1. Introduction

With total area of 481 square miles, Morris County is the seventh largest county in New Jersey. It is also the sixth wealthiest county in the United States, by median household income. The county is divided into 39 municipalities, with dense town centers interspersed among less dense residential and empty wooded areas. Morris County is an attractive place to live and has experienced large economic and population growth, and current transportation systems are strained and congested. The proposed Personal Rapid Transit system would not only ease congestion on the strained road network, but also link together urban centers and augment existing transportation infrastructure.
2. Land use

Residential:

As of 2000, there were over 470,000 people living in Morris County. These comprised 124,907 families and 169,711 households. The population density was just over 1000 people per square mile. The eastern and central regions of the county are the densest, with urban towns such as Morristown, and in general the south and west are less populated.

In designing the PRT system, we polled the US census data and obtained block by block information on location and population. We geocoded the census block data to give us a residential land use distribution. We were able to represent this data visually in Google Earth to guide our system design.

Commercial

Morris County is an attractive place to live, as well as an attractive place to have office space. Though office space has not grown at the rate of residential regions, many large companies have offices in Morris County. In fact, more than 50,000 people are employed at world headquarters buildings that reside in the county. The Morris County Chamber of Commerce reports there are 1,139 non-retail employers in the county with 10 or more employees.

Education

The county has several hundred schools, and upward of 90,000 children of school age.

3. Trip Types

Work related trips:
Morris County is the sixth most affluent county in the nation, by median household income. There are many office parks within the county, and with New York only 25 miles east, many residents commute. Many large companies have facilities in Morris County, including Honeywell, Wyeth Consumer Healthcare, Novartis Pharmaceuticals Corp, and Sun Chemical corp. Thus there are a large number of work related trips both within the county and out of the county. Bus and rail transit systems currently service the trips to New York, while roads and bus mostly service the trips within the county.

School related trips:

The county reports that nearly 90,000 children between the age of 5 and 19 live in Morris. The county has 165 elementary schools, 33 middle schools, and 29 high schools. Therefore, many daily trips are generated by children travelling to and from school. The schools and their enrollments were included in generating our trip attractions.

4. Existing Transportation Systems

Naturally, Morris County has existing transportation systems, and the aim of this proposal is to integrate the PRT system to complement these systems.

Morris County is crisscrossed by several New Jersey Transit rail lines, including the Morristown Line, the Gladstone branch, and the Montclair Boonton line. Together, these stations service 11,400 trips per day. These rail lines provide access to New York City, and act as arteries into and out of the county. However, there are not enough stations to represent a useful intra-county transit system. The PRT system will augment the NJT rail lines by providing access to and from the stations, and link the Montclair Boonton line to the Morristown Line.

Below is a list of NJT rail stations in Morris County, along with the number of daily trips serviced there.
Morris county also has in place an existing system of roads, which will be largely outdated by this PRT system. There are over 2000 miles of interstate freeways, and state, county and municipal roads.

Currently, several bus lines service the county, including dedicated links to Manhattan and local lines. The Morris County Metro system consist of seven bus routes that serve within the county. New Jersey Transit buses connect various parts of the county to Newark and the Port Authority in Manhattan. Two WHEELS bus services run in the county, one linking office parks with Convent railroad station and another linking Sussex County and Parisppany and Jefferson. Several services operate lines directly to the Port Authority in Manhattan, and several other bus services operate within the county itself. On the whole, these bus routes serve a large number of trips, which will be mostly replaced with the PRT system.

5. Station Placement

Maximizing efficiency: The goal of this PRT system is to accommodate at least 90% of the trips currently serviced by road vehicles. In order for a trip count as serviced by the PRT system, a station must be located within one quarter mile of both the origin and destination of the trip, which is considered reasonable walking distance. For this reason, the stations must be placed very densely across the county. Considering the cost of up to $250 million per station, a considerable premium is placed on minimizing the number required to achieve the goal. Thus, the stations are laid out in a manner that will maximize the number of productions and attractions serviced by each location.

Integrating with current transportation infrastructure:
As mentioned above, it was the goal of this system to integrate with existing transportation infrastructure. We therefore attempted to place stations at any location that would augment access to the three NJT rail lines that bisect the county. Specifically, we placed PRT stations at each rail station, with the expectation that a substantial portion of the daily trips to and from these stations will be serviced by the proposed system. Park and ride facilities are also serviced; those trips that used to access NJT stations by car will now be accessed by PRT. The number of daily trips generated by the NJT rail stations were used to simulate the trips serviced by the adjacent PRT station.

6. Network design

For simplicity's sake, the design of the personal rapid transit network is limited in complexity. Each station is one way, and has a guideway coming in and a guideway going out. Each guideway represents a one-way link between stations. Thus, the fundamental unit of the system is the loop. Because the guideways are one way, the network must be some kind of loop to access every station from any location.

Interchanges allow local loops to be connected to each other, creating the required complexity for a real transportation network. Each interchange can have up to 4 guideway coming in or going out in any feasible combination.

Reconciling this limited network design with the actual geography of productions and attractions proved to be quite a challenge. The proposed system represents a considerable amount of effort devoted to minimizing the distance between any two stations on the network, keeping in mind that often times a car will have to traverse many stations and interchanges to arrive back at the original location.

For sparse areas, we used a system of connected loops which daisy chain to each other in order to provide a tradeoff between cost, complexity, and trip distance.
The above image shows the design strategy for sparsely populated areas. Loops are linked end on end to at once minimize the number of network elements, minimize round trip distance, and maximize coverage.

More densely populated areas require a mesh of stations and interchanges in order to service the area effectively. In this case, we use a system of loops that are connected at more than one side, creating a grid, which minimizes both the number of interchanges, and the round trip distance:
7. Network statistics:

The proposed system has 858 stations, 321 interchanges, and over 654 miles of guide way. The network services the vast majority of trips that are currently serviced by roads. By our estimation, over 85% of all trip productions (households) and fully 98% of attractions are serviced. At $2 million per station, $5 million per mile of guide way, and $100,000 per car, this network represents a high cost to society. However, if we allow for a 10 year payback period, the break even cost of a ticket could be as low as $2.32 dollars a ride. The following table shows a summary of the proposed finances.
The total cost of the infrastructure would be almost 6 billion dollars. However, allowing for a ten year payback period, without interest, we arrive at $2.32 dollars as a lower bound for ticket prices. Our analysis depends on the assumption that the size of the fleet depends only on the number of expected trips at peak hours. We assumed that 15% of the daily trips would occur at this time, and that our cars could manage 5 trips per hour during rush hour. Allowing for a modest 2.5 people on average to share a car at rush hour, we arrive at the fleet size of 8,232 cars.

The cost of nearly 6 billion could be substantially reduced by pruning certain parts of the network. The proposed number of stations, 858, is probably more than needed to provide a high level of service to the county. By looking at the projected distribution of trips per station, it is clear that there are too many stations that service only a few productions or attractions. In fact, by simply removing the stations that service fewer than 300 trips per day, we could remove 134 stations saving $268 on stations alone. If we assume that the number of miles of guideway was proportionally reduced, it would represent another $500 million in savings. Thus, implementing a slightly less aggressive design would allow the county to save upward of a billion dollars without sacrificing the vast majority of the benefit of this system.
The above histograms help to illustrate that the system could be improved by pruning away some stations. The fat tails represent the scattered few stations that service especially dense areas; these stations are expected to be very busy and represent the most profitable installations. The tail to the left, highlighting the stations that service the least trips, should be reduced to save value.

8. Conclusion

The proposed PRT system will reduce transit times, save precious opportunity cost of half a million resident’s time, and save lives. While the system would certainly be expensive ($5.8 billion estimated), it would also at tremendous value to Morris County. The system would ease access to schools, connect urban areas, and enhance connectivity with existing mass transit. Commute times to New York City could be substantially reduced, as well as transit times within the county. Furthermore, lives would be saved as a result of fewer traffic incidents. These benefits are very attractive considering the rising congestion of the region.