the following two primary reasons: 1) ease of revision/redesign of network; 2) decreased travel time / decreased congestion / increased transportation efficiency. While the first reason was more a coup for our purposes in designing the PRT system, the second reason presents a very compelling argument as to how increased marginal costs, in this regard, may be more than offset by efficiency factors. While we did not formulate a generalized mathematical justification of this notion, we believe strongly in its plausibility. Such a mathematical model might include an objective function feature a trade-off between efficiency and cost. One must consider how big the coefficient in front of cost should be. While it would be irresponsible to make it zero, the coefficient should be quite small.

On a more practical level, many of our loops are relatively small with more disperse regions having larger loops. The idea behind the smaller loops is that we feel that PRT will be extremely effective for short trips and that it allows people to easily move throughout their neighborhood. The smaller loops though are connected bidirectionally such that it is still possible to travel relatively large distances without having to traverse too many nodes as may be the case in a large loop. This comes in very handy when potential train riders live far from stations—the PRT will connect to these trains rather than having these commuters park and ride (when they might feel they can just

drive to work). We do mention that bidirectional guideways are handy for the actual assignment but they also make a bit of practical sense in that they will prevent longer roundabout paths. We do notice that we do have some very concentrated PRT stations in some areas—ideally, we would like some more dispersion, but the cluster of stations may help alleviate tremendous traffic at one station. Thus it may seem financially impractical to have several stations (in our case mostly shopping/recreation POIs) within a quarter mile radius, but at the same time, we must acknowledge a certain bottleneck on capacity at any given station and may need several stations to cover one area. We also imagine that the PRT stations will have one pass-through lane and a pick up lane such that the PRT vehicles will be able to zip through stations it is not stopping in.

The PRT system would also cater to a broad spectrum of individuals of all social classes and physical conditions. We especially like PRT systems around universities where a lot of the undergraduates live off campus and likely depend on some campus shuttle or personal car to get around. The PRT system will allow them to reach all sorts of attractions directly and conveniently without undo financial or environmental stress. The PRT system may also help lower highway accident rates with fewer young drivers on the road. The PRT system also has a natural appeal to rail/bus commuters who in the past needed to drive to connect to their means of mass transit and had to pay for a parking spot in the park and go area. The PRT system would come equipped with almost futuristic amenities catering to the physically disabled, such as handicap accessibility and unprecedented ease of entrance and exit. The PRT system would work nicely for school children (provided they are accompanied by an adult) to get to and from school as the network directly connects housing with schools with recreational attractions (for afterschool activities). On the whole, the PRT system will boost mobility for those living further from the centers of town or cities and may result in a mini-economic boom as shopping and recreational attractions become "closer to home." Even the rich and retired may appreciate being able to save the environment while using the PRT system to get to their country clubs.

Efforts to revisit and revise our PRT network designs for all of these counties would essentially require one to carefully select more disperse POIs and have a better idea of the total number of the various POI types that exist throughout the county (though obviously we would not use all of them as stations). Finding the total number of attractions may be greatly simplified if we could have a more precise means of understanding the average number of visitors to the various POIs. In addition, having a better idea of the distribution of different POI types within a quarter mile radius of a given POI type may better help determine the total trip attractions serviced within a quarter mile of a station due to spillover. Considering more specific POI types may also allow one to spend less time reviewing individual POIs which appear to be outliers in a certain broad class of POIs currently (maybe turn shopping into food shopping, malls, boutiques etc.). The creators of the network would also benefit from the tool discussed earlier on helping aggregate POIs that cover essentially the same area to prevent double counting of attractions and creating potentially unnecessary stations.

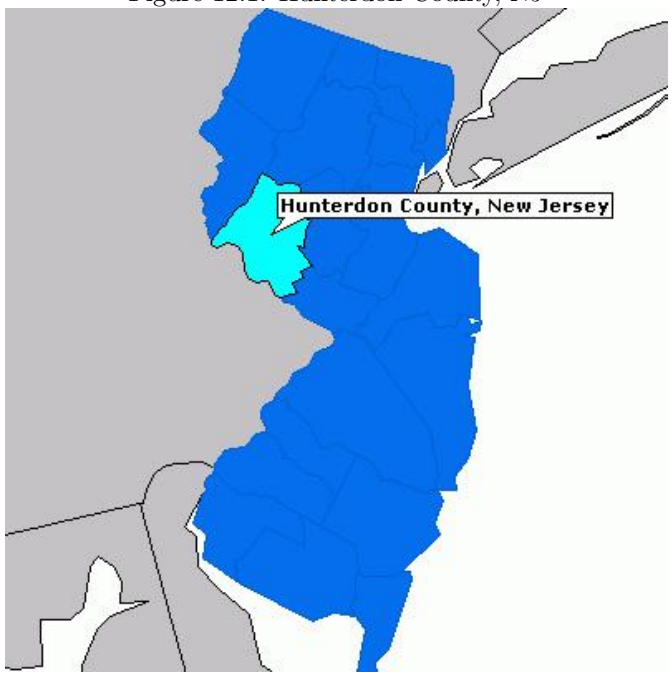
Chapter 12

Hunterdon County

Characterized by its large percentage of farmland and small, historic towns, Hunterdon County, at 437 square miles, is the eighth largest county in New Jersey. According to 2000 Census data, the county is home to a population of 121,987, just over 43,000 households. At 284 persons per square mile, Hunterdon County has the third lowest population density of all counties in the state, behind only Sussex and Salem Counties.

Hunterdon consists of twenty-six municipalities, which include fourteen townships, ten boroughs, Clinton Town, and Lambertville City. The county seat is in Flemington, located in Raritan Township, and is the county's oldest community. From 1990 to 2000, Hunterdon witnessed steady growth in population, rising 13.2% over the ten-year period compared to 8.9% growth for all of New Jersey. This growth has concentrated mostly in larger towns, including Raritan, Readington and Clinton Town, where major business activity has developed and residential neighborhoods have grown due to their attractive locations to commuters working in Philadelphia and New York City.

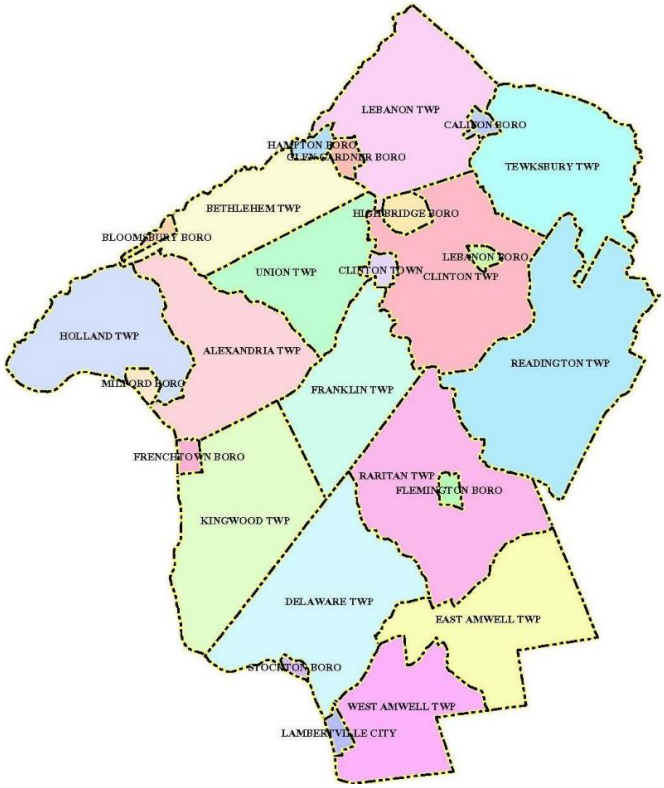
Figure 12.1: Hunterdon County, NJ



12.1 Land Use Overview

Hunterdon County has a total of approximately 280,450 acres, of which 109,240 acres is farmland. Containing 13.6% of New Jersey's total farmland and the state's highest number of farms, Hunterdon County is one of the most rural areas in the New Jersey. The preservation of the county's rural character is a guiding theme in community design.

Figure 12.2: Hunterdon County Map of Municipalities



In fact, thirteen of the twenty-six municipalities include preservation of rural character in their master plan goals. Given continuing development pressure, Hunterdon has instated aggressive open space and farmland preservation planning programs, along with design guidelines that call for more compact patterns of growth so as to create the appearance that the natural environment is still the dominant feature of the landscape.

Figure 12.3: Hunterdon Farm

To illustrate these efforts, Hunterdon County Land Trust Alliance is a non-profit land conservation organization

that currently oversees the protection of seventeen different land spaces within the county. Since 1996, the Alliance has facilitated the preservation of over 2,200 acres of critical farmland and natural areas. In addition, the Hunterdon County's Agricultural Development Board's Farmland

Preservation Programs allow landowners to sell development rights on their farms in exchange for a permanent restriction on the land that requires it to be available for agriculture in perpetuity.

With its strong emphasis on preserving rural character, Hunterdon County has witnessed limited land development rates compared to those of other New Jersey counties. Indeed, in 1972 only 4.5% of the County was developed. By 2001, this figure increased to 24% due to improved highway systems, increased access to employment centers in nearby counties, and a desirable quality of life. During the 1970s and 1980s, a number of higher-density residential developments were built throughout the County in areas such as Raritan Township, Union Township, Lambertville, Clinton Township, and Readington Township. These developments contained several hundred units with single-family homes on small lots, as well as townhouses, apartments, and condominiums. Several high-density housing development projects that took place in the 1980s and 1990s included low to moderate-income units.

Due to land preservation considerations, residential development in the County today is encouraged to take place in more compact forms as centers, rather than spreading out as low-density, land consuming sprawl. However, large single-family homes on expansive lots (typically 3 to 15 acres) still dominate new residential construction. Some communities have attempted to retain open space and farmland by encouraging open space subdivisions, which have reduced minimum lot size in exchange for large contiguous areas of preserved land.

The aggregate amount of land in Hunterdon County taxed as commercial or industrial development in 2001 was just 7,952 acres, or 2.8% of the county's gross land area. Municipalities with the highest value of commercial and industrial development are Readington, Clinton and Raritan Townships. The municipalities with the largest overall percentage of commercial and industrial development are Flemington and Lebanon Boroughs, the Town of Clinton, and Union Township.

Most of the County's commercial centers, whether office, industrial, warehouse, or retail, concentrate along Hunterdon's major highways: Routes 78, 202/206, 523, 22 and 31. These high-volume corridors have attracted a number of large corporations, such as Merck (along Route 78) and Chubb Insurance Co. (along Route 523), which, in turn, has compounded the amount of economic activity in those areas. Retail development largely clusters in centers around the highway corridors rather than in sporadically placed "strip" commercial developments. The design of these centers call for separation from each other at prescribed distances to minimize traffic congestion and to create dense areas for one-stop shopping.

Additionally, traditional downtown areas (i.e. "Main Streets") have allowed new development in their revitalization initiatives to attract more local residents and tourists.

12.2 Current Transit Service

Automobile traffic largely comprises transportation activity within Hunterdon County. The County contains 1,653 roadway miles, including sections of I-78 and US 202, both major highways. Despite heavy automobile presence, transit services do exist, particularly to serve commuters traveling to Philadelphia and New York City, as well as local residents wishing to travel between the larger towns in the county.

NJ Transit's Raritan Valley Line provides rail service to Hunterdon County commuters traveling to Newark Penn Station for the PATH train and to New York Penn Station. High Bridge, Annandale, Lebanon, and Whitehouse are the four stations in Hunterdon serviced by this line. However, only nine of the thirty weekday daily trains on this line stop at any of these stations, whereas nearby Raritan and Somerville stations are serviced by twenty-eight of the daily trains and also have more express options. While the train service offered to Hunterdon County commuters by NJ Transit does occur during peak commuting times, the lack of flexibility in travel times may impel some to consider commuting to stations in other counties and boarding NJ Transit trains from there. On the weekends, there is no service on the Raritan Valley Line from the Hunterdon County stations.

A PRT system in Hunterdon County would provide access to more convenient NJ Transit stations located in neighboring Somerset County. Commuters could travel directly to these stations from their local PRT station, thus eliminating the need to drive and park at train stations where the battle for parking spaces plays out every weekday morning. In this sense, using NJ Transit to travel to New York would be a more viable option for the residents of Hunterdon County.

NJ Transit also offers limited commuter bus service. Bus lines include Clinton to Somerville (weekdays only), Bridgewater to New York, Somerville to Newark, and Lambertville to Trenton.

Trans-Bridge Lines based in Bethlehem, Pennsylvania also operates bus service. One of its most popular lines starts in Bethlehem and makes stops in Lambertville, Frenchtown, Baptistown, Flemington, and other locations in

Figure 12.4: Hunterdon Highway Map

Figure 12.5: Raritan Valley Line

New Jersey before continuing on to Newark Airport, the Port Authority Bus Terminal, and JFK Airport. For a commuter who travels to the Port Authority in New York, the round-trip cost is $33.85. However, like many other commuter options, daily trips with stops in Hunterdon County are not frequent, and weekend options are limited.

For intra-county travel, LINK Bus Service serves the general public throughout Hunterdon County and is funded by Hunterdon County, NJ Transit, and the Federal Transit Administration. Rather than servicing regular routes, riders schedule trips on LINK buses by calling a Central Dispatch. The LINK fleet consists of 30 vehicles that run Monday to Friday from 7am to 11pm. Fares are based upon travel within established "fare zones" at $0.10 per zone mile ($0.75 one-way trip minimum). Discounts are offered to senior citizens and those with low income or disabilities.

Figure 12.6: LINK Bus Service

For more popular destinations in Flemington, LINK also offers the Flemington Shuffle Service at a cost of $1 per day for unlimited boarding and does not require prior scheduling.

Despite its cheap fares and seeming convenience of being able to schedule one's own trips, LINK is not a widely used transit option; in fact, it is mainly used by the elderly and disabled. Moreover, it is a costly operation and requires more staff than its actual services provided may justify. Given these concerns, PRT would be an excellent replacement for LINK since it will service all the popular destinations that LINK currently travels to without the requirement of prior trip planning. With PRT, public transit would become a popular transportation option for commuters, school children and the elderly alike, instead of merely serving those who otherwise have no means of transportation.

Information on all transit services in Hunterdon County can be found at http://www.hart-tma.com/home/default.asp.

12.3 PRT in Hunterdon County

The introduction of Personal Rapid Transit (PRT) to Hunterdon County will greatly facilitate public transportation between isolated areas of the County and also benefit developed regions that house a high concentration of economic activity, such as the Route 202 corridor. Most of Hunterdon's housing and commercial activity takes place in the eastern portion. The PRT network in this area is based on a comprehensive grid structure with numerous interchanges that allows for convenient access within this busy region. One of the north-south lines, for example, runs along Route 31 in Flemington, a popular shopping destination. The grid structure is easily expandable and can accommodate additional stations without much disruption in the network. Such a feature is ideal for this region of high projected growth.

In the western and southern parts of the County where farmland and nature preserves dominate the landscape, stations are connected in loop routes, and interchanges connect these routes.

The current PRT station network is designed to accommodate most of the daily trips that are taken within the county. Stations serving residential areas are located so that no more than a quarter-mile walk is necessary to obtain PRT access. For all types of trips in the County, whether for employment, shopping, recreation, or education, the convenience of PRT provides a viable alternative to the automobile.

The stations with the highest number of trips served are located at Liberty Village Premium Outlets (7,200 trips), Flemington Marketplace (6,500 trips), Hunterdon Medical Center (3,200 trips), Merck (3,600 trips) and Hunterdon Central High School (6,000 trips). The first two stations serve a large numbers of people who travel from across the County to shop at the popular stores in each location. Hunterdon Medical Center and Merck at the two largest employers in the County, and Hunterdon Central High School has the largest public school enrollment of approximately 3,000 students.

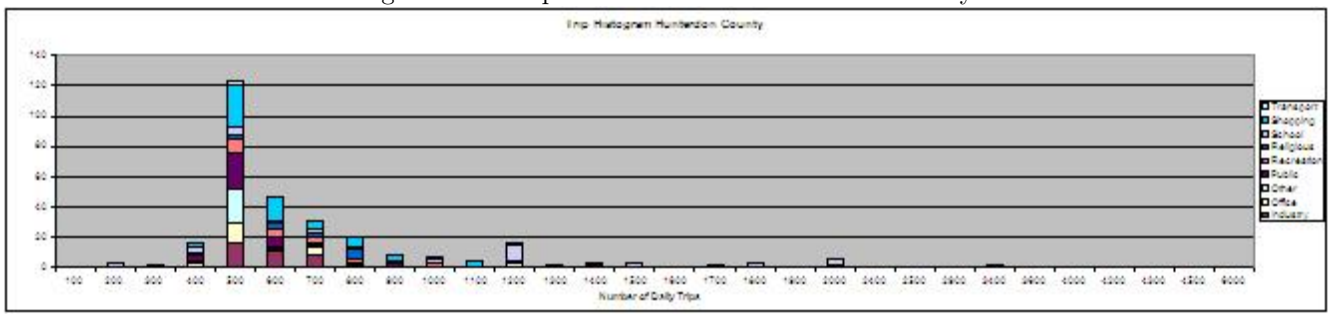
The lowest volume stations in the County serve rural residential areas where houses are spaced far apart. A discussion of these stations and the difficulties in servicing these areas is located in Section 12.8. Other low volume stations serve public buildings, such as courthouses and township government offices. These stations generally serve no more than 300 trips per day. Strictly from a trip volume standpoint, the actual services provided may not justify the exorbitant construction and operational costs of these stations. However, these locations are considered

important and some residents may voice concerns if there is no transit service for them. The overall cost-effectiveness would have to be evaluated on further iterations of the network.

The current PRT network would serve an average of 394,503 trips per day. To accommodate this number of trips, over 15,248 PRT vehicles would have to be purchased at $150,000 each, costing $2,286,259,785. Additional costs include the construction of 323 stations, 82 interchanges (stations and interchanges cost $2.5 million each) and 483 miles of guideway at $5 million per mile. In total, the PRT system for Hunterdon County alone would cost upwards of $5.7 trillion dollars.

Figure 12.7 shows a trip distribution of the PRT stations. Most stations, as evident from the graph, serve between 400 and 1300 trips per day.

Figure 12.7: Trip Distribution for Hunterdon County

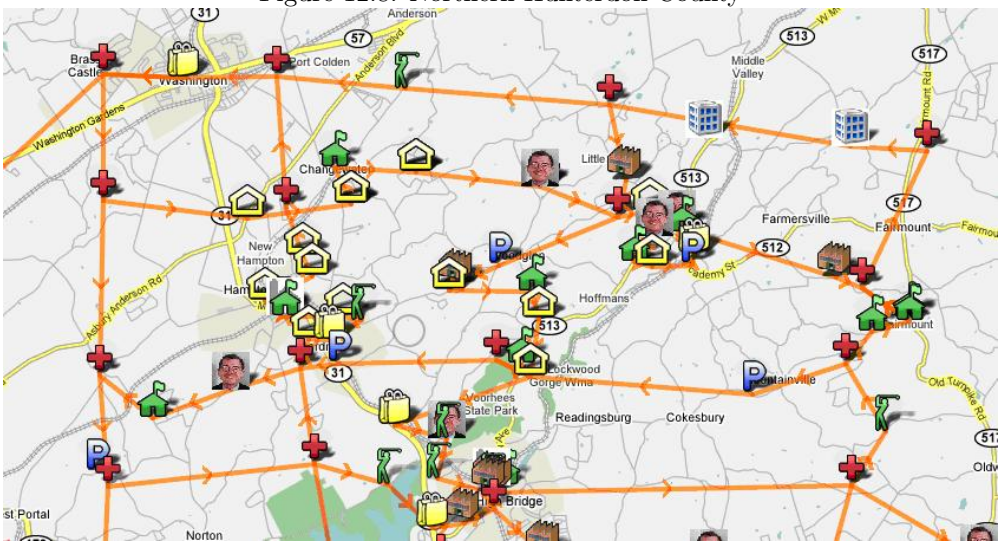


To determine how effectively the PRT stations will service daily trips in Hunterdon County, trip estimates for each type of station were made. Those stations that predominately serve residential areas were divided into "rural" housing stations and "urban" housing stations. Trip estimates for these stations were calculated from an average population density for both types of residential area in Hunterdon County. Trip estimates for stations serving schools are based on school enrollment, and the estimates for industrial and office stations are based on employment records. For all other types of stations, trip estimates were determined as a function of location, population in the immediate surrounding area and relative popularity of nearby destinations.

The PRT network in Hunterdon contains approximately 483 miles of guideway, and 323 stations and 82 interchanges where passengers may switch lines. Given Hunterdon County's population and rough trip estimates, this network will accommodate 3.26 one-way trips per person each day, on average.

The following images display two sections of the PRT network. Figure 12.8 is of the northernmost part of the County, an area serviced by a grid structure of PRT links. Figure 12.9 displays the far western area of the County, a largely rural area with PRT service organized in loop routes.

Figure 12.8: Northern Hunterdon County



12.4 Employment

Hunterdon County's labor force of over 70,000 is largely a commuting one; only 41% of the labor force works within the county. Since it is situated halfway between New York and Philadelphia and provides convenient automobile access to both, Hunterdon County is known as a "bedroom community" of these large metropolitan areas. In addition, growing employment areas in nearby Mercer, Somerset, Middlesex, and Morris Counties are all within a reasonable commuting distance.

Within Hunterdon County, the marketplace consists predominately of small businesses; in fact, out of 7,564 businesses today, 7,220 (95%) employ fewer than 25 people, while only 61 (<1%) employ more than a hundred people. While smaller businesses tend to be more geographically scattered, a large portion of them cluster around the main economic activity centers along highway corridors. These businesses also cluster in "Main Street" communities in the twelve municipalities that have traditional downtown areas.

A growing number of national companies have opened offices or headquarters in Hunterdon County in recent years, or have built additions in order to accommodate growth. These companies, among the largest employers in the County, include Chubb Insurance Company (Readington Township), Foster Wheeler (Union Township), and Merck (Readington Township). Recent office construction has taken place in Raritan, Readington, and Union Townships along Routes 31, 173, and 78. Table 12.1 on page 116 lists the major employers of Hunterdon County.

The PRT network directly services all employers with over a hundred employees. Hence, all employers in Table 12.1 have a station located on its premises. In addition, PRT may be appropriate as an inter-modal connection to NJ Transit's regional rail lines for access to employment in larger metropolitan areas.

12.5 Shopping

The most popular retail destinations in the County are Liberty Village Outlet Shopping Center in Flemington and Flemington Marketplace (formerly Flemington Mall). Liberty Village contains over 60 name-brand stores, attracting a large number of residents outside Hunterdon County. Flemington Marketplace was recently renovated and includes popular big-box stores such as Kohl's, Borders Books & Music, and Burlington Coat Factory. Another major shopping center is Circle Outlet Mall, which includes ShopRite, Linens 'N Things, and Marshall's. Other popular shopping destinations include historic downtown areas that are home to a number of specialty shops and

Figure 12.9: Western Hunterdon County

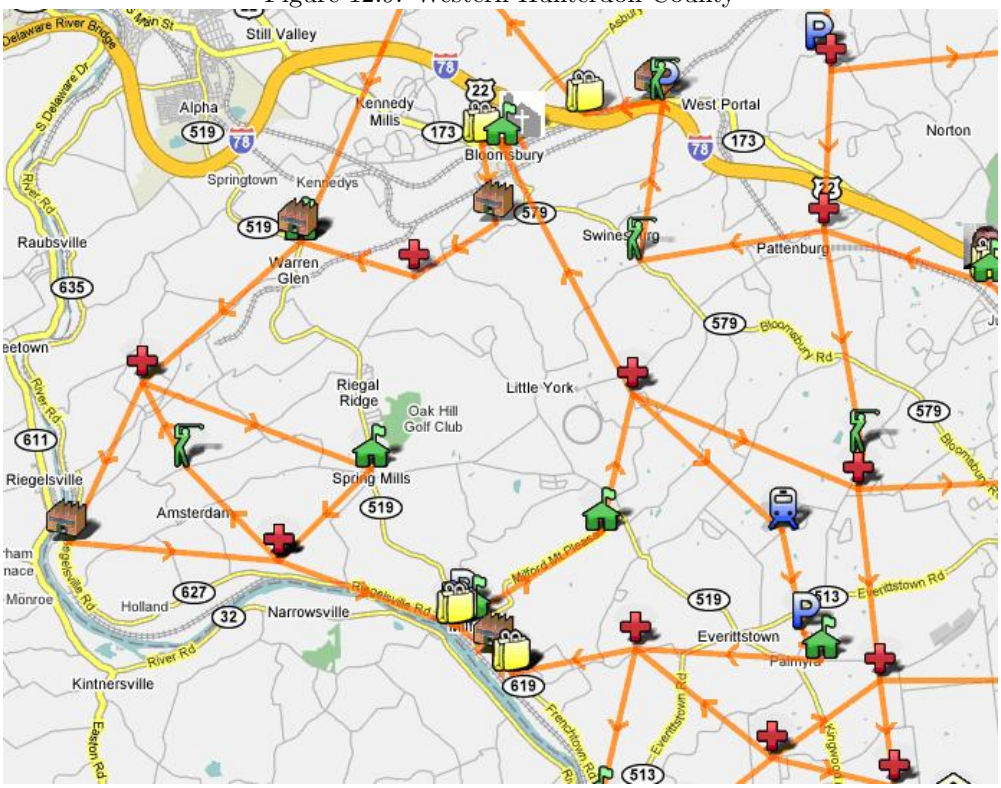


Table 12.1: Major Employers in Hunterdon County in 2001, Source: Hunterdon Economic Partnership

Employer	**Municipality**	**# Employees**
3M	Raritan Twp.	170
A.M. Best	Tewksbury Twp.	250-500
ADP	Clinton Twp.	100-249
Atlantic Spring	Raritan Twp.	100-249
Bemis Co.	Flemington	100-249
BOC Inc.	Lebanon	250-499
Burlington Coat Factory	Flemington	100-249
Chubb Insurance Co.	Readington	1500
Curtis Specialty Papers	Milford	100-249
ExxonMobil Research & Eng.	Clinton Twp.	500-999
Fibermark Inc.	Milford	100-249
Flemington Car & Truck	Raritan Twp.	293
Flemington Dept. Store	Raritan Twp.	100-249
Foster Wheeler	Union Twp.	¿1500
Georgia Pacific	Milford	100-249
Hitran Corp.	Raritan Twp.	130
Hunterdon Care Center	Raritan Twp.	175
Hunterdon County	Flemington	500-999
Hunterdon Hills Playhouse	Union Twp.	100-249
Hunterdon Medical Center	Raritan Twp.	1600
Ingersoll Rand Tool & Hoist Div.	Clinton Twp.	150
Ino Therapeutics	Union Twp.	100-249
Interstate Iron Works	Readington Twp.	100-249
Johanna Foods	Raritan Twp.	250-499
Kitchen Magic	Bloomsbury	100-249
Kullman Industries	Clinton Twp.	250-499
Lambertville Station	Lambertville	100-249
Magnesium Elektron Inc.	Kingwood Twp.	120
Merck & Co.	Readington Twp.	1800
New York Life	Clinton Twp.	400
Quick Chek	Readington Twp.	n/a
Raritan Valley Disposal	Raritan Twp.	100-249
Readington Farms	Readington Twp.	100-249
Shop-Rite of Hunterdon	Clinton & Raritan Twps.	440
Smurfit-Stone Container	Kingwood Twp.	125
Sprint	Clinton Twp.	148
Tekni-Plex Inc.	Flemington	100-249
WalMart	Franklin Twp.	200
Wedco	Bethlehem Twp.	250-499

restaurants. Downtown Lambertville, for example, has at least eleven antiques shops alone and markets itself to visitors as "The Antique Capital of New Jersey." Clinton and Frenchtown are two other towns that draw a large number of residents and visitors to its downtown shopping districts.

Figure 12.10: Liberty Village Outlet Shopping Center

Plans are underway for the proposed Raritan Town Square to be built on the former Flemington Fairgrounds. It will be the largest retail center in Hunterdon County with approximately 500,00 square feet of mixed-use stores, offices and services.

All of the major shopping districts in the County have PRT stations on the premises, including Liberty Village, Flemington Marketplace and Circle Outlet Mall. All downtown shopping areas also have PRT access since these are dense activity centers and tend to attract people for other purposes as well, such as recreation and employment.

12.6 Recreation

Hunterdon County has an extensive parks and recreation system totaling 7,430 acres that features preserved trails and nature reserves located throughout the County. There are 24 individual park areas, the majority of which are located in Raritan, Readington, Clinton, and Lebanon Townships.

The County has a long-term goal to add another 100,000 acres to the Park System for total parkland holdings of about 6% of total available land area. Other plans include the creation of South County Park, a large general use park that will build upon the existing County Fairgrounds in East Amwell Township.

In addition to parks, the numerous museums in Hunterdon County are popular visitor sites, particularly the Hunterdon Museum of Art in Clinton. Other recreational facilities include the six golf courses located in the central part of the county, Hunterdon Hills Playhouse in Hampton, All Children's Theatre in Clinton, as well as a vineyard, Amwell Valley Vineyard, located in central Hunterdon County in Ringoes.

Not all parks and recreational facilities have PRT stations directly on their premises, due to their large number and scattered nature around the county. Those that are already located in activity-dense areas may share PRT access with riders accessing the shopping and employment opportunities in the region.

For example, Hoffman Park, located in Lebanon, does not have direct access to a PRT station, but is located next to Main Street in Lebanon and may share access with the station serving the downtown commercial district. All golf courses in the county, including Heron Glen Golf Club and High Bridge Hills Golf Club, are serviced by a PRT station.

12.7 Education

Hunterdon County has 31 school districts serving over 23,000 students. The 23 elementary school districts, which also include middle schools, largely correspond to the municipalities. Elementary schools are located so that there is at least one in each municipality, but as many as four elementary schools serve a school district, as is the case with Flemington-Raritan. There are ten middle schools among the 23 elementary school districts.

Table 12.2: Hunterdon County Public School Enrollment, 2006-2007, Source: Hunterdon County Superintendent of Schools

District	**# Public Schools**	**Elementary Enrollment**	**High School Enrollment**
Alexandria Township	2	654	
Bethlehem Township	2	621	
Bloomsbury Borough	1	154	
Califon Borough	1	141	
Clinton Town	3	555	
Clinton Township	4	1,805	
Delaware Township	1	484	
Delaware Valley H.S.	1		983
East Amwell Township	1	495	
Flemington-Raritan	5	3,586	
Franklin Township	1	351	
Frenchtown Borough	1	141	
Hampton Borough	1	187	
High Bridge Borough	2	430	
Holland Township	2	718	
Hunterdon Central H.S.	1		2,976
Kingwood Township	1	488	
Lambertville City	1	154	
Lebanon Borough	1	81	
Lebanon Township	2	830	
Milford Borough	1	117	
N.H. Voorhees H.S.	2		3,032
Readington Township	4	2,234	
South Hunterdon H.S.	1	115	226
Stockton Borough	1	49	
Tewksbury Township	2	768	
Union Township	2	601	
West Amwell Township	1	254	
Total	48	16,013	7,217
H.C. ESC		5	31
H.C. Polytech			446

There are four high school districts containing five high schools. Each high school district covers the elementary school districts that send students to the respective high schools. The high school districts are based more upon geographic location than population considerations. Thus, Delaware Valley and Hunterdon South High Schools, both located in rural parts of the county have considerably smaller enrollment than their counterparts in central Hunterdon County.

The sole post-secondary education facility is Hunterdon County Polytech, a vocational school located in Flemington. Its enrollment of 446 students includes non-Hunterdon County residents.

All private schools in Hunterdon County have Pre-K and elementary-age enrollment. Five private schools are located in Flemington-Raritan, two in Clinton Township, and one each in Franklin Township, Lambertville City, Lebanon Borough, and Lebanon Township. The largest, Immaculate Conception School in Clinton, has an enrollment of 396 students.

All public schools, Hunterdon County Polytech and Immaculate Conception School have direct PRT station access. PRT will serve as a convenient alternative to the current pupil transportation system using school buses.

12.8 Housing

Using the number of residential building permits authorized in each municipality over the 1990-2002 time period as a rough measure of housing activity, Clinton Township, Raritan, and Readington have the most residential development. Accordingly, these three municipalities also have the highest population according to the 2000 Census. However, Flemington Borough and Lambertville City have the highest densities per square mile, in both population and in housing units, due to the their small land areas. A number of apartment complexes, otherwise rare in Hunterdon County, are located in Flemington. PRT stations are clustered to conveniently service these dense residential areas. In rural parts of the county, namely in Delaware, Franklin, Kingwood, and West Amwell townships, where the number of housing units per square mile is less than fifty, PRT service will mainly serve to connect these areas with destinations in larger towns; limited service is provided between these rural areas. Population statistics of selected municipalities are provided in the table below:

Table 12.3: Population Data by Municipality, Source: 2000 U.S. Census

				Density per Square Mile	
Municipality	**Population**	**Housing Units**	**Land Area (miles)**	**Population**	**Housing Units**
Raritan Twp.	19,809	7,094	37.84	523.5	187.5
Readington Twp.	15,803	5,794	47.69	331.4	121.5
Clinton Twp.	12,957	4,234	30	431.9	141.1
Union Twp.	6,160	1,725	18.97	423.8	90.9
Lebanon Twp.	5,816	2,020	31.69	183.5	63.7
Flemington Boro.	4,200	1,876	1.07	3,927.4	1,754.2
Lambertville City	3,868	1,961	1.13	3,408.6	1,728.1

The population of Hunterdon County is projected to increase to 136,919 in 2010 and 152,889 in 2020, representing an average growth of 25.3% over the 20-year period from 2000. Much of this growth is expected to occur in areas that are already home to a large population. Hence, not only do current population figures and economic activity warrant extensive PRT service to Raritan, Readington, and Clinton Townships, as well as Flemington Borough and Lambertville City, but also expected population growth in the same regions ultimately means that current planning must cater to growing transit needs.

Of all land use types in Hunterdon County, the residential type is the most difficult to service with PRT. A major concern regarding servicing residential areas with PRT is inconvenience in accessing stations, particularly for those residents who live in the rural areas of the county and in neighborhoods with large (> 3 acres) lot sizes. Residents who live in compact subdivisions with small lot sizes and make daily trips to activity-dense areas are ideal customers for PRT service. PRT station locations are chosen such that the greatest number of Hunterdon County residents receives convenient access, defined as living less than a quarter-mile from any station. In general, stations in subdivisions are placed such that they are located approximately a quarter-mile away from each other. In rural areas, stations are located such that at least three houses are conveniently located within a quarter-mile. Certainly many rural housing areas will not have the convenience of direct PRT access, but this is a concession that must be made for the network to be cost-effective. In fact, a critique of the network design may find that

three housing units is not enough, and perhaps at least five or six houses are necessary to justify the construction of a station.

Chapter 13

Mercer County

13.1 Land Use

Mercer County, located in west-central New Jersey, includes the City of Trenton, Townships of East Windsor, Ewing, Hamilton, Hopewell, Lawrence, Princeton, Robbinsville, and West Windsor, and the Boroughs of Hightstown, Hopewell, Pennington, and Princeton. As of 2000, the population of Mercer County was 350,761 people. As of 2006, it has been estimated that the county's population has risen to 367,605 people. This amounts to a population growth of 4.8%. The county is one of the highest-income counties in the nation, ranking 79th, with a per capita income of $27,914. 41.71% of Mercer County's 146,426 acres is currently developed with 31,816 acres being used for agriculture and more than 8,400 acres is designated for recreational use. It has 3 airfields and 3,202 hotel, motel and resort rooms.

The census of 2000 reported 125,807 households, and 86,303 families living in the county. Population density was calculated to be 1,552 people per square mile. As of 2006, there were 139,887 housing units with average density of 590 people per square mile. Average household size was 2.62 and average family size was 3.16. The county's population is well-distributed across age groups—24.00% are under the age of 18, 10.20% are 18 to 24, 30.60% are 25 to 44, 22.50% are 45 to 64, and 12.60% are 65 years of age or older.

13.2 Description of Current County Transit Service

Mercer County's primary public transit system is supported by the New Jersey Transit (NJT). NJT offers bus, rail and light rail services that provide about 241 million passenger trips each year. This accounts for approximately 800,000 daily trips on 242 bus routes, 3 light rail lines and 11 commuter rail lines. It has 162 rail stations, 55 light rail stations and more than 22,000 bus stops. NJT operates 3,075 buses, 907 trains and 72 light rail vehicles. Of the 242 bus routes only 13 routes service Mercer County and only the Northeast Corridor and Princeton Branch of NJT's rail provide service to Mercer County.

13.3 Overall Demand for PRT System

Large, densely populated towns such as Princeton and Trenton can be fully accessible by a PRT system since a relatively fewer number of stations can still service the area effectively. If spaced properly, residents would only need to travel about 0.25 miles to reach a station. However, this county also has its share of sparsely populated areas where a PRT system would not be optimal since a low-traffic station would need to be constructed. With a growing population, it is clear that the burden on state highways is making driving a less attractive option. A PRT system would be great in providing this growing population with mobility and serviceability, while helping to reduce fossil fuel emissions across the state created by large amounts of traffic.

We can also look at average travel times within Mercer County and compared that data with wider state and national averages to show the existence of such demand for an effective, extensive PRT system. This data is sourced from the 2003 American Community Survey performed by the United States Census Bureau.

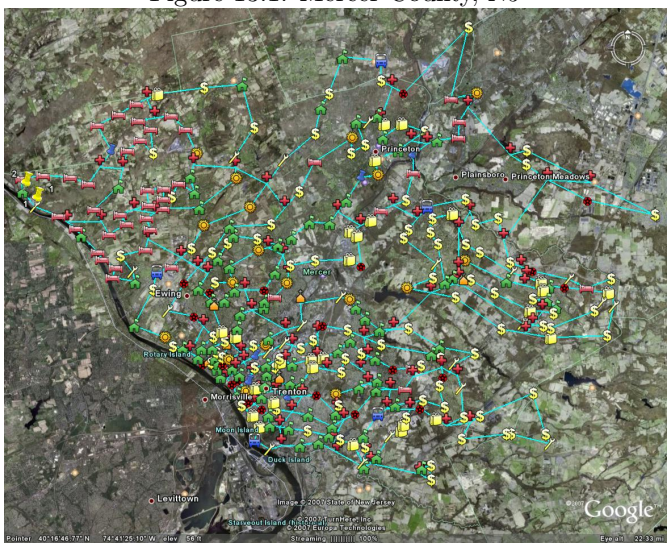
While the United States average has stayed relatively constant over the past four years, it appears that the New Jersey average has seen a slight decline in average travel time. Mercer County however, seems to move opposite to that trend in that average travel time to work has in fact increased from 24.9 minutes in 2000 to 26.8 minutes

in 2003. Due to the increased population, it seems that an improved network for transportation is required in this county to alleviate the increased traffic burden.

13.4 Network Design

We considered different designs for Mercer County's PRT system. We consulted previous reports and looked at subway and street layouts of various cities, but many proved to be sub-optimal. Tokyo's metro system is laid out in a haphazard fashion with many interchanges laid on top of one another. New York City's street grid is beneficial in that paths lie parallel and perpendicular to one another. However, I felt that the arrangement of streets in the city of Paris gave us the greatest inspiration for Mercer County's station-to-arc-to-station layout. Streets are arranged in concentric rings radiating outwards from the city centre. Consecutive rings, known as arrondissments, are connected by bridges or roads directed outwards like rays from the city centre. Likewise, we arranged arc connectivity in this fashion. We clustered locations into 4 regions: North—spanning from Princeton south to Ewing, West—spanning from Hopewell east to Pennington, South—spanning across Trenton, and East—spanning from Princeton Junction east to Hightstown. Two extra rings were created near the towns of Cranbury to the northeast and Shrewsbury to the southeast. Both of these locales were too isolated to warrant inclusion in one of the larger clusters and thus are extensions of the closest cluster using an interchange link. Each cluster features 2 or 3 concentric rings with traffic flowing in a counterclockwise motion. Having arcs flowing in one continuous direction, we avoid breaking any conditions that restrict us in our design (1 arc in and 1 arc out of each station, etc.). Also, interchanges every 3 or 4 stations apart connect consecutive rings together and ensure there is a fairly direct path from one location to another within the county. Below is a Google Earth image of our county's PRT layout complete with station and arc placements.

Figure 13.1: Mercer County, NJ



In all, this proposed PRT system for Mercer County consists of 413 stations and 403.06 miles of total guideway. There are 534 arcs proposed, amounting to an average arc length of 0.75 miles.

Table 13.1: Mercer Commute Times For Workers 16 Years and Over Who Did Not Work at Home (Minutes), Source: http://www.census.gov/acs/www/Products/Ranking/2003/R04T050.htm

Commute Time	Mercer County	New Jersey	United States
Average Travel Time to Work (2003)	26.8	28.5	24.3
Average Travel Time to Work (2002)	26.4	28.3	24.4
Average Travel Time to Work (2001)	26.7	29.1	24.3
Average Travel Time to Work (2000)	24.9	28.7	24.4

13.5 Station Types

As can be seen from the diagram and the network, we chose to represent a wide diversity of station types to provide some variety within the county. However, in the Western cluster, it is clear that housing stations are in abundance since that region of the county is sparsely populated with few businesses located. On the other hand, the Southern cluster in Trenton is filled to the brim with station types other than housing. We felt that since the population in the city of Trenton is denser, townspeople can access the PRT system through regular stations.

13.6 Service to Housing

Mercer County is home to 125,807 households living in 139,887 housing units. Due to a high population density, we wanted to ensure individuals have easy access to the PRT system. We tried to make sure stations were spaced out about 0.5 miles apart from one another so that individuals were within 0.25 miles of any station. This was difficult to ensure in sparsely populated areas. Balancing the realistic cost of station and arc construction, we understand that not all individuals will be 0.25 miles away from any station. But clearly a few customers will need to walk further to access a station, but this is in an effort to create an optimal PRT system that is also financially reasonable. Surely an extensive system can reach each individual in the county with a limited walking time, but we have considered the financial consequence of such spurious spending.

13.7 Trip Estimation

Trip estimation was a difficult task for Mercer County. The county is home to several universities and post-secondary education institutions such as Princeton University, The College of New Jersey, Rider University, and Mercer County Community College. Each of these locations covers a large expanse of land and certainly requires a station that can handle a large volume of travel. For example, trip attraction for Princeton University is estimated at 30,000. Although about 98% of the undergraduate student population of 4,600 lives on campus, we must consider the number of staff, faculty and visitors who visit the university. According to Princeton's published statistics, the university employs around 5,500 full-time employees (not including part-time, seasonal). Also included in this estimated number are students who wish to travel off campus for activities and entertainment and township residents who travel onto campus to make use of the university's resources. On the other hand, higher trip attraction numbers can be found for the College of New Jersey and Mercer Community College since a lower percentage of students live on campus and must commute to school instead. However, there are a few stations in the nearby area that can also handle some traffic load. According to a National Center for Educational Statistics report published in 2000 (http://nces.ed.gov/pubs2001/overview/table05.asp), the average secondary school enrollment was 1,053 and the average elementary school enrollment was 588 for the state of New Jersey. Therefore, we assigned each secondary school with an average trip attraction of about 2000 and elementary schools with an average trip attraction of about 1000 (multiplying both averages by two to get trip attraction).

In several cases, we were faced with stations that serviced many different shops, offices, and schools. As a result, we were forced to choose a designated type for that station. However, trip attraction for that station would depend on nearby establishments that added to that station's current trip attraction. For example, the New Jersey Department of Transportation station located in the North cluster serves trips arriving at the actual state department, a RiteAid pharmacy, a Sovereign Bank branch, a drilling company office and Ewing High school. Combined, this places the trip attraction for this specific location well in to the thousands. Other instances of such aggregation of trip attraction into one station include the Hightstown Library station, the East Windsor Regional School station, the Johnson and Johnson Consumer station, the West Windsor Public Works station (which services trip attraction to a nearby golf course), the Village Charter School station, and the Trenton Public Library station.

13.8 Conclusion

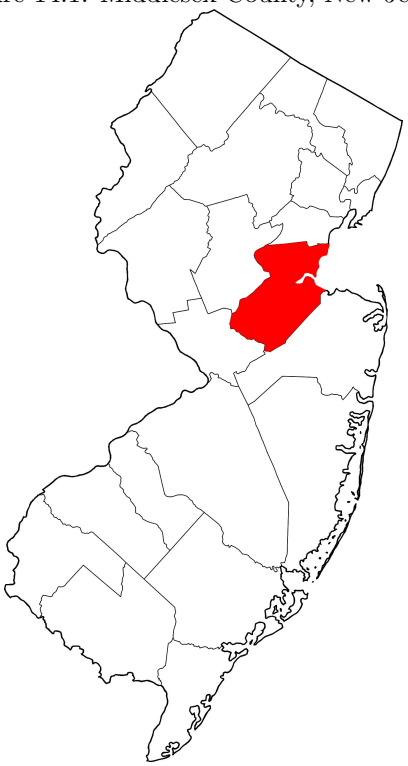
Considering the demographics of the county, the demand for a Personal Rapid Transit (PRT) system, and the resulting benefit to the county's communities, it is clear to see that Mercer County is a prime candidate for a PRT system. The proposed network provides a high level of serviceability and mobility to approximately 80% of the county population and a good level of serviceability to the remainder of the population. The densely populated towns of Trenton and Princeton will benefit from such a PRT system, and so will students attending large university campuses within the county such as Princeton University. A PRT system in Mercer County brings added value to the community.

Chapter 14

Middlesex County

Middlesex County is located in the heart of New Jersey, just south of New York City. It is bordered to the North by Union County and the Rahway River, to the East by New York City, Raritan Bay, and Monmouth County, to the South by Mercer County and to the West by Somerset County.

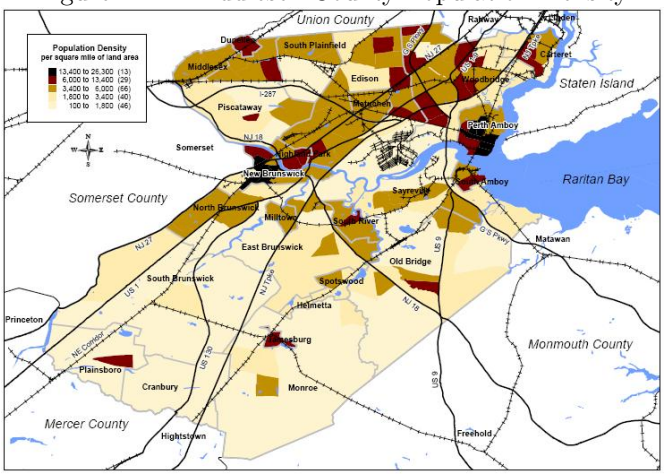
Figure 14.1: Middlesex County, New Jersey



Mddlesex is one of the fasted growing counties in New Jersey, having gained 154,000 residents between 1980 and 2000, and it was estimated at 786,971 residents in 2006. [1] The population is denser in the north and northeast areas, while the southern part of the county is less populated.

[1] http://quickfacts.census.gov/qfd/states/34/34023.html

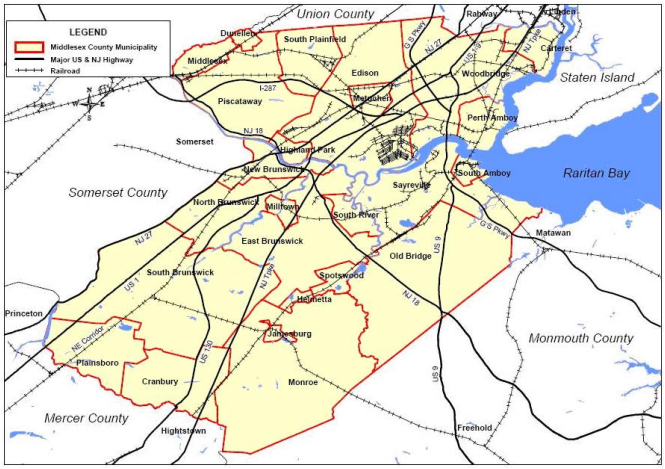
Figure 14.2: Middlesex County Population Density



14.1 Current Transportation

Current public transportation in the county includes a few small airports, the two public ones being Monmouth Executive Airport and Old Bridge Airport. There are eleven NJ Transit rail lines, including the Hoboken Division (Morris & Essex, Montclair-Boonton, Main/Bergen, and Pascack Valley lines), the Newark Division (Northeast Corridor, North Jersey Coast, and Raritan Valley lines), and the Atlantic City rail line. These lines access 10 stations within the county. NJ Transit buses also access most of the county. Sea Streak Ferry operates a ferry service from South Amboy to Manhattan.

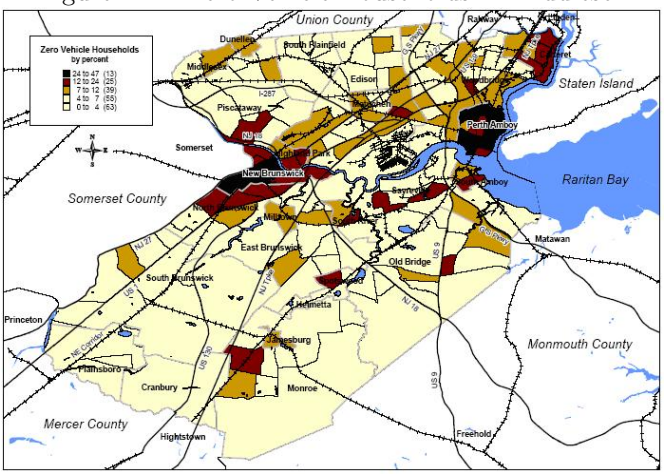
Figure 14.3: Major Roadways in Middlesex County



Middlesex is located in the largest transportation corridor in New Jersey, which includes major state roads I95 (New Jersey Turnpike), which runs NE to SW between New York and Philadelphia, and I287 (Garden State Parkway), as well as public transportation. Of the commuters in the county, about three-quarters drive alone to work, while 11% carpool and 9% take public transit. A little over half of residents work in Middlesex County and 10% commute to New York.[2] The northern half of the county has many more households with that do not have vehicles available. In New Brunswick on the west and Perth Amboy on the east side, between a quarter and a half of households do not have a vehicle available. In the southern half of the county, generally at least 95% of households have access to a vehicle.

[2] http://www.co.middlesex.nj.us/planningboard/MiddlesexTransStudyreport.pdf

Figure 14.4: Zero Vehicle Households in Middlesex



14.2 Land Use

Of the 375 square miles in Middlesex County, it breaks down into about half developed land and half undeveloped. Almost one quarter of the county is residential and one tenth is commercial and industrial.

Table 14.1: Land Use in Middlesex County

Land Use Description	Square Miles	% of County
Residential—Low Density	7.8	2.31
Residential—Moderate Density	65.12	19.28
Residential—High Density	7.73	2.29
Residential—Total	80.65	23.88
Commercial—Urban	9.61	2.85
Commercial—Suburban	3.92	1.16
Commercial—Total	13.53	4.01
Industrial	21.26	6.29
Recreational	27.31	8.09
Agricultural	41.88	12.40
Forested	82.85	24.53
Wetlands	70.28	20.81
Land Area—Total	337.76	90.25
County Area—Total	374.25	100
Developed Land—Total	179.25	47.90
Undeveloped Land—Total	195.00	52.10

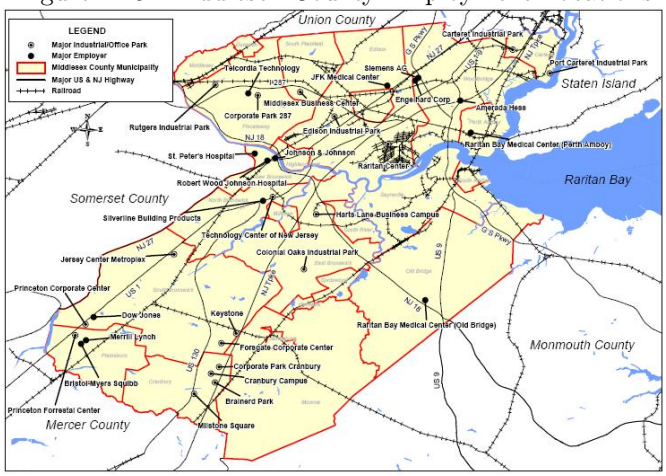
Major recreational areas include two shopping malls over 1 million square feet: Woodbridge Center Mall in Woodbridge and Menlo Park Mall in Edison. There are also many parks and open space areas, including Thompson Park in Monroe/Jamesburg, which totals 675 acres, and Johnson Park in Piscataway/Highland Park, which totals 473 acres.

Within Middlesex County, there are clusters of employment sites, including offices and industrial parks, along the Turnpike and also along US Route 1.

The top 10 major employers in the county (serving 2000 or more employees) are

- Bristol-Myers Squibb
- Merrill Lynch & Company
- Prudential Insurance Company
- Telcordia Technology
- Johnson & Johnson

Figure 14.5: Middlesex County Employment Locations



- Robert Wood Johnson University Hospital
- Silverline Building Products
- JFK Medical Center
- Raritan Bay Medical Center
- St Peters University Hospital

Commuters travel to five sites of higher education within the county: Middlesex County College, Rutgers University, Princeton University's Forrestal Campus, University of Medicine and Dentistry, and DeVry Institute.

Middlesex County contains 22 major high schools, as well as over 100 lower educational facilities. Some of the largest high schools, with enrollment over 2,000 students, are East Brunswick HS, Edison HS, JP Stevens HS, Old Bridge HS, Perth Amboy HS, Piscataway Township HS, and South Brunswick HS.

14.3 Personal Rapid Transit

Our Personal Rapid Transit system was designed with 366 stations and 71 interchanges, connected by 690 sections of guideway, totaling almost 145 miles. The system will include just over 227,000 vehicles and serve almost 6 million trips per day with an average of 18 minutes per trip and 1.6 people per vehicle during peak hours.

Because three-quarters of the commuting county population drives alone to work, a PRT system should be convenient for workers and provide accessibility to employment sites. The system was designed with stations added near major employment, industrial, and recreation sites and existing transportation sites. There are also stations in residential areas with the goal of stations within a half kilometer of most houses. The northern half of the county is more densely populated and so there are more stations there than in the southern half, which has more open space.

The stations are connected with sections of guideway to create small loops that are then connected to other loops by interchanges. The guideway between stations travels in one direction around the loop and the interchanges are connected in both directions.

14.4 Stations

The Middlesex county PRT network includes 366 stations, distributed as follows.

Five stations are estimated to serve at least 200,000 trips per day. This includes the two largest shopping centers, both over 1 million square feet: Woodbridge Center Mall and Brunswick Square Mall, as well as three industrial centers: Jersey Center Metroplex, Turnpike Industrial Park, and Keystone. Jersey Center Metroplex includes 506 acres in Monmouth Junction and Turnpike Industrial Park consists of 210 acres in East Brunswick. Keystone includes 610 acres in Cranbury. These locations would require larger stations to handle this capacity and would provide a significant reduction in traffic. The industrial centers serve a large number of employees, most

Figure 14.6: Middlesex County PRT

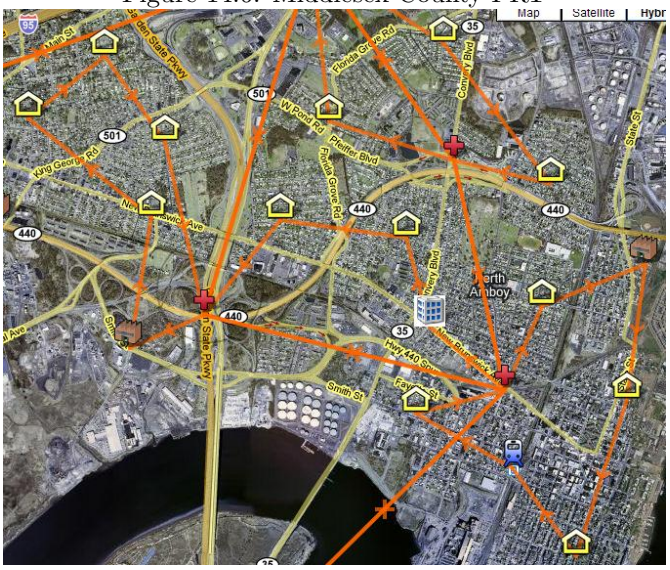


Table 14.2: Middlesex County PRT Statistics

Statistic	**Number**
Number of Vehicles	227,023 vehicles
Cost per vehicle	$150,000 / vehicle
Total Vehicle cost for your County	$ 34,053 million
# Daily Trips	5,873,481 daily trips
Average Trip Time during peak hour	18.14 minutes
Empty Return Factor during peak hour 1.4	
% daily trips during peak hour	15%
Average Vehicle Occupancy during peak period	1.64 people / vehicle
Average speed of cars on network	35 miles per hour
Average station dwell time (peak time)	1 minute
Average trip length	10 miles
People in cars with people during peak times	2.3 people

Table 14.3: Middlesex County PRT Station Statistics

	# Stations	**# Trip Ends**	**Avg. Trip Ends / Station**
housing	206	1,618,152	7,855.107
industry	94	2,565,700	27,294.681
office	16	168,500	10,531.250
public	6	90,000	15,000.000
recreation	8	1,890	236.250
school	15	231,639	15,442.600
shopping	9	1,150,000	127,777.778
transport	12	47,600	3,966.667

of whom commute alone in a car. Traveling to a shopping center is typically easier in a personal vehicle than in public transportation, because of having to carry purchases. A PRT system would provide the same potentially private travel and direct service to residential areas. These stations would be a key component of the success and profitability system.

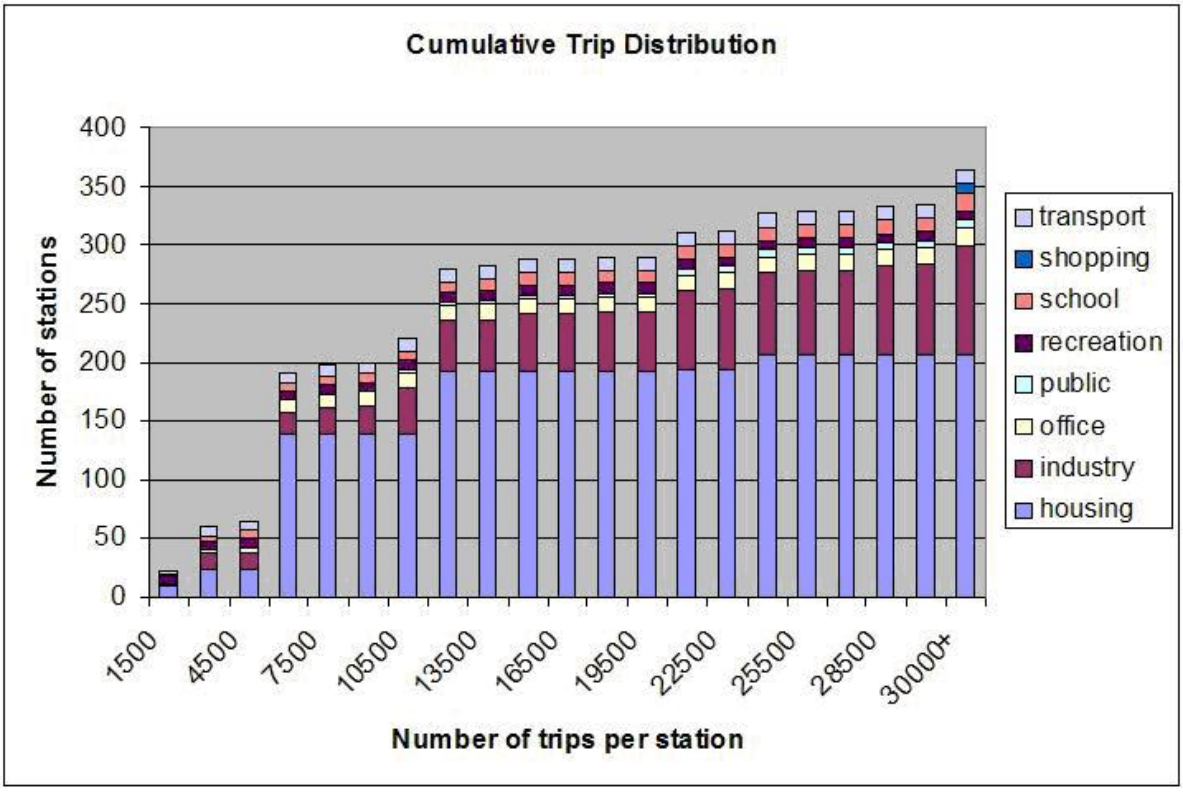
There are four parks that serve fewer than 300 trips per day. They include 473 acres at Johnson Park in Piscataway and 675 acres at Thompson Park in Monroe. Fords Park and William Warren County Park in Woodbridge total 144 acres and the last recreational area is Fairway Golf Centre in North Stelton. These recreational locations may not serve as many trips, but they are located in residential areas that may spill over. There is a lot of undeveloped land in Middlesex County and it is important to provide access to the open space areas like these recreation areas.

The system connects with current transportation in the county, with stations at the two airports and the ten New Jersey Transit stations. There are also stations at all of the major Park and Ride lots in the county in order to provide access to travelers who might not live near a station or don't want to drive their entire commute. There are all stations at all major industrial parks and office complexes, including those containing the ten biggest employers.

The stations aim to serve all residential areas by providing a station within a half mile of any house. This was more or less accomplished in the densely populated areas, as in the northern part of the county, but not always in the southern area, where the houses are more spread out.

There are stations serving the five sites of higher education, while the distribution of residential and commercial stations seems to cover enough area to serve the high schools and lower schools.

Figure 14.7: Trip Distribution for Middlesex County



14.5 Trip Estimates

We estimated the number of productions and attractions through each of the stations, based on the land use of the surrounding area, using the following assumptions.

Residential For all residential stations, the number of estimated trips is 4 times the approximate population within a half mile of the station, calculated using population density for each township. This is based on the national transportation average of 4.1 trips per person per day.

Education For stations serving educational facilities, it is assumed that each student, faculty member, and staff member would make two trips through the station per day.

Transportation We assumed that there were two daily trips through the station for each weekday boarding at the train stations, recorded by NJ Transit. We also assumed there were four daily trips made for each flight at the two airports.

Industrial and Office If there were available employment numbers, it is assumed that each worker used the stations twice each day. If the information was not available, estimates are based on the area of the buildings or the number of buildings (estimated by Google Earth), with the assumption of 500 employees per building, 200 employees per acre, or 100 employees per square feet.

Recreation For shopping centers, we assumed 25 visitors per 100 square feet of mall space. For parks, we assumed that there was 1 visitor per 10 acres of open space, based on national park estimates, with the assumption that each visitor made 2 daily trips through the station.

Hotels Trips were based on the assumption that the residents of each room made 4 daily trips and that half of the rooms were occupied.

14.6 Cost of PRT System

The system will include just over 227,000 vehicles, at a cost of $150,000 per vehicle, 336 stations, at a cost of $2.5 million per station, and 145 miles of guideway, at a cost of $5 million per mile, for a total cost of almost $36 billion.

The most costly portion of the system by far would be the vehicles required to transport all of the passengers. Initially it would be make more sense to purchase fewer vehicles because the system would most likely not start running at full capacity. As more travelers become accustomed to the PRT system, the number of vehicles could be increased to match.

14.7 Value of the PRT System and Next Steps

Current public transportation in Middlesex County is limited to a few rail lines and bus service, but the majority of travel is on major roads. A Personal Rapid Transit system would be extremely valuable to Middlesex County because of both the number of households without cars and the number of commuters who drive alone to work. By offering access to major employment sites and covering the developed land of the county with stations, our network would serve both of these groups.

Our research and network, however, are only an initial look into the needs of the county. More in-depth study would need to be done into where stations would be most useful and where there is space for stations. One of the biggest flaws in our network is that there is not necessarily room for a station in each place we'd like to locate one. We also assumed that virtually all travelers would use the system, which is not a fair assumption to make. The numbers would need to be adjusted based on actual use, which would not necessarily be uniform across the county.

Located in a major transportation corridor in New Jersey, Middlesex sees a significant amount of automobile traffic. An effective PRT system would help to alleviate that traffic, while still being accessible and efficient for travelers. With fewer people in cars, there would also be a positive effect on pollution and air quality.

Middlesex's roads are crowded and likely to get more crowded without an effective public transportation system. Middlesex's residential development increased by 9.4% from 1990 to 2000, greater than New Jersey as a whole, which increased development at 7.6%. The county is expected to grow at a rate of 8% between 2000 and 2010 and it lacks the capacity to handle these travelers.

In order to clear up the traffic, the county needs to find a compromise between the crowded public transportation and the congested roads. A PRT vehicle would allow solitary travel, while also providing a convenient opportunity to share vehicles. The next step in Middlesex County transportation is a Personal Rapid Transit system.

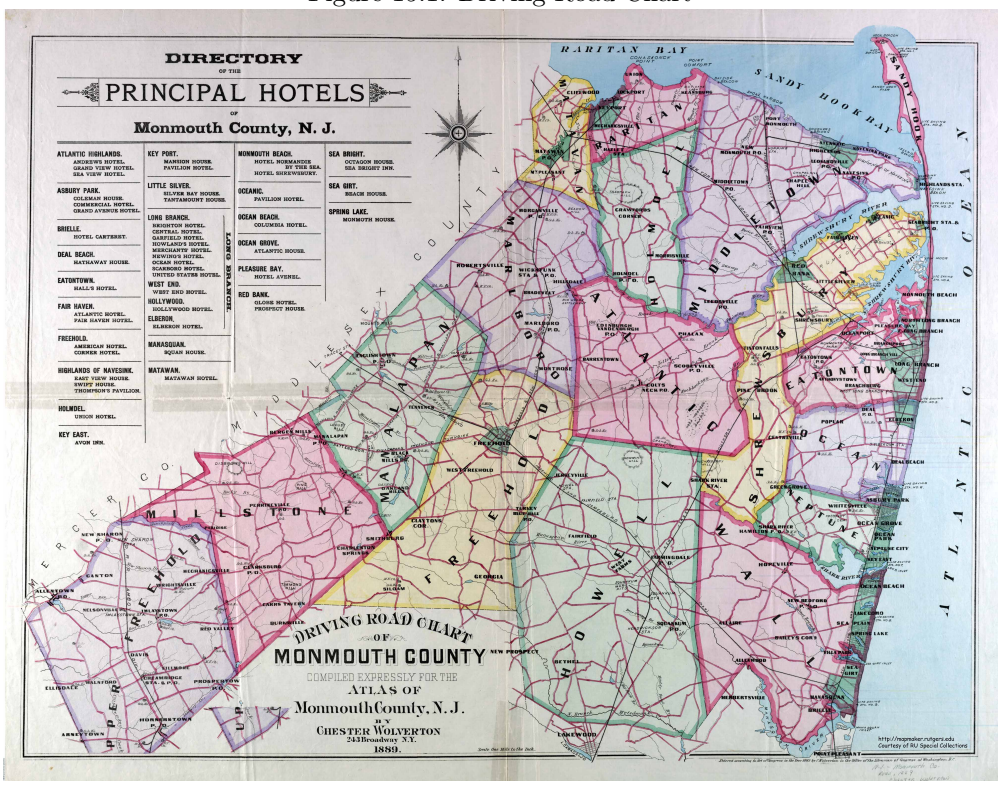
Chapter 15

Monmouth County

15.1 Overview

Monmouth County is located in central New Jersey along the Atlantic Coastal Plain. The county seat is in Freehold borough. Given its convenient position on the Jersey Shore and its proximity to New York City, Monmouth serves as an ideal residence for city commuters and boasts an increasing population as well as cost of living. It has been ranked many times by Money magazine as one of the top 10 best regions to live in the country.

Figure 15.1: Driving Road Chart



Monmouth County has historically been characterized as suburban and agricultural though its economy is mainly military and industrial. The key statistics of Monmouth County can be summarized in Table 15.1.

As we see, Monmouth is relatively wealthy compared to the rest of New Jersey, as the median household income is approximately $14,000 greater than that of the state.

15.2 Transportation Needs

This section will outline the current public transportation needs of Monmouth County as indicated by its demographics. We will apply the results of the analysis from this section when designing an effective transportation network across the county. Furthermore, we will identify foreseeable challenge areas when designing a network for this county after considering the demographic and geographic characteristics specific to Monmouth.

As identified by the New Jersey Department of Transportation, the most common demographic attributes that define populations in need of public transportation include old age, mobility limitations, low income, and limited access to private personal transit. When planning a public transportation system in general, it is important to target populations that fall into these categories. Furthermore, a transportation system with foundations in addressing disadvantaged populations such as those listed above could potentially address other macroeconomic issues such as unemployment, mobility restrictions, and pollution and thus contribute to the advancement of the county as a whole.

According to the 2000 Census, 12.5% of the population of Monmouth County was age 65 or older. Individuals in this age group typically have higher than average transportation needs and will probably make the most use of a public transit system. Regions with high population densities tend to also have high populations of the elderly. Therefore, as part of the transportation network planning process, one should target high population density areas.

Those who have "Mobility Limitations," as defined by the U.S. Census Bureau would also utilize a public transportation network. This term refers to people who have physical or mental health conditions which make it difficult to travel outside of the home alone and participate in activities such as shopping or medical appointments.

According to the Census of 1990, 4.1% of the population of New Jersey classified themselves as having a mobility limitation. For Monmouth County, 15,688 people, or 3.7% of the population were identified with mobility limitations. It is important to note that Monmouth County has one of the lowest percentages of people with mobility limitation in the state of New Jersey.

Another noteworthy demographic indication of the transportation need in an area is household income. Those with higher incomes may be able to afford more expensive modes of travel, such as the automobile. The median income for households in Monmouth County according to the 2000 Census was $71,464 compared with $57,338 for the entire state. This is a $14,000 difference! Moreover, 5.9% of people in Monmouth County were classified as being below the poverty level as compared to 8.4% for the entire state. From these figures, we see that Monmouth County, relative to the rest of New Jersey, is one of the more wealthy counties. Hence, the people of Monmouth may not be as inclined to participate in a public transit system, at least at its initial introduction. Upon further analysis, we establish that Asbury Park, Keyport, Bradley Beach, and Keansburg are the areas within Monmouth County with the greatest number of low income households. Therefore, we will try to target these areas when designing our transportation network.

For our initial introduction of a personal rapid transit network, we would like to target our need-based areas, namely those regions within Monmouth County with minimal automobile usage. As per the 1990 Census, the percentage of housing units with a lack of access to automobiles within the state of New Jersey was 12.9%, while this figure was around 8.5% for Monmouth County. One foreseeable problem with designing a public transportation network within Monmouth County is that the county is characterized by large areas of low density suburbia, rendering transportation by means other than a privately-owned vehicle less likely. In this regard, we will once again target Asbury Park, Keyport, Bradley Beach, and Keansburg as these are the areas within Monmouth County with some of the highest percentages of their respective populations without direct access to automobiles.

One of the largest factors affecting household income is unemployment. Though Monmouth County has a lower unemployment rate than the rest of the state overall, there are communities within Monmouth that hold higher unemployment rates. These include Asbury Park, Bradley Beach, Brielle, Englishtown, Freehold, Highlands,

Table 15.1: Key Statistics

Key Statistics	**Monmouth**	**New Jersey**
Population, 2006 estimate	635,285	8,724,560
Land area, 2000 (square miles)	471.94	417.34
Persons per square mile, 2000	1303.6	1134.5
Median household income, 2004	$71,464	$57,338
Housing units, 2005	252,569	34,443,981
Persons per household, 2000	2.7	2.68
Private nonfarm employment, 2005	226,344	35,948,621

Keansburg, Long Branch, Red Bank, South Belmar, and Union Beach. Once again, we see our "target communities" include Asbury Park, Bradley Beach, and Keansburg.

In summary, we will focus on six demographic features when targeting areas to design an optimal transportation network: population density, age, mobility limitations, low income level, lack of direct access to a private automobile, and unemployment. Furthermore, we will target the geographic locations of Asbury Park, Bradley Beach, Keyport and Keansburg as they often seem to fall within the aforementioned six demographic categories for need-based public transportation. One key issue we predict in our introduction of a public transit system to Monmouth County, even though it may be a personal rapid transit system, is that due to its relative wealthy status and large low density areas, it may not be utilized as much as it could be, at least initially.

15.3 Personal Rapid Transit System

15.3.1 Objective

Though Monmouth County already has a public mass transit system provided by NJ Transit, we hope to combine the benefits of a public transit system with the convenience of a personal transit system and create a personal public rapid transit system. In the following section, we examine the methodology used in the station placement and actual network creation for such a personal rapid transit system.

15.3.2 Station Placement by Land Use

Transport Hubs

Ideally, the new personal transit system would be well integrated with the existing mass transit system. Therefore, we will place PRT stations at all the existing mass transit stations. We will also place PRT stations at the existing "Park and Rides" since these areas tend to attract a lot of commuters. It is important to note the attraction of commuters to Monmouth County because of its proximity to New York City and its large low-density suburban areas which are desirable for family-oriented workers. To calculate a production statistic, we found the number of passengers that go through each one of these stations on a daily basis. Assuming that each passenger requires two trips through the station (one to and one from), we calculated the number of trips for each station.

Schools

Since school-aged children constitute a large portion of the population in general, it would be optimal to place PRT stations at education centers. We began by identifying the largest schools and colleges in the county and placed a PRT station at each of these schools. Then, we found the enrollment for each school. Assuming that each student makes one trip to school and one trip from school, on average, we calculated the number of trips that go through each school-station. This was our production statistic. Table 15.2 shows the largest schools in Monmouth County.

Housing

To determine where to best place stations to specifically address residential needs, we examined two main types of residences: hotels and senior centers. We also placed stations at all the different residential city centers in Monmouth County.

Our research indicates that Monmouth is a popular tourist destination. Not only does it boast proximity to New York City, it also has a long shore line along the Atlantic Ocean. Hence it has many beaches that are popular attractions. We identified the most frequented hotels in the county as station locations for our Personal Rapid Transit network. We then extracted the number of rooms for each hotel. Assuming an average daily occupancy of 60%, we calculated an approximate number of guests at each hotel. Using the national statistic in 2001 of 4.1 daily trips per person, we calculated the number of trips as a production statistic for each of these stations.

We also decided to target Senior Centers after our transportation need analysis as described above. As outlined in the previous section, we identified senior citizens as a category that is most in need of a public transportation service due to a general disinclination toward owning and operating a private vehicle. Therefore, senior centers would be ideal as PRT station locations. After first identifying the senior centers in Monmouth County, we approximated the number of patrons who live in each of these centers. Lower figures would be offset by visitors since senior centers do tend to attract many family members. Then using the same national statistic of 4.1 daily trips per person, we calculated the number of trips for each station if placed at each of these senior centers.

Table 15.2: Monmouth County Schools

School	**Enrollment**
Colleges	
Monmouth University	5,857
Brookdale Community College	11,552
High Schools	
Matawan Regional High School	1,052
Allentown High School	1,151
Colts Neck High School	1,766
Manalapan High School	1,973
Howell High School	1,949
Freehold Borough High School	1,385
Freehold Township High School	2,144
Raritan High School	1,039
Red Bank Regional High School	1,157
Long Branch High School	1,204
Manasquan High School	1,026
Marlboro High School	2,241
Middletown High School North	1,692
Middletown High School South	1,435
Neptune High School	1,580
Ocean Township High School	1,447
Monmouth Regional High School	1,197
Wall High School	1327
Middle Schools	
Manalpan-englishtown Middle School	1,420
Howell Township Middle School South	1,053
Long Branch Middle School	1,019
Marlboro Middle School	1,169
Neptune Middle School	1,104
Ocean Township Middle School	1,401
Intermediate Middle School	1,121

Parks & Recreation

To establish stations targeting visitors to recreation areas, we looked at the two main attractions in Monmouth County: parks and golf courses. The Gateway National Recreation Area in the New Jersey-New York region is 26,000 acres and had 8,456,456 visitors in the year 2006. We divided this by 364.25 to get the number of visitors per day and then divided by 26,000 to get the number of visitors per day per acre. We used this ratio and also assumed that each visitor would make 2 trips per visit to the park to get the number of trips per day for each park.

For golf courses, we assumed that an 18-hole course was on average, 120 acres and used this ratio to determine an approximate number of acres per golf course. We then used the same ratio as above of number of visitors per acre to determine the number of visitors and the number of trips per station located on a golf course.

Employment

To place stations for the benefit of local employees, we identified the major employers of Monmouth County. Using the number of employees at each of these offices, we generated the number of trips per station assuming that each employee would go through the station twice daily. Table 15.3 shows the major employers in Monmouth County.

Table 15.3: Monmouth County Employers

Employer	**# Employees**
Meridian Health System	7,600
U.S. Army Communications	5,500
County of Monmouth	3,545
CentraState Healthcare Systems	2,156
Monmouth Medical Center	2,050
Asbury Park Press	1,300
Food Circus Super Markets	1,263
Monmouth University	1,200
Naval Weapons Stations Earl	1,100
Norkus Enterprises	1,100
Horizon Blue Cross Blue Shield	950
Visiting Nurse Assoc. of Central NJ	769
Brookdale Community College	737
Avaya Inc.	650
NJ Resources Corporation	569
JCP&L/First Energy	529
CPC Behavioral Healthcare	435
Schoor DePalma	409
Waterford Wedgewood USA	350
YMCA of Western Monmouth County	350
Ladacin Network	350
CommVault Systems	340
Osteotech	330
IVC Industries	314
Wheelock	309
West-ward Pharmaceuticals	300
L-3 Communications IIEX System	293

Industrial

Monmouth County is characterized, like much of the rest of New Jersey, by mainly manufacturing and pharmaceutical industries. We looked up a few of these industry locations inside the county and decided to place stations there. We then estimated the number of employees who worked at each location and calculated an average number of daily trips through the station by assuming each employee would go through the station twice daily.

Public Buildings

We identified municipality centers and libraries as the main public buildings that need to be accessible by a Personal Rapid Transit system. From the Monmouth County website, we found the locations of the Main Library as well as the branch libraries. Using yearly circulation numbers as a production statistic along with the assumptions that each person makes a total of two trips through the library station and checks out, on average, two books per visit, we calculated the number of trips through each library station.

To calculate a production statistic for municipality stations, we assumed that each square mile would have approximately four stations. Therefore, we divided the population density of each municipality by four to calculate an approximate number of trips per station.

Shopping

We identified the major malls, outlets, flea, and auction markets within Monmouth County. To calculate a production statistic for each of these shopping centers, we looked at known statistics for the Mall of America. The Mall of America is 2.5 million square feet and received 40 million visitors in the year 2006. We used these statistics to estimate the number of visitors per square foot per day for each mall. Assuming that each visitor makes 2 trips through a shopping center station for each visit, we calculated the total number of trips per day per station.

Religious

We located the main religious centers of various religious denominations within Monmouth County. Estimating the number of parishioners attending each religious facility a day, we came up with a production statistic. Using this statistic, we calculated the daily number of trips through each station at each religious center.

Other

As mentioned before in our transportation needs analysis, physically disadvantaged people will need public transportation since they cannot easily operate private vehicles. Therefore, we identified hospitals as key locations to place personal rapid transit stations. We identified the largest hospitals in Monmouth County and placed stations there. To calculate a production statistic, we found the number of beds at each hospital. We used this number as a base to calculate the number of trips through each hospital-oriented personal rapid transit station.

15.3.3 Personal Rapid Transit Network

To establish the actual personal rapid transit network between the stations created using the guidelines as discussed above, we first isolated the densely populated areas within the county. Most often, these areas occurred as suburbs. We then created a circular loop around these suburban areas, linking all the stations within close proximity. This way, people would be able to return to their station of departure without leaving the vehicle if necessary. Moreover, since these loops cover a small geographical area, travelers would be able to return to their destination in a relatively short period of time, though they would have to traverse the entire loop. Monmouth County is characterized by many of these suburban population hubs separated by large expanses of open area. To connect the entire county, we placed interchanges between these suburban loops to connect across vacant spaces.

Monmouth County also boasts a long Atlantic coastline that attracts many visitors. Therefore, a highly efficient personal rapid transit network is most necessary for this area. With this in mind, we tried to fashion our guideways on the coastline to allow for fast north-south movement. This lets visitors traverse the coastline with ease.

15.4 Conclusion

Our final network reflects the high transportation needs of the coastline as well as the concentrated population of the western section of the county. These two regions are separated by the sparsely populated middle section which consequently requires fewer transit stations. The guideways on the coast were designed to allow for quick north-south traversal whereas those in the western section are placed in a general loop to allow circumnavigation of the area. On a more micro level, guideways are designed to service a cluster of stations, usually situated around a city. In total, our network had 335 stations and about 70 interchanges. We had approximately 565 miles of guideway over the entire county.

Tables 15.4, 15.5, and 15.6 outline the summary statistics for the Monmouth County Personal Rapid Transit System.

Table 15.4: Monmouth County PRT Network Summary

Statistic	Number
Number of Stations	335
Miles of Guideway	565.08
Cost of Stations	$837,500,000
Cost of Guideway	$2,825,400,000

We aimed for approximately 300 stations for the entire county to make this project cost-feasible.

Table 15.5: Monmouth County PRT Vehicle Summary

Statistic	Number
Number of Vehicles	85,408
Cost per Vehicle	150,000
Total Vehicle Cost	$12,811 million

The number of vehicles in Table 15.5 reflects the travel needs of Monmouth County residents during peak travel hours.

Table 15.6: Monmouth County PRT High Volume Stations

Name of Station	Volume
Monmouth Mall	131,778
Freehold Raceway Mall	140,114
Englishtown Auction	153,073
Collingwood Flea Market	95,671

These stations have the highest volume of passengers traveling through them on a daily basis. Note that all of these stations fall under the "shopping" category. In the Transportation Needs Analysis above, we identified Monmouth County as an ideal destination for tourists. Therefore, our recreation and shopping-based stations serve the greatest number of travelers. To mitigate this volume, we could have allocated more stations to serve these needs. However, this would require the added cost of these extra stations as well as the added guideway cost. As this is already a quite costly endeavor, we believed that a slightly larger station that could serve more travelers would be more cost-effective than more stations with fewer travelers. Low Volume Stations Station Name Volume Manalapan Senior Center 100 Middletown Senior Center 102 Neptune Senior Center 103 Freehold Township Senior Center 112

We see that the stations with the lowest volumes have about 1/1000 the volume of the high volume stations. Note that all these low-volume stations are housing-based stations. Out of all the different types of stations, most are devoted to housing-based needs. Therefore, it is understandable that the housing stations would serve the fewest number of travelers. Furthermore, we can see that all these low-volume stations are located at senior centers. As per our Transportation Needs Analysis, senior citizens are one of the primary demographic categories in need of a transportation system. A PRT system would arguably increase the marginal utility of senior citizens more than the average citizen of Monmouth. Hence, we are justified in placing stations here despite the low volume of travelers.

The following are pictures of the actual PRT network system:

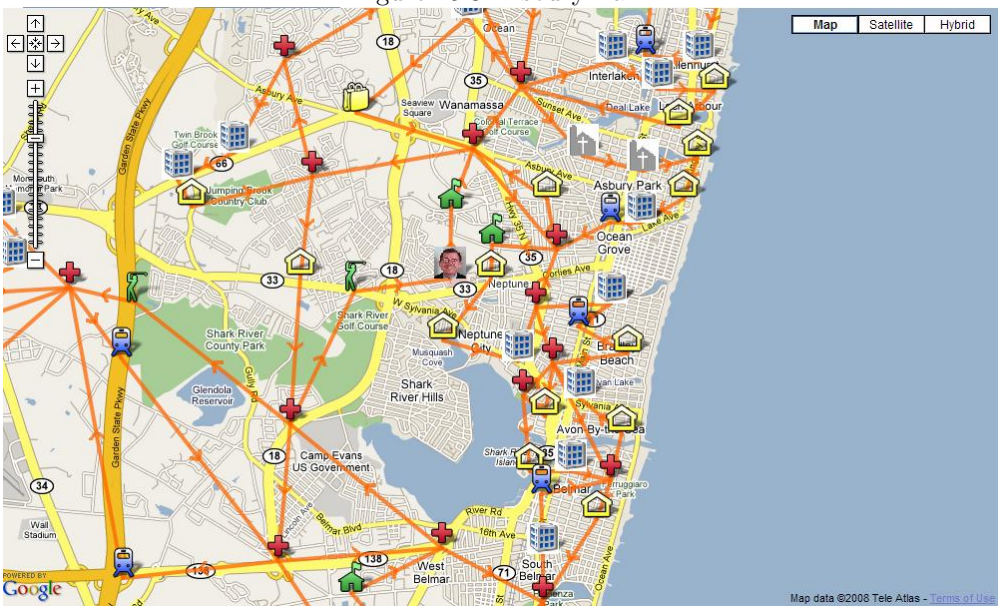
Figure 15.2 is a very general view of the station placement across Monmouth County. Note the density of stations along the shoreline as well as the cluster in the south-west portion of the county. This correlates with the population density of the county. These two regions are separated by a relatively sparsely populated middle portion.

Asbury Park, shown in Figure 15.3, was identified in the Transportation Needs section above as one of the most PRT-needy areas of Monmouth County. Therefore, many stations are clustered around this area.

Figure 15.4 shows detail of the PRT network along the southern shoreline of Monmouth County. Note the north-south movement along the shoreline and the less dense guideway network leading away from the shoreline to the western part of the county. This is a result of the less-populated middle expanses of the county.

Figure 15.2: Station Placement

Figure 15.3: Asbury Park



15.5 Sources

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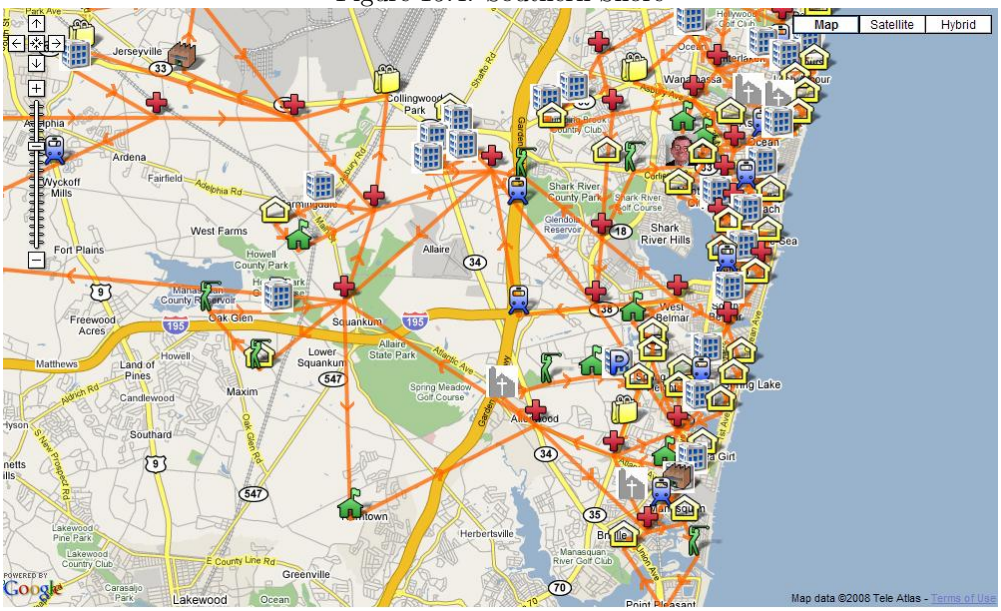
"Monmouth County." Monmouth County New Jersey DOT. 2000. 13 Dec 2007. http://www.co.monmouth.nj.us/06612trans/mon_co.htm.

North Jersey Regional Transportation Model Update. August 1996. URS Consultants Inc. 13 Dec 2007. http://www.njtpa.org/DataMap/Perf/Model/documents/NJRTM_documentation.pdf.

Figure 15.4: Southern Shore

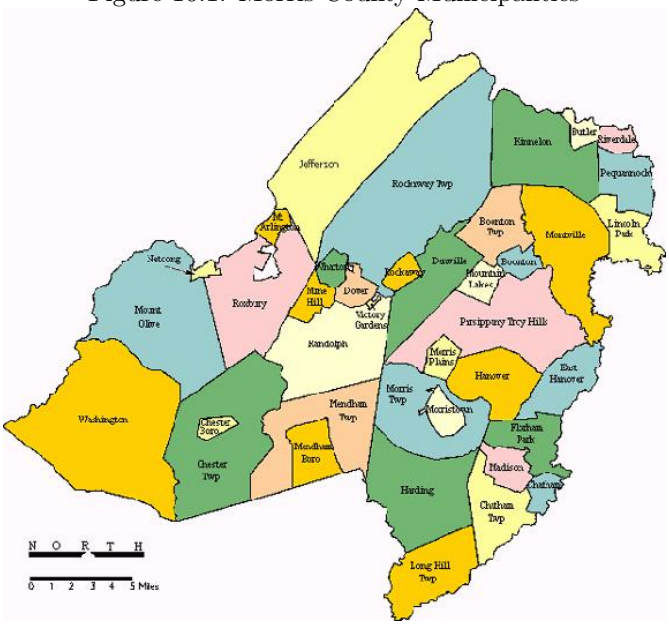


Chapter 16

Morris County

With 469 square miles of land, Morris County is New Jersey's seventh largest county with respect to total land area. It is divided into 39 municipalities, from the urban towns of Morristown and Parsippany in the eastern section of the county to the more rural Washington in the southwestern section. It is listed among the wealthiest counties in the United States, and is also one of the most rapidly growing. The economic boom in Morris County combined with the great increase in population over the past several years (total population grew 4.3% from 2004 to 2005 to a total of 490,503 people) have caused the county to grow faster than the existing transportation infrastructure can support. The proposed Personal Rapid Transport System would provide some relief to the stressed system already in place, and would service major employers, residential neighborhoods, educational facilities, recreation centers, and commercial and industrial establishments.

Figure 16.1: Morris County Municipalities



A PRT system operates based on the land use of the area; therefore, this proposal outlines a thorough examination of land use in Morris County.

16.1 Land Use

16.1.1 Empty Space

Over the past thirty five years, Morris County has experienced rapid economic and physical development. In 1970, 63% of the county was considered "vacant land", which is defined based on the county tax regulations. Land considered vacant must be under private ownership, and this categorization does not include agricultural, parks,

or watersheds. By the end of 2005, the amount of empty space in the county had been reduced to just 9% of the total area. These empty areas are scattered in small parcels throughout the county, rather than being congregated in one central location. In general, however, the northern and south western parts of Morris County are the least developed, with the central and eastern areas being highly developed.

16.1.2 Residential Land

Residential space makes up the majority of the developed land in Morris County, rising from 16% of land use to 33% of land use in the past 35 years. In 2000, there were a total of 174,379 housing units in the county, with a population density of just over 1000 people per square mile. The majority of the people can be found in the more developed sections of the county, primarily in the east.

In Morris County, single family, detached housing is the primary type of residence. This type of housing accounts for approximately 69% of the total housing in the county. With the rapid growth that Morris County is experiencing, however, this percentage is beginning to fall. Mainly, it is being replaced with connected single family housing, such as condominiums. New Jersey State mandates for affordable housing instigated the current change that the county is experiencing, and as the cities of Morris County grow larger, it becomes more space efficient to have large buildings with multiple housing units, as opposed to residential areas with large plots of land.

16.1.3 Commercial Space

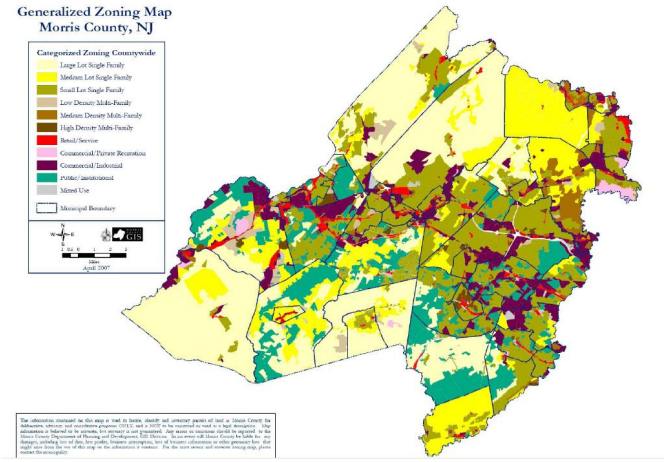
Currently, commercial space comprises about 5% of total land use in the county, rising from just 1% thirty five years ago. Commercial space is defined as office space and retail. The eastern portion of the county has experienced the biggest growth in terms of commercial area. While the office space is more uniformly located throughout this region, the retail space tends to be built around the existing highways in the county. However, in the next several years, the amount of retail space is expected to continue rising considerably. As the populations in the municipalities continue to grow, more retail space is needed to accommodate everybody.

The growth of office space, however, is expected to slow, potentially falling to zero in the next several years. Morris County currently has a total of 27 million square feet of office space, and they have recently faced a problem filling all of the space available. The completion of the interstate highway system, which originally brought on the growth in office space, has also made it easier for people to travel out of Morris County to work. Therefore, future development in the county will be focused elsewhere, rather than on continuing to focus on this commercial space.

16.1.4 Industrial

Industrial space has faced smaller growth than the other types of land use, growing a single percent since 1970. This is because New Jersey as a whole has been cutting down on traditional heavy manufacturing. The growth comes from smaller companies, such as specialty manufacturers and storage facilities. This pattern is not expected to change; therefore, industrial land is anticipated to remain relatively stable in the future. All together, Morris County contains about 116 square feet of commercial and industrial space.

Figure 16.2: Map of land use and development regulations within Morris County



16.1.5 Parks and Open Space

Morris County puts a high value on preserved public parks and open space. Through funding initiatives and conservation efforts, this recreational space has increased to a total of 22% of the land area in Morris County. These parks and gardens are meant to help foster tourism within the county and also to provide clean, relaxing outdoor recreation for the people who live in Morris. These parks are widely dispersed throughout the county to ensure that all residents of the county live relatively nearby one of the major sites.

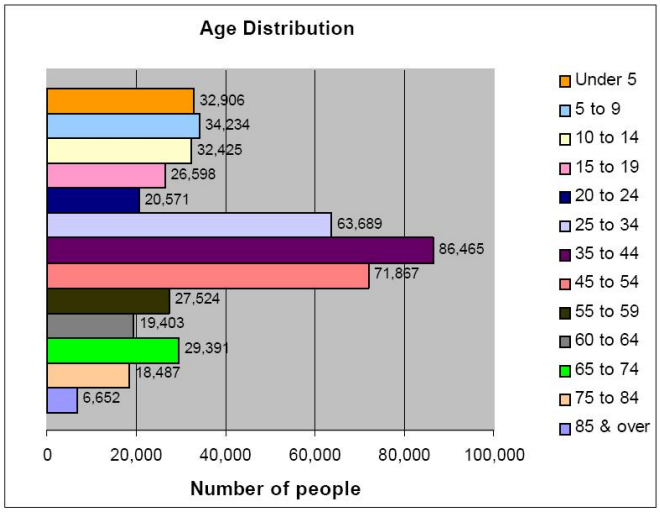
16.1.6 Agriculture

The majority of the agricultural land in Morris County can be found in the southwestern portion, in the municipality of Washington, and along the northern border. Statistics have shown that the amount of agricultural land has risen over the past several decades; however research has shown that this is due to a change in the qualifications of farmland, as opposed to an increasing increased amount of farming. Land assessed for tax purposes as farmland currently makes up 10% of the county.

16.1.7 Education

While Morris County is predominantly composed of middle aged people, the younger generation outnumbers the older generation, a result from the population boom that the county has experienced. Included are more than 116,000 children under the age of 18. The county has a total of 40 public school districts as well as many private schools to ensure top-quality education for the children living there. In addition, the county is the home to 3 four-year colleges as well as the County College of Morris, which enhance continued education within the county.

Figure 16.3: Age Distribution in Morris County



16.1.8 Other Public Space

This category of land use is much more generalized, including facilities such as libraries, churches, cemeteries, correctional facilities, and other general public areas. This land use, combined with education, currently accounts for 13% of the total land area in the county. This figure has been growing in the recent past, largely due to increasing population in the county and the resulting increased demand for these public areas.

16.2 Existing Transportation Systems in Morris County

The Morris County Department of Transportation is responsible for all transportation throughout the county, including rail, bus, paratransit options, park-and-rides, bicycle and pedestrian travel, and carpooling. In terms of public transportation options, the MCDOT emphasizes the availability of bus travel. The Morris County Metro bus system consists of seven different bus routes that have service to nearly all of the different municipalities. Bus scheduling is also provided on the MCDOT website for the different routes. The problem with this system comes

with the reliability of these schedules. Sometimes, if buses break down or are running late, wait times at the station can be very long. There is currently no way to estimate the expected wait time at the bus stations. A PRT system would be more reliable in estimating wait time because it allows the user to make decisions in real time, and multiple cars ensure that a malfunction in one vehicle will not bring down the entire system.

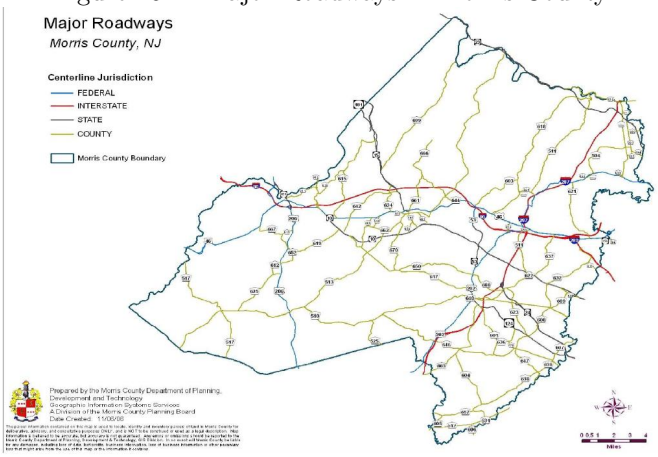
Rail travel is also a very important aspect of current transportation in Morris County. Passenger railroad travel is served primarily by NJ Transit, which provides three rail lines through the county. Both the Morristown and Gladstone Branch lines provide service to Penn Station in New York City, Newark, and Hoboken. The Montclair-Boonton line is linked to Montclair, Hoboken, and Newark, with connections to New York City. Rail travel provides an easy and accessible way out of the county, but transportation within the county is a little more difficult because there are not an adequate number of stations. PRT would improve intra-county travel by targeting major attractions and providing efficient, safe, and reliable service to these individual places.

The MCDOT also encourages people within the community to bike to work through NJ Transit's Bike Aboard program. This program allows people to bring their bicycles aboard the train during off-peak hours and weekends and provides storage for bicycles at each of the train stations in Morris County. They also emphasize the health and financial benefits of biking to work daily.

Morris County has also instituted a program designed to help with transportation needs for the elderly and those with disabilities. The Morris Area Paratransit System (MAPS) relies on force of small buses, vans, and station wagons. This service is used to transport those who are unable to drive themselves to medical facilities, employment centers, or education sites.

In terms of air travel, Morristown Memorial Airport (in Hanover Township) (MMU) and Lincoln Park Airport are both small, private airports within the county. They are used to service private pilots and corporate aircrafts. MMU averages many more flights per day than does Lincoln Park, and due to the larger size, many companies choose to use MMU's facilities.

Figure 16.4: Major Roadways in Morris County

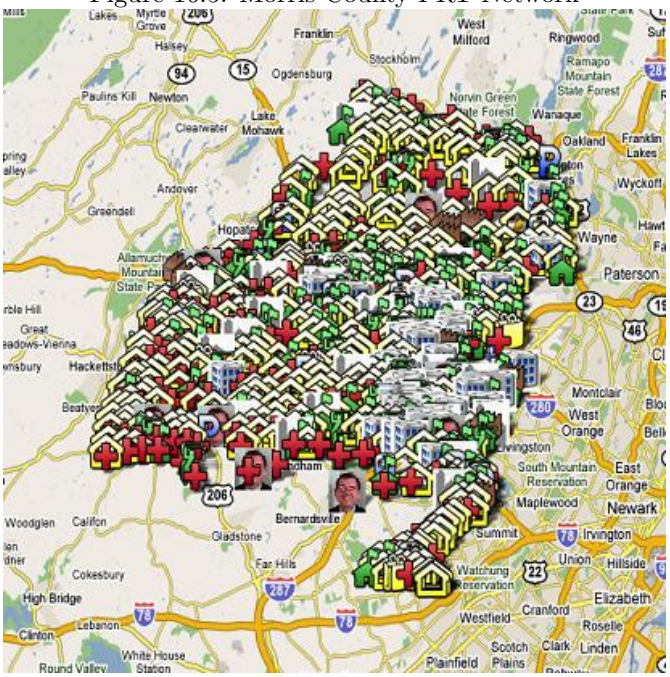


Road and highway land usage have increased to about 6% of the county's total land area in 2005. This is caused by expansion of the major highways and the development of the local roads as population has increased through Morris County and people have begun to spread out. Officials expect that the percentage of this land use in the county will remain constant over the next several years, mainly due to difficulties receiving approval for further development. They believe that the highway system in Morris County is already well enough developed. However, the local roads and highways in some of the more developed areas within Morris County suffer from serious traffic problems due to lack of capacity. I have included a picture of the highway system in the county. While highways do cover an extensive part of the county, capacity needs to be increased. The highway system is already showing signs of strain, and with the growing population in the county, the situation is only going to continue declining.

16.3 Description of the Personal Rapid Transport System in Morris County

The intent of the PRT network in Morris County was to place a station within a quarter mile of every main attraction. To identify the stations, much of the data I used was found online, for example, school enrollments.

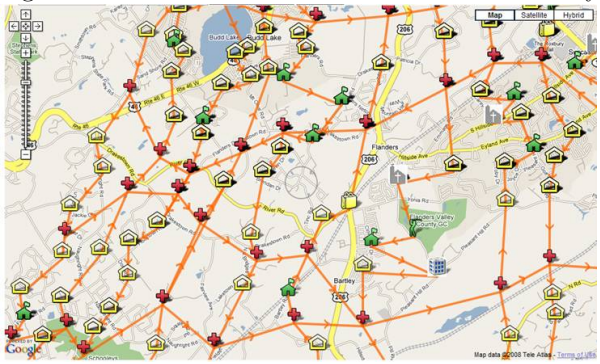
Figure 16.5: Morris County PRT Network



This was augmented by a trip to Morris County, where I spoke to the Morris County Visitor's Center, the Chamber of Commerce, and the Economic Development Corporation. They gave me information that helped me to distinguish major attractions throughout the county. To locate residential areas, I used the hybrid feature of google maps and found key neighborhoods where the housing seemed to be dense.

Figure 16.6: Rural PRT Network in Morris County

Figure 16.7: Urban PRT Network in Morris County



Once the locations for the stations were located, I estimated trips for each of the different locations. For housing complexes, I divided the county into urban and rural areas and used the population density of the county to assign trips. Education and employment center trips were based off of total enrollment and the student to teacher ratio or number of employees. Commercial centers were based on their location and the size and development of the area and facility. Recreational trips were dependent on the size and type of the area, for example, a national park with 900 acres was expected to draw more visitors than a 2 acre garden. Finally, religious centers were assumed to attract a certain percentage of the population of the town in which they were located. Afterwards, I connected the county in a modified grid. I have alternating horizontal and vertical lines which allow the rider to travel from any point in the network to any other point in a relatively convenient manner.

The PRT system is relatively dense throughout the county; however, concentrated zones exist in some of the more densely populated areas. Much of Morris County's land usage is agricultural, open space set aside for parks and wilderness protection, and residential. Aside from the major towns, such as Chatham, Morristown, and Parsippany, attractions are relatively spread out, with residential space filling in the gaps between the large towns. By identifying more stations within these larger towns, walking distance to the primary attractions is limited, and therefore the system is more effective. The goal of the network is to unite the rural areas of the county with the urban areas and to provide a convenient public transportation system throughout the county. Overall, due to the extensive coverage of the network, this system provides a feasible alternative to the automobile for all residential, commercial, office, and recreational land usage within Morris County.

Table 16.1: Morris County PRT Design

Attribute	**Number**
Number of stations	732
Number of interchanges	128
Miles of guideway	693.88
Average arc length	0.71
Trips/Person/Day	3.33

The histograms that follow describe the number of stations in the total network that service a given number of people. I originally had each bar represent 100 trip groups, however, due to the large difference in trip numbers between the urban and rural sections of Morris County, this didn't make sense. Therefore, I resized the bin numbers so that 20 bars of the graph cover 95% of the attraction numbers. The remaining five percent are then covered in the final bucket. In the total network, the largest trip groups are 775-930 people and 2945-3100 people, primarily due to housing. As previously mentioned, to estimate housing trips I sectioned the county into rural and urban areas, and then used the population density to estimate trips in each of these sections. This caused all housing to be one of two values (792 for a rural area or 3057 for an urban area). Therefore, I included a second histogram in which the housing stations are taken out to get a better look at some of the smaller land use types. The histogram takes a generalized bell shape, with an extended right tail (which is condensed into the final bucket). The most stations are within the 930-1085 trips per day range. The number of trips to the different stations varies greatly throughout the county. This is because of the distinct separation between urban and rural areas in Morris County. Towns such as Morristown, Parsippany, and Florham Park are very dense and attract many visitors. Therefore stations located in these areas can expect a large number of people. The Northern and Western sections of Morris County, however, have not yet reached the level of development seen in some of the larger towns and therefore fewer attractions are seen at PRT stations located in these areas.

The stations expecting the largest number of attractions are primarily shopping areas. Commercial space is currently only 5%, which includes office buildings that are not used for shopping. Therefore, the residents of Morris County have a limited number of places to shop; everybody frequents the same areas. Another station expected to attract a large number of trip is the Morris Museum. Morris County is proud of its historical background, and this museum is located right in the center of activity in Morristown. The museum is also involved in a series of student and adult programs, which augments the number of expected visitors per day. Also included is the Bickford Theater, a 312 seat theater that puts on five performances a day. Other high trip estimates can be found in the employment locations and schools with a large number of employees or students. Atlantic Health, for example, has approximately 11800 employees spread out over its two primary locations. The stations located at these places are expected to serve about half of the total number of employees. Morristown High School has the largest enrollment in the county. This school can expect about 3500 trips per day including all students, teachers, and visitors.

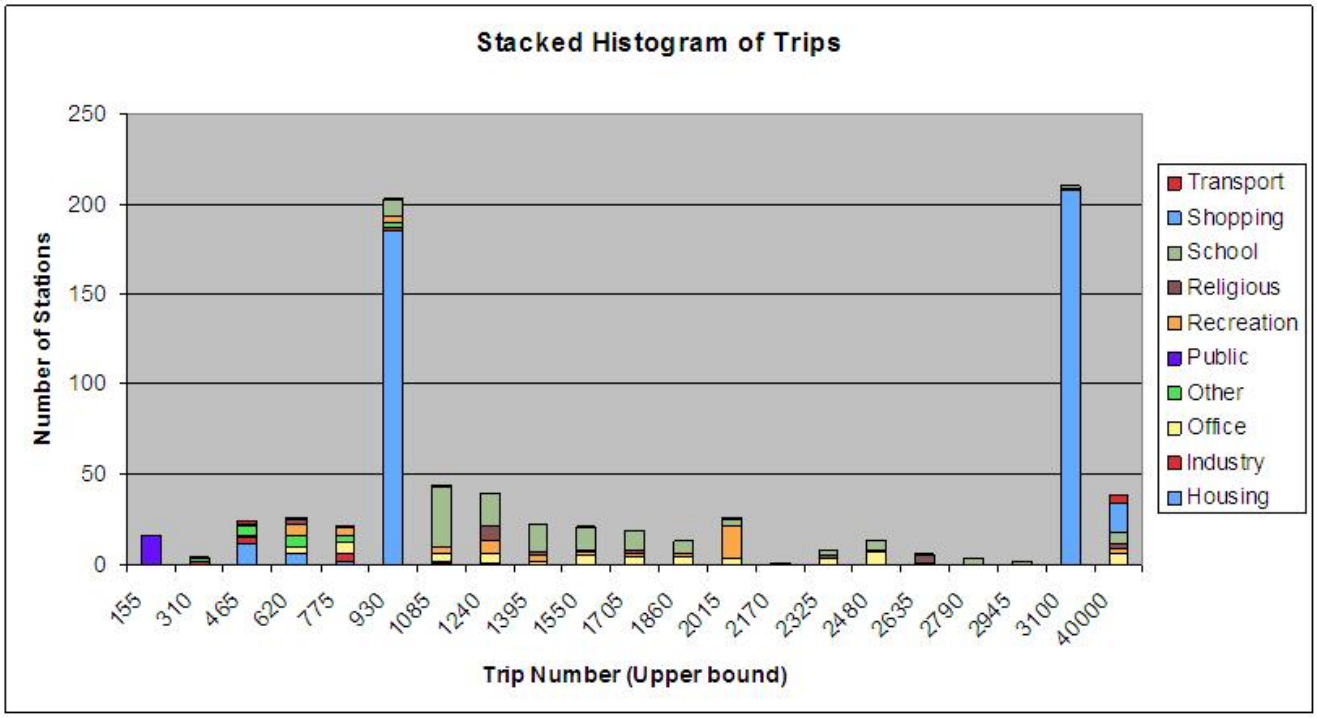
The smallest trip estimates can be found primarily in the public buildings, such as libraries and courthouses. These are locations that do not necessarily attract many people everyday, but are still important to put on in the

network. Residents may voice concerns if these locations were not included, however the overall cost effectiveness is still up for debate. Some of the other lower trip estimates can be found in existing transportation locations (i.e. train stations). Currently, the existing transportation networks in Morris County are not as efficient as they need to be. Train stations currently are not easily accessible to the general public, but they provide an easy route to New York City. The PRT network, by increasing the accessibility of the train stations, should also increase the number of trips each day to the existing train stations.

In total, the PRT system in Morris County is expected to serve 1,638,564 trips per day. Using a series of assumptions given to us about the number of people in the cars at peak times, the number of trips taken at peak times, and average trip length, we estimate that approximately 63,334 cars will be needed to satisfy the total demand in the county. Assuming that cars cost $150,000 each, we estimate a total vehicle cost of approximately $9.5 trillion. We also assume that each mile of guideway in the network costs $5 million. Therefore, to build the 693 miles needed to create this network, we expect a cost of about $3.47 trillion. Finally, we estimate stations to cost $2.5 million each. The total cost of building the stations outlined in this network is $2.15 trillion. All together, we expect that this network will cost approximately $15.12 trillion dollars.

Overall, this is just a primary attempt at designing a PRT network in Morris County. It is important to iterate the design, and continue going over the proposal to pinpoint stations that may not be necessary to reduce the total cost of the system. However, while this number is high, it provides a needed service to the surrounding area. Current transportation in Morris County is inefficient and under developed, and this method provides a potential solution to the problem.

Figure 16.8: Trip Histogram for Morris County



16.4 Service to Employment

Only 57% of the people who live in Morris County also work in Morris County. Therefore, for this area in particular, the statewide network is very important. Currently, the mean travel time to work for the average person is about 29 minutes. The development of a PRT system that identified the major employment centers could significantly reduce this daily commute. Morris County recently experienced a period of tremendous growth in the amount of office space offered, and now they are having trouble filling it all. As economic development continues, however, more people will be attracted to Morris County, putting further strain on the roadways during peak hours. By identifying these high-attraction zones, a PRT system could reduce this strain.

In designing the proposed system, I identified all businesses in Morris County that employed over 100 people

Figure 16.9: Trip Histogram without Housing for Morris County

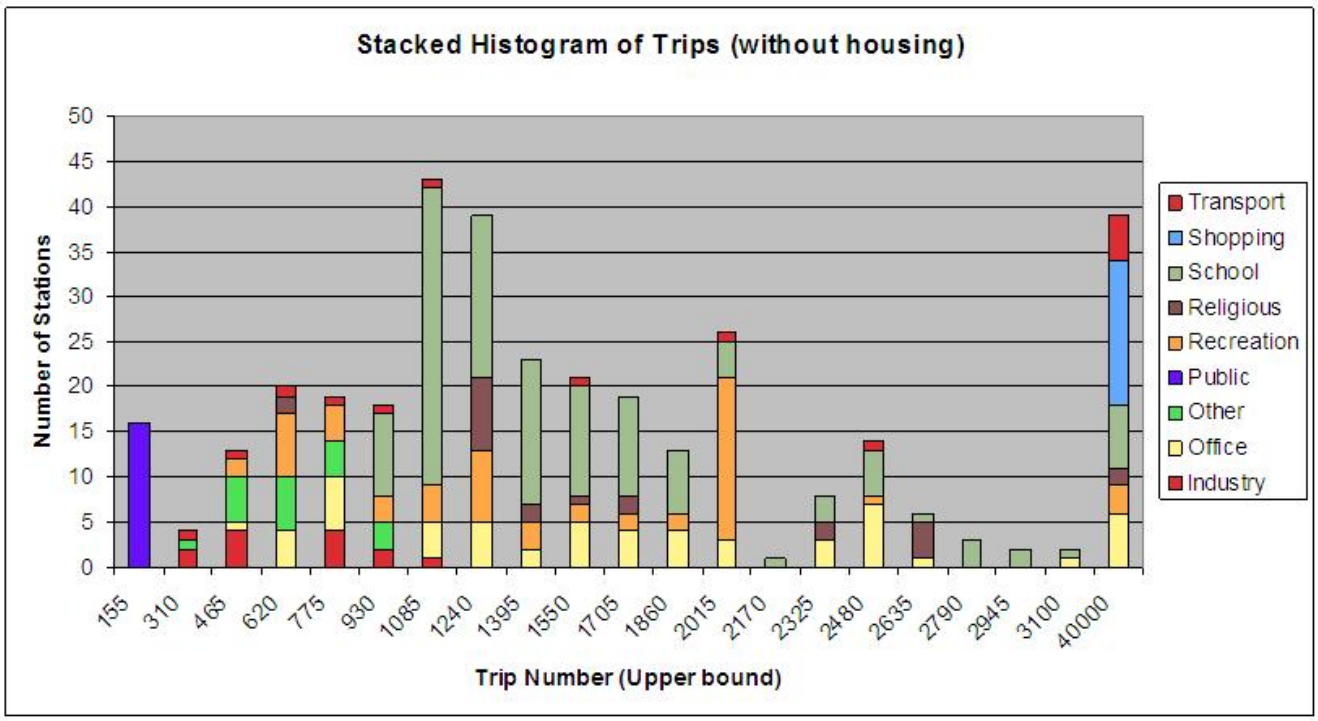
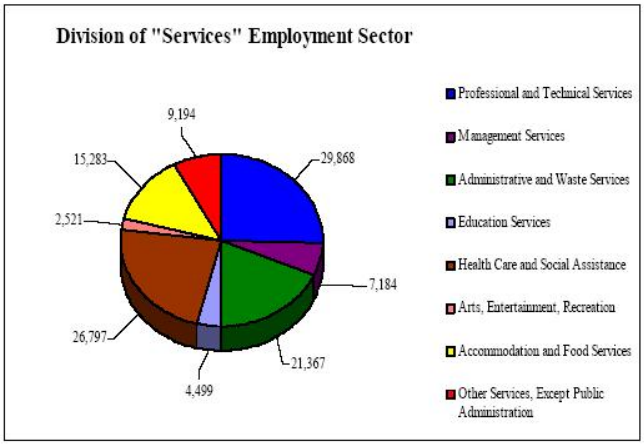


Figure 16.10: Breakdown of employment in Morris County by type



and included a station at the location for easy access through the PRT network. This way, I was sure to service the majority of the people traveling to work each day. I have included a list of the top employers in Morris County provided by the Morris County Economic Development Corporation at the end of this paper. This list includes the municipalities in which these businesses can be found. Each of the businesses on the list are directly serviced by the PRT network (with the exception of Morris County itself, as there is not a central location, but rather several small locations throughout the county that are serviced by various stations).

16.5 Service to Shopping

Shopping in Morris County tends to be separated into two distinct types, malls and other big shopping centers, and downtown stores on "Main Street" in the different municipalities. Most of the shopping in town centers was adequately covered by existing stations in the PRT networks.

Table 16.2: Shopping in Morris County

Shopping Center	**Town**	**Estimated Trips**
Rockaway Town Square Mall	Rockaway	6,410
ITC Crossings	Budd Lake	8,100
ITC Crossings	Mount Olive	13,182
Roxbury Mall	Roxbury	20,000
Ledgewood Mall	Ledgewood	2,558
Shopping Center	East Hanover	11,393
Morris Hills Shopping Plaza	Parsippany	9,205
Troy Hills Shopping Center	Parsippany	9,205
Shopping Plaza	Parsippany	9,205
Shopping Plaza	Morris Plains	5,236
Flanders Village Mall	Flanders	12,217
Randolph Shopping Center	Randolph	20,000
Valley Mall Shopping	Gillette	3,278
Downtown Morristown	Morristown	9,426
Pine Street Shopping	Morristown	9,426

Therefore, I focused on the larger shopping centers for which a significant flow of people were expected. By speaking to Christopher Marra, the executive director of the Morris County Economic Development Corporation, I was able to identify the primary shopping centers throughout the county. I have included a list of these principal shopping centers as well as the town in which they are located and the estimated number of trips per day.

16.6 Service to Recreation

Morris County is particularly proud of its rich background and historical importance. When I spoke to the people at the Morris County Visitor's Center, it was noted that public transportation between the more popular historic sites throughout the county was noticeably lacking. Visitors (and residents of the county) were forced to drive from one location to the other, as many of the museums are not within walking distance of each other. This is frustrating, as the roads in Morristown (the center of historic activity) are highly congested, and parking is limited. I have included a list of the museums that I identified through information gathered at the visitor's center as the busiest tourism attractions. All listed sites are targeted by the PRT system and are directly serviced by a station.

The parks and gardens were also identified as major recreation areas, they are a staple to the county's tourism industry. Therefore, I located a station at several of the different parks acknowledged in the official Morris County Visitors Guide. This guide represents the information given to people visiting Morris County and therefore gives an accurate sample of the parks and gardens that draw the most people.

Other forms of recreation such as movie theaters and restaurants are indirectly serviced by the PRT system proposed, as many can be found nearby major shopping areas. I also included stations at some of the restaurants listed in the Visitor's Guide, again because this information is given to people visiting, and therefore identifies places that people want to go.

16.7 Service to Education

Morris County has a total of 40 school districts to serve over 150,000 school aged children. In the proposed system all schools with an enrollment over 300 are easily accessed by a PRT station located within the school grounds. Targeting schools is one of the most important aspects of PRT. Instead of parents driving their children to school in the morning and commuting between home and school four times a day, students can easily use the PRT system, reducing number of trips to two times a day. In its initial stages, PRT will probably be the most valued by children and adolescents without their drivers licenses. Therefore, easy access to schools will encourage children of these age groups to use the public transportation system, rather than asking a parent to drive them somewhere.

There are also 3 four year colleges in Morris County as well as the County College of Morris. The PRT system provides a station at each of these campuses. The station at The College of St. Elisabeth provides a duel purpose, in that it also covers Convent Train Station, one of the busiest stations in the county. Included at the end of this report is a list of the twenty schools with the highest enrollment along with the four colleges.

16.8 Service to Residential

Residential service is the most important part of the PRT network, as without convenience access from peoples' homes, this system would fail. Many of the stations within the PRT system are located primarily due to their proximity to a residential community. With the exception of a few homes in extremely rural or underdeveloped areas, all homes are located within half a mile of a PRT station. As previously stated, urban housing stations should expect about 3000 passengers per day while rural residential stations should expect about 700 people per day, depending on the density of the municipality and neighborhood in which it is located. Having fully developed residential service adds to the viability of the entire system, as people are less apt to use the network if they cannot easily travel to it from their homes.

16.9 Value of PRT to the county

Morris County is experiencing a tremendous amount of growth that is placing strain on the preexisting transportations systems. Congestion is a serious problem on both the main highways and local roadways. It is taking longer for commuters to get to work and for children to get to school, as well as for everybody in the county to reach recreation, dining, or shopping centers. PRT is an attractive option, because it provides the same environment as a car without the unexpected wait times. The single family (or person) cars allow for maximum efficiency and because the main attractions in the county are targeted, it can be used for most everyday travel throughout the county. There are also fewer environmental problems associated with a PRT. The system would cut down on carbon emissions, and because it is overhead, would provide more space on the ground. Overall, PRT provides an efficient alternative to transportation without many of the negative effects one would see by expanding roads and railways.

Table 16.3: Museums in Morris County

Museum	**Town**
Boonton Historical Society & Museum	Boonton
Butler Museum	Butler
Community Children's Museum	Dover
Cooper Mill	Chester
Denville Historical Society & Museum	Denville
Fosterfields Living Historical Farm	Morristown
Historic Speedwell	Morristown
Lake Hopatcong Historical Museum	Landing
Ledgewood Historic Park Museums	Ledgewood
Montville Museum	Montville
Morristown National Historical Park	Morristown
Mount Hope Historical Park	Rockaway
Obadiah LaTourette Grist and Saw Mill	Long Valley
Schuyler-Hamilton House	Morristown
Washington Historical Society Museum	Long Valley

Table 16.4: List of 2007 Top Employers in Morris County

Company	**Municipality**	**Employees**
Atlantic Health	Morristown, Morris Plains, Morris Twp	5,900
Novartis	East Hanover, Florham Park Parsippany	5,000
Picatinny Arsenal	Rockaway	3,412
Lucent	Whippany	2,300
St. Clare's Health System	Dover, Denville	2,250
Morris County	Various Locations	2,228
United Parcel Service	Parsippany	2,131
ADP	Florham Park/Parsippany	1,986
AT&T	Morris Township and Florham Park	1,500
Greystone Psych.	Parsippany	1,300
Realogy Corporation	Parsippany	1,200
Tiffany & Co.	Parsippany/Hanover	1,200
Verizon	Madison & Various Locations	1,200
Accenture	Florham Park	1,200
Honeywell	Morris Township	1,200
Johnson & Johnson	Morris Plains	1,180
BASF	Florham Park/Rockaway	1,175
Bear Stearns	Whippany	1,119
Kraft Foods	East Hanover	1,100
PricewaterhouseCoopers	Florham Park	1,086
Wyndham Worldwide	Parsippany	948
Wyeth	Madison	930
Howmet, An Alcoa business	Dover	880
State Farm Insurance	Parsippany	830
Avis Budget Group, Inc.	Parsippany	800
Chilton Memorial	Pequannock	763
Lincoln Park Care Center	Lincoln Park	779
Deloitte & Touche	Parsippany	750
Biomet-NJ	Parsippany	750
Pfizer	Morris Plains Parsippany	600
Colgate	Morris Township	600
GSK	Parsippany	500
ASCO Power Technologies	Florham Park	500

Table 16.5: Schools with the highest enrollment in Morris County

School	Town	Enrollment
Morristown High	Morristown	3018
Roxbury High	Succasunna	2984
Morris Knolls High	Rockaway	2862
Long Valley M.S	Long Valley	2600
West Morris Central High school	Chester	2434
Mt. Olive High School	Flanders	2422
Mt. Olive Middle School	Budd Lake	2272
Parsippany Hills High	Morris Plains	2272
West Morris Medham High	Mendam	2190
Morris Hills High	Rockaway	2060
Montville High	Montville	2028
Kiel School/Pearl R Miller Middle	Kinnelon	2022
Copeland Middle	Rockaway	1956
Frelinghuysen	Morristown	1948
Jefferson Twp. High/Middle	Oak Ridge	1922
Parsippany High	Parsippany	1858
Robert R. Lazar Middle	Montville	1802
Lincoln/Roosevelt	Succasunna	1782
Brooklawn Middle	Parsippany	1720
Dover Middle School	Dover	1662

Table 16.6: Colleges in Morris County

School	Town	Enrollment
County College of Morris	Randolph	15200
Fairleigh Dickinson University	Madison	6962
Randolph High and Middle	Randolph	5636
Drew University	Madison	5000

Chapter 17

Ocean County

17.1 County Overview and Land Use

Located in a region known as the "Atlantic Coastal Plain" in central New Jersey, Ocean County is the second largest in the state in terms of actual size, and one of only four New Jersey counties that borders the Atlantic Ocean. For this reason, beach tourism in Ocean County is a very popular recreational activity, both for residents of the county and for those traveling from other New Jersey counties and other states. Other very popular centers of tourism that put Ocean County on the map include the theme park Six Flags Great Adventure (containing a unique wildlife safari, a water park, and some of the largest, longest, and tallest rollercoasters in the nation), and the seaside resort towns of Point Pleasant, Seaside Heights, and Bay Head.

Figure 17.1: Ocean County, New Jersey

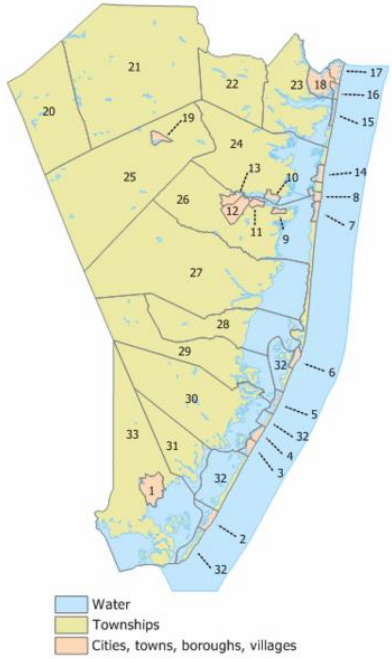
Commercial centers and seasonal resorts on the coast quickly shifted the county's main economic mainstay from agriculture and fishing to the cash machine of beach tourism.

In the 1950s, Ocean County saw a wide degree of suburbanization. Being just 60 miles from New York City and 50 miles from Philadelphia, Ocean County became the perfect spot for city workers looking to raise a family, as

well as retirees looking to get away from it all. These groups found immense solace in the wide stretch of sparsely populated, rural areas of the county.

Due in part to this continued population growth, a wide variety of other industries have sprung up in the county. In fact, Ocean County has seen some of the fastest growing employment numbers in the state for the past 10 years. Among these new industries, health care has taken the forefront as many large corporations have sought to set up large corporate headquarters, due to the lower land value and ready access to two of the nation's largest cities.

Figure 17.2: Municipalities of Ocean County



One other important aspect to consider is Ocean County's vast amount of environmentally protected open space. Much of the western part of the county contains large areas designated as state parks, wildlife refuges, and protected forests. In addition, the 20,000 acre Edwin B. Forsythe National Wildlife Refuge to the east and the 1,580 acres of protected farmland to the northwest provide a wide area of undeveloped, natural land.

Ocean County is 636.28 square miles and encompasses 33 separate municipalities. The 2006 census estimates the county's population at around 553,251 in around 200,402 households, making it the fastest growing county in the state. The census shows that the population demographics of Ocean County are spread out fairly broadly. 28.10% of households had children under the age of 18, 56.40% were married couples, 9.20% had a female householder with no husband present, and 31.20% were non-families.

Interestingly, the working population of Ocean County consists of just over 200,000 individuals, and around 56% of these workers work within the county borders. Contrarily, of the 133,000 persons employed within Ocean County, 85% are residents living in the county. When coming up with a specifically tailored PRT system for the region, we used these metrics and the various overarching facts mentioned above to create a usable system that would serve the most people.

17.2 Transportation Systems Overview

Public transportation in Ocean County can be divided into the main 4 groups of air, bus, highway, and rail. Before PRT can be implemented, a brief overview of each of these systems already in place is necessary.

17.2.1 Air

The major mode of air travel within Ocean County is the Atlantic City Airport. Although a secondary airport when compared to the relatively nearby international airports of Newark and Philadelphia, the Atlantic City Airport is also international, and is owned by the South Jersey Transportation Authority. Although not in Ocean City, the Atlantic City Airport provides services for many businesses located within the county.

17.2.2 Bus

There are three main groupings of bus routes in Ocean County. Academy Bus LLC provides private bus service between Atlantic City and New York, with stops in various Ocean County municipalities. This charter service provides transportation for corporate events and a wide range of groups seeking recreation. New Jersey Transit, a public entity, provides the most comprehensive scheduled service within Ocean County. In addition, scheduled service is available to New York, Newark, Philadelphia, and a wide range of other major cities in New Jersey. Transfers are also available to Greyhound buses. Finally, the Ocean County Department of Transportation provides the "Ocean Ride" service.

Figure 17.3: OceanRide Service

17.2.3 Highways

Car travel on major roads in Ocean County spans a wide range from county, statewide secondary, statewide, and interstate roads. County roads are delineated by the 600-series system, and include route 614 in the middle of the county. There are a few statewide secondary roads, designated as such by being part of the 500-series road system. These roads include 528 and 547 in the north, and 539 in the south. The only major highway in the county is a stretch of the famous Garden State Parkway, which provides a coastal route from New York City all the way down to the southern tip of the state. The Garden State Parkway is a toll road, and provides the often-traveled route to the various seaside resorts for vacationers.

17.2.4 Rail

New Jersey Transit, a public entity, controls all personal rail service in the state of New Jersey. Interestingly enough, via government mandate NJ Transit trains can run on Amtrak owned track for free. Although no Amtrak trains provide service in New Jersey, most of the track laid in New Jersey was originally laid by Amtrak, and is still maintained by Amtrak today. The NJT system provides scheduled rail passenger service on the "New Jersey Coast Line" to the towns of Point Pleasant and Bay Head.

17.2.5 Notes

Basic modal split in Ocean County is highly skewed towards transportation by car. Specifically, 92.5% of working residents use cars to commute work, and a wopping 89.2% of these car-traveling residents commute to work alone. A staggeringly small 1.9% of working residents actually use public transportation. This makes sense, given the lack of any real train service nearby to residencies or even town centers in Ocean County, and the aversion many people have to taking a bus to work. A PRT system correctly implemented in the region would have a remarkable and highly beneficial change on the transportation practices of the county's residents.

17.3 PRT Overview:

17.3.1 Size and Coverage

The PRT system proposed in this document was built with two major considerations in mind. In order to specifically deal with the population densities and dense areas of employment, we needed to think of the county as a functioning whole. As mentioned elsewhere in this proposal, there is a major economic and commercial center in the eastern

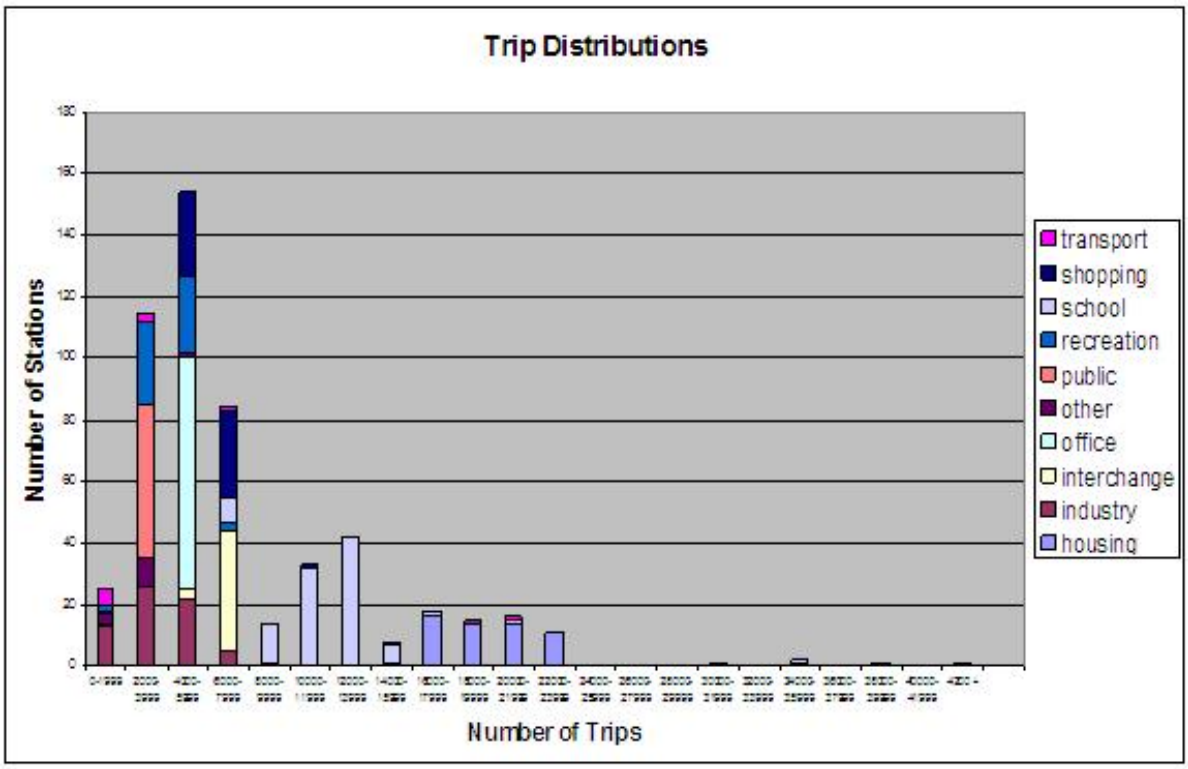
part of the county, and a major population center in the mid and western part. In order to connect these two centers we formed major "highways" that served the flow of traffic from west to east in the beginning of the day and east to west as people returned home from work.

We also noticed that there was a major traffic flow as people moved from south to north and north to south along the beach or near to the beach. In order to compensate for this we added major highways running north and south along the beach and another set a couple blocks from the beach. As mentioned elsewhere this will allow us to transport traffic that would have otherwise drove rapidly up and down the commercial and recreational areas of the beach.

In addition to these networks of major highways, we created a "cycling" system for the remainder of the nodes. We felt the most cost effective way to create the network of arcs would be to segment a certain number of nodes into its own circular network. By creating these smaller "cycles" and then connecting them to each other, we were able to save a lot of money on track, but still connect each node to every other. In addition to fulfilling the connection constraint, we were also able to provide a very rapid transport by keeping each cycle to less than 10 or so nodes. All in all, this system provides a very rapid and cost effective way for the citizens of Ocean County and the greater New Jersey area to get to their destinations and safely home again.

This system estimates the use of 7.79 trip ends per person, and we believe it does a good job of alleviating traffic concerns by taking a remarkable number of cars off the road. The system of cycles provides a speedy and cost efficient way for travelers to reach their intended destination without traveling through too many other stations. The cycle in effect create an express transit system where other county's proposals create a track consistently in "local" mode. Below is a histogram of trips ends for each station type. The most trip ends rightfully fall in housing stations, while the least trip ends service industry (this county does not have that much in the way of industrial workplaces).

Figure 17.4: Distribution of PRT Trips for Ocean County



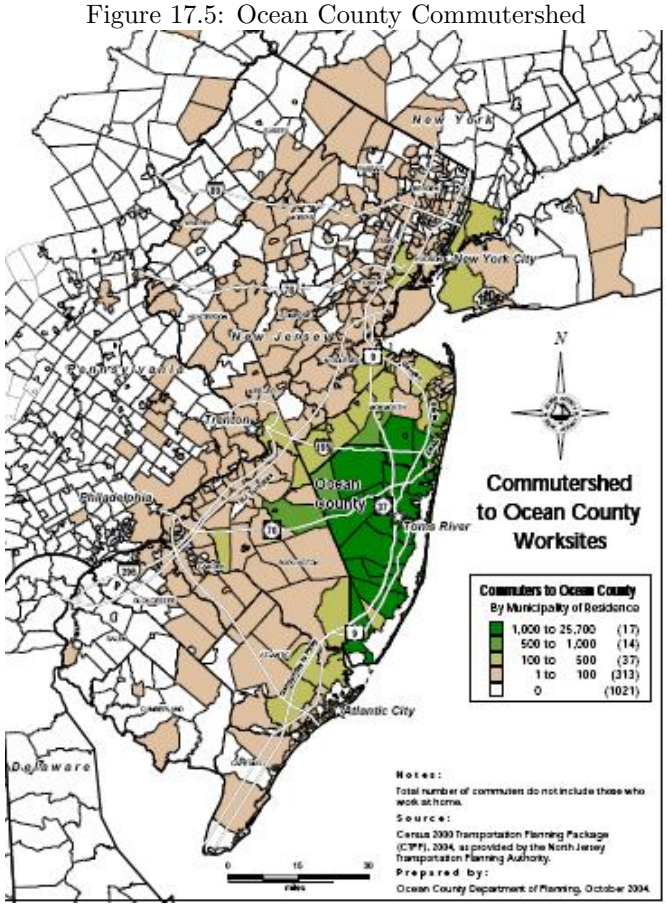
17.3.2 Service to Employment

The optimal output for any PRT system is to provide a system that will raise the space and time utility of the act of transportation, a secondary good. Research into the current state of employment in Ocean County shows that roughly half of the county's residents work in the county, and half work in either Philadelphia or New York (The figure shown here gives a general view of employment density in the county and how the morning commute

looks). This means we must put equal emphasis on those working within county lines and those commuting to a major city. In order to maximize the utility of each traveler, these trips to employment must be cheaper than transportation by car or bus and take less time.

As far as service to the major cities is concerned, the network of PRT stations does a good job in connecting travelers to major rail lines that lead to the traveler's ultimate destination. Service to the New Jersey Transit stations at Point Pleasant and Bay Head is as direct as possible, and provides for a large capacity of travelers, since many will be using these arcs in the network during peak hours of travel. Those residents working in Philadelphia must take the PRT rail south to Atlantic City and switch to the New Jersey Transit line that runs straight to the city. This path is also optimized for large capacity and quick transport, especially during peak hours.

Figure 17.5: Ocean County Commutershed



Conservative estimates through the US census show that the average commute of a resident working in the county lies somewhere around 32 minutes. In order to maximize utility for these travelers, it is immensely important that this number be reduced. The PRT system proposed here aims to cut this average length to around 20 minutes, allowing for walks to and from the various stations. Stations are placed strategically at all major employment centers and corporate parks. Although very few companies in Ocean County employ more than a thousand workers, there are additional corporate campuses that will have their own designated stations.

To get a good idea of specifically how the proposed PRT system provides service to employment, one can look to a few stations as direct examples. For instance, the system of different cycles provides perfect access to the office complexes in and around New Egypt. Other than housing, offices provide the most trip attractions, so we took special care to make sure all major complexes were given direct access on their own cycles.

17.3.3 Service to Shopping

According to US census statistics from 2000, the average resident of Ocean County is well above the poverty line. The table below details the median household income by age and compares each income to the state and national average. The relative wealth of NJ counties such as Bergen and Union drives up the median for New Jersey, but it is important to note that the median Ocean County income for each age group is larger than the national average.

In addition to shoppers from Ocean County itself, there is a large influx from both the north and south of the county as tourists flock to seaside attractions. No surprisingly, shopping in Ocean County is situated almost completely on the eastern side near the shore. This presents 2 specific problems for transportation by car that are solved by the proposed PRT system.

First, since most shopping is located in the east, roads running north and south near the shore quickly become congested. The PRT system helps to alleviate this by creating free-flowing transportation routes running up and down the shoreline, coast, and a small distance from the shore. Stations are selected around large shopping districts and commercial areas of seaside towns. This will prevent shoppers from driving their cars from shop to shop and adding to the traffic problem.

Figure 17.6: Key Roadways in Ocean County

Specifically, in order to reach any of the key shopping areas on the barrier reef, a consumer need only hop onto

Table 17.1: Median Household Income by Age ($ in Previous Year)

	Ocean County	**NJ**	**US**
Median household income	$46,443	$55,146	$41,994
Householder under 25	$30,356	$30,108	$22,679
Householder 25-34	$52,351	$53,612	$41,414
Householder 35-44	$61,982	$65,149	$50,654
Householder 45-54	$70,277	$73,188	$56,300
Householder 55-64	$55,132	$63,775	$47,447
Householder 65-74	$33,931	$38,155	$31,368
Householder 75 and older	$23,828	$24,700	$22,259

a PRT car and take it to any interchange along this main coastal "highway." Once on the main track, a wide variety of jumping off points provide the perfect amount of service to Barneget Light, Surf City, and Long Beach Island. Some of the total trips for these stations are in the seven thousands, and so these stations will alleviate a great deal of traffic.

A completely different problem exits for those Ocean County residents who do not live near the shopping districts in the east. Those who live in the more rural parts of central and western Ocean County must take their cars across the county in order to participate in the degree of shopping described above. The web of stations and routes connecting all population centers and municipalities to the east of the county solves this problem. A webbed system like the one proposed here will give shoppers a faster, better alternative to driving across the county to shop.

17.3.4 Service to Recreation

Figure 17.7: Ocean County

Areas of recreation in Ocean County fit into a few simple categories. As mentioned many times above, the resorts and beaches on the eastern shore provide a large amount of recreation that has attracted immense waves of commercial tourism for many years. When one thinks of the "New Jersey Shore," one is most probably thinking of Point Pleasant, Tom's River, or Long Beach Island. As described in depth above, the same PRT system that serves shoppers wishing for an alternative to driving up and down the coast will be able to serve beach goers on a long vacation or just looking for a weekend away. The "beach traffic" created by these recreational trip attractions will be greatly alleviated by the implementation of this system.

In addition to beach recreation, Ocean County is home to a variety of parks, wildlife refuges, and camping grounds. PRT stations are located at the entrance to all major outdoor cites in the county, and serve as a recreational destination for both travelers seeking a few hours of relaxation and exercise, and those interested in a longer camping excursion. These environmental spots are spread throughout the county and located in practically all of Ocean County's municipalities. The same network that connects workers throughout the county to their place of employment serves to connect those seeking recreation to these spots. To the left is a map plotting the most important parks of Ocean County, all of which are included in our network. The park names and park information are included in the appendix.

Finally, several PRT stations are located at the remaining major recreational destinations, including Six Flags Great Adventure and the minor league baseball park (home of the Lakewood Blueclaws). These attractions draw a large number of travelers from both within and outside of the county on a daily basis, and parking lots continuously overflow. Special service to these larger attractions will help to alleviate the problem.

17.3.5 Service to Education

Trip attractions based on educational institutions provide a large amount of trips generated in any given city or town. All residents under the age of 16 must make one trip in the morning and one trip in the afternoon to the specific school in which they are enrolled. A PRT system is a perfect utility enhancing substitution for any bus route or carpool created to bring students to school. A PRT station is placed at each educational building that houses 250 students and above. This encompasses practically all schools in Ocean County, and specifically accounts for 98 public schools, including elementary, middle, and high school, and 10 private/vocational schools.

When using a car as a source of transportation, school based trips are remarkably inefficient. Since the majority of children traveling to school are not of age to drive themselves, another individual, usually a parent or nanny will make the trip as well. Although there are two people traveling from the place of residence to the place of education, only the schoolchild is actually realizing some increase in utility as a result of the trip. The individual acting as "chauffeur" is not even considered an occupant of the car by most transportation based statistical measures. The

PRT system will fully alleviate such a remarkable inefficiency, especially because most Ocean County residents use cars from basic transportation.

Figure 17.8: Ocean County College

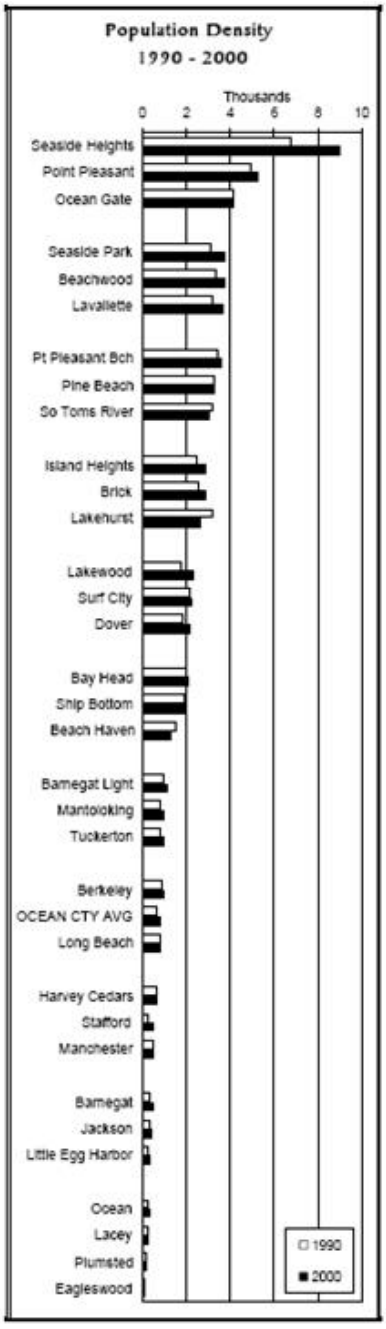
The overall efficiency of these school based trips becomes apparent when one looks at the trip distributions for the various schools in the system. Total trips for schools average in the fifteen thousands, and many of the cycles were specifically created in order to incorporate major trip attractions due to schools in the area. Any student can easily hop on a PRT car and select passage to the correct cycle that his school is a part of. For instance, the Waretown Center School in Waretown is easily reachable from all directions, including a student traveling from either the populated coast or the rural western part.

17.3.6 Service to Housing

The main purpose of the PRT system we are designing is to create a network connecting main residential areas to New Jersey's main attractions, both inter and intra city and inter an intra county; that is, the state's major shopping, amusement, education and employment areas to its residential areas, creating an effective, eco-friendly and cheap transportation mode so New Jersey residents can reach all of the state's main attractions more practically.

Census Bureau estimates show Ocean County is the fastest growing county in the state and one of the fastest growing counties in America. We accounted for this growth in setting up stations in specific residential areas, targeting not only more densely populated areas, but also municipalities of greater growth and the expanding residential areas within. With this, we can make sure the PRT system will not become obsolete after some time, and will in fact be a viable, safe, and very importantly, practical transportation option for the residents of Ocean County for many years to come. As of the census in 2000, there were 510,916 people living in 200,402 households within 137,876 families in the county. Overall, the population density was 310 people per square kilometer, and there were 248,711 housing units with an average density of 151 units per square kilometer. Our goal was to reach at least 80% of residents with PRT stations within a quarter mile radius of their residence, and have about 90% of residents within a half mile of a PRT station, thus connecting most Ocean County residents to the PRT system. Ideally, we would provide service to all of the residents in the county; however, since it contains rural areas of low population density, we found it impossible to do so without incurring unfeasible costs. Analogously, we placed more stations in more densely populated areas; we found housing developments and residential centers using satellite imaging (Google Earth and Google Maps), and also used the 2000 census data for population density; the figure below shows the population density (in population per square mile), and we used the data and the satellite images to locate the higher population density areas and create our network accordingly. The eastern coast of Ocean County is far more heavily populated than the more rural west. This s apparent in the way we set up our network; there are some attractions in the west (though these are not as prevalent as they are in the east, and they don't

Figure 17.9: Population of Ocean County



attract as many people as the east's bigger, more popular, and better located attractions.

Figure 17.10: Ocean County

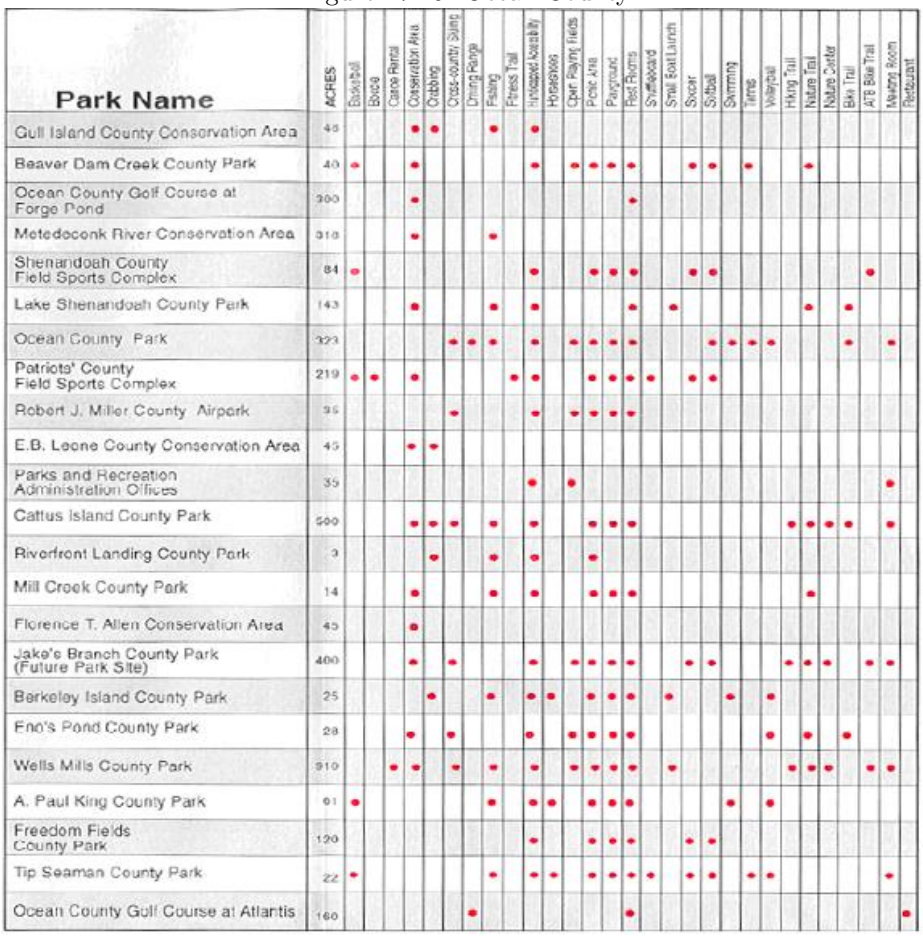


Table 17.2: Historical Populations in Ocean County

Census	Population	% ±
1850	10,032	-
1860	11,176	11.40%
1870	13,628	21.90%
1880	14,455	6.10%
1890	15,974	10.50%
1900	19,747	23.60%
1910	21,318	8.00%
1920	22,155	3.90%
1930	33,069	49.30%
1940	37,706	14.00%
1950	56,622	50.20%
1960	108,241	91.20%
1970	208,470	92.60%
1980	346,038	66.00%
1990	433,203	25.20%
2000	510,916	17.90%
Est. 2006	562,335	10.10%

17.4 Works Cited

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Chapter 18

Passaic County

18.1 General Description of County

Please refer to Section 4.1 for Bergen County, which provides a comprehensive overview of both Bergen and Passaic Counties.

18.2 Passaic Land Use and Existing Transit

18.2.1 Employment

Passaic County contrasts sharply with Bergen County in its job and income distribution. Per capita income, at $21,370, is more than $10,000 less than the figure of $33,638 for Bergen County. Twelve percent of persons are officially below poverty in Passaic, while only six percent approximately of the (much larger) population of Bergen County fits this classification. There were 12,439 private nonfarm establishments in Passaic County as of 2005, employing 163,768 people. Though in isolation this latter statistic appears high, historically over the five-year period from 2000 to 2005 employment has actually declined in Passaic County by 3.7%. The current job economy in Passaic, however, must be seen in light of the largely local workforce and the cyclical effects to which it is exposed. The county's two largest employers are the Patterson Public School District and Hoffman-La Roche Pharmaceutical Company, each with seven thousand employees. Also notable in size is St. Joseph's Regional Medical Center, employing five thousand Passaic residents. Overall, the County of Passaic itself employs some ten-thousand people. Between the public schools and county boards, the highest concentration of jobs in Passaic is in the public sector, and so we were careful to ensure the feasibility of travel to public areas in Passaic from residential and commercial zones, not just those directly nearby, but also those community clusters in the fringes for which efficient transport to the major public centers in Passaic—most located in the southeast of the community and responsible for the majority of county jobs—is otherwise lacking. Our calculated total trip ends for the proposed network for Passaic County attest to the success of our efforts: over thirty-percent of the approximate 3.2 million trip ends for Passaic County serve public employment needs (exemplified by the trips ends for office, industry, and public station types).

Fundamentally, Passaic County's currently economy would be greatly served by the PRT system that we have put in place. Because many of the jobs employing Passaic County residents are exported to neighboring Bergen County, a PRT system such as we have designed would save residents a considerable amount of time and money spent just getting to work each day. Easier access to more remote parts of the county, particularly West Milford, for which we allotted a fair array of stations in laying out our system, could undoubtedly bring more jobs to Passaic as well, a significant benefit.

18.2.2 Shopping

With approximately half of Passaic County set aside as recreational and public open space, mostly in the northwest, shopping possibilities are restricted to the southeastern region of Passaic, where the greatest residential population lies. The largest malls and shopping centers are tabulated in Table 18.1. Because the residential population of Passaic County is much less densely concentrated than in Bergen County, shopping and commercial areas here are more sparsely spread, catering to individual population pockets as they arise rather than to large residential or workplace zones, as we find in Bergen. For our proposed network of PRT stations, we strategically placed

stations first, at those large malls and shopping centers that abutted residential communities and would therefore account for considerable daily trip demand. In consequence of this fact, the majority of the 58 stations assigned for shopping in Passaic lie in the more populous southeast; however, a second consideration of ours in designing our station layout was to ensure the connectedness of the more remote communities to popular commercial zones as well, boosting these destinations' overall enjoyment of patron dollars. For this reason, commercial areas small in comparison to the southeast, but comparatively vital to the health of the scattered northwest communities, were also taken into account and given stations linking them to the overall PRT network.

Table 18.1: Passaic County Shopping

Largest Malls and Shopping Centers
Bearfort Shopping Village
Berdan Shopping Center
Lyons Mall
Ringwood Commons
Styertowne Shopping Center
Wayne Hills Mall
Wayne Towne Center
Willowbrook Mall
Wyckoff Shopping Center

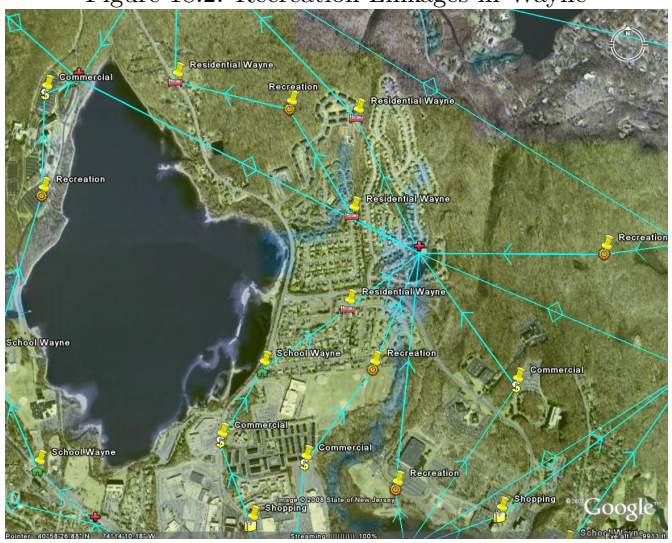
Figure 18.1: Shopping Linkages in West Milford

18.2.3 Recreation

Befitting the rugged and mountainous topography of Passaic County's northwest, and the hilly sections of much of the surrounding area, all with sparse residential populations, but idyllic terrain, a number of nature preserves and recreational parks may be found, enjoyed by the communities of Passaic County and Bergen County to the west. Many popular parks are located in Paterson, West Paterson or Wayne, Great Falls State Park (Paterson), Garret Mountain Reservation (West Paterson), and High Mountain Park Preserve (Wayne) particular among them. In addition to these parks, one finds also in Passaic County: Goffle Brook Park, Weasel Brook Park, Tranquility Ride Park, SanCap Park, and the Apshawa Preserve. Notably, Skylands, the New Jersey State Botanical Garden, is located in Passaic County as well.

Because of the tendency of these parks to arise in clusters, we situated stations at the center of the entrances for contiguous nature preserves, but assigned individual stations to sports complexes, such as the Yogi Berra Stadium in Little Falls, and for educational diversion, the Rogers Locomotive and Machine Works in Paterson. By popular interest, these sports and educational attractions (of which there are comparatively few in Passaic County) will draw considerable visitors daily. Putting more stations here both mitigates congestions and enhances convenience for visitors of disparate origins—distributed across the long geography of Passaic—to reach these destinations.

Figure 18.2: Recreation Linkages in Wayne



18.2.4 Schooling

Passaic County currently provides a number of primary and secondary educational facilities, including (all public) one hundred elementary schools, twenty-seven middle schools and twenty-one high schools. The five largest high schools are Clifton, Eastside, Passaic, John F. Kennedy, and Passaic County Technical Institute, each with more than two thousand students.

Figure 18.3: School Linkages in Clifton

Most schools are neighborhood schools, and the primary means of transportation to date (as concerns school-based trips) has been by car. As an alternative, the PRT system we have designed for Passaic, with school stations as situated, thus not only eases morning traffic, but also enhances connectivity among scattered communities.

Table 18.2: Passaic Public School Statistics

# High Schools	# Middle Schools	# Elementary Schools
21	27	100

For higher education in Passaic County, there are three primary institutions: Passaic County Community College, William Paterson University, and Montclair State University. Passaic County Community College includes campuses in Paterson, Wanaque, and Wayne and serves a broad cross-section of the Passaic college student pop-

Table 18.3: Passaic County's Most Populated Schools

School	# Students
Clifton High School	3,375
Eastside High School	3,087
Passaic High School	2,818
John F. Kennedy High School	2,795
Passaic Co. Technical Institute High School	2,301
West Milford High School	1,727
Number 4 Lincoln Middle School	1,648
Wayne Hills High School	1,385
Wayne Valley High School	1,381
Christopher Columbus Middle School	1,285

ulation; it merits the multiple stations we elected to link these population segments. William Paterson, a public university located in Wayne, currently enrolls 9,110 undergraduate and 1,860 graduate students, while Montclair State, also a public university, enrolls about 9,600 full-time and 2,200 part-time undergraduate and 3,800 graduate students. Together, the three institutions serve approximately thirty-thousand students, a high proportion of which are native to Passaic and its neighboring counties in New Jersey. College students alone in Passaic County thus account for almost eight percent of the near seven-hundred thousand daily trips served in our finished PRT network, as listed in Section 18.3.

18.2.5 Housing

As the map in Figure 18.4 demonstrates, the northwest section of Passaic is sparsely populated, with only one thousand persons per square mile on average. The two most densely populated municipalities are Paterson and Passaic, each with about twenty thousand persons per square mile and located in Passaic County's southeastern tip. Paterson and Passaic accordingly account for the majority of housing trip ends in our completed PRT system, but smaller groups of housing stations situated in the northwest less representative in terms of numbers were no less essential in integrating the overall county population into the main PRT network. In charting an effective distribution of PRT stations for Passaic County, tighter PRT networks serving the more densely populated areas of the southeast therefore had to be connected to much wider loops that extended to reach population pockets in the northwest separated by considerable distances, particularly in West Milford and Ringwood municipalities, seen in the upper left of the map. The composite residential density of 2,639 persons per square mile for Passaic County reflects the preponderance here of mostly small, scattered residential communities, abutted by enormous tracts of open land.

Figure 18.4: Population Density in Passaic County

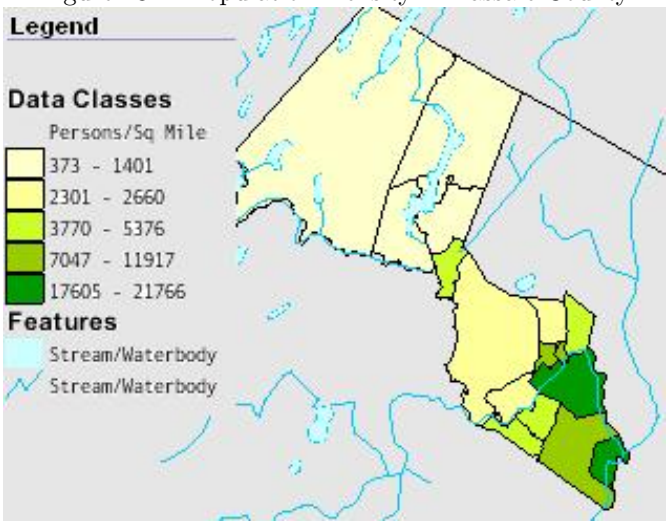
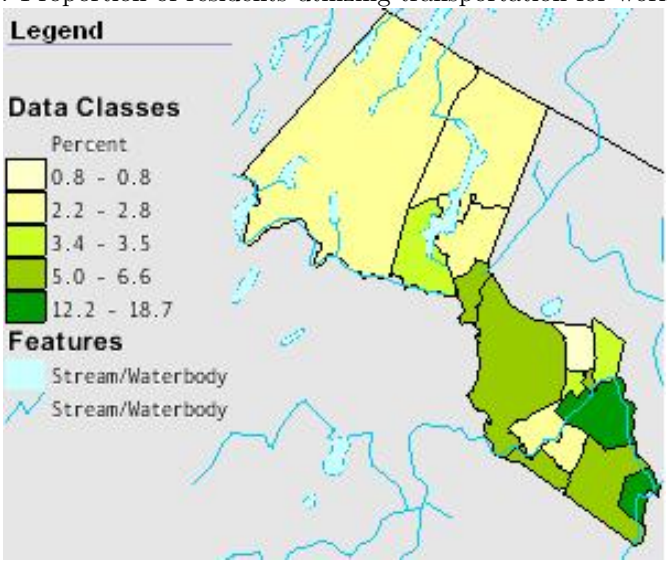


Figure 18.5: Residential Linkages in Passaic County

18.2.6 Transportation

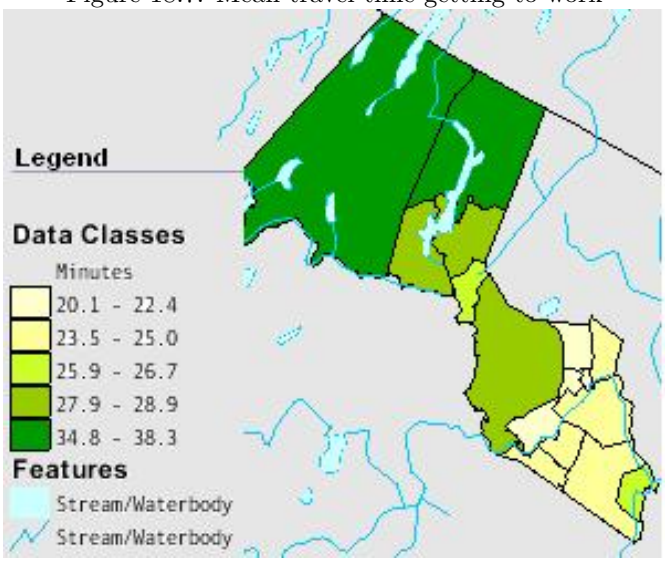
The following diagram in Figure 18.6 exemplifies the local focus of the Passaic County workforce. Of the two densest regions in the southeast, dominated by Paterson and Passaic, less than twenty percent, fifteen percent on average, use transportation to get to work. In all other regions, this figure falls below seven percent. While one might casually draw the conclusion that such low transportation numbers reflect the convenience of major centers of employment, that the mean travel time to work (see Figure 18.7) is by far the highest in the northwest—over thirty minutes per day—where transportation is least available or least frequented, makes the opposite case. Getting to work for many appears still as a chore, pointing to the dire need here for new, improved modes of transportation made efficient and accessible. Through successful integration of PRT stations into the overlying geography, as proposed, these wants will be met.

Figure 18.6: Proportion of residents utilizing transportation for work commutes



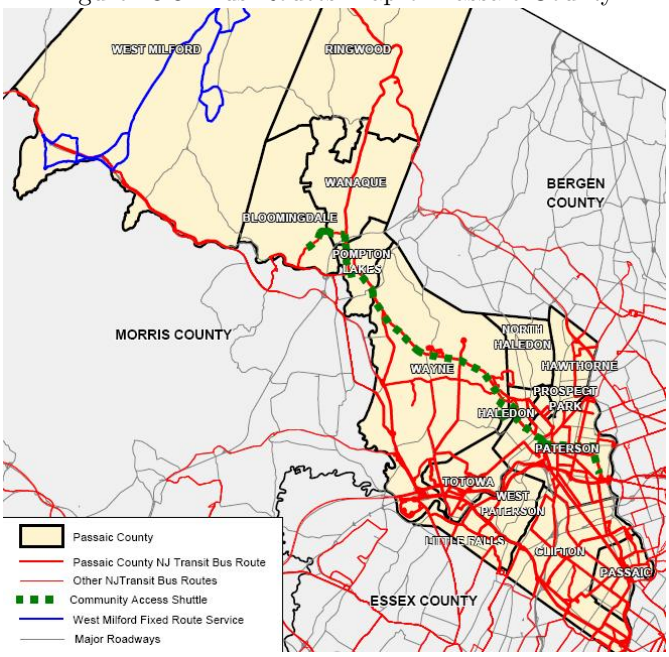
A map of existing transportation routes in Passaic County is reproduced in Figure 18.8. Most noticeable is the paucity of bus routes or roadways serving West Milford, Ringwood, Wanaque, and Bloomingdale municipalities in the northwest, in stark contrast to the much denser distribution of transportation networks to the south. Though the populations of these northwest counties may be comparatively small, their land area is gigantic, replete with numerous recreational opportunities, currently inaccessible to many residents because of poor lines for transit. A select group of stations were placed in West Milford, Ringwood, Wanaque, and Bloomingdale—previously isolated

Figure 18.7: Mean travel time getting to work



in the northwest—to link these regions to outlying transportation lines as well as to promote inter-municipality trip traffic here as well.

Figure 18.8: Bus Routes Map of Passaic County



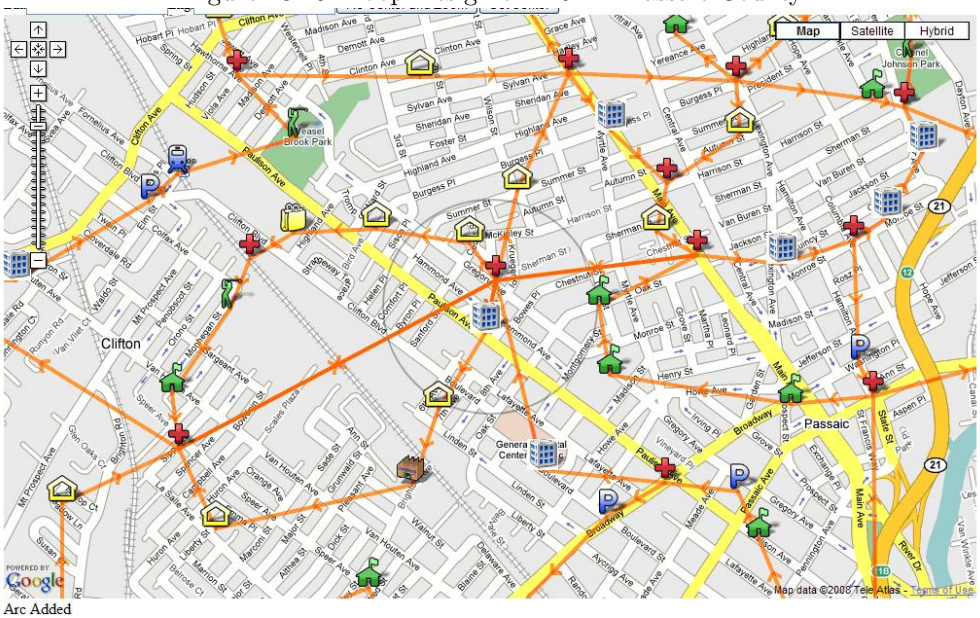
At an aggregate level, only the eastern part of Passaic County is served by New Jersey Transit's Main Line, with limited other areas reachable by bus. The current layout of PRT transport stations for Passaic County now all connect to existing bus and highway lines. Those major highways traversing Passaic County include Interstate 287, Interstate 80, US Route 202, US Route 46, Route 23, Route 21, Route 20, Route 19, Route 4, Route 3, and the Garden State Parkway. The sole local airfields are Greenwood Lake Airport and Westbrook Valley Airport; all major commercial air traffic, as with Bergen County, is handled by Newark.

Figure 18.9: Transportation Linkages in West Milford

18.3 Proposal for Network of Personal Rapid Transit Stations

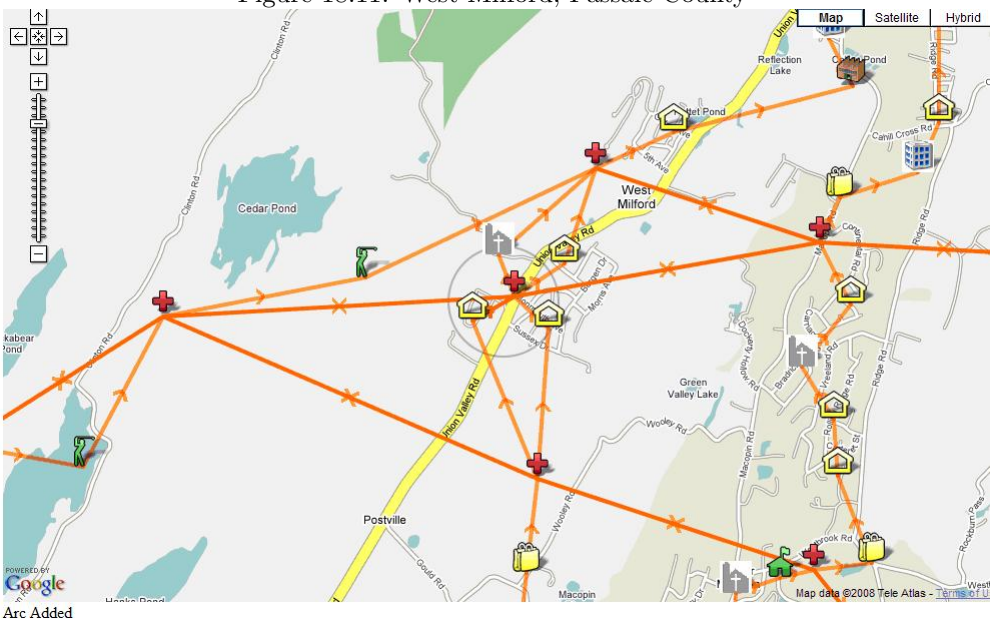
For Passaic County, owing to the elongated geography and large tracts of undeveloped land in the northwest, it was difficult to create a modular network that was also organized. Since the population density and topography of Passaic County was far from uniform, an efficient network of personal rapid transit stations serving all regions needed to be customized according to the features of the locale and the distribution of sites there. As seen in Figure 18.10, for example, in the densely populated municipality of Clifton, arcs are arranged in loops, with interchanges on the perimeter of local "circles" connecting clusters of stations from without, while making possible path reversals with a given cluster via two-way arcs from within. One-way arcs, in turn, link neighboring stations for each cluster.

Figure 18.10: Loop Design of PRT in Passaic County



Despite some natural irregularities in the overall network design, the completed network, with its tight connectivity of stations and pattern of loops stretching into the fringes of the county, where popular recreational attractions lie, is sufficient for serving current population and transportation needs—not to mention a vast improvement over existing transportation. Even West Milford municipality, previously devoid of any significant system for rapid transit, is now "connected," as Figure 18.11 demonstrates.

Figure 18.11: West Milford, Passaic County



Please also see results for the Passaic PRT network in Table 18.4. Calculating trips per mile of guide-way, taking 1360.49 miles into 3,240,585 total trips served daily, gives 2381.925 trips on average per mile of guide-way for the Passaic County network. These figures all support current county numbers for Passaic, with a population of about five-hundred thousand (doubling this figure gives one million residential trips), approximately one-hundred thousand enrolled students (from nursery school to high school), and a work force of approximately two-hundred eighty thousand.

Table 18.4: Passaic County PRT Summary

Node Type	Count	Daily Trips Served
Housing	287	974,932
School	152	679,026
Office	104	646,239
Industry	65	220,700
Public	39	117,311
Recreation	110	35,640
Shopping	58	113,628
Religious	71	284,691
Transport	38	168,417
Other	0	0
Total Stations	924	3,240,585
Interchanges	261	
Total Length of Guide-ways	1360.49 mi	
Average Arc Length	0.63 mi	

18.3.1 Economic Considerations

With out Project Integrator's calculations, taking into account the required number of vehicles, for Passaic County estimated total costs for building the PRT system proposed are shown in Table 18.5.

Considering Passaic County's dubious economic position at present, such colossal costs would be a significant burden: It would cost Passaic County $73,000 per person to build a PRT system, a figure far exceeding than the average per capita income! Passaic would necessarily need to charge at least the following numbers displayed in Tableřeftbl:PassaicPRTTrips per one-way trip to offset just the cost of building the proposed system within five years (ignoring operating costs):

Table 18.5: Passaic County PRT Costs

	Number (miles)	Cost per unit (mile)	Total Cost
Guideway (miles)	1360.49	$5,000,000.00	$6,802,450,000
Stations (inc. Interchanges)	1,185.00	$2,500,000.00	$2,962,500,000
Vehicles	177,903.00	$150,000.00	$26,685,450,000
Total Cost			$36,450,400,000

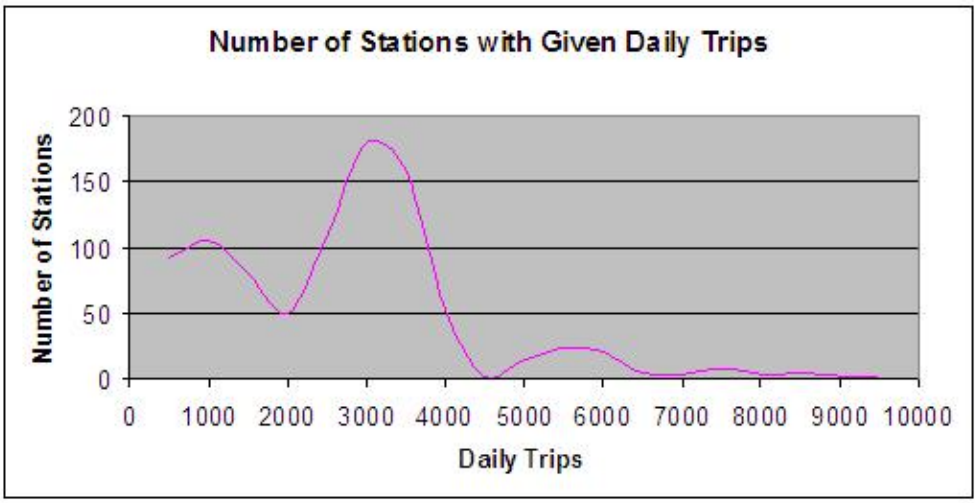
Table 18.6: Passaic County PRT Trip Costs

Recoup Costs	Passaic
Total Cost	$36,450,400,000
Trip Ends per Day	4,602,664
Trip Ends in 5 years	8,399,862,594.35
Cost per One-way Trip	$4.34

Thought not outrageous, the estimated fare of $4.34 per trip is not insignificant—many blue-collar Passaic County workers might shy from paying any fare in excess of a dollar. This estimate, of course, only gives a rough approximation of what on average would need to be charged, and could be adjusted further to account for trip length as well. Financial considerations notwithstanding, Passaic County otherwise is struggling economically, and long-term it could be expected that the cheaper access to employment allowed by a PRT system would be a considerable benefit.

18.3.2 Distribution of Trips per Day

Figure 18.12: Passaic County Trip Distribution



Passaic County, we may observe, is similar to Bergen County in that the majority of stations serve near four thousand trips. However, the range of daily trip numbers for Passaic County, at around nine thousand, is much smaller than the spread of twenty-thousand recorded for much more populous Bergen County. The largest station, incidentally, in Passaic County serves less than ten-thousand trips, in fitting with the reality that Passaic County does not house any large malls or sports complexes.

18.4 Methodology for Daily Trip Calculations

The methodology used for Passaic county was also used for Bergen county. Please see Section 4.4 on page 28 for this information. Please additionally note that, while in Bergen County, we had assumed that each person per housing station takes 2.3 trips per day, yielding 4.1 trips per person per day across all stations, as intended, in Passaic, however, assuming that each person per housing station area takes 2.0 trips a day, the total number of

trips per person across all station is approximately 5.0 trips per day. This figure is much higher than for what we initially had aimed, but after considerable debate, we decided against lowering the number of trips per person per housing station below 2.0. The figure of 5.0 trips per day for Passaic probably stems from Passaic County's elongated geography, Passaic being less naturally connected than compact Bergen County, but with about half its population. We needed many more stations to cover a much smaller amount of people.

Chapter 19

Salem County

Figure 19.1: Salem County

19.1 Overview

Located in the southwest corner of New Jersey, Salem is the least densely populated county in the state. As the terrain is mostly flat costal plain, much of Salem's 338 square miles remains rural farmland with an additional 35 square miles of water. As the oldest county in New Jersey, Salem is home to many historical attractions in addition to an aging infrastructure. With a population density of 190 persons per square mile, the density in the larger municipalities is much higher than is more rural areas. Each of Elsinboro, Salem, Penns Grove, Pennsville, and Quinton has a population density greater than 2,000 persons per square mile.

19.2 Population Density

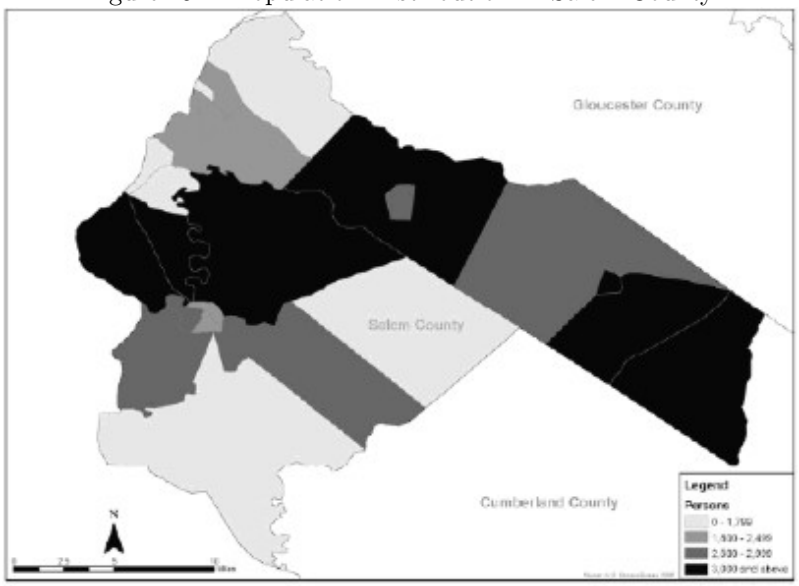
According to the 2000 U.S. Census, the 2006 estimated population of Salem County is approximately 66,595 persons spread over 338 square miles—a total population density of 197 persons per square mile. There are approximately 27,297 housing units—with a density of 80 per square mile. Pennsville Township, located on the western coast of the county, is home to 13,194 persons and is Salem's largest municipality. The following chart shows the population's distribution throughout the county with the darkest areas signifying the highest concentration.

Projections show overall population and distribution remaining relatively stable between 2000 and 2010.

19.3 Existing Transit System

The current transportation system in Salem depends heavily on private vehicle travel. Public transit services are provided by NJ Transit and the Salem County Community Bus Service and operate on Routes 401, 402, 410, 423

Figure 19.2: Population Distribution in Salem County



and 468. As a consequence of its low density, much of Salem is not served by bus service. Moreover, bus transit is focused along major highways with low frequency—a bus every 1 hour during peak travel periods and every 2 hours off peak. In short, the current public transportation system in Salem provides limited accessibility to its citizens, as is to be expected with low populations in its most urban centers.

In addition to fixed-route bus service, Salem also hosts a number of non-fixed-route services operated by NJ Transit's Access Link in addition to several other public and private client providers. All of these have unique limitations—many accessible only to residents 60 years old or over, operate limited hours, and require reservation 1 to 7 days in advance. Furthermore, those accessible to the public service limited routes—no publicly accessible service provides access to any desired location, but rather a fixed set of destination.

Of Salem's approximately 14,210 commuters, only 190 use public transit to travel to and from work. Barring major changes, employment figures and associated travel mediums are projected to remain relatively constant. For any public transit system in Salem County, the high travel concentration between large municipalities seems to imply fixed routes servicing these city centers would be the most appropriate.

19.4 Highway Infrastructure

Salem's existing highway infrastructure provides direct routes between the largest municipalities with service continuing into neighboring counties and across the Delaware River. The following chart shows the layout of the existing highway system.

19.5 Travel Time Distribution

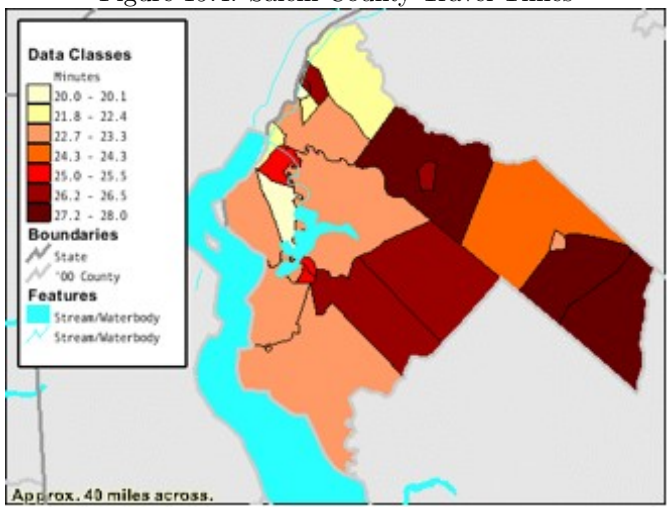
The average travel time to work for Salem workers age 16 and older is 24.6 minutes. The following chart shows the distribution of travel times with the darkest areas signifying the longest travel times.

19.6 PRT Network Coverage

The proposed Personal Rapid Transit System for Salem County consists of 275 stations and approximately 50 interchanges—far fewer locations than is necessary for the average New Jersey county. The core of the system is the network of interchanges which provide efficient, "one-way" flows across the county in both the North-South and East-West direction. Branching out from these interchanges, two-way tracks connect each station to the network via the nearest interchange. Reflecting the rural nature of the county, the majority of stations are focused around more urban areas, specifically in the centers of Pennington and Salem Townships. Though two-way tracks may create a logistical concern, they are favorable given increased functionality, speed and simplicity of transport.

Figure 19.3: Highway System Layout in Salem County

Figure 19.4: Salem County Travel Times



19.7 Image of Salem County PRT Network Design

Figure 19.5: Salem County PRT Network

19.8 Service

The PRT system proposed for Salem County services all major offices, schools, recreation facilities, shopping locations, religious facilities, housing, mass transport facilities, industrial facilities, and public facilities. Stations are designed to be within 0.25 miles from any regularly accessed location in the county.

Table 19.1: Salem County Major Employers

Employer	**Location**
PSEG Nuclear	Hancock's Bridge, Salem
Mannington Mills	Salem
Memorial Hospital of Salem County	Mannington Township
JE Berkowitz	Pedricktown, Oldmans Township
DuPont	Pennsville Township
Siegfried International	Pennsville Township
Anchor Glass	Salem
South Jersey Hospital	Elmer Borough
Salem County Nursing Home	Mannington Township
South Gate Nursing Home	Carneys Point Township
Atlantic City Electric	Carneys Point Township
Ranch Hope	Alloway Township
Gateway Business Park	Pedricktown, Oldmans Township
DRBA Business Park	Carneys Point Township
Pureland Industrial Park	Logan Township

19.9 Recommendations

The key contributions of a PRT network in Salem County are myriad—such a system would revolutionize the way citizens go about their daily lives. The key characteristics and benefits are:

- On-demand, origin-to-destination service- Travelers would board a waiting PRT vehicle at an originating station and be transported quickly and efficiently to a station conveniently located near their destination.
- Compact, comfortable, and automated vehicles- The PRT vehicles require no driver or conductor and would provide exceptional comfort and safety relative to current transportation options.
- Exclusive-Use Tracks- The elevated systems supporting the PRT vehicles must be designed to avoid intersection with pedestrians or other forms of vehicular transport. Traffic is a distant memory!
- Integrated switching- The PRT system would incorporate an intelligent operating engine that would bypass stations that are not current destinations of passengers, increasing speed and efficiency.

Although PRT systems on this scale are state-of-the-art and relatively untested, the benefits to Salem County stemming from the implementation of such a system are clear. Advanced travel, enhanced safety, on-board switching and navigation, and high speed all contribute to make PRT systems a next-generation paradigm for mass transit.

19.10 Trip Matrix Calculation

We generated our productions-attractions trip matrix for Salem County by analyzing data from a variety of sources. Home based trips were based not only on population density estimates but also work and industry data compiled from employment data and empirical data gathered during a recent study of the transportation network in southern New Jersey conducted by a private consulting agency. The empirical data detailed the number of commuter trips to and from each region of the county, providing a valuable check for our estimated figures. Recreation, religious, and shopping trip numbers were determined through analysis of population statistics and utilization of the Google Maps hybrid floor space calculator functionality. In total, we estimated that in Salem County there would be an average of 265,960 trips per day on our PRT network, an average of 3.99 trips per person. This figure makes sense in accordance with national trip per day averages, validating our model.

19.11 Additional Information

Figures 19.6 and 19.7 show the trip generations for the top five municipalities of work locations by municipality of residence from 2000 U.S. Census data. Figures 19.8 and 19.9 show the same data projected for 2010 also based on data from the 2000 U.S. Census. Figure 19.10 shows the major trip generators within Salem county.

Table 19.2: Salem County Major Retail Centers

Center	**Location**
WalMart Shopping Center	Pennsville Township
Acme Shopping Center	Pennsville Township
Acme Shopping Center	Woodstown Borough
Cowtown	Pilesgrove Township
Cranbury Plaza	Pennsville Township

Table 19.3: Salem County Major Education Institutions

School	**Location**
Salem Community College	Carneys Point Township
Salem County Vo-Tech	Pilesgrove Township

Figure 19.6: Salem Employment by Residence (1 of 2)

Top Five Municipalities of Work Location by Municipality of Residence

Residence Location	Employment Location		Total Workers	Commute by Transit
	Municipality	County		
Alloway Twp.	Alloway Twp.	Salem	155	0
	Salem	Salem	125	0
	Woodstown Bor.	Salem	75	0
	Pennsville Twp.	Salem	70	0
	Pilesgrove Twp.	Salem	70	0
Carneys Point Twp.	Countywide	New Castle, DE	510	0
	Carneys Point Twp.	Salem	395	0
	Pennsville Twp.	Salem	375	0
	Logan Twp.	Gloucester	300	0
	Penns Grove Bor.	Salem	300	0
Elmer Bor.	Elmer Bor.	Salem	160	0
	Vineland	Cumberland	70	0
	Pittsgrove Twp.	Salem	30	0
	Upper Pittsgrove Twp.	Salem	25	0
	Philadelphia	Philadelphia, PA	25	0
Elsinboro Twp.	Salem	Salem	105	4
	Countywide	New Castle, DE	65	0
	Elsinboro Twp.	Salem	60	0
	Mannington Twp.	Salem	45	0
	Pennsville Twp.	Salem	45	0
Lower Alloways Creek	Lower Alloways Creek	Salem	200	0
	Salem	Salem	130	0
	Mannington Twp.	Salem	95	0
	Countywide	New Castle, DE	65	0
	Pennsville Twp.	Salem	60	0
	Pilesgrove Twp.	Salem	60	0
Mannington Twp.	Manningron Twp.	Salem	135	0
	Salem	Salem	70	4
	Countywide	New Castle, DE	65	0
	Pennsville Twp.	Salem	65	0
	Carneys Point Twp.	Salem	40	4
Oldmans Twp.	Countywide	New Castle, DE	140	0
	Oldmans Twp.	Salem	90	0
	Logan Twp.	Gloucester	70	0
	Pennsville Twp.	Salem	65	0

Figure 19.7: Salem Employment by Residence (2 of 2)

Residence Location	Employment Location		Total Workers	Commute by Transit
	Municipality	County		
	Carneys Point Twp.	Salem	60	0
Penns Grove Bor.	Penns Grove Bor.	Salem	275	0
	Logan Twp.	Gloucester	165	4
	Countywide	New Castle, DE	145	0
	Pennsville Twp.	Salem	90	0
	Carneys Point Twp.	Salem	75	0
Pennsville Twp.	Pennsville Twp.	Salem	1,815	4
	Countywide	New Castle, DE	1,445	0
	Logan Twp.	Gloucester	360	0
	Salem	Salem	345	0
	Carneys Point Twp.	Salem	325	0
Pilesgrove Twp.	Pilesgrove Twp.	Salem	275	0
	Woodstown Bor.	Salem	165	4
	Countywide	New Castle, DE	145	0
	Pennsville Twp.	Salem	90	0
	Salem	Salem	75	0
Pittsgrove Twp.	Vineland	Cumberland	935	0
	Pittsgrove Twp.	Salem	405	10
	Deerfield Twp.	Cumberland	175	0
	Bridgeton	Cumberland	165	0
	Millville	Cumberland	155	0
Quinton Twp	Salem	Salem	160	0
	Quinton Twp.	Salem	120	0
	Mannington Twp.	Salem	100	4
	Countywide	New Castle, DE	95	0
	Lower Alloways Creek	Salem	85	0
Salem	Salem	Salem	570	10
	Countywide	New Castle, DE	215	20
	Mannington Twp.	Salem	170	40
	Pennsville Twp.	Salem	155	4
	Logan Twp.	Gloucester	120	0
Upper Pittsgrove Twp.	Upper Pittsgrove Twp.	Salem	280	15
	Vineland	Cumberland	115	0
	Elmer Bor.	Salem	80	0
	Pilesgrove Twp.	Salem	70	0
	Woodstown Bor.	Salem	65	0
Woodstown Bor.	Woodstown Bor.	Salem	250	0
	Countywide	New Castle, DE	115	0
	Pennsville Twp.	Salem	110	0
	Pilesgrove Twp.	Salem	95	0
	Salem	Salem	75	0
	Logan Twp.	Gloucester	75	0

Source: Bureau of Transportation Statistics, CTP Package 2000 Part 3 – Journey to Work Tables

Figure 19.8: Salem Residence by Employment (1 of 2)

Top Five Municipalities of Residence Location by Municipality of Employment

Employment Location	Residence Location		Total Workers	Commute by Transit
	Municipality	County		
Alloway Twp.	Alloway Twp.	Salem	155	0
	Pennsville Twp.	Salem	35	0
	Upper Pittsgrove Twp.	Salem	30	0
	Quinton Twp.	Salem	25	0
	Pittsgrove Twp.	Salem	25	0
	Bridgeton	Cumberland	25	0
Carneys Point Twp.	Carneys Point Twp.	Salem	395	0
	Countywide	New Castle, DE	355	0
	Pennsville Twp.	Salem	325	0
	Penns Grove Bor.	Salem	145	0
	Salem	Salem	100	10
Elmer Bor.	Elmer Bor.	Salem	160	0
	Pittsgrove Twp.	Salem	130	0
	Vineland	Cumberland	130	0
	Upper Pittsgrove Twp.	Salem	80	0
	Franklin Twp.	Gloucester	55	0
Elsinboro Twp.	Elsinboro Twp.	Salem	60	0
	Countywide	New Castle, DE	15	0
	Pennsville Twp.	Salem	15	0
	Quinton Twp.	Salem	15	0
	Pilesgrove Twp.	Salem	10	0
Lower Alloways Creek	Countywide	New Castle, DE	320	0
	Pennsville Twp.	Salem	205	0
	Lower Alloways Creek	Salem	200	0
	Quinton Twp.	Salem	85	0
	Pittsgrove Twp.	Salem	75	0
Mannington Twp.	Pennsville Twp.	Salem	215	0
	Salem	Salem	170	40
	Carneys Point Twp.	Salem	135	0
	Mannington Twp.	Salem	135	0
	Quinton Twp.	Salem	100	4
Oldmans Twp.	Oldmans Twp.	Salem	90	0
	Pennsville Twp.	Salem	70	0
	Carneys Point Twp.	Salem	55	0
	Countywide	New Castle, DE	30	0
	Deptford Twp.	Gloucester	25	4
Penns Grove Bor.	Carneys Point Twp.	Salem	300	0
	Penns Grove Bor.	Salem	280	4
	Pennsville Twp.	Salem	130	0
	Oldmans Twp.	Salem	35	0
	Countywide	New Castle, DE	25	0

Figure 19.9: Salem Residence by Employment (2 of 2)

Employment Location	Residence Location		Total Workers	Commute by Transit
	Municipality	County		
	Washington Twp.	Gloucester	25	0
Pennsville Twp.	Pennsville Twp.	Salem	1,815	4
	Countywide	New Castle, DE	745	0
	Carneys Point Twp.	Salem	375	0
	Salem	Salem	155	4
	Penns Grove Bor.	Salem	150	10
Pilesgrove Twp.	Pilesgrove Twp.	Salem	275	0
	Woodstown Bor.	Salem	95	0
	Pittsgrove Twp.	Salem	85	0
	Carneys Point Twp.	Salem	85	0
	Salem	Salem	75	0
Pittsgrove Twp.	Pittsgrove Twp.	Salem	405	10
	Millville	Cumberland	100	0
	Upper Deerfield Twp.	Cumberland	65	0
	Bridgeton	Cumberland	50	0
	Woodstown Bor.	Salem	40	0
Quinton Twp	Quinton Twp.	Salem	120	0
	Carneys Point Twp.	Salem	25	0
	Salem	Salem	25	0
	Pennsville Twp.	Salem	20	0
	Vorhees Twp.	Camden	15	0
Salem	Salem	Salem	570	10
	Pennsville Twp.	Salem	345	0
	Countywide	New Castle, DE	255	0
	Quinton Twp.	Salem	160	0
	Carneys Point Twp.	Salem	145	10
Upper Pittsgrove Twp.	Upper Pittsgrove Twp.	Salem	280	15
	Pittsgrove Twp.	Salem	135	0
	West Deptford Twp.	Gloucester	50	0
	Pennsville Twp.	Salem	50	0
	Vineland	Cumberland	40	10
Woodstown Bor.	Woodstown Bor.	Salem	250	0
	Pilesgrove Twp.	Salem	165	4
	Alloway Twp.	Salem	75	0
	Pennsville Twp.	Salem	75	0
	Upper Pittsgrove Twp.	Salem	65	0

Source: Bureau of Transportation Statistics, CTP Package 2000 Part 3 – Journey to Work Tables

Figure 19.10: Major Trip Generators for Salem County

Other Major Generators

Site	Location	Category
Salem One Stop Center	Salem	Job Training/Social Services
Memorial Hospital of Salem County	Mannington Twp.	Hospital
South Jersey Hospital	Elmer Bor.	Hospital
Free Clinic	Salem, Pennsville	Hospital
Salem County Nursing Home	Mannington Twp.	Nursing Home/Assisted Living
South Gate Nursing Home	Carneys Point Twp.	Nursing Home/Assisted Living
Merion Gardens	Carneys Point Twp.	Nursing Home/Assisted Living
Friends Village	Woodstown Bor.	Nursing Home/Assisted Living
Atlantic Rehabilitation Center	Penns Grove Bor.	Nursing Home/Assisted Living
HomeCare & HospiceCare	Salem	Nursing Home/Assisted Living
WalMart Shopping Center	Pennsville Twp.	Retail Center
Acme Shopping Center	Pennsville Twp.	Retail Center
Acme Shopping Center	Woodstown Bor.	Retail Center
Cowtown	Pilesgrove Twp.	Retail Center
Cranbury Plaza	Pennsville Twp.	Retail Center

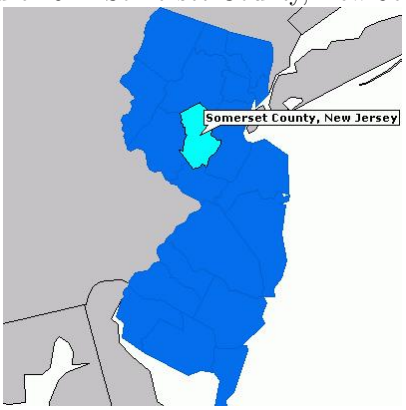
Chapter 20

Somerset County

20.1 Land Use

Located in the northern part of central New Jersey, Somerset County is bordered by Morris County to the north, Union County to the east, Middlesex County to the southeast, Mercer County to the south, and Hunterdon County to the west. Somerset's geographic location divides it into two halves: the northern hilly region and the southern flat lands.[1]

Figure 20.1: Somerset County, New Jersey



The 21 municipalities of Somerset County cover 305 square miles in area[2] and are populated by approximately 324,186 people.[3] With a labor force of 172,760 in the private and public sectors,[4] Somerset residents make up the seventh-highest earning county in the United States based on per capita income. This affluence can be seen in Somerset's abundance of golf courses and residential communities, along with a wealth of primary and secondary schools. Tourists have been drawn to Somerset's historical appeal, since it was established in 1688, as well as the modern combination of suburban homes, growing businesses, and open space, which include 9,750 acres of parkland and 5,123 acres of farmland.[5]

20.2 Existing Transit Service

With an average travel time to work of 29.8 minutes, close to 78.5% of Somerset's population drive alone to work.[6] The major form of public transportation is the statewide New Jersey Transit Rail and Bus Service. [7] There are local bus and shuttle services that run along the existing network of roads within the county, mainly from residential

[1] http://en.wikipedia.org/wiki/Somerset_County%2C_NJ
[2] http://www.co.somerset.nj.us/
[3] http://www.co.somerset.nj.us/quickfacts.html
[4] http://www.co.somerset.nj.us/quickfacts.html
[5] http://www.co.somerset.nj.us/about.html
[6] http://www.co.somerset.nj.us/quickfacts.html
[7] http://www.beachcomber.com/Somerset/Public/transit.html

areas to large office complexes. [8] Additionally, three airports are found in northern, central, and southern Somerset County. [9] From the table above, we see that the average travel time to work using existing public transportation is significantly longer than the average travel time to work using other transportation, the average travel time to work in New Jersey, and the average travel time to work in the United States. This likely corresponds to the vast majority of Somerset's labor force not using public transportation to travel to work, and this indicates a clear need for an improved public transportation system.

20.3 Somerset County PRT Design

As is typical of suburban New Jersey, Somerset spans the spectrum from dense residential communities to vast open spaces of undeveloped land. With the goal of achieving a high percentage of residents being within a quarter-mile radius from a PRT station, and using Google Earth as our assignment tool, we chose the strategy of assigning stations to visibly dense ($\tilde{1}0$ or more living units or larger conglomerates) areas of houses, apartments, and hotels. On the attractions side, we also assigned stations to visible areas of recreation, industry, office complexes, shopping, and education. In contrast to the gathering of commercial centers commonly found in urban landscapes, the decentralized attractions and productions of Somerset County made it necessary to examine the entire region on a zone-by-zone basis.

To keep track of our examination of the county, we divided Somerset County into 188 roughly rectangular zones (see below). Our process was a repeated iteration of plotting the attractions/productions of each zone using the Google Earth placemark tool and retrieving the latitude and longitude coordinates of these plotted locations. We found many locations using various Google Earth overlays, e.g. schools, parks, restaurants, etc., which we could also click to find a website affiliated with the location and estimate the daily number of people traveling to and from the location. In areas on the map where 10 or more houses were visible within a quarter mile radius, we

[8] http://www.co.somerset.nj.us/scootdash.html
[9] http://www.beachcomber.com/Somerset/Public/transit.html

Figure 20.2: Somerset County Municipalities

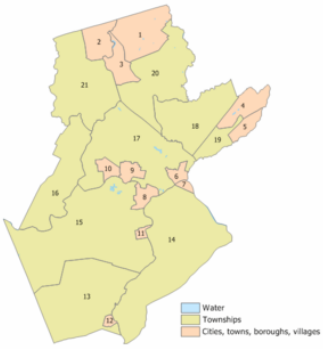


Table 20.1: Somerset Transportation to Work, Sources: U.S. Census Bureau, 2000 Census; ePodunk

	Somerset		**NJ**	**US**
Workers 16 and over	11,543			
	Number	**Pct**	**Pct**	**Pct**
Public transportation	663	5.7	9.6	4.7
Car, truck, van or motorcycle	10,364	89.8	83.6	88.0
Walk	158	1.4	3.1	2.9
Work at home	240	2.1	2.7	3.3

Table 20.2: Somerset Commute Times, Sources: U.S. Census Bureau, 2000 Census; ePodunk

	Somerset	**NJ**	**US**
Average travel time to work (minutes)	29	30	26
Average travel time to work using public transportation	78	57	48
Average travel time to work using other transportation	26	27	24

would determine the number of daily riders using the average household size, 2.7, for Somerset County.[10] Once we compiled all of the coordinates for PRT stations, we decided to use a series of linked cycles to connect the stations, that is, pathways would connect the stations in regional cycles, which would in turn be linked by interchanges. We note that closely placed stations within regional cycles allow residents to travel very locally as well as across the county, while the interchanges allows them to return to their original location. The Somerset PRT system consists of 571 stations, 432.51 miles of guideway, 675 arcs (sections of guideway between stations), and average arc length of 0.64 miles. The total number of daily trips is estimated to be 344,700, and the daily trips per person is estimated to be 1.1.

Figure 20.3: Somerset County PRT Design

20.3.1 Housing-based PRT Stations

Based on the current working population that drives to work alone, we estimate 80% or more of the residential community will be serviced by the PRT stations in Somerset County. To solve the scarcity and expenses of assigning stations to decentralized, low population density areas, we note that due to Somerset's unusual level of affluence, the trend of the most wealthy living in secluded rural residences may be applicable here, and county officials could reason that higher priced PRT tickets in these more remote locations would be paid for by people willing to gain the marginal value of obtaining access to easy and efficient transportation.

20.3.2 Business-based PRT Stations

Somerset County houses numerous international "pharmaceutical, biotechnology, engineering, communications, and management services corporations. Among the county's largest employers are AT&T, Avaya, Brother International, Chubb & Son, Dendrite, ICI/National Starch, Johnson & Johnson, L'Oreal, Life Science, Philips Lighting, Pfizer, Phillips, Van Heusen, Roche Diagnostic, Sanofi Aventis and Verizon."[11] Below are some employment figures from 2002, from which we saw the need to place stations especially near locations related to top employment industries, such as hospitals, shopping areas, restaurants, pharmaceutical complexes, and office buildings.

[10] http://www.city-data.com/city/Somerset-New-Jersey.html
[11] http://www.villageprofile.com/newjersey/somerset/chamber05.html

Description[12] Establishment Sales, receipts, or shipments (1000)$Annualpayroll$(1000) Paid employees

Table 20.3: Somerset Employment, Sources: http://www.census.gov/econ/census02/data/nj/NJ035.HTM

Description	**Establishment**	**Sales, receipts, or shipments ($1000)**	**Annual payroll ($1000)**	**Paid employees**
Mining	24,087	182,911,093	21,173,895	477,840
Utilities	17,103	398,907,044	42,417,830	663,044
Construction	710,307	1,196,555,587	254,292,144	7,193,069
Manufacturing	350,828	3,916,136,712	576,170,541	14,699,536
Wholesale trade	435,521	4,634,755,112	259,653,080	5,878,405
Retail trade	1,114,637	3,056,421,997	302,113,581	14,647,675
Transportation & warehousing	199,618	382,152,040	115,988,733	3,650,859
Information	137,678	891,845,956	194,670,163	3,736,061
Finance & insurance	440,268	2,803,854,868	377,790,172	6,578,817
Real estate & rental & leasing	322,815	335,587,706	60,222,584	1,948,657
Professional, scientific, & technical services	771,305	886,801,038	376,090,052	7,243,505
Management of companies & enterprises	49,308	107,064,264	178,996,060	2,605,292
Administrative & support & waste management & remediation service	350,583	432,577,580	206,439,329	8,741,854
Educational services	49,319	30,690,707	10,164,378	430,164
Health care & social assistance	704,526	1,207,299,734	495,845,829	15,052,255
Arts, entertainment, & recreation	110,313	141,904,109	45,169,117	1,848,674
Accommodation & food services	565,590	449,498,718	127,554,483	10,120,951
Other services (except public administration)	537,576	307,049,461	82,954,939	3,475,310

20.3.3 Recreation-based PRT Stations

In addition to golf courses, we included bars, outdoors associations, tennis courts, etc. The hope is that the PRT system should not only encompass home-based work trips but all major types of trips. Access to recreation may foster tourism and consumer spending.

20.3.4 School-based PRT Stations

According to the U.S. Census Bureau, "the total school enrollment in Somerset County was 86,000 in 2006. Nursery school and kindergarten enrollment was 11,000 and elementary or high school enrollment was 57,000 children. College or graduate school enrollment was 18,000."[13] The vast majority of Somerset County schools will have PRT stations within a quarter mile of the school grounds. In the way of transportation, this could make schools that may be far from children's homes, especially private institutions, more accessible without parents having to transport their children through morning and evening rush hour. The Table 20.4 lists enrollment for selected Somerset County public and private schools.

[12] http://www.census.gov/econ/census02/data/nj/NJ035.HTM

[13] http://factfinder.census.gov/servlet/NPTable?_bm=y&-geo_id=05000US34035&-qr_name=ACS_2006_EST_G00_NP01&-ds_name=&-redoLog=false

Table 20.4: Somerset Schools, Source: http://www.city-data.com/city/Somerset-New-Jersey.html

School	**Enrollment**
Franklin Twp High	1,617
Sampson G Smith	1,069
Elizabeth Ave.	649
Macafee	646
Hillcrest	597
Conerly Road	479
Pine Grove Manor	404
St. Matthias Elementary School	597
Community Baptist Christian Academy	124
Oak Crest County Day School	112
Robbins Nest Child Care Center	100
High Road Upper School	90

Chapter 21

Sussex County

21.1 Land Use Description

Sussex County is the northernmost county in New Jersey. Of all New Jersey counties, Sussex contains the highest land area of the Appalachian Mountains, though most of this land covers the western half of the county. This leaves the rugged eastern half available for agriculture, chiefly dairy farming, and suburban development. Sussex has little industry due to its hilly and rugged landscape, climate, and geographic location. Since agriculture is declining, most residents commute to work in neighboring counties and New York City.

Figure 21.1: Sussex County in New Jersey

Sussex County covers 536 square miles, of which only 2.75% is water. Of the land area, 40% is preserved through state and federal conservation efforts and is divided into eight protected areas: Stokes State Forest, High Point State Park, Swartswood State Park, Wawayanda State Park, Kittatinny Valley State Park, Allamuchy State Park, Hopatcong State Park and the Delaware Water Gap.

The ubiquity of farmlands and protected parks is evidenced by the 2000 census data in Table 21.1.

Table 21.1: Population Data for Sussex County

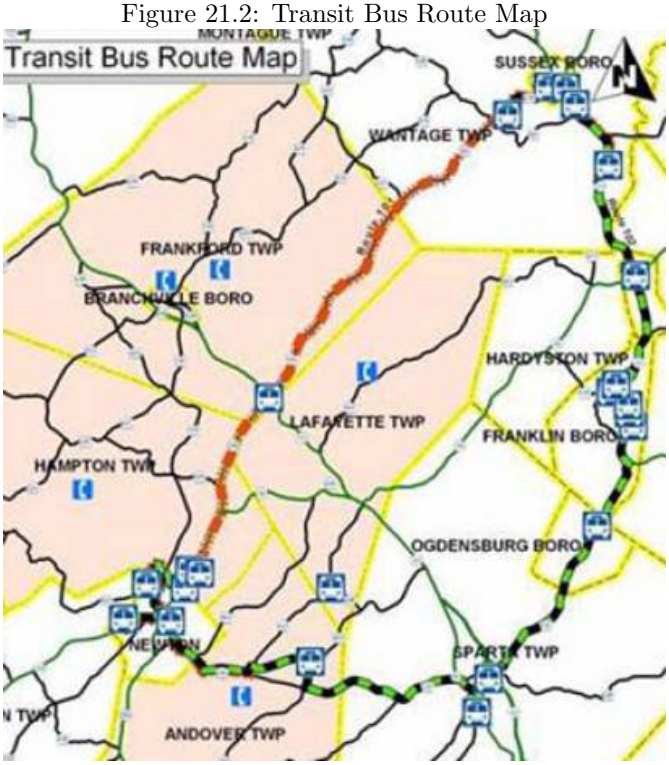
2000 Census Data	**Sussex County**	**New Jersey**
Land area, 2000 (square miles)	521.26	7,417.34
Persons per square mile, 2000	276.7	1,134.5

The unusually low number of persons per square mile indicates that much of the land is uninhibited. This land is instead used for agriculture or protected by government conservation efforts. The land that is used for residential and commercial purposes is fractured. It is not connected due to the geographic landscape of Sussex County. This makes the trip between townships and municipality centers lengthy and inconvenient.

21.2 Description of Existing Transit Systems

New Jersey Transit does not have any train or bus stations in Sussex County. The only public transportation available is the Sussex County Bus Transit Route. As the map in Figure 21.2 indicates, there are two bus routes, Route 101 (red) and Route 102 (green). These routes make stops in Sussex, Newton, Franklin and Sparta, among other Sussex County municipalities. Each route runs only six times per weekday and neither route runs on the weekends. Because these buses travel on the same roads as personal vehicles do, the travel time is extremely vulnerable to traffic congestion on their routes.

Figure 21.2: Transit Bus Route Map



According to 2000 Census Data and the Sussex County Public Transportation Department, most users of the bus route do not own a vehicle and only 4% of Sussex residents do not own a vehicle. Only 1.1% of the Sussex County population uses the bus route to commute to work. As a result of infrequent scheduled stops and susceptibility to travel time delays, the Sussex County Bus Route is used minimally by residents and visitors.

Census Data also recorded information on travel times to work for Sussex County residents. The results are summarized in Table 21.2.

Table 21.2: Travel Time Data for Sussex County

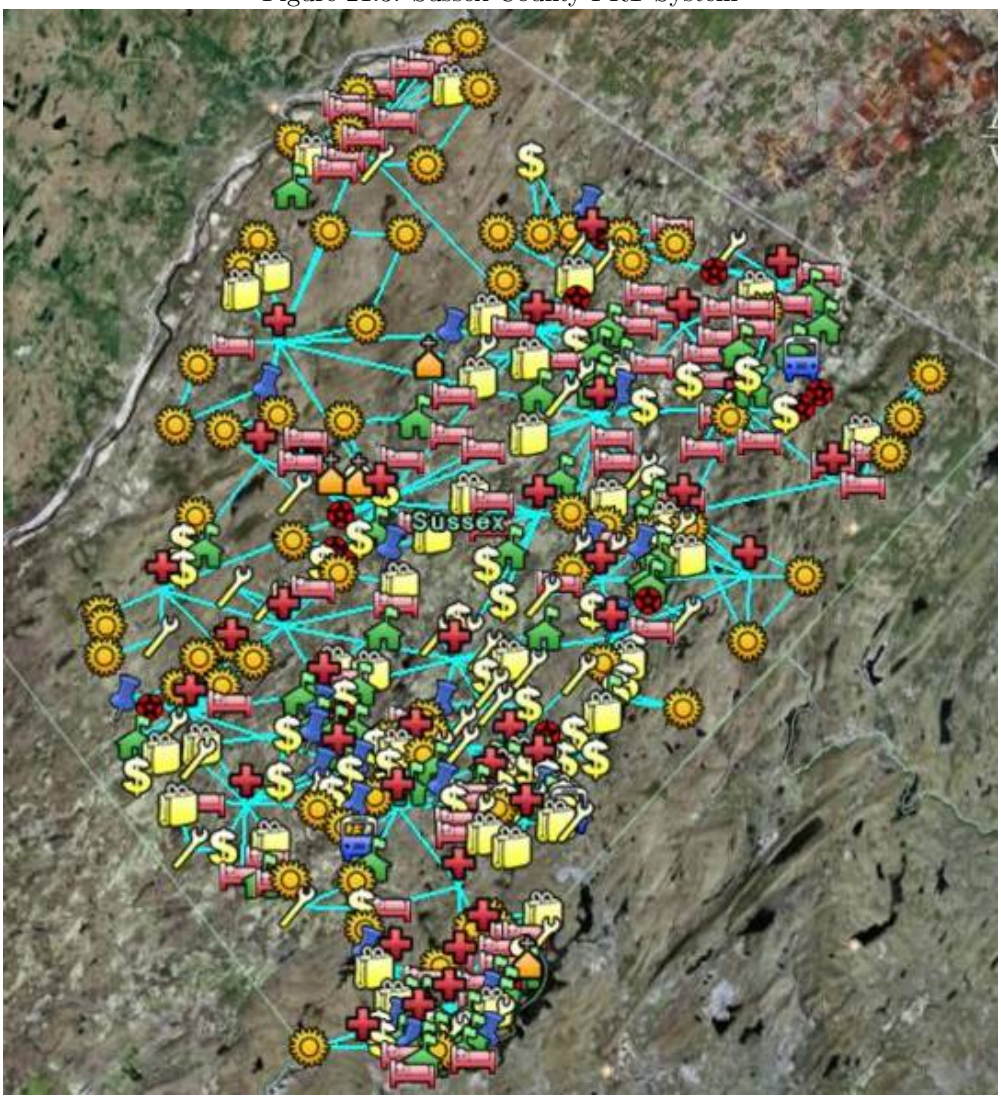
2000 Census Data	**Sussex County**	**New Jersey**
Average Travel Time to Work (minutes)	38	30
Average Time to Work Using Public Transportation	94	57
Average Time to Work Using Other Transportation	37	27

Public transportation is nearly 3x slower than private transportation. In Sussex County, there is little public transportation available; even so, the public transportation that is available is unreliable and inconvenient. The need for a more accessible and efficient transportation system in Sussex County is undeniable.

There are three airports in Sussex County. Aeroflex Andover Airport, Newton Airport, Sussex Airport are all privately owned. These airports mostly cater to vocational pilots.

21.3 PRT Network

Figure 21.3: Sussex County PRT System



The final PRT network in Sussex County had 404 stations, 37 interchanges and approximately 765 miles of guideway. Each station has only arc coming into it and one arc coming out of it. Interchanges have several arcs coming in and out of them. Because the geographic landscape has created a fractured county, most of the population and commercial centers are located in certain township areas. As a result, most stations were placed in or around the denser municipality centers. Other locations of stations include the borders of the protected forests and parks. As a result, there are some long stretches of guideway connecting dispersed stations of different townships. The economic and environmental cost of the guideway will be minimized by laying the guideway above existing roads, eliminating the need to cut down trees and buildings. In addition, no stations were placed within the protected forests and parks as this would only create larger political obstacles. Only one guideway crosses a protected area. This guideway crosses High Point State Park and connects two interchanges. It is designed to be built over Route 395, therefore not interfering with the protected forest. The PRT network efficiently connects the distinct townships of the somewhat fractured Sussex County.

Our model estimated that Sussex County residents would make 3.75 trips per day, mostly comprised of residential and shopping trips. The breakdown of trip ends is shown below.

Table 21.3: PRT Stations for Sussex County

	# Stations	Daily Trips Served
Office	53	60,350
Public	18	28,500
Religious	4	800
Shopping	39	279,900
Other	23	52,540
School	56	126,200
Recreation	87	75,210
Housing	79	532,224
Industry	41	42,800
Transport	4	1,800
Total	404	1,198,324

Table 21.4: PRT Trip Ends for Sussex County

Trip Purpose	Trip Ends per Person
Housing	3.31
Industry	.28
Office	1.50
Other	.09
Public	.18
Recreation	.22
Religious	.01
School	.82
Transport	.01
Shopping	1.09
Total	7.52

NOTE As expected, work (industry + office) accounts for approximately two trips per day. The number is slightly lower because some work trips were actually categorized under a different heading. For example, the County of Sussex is the 5th largest employer in the county. The County House was a "public" station not an "office" station. Therefore, all trips for jobs that are employed at the County House were put under "Public" instead of "Office." Some of the numbers were recalculated to best reflect the actual distribution. However, not all numbers were adjusted.

The distribution of trip ends is graphed in Figure 21.4.

As shown, the majority of the stations will serve fewer than 3,000 trips per day. The following sections detail how station locations were chosen and trips per day were calculated. The PRT system includes stations that will serve employment, shopping, recreation, education and residential purposes.

21.3.1 Employment

Many adults in Sussex County work in neighboring counties or New York City. Major employers that are located in the county are widely scattered among the denser areas of the townships. Mean travel time is 38.3 minutes and most traveling is done by personal vehicle.

Table 21.5: Employment Data for Sussex County

	Number	Percent
Population 16 years and over	108,225	100
In labor force	76,705	70.9
Civilian labor force	76,632	70.8
Employed	73,913	68.3
Unemployed	2,719	2.5
Armed Forces	73	0.1
Not in labor force	31,520	29.1

Figure 21.4: Sussex County Distribution of Trip Ends

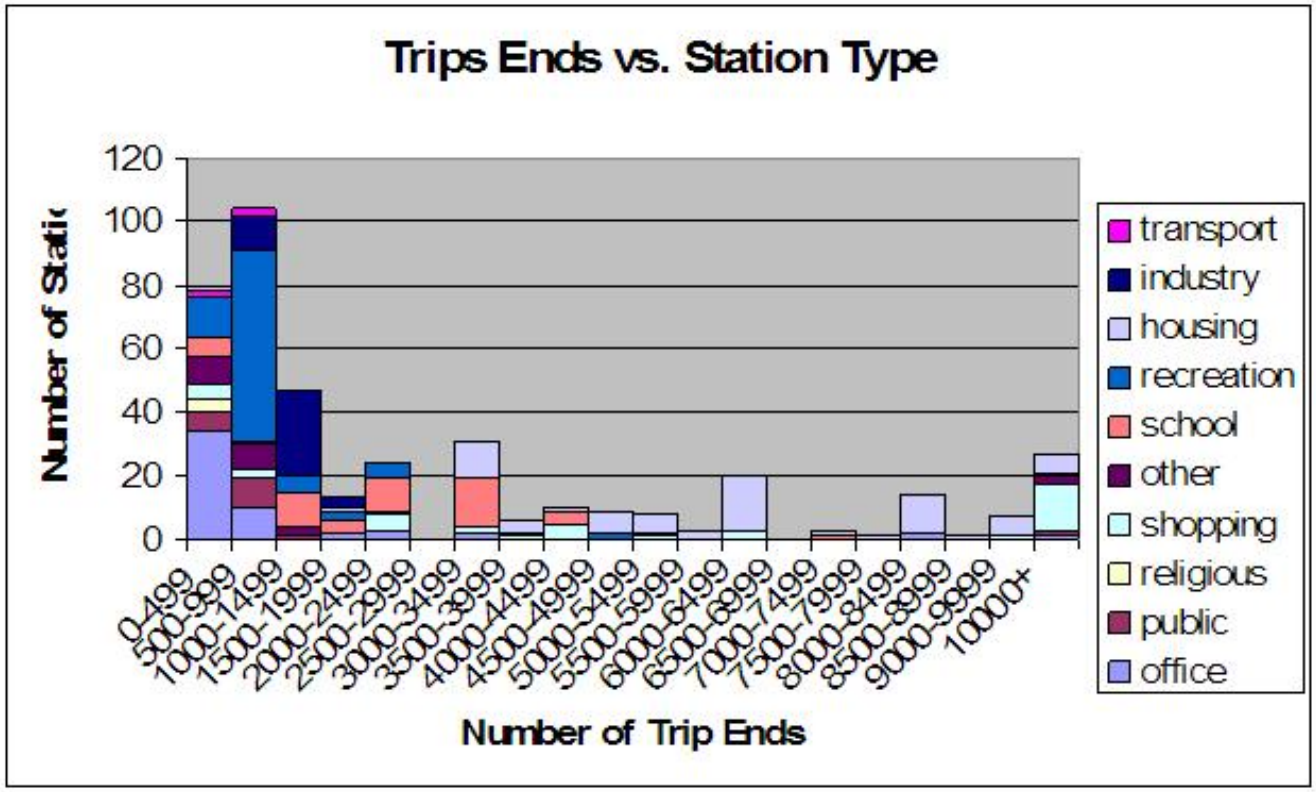


Table 21.6: Commuting Data for Sussex County

	Number	Percent
Workers 16 years and over	72,728	100
Car, truck, or van–drove alone	61,033	83.9
Car, truck, or van–carpooled	6,836	9.4
Public transportation (including taxicab)	1,046	1.4
Walked	965	1.3
Other means	406	0.6
Worked at home	2,442	3.4
Mean travel time to work (minutes)	38.3	

The PRT system within Sussex County will be integral to both intracounty and intercounty commuters. When designing the PRT system within Sussex County, the focus was placed on major employers in the county. Major employers out of the county were included when designing the PRT system for the other counties. The aggregate PRT system will decrease the high percentage of commuters using a personal vehicle. By decreasing rush hour congestion on roads and building efficient PRT routes, the New Jersey PRT system will decrease the mean travel time of 38.3 minutes. On a recent trip to Sussex County's Chamber of Commerce located on Hampton House Rd. in Newton, the Chamber provided a list of the top 50 employers in Sussex by number of employees. Stations were placed at all 50 locations. The top 14 employers are listed in Table 21.7. Some of these stations, such as ShopRite, were also shopping centers. In these cases, the station was labeled as shopping and not office. Stations were placed at approximately 80 other employers in Sussex County.

To calculate the number of trips per day for each station for work purposes, the number of employees was multiplied by 3. This assumes that approximately half of employees leave their work environment during their lunch break. The other half is assumed to take their lunch break in their work environment.

Table 21.7: Employment Data for Sussex County

Employer	**Location**	**# Employees**
Mountain Creek / Intrawest	Vernon	1247
Newton Memorial Hospital	Newton	1200
Crystal Springs Golf and Spa Resort	Vernon/Hardyston	1154
Selective Insurance	Branchville	954
County of Sussex (Figure 21.5)	Newton	800
Ronetco Supermarkets, Inc. (Shop Rite)	Newton/Franklin	722
Andover Sub acute and Rehab Center	Andover	700
Vernon Township Bd. Of Education	Vernon	664
Sparta Board of Education	Sparta	557
Sussex County Community College	Newton	516
Wal-Mart	Franklin & Newton	426
Hopatcong Bd. Of Education	Hopatcong	400
Willow Glen Academy	Sparta	325
Schering-Plough Corporation	Lafayette	310

Figure 21.5: Sussex County House

21.3.2 Shopping

Frequently visited shopping centers in Sussex County are located among the denser township areas. A Sussex County visitor's guide listed the most frequented shopping areas (Table 21.8)in the county. Stations were placed at each of these commercial areas and at each municipality's downtown area, where several small businesses are located. For example, Newton's downtown area (Figure 21.6, 12/14/07) consists of mostly small businesses. In total, 39 stations were placed to serve shopping purposes. To calculate the trips per day produced by shoppers for these stations, data was collected on how many stores were within walking distance of the station. Next, the stores were categorized as either large business or small business. Assuming that large business stores have more customers than small business stores, the trips per day was calculated by adding the trips generated by large businesses and the trips generated by small businesses.

Figure 21.6: Newton's Downtown Area

Table 21.8: New Jersey Visitors Network, municipality websites

Shopping Area	**Town**
Menlo Park Mall	Edison
Olde Lafayette Village	Lafayette
Extreme Paintballz	Vernon
McAfee Ski & Snowboard	Vernon
North Country Outfitters	Lafayette
The Lafayette Mill Antiques Center	Lafayette
Clayworks	Branchville
Sparta Shopping District	Sparta
Sussex Shoppping District	Sussex
Newton Shopping District	Newton
Franklin Wal-Mart	Franklin

21.3.3 Recreation

Outdoor recreation is arguably the main attraction of Sussex County. The county is home to nine wildlife management areas, six state parks and two national parks. Camping, mountain biking, rock climbing and hiking are popular activities. PRT transportation to the campsites and forest paths would be convenient for outdoorsmen who do not want to worry about available parking when they arrive. Forty-four PRT stations were placed along the borders of these protected areas for the convenience of outdoor enthusiasts. In total, 88 stations were designed for recreational purposes.

Sussex also has several large lakes and rivers that are major attractions for water sports, fishing, swimming and boat launching during the summer. In addition, the county has two major ski areas and twenty golf courses. Indoor recreation includes museums, resorts, restaurants and theaters. Table 21.9 shows several of these attractions listed by the New Jersey Visitors Network and the Sussex County tourism website.

Table 21.9: Sussex County Attractions

Attraction	**Town**
Mountain Creek Ski Resort	Vernon
Space Farms Zoo and Museum	Sussex
Sterling Hill Mining Museum	Ogdensburg
Franklin Mineral Museum	Franklin
New Jersey Cardinals Baseball	Augusta
Hidden Valley Resort	Vernon
Tri-State Actors Theater	Sussex
Waterloo village	Stanhope
Bear Brook Golf Club	Newton
Crystal Springs Resort	Vernon
Lake Mohawk Golf Club	Sparta
Newton Country Club	Newton
Rolling Greens Golf	Newton
New Jersey 4H Camp	Branchville

21.3.4 Education

Approximately 31,000 students reside in Sussex County. It has approximately 80 schools in the county, and almost all students who live in Sussex also attend school in Sussex. Therefore there is high demand for transportation between residential areas and schools. 57 stations were placed near educational facilities.

Table 21.10 the 10 largest schools in Sussex County. All data and statistics on education in Sussex County were provided by www.publicschoolreview.com and www.privateschoolreview.com.

Table 21.10: Sussex County Schools

School	**Student Enrollment**	**Station Trips / Day**
Vernon Township High School	1,590	3,500
Kittatinny Regional High School	1,302	2,800
High Point Regional	1,234	5,100
Sparta High School	1,046	2,300
Lounsberry Hollow School	1,026	4,300
Sparta Middle School	964	4,000
Glen Meadow School	917	3,800
Sparta Alpine School	862	3,700
Wallkill Valley Regional High School	841	1,800
Hopatcong High School	836	1,800

The number of trips per day for educational PRT stations included trips for students, faculty and school workers, and parents accompanying students. These numbers were calculated using student enrollment, student:faculty ratio, and the ages of students. It was assumed that all elementary students are accompanied by a parent, half of middle school students would be accompanied, and no high school students would be accompanied. For example, Vernon

Township High School has an enrollment of 1,590 students. It has a student:faculty ratio of 12:1. Because it is a high school, it was assumed that parents do not accompany their child to school. For Vernon High School, 3,180 trips come from students and approximately 270 trips from teachers. This final sum was rounded up to accommodate for irregular visitors daily.

21.3.5 Higher Education

Sussex County Community College (SCCC) is the only higher education institute in Sussex County and is located on the border of downtown Newton. It enrolls both full-time and part-time students. The college website www.sussex.edu indicates a total enrollment of just over 3,500 students. The college has approximately 270 faculty and staff, and employs a total of about 500 workers.

The SCCC also holds theatrical performances, guest speakers and sporting events that are popularly attended by local residents. Transportation to the college would serve employment, school and recreational purposes. Because SCCC is a small and walkable campus, there is only one station placed at Sussex County Community College. It is estimated that this station will handle approximately 6,000 trips per day. This number is derived from roundtrips created by 500 employees, 2,000 part-time students, 150 visitors, 350 full-time students making trips to downtown Newton.

21.3.6 Housing

Because so many residents of Sussex work outside of the county, PRT's service for residential purposes is even more significant. According to 2000 Census Data, Sussex County has 56,528 housing units and 13% of these units are part of multi-unit structures. The difficulty in deciding where to build housing PRT stations is that there are few neighborhoods in Sussex County. Instead, houses are widely scattered because of the rural landscape and the history of farming. Because of cost efficiency, PRT stations were only placed in neighborhood, not amongst farmlands. An average neighborhood PRT station would handle 400 trips per day. However, if a PRT station were placed among two or three farms (the most within 1/4 mile) the station would only handle about 30 trips per day. This did not seem worth the capital investment to build the station. In total, 79 stations were designed for residential purposes.

Table 21.3 indicates the number of residents of the ten most populated municipalities and the number of neighborhood stations. The trips per day were calculated by first finding the number of housing units within 1/4 mile of the station. This number was then multiplied by 2.80, the average number of persons per household in Sussex County according to 2000 census data. Assuming the average person takes two trips from home per day, the number of residents was then multiplied by 4 to get the total trips per day per station.

Table 21.11: Stations by Town

Town	Population	Residential Stations
Vernon Township	24,686	14
Sparta Township	18,080	7
Hopatcong Borough	15,888	7
Wantage Township	10,387	6
Byram Township	8,254	6
Newton Township	8,244	7
Hardyston Township	6,171	6
Andover Township	6,033	4
Frankford Township	5,420	5
Franklin Borough	5,160	5

21.4 Value of PRT to the future of Sussex County

The geographic landscape of Sussex County has impaired its economic growth and prevented unity among its municipalities. Instead, the township centers are separate and difficult to travel between. There is no public transportation or major highways providing convenient access between townships. Due to the low accessibility of Sussex County, corporations and commercial enterprises do not find the county to be an attractive location. This hurts the economic growth in two ways. First, it makes the resources that these corporations could supply more

difficult to obtain. Second, it forces residents to look for employment outside of the county. The Sussex County Chamber of Commerce estimates that approximately 60% of the workforce is employed outside of the county.

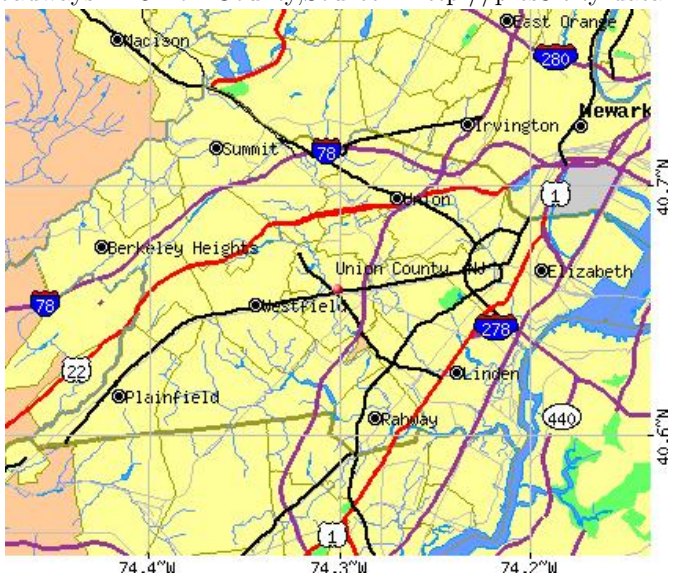
A PRT system would represent an opportunity for growth and restructuring of the Sussex County economy. New commercial, industrial and residential centers could be built concurrently with the planning of the PRT. Stations would be strategically placed in currently underdeveloped locations. These developments would be in high demand by businesses and residents. Because accessibility would no longer be a concern, businesses would have strong incentive to tap the potential in Sussex and locate in the county. New businesses within the county would solve both problems hindering the Sussex County economy. They would bring new resources to residents and they would generate many jobs for county residents. This result is especially beneficial to employees who currently work outside the county and have a lengthy commute.

Since the PRT system is connected to surrounding counties, it also makes Sussex more accessible to out of county visitors. This will generate more income for recreational facilities and increase the popularity of the protected state forests. This can lead to increased funding for the state and national parks and help better protect the environment. PRT is a better option than laying down more roads. It is less imposing on the environment because trees do no have to be cleared for its construction. By increasing the accessibility of Sussex County's attractions, PRT will open the economy to more corporations, generate more jobs and draw more visitors to the numerous recreational activities.

Chapter 22

Union County

Figure 22.1: Major Roadways in Union County,Source: http://pics3.city-data.com/tym/un1790.png



Union County, established in 1857, ranks as New Jersey's 6th most popular county despite being the 21st largest (making it the 3rd most dense—Hudson being the most dense). According the Union County website, the top industries are Manufacturing, Retail, Pharmaceuticals, Petroleum, and Telecommunications. Of the 21 municipalities that comprise Union, Elizabeth is the largest (it also is the county seat). Union County is home to Port Elizabeth, the largest container cargo port on the east coast as well as Arthur Kill, one of the world's busiest waterways.[1]

The following is a quoted summary of statistics based on US Census data: "As of the census of 2000, there were 522,541 people, 186,124 households, and 133,264 families residing in the county. The population density was 5,059 people per square mile (1,953/km^2). There were 192,945 housing units at an average density of 1,868 per square mile (721/km^2). There were 186,124 households out of which 34.00% had children under the age of 18 living with them, 52.60% were married couples living together, 14.20% had a female householder with no husband present, and 28.40% were non-families. 23.60% of all households were made up of individuals and 10.20% had someone living alone who was 65 years of age or older. The average household size was 2.77 and the average family size was 3.28. In the county the population was spread out with 24.90% under the age of 18, 7.90% from 18 to 24, 31.30% from 25 to 44, 22.10% from 45 to 64, and 13.80% who were 65 years of age or older. The median age was 37 years. The median income for a household in the county was $55,339, and the median income for a family was $65,234. About 6.30% of families and 8.40% of the population were below the poverty line, including 10.50% of those under age 18 and 8.00% of those age 65 or over."[2]

[1] http://www.unioncountynj.org/about/places.html
[2] http://en.wikipedia.org/wiki/Union_County%2C_New_Jersey

For our PRT projections, we anchored our assumptions in the data found in Union's 2000 Census seen in Tables 22.1, 22.2, and 22.3. Please note that the steadying population size indicates that our trip generation numbers will not become obsolete solely due to continued population growth

Table 22.1: People QuickFacts for Union County,Source: http://quickfacts.census.gov/qfd/states/34/34039.html

People QuickFacts	**Union County**	**New Jersey**
Population, 2006 estimate	531,088	8,724,560
Population, percent change, April 1, 2000 to July 1, 2006	1.6%	3.7%
Population, 2000	522,541	8,414,350
Persons under 5 years old, percent, 2006	6.9%	6.4%
Persons under 18 years old, percent, 2006	25.2%	23.9%
Persons 65 years old and over, percent, 2006	12.5%	12.9%
High school graduates, percent of persons age 25+, 2000	79.3%	82.1%
Bachelor's degree or higher, pct of persons age 25+, 2000	28.5%	29.8%
Persons with a disability, age 5+, 2000	87,207	1,389,811
Mean travel time to work (minutes), workers age 16+, 2000	28.7	30.0
Housing units, 2006	195,890	3,472,643
Homeownership rate, 2000	61.6%	65.6%
Housing units in multi-unit structures, percent, 2000	42.5%	36.1%
Median value of owner-occupied housing units, 2000	$188,800	$170,800
Households, 2000	186,124	3,064,645
Persons per household, 2000	2.77	2.68
Median household income, 2004	$55,247	$57,338
Per capita money income, 1999	$26,992	$27,006
Persons below poverty, percent, 2004	9.1%	8.4%

Table 22.2: Business QuickFacts for Union County,
Source: http://quickfacts.census.gov/qfd/states/34/34039.html

Business QuickFacts	**Union County**	**New Jersey**
Private nonfarm establishments, 2005	14,776	242,128
Private nonfarm employment, 2005	232,171	3,594,862
Private nonfarm employment, percent change 2000-2005	-0.5%	1.3%
Nonemployer establishments, 2005	33,845	573,134
Total number of firms, 2002	43,319	708,837
Manufacturers shipments, 2002 ($1000)	14,213,445	96,599,807
Wholesale trade sales, 2002 ($1000)	15,830,565	256,925,492
Retail sales, 2002 ($1000)	5,877,136	102,153,833
Retail sales per capita, 2002	$11,099	$11,910
Accommodation and foodservices sales, 2002 ($1000)	555,283	15,715,595
Building permits, 2006	1,593	34,323
Federal spending, 2004 ($1000)	2,745,978	55,264,3501

Table 22.3: Geography QuickFacts for Union County,
Source: http://quickfacts.census.gov/qfd/states/34/34039.html

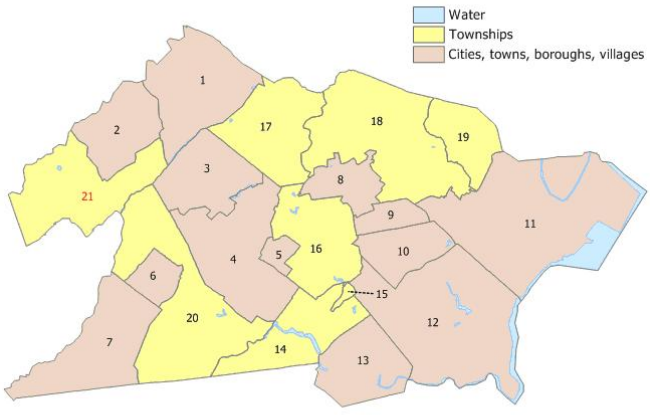
Geography QuickFacts	**Union County**	**New Jersey**
Land area, 2000 (square miles)	103.29	7,417.34
Persons per square mile, 2000	5,073.2	1,134.5
FIPS Code	039	34
Metropolitan or Micropolitan Statistical Area	New York-Northern New Jersey-Long Island NY-NJ-PA Metro Area	

Union already features several modes of available transportation and supporting infrastructure including, but not limited to, highway, port, rail, and air. "Major highways which traverse the county include the New Jersey

Table 22.4: Union County Population Growth

Census	**Population**	**% ±**
1870	41,859	50.70%
1880	55,571	32.80%
1890	72,467	30.40%
1900	99,353	37.10%
1910	140,197	41.10%
1920	200,157	42.80%
1930	305,209	52.50%
1940	328,344	7.60%
1950	398,138	21.30%
1960	504,255	26.70%
1970	543,116	7.70%
1980	504,094	-7.20%
1990	493,819	-2.00%
2000	522,541	5.80%
Est. 2006	531,088	1.60%

Figure 22.2: Map of Union Municipalities



Turnpike, Garden State Parkway, Interstate 78, Interstate 278, U.S. Route 1, U.S. Route 9, U.S. Route 22 and the Goethals Bridge. Passenger rail service is provide by New Jersey Transit via the Northeast Corridor, North Jersey Coast Line, Raritan Valley Line, the Morristown Line and the Gladstone Branch. Freight service is provided by on Conrail's Lehigh Line and Chemical Coast Branch. The Elizabeth Marine Terminal is part of the Port Authority of New York and New Jersey. The southern portion of Newark Liberty International Airport is located in Elizabeth, within Union County."[3]

Union township should also be commended for its active desire to improve its transportation system by improving the quality of its roads, decreasing congestion, and bolstering the quality of its public transportation efforts. Specifically, the townships of Springfield, Union, Essex, and Milburn met most recently on November 3, 2006 to make strides on these matters.[4] Quoting the minutes from the meeting: "The New Jersey Department of Transportation (NJDOT) is presenting design for improvements to Route 78 in the Township of Union. The meeting provides an opportunity for the Union Township Public to offer comments and suggestions relating to the project. This meeting will also present the scope of the project to the public."[5] Hence, the citizens of Union have made transportation-related municipal improvements a major priority. The main thrust of the project is the re-pavement, "rideability" improvement, and safety improvement of Union's section of I-78. The project also makes provisions for increased vertical clearance on overpasses, which clearly suggests that Union is probably expecting more commercial freight traffic (especially trucks) in the near future. At the very least, they are making accommodations for such a possibility. Even with improved road conditions, more freight traffic might have the effect of increasing congestion on I-78, making small cars feel cramped on the road. Hence, establishing a PRT system could be very important in both enabling more freight traffic to come through on I-78 (via reducing commuter congestion) while still allowing people who would otherwise travel by car to still get where they need to go, and get there in a more efficient manner.

As indicated above, a significant percentage of Union's citizens are currently enrolled students who require more effective transportation techniques to get to their respective schools. For example, Kean University is a big attraction located within Union. With a large student body of 13,050,[6] Kean is clearly a major draw in and of itself. Kean is in fact primarily a commuter school with only 900 students living on campus and hence there is a very clear indication that students would have a use for PRT (particularly many studying Physical Therapy in

[3] http://en.wikipedia.org/wiki/Union_County%2C_New_Jersey
[4] http://www.njcleanwater.org/transportation/commuter/roads/I78/outreach.shtm
[5] http://www.njcleanwater.org/transportation/commuter/roads/I78/pdf/pic110305.pdf
[6] http://www.kean.edu/about.html

Table 22.5: Map of Union Municipalities, Key

Index	**Name**
1	Summit
2	New Providence
3	Mountainside
4	Westfield
5	Garwood
6	Fanwood
7	Plainfield
8	Kenilworth
9	Roselle Park
10	Roselle
11	Elizabeth
12	Linden
13	Rahway
14	Clark Township
15	Winfield Township
16	Cranford Township
17	Springfield Township
18	Union Township
19	Hillside Township
20	Scotch Plains Township
21	Berkeley Heights Township

conjunction with UMDNJ). [7] Certainly not all students are in a position to afford owning and maintaining vehicles and thus PRT may make Kean University more appealing to college bound students. In addition, PRT prevents the possibility of drunk driving, a prospect both parents and undergraduate administrators would appreciate. In fact, administrators may appreciate this notion, as well as enhanced mobility for students and staff, so much as to provide university-granted funding for further research/design/construction of a PRT system.

The usefulness of PRT to undergraduates also extends down to the primary and secondary school level. In fact, 20.34% of the population of Union falls under this category. Hence, a significant percentage of Union's population makes a daily round trip to get to and from an academic venue. As it stands, elementary through high school students usually are driven by car or school bus to and from school. PRT has the potential to improve upon these modes of student transportation. Fewer trips would be needed, ameliorating congestion and decreasing polluting gas emissions. These factors make PRT preferable to existing transportation modes. However, to further convince worrisome parents, PRT will be equipped with supplementary safety features and will not make extraneous stops that may put young children at risk in unsafe environments.

Given the above statistics, we again see a strong case for the PRT system in Union County. For example, the average travel to work using public transportation is 57 minutes, essentially a full hour! The potential for PRT to reduce this time, as will be discussed throughout, is enormous! Certainly, the opportunity to reduce the travel time associated with the use of existing public transportation will come as a result of better connections to these transportation systems as well as lowered road congestion (make buses a little faster) by reducing the staggering percentage of workers who use personal vehicles to drive to work. Moreover, the comprehensive and expansive nature of our PRT network would not necessitate the need to access connecting public transportation systems since most destinations within Union would likely be reachable with PRT. While PRT may never produce remarkably faster travel times (since it may alleviate congestion and benefit drivers as well), it may prove to be a more economical means of travel (certainly more environment-friendly).

By examining the above statistics on households, we understand that the average number of household members is 2.95. This suggests that at least one member of each family avidly shops. In Union County, the Jersey Gardens Mall provides an extremely active draw for Union citizens to shop. As this mall is only 30 minutes from midtown Manhattan, 5 minutes from Newark airport by mall-provided shuttle, has over 200 stores boasting tax-free shopping, deluxe food courts, and children's play areas, a PRT system could be very effective in helping citizens gain greater access to shopping opportunities. These PRT shopping modules could be designed to avoid rush hour traffic and could be programmed to respond to acutely heightened demand on holidays and the such. Thus, we have made an

[7] http://en.wikipedia.org/wiki/Kean_University

Table 22.6: Union School Enrollment,
Source: http://www.epodunk.com/cgi-bin/housOverview.php?locIndex=18482

School	**Number**	**Pct. of Total**
Preschool and kindergarten	19,029	14
Grades 1-12	88,985	65.3
College	28,216	20.7

Table 22.7: Union Commuting Methods,
Source: http://www.epodunk.com/cgi-bin/housOverview.php?locIndex=18482

Method	**Number**	**Pct. of Total**
Public transportation	25,294	10.6
Car, truck, van or motorcycle	197,145	82.6
Walk	7,729	3.2
Work at home	5,692	2.4

Table 22.8: Union Commuting Time,
Source: http://www.epodunk.com/cgi-bin/housOverview.php?locIndex=18482

Mode	**Time**
Average travel time to work (minutes)	29
Average travel time to work using public transportation	57
Average travel time to work using other transportation	25

effort to ensure that there are PRT stations serving many of the major points of interest described above (details to follow).

It should be noted that there are some areas in Union where PRT stations appear to be clustered together and thus may be perceived as a design flaw. While it is obviously not economical to have seemingly independent stations right next to each other, we must realize that any of these PRT stations is likely to see a tremendous amount of commuter traffic through the station and simply putting one station down may be wholly insufficient in dealing with potential PRT demand. While our maps currently propose having certain stations right next to each other, we could instead use the POIs that make up the stations locations to be a proxy for where we would put a very large station. Hence the cluster of PRT stations currently shown could instead be interpreted as a magnitude calculation for the size of station needed in that vicinity. In addition, the choice of certain points of interest may seem somewhat bizarre for a station location; for instance, a Chinese Restaurant may not appear to be the best location to have a station, yet it demarcates an area likely filled with other businesses, who in aggregate, would be a fine candidate for a PRT station.

That said, since we already account for the surrounding POIs within a quarter mile radius when we derive our attraction numbers (which is why they may seem a bit high in areas), some efforts could be put forth to remove clustered stations. The issue is that we describe the process of getting attraction numbers as being one that accounts for the surrounding areas; this assumes no other stations within the immediate area, which is inaccurate for these clusters. We attempted to create an excel function to measure distances between stations to determine whether or not some were excessive; we ran into issues dealing with the different possible geometric configurations of the stations and the resulting logic decisions. We believe that such a function that could aggregate POIs that are within a certain distance of each other would be an extremely useful tool in consolidating station locations. As we mentioned before, the cluster of stations indicates that this is an area of high traffic—we could, however, just keep one of the stations and utilize the average trip attraction numbers of the stations since all are within a quarter mile radius of each other. This, we believe, may help reduce the excess number of PRT stations in some areas and give more realistic numbers for the total number of trip attractions since we will no longer have the issue of overlapping station coverage areas. That said, we stand by our numbers as our POIs were geographically selected at random, and due to the fairly consistent land use patterns within the county, the numbers associated with a station in a cluster may be preserved if this station were moved out sufficiently. Thus as described below, we do not believe this will impact the economics of the PRT systems, it just may make them look a little more polished.

We have also put forth a significant effort is trying to ensure that there are stations in every municipality in Union to ensure maximum mobility. The nature of our search for POIs had lead us to have clusters of areas where we perceive for there to be significant demand, although it is quite possible demand may be slightly more uniform across the county. Efforts to improve our PRT network design would certainly begin with an effective means of getting disperse POIs that would serve as proxies for station locations. This would most easily be accomplished by individuals with a clearer sense of major and relevant locations within the county. Our searches for POIs in the yellowbook mostly left us with several POI intensive areas which are somewhat congruent with the population

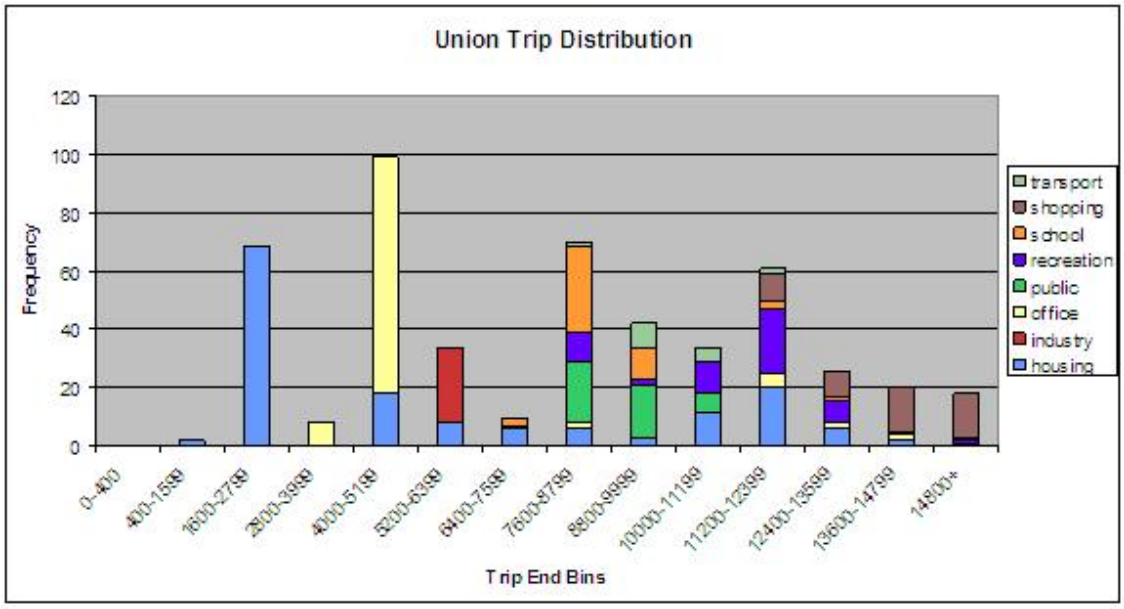
Table 22.9: Union Housing,Source: http://www.epodunk.com/cgi-bin/housOverview.php?locIndex=18482

Renter-Occupied Housing Units	
Average number of household members	2.47
Average number of rooms	3.9
Average number of vehicles	1.13
Median year structure was built	1956
Median year householder moved in	1997
Median rent ($)	676
Median rent asked for vacant units ($)	704
Rent includes utilities	10,082
Rent as a pct of household revenue	25
Owner-Occupied Housing Units	
Average number of household members	2.95
Average number of rooms	6.83
Average number of vehicles	1.67
Median year structure was built	1952
Median year householder moved in	1986
Median value ($)	185,200

density distribution: Elizabeth naturally has the most PRT stations with special attention paid to the area south of Newark International Airport, which is indeed part of Union County. We were able to find additional station locations by analyzing the Google Map in hybrid mode to find what appeared to be relevant locations in areas within Union that did not appear to be properly served by the PRT network. Mountainside and counties west of the Watchung Reservation perhaps would require the most attention in terms of adding new stations. Also of note is that Port Elizabeth is not currently served by our PRT network. While there are a fair amount of worthy attractions there, it would require a substantial amount of PRT guideway and stations for just that area (there would be no spillover from other areas since it is a port). In addition, the fact that cargo needs to be transported from the port does not make PRT a viable option for reducing the freight traffic load into the area. It could be said that the PRT network should perhaps be confined to certain areas first anyways to test its viability and gather information prior to making extensive investments in the rest of the county (this can be said for all networks in all counties).

22.1 Histogram Analysis

Figure 22.3: Trip Distribution in Union County



The following is a description of the distribution of PRT stations by attraction size in Union (please see Figure 22.3). In Union, most stations were placed in areas with multiple attractions within a quarter of mile, which would result in nice size attraction numbers for the respective stations. If we analyze the bar graphs specifically, we see that our most "low volume" stations are housing POIs in the more diffuse Middle and Western Union regions (think some parts of Scotch Plains and Montainside). Several of these low volume stations cover the more spread out suburban areas, but these housing areas are still relatively close to other possible attractions. We feel that the PRT network should obviously not leave any particular demographic completely out of the picture and thus, we stand by these relatively low volume stations. We also note that Union is indeed one of the densest counties in New Jersey and we certainly have higher volume PRT stations near these denser housing areas (more on this soon).

Our second spike in PRT stations are for stations with around 4,000 to 6,000 one way trip ends per day. In Union, the POIs surrounding these stations are smaller offices, medium density housing and industry locations. We were able to distinguish office size and industry plant size by the Google Earth images. As a note on industrial plants, they generally appear bigger than the offices but generally have less traffic coming through them per square foot (generally few surrounding attractions as well).

Our third spike in PRT stations are for stations that serve around 7,500 to 10,500 trip ends per day. As shown on the graph, these are pretty much public offices and popular schools as well as medium sized transportation stations (not all stations on NJ Transit get the same traffic level!). Again, these schools and public offices are not in isolation and hence, their stations get a fair amount of spill over from other possible POIs spotted on Google

Earth. School enrollment numbers as well as public office sizes aided with the ascertainment of the trip attraction numbers (more on this later).

The final hump on the bar graphs picks up from 10,500 trip ends and larger—we do see, however, the tail tapering off for PRT stations with attraction levels above 13,600 trip ends per day. These attractions are made up of more dense housing (think Elizabeth or another dense area) as well as recreation and shopping POIs in these dense neighborhoods. We also see some offices, which correspond to some of the more major office locations in Union. The high attraction numbers from shopping come from some of the relatively large shopping centers (identified by parking lot size and building size) that we noticed. The final bucket, 14,800+, if broken down into its own distribution, would be shown to be heavily weighted towards the lower end (meaning a lot of recreational and shopping attractions hover within a few thousand above 14,800). The biggest attractions in Union actually are a few shopping centers—most notably Jersey Gardens (23,500 one way trip ends)—the largest outlet mall in the state, and Kean University (21,313 one way trip ends). The shopping centers (including the likes of Target and Walmart) are both a hotbed for customers and workers and would likely continue to see increases in trip attraction with greater mobility for consumers. These shopping attractions, particularly Jersey Gardens, would like also get out of county residents to travel through on their PRT networks to make trips. Kean University has well over 10,000 students and staff with an overwhelming majority of the students living off campus—and as described earlier, due, in part, to both the economic status of the students and staff, they will likely take full advantage of the network.

Our graphs, therefore, appear as a double humped bell curve, where the leftmost hump comes from stations serving the more diffuse areas and the rightmost bump comes from stations in the more dense areas.

22.1.1 Snapshot of Major Stations

Figure 22.4: Kean University

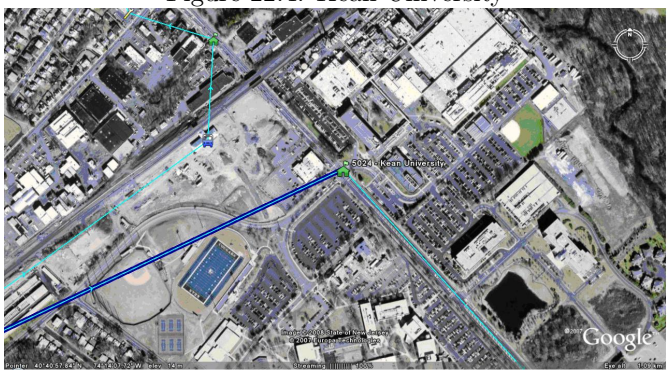
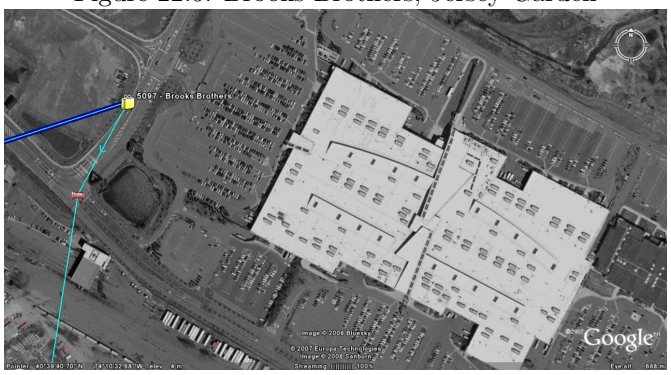


Figure 22.5: Brooks Brothers, Jersey Garden



22.1.2 Snapshot of Network

Figure 22.6: Macro View of PRT Network in Union County

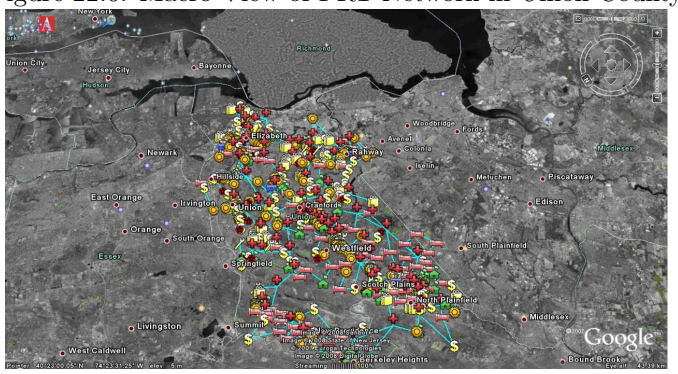


Figure 22.7: Eastern Union County

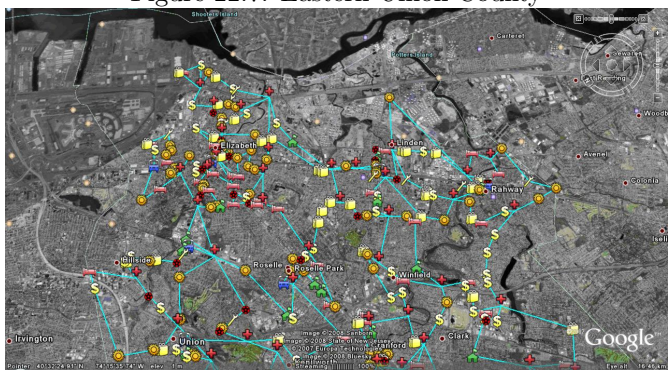
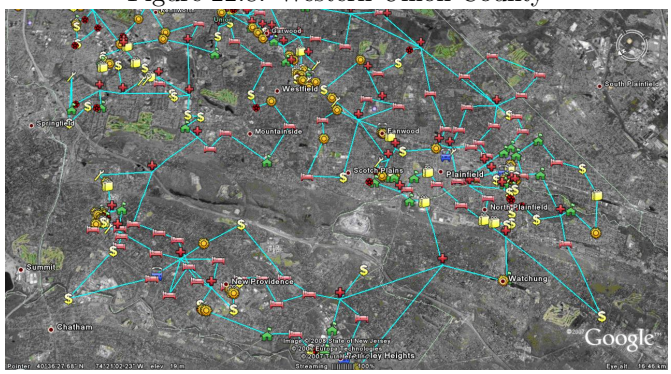


Figure 22.8: Western Union County



22.1.3 Cost Projections

One of the keys of getting any PRT network off the ground is to have a sound understanding on the likely costs. As of now, we will consider the costs of the guideway stations, and cars and explain any changes that may minimize these costs. As of now, all of our counties have guideway that extends to every area within the county—thus we feel that even with a modified network, our amount of guideway should already give an excellent prediction of what is needed to fully serve the county. As for stations, as described earlier, we do have some clusters of stations which may on the surface appear wasteful but can be thought of in several ways: One way to think of a cluster of stations is that they indicate the need for a superstation and hence the cost would likely be several multiples of a single station cost (perhaps similar to the number in the cluster). A second way to consider this is to imagine that since

the POIs were selected geographically at random, since many of the counties have areas with consistent land use patterns, a station placed in a cluster could well serve the same number of trip attractions if it were indeed moved somewhere else. Thus using this logic, we will also use the number of stations currently down as a proxy for the total number of needed stations for cost purposes (even if the network gets modified at some point). As for cars, we utilized a special formula not discussed here to get the cost of cars (we assume average trip length, though to be 7.5 miles rather than 10 miles):

Cost of Guideway: 254.24 Miles * $5 million/mile = $1,271 million
Cost of Stations: 493 Stations * $2.5 million/station = $1,232 million
Cost of Cars (ascertained using an excel file described in our leader's report): $8,550 million
Total Cost: $1,271 million + $1,232 million + $8,550 million = $11,054 million

22.2 Overview of Trip Number Generation

See Section 9.2 on page 81 for information.

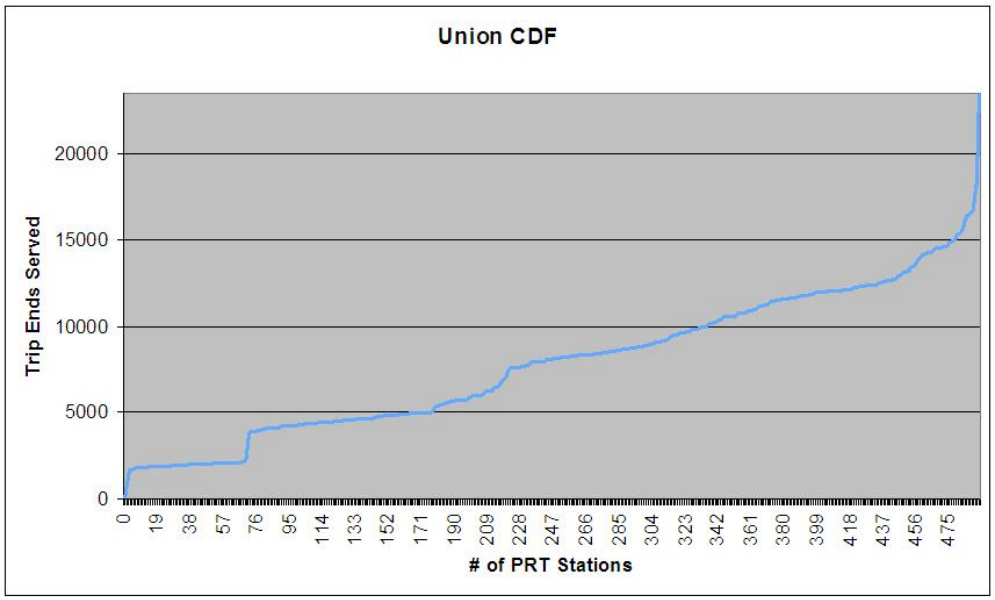
22.3 Overview of Absolute Expectation Levels

See Section 9.3 on page 82 for information.

22.4 PRT Network

Summary statistics can be obtained on total number of stations and interchanges (including bidirectional interchanges), length (in miles) of guide way, total network arcs, and top 5 attractions by trip number. Union County had 254.24 total miles of guide way, 692 total arcs, and 0.37 miles average arc length. Trip end statistics were the following: min = 417; max = 23,500; mean = 7,834; median = 8,124; 10% level → 50 PRT stations; 90% level → 444 PRT stations.

Figure 22.9: Station Usage in Union County



After going through all the aforementioned steps of the methodology, our attractions with their relevant trip numbers were finally plotted on the map. We initially flirted with the idea of creating PRT stations in parking lots we located through the Hybrid view of Google Maps, ideally creating enough stations to cover upwards of 90% of all attractions within a reasonable circular radius (this was done over break successfully but recently scrapped when we realized that the means by which the networks were checked would give us problems—the POIs would not actually be PRT stations but would be proxies for PRT stations and thus would be linkless) . Although this idea sounded good on a cost-efficiency basis and a minimal urban interference basis, it ultimately proved highly

impractical and less direct. Hence, we opted to assign a PRT station individually to each attraction plotted on the map. Although this greatly elevated the total number of PRT stations and, hence, network arcs and total guide way needed, from our previous idea, we found compensation in our confidence that each attraction would be dealt with in a direct manner (i.e. each attraction would definitely be directly incorporated into the network).

With these PRT stations now established, we were now ready to connect the system into one giant direct arc system. We generally employed a strategy of creating mini-circular networks to which we attached interchanges. This technique allowed us to carefully monitor and frequently back-test the network requirement of having one arc go into and one arc go out of each node. The interchanges associated with the previously described mini-circles created some breathing room in our design, as they can accept multiple arcs coming in and they can support multiple arcs going out. Also somewhat commonly, we opted to connect two interchanges to one another bidirectionally (i.e. arc going from interchange X to interchange Y and another arc going from interchange Y to interchange X). These bidirectionally supported particularly well the revising/re-routing/de-bugging process needed in response to the feedback provided by the ultimate network testing software. In general, throughout the network creation process, we kept up a consciousness about the relative travel distance between nodes.

As a general note about cost/budget, we were significantly more concerned about the fluidity of the network than potentially comprising designs that might have been more cost-effective. For example, our network is full of bidirectional interchanges. In the real world, urban planners may frown on such an abundance of these as not being cost-efficient. However, in our case, we believe they were justified for the following two primary reasons: 1) ease of revision/redesign of network; 2) decreased travel time / decreased congestion / increased transportation efficiency. While the first reason was more a coup for our purposes in designing the PRT system, the second reason presents a very compelling argument as to how increased marginal costs, in this regard, may be more than offset by efficiency factors. While we did not formulate a generalized mathematical justification of this notion, we believe strongly in its plausibility. Such a mathematical model might include an objective function feature a trade-off between efficiency and cost. One must consider how big the coefficient in front of cost should be. While it would be irresponsible to make it zero, the coefficient should be quite small.

On a more practical level, many of our loops are relatively small with more disperse regions having larger loops. The idea behind the smaller loops is that we feel that PRT will be extremely effective for short trips and that it allows people to easily move throughout their neighborhood. The smaller loops though are connected bidirectionally such that it is still possible to travel relatively large distances without having to traverse too many nodes as may be the case in a large loop. This comes in very handy when potential train riders live far from stations—the PRT will connect to these trains rather than having these commuters park and ride (when they might feel they can just drive to work). We do mention that bidirectional guideways are handy for the actual assignment but they also make a bit of practical sense in that they will prevent longer roundabout paths. We do notice that we do have some very concentrated PRT stations in some areas—ideally, we would like some more dispersion, but the cluster of stations may help alleviate tremendous traffic at one station. Thus it may seem financially impractical to have several stations (in our case mostly shopping/recreation POIs) within a quarter mile radius, but at the same time, we must acknowledge a certain bottleneck on capacity at any given station and may need several stations to cover one area. We also imagine that the PRT stations will have one pass-through lane and a pick up lane such that the PRT vehicles will be able to zip through stations it is not stopping in.

The PRT system would also cater to a broad spectrum of individuals of all social classes and physical conditions. We especially like PRT systems around universities where a lot of the undergraduates live off campus and likely depend on some campus shuttle or personal car to get around. The PRT system will allow them to reach all sorts of attractions directly and conveniently without undo financial or environmental stress. The PRT system may also help lower highway accident rates with fewer young drivers on the road. The PRT system also has a natural appeal to rail/bus commuters who in the past needed to drive to connect to their means of mass transit and had to pay for a parking spot in the park and go area. The PRT system would come equipped with almost futuristic amenities catering to the physically disabled, such as handicap accessibility and unprecedented ease of entrance and exit. The PRT system would work nicely for school children (provided they are accompanied by an adult) to get to and from school as the network directly connects housing with schools with recreational attractions (for afterschool activities). On the whole, the PRT system will boost mobility for those living further from the centers of town or cities and may result in a mini-economic boom as shopping and recreational attractions become "closer to home." Even the rich and retired may appreciate being able to save the environment while using the PRT system to get to their country clubs.

Efforts to revisit and revise our PRT network designs for all of these counties would essentially require one to carefully select more disperse POIs and have a better idea of the total number of the various POI types that exist throughout the county (though obviously we would not use all of them as stations). Finding the total number of attractions may be greatly simplified if we could have a more precise means of understanding the average number

of visitors to the various POIs. In addition, having a better idea of the distribution of different POI types within a quarter mile radius of a given POI type may better help determine the total trip attractions serviced within a quarter mile of a station due to spillover. Considering more specific POI types may also allow one to spend less time reviewing individual POIs which appear to be outliers in a certain broad class of POIs currently (maybe turn shopping into food shopping, malls, boutiques etc.). The creators of the network would also benefit from the tool discussed earlier on helping aggregate POIs that cover essentially the same area to prevent double counting of attractions and creating potentially unnecessary stations.

Chapter 23

Warren County

Figure 23.1: Warren County Sign

Warren County is located in the northwest corner of New Jersey along the Pennsylvania border. While a large portion of the land is undeveloped as either woodlands or farmlands, as was observed in a visit in December 2007, the part that is developed has a wide range of activities and services for members of the county to use. The county is noted for its recreational opportunities as a result of the open area. With a population of 102,437 (growing at an 8% rate over the years 2000-2006), the need for transportation is constantly increasing. The current transportation options in the county are limited. The predominant form of transportation is motor vehicles, and the county is dissected by two of the largest highways in New Jersey—Interstate 80 and Interstate 78. The only non-motor vehicle form of transportation (outside of bikes and walking) is through the singular New Jersey Transit train station in Hackettstown. The county could be well served by an improved transportation system that would bring more jobs and development to the county. Personal transportation is also a major user of energy and producer of pollution, and decreasing the reliance on that system can only benefit society.

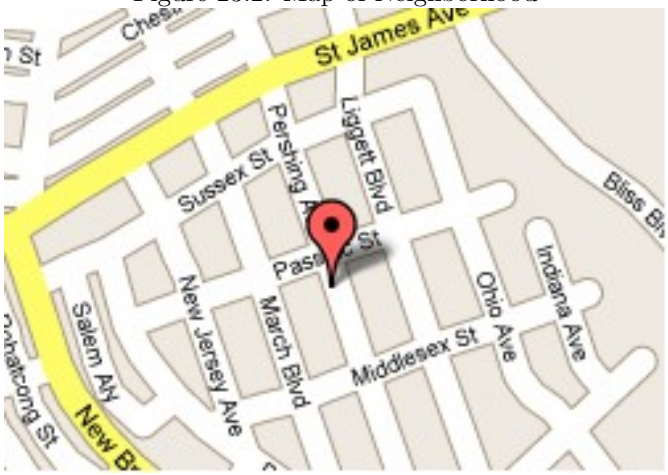
23.1 Overview of PRT in Warren County

The new PRT stations in Warren County will take into account the range of activities and the pre-existing structure of the county (population densities, school enrollments, employment needs) to fit a system to the needs of the county. The new PRT system must compete with motor vehicles and win if it is to be successful, and the design of this county's system takes this competition into account through the accessibility of stations.

The network designed for Warren County has 484 stations of 9 major types: housing, office buildings, industry, schools, recreation, shopping, religious, public buildings and transportation. The majority of the stations are housing, the two employment types, schools, recreation and shopping. The characteristics of each of these factors in Warren County will be described so as to place the system in its appropriate context.

The land use in Warren County, as already mentioned, revolves around farming and undeveloped territory. In a county of 233,000 acres, 110,000 acres are woodlands and 78,000 acres are devoted to farmland. This means that the portion of the county that has immediate need for PRT stations in close proximity is around 20%. The land use primarily affects the housing and the recreation stations. There are over 200 PRT stations devoted exclusively for housing use. When there are houses in the county, they tend to be very close together in neighborhood format. As shown in Figure 23.2, one station suffices to serve an entire neighborhood of people (who are in higher density than the overall county population densities might suggest). As a result of the land use characteristics, there are portions of the county where there are no PRT stations located and then portions of the county where there are many stations in close proximity to one another. This is because the residential areas are significantly more developed than the open space and the woodland areas. The housing stations are all in neighborhoods where the number of people served is high.

Figure 23.2: Map of Neighborhood



The land use also directly affected the recreation stations. There are almost 50 recreation-based PRT stations, just about 10% of the total, a high percentage given the amount of stations traditionally devoted to housing and employment. But, because such a large portion of the county is undeveloped and woodland, the residents of the county love outdoors activities and the high percentage of stations devoted to these activities is understandable. The Delaware Water Gap National Recreation Area is located within the county, providing a scenic opportunity for hiking, biking and exploring. The numerous golf courses also provide a chance for residents to get outside and enjoy the undeveloped land. There are countless ponds, reservoirs, lakes, and even a few other state parks and forests (Stephens State Park and Jenny Jump Forest) which provide recreation opportunities for residents. With such a great portion of the land devoted to open space and woodlands, it is important for the PRT system to reflect the land use and include enough stations nearby where these activities can still be enjoyed.

The school system in Warren County is designed in a way to match the land use. While there are many elementary schools in the county (almost one in every township), at the high school and middle school level the county has turned more towards regional schooling with one larger school in the more populous townships. The schools that exist in the same towns are frequently located next to one another, creating a situation for the PRT system where one station suffices to meet the demand. There are also two colleges in the county–Centenary College and Warren County Community College. Both of these are also served by the new PRT system.

The employment opportunities in the county dictate the majority of the remaining stations in the PRT system. With a county as undeveloped as Warren County, industry and business employment positions are few and far between. According to the U.S. Census, over 25,000 people commute to places of employment outside of the county, and almost 4,000 commute to employment outside of the state. This leaves only approximately 20,000 workers in county. While there are several large manufacturing firms in the county, the number of employees decreases drastically moving down the list of the largest industries.

The 10th largest industrial employer in the county employs only 150 people, showcasing the wide distribution of employees. With such few employees in the industrial sector, there is not much demand for the small manufacturing firms to have their own stations. Many of these smaller use stations are combined with other stations to increase ridership.

Non-manufacturing employment opportunities are also scattered across the county. The 10 largest non-manufacturing employers in Warren County are listed below.

Figure 23.3: Delaware Water Gap

Table 23.1: Ten Largest Warren County Manufacturing Firms

Rank	**Firm**	**Number of Employees**
1	Masterfoods USA	1600
2	Mallinckrodt/Baker, Inc.	500
3	Alcan Packaging	450
4	Atlantc States Cast Iron Pipe Co.	300
5	DSM Nutritional Products	267
6	Bihler of America	230
7	Spectra Gases	200
8	Graham Packaging	160
9	Compac Corporation	150
10	Zappa Plastics	150

Table 23.2: Ten Largest Warren County Non-Manufacturing Firms

Rank	**Firm**	**Number of Employees**
1	Warren Hospital	1000
2	County of Warren	928
3	Hackettstown Regional Medical Center	794
4	Abilities of Northwest Jersey, Inc.	440
5	Genesis Health Center	425
6	ShopRite of Greenwich	365
7	Centenary College	350
8	ShopRite of Mansfield	300
9	Staffing Alternatives	250
10	NORWESCAP	225

While the non-manufacturing opportunities for employment are greater than the industrial ones, they still do not make up close to all the jobs needed for people who are employed in the county. The other people who work within the county have jobs that can be filled in the shopping and other categories. As seen in the rest of the top employer lists, many of the large shopping centers employ a large number of people. Home Depot for example employs 170 people in Greenwich. Therefore, the PRT stations at the shopping centers will have a large portion of trips provided by the employees of the shops.

23.2 Vignettes

There are nine major types of stations in Warren County: office buildings, industry, housing, school, recreation, shopping, public buildings, religious, and transportation. One specific station in each category will be described more fully here.

23.2.1 Office

The employment situation in Warren County is unique, as was described above. The number one non-manufacturing employer is the Warren Hospital in Phillipsburg with 1,000 employees. The PRT system here has a station explicitly for the Warren Hospital, both for employee needs and for emergency needs. Without a car system working in conjunction with the new PRT system, emergency assistance will need to be provided in some other manner. With a PRT system that has stations near the emergency room and one for employees to use, the hospital can continue serving its dual functions as both an employer and as a service provider for county residents.

Figure 23.4: Warren Hospital

23.2.2 Industry

The number one manufacturing employer in Warren County is Masterfoods USA, more commonly known through its Mars/M&M brand name. Masterfoods employs over 1600 people in the county, through its offices and factories located in Hackettstown. Masterfoods has its own PRT station in the new system so as its great number of employees can have continued easy access to work every day. Another large manufacturing industry within Warren County is BASF in Belvidere. BASF is an extremely large international chemical company with 57 locations in North American alone. While the site in Belvidere is only a production facility (no main office support), there are over 100 employees at the location. There are also 65 BASF employees at the Washington plant location, moving BASF up to one of the top positions as a manufacturing employee in the county. The PRT system takes this into account, providing direct service to the BASF locations in both Belvidere and in Washington.

23.2.3 Housing

One PRT station is located at the Fairway Greens condominium complex outside of Belvidere. Both a recreation and a housing station, it showcases both the housing aspect of the PRT system and the dual nature of many of the stations. The Fairway Greens condominium complex is right on the links next to the Fairway Golf Course, one of the many recreation opportunities in Warren County. While exact condominium resident numbers are not possible to ascertain, given the population density of the surrounding towns and the number of households in the area, there are approximately 311 people living in the condo complex. This means that there are between 100 and 200 condos available for rental given the number of people per household in the county (2.61). With around 300 people, there are 160 workers and 75 school-age children. The needs of these workers and children on a daily basis form the majority of the trips in and out of the Fairway Greens station as they move to and from work and school respectively. The dual nature of the station also means that there are trips in and out of the station for the

recreation opportunities at the golf course. The PRT station accessibility means that the people living at the condo complex don't have to use cars to get to and from their work and school locations. A flexible and wide-reaching PRT system allows residents to use the system for all their needs.

Figure 23.5: Fairway Greens

23.2.4 School

One of the schools on the PRT system in Warren County is Belvidere High School. Belvidere High School has an enrollment of 568 students, who provide the majority of the station usage on a daily basis. However, there are also employees of the school who use the station. Figure 23.6 taken in December, 2007 shows the Belvidere Elementary School, which is located immediately next to the High School. This is important in the design of the PRT system as neighboring schools can share a station, reducing costs and maintenance needs. The number of trips in and out of a station is increased through the combination of these uses. Allowing access to schools is crucial if the PRT system in Warren County is to be successful as the schools have high enrollment levels.

Figure 23.6: Belvidere High School

23.2.5 Recreation

The first is the Delaware Water Gap National Recreation Area. As seen in Figure 23.7, there are 19 PRT stations placed in the official recreation area and along the Delaware River. Warren County, as mentioned before, is known for its outdoor activities and opportunities. The Delaware Water Gap is probably the most famous natural

landmark within the county, and as both residents and visitors alike flock to the region for outdoor possibilities, it is important that the new PRT system meets these needs. With stations approximately every $\frac{1}{2}$ to $\frac{3}{4}$ of a mile along the river, people are free to get off, walk, hike and explore, but then also get back on the system to be shuttled back in to town. The Delaware Water Gap Recreation Area is an extremely large tract of land devoted for outdoor activities, and it is important that accessibility to the site is preserved under the new system. There are also three stops that directly service the Appalachian Trail. The Appalachian Trail runs through the Delaware Water Gap National Recreation Area, and its accessibility is important for visitors who are interested in hiking the trail. The frequency of stops is also important for safety reasons. As the PRT system will replace the majority of motor vehicle use, ambulances and other forms of emergency transportation will be limited. Multiple stops in the recreation area allows for greater safety for people in the area as if they are hurt or need assistance, they are never too far from a PRT station.

Figure 23.7: Network around Delaware Water Gap

23.2.6 Shopping

Another PRT station is located at the Phillipsburg Mall. Phillipsburg is one of the main towns in Warren County, located on the Pennsylvania border along Interstate 80. Currently one of the more developed areas of the county, the mall is an important shopping resource for members of the county and also for visitors from out of state. With over 72 stores including department stores such as Sears, J.C. Penny, Kohl's and H&M, the Phillipsburg Mall is a huge draw for shoppers. The easy access of the new PRT station in the mall's current parking lot will bring shoppers to the mall just as easily as if they were driving.

Figure 23.8: Phillipsburg Mall Logo

23.2.7 Public Buildings

One of the more than 30 public building PRT stations in Warren County is the Washington Borough Municipal Building. As Warren County is not an extremely populated county in New Jersey (ranked 19th out of 21), the county government offers the same major public services on a smaller scale. As seen in Figure 23.9 taken in December 2007, the Washington Borough Municipal Building is only several thousand square feet, but it houses the tax collector's office, the registrar's office, the town clerk's office, and the police and fire station. With so many services being run out of one centralized location, the existence of a PRT station exclusively for the building is important. Residents will still have easy access to all the functions they need performed by the town, from permit

approval to road maintenance to fire and public safety, and a PRT station with connections in to the rest of the town and county system will provide them with continued service.

Figure 23.9: Washington Municipal Building

One of the other public building stations is the Oxford Public Library, shown in Figure 23.10. Libraries are an important resource for towns, as they provide learning opportunities for young children and adults everywhere. While the Oxford Public Library may seem to be a very small place, it still has hundreds of books available for rental. Continuing access to places such as libraries is important to ensure that town services are still all accessible. Placing a PRT station at the Oxford Public Library could even encourage more visitors than the library currently receives. As seen in the photograph, the parking available at the library is not extensive. The PRT system does not require parking outside of the station to be available for patrons to use the facility, and thus by increasing the accessibility of the library through both decreasing constraints on capacity and improving recognition of the space (by giving it its own PRT station), library usage should increase. This can only have beneficial effects on the town and its inhabitants as education levels can rise and a thirst for learning and discovery can be encouraged.

Figure 23.10: Oxford Public Library

23.2.8 Religious

The PRT system in Warren County will also include a station at the St. Rose of Lima Church. While there are dozens of churches in the county, only a few have specific PRT stations because of their unique locations. The St. Rose of Lima Church is up on a hill overlooking a large portion of the county's territory. Without much surrounding

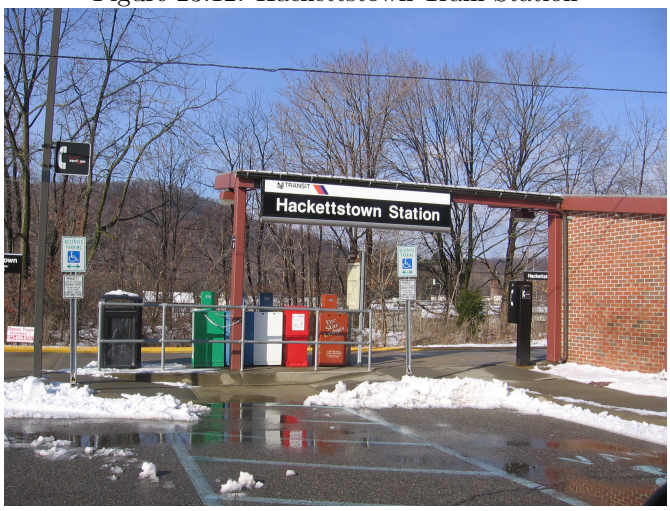
it, it is necessary for the church to have its own PRT station. As religion is an important part of many people's lives, allowing continued access to spiritual locations is crucial for the success of the PRT system in the county.

Figure 23.11: St. Rose of Lima Church

23.2.9 Transportation

One of the most important stations on the new PRT system in Warren County is the station at the Hackettstown Train Station. The Hackettstown train station is the only New Jersey Transit station in the county, providing direct access to New York City. While the train station may seem small from Figure 23.12 taken in December 2007, the number of people in the county who work out of state is astounding–3,915 of the approximately 60,000 workers commute on a daily basis to a job outside of New Jersey. The new PRT system has a station at the Hackettstown train station to connect the system to these jobs outside of the state. Working with the pre-existing transportation systems in the state is an important part of the new PRT system, decreasing costs and also allowing people to use some of their more familiar and already efficient methods of transportation to and from places.

Figure 23.12: Hackettstown Train Station



23.3 System Design

The entire system for Warren County is shown in Figure 23.13. It contains 462 stations and 22 interchanges for a total of 484 nodes. There is one incoming arc and one outgoing arc per station node. The number of each type of station is listed in Table 23.3.

Figure 23.13: Warren County PRT Network

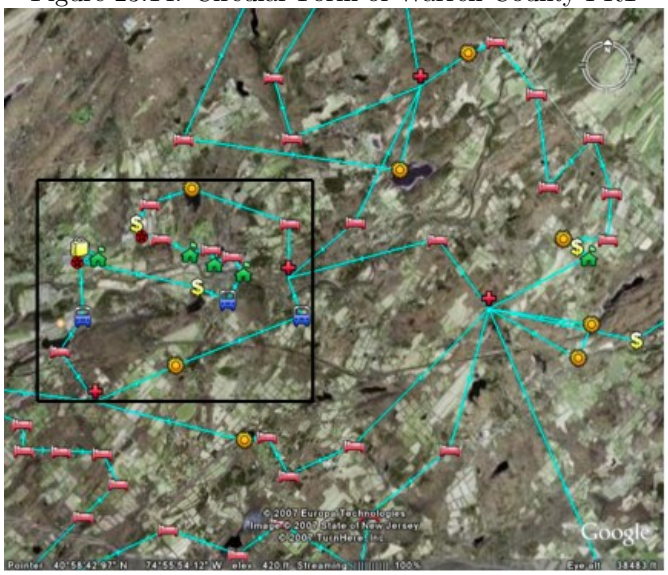
Table 23.3: PRT Stations for Warren County

Type	**# Stations**
Housing	217
Industry	32
Office	55
Other	11
Public	28
Recreation	45
Religious	1
School	42
Shopping	20
Transportation	11

The majority of the stations are housing, followed by both categories of employment stations (industry and office). Recreation and school stations make up a large portion of the remaining. There are 524 arcs in total (since interchanges can have more than one arc in and out). There are 436.62 miles of guideway in the system and the average arc length is 0.83 miles. The system is designed so that all stations serve people and locations within $\frac{1}{4}$ mile radius all around. This creates a situation where the housing stations are most effectively placed in neighborhoods. The stations are connected by guideway. This PRT system is designed to be above ground with the guideways supporting the cars from below. The connections between stations are arcs that allow one-way traffic. The importance of the one-way traffic is to minimize costs. In order to connect a set of stations using one-way guideway, Warren County has a PRT system that was designed through "neighborhoods" or "groups" of stations. A set of stations would be combined in a circle using one-way track. At one point in the circle, two adjacent stations would be connected through an interchange that allows movement to another circle of the network. Across the county, all the circles are connected in this manner. This allows a minimal amount of guideway to be needed while also still ensuring that travel from any one point in the system to any other point in the system is possible.

The "pearl necklace" design finally used here (with stations strung out on a chain like a pearl necklace) won out over a more grid like design with one way streets in alternating directions. The adaptation of the grid system (such as that used in Manhattan) to a rural area like Warren County proved too difficult given the collection of stations in groups without much in the middle. The pearl necklace both minimized the miles of guideway needed and connected stations in commonly used sets (for example, one town's residential, shopping and schools can be on the same chain). The final design is shown in Figure 23.14. As seen here, the network moves around in a circle like described with the crosses playing the role of interchanges in the guideway to allow connections to another circle. One of the circles of connecting nodes is highlighted inside the square.

Figure 23.14: Circular Form of Warren County PRT



There are, of course, cost issues to be taken into consideration in the design of the network. Stations and miles of guideway can run into the millions of dollars, but they are not the only costs—interchanges also need to be accounted for. In this portion of the network alone, there are multiple designs of interchanges included. The number of guideways in and out of the interchange can increase the cost and can also potentially decrease the efficiency of the network, and thus need to be taken into consideration.

The design of the system was also influenced by a visit to the county. While up in the region, it was very clear that the stations would be grouped together in areas where there was more development and that very few stations would be located in areas where the land was wooded. The majority of the county is very rural, which influenced the design of the network to a large extent.

23.3.1 In-Depth Cost and Station Analysis

As was mentioned before, the Warren County system has 462 stations (not counting interchanges), many of which serve housing and employment locations. With 436.62 miles of guideway and 22 interchanges, the cost of the network in the county will be high. Approximating using cost estimates of $5 million per mile of guideway and of

$2.5 million per station, the total cost of the Warren County network will be approximately $3 billion dollars (not including the number of vehicles. Using a vehicle estimator based on the number of trips, the number of stations and the average trip length, Warren County will need approximately 24,500 vehicles, each at a cost of $150,000. Total costs are detailed in Table 23.4.

Table 23.4: PRT Network Cost for Warren County

Part of Network	**Amount of Part Needed**	**Cost per Part**	**Total Cost**
Guideway	436.62 miles	$5 million	$2.183 billion
Stations	462 + 22 interchanges = 484	$2.5 million	$1.210 billion
Vehicles	24,513	$150,000	$3.676 billion
Total			$7.069 billion

For a county with a population of just over 100,000, this is a very high cost. However, the cost can be justified on a few levels. The PRT system in its current form will not require extreme amounts of maintenance. When compared to the road and highway system used today, the cost is understandable. The U.S. government (including federal, state, and local authorities) spends hundreds of billions of dollars per year, and according to the Bureau of Transportation, the state of New Jersey spent over $4 billion in 2006 on transportation systems (not including federal funding). The cost of installing a PRT system is comparable to several years worth of transportation funding, however the current expenditures on the highway and road systems are for maintenance only. The PRT system, once installed, will not have maintenance costs nearly that high. Spending more to create the system will lead to lower expenditures in the future, something that can be justified.

It is also important to understand the use of each station. Daily trips per day were calculated for each station based on the number of people served and the locations within the quarter-mile radius reach of each station. For example, stations in housing centers are used by people going to and from work, to and from school, to and from shopping, to and from recreation, and to and from both other and different housing stations. Using population density numbers (adjusted for the fact that only 20% of the land in Warren County is developed) and the amount of land served by each station (the area of a circle with a $\frac{1}{4}$ mile radius), the number of people living in each station's service area was determined. This was then compared with an approximation of the number of people served, found through the number of households and the number of people in each household. Then, by using other national and local statistics, it was possible to find the number of people going to school, the number of people going to work, etc. based on the number of people living within each station area. The same type of analysis was conducted for other types of stations, but with specific formulas based on their characteristics. Some trip numbers were known exactly, based on the enrollment of a school or the number of employees. More detail on the trip calculation method is available by request. The total number of trips (starting and ending) in the system is 634,192. When divided by 2 (to get to the total actual trips) this results in more than 300,000 total trips in the county system, equating to approximately 3 trips per day per person in the county. While seemingly low (since the average person makes just under 3 trips per day), this can be explained by the low employment numbers within the county. Many (over 25,000) of the people who live in Warren County work outside of the county. The end station for these trips is not counted in these numbers, skewing the number of trips per day lower than it should be.

The number of trips through each station can be a good tool for the analysis of cost, because higher use stations can essentially "pay for themselves". The highest use station in Warren County is the Belvidere Downtown area, receiving 9,852 trips per day (both those starting and ending in the station). The second largest station is the Phillipsburg Center (including the Phillipsburg Mall). The Phillipsburg Mall (which is profiled above) includes a wide range of stores, and is a huge draw in the area for both shopping purposes and employment purposes. The next top 13 stations in terms of trips per day are all housing stations, scattered around the county in the larger townships—Washington, Belvidere, Phillipsburg and Hackettstown. The use of each of these stations is around 8,000 trips starting and ending per day. This is also understandable because of the higher population densities of these townships. With more people living in a small area, each residential station can serve more people. Each of these people leaves the house to go to work, to go to school, to go shopping and for other trips—all of which start and end in the housing station. The 8,000 trips per day make sense given these characteristics.

While it may be surprising that none of the top stations are employers (either industrial or other office buildings), this is entirely understandable given the dispersal of employment locations (as was mentioned before, the top employers only have 1,000 or so workers). The number of trip ends served by each station type is shown in Table 23.5.

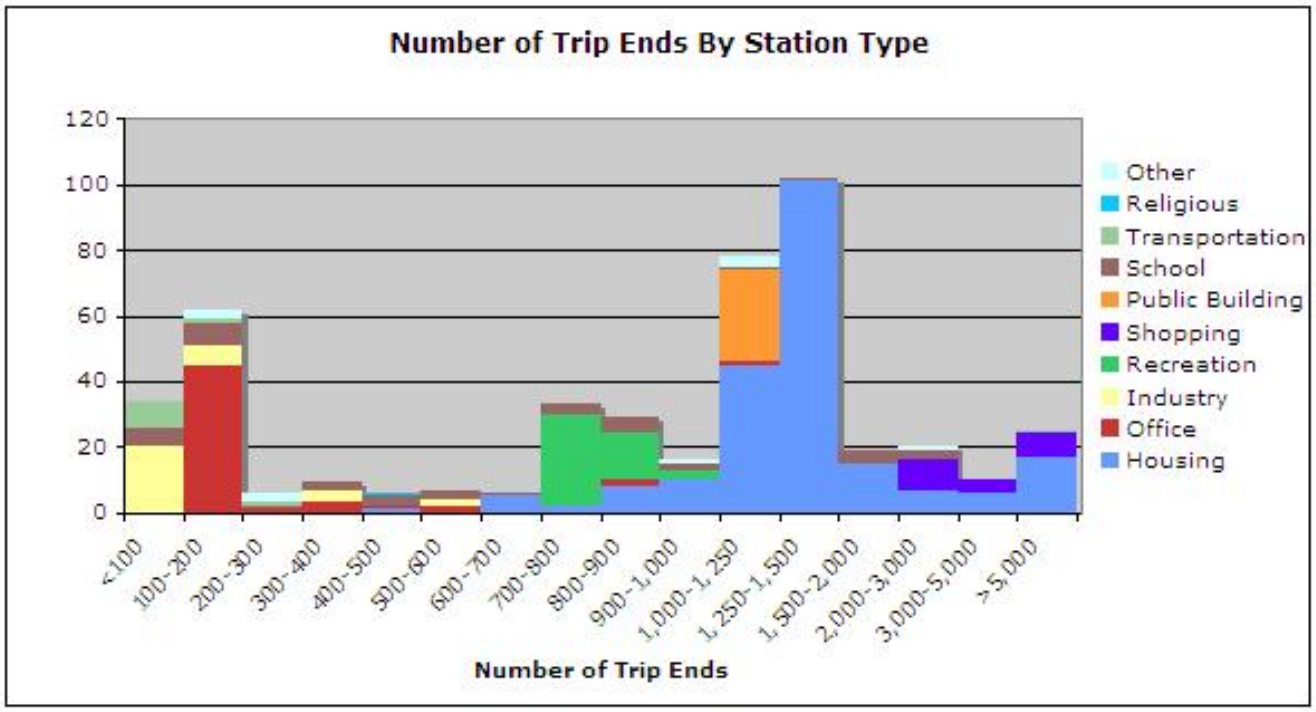
Looking at a histogram of the number of stations in each range of trip ends per station is useful to understand how the number of trips served by station type corresponds to the number of each type of station. The majority of

Table 23.5: PRT Network Trips for Warren County

Station Type	# Trip Ends per Day
Housing	409,512
Office	10,458
Industry	3,594
Recreation	36,689
Shopping	95,628
School	30,952
Public Buildings	30,438
Transportation	8,430
Religious	492
Other	8,000

high use stations are residential and shopping, while the low use stations are the employment and transportation stations (with the exception of the Hackettstown Train Station which has over 7,000 trips per day).

Figure 23.15: Trip Distribution of Warren County PRT



As shown in Figure 23.15, there are also quite a few stations without many trips. Warren County is a very dispersed county, with many recreation and employment opportunities far away from other regions. As such, one station may only serve a handful of trips. For example, several of the industrial stations will have less than 25 trips per day going in and out of the station. The Atlas Concrete Corporation will only have 20 trips per day. As was mentioned before, the number of employees in manufacturing firms declines quickly. Since the Atlas Concrete Corporation is not one of the top 20 manufacturing firms, it must have fewer employees than the number 20 employer. However, the number 20 employer only serves 25 employees, meaning that Atlas Concrete must have less than 25 employees. There are quite a few other industrial station locations that serve fewer than 50 people per day. There are also several housing stations, such as those located by the Delaware Water Gap (along Route 46) that serve only a couple hundred of trips per day. The low population density in the area contributes to the low service numbers.

Warren County has a low population figure (approximately 100,000) compared to other counties in New Jersey. Therefore, low trip numbers are understandable and even expected. However, when looking at costs, it is important to justify the funding of these stations. In order to understand whether or not the majority of the Warren County stations will fund themselves, a cost per trip needs to be set. Even without setting one, however, it can be assumed

that stations with service as low as 20 people per day will not be covered. While each station does not necessarily have to hold its own (as higher use stations will more than cover their costs), it is important to make a justification for why all the stations in this system should be included. The PRT transportation system is being designed in New Jersey to replace old methods of transportation. The ultimate goal is to get more than 90% of the population to use the system, for almost all trips. While some stations may have very small usage numbers, without locating stations in the very far corners of Warren County (or next to an industrial plant with only 25 workers), not everyone will be served. The more places which are not served, the less people will be willing to start using the system in the first place. For example, if a person from Frelinghuysen Township (with a population density of only 89 people per square mile) cannot get to a station because their house is out of range of another one, there is very little chance that this person will begin to use the PRT system for all trips. The same story holds for someone who cannot get to his or her place of work because of the lack of a station nearby. While some stations may have very low usage numbers, in order to encourage use all places people would go on a normal day must be covered—whether somewhere in the center of a city or somewhere in the country, with nothing else in sight. Looking at PRT as a system-wide goal across the state of New Jersey, these low-use stations are necessary to take on as a cost in order to encourage use in the system and to ensure that the costs of all the other stations are worthwhile.

23.4 Value of the PRT System

There is significant potential value to installing a PRT system in Warren County. Currently, much of the development is based around the corridors of Interstate 80 and Interstate 78, but there is a large portion of the county beside just these two areas that still has need for more employment and housing developments. Transportation can be one of the means through which development is cultivated, and creating a system where far reaching areas of the county can be accessed easily and quickly has the potential to encourage growth in the county. As was noted before, only a third to a half of the labor force works in the county with everyone else commuting out to find work. With more development, more jobs will be created, keeping people in the county both for work and for shopping and recreation. However, there is some pause to be taken when considering the negative impact the system could have on the county. As was mentioned previously, the county is extremely popular for its recreation opportunities. While the PRT system will be designed with aesthetics in mind, it is very important that the outdoor opportunities not be lost in the development, as they are crucial to the county's character and atmosphere. As was mentioned in the introduction, reducing reliance on motor vehicles can help in both energy consumption and pollution production. While the PRT system will not be pollution free, it certainly can help move society's transportation system to the next sustainable level.

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