TRANSPORTATION TIME EFFECTS ON ECONOMIC DEVELOPMENT

BY

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Abstract

Mobility is essential to the economic health of a region. The opening of the Washington D.C. Metrorail system in the 1970s and the electrification of the Long Island Rail Road in the 1980s provided faster modes of transit, resulting in greater access to business and services for individuals in these areas. Cutting travel time spurred dramatic economic development for both of these regions. Upstate New York is primed for the development of new transportation systems. Through reviewing the history of transportation improvements we evaluate what effect reduction in travel time and increased mobility will have on individuals and communities throughout our region. We propose that enhanced mobility will improve Upstate New York through establishing connections to major city centers while providing efficient transportation alternatives for the region.

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1.1 - Introduction

The question of how people, business, and services move into an area as a result of changes in transportation is one that has evolved over time with the development of new analytical methods and transportation technologies. In the United States, designated transportation planning became mandated with the passing of the Federal-Aid Highway Act of 1962. Much of the planning that occurred before the 1960s was simply based on advice from prominent individuals in the areas where development occurred.

The canal systems of the United States provided the earliest form of organized mass transportation. Early planning for canals followed waterways from major city to major city along their route. With advancements in transportation, planners often developed along existing infrastructure to increase the benefit to towns already invested in the older technology. Railroads enabled more freedom in planning yet many initial routes connected different canal systems. With the rise of automobiles, planning became a highly complex issue. This issue was only magnified as technologies came about introducing light and high speed rail as well as air travel into the transportation system. Careful evaluation of benefits and costs to individuals and a region became the status quo when building infrastructure.

With the expectation that introduction of new transportation technologies will help address the weaknesses in our current infrastructure, we have the ability to optimize that development through a-priori planning. To introduce these systems in the most efficient fashion, it is important to understand decision making behind developments of the past. Through this knowledge we can ensure planning and development will be most beneficial to societies of the future.

Overall two major goals can be identified for development of transportation infrastructure in the United States. The first is mobility, the enabling of individuals and companies to reach one another for mutual benefit. The second is economic benefit. Transportation of goods from one area to another is of critical importance to the economic development of a nation. By evaluating mobility through travel time, and economic benefit of existing systems, we can apply that knowledge to the planning of systems in the future.

1.2 - The Canal System

Starting with the opening of the Erie Canal in 1825, the major contributor to moving passengers and large volumes of goods in the United States was the canal systems. The Erie Canal is credited as providing the first navigable waterway from the Hudson River and New York City to the Great Lakes. This system was able to provide the route at great speed and with vastly decreased cost.

The prevalence of canals in the north east was mainly constricted to water right of ways that existed along the routes between cities. In part due to the cost of artificially created right of ways. The usage of canals dramatically changed the transport of goods in the United States. At the most basic level, the increase in the volume of goods that could be shipped could be seen as the main benefit of the systems. Costs per ton of shipping along the canal only reached around $4 per ton. This was a vast improvement from the shipping costs near $100 a ton frequently reached prior to the development of the canal. Through the increased volume, the profits that would come about from the transport could be seen as a huge economic boost to a region. There existed many benefits to the use of canal transportation over the rail systems that were beginning to become more prominent (Kirkaldy and Evans 1924).

The major benefit that was seen in terms of canal transport was its low cost of utilization. For large barges carrying a substantial amount of goods, a large profit could be made due to the set shipping prices of the system. This shipping of goods existed as the main income generation for the canal system. While overall speeds of the canal system were slow, passenger transit was still popular along the canal system. Roadways of the time period were not well developed and often difficult to traverse, leading to the canals' role in transit. The low maintenance cost was seen as the major benefit over the utilization of rail transport as long as shipping logistics allowed for it. Maintaining the water right of way was virtually free in comparison to maintenance costs that involved utilizing track with alignment and repair issues. It is often suggested that the maintenance for rail was around five times the maintenance cost for the canal system (Channon 2001).

Even with high volume and low costs, canal use was hampered by disadvantages. For those running the canals it became difficult to maintain profits and keep up with periodic maintenance issues. Day to day maintenance did not exist in these systems but over time larger costs could accumulate due to lock maintenance and the overall cleanliness of the system. This eventually led to scaled tolls across a route. Depending on the length of the trip the toll would be adjusted accordingly. These tolls discouraged through-traffic from being prominent on the canals. Over time, goods that shipped on the canals also had rail transportation as part of their trip as a multimodal solution occurring either before or after their stretch on the canal (Channon 2001). The presence of the canal systems throughout the United States led to an uneasy partnership between the canal systems and railroads with the continuous growth of rail lines. As the development of the rail network progressed price wars began to force the canal systems dependent on freight transport out of business by cutting profit margins (Channon 2001).

1.3 - The Early Railroad

With the development of rail transportation systems, starting in the 1830s, more direct routes could be established as canal routes depended on access to substantial water sources. Over time this led to less utilization of canals when a route could simply be traversed directly by rail transportation lines. Despite this disadvantage many canals including the Erie Canal still play a commercial role today. The initial development of railroads included connecting the major developed areas of the country together and granting access to markets for goods traveling along the rail.

One goal of early rail development was connecting existing transportation infrastructure. Many of the first rail lines ran between different canal systems in the United States. As a result, canals saw an initial growth in utilization to supply these new rail systems for longer distance travel. The growth of rail in the United States was drastic after the establishment of this initial infrastructure. This growth often connected rail routes previously connected by the canal system. In addition, rail companies would purchase canals for the use of their right of ways (Channon 2001). As a result, funding towards these purchased canals dropped and their utilization was forced out in a way by the competitive advantage of the rail systems.

The reality of the canal systems and railroads is that while they were utilized for the transport of people from one location to another, the main method of income generation for these systems was the hauling of freight. The use of heavy rail is still widespread for the transport of goods in the United States today. With the adoption of the automobile and the development of the interstate highway system change has occurred in the usage of rail lines across the United States. Many rail lines that were present during the height of rail usage have fallen out of use and purchased by various entities in the states where they reside. For example many power delivery companies, such as New York State Electric and Gas (NYSEG) have bought up various unutilized rail right-of-ways in an effort to have land available for future power system infrastructure as well as having this land available for other research partnerships and economic development. Rail lines that are still heavily utilized are now owned by private companies, usage of these lines is now restricted to the shipping railcars that are owned by the company and these lines make up the majority of the shipping business by rail that is performed by the United States today.

1.4 - The Rise of the Automobile

The automobile is the dominant transportation modality present in the United States today. This dominance occurred through the gradual but continuous development of roadways since the early 1900s. Originally the automobile served as a leisure vehicle providing transportation from city centers to the country for vacation purposes. With the growth of the population of vehicles on the road the beginning of demands for connecting city centers was established. By 1930 the major city centers were connected by a rudimentary road system that created the possibility of driving cross country in your vehicle, establishing a system to rival the transcontinental railroad of the 1870s (Weiner 1999).

The increase in vehicle traffic and weight, mainly by trucks used for transport of goods highlighted the need for a road system with materials and construction practices that would suit this growing use. This growing usage could be seen as a major point in the shift towards utilizing road systems for freight transport over rail for loads that did not need the benefit of high volume (Weiner 1999). Utilizing the road systems also allowed for direct transit between destinations as the building of new roadways increased. Once again the development of the road system enabled even a wider variety of access to shipping routes while the rail systems were stuck with the issue of limited infrastructure. Despite this disadvantage, the shipping of heavy goods was still primarily performed on rail.

The adoption and development of road systems created a greater need for planning new infrastructure. This contrasted with the methodologies used previously. Canal systems simply followed waterway passages mainly due to high cost of construction of artificial canal ways. Rail systems originally would connect different canal systems for shipping purposes. Road systems could realistically be established anywhere and this adaptability led to a greater need in planning. Planning was particularly important to road systems as it was the state's responsibility to develop the roadways. This often required cooperation between the adjacent states especially when developing roadways to connect between them. With the advances of the roadways, the federal government was able to provide money towards this planning.

1.5 - The Origins of Planning

The ability for states to easily obtain money for planning research came about in 1934 with the first Federal-Aid Highway Act. This act allowed up to 5% of funds apportioned to a state used for transportation studies for future road construction. By 1940 all states were participating in this program (Weiner 1999). This organized effort could be contrasted to the non-standardized effort that existed during the development of the rail systems. This coordinated effort allowed for faster development of infrastructure. This is especially due to the absence of competitive factors between different companies that existed during the development of rail systems such as gauge standardization and competition with monopolies.

Following these studies substantial data had been collected on various road systems based on observational information. In 1944 the first institution was created in order to summarize and optimize the results of all of the studies. The Highway Research Board published its first volume of information that streamlined the information on highway capacity into the Highway Capacity Manual published in 1950. With planning information in one location and generated from studies over the years it gave policy makers and highway officials in each state the power to access and create better decisions and plans for future highway development (Weiner 1999).

In 1950 analytical methods began to analyze the effects that different transportation plans might have on a region. The AASHO Committee on Planning and Design Policies published a benefit-cost analysis to determine where to develop new systems. The main concept from this manual was that there should be profit returned on investments in the cases of highway or transportation developments. The study also identified a value to time in regards to transportation. They found that this measure of time was valued at $1.35 per vehicle per hour or $.75 per person per hour in 1950 (Weiner 1999). If you assume a 4% inflation rate over time we can inflate that value to be about $8 an hour per person in 2012.

Having some value of time based on transportation is beneficial for decision making purposes. This value of time and time as a consideration in transport is present even today in dealing with how individuals will use the transportation systems available to them. The cost often plays a factor in personal decisions on what modality will be utilized for transit. The modeling behind determining what modality will be used by an individual is called Modal Split modeling.

Modal Split modeling is involved in determining which method of transport an individual will take given multiple choices to reach his or her destination. Time is a main factor in this as a long trip time utilizing one method might influence an individual to take another. High traffic in a region may promote an individual to take light rail instead of utilizing highways. These techniques were not widespread put into place until well after the first model of traffic forecasting was developed by Alan Voorhees.

The first widespread analytical technique for travel forecasting was proposed in 1955 by Alan Voorhees in a paper titled "A General Theory of Traffic Movement". Prior to the adaptation of this model, most analysis done for the prediction of traffic flow was based off of a land use model. Land use models based the travel time and the destinations off of the particular area zoning. The development of computers allowed for more technical models to be implemented that could highlight areas of productions and attractions that may direct the flow of individuals (Weiner 1999). Combining these factors with time could then be used to identify which changes to infrastructure would have the greatest benefit for a region. This development in planning allowed for many models to be computed for transportation planning at a much greater rate than that of the land use techniques previously utilized. This benefit of quick and adaptive models is beneficial to the team performing the analysis of future transportation development. It allows for multiple solutions to be investigated at a fast rate, in turn allowing for better final results.

Many of the early planning models and funding were focused on furthering the development of the growing highway and road systems in the United States. As more roads were developed funding began to be directed towards mass transit. In 1964 President Kennedy passed the Urban Mass Transportation Act (Weiner 1999). This act was focused on planning and development funding towards mass transit in order to develop more urban areas more effectively. Unfortunately the funding for this act was not generously given by congress and development of these methods of transport were slowed.

In 1966 an act was passed that created the Department of Transportation. One of the main goals at this time was to coordinate transportation programs and to facilitate the development and improvement of existing systems. Through this act a new, centralized body for developing transportation planning methods was created. The Department of Transportation has sense had a pronounced impact on all transportation developments that have occurred in the United States (Weiner 1999). Its various research arms have ensured up to date and consistent planning procedures have been maintained over time.

One of the major organizations that cooperated with the DOT was the U.S. Census Bureau. In 1969 the first National Personal Transportation Study was performed by the Census. While the census stopped performing the test themselves in 1990, this study has been performed about every seven years and was last performed in 2009. The NPTS enables researchers to analyze the impact of transportation systems on the population. Surveys such are valuable for transportation models as they provides real world data for comparison purposes. These surveys ask individuals various questions about the trips that occurred in their household on a routine basis.

Over time with the aging of our national roadway system much of the funding towards planning was directed towards short term modeling and focused on urban areas instead of looking at larger regions. As the development of roads increased and the national highway system became established, there was a greater need in helping to simplify the traffic flow affecting the city centers. With this planning on a smaller scale, new areas for focus included environmental impact, noise pollution, and major analysis of age of infrastructure. While there is still work in the long range and regional transportation models most improvements are simply made in local areas. This can be due to maintenance costs of existing infrastructure and the lack of technology to dramatically change long range transportation.

1.6 - High Speed Rail

Trains utilized for high speed rail look to efficiently move individuals throughout an area. It is important to realize the specific markets that this method of transit is majorly focusing on. High speed rail found outside the US is mainly utilized for inter-city travel and the structure of the system and layout of the population is often conducive for this particular usage. High speed rail can be seen as targeting a market that is at the limit of what people are willing to drive but under the distances that people would determine it easier to fly. This mode of inter-city travel serves as a popular target for further infrastructure developments as the nature of business has only broadened the distance at which transactions are being made and meetings are being held.

Two major examples of high speed rail development outside of the United States include the efforts present in China as well as France. In France, the TGV is a maglev technology based system that has been in operation since the first line was completed in 1981. Despite widespread usage in the world as a primary method of transit the adoption of HSR in the United States has been minimal. The only high speed rail system currently in use within the United States is located between Boston and Washington D.C. and run by Amtrak. This Amtrak line specializes on running express trains to different destinations on the route including NYC. The location of this particular rail corridor helped to justify its development as it serves major cities along the eastern coast of the United States. Even while running as an express line between the different cities the speeds that the train ascertains on average reach around 75 mph for the duration of the trip.

One of the reasons for the slower travel speeds in the United States versus high speed rail lines present in other countries highlights one of the disadvantages the United States has in adopting traditional high speed rail systems. The grade crossings and present infrastructure puts the development and implementation of the high speed rail lines in the United States at a disadvantage. Still there is increasing support from legislature to implement high speed rail in the United States. Development of new lines often would require the purchase of new land and development of these new right-of-ways which would have to be secured before any building takes place.

Another issue that is present in the United States related to high speed rail lines on existing rail infrastructure is the ownership of the current infrastructure. Many freight line companies own the railways that are in consideration for high speed rail systems. The profit margins that exist for freight transport are much greater than that of moving passengers and introducing passenger lines on the freight line systems would greatly slow the freight routes. This conflict results in fright line owners not allowing passenger rail on their lines. Even if right-of-way purchase is not needed, say in the case of upgrading an existing line to higher speeds, grade crossing issues come up as slower traditional rail and high speed rail will have different requirements for turns and grades relating to the g-forces or comfort of the passengers. One technology that has been utilized to help address this issue is leaning-cars for these high speed trains, while this can alleviate some issues it is not a complete solution, more of a patch to help decrease costs in comparison with building a new line.

Many of these issues have hindered the development of high speed rail in comparison to other countries. In contrast, the United States has devoted a large amount of its infrastructure development into the construction of a complex road network. Some of this reasoning comes from history while public policy has also been a driving force towards the adoption of roadways as our main transportation modality.

1.7 - Light Rail Systems

The development of light rail was mainly focused on the issues of urban transportation problems. Their development highlights the benefits of lower cost transport (comparing to car transportation) while allowing for the efficient movement of large quantities of people. The population breakdown of the United States has large urban centers with much of the land dedicated to suburbia. This is particularly conducive to the development of light rail systems as a transit method from outlying areas to the city centers for employment, commerce, and entertainment purposes.

The major benefit of utilizing a light rail system for city transit is the increase in volume of passengers versus the development of additional road infrastructure. Speed is not seen as a benefit here as speeds typically remain the same or slightly slower than using road transit to reach your destination. Right of ways for light rail systems often follows alongside traditional road systems. Light rail's size commonly equals that of a traditional lane in a highway right of way. Another common solution for developing a light rail system is to have a dedicated right of way for the system at the cost of purchasing the land rights. One of the major deterrents towards the adoption of high speed rail in the United States is based on historical policy. The promotion of road and the international highway system of the Eisenhower Presidency set a precedent for widespread use of roadways as the prominent form of transit in the United States.

Another major factor that deters the adoption of light rail systems in the United States is a social factor. This is in part due to the adoption of the automobile as the major transportation method for the nation. Individuals would often rather get into their own car and drive versus utilize some other form of transit during their daily commute. Utilizing their own automobile gives them the freedom to set their own schedule in transit as well as the safety factor of not sharing a vehicle with others (Schrag 2006). This factor of security is also a major deterrent of the utilization of mass transit in general. These beliefs however only add to more congestion on the roadways which can lead to a major increase in travel speed if enough individuals instead utilized light rail for their transit needs within a city.

This lack of adoption of light rail in the United States is unfortunate due to the breakdown of the population living in the country. The United States is broken up into many small city centers with high population zones with abundant suburban areas. This breakdown lends itself well to light transit systems which could be implemented from the city centers out towards suburbia therefore placing less of a dependence on city road systems and greater throughput of individuals into and out of a city. Some of the major light rail systems that do exist in the United States include New York's subway system, Boston's T system, the Washington D.C. Metro, San Francisco's Bay Area Transit Authority, and Atlanta's MARTA.

1.8 - Future Transportation Developments

With the introduction of new technologies, new methodologies of transit will be developed to improve or target new development of transportation systems. Work in recent past has identified a market in which a new methodology could be implemented. The SATS program worked on and developed by NASA in the end of the 20^{th} century worked to develop a methodology for personal transport that targeted a market area not seen before while taking into consideration the personal benefits of the automobile and the long range usability of airline travel. The main benefits of this type of a system was defined as having a transit system that is highlighted by on-demand, widely distributed, point to point air mobility (Holmes and Durham 2004).

One of the benefits to this point to point infrastructure is the increasing market share of rapid transit over time. Personal travel budgets globally on average hover around 1 hour a day. By increasing the speed at which you are able to travel you greatly increase the accessibility for both employers and employees (Holmes and Durham 2004). At the speeds of car transportation you can average about a 50 mile travel radius in a day for transportation following this average. Development in SATS can see this travel radius increase to around 500 miles in a day, an increase overall as a factor of 10 (Holmes and Durham 2004). By targeting an area of under 1500 nautical miles the SATS program looks to position itself to provide high speed transit between the ranges accessible by traditional hub and spoke airline systems and getting in a car and driving to your destination.

Average door to door speed is a factor often considered when looking at different transportation choices. While airliners fly at speeds of 400 nautical miles per hour, the average speed door to door is often only 75 nautical miles per hour. Trips utilizing the hub and spoke airline network perform better however at longer ranges of around 1500 nautical miles (Holmes and Durham 2004).

The major economic goal of SATS is to help further develop and utilize the almost 5,000 public use airports currently in small towns and communities within the United States. Having an air taxi system like one proposed by the SATS program could help to connect over 90% of Americans that live within 30 minutes of these small public use airports. Utilizing this air taxi system would reduce congestion on hub and spoke airline and provide an alternative method to reduce demand on other transit infrastructure. Enhanced mobility leads to industry developments, the creation of jobs, and the ability to have access to a much greater population of people to reach for employment.

1.9 - Conclusion

Technology is continuously developed that has the potential to target the same regions as was planned by the SATS program. The utilization of a system fulfilling this need could ensure a reduction in demand on the current transportation infrastructure, an increase in mobility for any region influenced, and a step towards a more multi-modal system overall in the United States. The economic impact of a system such as this could help to encourage a major economic boost to a region.

The motivations for the development of transportation systems can be narrowed down to two key concepts, increasing mobility and providing an economic benefit. It would be foolish to say that these two concepts are not related. Both of these goals in a sense go hand in hand. By increasing one of the factors the other will also increase. Mobility affects quality of life for individuals every day. Low mobility can leave individuals without access to employment, adequate healthcare, and other essential necessities and adversely affect the economy of an area. The economic benefit that comes from an efficient multimodal transportation network is more than access to jobs. An efficient transportation system promotes development of new business in an area. Increased mobility for the businesses and increased market of potential employees can be a driving factor for a business opening a location in an area. Enhanced mobility could enable a company to bring workers in from other areas to work on a daily basis if this mobility could be provided affordably and made accessible to the workers.

Transportation improvements that have been made in the past started with a large focus on planning and researching the area of improvement. Being able to evaluate the benefit of a transportation system improvement or the introduction of a new line is a necessary process in every decision made revolving around transportation. Here we will look to see the analysis performed on transportation infrastructure improvements in the past. This analysis can stem from basic surveys to complex models in order to supplement and reinforce proposed systems stemming from new technology improvements. Through this a new efficient and rapid system for analysis can be proposed to evaluate the effects of travel time and the economic development that results throughout a region.

2 - Transportation Modeling

2.1 - Introduction

Transportation planning to model the effects of system improvements began with simple rules of thumb and evolved to the complex computer simulations that are only possible today. Throughout history, techniques were shared between different states and local governments in order to help facilitate the creation of the transportation network that connects our nation's cities. Tools such as surveys have been present since the beginning of transportation planning and will continue to be a key component in decision making in the future. The use of modeling techniques in planning began in the 1950s and has only become more complex and more widely used with the increasing power of computers today. In addition newer tools such as geographic information systems (GIS) help to analyze the spatial nature of transportation. It is a combination of many tools that account for the planning being performed in the United States today.

2.2 - Surveys

Travel surveys have been utilized as a data collection method to support models and transportation infrastructure decisions since the start of transportation planning. These surveys have evolved over time focusing on different aspects of transportation and on different pools of transportation related questions. Starting with the Federal Aid Highway Act of 1934, states began to utilize studies in order to determine the best methods for pursuing future transportation improvements. Initial activities in mapping transportation systems included taking inventory of the extent of the transportation network present in a state or nationally (Weiner 1999).

Roadway or mass transit studies not only consist of interviewing individuals about their use of the systems but also take into account the infrastructure essential for the transit to occur. There is a wide variety of data often collected from this type of survey. Surveys are performed through looking at a subset of the infrastructure or individuals present in an area. It would prove far too costly and time consuming to perform a complete survey so sampled data is used and estimates for a region are extrapolated (Wright and Ashford 1989).

Volume counts of traffic are often calculated at key locations throughout an urban area. Through these surveys, planners have a general picture of how traffic is moving. Travel time surveys are often performed by observing the average speed of the vehicle over the course of time at various locations in the system. These surveys are also performed at varying times of day to have a picture of both high and low traffic periods. Mass transit systems, such as buses or light rail, can have additional data recorded including delay times, service frequency reviews, route coverage and inventory, as well as passenger feedback in addition to the volume data collected. (Wright and Ashford 1989).

General public surveys often take place in the form of interviews based on two general categories. The first type is origin-destination studies. These studies are considered the most time consuming and costly of studies performed today. They look at the characteristic information of the households and individuals doing the traveling as well routine trips made by the individuals in the household over the course of the day (Wright and Ashford 1989). The Federal Highway Act of 1962 mandated that transportation studies would be performed for areas with a population greater than 50,000 (Weiner 1999). The other type of transportation study can be considered an attitude survey. An attitude survey is performed to evaluate the public's view on the transportation infrastructure present. Some tools utilized in this type of survey include focus groups on the issue, rating panels, and Delphi panels (Wright and Ashford 1989).

With a shift in focus towards shorter range planning after the development of the interstate highway system, surveys shifted to look at issues important to communities. These issues include noise, pollution, and environmental impact. The investigation into these factors began with the Clean Air Act of 1963. Through this act and those following it, planners now are able to look at data reflecting noise or environmental concerns such as drainage and water reclamation that could be taking place in an area and see what kind of an impact transportation changes may have on the local environment (Weiner 1999).

One of the main goals of a survey can be to help determine the effect of congestion on an area. Congestion data can be used to analyze travel behavior as well as assist in building models looking at a wide variety of spatial and time characteristics related to transportation planning. Many of the surveys performed for various state and local entities are carried out through third party companies. Over time the Department of Transportation utilized many different entities to perform its surveys. One of the first external agencies to help with performing surveys was the Census Bureau when it performed the Nationwide Personal Transportation Survey in 1969.

The personal transportation survey, now called the National Household Travel Survey was designed to assist transportation planners with transportation patterns present in the United States. Some of the factors that this survey looks at include the purpose of a trip, means of transportation, travel time, and time of day. The latest version of the survey was performed in 2009 by the Oak Ridge National Laboratory's Center for Transportation Analysis. Utilizing these outside agencies helps to lower costs for the Department of Transportation and ensure efficient and effective data collection (Department of Transportation 2011).

While the data collected through surveys was initially the sole reasoning behind policy regarding infrastructure, today it serves an even greater role. Many of the computational models used today utilize surveys as a confirmation for models that are developed. Results obtained from a computational model can now be compared against the data gathered from surveys. This allows the model to be calibrated with the existing infrastructure, and then adapted by proposing changes to the area and finding what effect those changes might have. This survey data remains essential to the confirmation of analytical models utilized in transportation planning today.

2.3 - Analytical Models

The establishment of the Highway Research Board had a dramatic effect on the work that was done for surveys and the ability for the knowledge to be disseminated to state level planning committees. Analytical methods became more common and advanced dramatically in the 1950s. During this time the first look into the relationship between transportation and land use was performed at Columbia University (Weiner).

The premise of land use modeling was to find a relationship between what was present in an area and the types of traffic that would be generated in that area (Voorhees 1956). These studies helped pave the way for early analytical planning techniques and led to the first major breakthroughs in these analytical methods. Early models took known mathematical rules and made alterations to them in order to help predict different factors related to transportation usage. One of the first models for predicting movement of individuals was developed by Alan Voorhees.

In 1955, Alan Voorhees published a paper titled "A General Theory of Traffic Movement". In his paper, Voorhees introduced a modified gravity model to link land use to urban traffic flow. He was able to do this utilizing the substantial amount of origin and destination data that had been provided for years through traffic planning surveys.

The general formulation for the model is shown in Figure 1. In this equation, i and j can be considered the current area and area of interest respectively. P indicates productions in the model, while A is considered attractions. Time is expressed in the model through the friction factor F. F is expressed for travel between any areas with productions to areas of attractions. K is a calibration factor that is altered to ensure the model fits survey results present from the region. This process is performed in order to match the trip generation prediction to the empirical data for an area (Voorhees 1956).

Viewing Figure 2 we can see how the model would be set up and initiallized. The model is set up in the structure of a network. Nodes in this network represent a spacial

$$T_{ij} = \frac{P_i x\ A_j\ x\ F_{ij} x K_{ij}}{\sum_{j=1}^{n} (A_j x F_{ij} x K_{ij})}$$

Figure 1 – Formulation of Voorhees' early gravity model for trip generation.

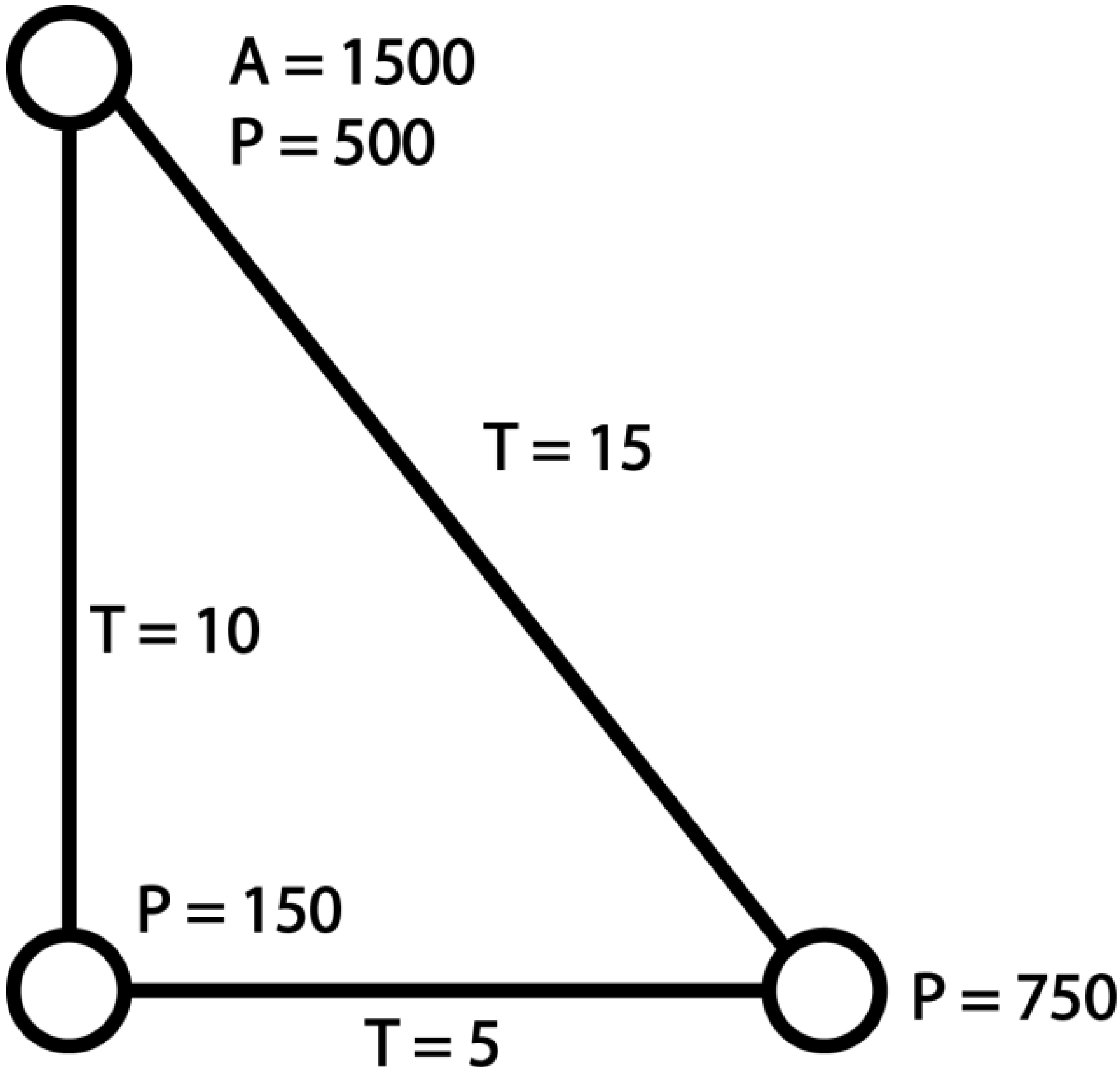

Figure 2 – A trivial example of the formation and assignment of parameters for the gravity model for trip generation

component on a map. This could be a metropolitan area (if running this model for inter-city travel) or a city block (for intra-city travel). The nodes have two characteristics in this model. The first is defined by A in the figure, these are attractions to this node. This can be thought of as the number of jobs present in the area. The second characteristic, defined by P, are productions. Productions can be considered the population at this node or the amount of people that are looking for attractions present in this node. The edges that connect the nodes together also have a time characteristic attached to them. This time can be considered as the travel time between the nodes taking into consideration the modality of travel that is being utilized. When studies are being performed in order to determine impacts of new infrastructure, a new line can be placed in the model with its approprate travel time. By running the model you will have a measure of the utilization of the new line and the impact on the utilization of the other lines in the system.

One of the major benefits for this type of model was that it was not dependent on the land use characteristics of the area. The model can be utilized for various different types of trips that could occur across an area. For example this model was often utilized for work and home trips and then later defined for shopping to home or other combinations. Home was often used as a destination or starting point as it was found that around 40% of trips would involve home as a destination or source (Voorhees 1956). Once a model is designed, survey data is then utilized to set the parameters for the model. These parameters are adjusted until they sufficiently match with the data collected from the area (Wright and Ashford 1989).

The ability to have an analytical model was very beneficial to transportation planning at the time as it enabled dynamic evaluation of different transportation improvements. This allowed policymakers to make informed decisions on the investments upon infrastructure. In addition to these analytical methods a large amount of survey data was collected to correlate with these models and as seen in Voorhees model this data was often necessary to calibrate a model to an area (Voorhees 1956).

Many different models were developed over time to analyze every aspect of transportation. The models developed generally fell into three classes. These classes were models of trip generation, modal split, and traffic assignment. Each of these models answered a different question about the transportation that is occurring throughout a region. Voorhees' early model fell under the category of a trip generation model. These models simply looked to see where a trip may be coming from, where it would be going, and when the trip may occur. Trip generation analysis looked to relate land use, travel, and the socioeconomic characteristics of an area. Looking at the land use factor of an area can help to predict the amount of trips that are occurring from that area.

2.4 - Trip Generation

The three factors that most heavily impact trip generation in land use are the intensity, character, and location of the activities taking place in an area (Wright and Ashford 1989). Intensity could be defined as the amount of people living or working within a given area. Character of the area could look at more socioeconomic characteristics of the people living within that area such as income or average family size. Location can become important as it relates how close the study is to other relatively high populated locations.

Trips generally fall into only a few different categories. The largest category can be considered trips going to or from work. Other categories could be personal business trips, trips to school, social trips, recreational, shopping, or others. Multiple use trips have only recently been analyzed as a special case. Early models did not look into this possibility which left calibration of models often difficult. With the majority of trips either starting or ending at home however, many models and initial planning looks at this data as a good rule of thumb for calculating the trip generation for a region (Voorhees 1956).

2.5 - Modal Split

Modal split is a technique used by researchers to look at what modality people will take for transit and what kind of occupancy will be occurring. This is most often utilized after a trip generation model. Once the trips are generated the modal split model will predict what proportion of the trips will occur upon rail, road, or other modalities. Many of the factors that look at what mode will be taken for a trip is those looked at by the trip generation models themselves.

Important factors going into modal split can be the type of trip an individual is making. This can relate to the trip's purpose or even the time of day the trip is occurring. The second factor going into modal split can be the characteristics of the trip maker themselves. This could factor into personal issues such as income or if they have a car as well as environmental issues such as the weather or population density of an area. The final factor that can be looked at is the service provided by the transportation system as a whole. Regardless of the other factors a system that does not have a high benefit to cost ratio will probably not be utilized by the individual making the trip (Wright and Ashford 1989).

Diversion in transportation models is simply a measure of how people will take one modality over another for their transportation decisions. Generally, trip diversion is decided upon by the shortest route from an individual's location to their destination in terms of time. Exceptions to this can often be made as some individuals may prefer to take a route that is less congested, say for example highways instead of local roads even if this distance is a little shorter (Wright and Ashford 1989). Once the modality being utilized has been predicted, often there has to be a measure of what traffic will be present on different portions of the transportation system. Traffic assignment looks at this issue in order to finally complete the picture of transportation developed by the models.

2.6 - Traffic Assignment

Traffic assignment takes the information regarding modalities and trips generated and assigns this traffic on the different transportation facilities. There are various techniques that are utilized in order to help place the information on the various transportation systems. The flow of passengers from one area to another likens itself to a network model. You can see a typical layout of this network model represented as the roadways across a small city in Figure 3. Traffic assignment often looks to find the shortest path in terms of time that occurs between the two points on the network model. One of the most simplistic models for traffic assignment is often referred to as all or nothing assignment. In this form of assignment shortest paths across a network from the trips starting location to end point are calculated. The path that has the shortest time or

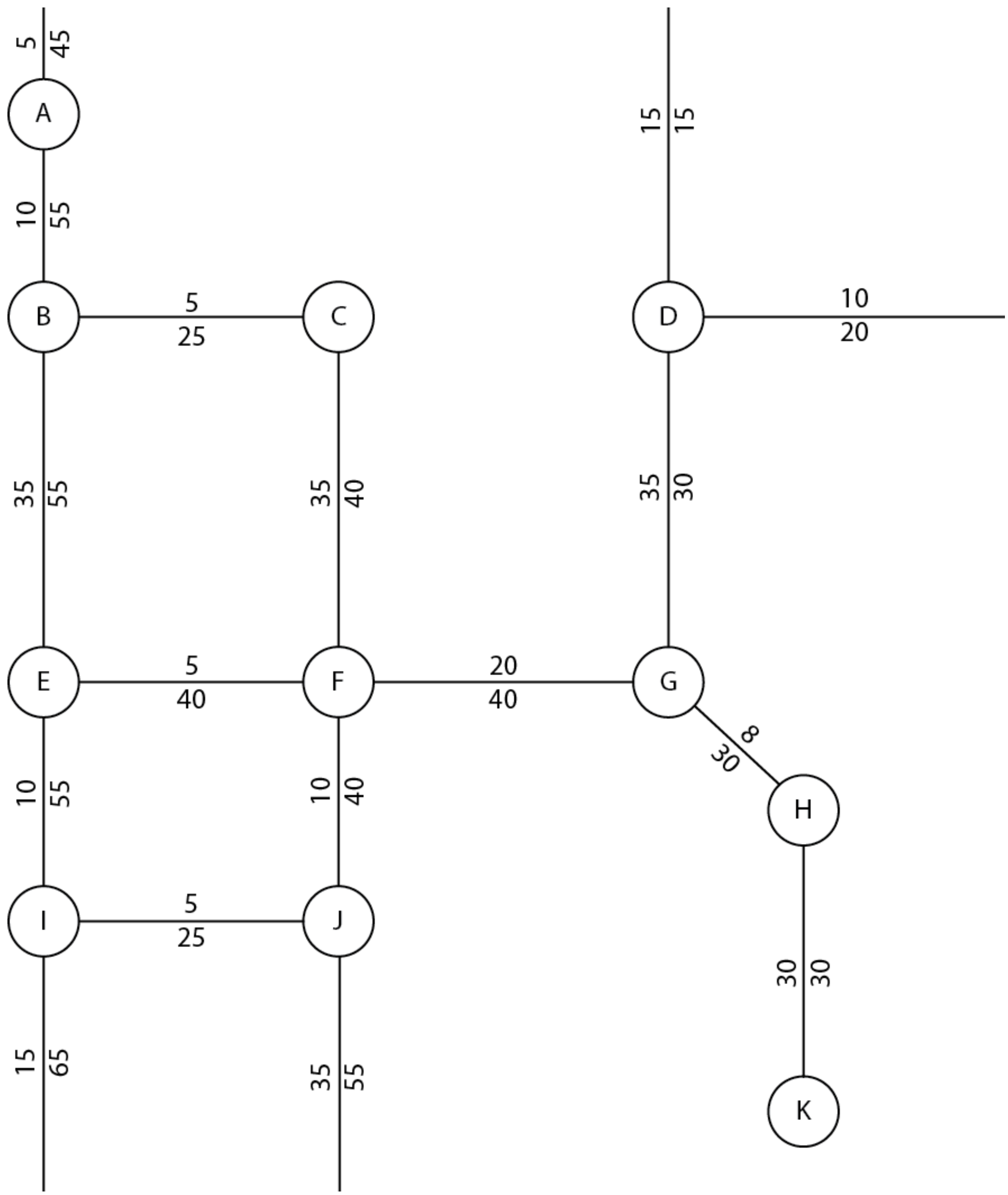

Figure 3 – Basic layout of a traffic assignment model applied to a city network.

cost is selected and all trips flow through that path. While this model can seem ideal it is often not the case in actual practice where individuals may take different paths for different reasons depending on where they are going. Diversion assignment looks to allow for multiple paths to different routes in the same sense as how diversion is calculated for modal split. There may be various factors leading into the decision on which path to take, this calculation often creates more realistic traffic assignment across a region (Wright and Ashford 1989).

In the early days of transportation planning all of these models and their work often had to be calculated on large mainframes due to the computational complexity involved. Over time with the development of more powerful computers, individual planning boards were able to run many of these simulations right in their offices. This enabled planners to become more efficient and gave them much greater tools to undertake planning studies and model the costs and benefits of their potential transportation improvements (Wright and Ashford 1989).

2.7 – The TRANUS Land Use Model

Models commonly in use today for transportation planning are designed for ease of use and the ability to run in a timely fashion. Many of the models take the three different stages of transportation modeling and combine them together in order to make a more seamless experience for the end user. These models often utilize a vast amount of data for making their calculations and can often be more specific than simply generating trips and assigning them on the region. They often look at how individuals move or how a region's economy may be affected.

The TRANUS model, developed at the Universidad Central de Venezuela utilizes a decision tree approach to the transportation planning issue to predict the impact of infrastructure changes. While utilizing a decision tree, the choices being made by individuals in the model is done through a random utility approach. Here different decisions that could be made by an individual in the simulation, say which methodology to take for transit or where to travel to work is ranked by a utility value. The highest utility or benefit to the individual is then selected and is pursued through the simulation. The elements of this model include the locations of activities, location of floor space, the property market, and the transportation system (T I deBarra 1984). The procedure calculates characteristics of the land use initially. These characteristics include the location of activities, availability of space, and the activity location. Once the land use factors are calculated and their cost identified the method of transport can be evaluated for an individual.

This process goes through the typical structure of trip generation, modal split, and traffic assignment to end with travel costs which can then be compared and the optimum route selected by the individual in the simulation (T I deBarra 1984). A major benefit of this particular model for transportation planning is the utilization of the decision tree structure which simplifies the computational cost of the model. TRANUS would often be utilized in a Monte Carlo technique due to the stochastic nature of the model's highest utility generation in order to provide estimates towards changes in the regional infrastructure.

2.8 - Geographic Information Systems

Through the use of modeling techniques analysis of the spatial nature of land use and transportation planning is performed. The connection between transportation planning and geography is present throughout the usage of all the models we have discussed so far. While geography concepts were utilized in the models, the visualization of this geography was often not very clear. The development of the Geographic Information System (GIS) has helped to create more detailed and informative displays of the information that was historically generated. This tool creates a visualization of the data for an individual to share or analyze, creating more information about the particular location and how that location may be impacted by different decisions.

The development of computer-based GIS has been ongoing since the late 1960s. It was soon after the development of the first computer based models for transportation planning that this tool became further developed. Research into the usage of GIS was primarily focused in the United States in this time and the United States is known for its large contribution towards GIS over the course of its history. Part of the reasoning behind this large contribution can be due to the prominence of funding and research into the field by the US Census Bureau, the US Geological Survey, and the Harvard Laboratory for Computer Graphics Experimental Cartography Unit. The ability to project data from multiple sources onto a map for visualization purposes proved to be a valuable tool for all of these institutions at a time when most cartography was being done by hand.

A strict definition that can help to identify GIS is that it is considered a "computer-based system for analyzing spatial referenced data" (J.T. Coppock 1991). A more wide reaching definition could be that GIS "is any system for handling geographical data" (J.T. Coppock 1991). With the vast amount of data that organizations like the census and geological survey deal with, companies worked to evolve the tools that were consistently being utilized in GIS applications. The Environmental Systems Research Institute (ESRI) was one of the early pioneers of the tools and is currently one of the largest GIS advocates today. Their software ArcGIS is one of the most commonly used tools in GIS research. The development of the technology in the 1950s with computing power helped to produce the GIS tools that we have today. It is very interesting to note that one of the earliest uses of computerized GIS in the United States can be traced back to the University of Washington in the 1950s. Here both geographers and transportation engineers were using GIS to help develop their transportation planning methods (J.T. Coppock 1991).

Data that is utilized in GIS applications can be any information that has a spatial component to it. GIS is used across a wide variety of fields due to its ability to visualize information in an easily decipherable way. Looking at data in its raw form can often lead to difficulty in drawing conclusions compared to visualizing data in a spatial sense. GIS is used in everything from transportation planning to crime modeling and visualization, city planning, biological surveys, and more. One of the major data sources for GIS is the US Geological Survey. The geological survey is often involved in looking at the geography of the United States but it also looks at geology, biology, and hydrology information.

2.9 - Conclusions

The methodologies utilized in the past are still often found in the new models developed today. Transportation planning has become a necessary step in the decision making process that occurs on both a local and nation level. The introduction of new technologies can have the impact of generating faster models at a lower cost. While the government mandates thorough surveys for cities with population of greater than fifty-thousand, techniques that can be deployed on areas with a lower population limit with less access to surveys could be very beneficial. Developing a methodology towards utilizing low cost data sources will provide planners with alternative methods for quick initial evaluation of proposed transportation improvements.

3 - Utilizing the Census and GIS for Transportation Analysis

Planning plays a critical role in the evaluation of transportation system improvements. Utilizing traditional planning methodologies, surveys are required for the analysis. The use of surveys comes at a high cost both in terms of monetary cost for the execution of the survey and time due to planning and response processing. Utilizing Census data can provide an alternative method to the evaluation of spatial patterns present in a region. This alternative can come at a lower cost with a higher speed of development.

In selecting areas for performing a study on transportation improvements, it is important to identify regions where improvements have occurred after the 1950s. The reasoning behind this restriction is twofold. First, census data is often not completely reported prior to the 1960 census for all areas in the United States. Secondly, targeting a system developed after the establishment of the Interstate Highway System by the Eisenhower administration can help ensure that developments from that infrastructure project are not compounding to skew the analysis.

3.1 - Census Data Sources

The U.S. Census Bureau provided the majority of data for the study. The Decennial Census as well as the American Community Survey both played a major role in analyzing the trends present in transportation developments. The Decennial Census is taken nationally in the United States every 10 years. This data includes information on populations and one of its primary purposes is providing redistricting for congress. In addition to the Decennial Census, the American Community Survey performs samples of the population every year. This program started in 2005. Prior to 2005, this more detailed information was sampled from a population on the Decennial Census. The American Community Survey looks at employment, housing factors, poverty levels, and more. Due to its yearly nature, planners now have access to updated information consistently without having to wait for a Decennial Census to occur.

Census data can be gathered at various levels of geography, as seen in Figure 4. Geographically, the Census Tract geography has been utilized throughout the study for many reasons. Spatially, the census tract does not change very much from Census to Census in terms of location. Census tracts are sometimes split over time as population increases. In some portions of the study, tracts are normalized by population. If new tracks were created by the Census, in order to make an equal comparison the tracts that had the lowest population were merged with neighboring tracts. This was performed by merging the low population tract with the lower of the two adjacent tracts. This was repeated until there were a common number of tracts for all years in the analysis.

In addition to the current data provided by the Census Bureau, the National Historic Geographic Information System holds historical data on every census performed in the United States. This organization is run by the Minnesota Population Center at the University of Minnesota through funding by the National Science Foundation and the National Institute of Health. The products available at this site allow for analysis to be

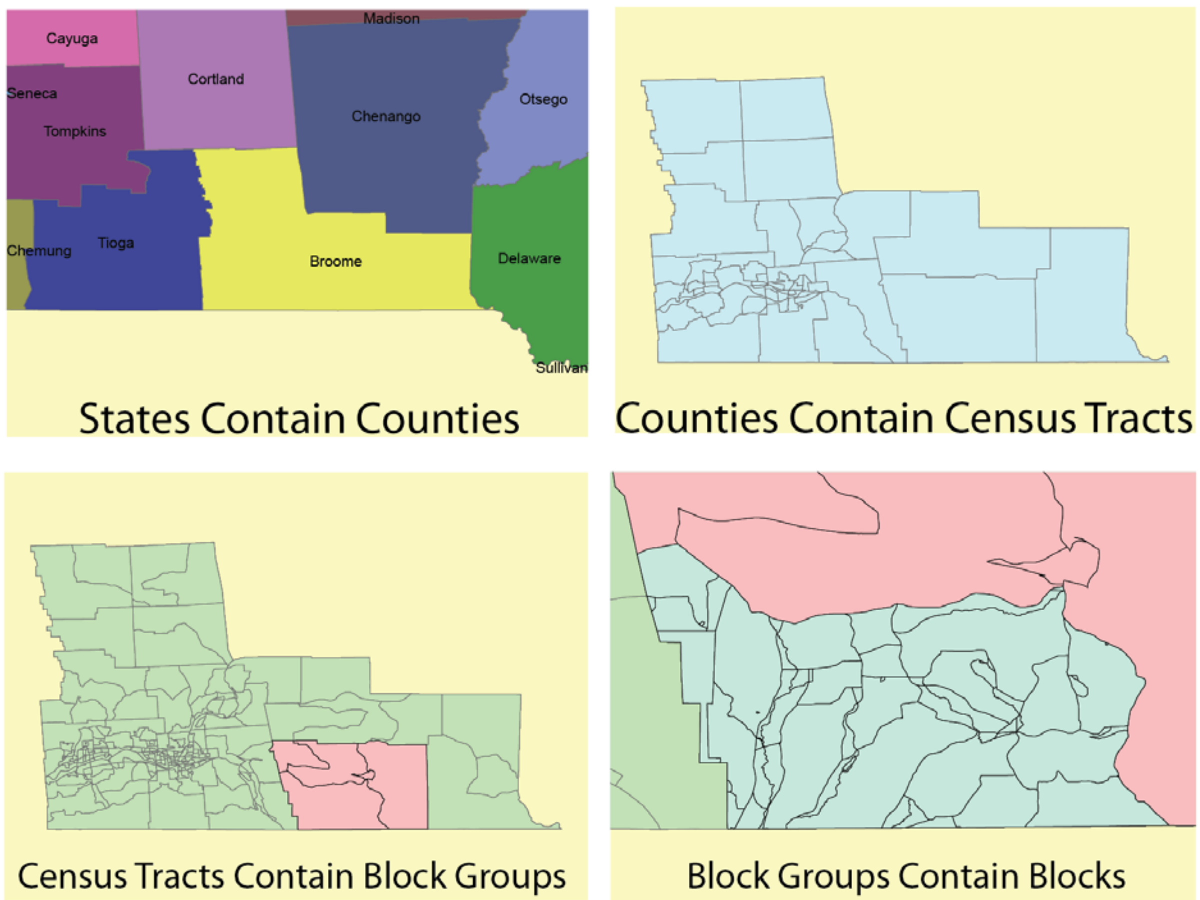

Figure 4 – Illustration of Census Geographies from County to Block level

done on Census data that is older than 2000. This was the source utilized for all data older than the year 2000.

3.2 - Investigation Study Areas

3.2.1 – Washington D C Metro

The Washington D.C. Metro has the distinction of being one of the largest systems in the United States today as well as one of the safest. The Metro serves as a great example of how difficult the development of a transportation system can be when you have to develop infrastructure on top of and around existing developed land. Advanced techniques in cut and cover development and careful planning were present throughout the development of the D.C. Metro.

For the first part of the study two sections of the Metro system were targeted for data analysis. You can see in Figure 5 the Orange Line that was targeted as well as the "Control" Line that was made in an attempt to avoid the rail system as much as possible and serve as a comparison. Data was provided through the US Census Bureau's Decennial Census every ten years from 1980 to 2000. The information that was gathered for the region included the population over time as well as the Housing Units present in the region. The Census Tract areas of interest recorded were made by identifying census tracts that the Orange Line and Control Line passed through. These tracks were then hand ordered based on distance from the center of the transit system, which for this study was situated at the Metro Center station near the national mall. Once the data has been sorted by geographic position, the analysis involves comparing the data for one census to

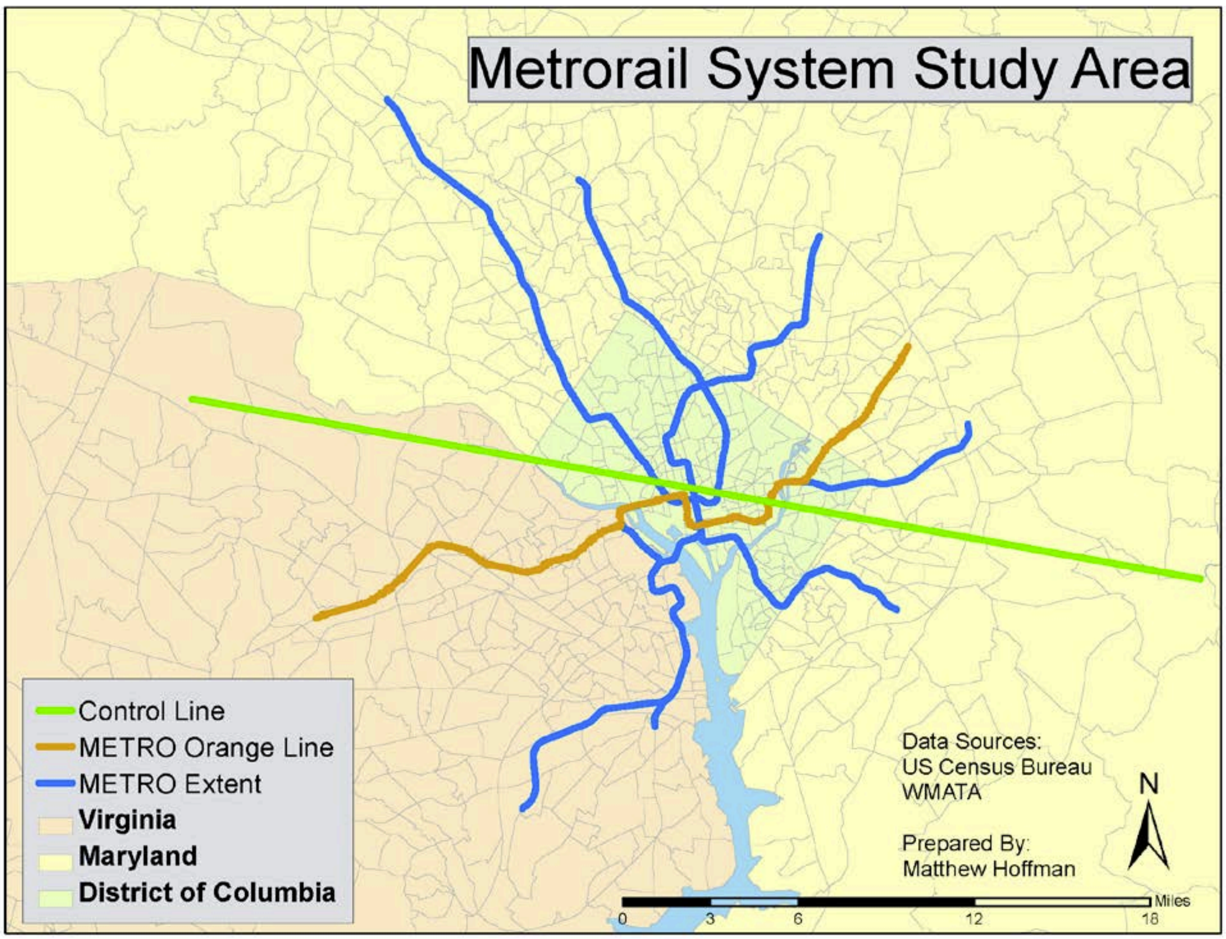

Figure 5 – Washington D.C. Metro study area

another. The data from simply looking at the route of a transportation line through the Capital Region can then be contrasted against looking at the region as a whole.

Despite the many positive sides to looking at the D.C. Metro system, there are a few issues regarding its use in this type of analysis. One of the main issues is the prevalence of the I-95 Capital Beltway that encloses the District of Columbia. The Capital Beltway is present at a range of around 10 miles from the center of the District of Columbia. The fact that this large and well utilized highway system is present in the area could be a confounding factor when performing comparisons with the rail system. Another issue is its location with regards to the waterways that are present around the area. The waterways influence the usable land as well as limit the movement of individuals to more heavily trafficked routes. While the two study lines were selected to minimize the effect of the waterways it is important to realize the effect that it may have on the results.

3.2.2 - The Long Island Rail Road

The Long Island Rail Road has been operating since the early 1800s and is the highest utilized commuter rail system in the United States today. This region proves to be an excellent area to study for a variety of reasons. The natural borders of the ocean, as seen in Figure 6 allow for a simple analysis to be performed, the area is relatively the same shape and size across the entire route of the LIRR. The age of the system provides a different situation than that of the D.C. Metro as the LIRR was an existing system that received an infrastructure improvement in the 1980s.

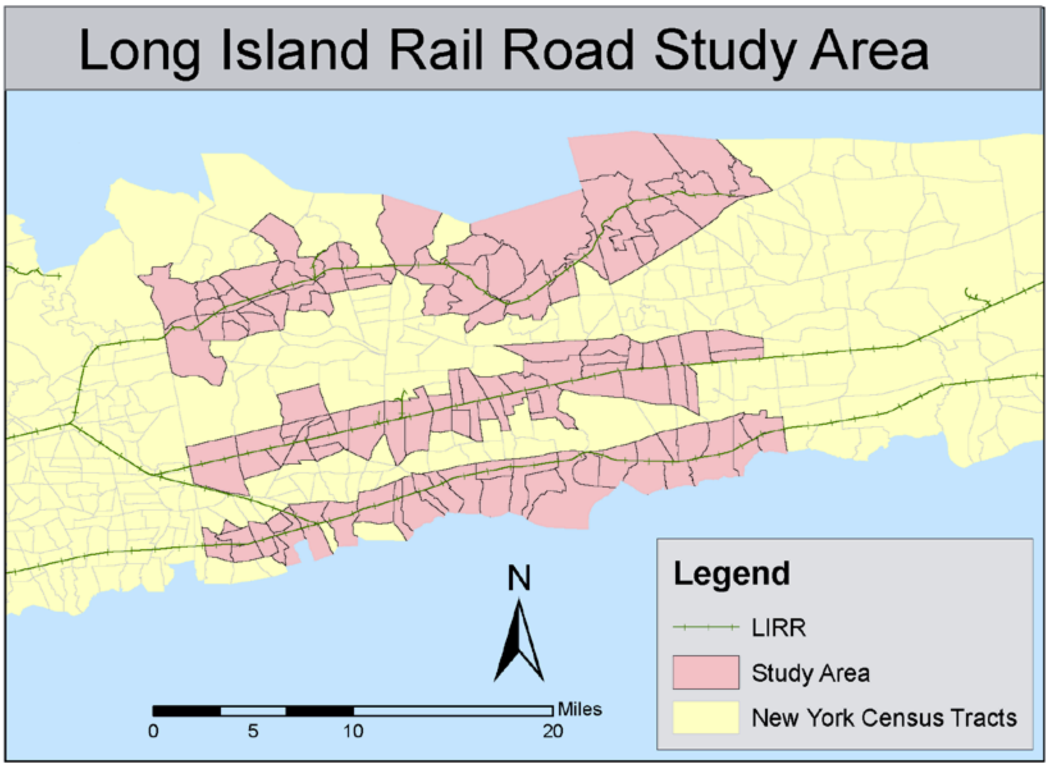

Figure 6 – Long Island Rail Road study area

The improvement that occurred on the LIRR was the electrification of the Middle Island Line out to Ronkonkoma which was opened in 1988. With the electrification of the central line, travel time into NYC decreased by an hour on average in comparison to the Northern and Southern lines. The development of this central line to Ronkonkoma has been seen as important to the transit in the area as routes more east along the Middle Island Line have seen much lower utilization in comparison to the Ronkonkoma station.

For this analysis Suffolk County was identified as the particular area of interest. This was to focus the analysis at the effect of the electrified line and the region of people surrounding it. Ronkonkoma is located on Long Island at a distance of about forty miles from New York City. Around this region, there has been greater development since the 1980s in part due to the electrification of the Middle Island Line and its increased mobility. For this portion of the analysis the three main stretches of the LIRR are identified across Suffolk County. The Northern, Middle Island, and Southern Line study zone is selected in much of the same way as the analysis was performed on the D.C. Metro system. Census tracts that have the rail line running through them and neighboring tracks are selected for the area of study. Some manual editing is then performed to ensure that no census tracts selected between the different lines are adjacent to each other. The data is then gathered from the Western side of Suffolk County to the Eastern portion where the upper line ends to ensure equal area for comparison between the routes.

3.3 – The Distribution of Travel Time

Travel time plays a huge factor into where individuals live. Accessibility to work, shopping, and entertainment are all based on efficient mobility. We know in the United

States that average travel time to work hovers around 30 minutes one way. While this average is commonly reported the actual distribution of travel time to work is much more difficult to find. Through calculating this distribution the knowledge of just how far people are willing to live from work can be established.

The IPUMS database or the Integrated Public Use Microdata Series developed by the Minnesota Population Center consists of samples from federal censuses as well as the American Community Survey at an individual level. The idea behind this is that individual's responses to the census can be obtained and while filtered to prevent disclosing an individual's information, this data can be used for analysis. For this study the American Community Survey of 2010's five year estimate was utilized in order to obtain a 5% sample of the ACS' response to travel time to work for individuals. This data, after filtering for missing data contained around 6.5 million answers to the question of what is your travel time to work. A histogram was generated from this data utilizing SPSS due to the large sample size and can be seen in Figure 7.

The distribution shows some interesting characteristics related to transportation time to work. While the average travel time is well expressed near the 30 minute mark, looking at longer travel times shows some interesting data. The last real peak in travel time occurs at around 90 minutes away. After this point very few individuals are traveling a longer amount of time to work. As speeds increase with transportation technology, transportation time decreases allowing individuals to have greater access to employment. Targeting a region between 30 and 60 minutes from work could be considered the maximum range individuals would travel for employment. Planners

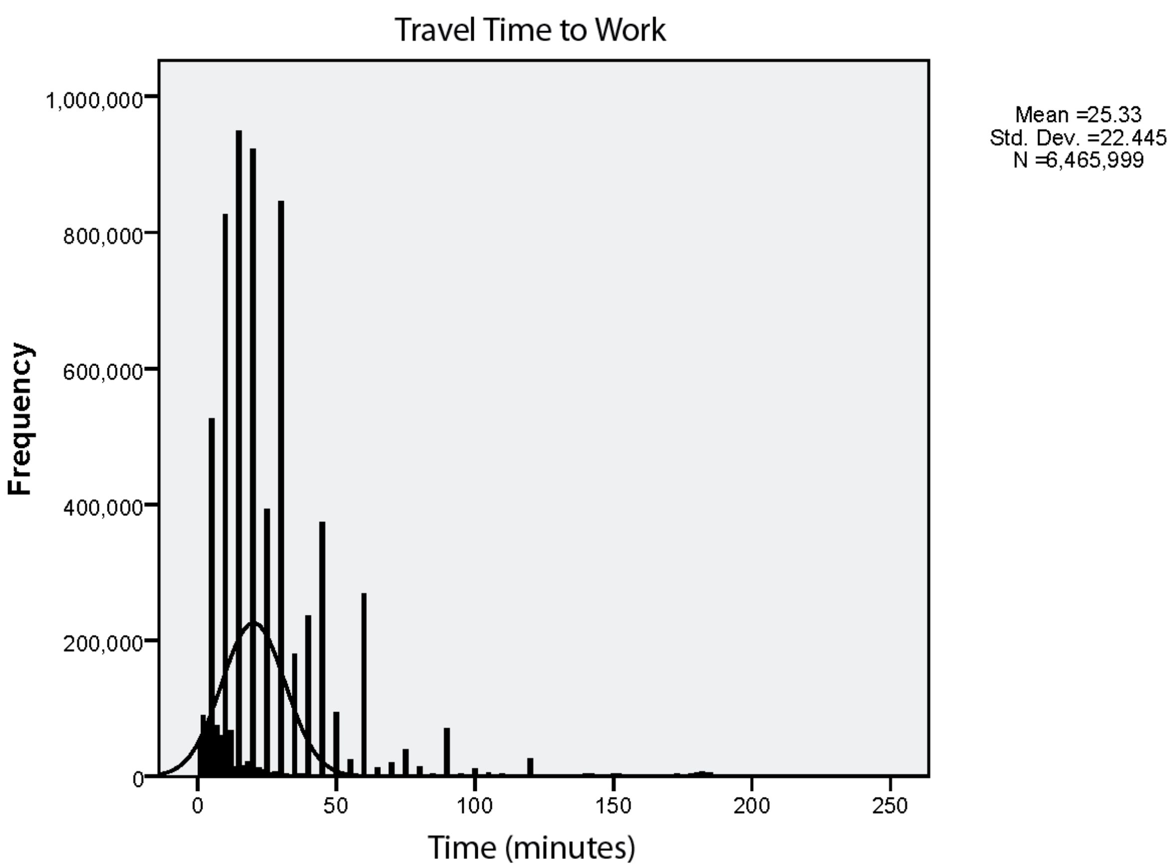

Figure 7 – Distribution of Travel Time to Work as reported in 2010 ACS (IPUMS)

should therefore target this goal in travel time when adding a new transportation system to a region.

4 - The Advancements of the D.C. Metro and LIRR Systems

4.1 - Introduction

Both the D.C. Metro and LIRR transportation improvements had a substantial impact on their respective areas. Being able to qualify what impact these rail improvements had is beneficial from a planning standpoint. Having historical examples of transportation infrastructure improvements can support the planning and development of future systems. With transportation systems across the United States reaching capacity, it is even more important to have examples to help in appropriating funding for new transportation infrastructure.

4.2 - The Washington D.C. Metrorail System

The addition of light rail service to the District of Columbia provided an alternative means of transportation to an already congested highway system. With the development of a new light rail system at a higher expense than further road building, policy and planning played a critical role in evaluating the potential effectiveness of such an investment. The Metro was able to flourish in a region primarily known for heavy automobile traffic (Schrag). Through analysis, we look to quantify what effect the introduction of the Metro had on the greater Washington D.C. region.

The analysis on the D.C. Metro region consisted of analyzing the population distribution and number of available housing units across the Orange Line and a preselected Control Line through the region. The Orange Line was selected for analysis due to its relatively straight nature and path that avoids waterways along its route. The Control Line was selected to avoid the majority of the other Metro lines to provide a comparison between characteristics along the line and the region as a whole.

The time to traverse the Orange Line runs around an hour in total. Starting from the Vienna-Fairfax station on the Western end in Virginia, the line proceeds to the Metro Center station located in the middle of the line. The end point of the Orange Line is situated in New Carrollton in Maryland. Population of individuals from 1980 and 2000 are plotted against time in Figure 8. Time is expressed from the center of the line so both ends of the graph indicate a 30 minute travel time with 0 positioned in the middle at the Metro Center station. In essence, we are looking at how population is distributed with travel time before and after the development of the Metro.

The population present in Maryland decreases over time after the development of the Metro system while the population present in Virginia increases. Looking at raw numbers around 12,000 individuals entered the region on the Virginia side while the Maryland side saw a loss of 5,000 individuals. The trend along the Virginia line is that of growth increasing with the transportation time out to 30 minutes. This would seem to support the belief that transportation time is a major factor on where people live as the majority of individuals are found around 30 minutes from work. In the Washington D.C. area, we can consider the District of Columbia a major source for employment and economic investment. The distribution of population along the Maryland side of the line

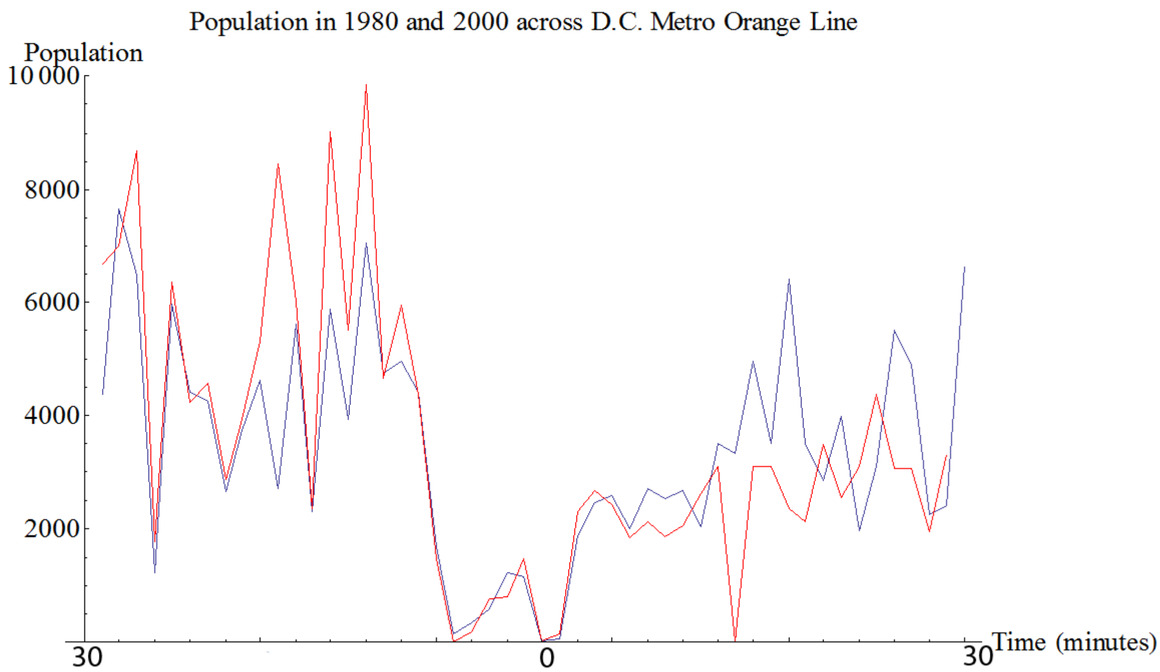

Figure 8 – Population across the D.C. Metro Orange Line (Blue: 1980, Red: 2000)

suggests that only one side of the Metro system benefitted from its development. In order to corroborate these findings we can compare this data to that of the Control Line studied.

The population distribution present along the Control Line can be seen in Figure 8. The trend present in this graph remains the same as that present for the Orange Line analysis although the magnitude of the difference is much smaller. Growth is still shown overall on the Virginia side of the cut while the Maryland side shows a slight loss. These results seem to indicate that there may be other factors influencing the distribution of population across the region. Other data can be utilized in order to determine if this theory is supported.

In addition to looking at population present across the study areas, number of housing units is also investigated. The reasoning behind this analysis is that if housing unit numbers are growing over the course of time, you can expect there to be increases in population and in the economic standing of the region. Looking at the net growth of housing units along the Orange Line in Figure 9 we see a similar trend to that of population. In fact, housing units increased along the western side of the line while many areas along the eastern side had less housing units in 2000.

Comparing the housing units along the Orange Line to the Control Line in Figure 10 shows that while the western side of the line still experienced growth, the eastern side of the line did not lose as many housing units as the region surrounding the Orange Line. This trend, conflicting with that of the trend present along the Orange Line, suggests that this particular area performed better over time in the Maryland area. The variability of these results suggests that other factors could be influencing the region.

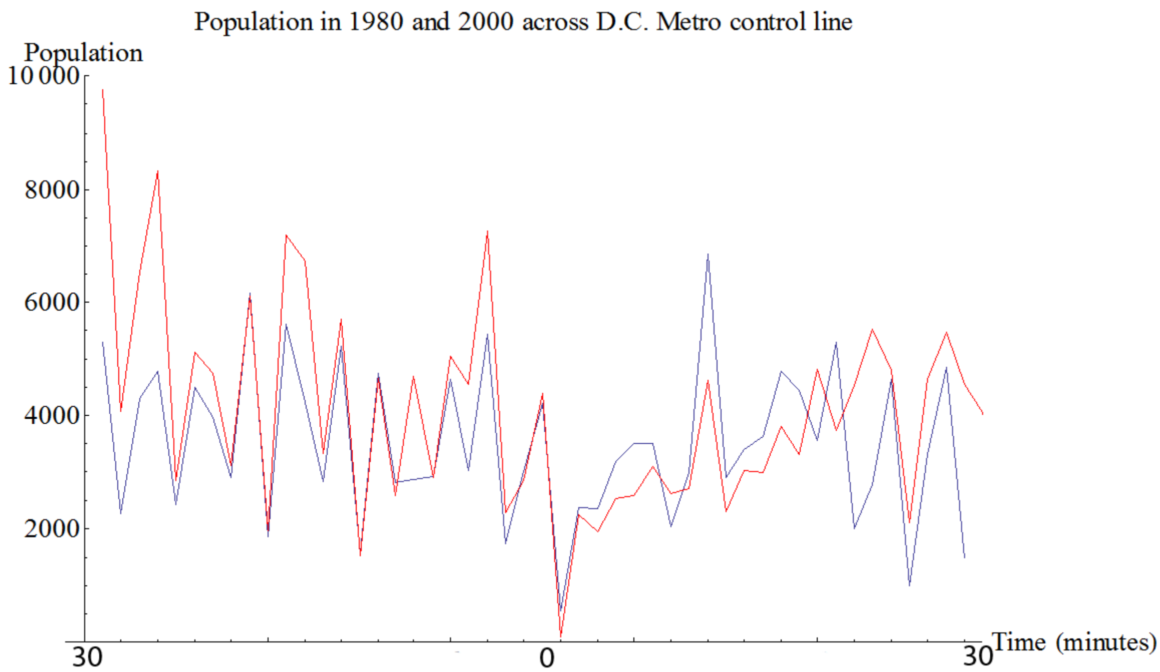

Figure 9 – Population across the D.C. Metro control study area (Blue: 1980, Red: 2000)

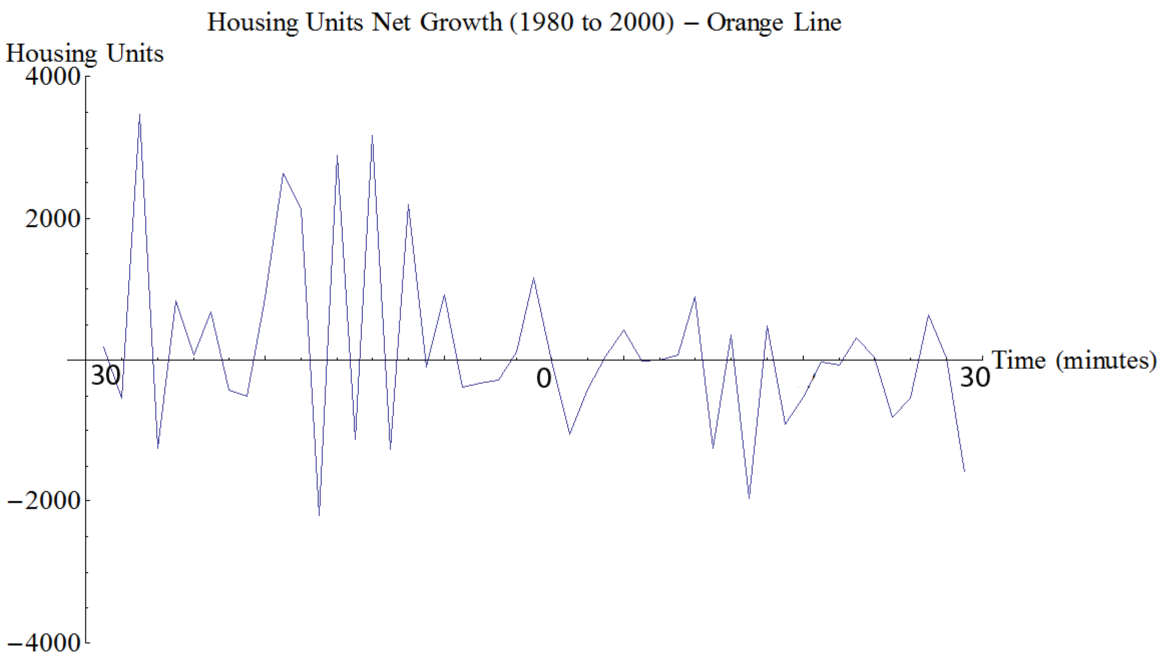

Figure 10 – Net growth of housing units across D.C Metro Orange Line

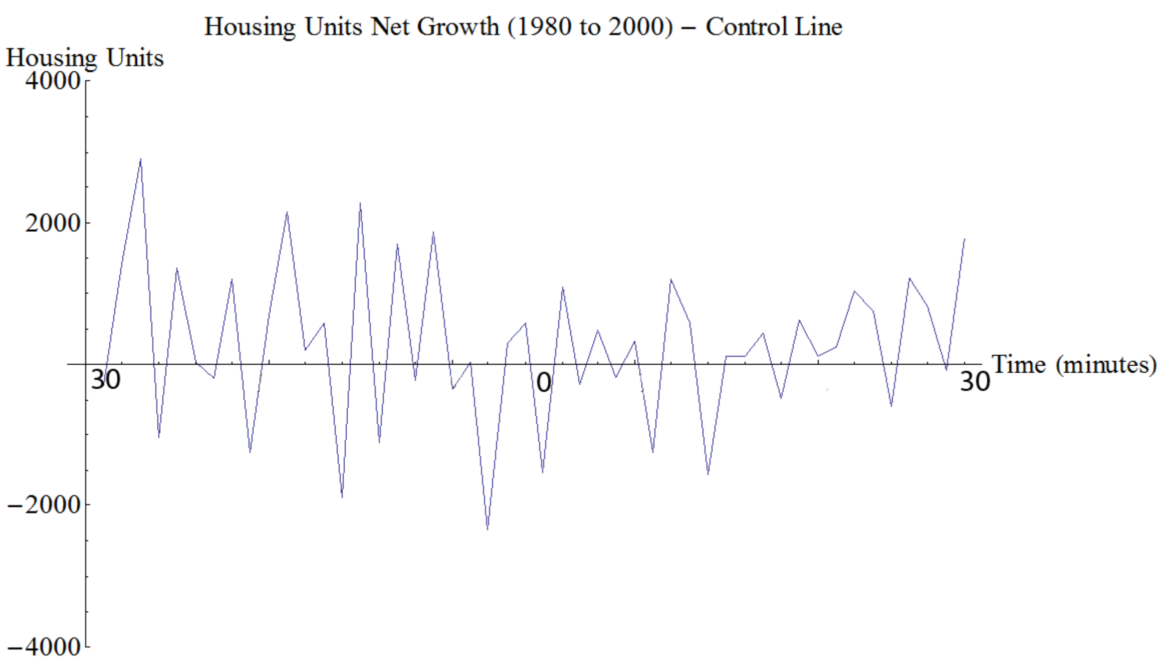

Figure 11 – Net growth of housing units across D.C. Metro control study area

The economic development and population changes that occurred in the region surrounding the Washington D.C. Metro system appear to have been influenced by more than simply the efficiency of the system's implementation. The data suggests the development of the Metro hindered economic growth in the Maryland area. This observation could be due to a combination of other outside factors. Individuals could have personal motivations or opinions surrounding certain areas of the Metro region. In addition the movement across state boundaries in this area could also play a major factor contributing to this difference. The tax rates for the three areas of the study are all different for example. These difficulties prevent the development of a reasonable model from this region to be utilized on other areas.

4.3 – The Electrification of the Ronkonkoma Line

The effects associated with the crossing of political borders (state and district) on the results from the analysis of the D.C. Metro System led to the search for an alternative transportation enhancement situation which existed within one political region. We therefore elected to analyze the effects of the Long Island Rail Road upgrades with occurred in the 1980s. Specifically, in the 1980s the LIRR electrified the middle island line resulting in close to a doubling of average train speed. In contrast with the D.C. Metro, the LIRR does not cross any state borders, eliminating effects of economic or political issues surrounding populations in different sections of the route. In addition, the geographic character of Long Island area benefits, rather than hurts, the study by constraining the analysis to a well-defined corridor along the island. Having water on the north and south and east ends of the region of interest provides rigid boundaries on three borders and for the eastern end of the island the width of the island is relatively constant.

Comparative analyses was performed on the three routes of the LIRR in order to evaluate the effect of electrification on the middle island route on the population distribution and economic development in the region surrounding this central island corridor. Census tracts were selected along the northern, central, and lower lines of the LIRR from the western edge of Suffolk County to an eastern point aligned with Port Jefferson, NY (a town on the northern shore of the island. This provided a similar area for each of the lines utilized in the study.

Two primary census data sets were utilized in the analysis, population and aggregate income. Population data was collected for all census blocks along the three lines for the time period from 1970 to those in 2010. Net growth in population was calculated by comparing the 2010 data to the 1970 and plotted along the routes from west to east based on time of travel into New York City. In addition a second order fit was performed on the data to see the overall trend in population as time from New York City increased. Aggregate income data from the 2010 census has not yet been posted and so data from the 2000 census was utilized for the income analysis. Aggregate income in each block was normalized to population in each block for each time period. Following this normalization the change in per capita income is calculated between 1970 and 2000.

Travel time was calculated utilizing train schedules from the Metropolitan Transportation Authority. The most western point of the study area (western border of Suffolk County) is situated (on the northern line) at approximately Cold Spring Harbor. Based on LIRR time schedules, the travel time from the Cold Spring to Penn Station is one hour. The upper line study area terminates at Port Jefferson Station. Reported travel time to Penn Station from Port Jefferson is approximately 2 hours. The lower study area terminates on the eastern edge near Patchogue Station. Published travel time to Penn Station from Patchogue is approximately an hour and forty five minutes; here we round this to 2 hours. The newly electrified main line terminates to the east at Ronkonkoma Station. The travel time from Ronkonkoma to Penn Station is approximately 75minutes.

Note that the LIRR improvements do not reflect an extension of the rail line, in fact this line had existed for over 100 years, and continues on to the town of Riverhead at the east end of the island. Rather, the enhancement simply represents a simple conversion from a diesel line, which not only operated at slower speeds, but required a transfer at Hicksville station, resulting in substantial delays. The electrification of the Ronkonkoma line resulted in close to a halving of travel time from Ronkonkoma.

We begin with an investigation of population densities in the time period leading up to and after the electrification of the LIRR middle island line. Figure 11 illustrates population growth along the northern line from 1970 to 2010 plotted against travel time along this route. It is evident that population density decreased in the eastern regions of Nassau County during this time, while population density was increasing in Suffolk County. This can in part be attributed to the proximity to New York City and the traditional very high population of this region in the past, and outmigration to more eastern communities over time. The highest growth observed occurs between one hour and an hour and a half in travel time into New York City. With the knowledge that people prefer to travel on average between 30 and 60 minutes into work, having the largest peak in growth of around 5000 individuals present within the 60 to 90 minute travel mark supports the data the previous census data. In addition, the trend of population loss occurring after the 90 minute mark also supports this critical 60 minute travel time value.

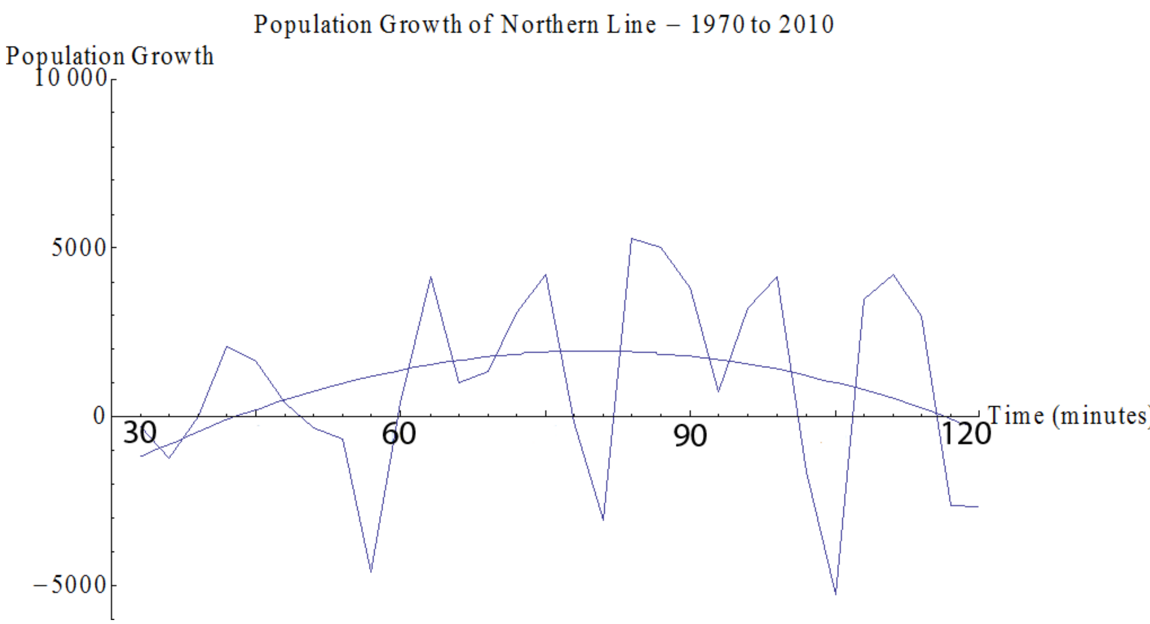

Figure 12 – Population growth along LIRR Northern Line

The second order curve fit of this data clarifies these trends. The apex of the curve occurs at around 75 minutes from New York City with a population increase reaching about 1250 individuals per census tract. This curve tells the story of individuals more heavily populating at a range of 45 to 75 minutes from the major economic center and trailing off after this point due to the disadvantage in terms of travel time present.

The trends present on the northern line of the LIRR are also present to a large degree along the southern line. Figure 12 shows the population increase as a function of time along the southern route. As observed with the northern line, we see a population decrease on the eastern edge of Nassau County. The maximum population growth again occurs between the 60 and 90 minute mark along the southern route. The peak population increase reaching around 6000 individuals at approximately 80 minutes east of NYC. The data trend continues to taper off as travel time is increased beyond 90 minutes though population continues to increase out past the two hour travel time point.

In comparing the northern and southern lines to the middle island line we see a different pattern of the population density changes (Figure 13). While the route is essentially the same geographic length, the speed at which you are able to travel into New York City is greater as no transfers are necessary in Nassau County. With no transfers the travel time is greatly decreased culminating in a total travel time of just over an hour from the Ronkonkoma station. While along this line we still have little or no growth in population near the Nassau County border, there is an abrupt increase in population growth at approximately the 40 minute travel time point. Between the 40 minute and 60 minute time points there are several communities which have experienced growth of more than 5000 individuals, with the community at the 40 minute time point (Hicksville)

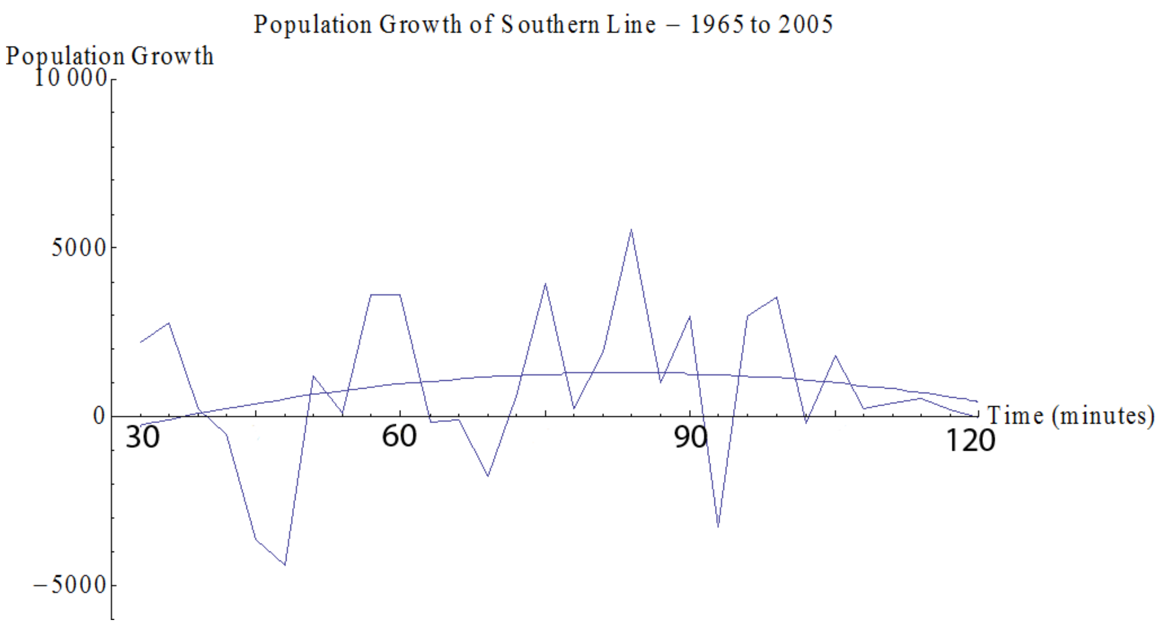

Figure 13 – Population growth along LIRR Southern Line

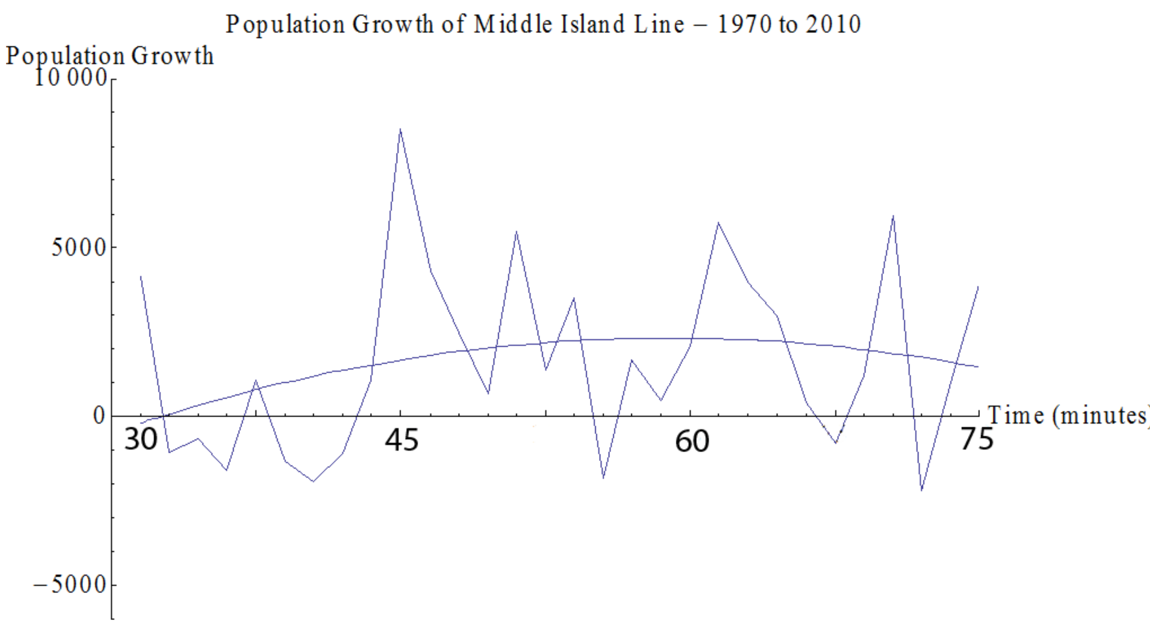

Figure 14 – Population growth along LIRR Middle Island Line

seeing an increase in population of over 8000. In turn when looking at our fit line we see the curve peaking around 50 minutes away from New York City, but in the range of 40-60 minutes outside of the city, the population growth averages approximately 2000 per census block. The effect of decreased travel time is prominent along the middle island route.

While travel time can be seen as influencing the population distribution across Long Island it is of particular interest to qualify the characteristics of the individuals that have moved into the region. In order to the degree of economic development from the influx of individuals present around the higher speed line some measure of economic status must be undertaken for comparison purposes versus the other two lines along the island. Utilizing data on aggregate family income for each census tract we can ascertain economic benefit of reduced travel time.

Figure 14 shows the aggregate family income growth per capita for the northern line, along with a best fit second order curve. Along this route we see a fairly consistent trend of income growth per capita hovering around $40,000 along the length of the route. It is interesting to see that after approximately 75 minutes of travel time along the route we see overall plateau in income growth for the remaining extent of the rail line. A notable point along the route is the spike that occurs around the 60 minute travel time mark, this spike suggests an income growth of around twice that of the average for this section of time along the northern line. Relating what we saw in the population distribution across the line we are seeing this high income growth in the region close to the peak growth in population across the line as well, indicative of an influx of very high wealth individuals to this region.

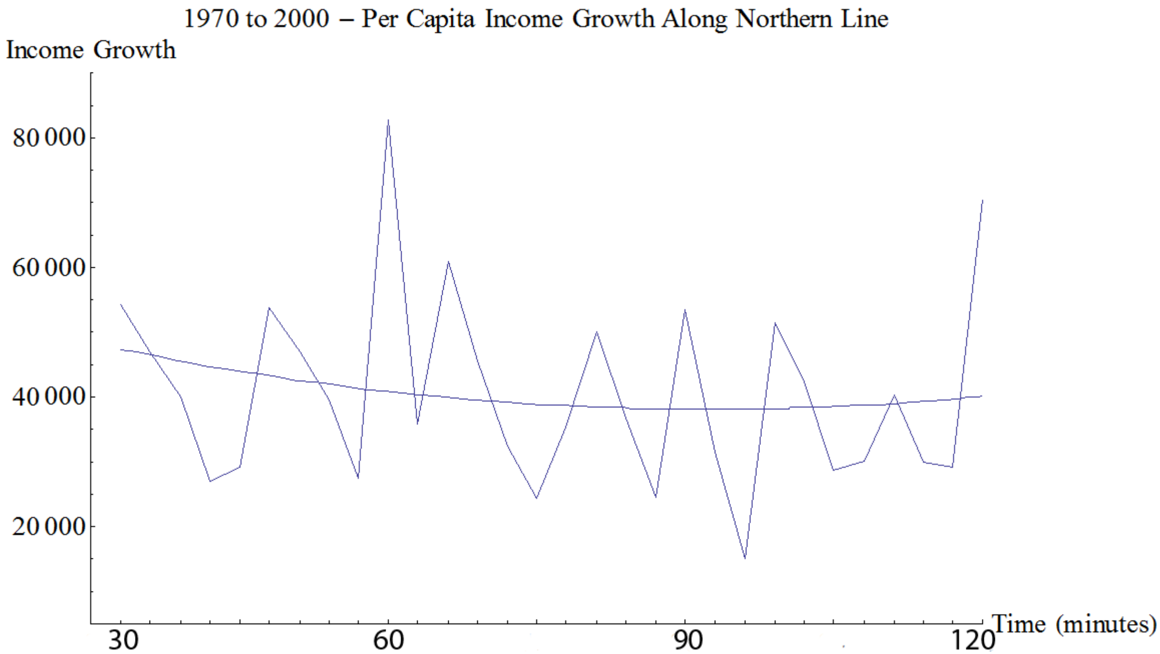

Figure 15 – Aggregate income growth per capita along LIRR Northern Line

The southern line (Figure 16) region experienced generally lower economic growth per capita overall. The greatest growth along the southern line occurs at the very beginning of the study area at a time of 30 minutes into New York City, but this peak is only at the level of the average income growth for the northern line. Along the remainder of the route the overall growth decreases and never exceeds $40,000 per census tract again, and averages approximately $20,000. An interesting trend with the growth is that of resurgence as we near the eastern edge of the study area with higher income growth per capita occurring around the 90 minute mark.

The in income growth per capita along the middle island route shows yet a different pattern (Figure 17). High growth occurs at the western edge of the line with multiple increases of $50,000-$60,000 per individual, in the 30-40 minute travel time range. While the 40-50 minute travel time range showed relatively poor income growth (similar to that of the southern line region), the most striking income growth occurred in the vicinity of Ronkonkoma station at a travel time between 50 and 75 minutes from New York City. This region shows the highest peaks of growth across any of the analyzed census blocks, including a peak of near $80,000 per capita at the east end of the line. This result, along with the observed population growth in this same region is indicative of the enormous economic impact on this region associated with reducing transportation times into NYC.

The correlation between travel time and economic development is expressed through the modeling of the middle island route of the LIRR. The patterns that occur in population and in growth of income both fall around the same region in terms of time. Through the electrification, the middle island route provided a much greater advantage in

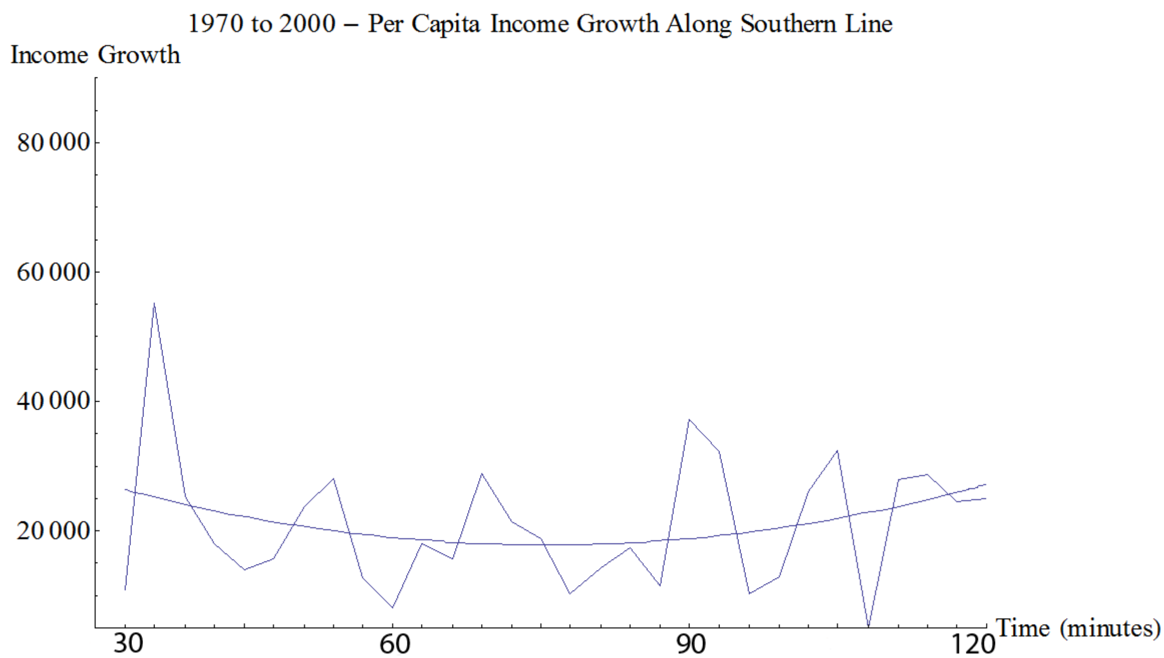

Figure 16 – Aggregate income growth per capita along LIRR Southern Line

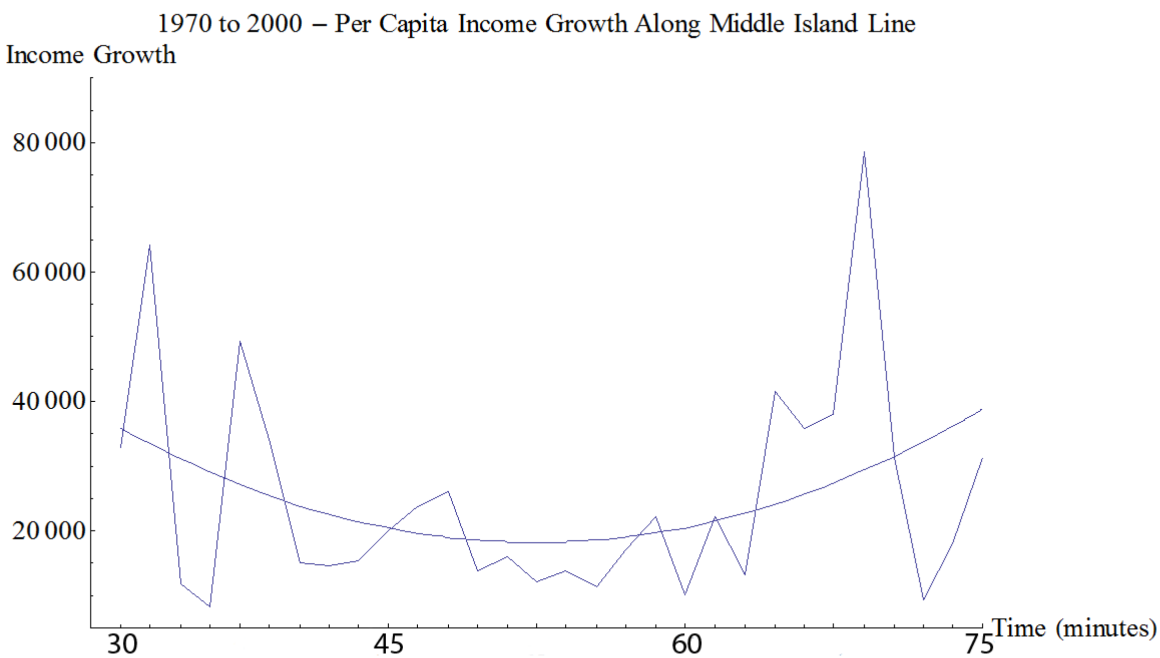

Figure 17 – Aggregate income growth per capita along LIRR Middle Island Line

travel time in comparison to living near, or establishing a business near, the northern or southern lines. It can be suggested that due to this advantage, companies and individuals moved towards this region, increasing population, affluence, and income as related to the benefits of having New York City as a major hub within an hour's travel time.

The lessons learned from the transportation improvement of the LIRR can be extracted and applied to other regions in the United States today. With the data regarding population growth and time of travel for the middle island route, we can then apply the fit curve to other regions in the United States in order to help create a predictor for evaluating the magnitude of transportation speed enhancements that would be required to achieve similar economic impact for a region.

5 – Implications for the Southern Tier of NY

5.1 – Introduction

Recognizing travel time as a critical driver of economic development has the potential to directly influence policy and planning occurring in the Upstate NY region. A primary goal of this study is to evaluate what impact transportation improvements could have on the Southern Tier of NY. Our observations on the effects of transportation enhancements to the LIRR system on economic development on Long Island can be applied directly to the upstate region. By postulating various improvements in travel speeds, we can determine how travel time would influence population growth and economic development in the region.

A recently released report titled NY in the World (Nostitz and Bowles 2011) has already suggested that enhanced linkage of upstate cities to New York City could have a significant impact on economic development of the Southern Tier. The report attributes much of the development in the Hudson Valley to ease of access to NYC (Nostitz and Bowles 2011). The benefit of having connections to NYC is suggested to be of immense benefit to the region in part through manufacturing. New York City is seen as rich in technology and research but having insufficient low cost space to support significant manufacturing capability (Nostitz and Bowles 2011). While manufacturing certainly played a critical role in the expansion of the Southern Tier in the past, it is unclear whether manufacturing will be capable of driving economic expansion of the region in the future. The more likely role for NYC is as a source of finance expertise, entertainment, as well as individuals and businesses looking for lower cost of living or operations.

This pattern is evident on Long Island, where the rapid economic development in the middle island regions was dependent on the travel time to New York City. The city provided both a destination and a source of products and services for people further out on Long Island. Therefore, when looking at the potential impacts to economic development in Upstate NY we can consider New York City as our target area. The route I-86 corridor has similar characteristics to the LIRR's central line as it is the most direct route for travel between the Upstate NY and Downstate NY regions. Alternatives to the utilization of I-86 exist for travel to the Downstate region. Route I-81 can be taken to route I-80 and from there into the NYC area. The utilization of I-86 allows for analysis to occur throughout one state boundary in terms of travel to the Downstate region, eliminating factors with state crossings that appeared to have affected the analysis of the D.C. Metrorail region.

5.2 – The Binghamton to NYC Corridor

The Binghamton, NY to NYC corridor is a route that follows along the existing highway system of Route I-86. This corridor serves as a major route from I-90 in Erie, Pennsylvania to Harriman, New York and provides access to New York City as well as a major shipping route between the Great Lakes and NYC. The Southern Tier of New York however represents a subset of that corridor, and is commonly defined as the region that runs along the Pennsylvania border from roughly Liberty, NY to around Hornell, NY an approximate 200 mile long region centered around route I-86.

Following the model developed for travel time and reported travel time to work from the US Census Bureau two key distances are indicated to be part of the analysis. The first distance occurs at 30 minutes from New York City and effectively describes the boundary of the urban core. The second distance is associated with one hour of travel away from the city, which represents the outer boundary at which people still feel closely connected to the city. With the target range for transportation time falling between thirty minutes and one hour, the question for the Southern Tier is what travel speeds would be required to effectively link the Tier to NYC thereby allowing the community to draw on the resources of NYC to drive economic development in the Southern Tier. Through the use of GIS this question can be evaluated by theorizing different travel speeds along the I-86 corridor and analyzing the expected changes in spatial distribution of population and economic development.

We begin with travel at typical highway speeds, that is, approximately 50 mph. Figure 18 indicates one hour travel time radii along the I-86 route from Newark, NJ at this travel speed. Traveling at an average travel speed of 50 mph will get you to the Monroe, NY region. Essentially at the northwestern edge of the NYC sprawl. This is consistent with our observation of what is considered a reasonable commute time. Figure 19 illustrates the population density across this region out to a distance slightly past Monroe, but at a distance reached within one hour by the highway system. Interesting characteristics of this plot include a greater peak in population occurring around the 10 minute and 25 minute time range. Due to intense traffic occurring along the highway

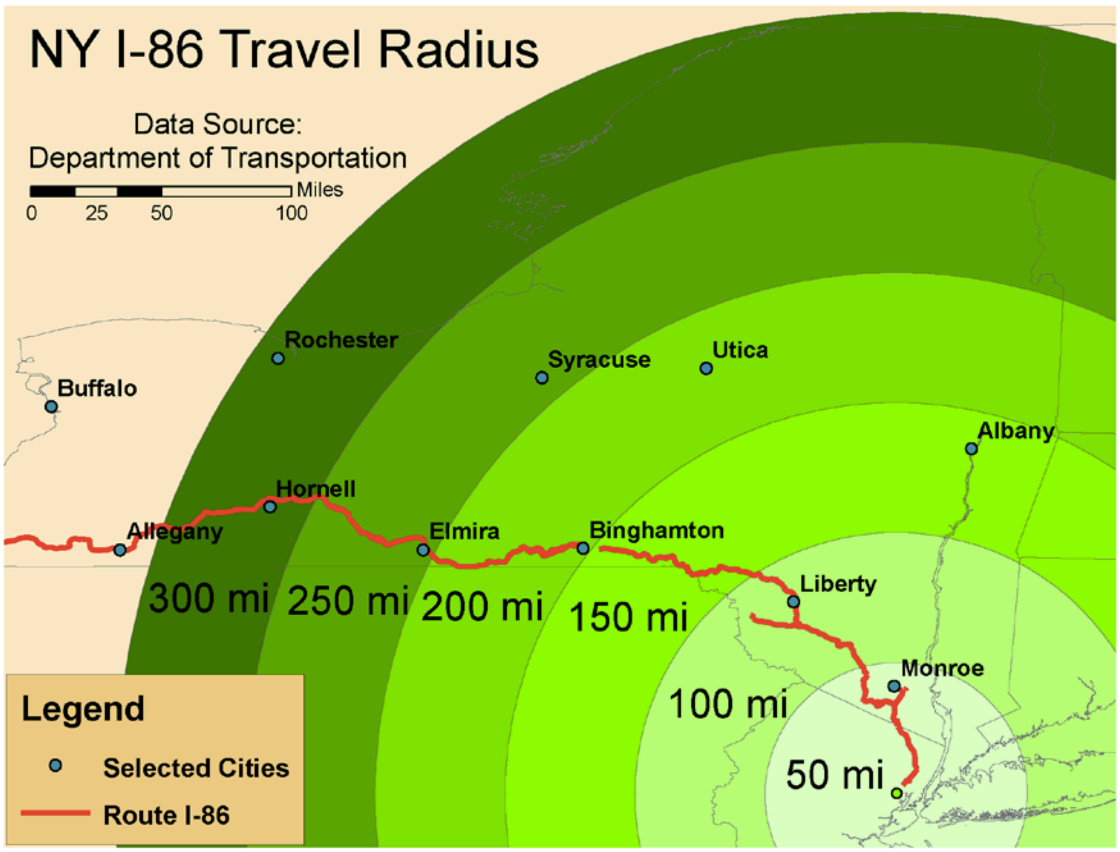

Figure 18 – Travel radii along I-86 corridor in New York

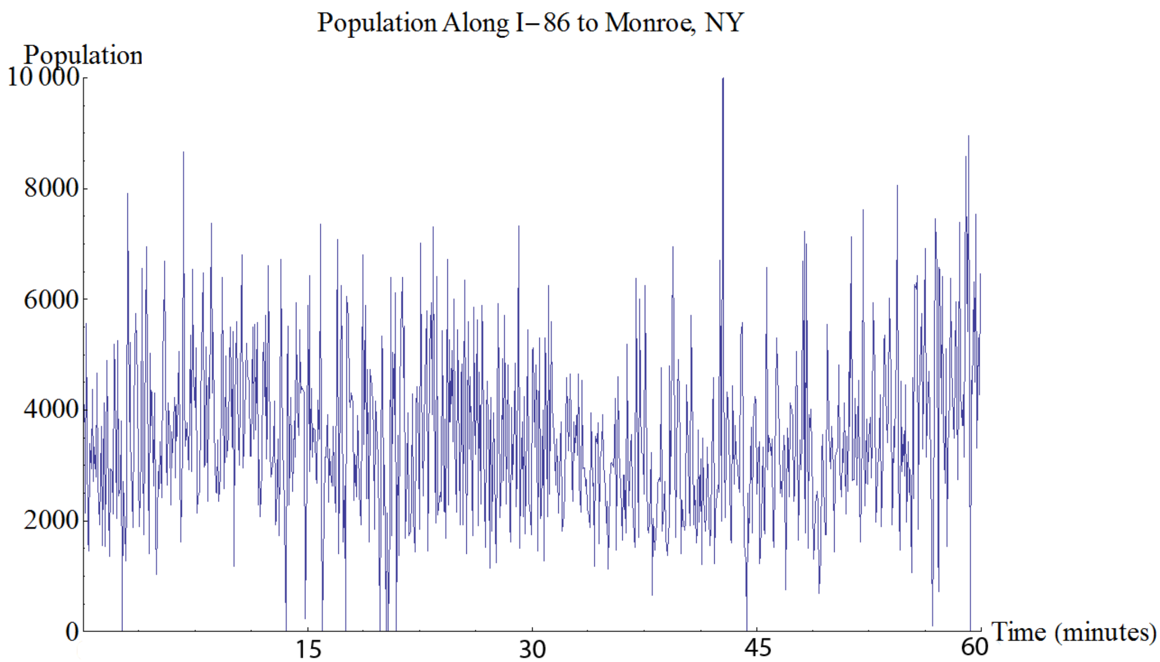

Figure 19 – Population density across I-86 to Monroe, NY

system this close to the city, our estimate of 50mph is likely too high, and this skew of the population centers closer to New York City is probably a good indicator of actual traffic speeds. Nonetheless, a distinct increase in population is observed at approximately the one hour travel time point from the city. The population distribution which has evolved due to the current transportation system is similar to those present on the northern and southern lines of the LIRR, even a standard speed transportation system improvement to this region such as that of the middle island route could have the effect of shifting the population distribution peak farther towards 60 minutes.

Increasing the speed at which travel could occur in the I-86 corridor should have an effect in parallel with the transportation improvements that drove the economic development on Long Island. At an average travel speed of 100 mph, the eastern edge of our range of interest (30 minutes from NYC) moves west to Monroe, NY and the western edge moves to Liberty, NY (representing a one hour commute along I-86). As speed increases and travel time decreases, the accessibility of NYC for all individuals and business in this region would be dramatically improved.

Another doubling of speed from the 100mph limit to 200mph would create a "bedroom community" region extending from Liberty, NY to Binghamton, NY. If we take the fitted curves that described population growth and economic growth from the LIRR middle island route and apply that distribution to I-86 under conditions where people and goods can readily move at 200 mph we see where different city centers would fall in terms of time. Figure 20 shows the distribution of population curve from the LIRR middle island line with cities along I-86 plotted across it. Here we can see that the Binghamton, NY region is placed closest to the maximum growth in population predictor.

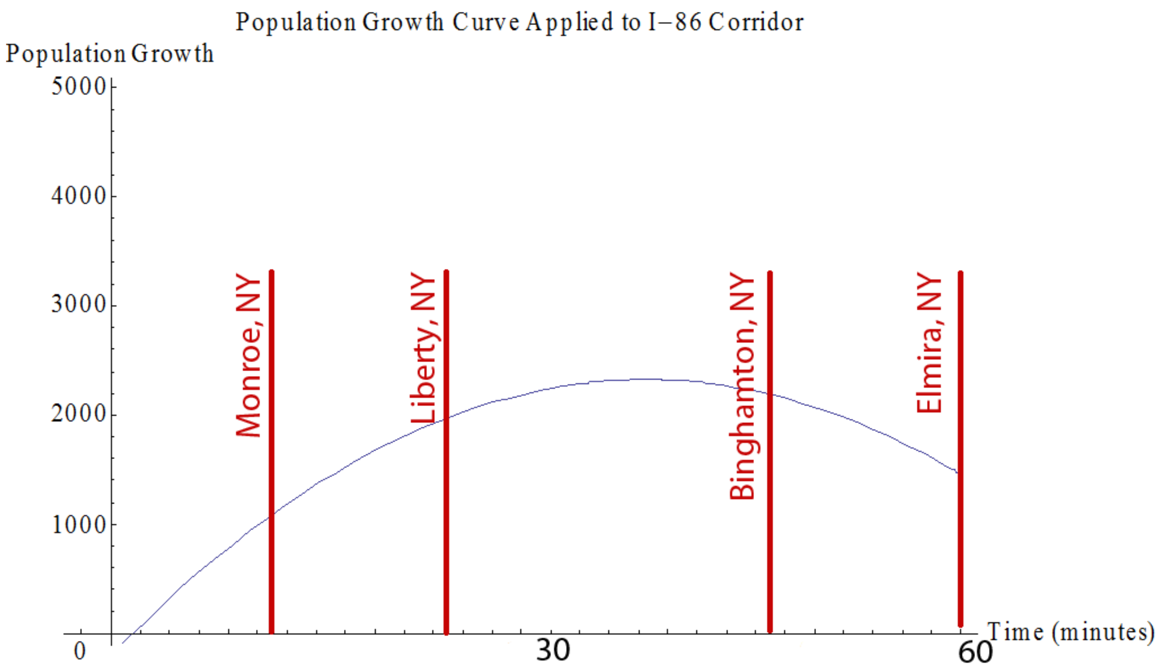

Figure 20 – Distribution of population seen along LIRR as seen along I-86

In addition, the population present at the end of the hour time will still have growth but to a lesser extent than that of the cities closest to the 45 minute time region. In addition to the population curve from the LIRR, the change in per capita income can be predicted as well (Figure 21). From the data we obtained from the LIRR analysis we know that a majority of the economic development occurred in a range between the 45 minute mark and the hour mark in travel time. At a speed of 200 mph, the time of travel places the Binghamton and Elmira areas with the greatest potential for additional development economically and in terms of population growth.

An average travel speed of 300mph would result in the NYC "bedroom community" encompassing the entirety of the Southern Tier out past Hornell, NY. It is important to realize that while this would enable the Hornell area to reach NYC in one hour, traveling at these speeds with this time consideration would also have major effects on time considerations between the Southern Tier city centers themselves. The travel time from Hornell to Binghamton would be cut to 30 minutes, creating the ability for different cities to serve as feed cities from each other. With every decrease in travel time, the mobility of a city is not only increased to NYC but to other major city centers along the route as well. While other centers would not necessarily serve as feeding cities initially, through population sprawl from NYC, other cities would have the potential as they grow to act as sources for towns further along the route.

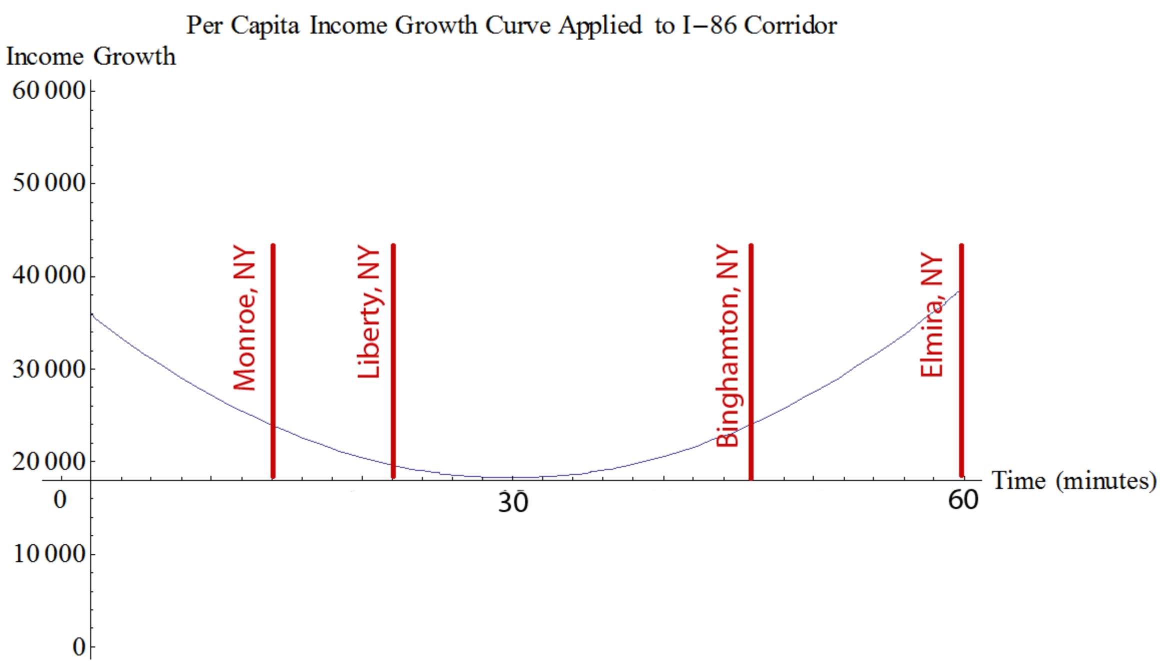

Figure 21 - Distribution of per capita income growth seen along LIRR as seen along I-86

6 – Summary and Conclusion

6.1 – Overview of Results

The evaluation of transportation time and its impact on economic development is critical to the identification and promotion of appropriate advancements in transportation technology. Economic growth is critically dependent on connections between economic hubs and outlying areas. However, an accurate evaluation of economic development can be difficult to undertake due to outside influences from political motivations, personal preferences or stigma against utilization of infrastructure, and the complexities of analyzing the behavior of individuals across time as was seen through the analysis of the D.C. Metrorail system. Nonetheless, the analyses completed here clearly show that shortened travel time can result in significantly higher growth in both population and regional wealth, as reflected through the analysis of the effect of enhancements to the Long Island Railroad system which were made in the 1980s.

Through the development of transportation throughout history, improvements in speed and travel time have led to dramatic redistributions of population, wealth, and the development of new cities and towns. With the ongoing development of new technologies the potential for transportation improvements necessitates cost effective analyses to evaluate impact of improvements on a region. Analytical methods relying on expensive surveys and heuristically reached assumptions can be supplemented through modern geospatial analysis techniques available through the development of GIS. Through geospatial analysis, a-priori planning can occur at a basic level to establish goals or identify areas to concentrate efforts with other modeling techniques, leading to effective evaluation and more successful investment in infrastructure.

6.2 – Limitations of the Modeling

Through the analysis performed in this work, an evaluation of travel time and its impact on economic development was performed. Limitations in the data gathered, analysis methods performed, and data resources available all affected the end result.

Census Tract geographies were utilized in all of the study areas due to their relative stability during the redistricting which occurs with decennial census. In comparing data over the time span of 1970 to 2010 however, changes did occur to Census Tracts. Normalization of the census tracts was performed to create equal comparisons between the different census years. However, some of these normalizations could have incorrectly assigned population groups to a particular census tract. This impact on the results could have spatially skewed the data across the study area. Care was taken to account for this fact in the analysis by calculating trends in data rather than focusing on specific census blocks in the study areas.

In addition to changing geographic boundaries, the appropriate census tracts selected for analysis were identified by hand. Human error could have come into play in creating orderings for census tracts or in the selection of census tracts across a region. Manual editing was performed in order to spatially represent equal areas across all studies. Without complete understanding of the distributions present outside of the selected areas, errors could have been made in selecting features for analysis corresponding to identical features in other census years.

Data resources that were available became a limiting factor in some analyses during the study. One example is that of the data set surrounding family income. Aggregate household income that was utilized in the study has been collected since the 1980 census. A count of household units is an easily obtained metric that can be used for normalization of this income data. Since our study began with the 1970 Census, we were restricted to utilizing aggregate family income. Unlike household units, a count of families is not performed by the census. Therefore, we do not have a method to normalize the data for each individual family. Aggregate family income instead was normalized for overall population to receive a per capita income measure. In addition, while we calculated population change on the LIRR route for 1970 to 2010, the lack of published 2010 data, at the current time, on family income required us to utilize the 2000 data for that part of the analysis.

6.3 – Future Work

Improvements to the model could mainly come through the increase in data available for the study. Having data characterizing businesses present in a given census tract would have been beneficial to utilize as another form of evidence for economic growth. With the addition of this data, as well as looking at other factors related to socioeconomic status of a region, such as poverty rates, educational attainment, and family age other trends in a region could prove to be quite informative.

Comparisons to other existing models could also be done as a next step for this investigation. While results from this investigation are promising, having a comparison to standard modeling techniques in planning could be utilized to support benefits or highlight weaknesses in the model. In doing so additional data could be collected or analyzed to increase the confidence in the end result.

In conclusion, the development of high-speed yet technically plausible transportation along the I-86 corridor could provide widespread economic benefit for the Southern Tier of New York. A system operating with speeds in the range of 200 to 250 mph would place the Binghamton region within a major hub for economic development due to efficiency in transportation time to the city for both individuals and businesses. Connecting upstate NY to such a major center in high tech development, research, finance, and entertainment would in turn spur growth through partnerships and greater industrial investments. These developments would promote the growth of individuals both living and working in the region, ensuring continuing economic growth for New York State.

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