ADA Paratransit Service Geographic Realignment (2012-19)

Final Report
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Submitted by

Eric J. Gonzales, Ph.D.
Assistant Professor of Civil and Environmental Engineering
University of Massachusetts Amherst

Devajyoti Deka, Ph.D.
Assistant Director of Alan M. Voorhees Transportation Center
Rutgers, The State University of New Jersey

NJDOT Research Project Manager
Paul Thomas

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INTRODUCTION

Access Link provides ADA complementary paratransit service across the state of New Jersey. The service is available for eligible customers with disabilities and their traveling companions for trips with origins and destinations with ¾ mile of NJ TRANSIT fixed route bus services and some additional urban core areas. Due to the large geographic extent of NJ TRANSIT's bus operations, Access Link must also provide service over a large area. NJ TRANSIT currently separates the state into 6 overlapping service regions, within which Access Link trips can be made without a transfer. Operations within each region are contracted to a private service provider.

The primary question that is addressed in this study is: How should these service regions be geographically aligned to minimize agency costs while maintaining high quality of service for users. Ideally, Access Link service will be organized in such a way that each region can solicit an operating contract through a competitive bidding process, and the structure of the service regions should be robust for future changing demand. As part of this study, the research team has investigated the existing practices for ADA paratransit service provision by Access Link, benchmarked this performance against other agencies in the United States, and then conducted an extensive demand and supply modeling effort to make predictions about how the costs of providing paratransit in New Jersey can be expected to change in the future. In addition to forecasting demand growth due to demographic changes, the study also includes analysis of how operations and related costs may be expected to change is the service areas are realigned or the coverage area for eligible trips is expanded.

Background

Access Link service is provided in response to the Americans with Disabilities Act of 1990 (42 U.S.C. 12111) and a subsequent US Department of Transportation regulation (USDOT 49 CFR). The purpose of this regulation was to ensure that no person was excluded from federally-funded transportation service solely because of his or her disability pursuant to Section 504 of the Rehabilitation Act of 1973 (29 U.S.C. 794). The Americans with Disabilities Act requires public transit agencies to provide paratransit service to individuals who are unable to use fixed-route buses as a result of their disability. First introduced in 1993, Access Link service fully shadowed the NJ TRANSIT local bus network by 1997.

Access Link service is designed to be comparable to local bus service. The service is provided to eligible persons by using dedicated vehicles on a shared-ride basis in areas served by NJ TRANSIT local fixed-route buses. Currently, service is provided between origins and destinations that fall within ¾ miles of local bus routes, often referred to as the service area. To determine eligibility, prospective passengers are required to attend an in-person assessment interview. Access Link service mirrors the same hours and days of operation as the fixed-route local bus service. Bus routes that are defined as commuter and all rail services are not included in the Access Link service area.

Eligibility is determined on the basis of a person’s ability to use fixed-route transit as well as local environmental conditions regarding access to a bus stop. Eligible customers are required to make a trip reservation between one and seven days prior to the trip. Access Link provides only curb-to-curb service, requiring customers to arrive at the curbside within five minutes of the vehicle’s arrival. In addition, Access Link operates with a 20 minute window, meaning that a customer may be picked up 20 minutes before or after the scheduled pick-up time. Customers are charged fares comparable to bus fares and the ride time between the origin and destination is expected to be not more than 1.5 times the time taken by local buses. Eligible customers can make trips by Access Link for all trip purposes, and they are allowed to travel with a personal care attendant, companion or a service animal. Depending on the length of the trip, customers may be required to make transfers from one vehicle to another. Since Access Link trips are one-way trips, customers are required to make a separate reservation for a return trip.

NJ TRANSIT is the largest statewide transit agency in the United States, and the Access Link service is provided in all counties of New Jersey except Sussex, Warren, and Hunterdon. This large service area includes diverse operating environments ranging from dense urban areas to dispersed rural communities. Because of the sheer size and diversity of its service area, Access Link encounters challenges that are not encountered by ADA paratransit services that serve homogenous urban areas, such as those in Los Angeles or Houston. As shown in Figure 1, Access Link’s entire service area is divided into five regions for the purpose of delivering service: Region 2, Region 3, Region 4 (East and West), Region 5, and Region 6.

Due to the concerns about growing costs of paratransit services, the Transportation Research Board initiated several studies in recent years with support from the Federal Transit Administration. These studies seek to find ways to improve paratransit service efficiency and effectiveness for persons with disability, increase the attractiveness of fixed-route transit for persons with disability, efficiently integrate paratransit services with fixed-route transit, improve travel response to ADA paratransit services, and improve communication with persons with disability.

Although there was a surge in Access Link ridership between 2010 and 2011, its performance over a longer term has been mixed. According to data from the National Transit Database, annual passenger miles for NJ TRANSIT demand response services decreased from 8.5 million to 5.9 million between 2005 and 2010. During that time frame, the annual unlinked trips decreased from 1.03 million to 0.92 million, while operating expense per vehicle revenue mile increased from $4.22 to $5.93. The increase in costs of providing demand response services is not unique to NJ TRANSIT. The National Transit Database shows an increasing trend for the cost of providing ADA paratransit services across the United States. Between 2008 and 2009 alone, ADA-related operating expenses for transit agencies nationwide increased by 8%, from $2.25 billion to $2.43 billion. The increasing cost of providing paratransit service for persons with disabilities has attracted the attention of both the Federal Transit Administration and the Transportation Research Board of the National Academies. Both agencies have

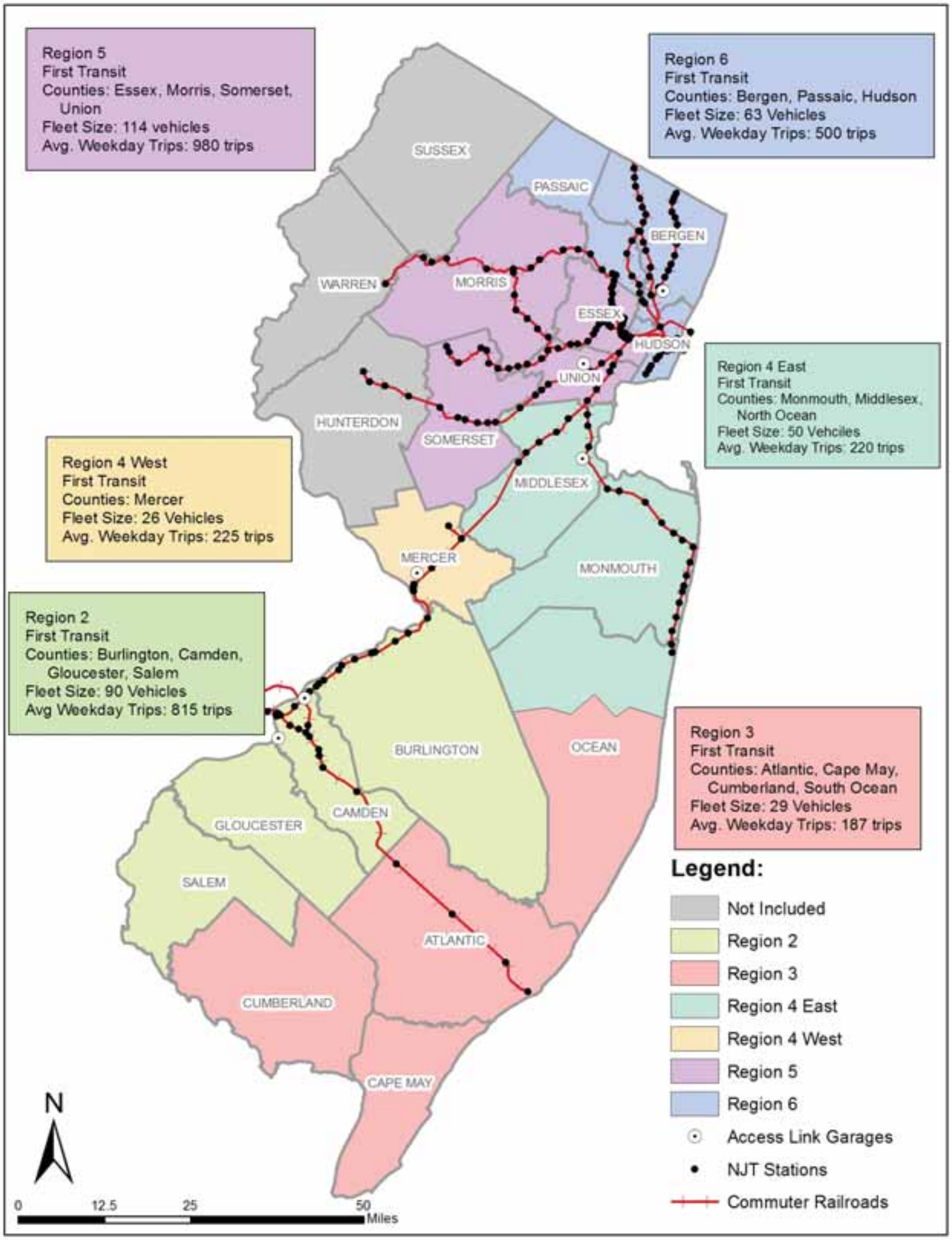

Figure 1. Access Link Service Regions and Garage Locations

initiated multiple efforts in recent years to identify ways to make paratransit services efficient and effective.

Like all transit agencies in the nation, NJ TRANSIT faces a challenge in increasing efficiency and effectiveness of its Access Link service. Since the passage of the Americans with Disabilities Act, New Jersey's population has increased by 14%, from 7.7 million to 8.8 million. Correspondingly, the number of persons with disability has also increased in the state. For example, New Jersey had 646,170 persons with disability among those age 16 and over in 1990, whereas, according to the 2005-07 American Community Survey (ACS) microdata analyzed by this research team, there were 974,100 persons with disability in the same age range. While 10.7% of the state's population age 16 and over had a disability in 1990, according to the 2005-07 ACS data, 14.2% of the persons in that age range had a disability. A reason for this increase in persons with disability in the state is an increase in the number of elderly persons, of which 39% are reported to have some form of a disability. Between 1990 and 2010, the state's population age 65 and over increased by nearly 154,000. A challenge for Access Link will be to keep up with the increased demand for service as the elderly population lives longer and the population groups with high rates of disability (e.g., returning veterans) increase.

In addition to the growth of overall population and the number of persons with disability, another challenge for Access Link in providing efficient access to persons with disability is the decentralization of population in the state. For example, when heavily urban Essex County lost 1.2% of its population between 2000 and 2010, predominantly suburban Ocean County gained 12.8%, Somerset County gained 8.7% and Middlesex County gained 8.0%. This shift in population from heavily urban counties to suburban counties poses a challenge to Access Link because shadowing local buses in sparsely populated areas can be less efficient and cost effective than doing so in urban areas, where there are many riders making relatively short trips.

The circumstances facing Access Link today are very different compared to the time when its service began in 1993. Due to the changing circumstances, it is now highly appropriate to find ways to make the service more efficient and effective in serving the persons with disability in New Jersey. Obviously, improving efficiency and effectiveness is a matter of resource optimization since these objectives cannot be achieved by sacrificing the level or quality of the service. A potential measure to improve efficiency and cost effectiveness of the service is a realignment of the geographic regions based on current circumstances as well as projected demographic changes in the foreseeable future. The existing regional alignment of Access Link was established in the 1990s. Since that time, NJ TRANSIT has endeavored to improve its overall service, including commuter rail and local bus service. During these years, it has expanded commuter rail service on several lines by adding off-peak and weekend service, introduced the Go-Bus service as a first step to introducing full-fledged Bus Rapid Transit, and conducted several studies to improve local bus service in the region.

Since the inception of Access Link, realignment of regions happened only once, when former Region 1 (Mercer County) was combined with Region 4 (NJ TRANSIT press release dated 2/11/2004). The justification for the re-alignment was cost savings. The current alignment of the Access Link regions is almost entirely based on county boundaries. Only Ocean County is broken down into two parts, the southern part being in Region 3 and the northern part being in Region 4-East. Although aligning the regions by county boundary can be beneficial for administrative purposes and for integrating services with county paratransit, from a purely network trip optimization point of view, there may be more efficient solutions for distributing service. However, such solutions cannot be identified without an understanding of the travel demand of current and potential Access Link passengers. For cost optimization purposes, it is not only important to understand the demand at specific geographic locations, but also between origin-destination pairs so that services can be adjusted with regard to modes, transfers, and vehicle dispatch from garages to specific locations.

Research Problem

Currently, the New Jersey Department of Transportation's Bureau of Research is soliciting proposals for research pertaining to a potential realignment of Access Link regions. The research will analyze possible realignment scenarios and provide cost and benefit estimates for alternative scenarios. The research will analyze the current methodologies used by Access Link regarding allocation of long distance trips and transfer trips as well as identification of transfer points.

In addition to analyzing the possibilities for realigning the Access Link regions, the research will examine the consequences of expanding the Access Link service area beyond ¾ mile of fixed-route local bus service. This analysis will include estimation of location-specific service demand as well as estimation of costs and benefits from expanding the service area.

The third objective of the research will be to separately analyze Region 5, consisting of Essex, Union, Morris, and Somerset Counties, to identify ways to increase efficiency and effectiveness of service. Region 5 is the largest of the five Access Link regions with 27,581 monthly riders, served by two garages and approximately 115 vehicles. This component of the research will include analysis of historical trip patterns, estimation of travel demand, and cost/benefit analysis for alternative scenarios. Among other considerations, this component of the research will consider the costs and benefits of breaking down the region into smaller parts for greater efficiency and manageability.

Project Objective

A primary objective of the proposed study is to review and analyze the provision of Access Link service in order to identify ways to improve efficiency and effectiveness. This research will include analysis of the existing geographical service regions and the methodologies for serving long trips and transfers. In addition, the study will estimate the effects of increasing Access Link's coverage area beyond ¾ mile of bus routes on service demand and costs.

The specific research objectives of the study include:

1. Review and document past and current state of practice for delivery of Access Link service, which includes the following areas of focus:

    - Methodologies used by NJ TRANSIT in the past to establish geographic regions for the delivery of Access Link service.

    - Past and present service performance for each region.

    - Currently used methodologies for ridership demand estimation and service delivery to Access Link clients regarding trip scheduling, trip matching between clients, and transfers.

2. Analyze Access Link trip data to examine trip characteristics, identify major and minor trip generators, and identify current and optimum transfer points.

3. Examine the consequences of changing Access Link service characteristics and the extent of coverage. The following service characteristics will be the focus of comparison of costs and benefits:

    - Alternative geographic boundaries of Access Link regions in terms of ridership demand, costs and benefits.

    - Expanding the service area of Access Link beyond ¾ mile of local fixed-route bus service in terms of ridership demand, costs and benefits.

    - Alternative configurations of Region 5 regarding efficiency and manageability of service.

4. Make recommendations regarding geographic realignment of the Access Link regions and expansion of service beyond ¾ mile of fixed route bus service.

Provide a spreadsheet toolkit that will allow NJ TRANSIT to conduct similar comparative cost analysis in the future with new data on demand patterns and the cost of service. The toolkit will be designed to provide simplified results from the model developed by the study.

LITERATURE REVIEW

Since the passage of the Americans with Disabilities Act of 1990, transit agencies nationwide have made significant progress in providing access to persons with disability. Our analysis of the National Transit Database (NTD) shows that ADA unlinked passenger trips increased nationally by 27% between 2004 and 2009, whereas total trips by all transit modes increased by only 13%. Similarly, the proportion of ADA-compliant transit stations increased from 70% to 75% between 2004 and 2009. However, these improvements in disability transportation services have been associated with a high cost.

The growing costs of disability transit services have often been attributed to the increasing demand for paratransit services. As noted in TCRP Synthesis 74, paratransit constitutes 1% of the transit trips nationally, but involves 9% of the transit operating costs. According to the same source, the operating cost per paratransit trip nationally is $22.14, whereas the cost per trip for all transit modes is $2.75. Partially due to the concerns about growing costs of paratransit services, the Transportation Research Board initiated several studies in recent years with support from the Federal Transit Administration. These studies seek to find ways to improve paratransit service efficiency and effectiveness for persons with disability (TCRP Synthesis 74), increase the attractiveness of fixed-route transit for persons with disability (TCRP Report 24), efficiently integrate paratransit services with fixed-route transit (TCRP Synthesis 76), improve travel response to ADA paratransit services (TCRP Report 95, Chapter 6), and improve communication with persons with disability (TCRP Report 150; TCRP Synthesis 37). As noted in TCRP Synthesis 74, different transit agencies have adopted different strategies to improve efficiency and effectiveness of ADA paratransit services, including improving data collection methods, using better technologies for vehicle dispatch, using diverse vehicle types, and establishing travel training programs.

Paratransit Services

As indicated in TCRP Synthesis 74, transit agencies adopt different practical approaches to improve efficiency and effectiveness of ADA paratransit services. In addition to these practical approaches, there is also a large body of research on the theory of providing demand responsive transit services. Logistics models have been developed based on the famous Traveling Salesman Problem and Vehicle Routing Problem to estimate the length of routes and the costs of serving demand that has origins and destinations distributed across a region (e.g., Daganzo, 1978; Daganzo, 1987).

The approaches to model and estimate the costs of demand responsive services can be classified in two categories: (1) detailed simulation models, and, (2) approximate mathematical models. Simulation models can be very useful for quantifying complex interactions between random demand patterns and service characteristics (Quadrifoglio et al., 2008). However, developing an accurate simulation is expensive because it requires detailed data inputs and a significant amount of time for model construction and calibration. While detailed data exists for past and current Access Link trips, origin-destination pairs and trip schedules are not available for hypothetical demand-service scenarios that will have to be created for analyzing restructuring of regions and expanding service areas.

Since we are most interested in the overall cost of providing ADA paratransit service, and in aggregated performance outcomes, approximate mathematical models may be better suited for this research. They are simpler to construct and require more readily available data inputs on demand and unit costs of service (e.g., cost per distance and per time of vehicle operation and labor). This type of models shows the connection between data inputs and cost estimates in a transparent way that can easily be implemented as a spreadsheet toolkit in MS Excel. For planning level analysis where there is uncertainty in data inputs, approximate mathematical models can be as accurate, or even more accurate, than detailed simulation models (Daganzo et al., 2012). Approximate mathematical models are continually being developed and improved to describe different types of operating strategies. Recent work has advanced its ability to estimate fleet requirements (Diana et al., 2006) and route lengths (Figliozzi, 2009) for demand responsive systems with time-windows for pick-up and drop-off. These models directly address systems like the ADA paratransit service provided by Access Link, and they provide a valuable tool for optimizing paratransit services.

In practice, an analytical model of demand-responsive transit operations approximates the real world with a simplified representation. Real paratransit demand is represented by specific origins and destinations spread across a geographic region that is connected by an asymmetric network of roads. This reality is represented by a simplified approximation as illustrated in Figure 2. By approximating the service area as a circular region with its size matching the real service area, and the origin-destination specific trip demand matching actual trips and average zone-to-zone distance, the simplified model allows us to derive equations to predict relevant values for cost estimation. The most useful models for gaining insights about how the system operates and how it should be optimized are those that focus on a few important factors that drive total and average costs without attempting to capture every fine detail.

The modeling approach is to calculate the average distance between demand points (for pick-up or drop-off) and then the average number of customers in each vehicle, which depends on the vehicle capacity and time constraints for serving each trip. Although this type of model does not reveal the specific routes to serve each demand pattern, estimates of vehicle occupancy and trip segment length can be used to calculate average vehicle route length and the required number of vehicles. These values are important determinants of the total cost of providing ADA paratransit service. Furthermore, the additional model outputs such as route lengths and passenger occupancy allow us to estimate metrics of service efficiency and effectiveness, including operating expense per revenue mile and operating expense per passenger mile.

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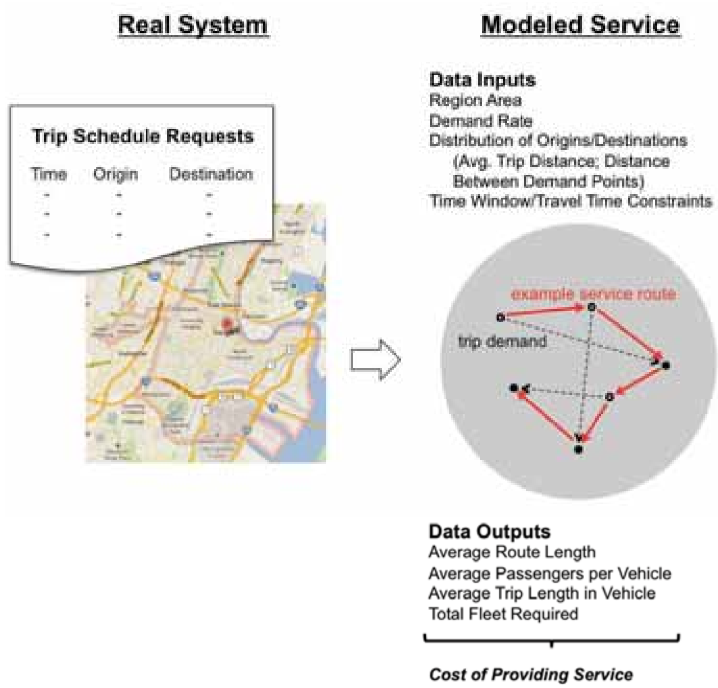


Figure 2. Real Paratransit Demand and Service Modeled to Gain Insights and Costs and System Performance

The approaches to model and estimate the costs of demand responsive services can be classified in two categories: (1) detailed simulation models, and, (2) approximate mathematical models. Simulation models can be very useful for quantifying complex interactions between random demand patterns and service characteristics (Quadrifoglio et al., 2008).

Quadrifoglio has evaluated the effect of zoning versus no zoning strategies on cost and productivity considering time window settings on total trip miles, deadhead miles and fleet size using simulation models. He has done several amount of research on the productivity and service quality of centralized and decentralized zoning strategies and the impacts of adding the flexibility of considering the transfer option for interzonal passengers.

However, developing an accurate simulation is expensive because it requires detailed data inputs and a significant amount of time for model construction and calibration. While detailed data exists for past and current Access Link trips, origin-destination pairs and trip schedules are not available for hypothetical demand-service scenarios that will have to be created for analyzing restructuring of regions and expanding service areas.

Since we are most interested in the overall cost of providing ADA paratransit service, and in aggregated performance outcomes, approximate mathematical models may be better suited for this research. For planning level analysis where there is uncertainty in data inputs, approximate mathematical models can be as accurate, or even more accurate, than detailed simulation models (Daganzo et al., 2012).

Approximate mathematical models are continually being developed and improved to describe different types of operating strategies. Recent work has advanced its ability to estimate fleet requirements (Diana et al., 2006) and average length of vehicle routing problems with varying numbers of customers, demands, and locations (Figliozzi, 2009).

There are also several studies about the impact of implemented technologies and management practices on productivity and the effects of Computer-Assisted Scheduling and Dispatching Systems on paratransit service quality (Pagano et al., 2002; Dessouky et al., 2003a; Dessouky et al., 2003b).

ACCESS LINK DEMAND: EXISTING AND FORECASTED

The objective of this task report is to provide projected future estimates of demand for Access Link service at the level of counties and provider regions. Demand has been defined here as the number of Access Link pick-ups. Since pick-ups and drop-offs occur in almost identical numbers at identical locations, demand for Access Link service would be the same irrespective of whether pick-ups or drop-offs are used as a measure of service demand. The horizon year for the demand analysis is 2030. The base period is 2010-2012.

In order to forecast Access Link pick-ups for the year 2030, an inventory of all Access Link trips for a two-year period (October 2010-Septermber 2012) was first obtained from NJ TRANSIT. Additional data were compiled from the 2006-2010 American Community Survey (ACS), 2010 Longitudinal Employer-Household Dynamics (LEHD), and 2010 Dun and Bradstreet® business database. ACS and LEHD data were combined with NJ TRANSIT's Access Link trip data at the level of census block groups for analysis. The objective of this analysis was to identify variables that are associated with number of Access Link pick-ups.

Based on several iterations of a model, a few key variables were identified to be associated with Access Link pick-ups in a statistically significant manner. Although preliminary analysis showed that total population and total jobs of census block groups are significantly and positively associated with number of Access Link pick-ups, we considered population by age because we suspected that elderly persons would be more likely to generate Access Link trips than younger persons, and we suspected that certain types of jobs would be more likely to generate Access Link trips than other types of jobs. Analysis revealed that the number of elderly and non-elderly persons as well as jobs in the retail trade sector, healthcare and social assistance sector, administrative and support sector, and accommodation and food sector in census block groups are significantly and positively associated with number of Access Link pick-ups in the block groups. In other words, these variables were found to be the most discernible generators of Access Link pick-ups.

By using the coefficients of the six aforementioned variables in a linear regression model, we determined how many Access Link pick-ups would be generated for given values of the predictor variables (e.g., how many pick-ups would be generated by 1,000 elderly persons or retail jobs). Projected estimates of elderly and non-elderly persons for the horizon year (2030) were directly obtained from the New Jersey Department of Labor (NJDOL). Since the NJDOL has made industry-specific employment forecasts only up to the year 2020, the growth rate between 2010 and 2020 was used to extrapolate the projections to the year 2030. The projected estimates of elderly and non-elderly persons as well as the projected estimates of jobs in the four industry types were combined with the pick-up generation rates from the model to forecast the county-level additional and total annual Access Link pick-ups for the year 2030. Pick-up forecasts were made for all 18 counties where Access Link service is available.

The analysis revealed that Access Link demand in the whole region covering the 18 counties could grow by about 31% between 2012 and 2030. In contrast, total population for the region is projected to grow by only 9.8% and jobs in the four industry types that are associated with Access Link pick-ups are expected to grow by about 25% during this time period. However, the number of elderly persons in the 18-county region is expected to grow by a massive 59% between the two time periods. In fact, because of the aging of the Baby-boomer generation, the growth of elderly persons is expected to account for 82% of the overall population growth of the region by 2030. Thus the aging of the service area population is expected to be the largest contributor to the increase in demand for Access Link service.

The analysis showed wide variations in the increase in demand for Access Link service among the counties and provider regions. Because of a high anticipated growth of elderly persons and jobs, counties such as Middlesex, Morris, Monmouth, Ocean, and Somerset – all located outside of the state's urban core – are expected to experience significant increases in demand. However, despite the increase, the urban counties where most pick-ups have historically taken place (namely, Essex, Camden, Bergen, and Union Counties) will continue to account for more pick-ups than these counties up to the year 2030. Among the provider regions, Region 4 East can be expected to experience the most increase in Access Link pick-ups in the future years. However, Region 5, Region 2, and Region 6 can be expected to account for more pick-ups than Region 4 East despite the substantial increase in pick-ups in the region.

Data Sources for Demand Analysis

At the outset of this research, we acquired an inventory of Access Link clients and trips from NJ TRANSIT. The client database acquired from NJ TRANSIT contains information on 29,006 registered clients, including the GIS coordinates of their home location, age, gender, and disability type. Out of the 29,006 clients, 9,884 (34.1%) are classified by the agency as active clients. The remaining 19,122 registered clients (65.9%) are considered inactive. By NJ TRANSIT definition, active clients are those who used the service at least once during the past six months. The residential location of the active Access Link clients is shown in Figure 3.

The trip database included all Access Link trips in a 24-month period between October 1, 2010 and September 30, 2012. Almost two million trips were made during this period. The data set included provider identification, vehicle number and capacity, as well as exact location and recorded arrival and departure time for 1,954,193 pick-ups and 1,923,767 drop-offs. Of the 1.95 million pick-ups, 871,954 (44.6%) occurred within 300 feet of the clients' homes. Of the 1.92 million drop-offs, 791,439 (41.1%) occurred with 300 feet of their homes.

In addition to the Access Link client database and the two-year trip database obtained from NJ TRANSIT, data were obtained and analyzed from the 2006-2010 American Community Survey (ACS), the 2010 Longitudinal Employer-Household Dynamics (LEHD), and the 2010 Dun & Bradstreet® business database. The ACS provides demographic and socioeconomic data on population for small geographic areas such as

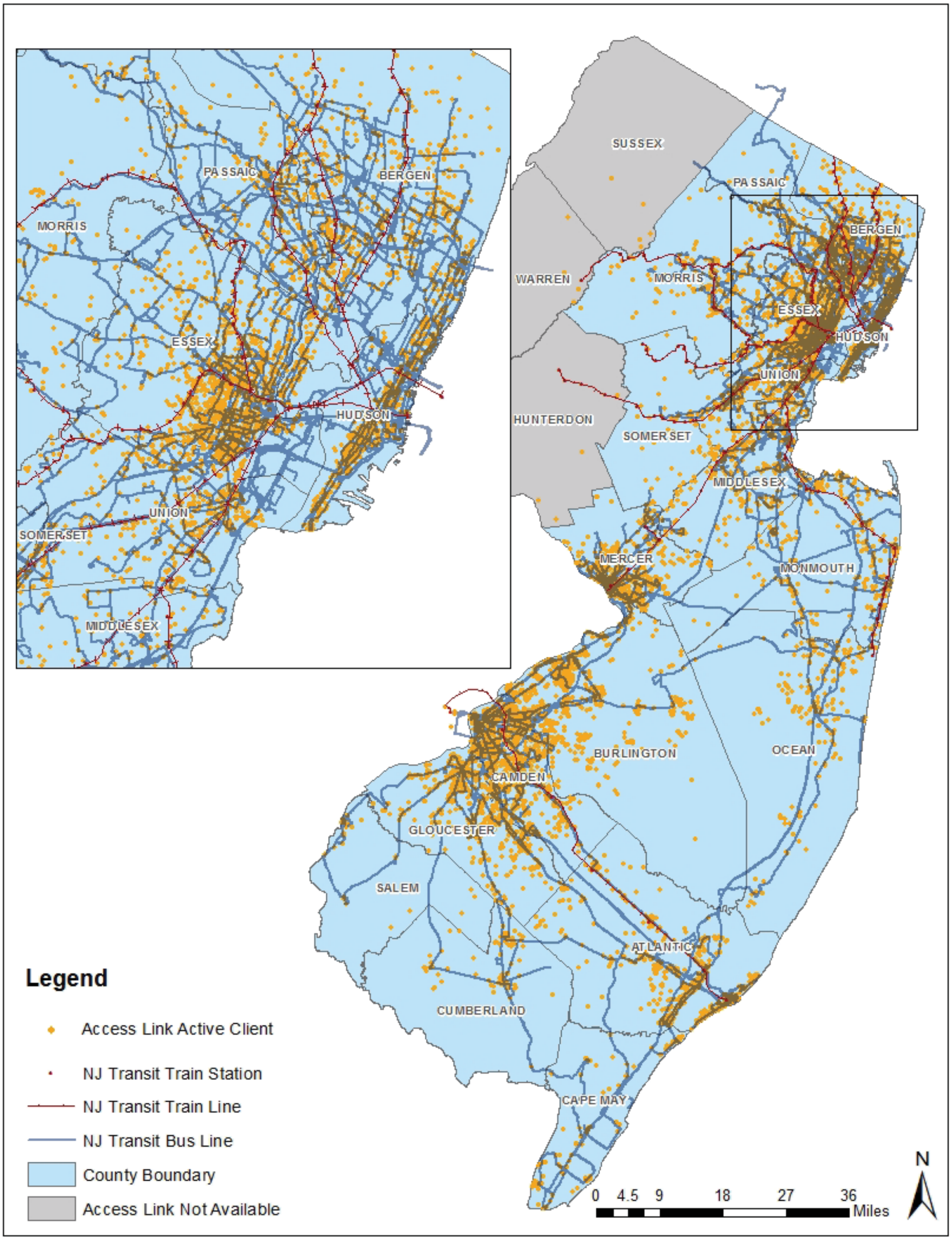


Figure 3. Residential Location of Active Access Link Clients

census blocks and block groups. Similarly, the LEHD provides information on number of jobs for small geographies such as census blocks and block groups. The LEHD data is available for 20 different industry types. The ACS and LEHD data were analyzed at the level of census block groups because data on a number of variables from the ACS are not available at the level of census blocks. The Dun & Bradstreet® business database includes names, addresses, number of employees, and industry classification of all businesses in New Jersey. The addresses of these businesses were geocoded for analysis.

Existing Access Link Demand

Preliminary analysis with combined data from NJ TRANSIT, ACS, and LEHD revealed that a number of characteristics of areas are associated with the number of registered clients, number of at-home pick-ups, and the number of non-home drop-offs. A map in Figure 3 shows the geographic distribution of active Access Link customers. The demand model is based on relating the number of active Access Link users in each region to the demographic characteristics of the area. For example, the analysis revealed that the number of registered Access Link clients and at-home pick-ups in block groups are significantly and positively associated with size of population, the proportion of elderly persons, and the proportion of African American persons in the block groups, whereas they are significantly and negatively associated with median home value, median rent, and average household size of the block groups. The analysis further showed that fewer Access Link clients live and fewer at-home pick-ups occur in block groups that are far from the places typically visited by the clients compared to other places.

The preliminary analysis also revealed some characteristics of the places where non-home drop-offs take place. The analysis showed that jobs in the health care and social assistance sector, administrative and support sector, retail trade sector, and the accommodation and food sector are significantly and positively associated with non-home drop-offs in block groups. Jobs in other sectors were not found to be significantly associated with non-home drop-offs. In addition to population size and jobs in the four sectors, the proportion of elderly persons in block groups was found to be significantly associated with non-home drop-offs, but the proportion of African American persons was not found to be associated with drop-offs.

To further investigate the types of places Access Link clients visit, non-home drop-offs of Access Link trips were matched with businesses in the vicinity of drop-offs locations by using the geocoded Dun & Bradstreet® business database. For this purpose, a business within 75 feet of the drop-off location was considered a match, or potential destination of the client. The top 25 industry types that matched the drop-off locations are presented

Table 1. The distribution of drop-offs potentially indicates that a significant proportion of Access Link trips are made for health-related purposes and for social services. However, the distribution also shows that a large number of trips are also potentially made for shopping and to acquire services of various kinds.

Table 1 – Top 25 Industry Types Located within 75 feet of Non-Home Drop-offs

Rank	Industry Type	2-digit SIC* code	Frequency of drop offs	Percen t
1	Health services	80	80,561	15.8%
2	Social services	83	47,004	9.2%
3	Business services	73	27,756	5.4%
4	Educational services	82	27,541	5.4%
5	Membership organizations	86	27,068	5.3%
6	Wholesale trade - durable goods	50	25,949	5.1%
7	Food stores	54	24,771	4.8%
8	Miscellaneous retail	59	18,101	3.5%
9	Construction - special trade contractors	17	17,269	3.4%
10	Building construction - general contractors & operative builders	15	15,643	3.1%
11	Engineering, accounting, research, management & related services	87	15,598	3.1%
12	Printing, publishing and allied industries	27	15,481	3.0%
13	Eating and drinking places	58	14,190	2.8%
14	Real estate	65	12,104	2.4%
15	Personal services	72	10,411	2.0%
16	Wholesale trade - nondurable goods	51	10,153	2.0%
17	Amusement and recreation services	79	9,701	1.9%
18	Apparel and accessory stores	56	9,355	1.8%
19	Automotive dealers and gasoline service stations	55	8,671	1.7%
20	Legal services	81	7,265	1.4%
21	General merchandise stores	53	6,741	1.3%
22	Depository institutions	60	5,777	1.1%
23	Transportation services	47	5,424	1.1%
24	Automotive repair, services and parking	75	4,954	1.0%
25	Chemicals and allied products	28	4,464	0.9%
Matched drop-offs captured by the top 25 industry types			451,952	88.4%
Other industry types			59,265	11.6%

* SIC=Standard Industrial Classification

From the knowledge gained from the preliminary analysis, a few variables were selected for modeling total pick-ups and drop-offs in block groups. The purpose of this modeling effort was to forecast future Access Link pick-ups. Although the analysis of at-home pick-ups and non-home drop-offs provided an in-depth understanding of the related independent variables, ultimately it is the number of total pick-ups (or total drop-offs) that best represents demand for Access service. Since the preliminary analysis of at-home pick-ups and non-home drop-offs included a number of independent variables that are difficult to predict for the future (e.g., household size, housing value), the models to predict total pick-ups and drop-offs included only those types of variables that have been projected into the future by others. These variables include population projections by age group and projections of jobs in different sectors.

From the regression models on total Access Link pick-ups and drop-offs, it was determined how many additional pick-ups and drop-offs can be expected from given amounts of age-specific population and sector-specific jobs. The expected annual number of pick-ups and drop-offs for given number of persons and jobs are shown in **Error! Reference source not found.**. Since each variable in **Error! Reference source not found.** is associated with Access Link pick-ups and drop-offs in a linear fashion, the total number of Access Link pick-ups and drop-offs are determined by their combined (additive) effect. The two variables on population provide the marginal population effect, whereas the four variables on jobs provide the marginal job effect on Access Link pick-ups and drop-offs.

According to the model results, 329 annual Access Link pick-ups or 319 annual drop-offs can be expected for an additional 1,000 persons in an area. Similarly, 386 additional annual pick-ups and 404 additional drop-offs can be expected for 1,000 additional administrative jobs. Although these estimates are obtained from current data, in the absence of data on changes over time in the relationship between the predictor variables in **Error! Reference source not found.** and Access Link trips, we hypothesize that the current relationships will at least tentatively prevail in the future.

The variables shown in **Error! Reference source not found.** were all statistically significant in predicting pick-ups and drop-offs at the census block group level. Two age-specific variables on population were included because elderly persons are far more likely to have disabilities and use Access Link service compared to non-elderly persons. Figure 4 demonstrates that the proportion of elderly persons among Access Link clients is far larger than the proportion of elderly persons in New Jersey as a whole. It can be observed from the proportions in Figure 4 that 44% of the registered clients and 52% of the active clients of Access Link

Table 2 – Expected Increase in Access Link Pick-ups and Drop-offs for Given Increases in the Predictor Variables

Predictor Variable (LEHD codes in parentheses)	Annual pick-ups per 1,000 of the predictor variable	Annual drop-offs per 1,000 of the predictor variable
Elderly persons - age 65 and over **	329	319
Non-elderly persons - below age 65*	26	26
Health Care and Social Assistance jobs (CNS16)**	125	130
Retail Trade jobs (CNS07)**	200	211

Administrative and Support, Waste Management, and Remedial Service jobs(CNS14)**	386	404
Accommodation and Food Services jobs (CNS18)**	151	162

** Significant at the 1% level
* Significant at the 10% level

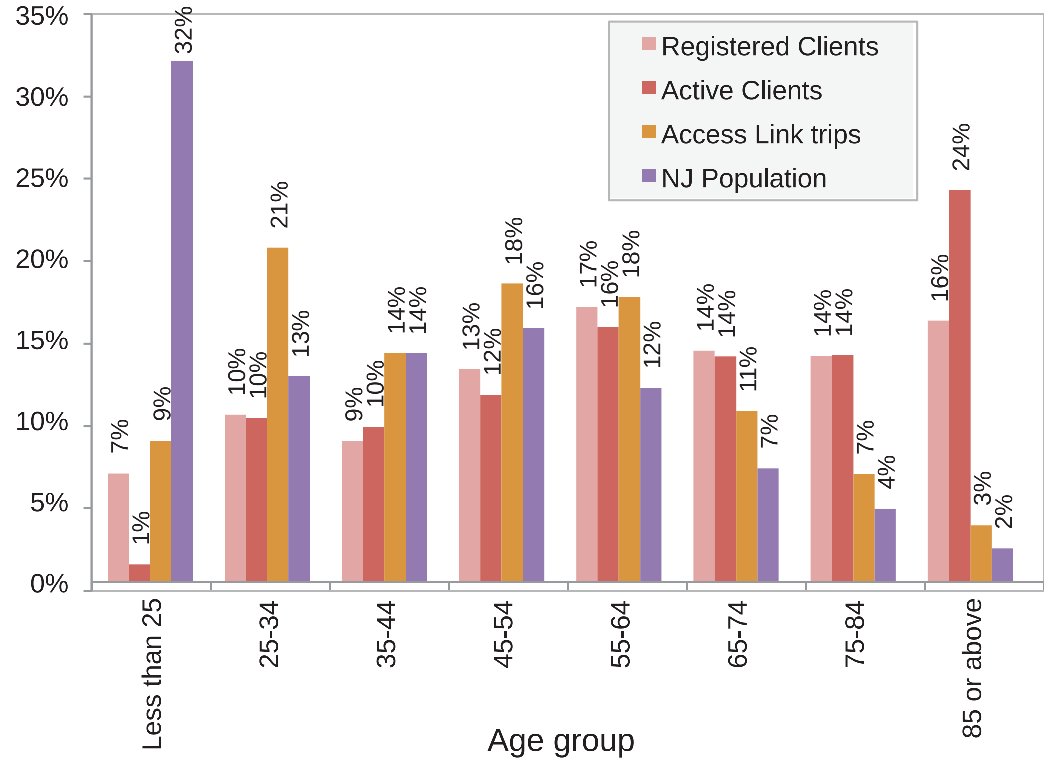


Figure 4. Proportion of Age-Specific Access Link Clients and Trips Compared to New Jersey Population

are elderly persons (age 65 and over), whereas only 14% of the New Jersey population is elderly.

Because of their greater propensity of to use Access Link service, the growth of the elderly is likely to have a far greater impact on Access Link demand than the growth of non-elderly persons. Moreover, as shown in Figure 4, the proportion of trips by clients between the ages of 45 and 64 is currently very high. As these clients become elderly over the next 18-20 years, many will presumably continue to make trips by Access Link, thereby further adding to the demand for the service.

Access Link Demand Forecast Model

The New Jersey Department of Labor (NJDOL) has made age-specific projection of population for counties up to the year 2030, whereas it has made industry-specific projection of jobs up to the year 2020. Since no other agency has made projections of county-specific and industry-specific jobs up to the year 2030, the anticipated 2010-2020 growth rates were applied to obtain the projected estimates of job for 2030. The NJDOL population projections for elderly and non-elderly population for the counties are shown in Table 3.

Table 3 – Elderly and Non-elderly Population Projections, 2030

	Population 65+, 2010	Population 65+, 2030	Increase in 65+ Population	Population below 65, 2010	Population below 65, 2030	Change in Population below 65
Atlantic	39,037	65,900	26,863	235,314	238,100	2,786
Bergen County	137,196	207,000	69,804	768,640	784,300	15,660
Burlington County	62,321	106,400	44,079	386,374	391,500	5,126
Camden County	65,994	105,700	39,706	447,509	442,400	-5,109
Cape May County	21,000	27,800	6,800	76,030	71,800	-4,230
Cumberland County	19,887	30,300	10,413	136,940	143,100	6,160
Essex County	90,689	129,100	38,411	693,037	695,500	2,463
Gloucester County	35,548	68,100	32,552	252,793	264,400	11,607
Hudson County	66,331	95,900	29,569	568,594	606,200	37,606
Mercer County	46,753	75,300	28,547	319,708	328,900	9,192
Middlesex County	100,107	174,600	74,493	709,949	734,600	24,651
Monmouth County	87,211	148,500	61,289	542,992	531,800	-11,192
Morris County	68,486	117,700	49,214	424,326	433,300	8,974
Ocean County	121,279	171,400	50,121	455,426	505,600	50,174
Passaic County	60,558	96,800	36,242	440,193	425,200	-14,993
Salem County	9,876	15,900	6,024	56,151	53,400	-2,751
Somerset County	40,163	79,500	39,337	283,349	288,100	4,751
Union County	67,903	100,700	32,797	468,565	474,600	6,035
Total	**1,140,339**	**1,816,600**	**676,261**	**7,265,890**	**7,412,800**	**146,910**

* Source: Obtained by aggregating age-specific population projections by the New Jersey Department of Labor. Available at: http://lwd.dol.state.nj.us/labor/lpa/dmograph/lfproj/lfproj_index.html. Accessed on 2/21/2013

According to the NJDOL projections, the total population of the 18 counties where Access Link service is available is likely to increase by approximately 823,000, from 8.41 million in 2010 to 9.23 million in 2030, indicating a 9.8% increase in 20 years. However, as shown in Table 3, 82% on the increase in population (i.e., 676,000 of the 823,000) will be accounted for by the elderly. This is obviously due to the transition of the Baby-boomer generation from non-elderly to elderly.

The projected growth of elderly and non-elderly population varies widely among the 18 counties. While the elderly population is projected to increase between 32% and 98% in the 18 counties, the non-elderly population is in fact projected to decrease in some counties and remain more or less stable in other counties. Somerset County is expected to experience the highest percentage increase in elderly population (98%), whereas

Middlesex County is projected to experience the highest absolute increase in elderly population (74,500). Essex, Union, and Camden Counties, where a large proportion of Access Link pick-ups and drop-offs occur, are projected to experience only a modest growth of elderly population.

The NJDOL has made projections of job growth only up to the year 2020. In the absence of other projections, we used the anticipated growth rate between 2010 and 2020 to project the sector-specific jobs for the 18 counties with Access Link service up to the year 2030. The number of employees in 2010 and the projected employees in 2020 and 2030 for the four industry types that were found to be significantly related to Access Link pick-ups and drop-offs are presented in Currently, approximately 977,000 pick-ups take place annually in the 18 counties and the surrounding areas, including Philadelphia. According to the estimates based on projections of population and jobs in selected sectors, an additional 301,000 pick-ups will occur annually by the year 2030, indicating a 31% growth of pick-ups compared to the present. In absolute terms, growth will be the highest in Middlesex County with an additional annual pick-up of almost 35,000, followed by Bergen County with an additional 31,500 pick-ups. Several counties of predominantly suburban nature, such as Burlington, Monmouth, Morris, Ocean, and Somerset can be expected to experience substantial growth in Access Link pick-ups. Yet, despite the potential increase in pick-ups in the predominantly suburban counties, pick-ups will most likely continue to be the highest in Essex, Camden, Bergen and Union Counties.

Table 4. According to these projections, jobs in the four industry types in the 18 counties will increase by approximately 355,000 between 2010 and 2030 (from 1.432 million to 1.787 million), indicating a growth of 25% in 20 years. Retail trade jobs are projected to increase 16% (from 419,000 to 485,200), health care and social assistance jobs are projected to increase by 31% (from 506,300 to 664,300), administrative and support jobs are projected to increase by 35% (from 234,400 to 316,600), and accommodation and food sector jobs are projected to increase by 18% (from 272,400 to 320,900). Projected job growth in the four sectors varies by county. Proportional job growth in the four sectors combined in the 20-year period is projected to be the highest in Somerset County (40% growth), followed by Mercer and Burlington Counties (36% growth for each). In absolute terms, Bergen County is projected to gain the most jobs (52,400) during the 20-year period, followed by Middlesex County (39,500).

Estimation of Future Pick-ups

By combining the pick-up generation factors in **Error! Reference source not found.** with the projections of elderly and non-elderly persons in Table 3 and the projection of jobs in each of the four industry types shown in Currently, approximately 977,000 pick-ups take place annually in the 18 counties and the surrounding areas, including Philadelphia. According to the estimates based on projections of population and jobs in selected sectors, an additional 301,000 pick-ups will occur annually by the year 2030, indicating a 31% growth of pick-ups compared to the present. In absolute terms, growth will be the highest in Middlesex County with an additional annual pick-up of almost 35,000, followed by Bergen County with an additional 31,500 pick-ups. Several counties of predominantly suburban nature, such as Burlington, Monmouth, Morris, Ocean, and Somerset can be expected to experience substantial growth in Access Link pick-ups. Yet, despite the potential increase in pick-ups in the predominantly suburban counties, pick-ups will most likely continue to be the highest in Essex, Camden, Bergen and Union Counties.

Table 4, the estimates of Access Link pick-ups were obtained at the level of counties for the year 2030. These estimates are presented in **Error! Reference source not found.**, where the additional pick-ups due to the growth of elderly and non-elderly populations are combined into one column and the additional pick-ups due to the projected growth of jobs in the four industry types are combined into another column. The total additional annual pick-ups due to population growth and job growth and the potential total number of pick-ups in 2030 are shown in two other columns. The first column of the table shows the annual average number of pick-ups during the base period (October 2010-September 2012).

Currently, approximately 977,000 pick-ups take place annually in the 18 counties and the surrounding areas, including Philadelphia. According to the estimates based on projections of population and jobs in selected sectors, an additional 301,000 pick-ups will occur annually by the year 2030, indicating a 31% growth of pick-ups compared to the present. In absolute terms, growth will be the highest in Middlesex County with an additional annual pick-up of almost 35,000, followed by Bergen County with an additional 31,500 pick-ups. Several counties of predominantly suburban nature, such as Burlington, Monmouth, Morris, Ocean, and Somerset can be expected to experience substantial growth in Access Link pick-ups. Yet, despite the potential increase in pick-ups in the predominantly suburban counties, pick-ups will most likely continue to be the highest in Essex, Camden, Bergen and Union Counties.

Table 4 – Projected growth of industry-specific employment by county

County/ Industry type	2010 Estimated Employment*	2020 Projected Employment*	2030 Estimated Employment**	Increase in Employment, 2010-2030
1. Atlantic				
Retail Trade	15,500	17,700	20,200	4,700
Health Care & Social Assistance	17,150	20,050	23,450	6,300
Administrative, Support & Waste	4,600	5,450	6,450	1,850
Accommodation & Food	46,700	50,700	55,050	8,350
2. Bergen				
Retail Trade	51,900	54,950	58,179	6,279
Health Care & Social Assistance	70,200	86,350	106,215	36,015
Administrative, Support & Waste	23,550	25,700	28,046	4,496
Accommodation & Food	31,400	34,100	37,032	5,632
3. Burlington				
Retail Trade	24,800	27,800	31,163	6,363
Health Care & Social Assistance	25,550	30,100	35,460	9,910
Administrative, Support & Waste	15,800	20,000	25,316	9,516
Accommodation & Food	13,050	14,200	15,451	2,401
4. Camden				
Retail Trade	23,400	24,800	26,284	2,884
Health Care & Social Assistance	37,250	41,300	45,790	8,540
Administrative, Support & Waste	14,500	17,250	20,522	6,022
Accommodation & Food	14,000	15,100	16,286	2,286
5. Cape May				
Retail Trade	6,550	6,850	7,164	614
Health Care & Social Assistance	4,850	5,400	6,012	1,162
Administrative, Support & Waste	1,050	1,300	1,610	560
Accommodation & Food	8,600	8,800	9,005	405
6. Cumberland				
Retail Trade	7,650	8,450	9,334	1,684
Health Care & Social Assistance	8,400	9,350	10,407	2,007
Administrative, Support & Waste	1,600	1,850	2,139	539
Accommodation & Food	3,350	3,650	3,977	627
7. Essex				
Retail Trade	27,500	29,400	31,431	3,931
Health Care & Social Assistance	54,150	57,000	60,000	5,850
Administrative, Support & Waste	20,500	23,100	26,030	5,530
Accommodation & Food	18,100	19,650	21,333	3,233
8. Gloucester				
Retail Trade	17,700	19,600	21,704	4,004
Health Care & Social Assistance	11,950	12,800	13,710	1,760
Administrative, Support & Waste	5,550	6,300	7,151	1,601
Accommodation & Food	7,700	8,200	8,732	1,032
9. Hudson				
Retail Trade	22,450	23,600	24,809	2,359
Health Care & Social Assistance	25,450	28,550	32,028	6,578
Administrative, Support & Waste	12,900	13,150	13,405	505
Accommodation & Food	13,600	15,150	16,877	3,277
10. Mercer				
Retail Trade	19,550	21,800	24,309	4,759
Health Care & Social Assistance	30,700	36,950	44,472	13,772
Administrative, Support & Waste	10,300	12,450	15,049	4,749
Accommodation & Food	10,950	12,050	13,261	2,311

11. Middlesex				
Retail Trade	39,300	42,000	44,885	5,585
Health Care & Social Assistance	41,450	48,200	56,049	14,599
Administrative, Support & Waste	37,950	45,700	55,033	17,083
Accommodation & Food	20,200	21,300	22,460	2,260
12. Monmouth				
Retail Trade	36,750	38,900	41,176	4,426
Health Care & Social Assistance	38,050	42,550	47,582	9,532
Administrative, Support & Waste	11,100	13,500	16,419	5,319
Accommodation & Food	21,750	23,650	25,716	3,966
13. Morris				
Retail Trade	28,700	30,600	32,626	3,926
Health Care & Social Assistance	32,350	37,350	43,123	10,773
Administrative, Support & Waste	23,150	27,000	31,490	8,340
Accommodation & Food	16,700	17,450	18,234	1,534
14. Ocean				
Retail Trade	25,600	27,500	29,541	3,941
Health Care & Social Assistance	31,850	37,500	44,152	12,302
Administrative, Support & Waste	5,500	6,500	7,682	2,182
Accommodation & Food	13,400	15,750	18,512	5,112
15. Passaic				
Retail Trade	23,600	25,100	26,695	3,095
Health Care & Social Assistance	24,800	27,400	30,273	5,473
Administrative, Support & Waste	14,350	15,900	17,617	3,267
Accommodation & Food	9,350	10,150	11,018	1,668
16. Salem				
Retail Trade	1,850	1,950	2,055	205
Health Care & Social Assistance	3,150	3,550	4,001	851
Administrative, Support & Waste	950	1,200	1,516	566
Accommodation & Food	1,500	1,600	1,707	207
17. Somerset				
Retail Trade	19,450	21,900	24,659	5,209
Health Care & Social Assistance	19,500	23,600	28,562	9,062
Administrative, Support & Waste	11,900	15,250	19,543	7,643
Accommodation & Food	9,750	10,800	11,963	2,213
18. Union				
Retail Trade	26,750	27,850	28,995	2,245
Health Care & Social Assistance	29,450	31,200	33,054	3,604
Administrative, Support & Waste	19,150	20,350	21,625	2,475
Accommodation & Food	12,300	13,250	14,273	1,973
Total				
Retail Trade	419,000	450,750	485,209	355,029
Health Care & Social Assistance	506,250	579,200	664,340	66,209
Administrative, Support & Waste	234,400	271,950	316,643	158,090
Accommodation & Food	272,400	295,550	320,887	82,243

* Source: NJ Department of Labor (NJDOL) Industry Employment Projection, available at http://lwd.state.nj.us/labor/lpa/employ/emp_index.html, accessed on 2/21/2013

** Estimated by using the 2010-2020 projected growth rate by NJDOL

Table 5 – Potential growth of Access Link Pick-ups by County based on Population and Employment Projections

County	Annual average pick-ups, 2010-2012	Additional annual pick-ups due to population growth, 2030	Additional annual pick-ups due to job growth, 2030	Total annual additional pick-ups, 2030	Potential annual pick-ups, 2030
Atlantic	56,283	8,896	3,670	12,566	68,849
Bergen	81,813	23,332	8,176	31,508	113,321
Burlington	58,395	14,612	6,533	21,145	79,539
Camden	120,373	12,913	4,293	17,206	137,579
Cape May	3,353	2,126	541	2,667	6,020
Cumberland	5,236	3,578	882	4,460	9,696
Essex	192,223	12,682	4,130	16,811	209,034
Gloucester	66,557	10,991	1,791	12,782	79,339
Hudson	60,715	10,676	1,950	12,626	73,341
Mercer	71,114	9,613	4,803	14,417	85,531
Middlesex	47,888	25,103	9,870	34,973	82,861
Monmouth	22,179	19,848	4,698	24,546	46,725
Morris	34,933	16,397	5,561	21,958	56,890
Ocean	9,659	17,749	3,882	21,631	31,290
Passaic	34,012	11,522	2,800	14,323	48,334
Salem	737	1,909	395	2,304	3,040
Somerset	3,398	13,044	5,442	18,486	21,884
Union	97,969	10,929	2,143	13,071	111,040
Total 18 counties	966,834	225,921	71,560	297,481	1,264,315
Philadelphia and other places*	10,263	2398	760	3,158	13,421
Total all places	977,097	228,319	72,320	300,639	1,277,736

* The projections for Philadelphia and other places were obtained by applying the average rates for the 18 counties because population and job projections are not available for those areas.

Table 6 – Percent Growth and Potential Change in the Share of Access Link Pick-ups

County	Percent growth of annual pick-ups, 2012-2030	Actual share of pick-ups, 2010-2012	Potential share of pick-ups, 2030	Change in county share between 2012 and 2030
Atlantic	22%	5.8%	5.4%	-0.4%
Bergen	39%	8.5%	9.0%	0.5%
Burlington	36%	6.0%	6.3%	0.3%
Camden	14%	12.5%	10.9%	-1.6%
Cape May	80%	0.3%	0.5%	0.1%
Cumberland	85%	0.5%	0.8%	0.2%
Essex	9%	19.9%	16.5%	-3.3%
Gloucester	19%	6.9%	6.3%	-0.6%
Hudson	21%	6.3%	5.8%	-0.5%
Mercer	20%	7.4%	6.8%	-0.6%
Middlesex	73%	5.0%	6.6%	1.6%

Monmouth	111%	2.3%	3.7%	1.4%
Morris	63%	3.6%	4.5%	0.9%
Ocean	224%	1.0%	2.5%	1.5%
Passaic	42%	3.5%	3.8%	0.3%
Salem	313%	0.1%	0.2%	0.2%
Somerset	544%	0.4%	1.7%	1.4%
Union	13%	10.1%	8.8%	-1.4%
Total 18 counties	31%	100.0%	100.0%	0.0%

shows the projected increase in additional annual pick-ups between the present time and 2030 in percentage form. It also shows the share of current pick-ups for each county and their share of projected pick-ups in 2030. In terms of percent increase in pick-ups between now and 2030, Somerset, Salem, Ocean, and Monmouth Counties rank the highest, but that is primarily because these counties currently account for far fewer pick-ups than counties like Essex, Camden, and Bergen. Another reason for a high projected growth rate of pick-ups for some counties is that they are projected to experience a rapid growth of elderly persons as well as a growth of jobs in those sectors that have been found to be associated with Access Link pick-ups. For example, Somerset County's elderly population is projected to increase by 98% between now and 2030 and its jobs in the four selected sectors are projected to increase by 40%. Other counties with very high projected growth of elderly population are Gloucester, Middlesex, Morris, and Monmouth.

Table 6 – Percent Growth and Potential Change in the Share of Access Link Pick-ups

County	Percent growth of annual pick-ups, 2012-2030	Actual share of pick-ups, 2010-2012	Potential share of pick-ups, 2030	Change in county share between 2012 and 2030
Atlantic	22%	5.8%	5.4%	-0.4%
Bergen	39%	8.5%	9.0%	0.5%
Burlington	36%	6.0%	6.3%	0.3%
Camden	14%	12.5%	10.9%	-1.6%
Cape May	80%	0.3%	0.5%	0.1%
Cumberland	85%	0.5%	0.8%	0.2%
Essex	9%	19.9%	16.5%	-3.3%
Gloucester	19%	6.9%	6.3%	-0.6%
Hudson	21%	6.3%	5.8%	-0.5%
Mercer	20%	7.4%	6.8%	-0.6%
Middlesex	73%	5.0%	6.6%	1.6%
Monmouth	111%	2.3%	3.7%	1.4%
Morris	63%	3.6%	4.5%	0.9%
Ocean	224%	1.0%	2.5%	1.5%
Passaic	42%	3.5%	3.8%	0.3%
Salem	313%	0.1%	0.2%	0.2%
Somerset	544%	0.4%	1.7%	1.4%

Union	13%	10.1%	8.8%	-1.4%
Total 18 counties	31%	100.0%	100.0%	0.0%

It is evident from the last column of Table 6 that the share of Access Link pick-ups may decrease slightly in counties like Essex, Camden, and Union, where a large number of pick-ups have taken place historically. In contrast, the share is expected to increase in counties such as Somerset, Middlesex and Ocean. While these trends may have a significant effect on where Access Link service is provided in the long run, for the next 15-20 year, service is still likely to be concentrated in the areas where Access Link pick-ups have been historically high.

Implications of the Projected Growth on the Access Link Regions

Table 7 shows the projected additional annual pick-ups and the total annual pick-ups for 2030 by Access Link provider region by aggregating the counties where the providers operate. The numbers in the table were obtained by applying the current proportion of pick-ups in each county by each provider. For example, since 97% of the pick-ups in Atlantic County are currently made by the Region-3 provider and 3% of the pick-ups are made by the Region-2 provider, the additional annual pick-ups and total annual pick-ups for Atlantic County were divided between Region-2 and Region-3 providers by using these proportions. Pick-ups in other counties were split between the provider regions in a similar manner. Since 100% of the pick-ups in Camden, Cape May, Gloucester, Monmouth, and Salem Counties were made by sole providers, pick-ups in these counties were not split between provider regions.

Table 7 – Projected additional pick-ups and total pick-ups by provider region, 2030

	Additional Annual Pick-ups		Total Annual Pick-ups, 2030	
Provider Region	**Pick-ups**	**Percent**	**Pick-ups**	**Percent**
Region 4 West	17,057	6%	87,824	7%
Region 2	55,857	19%	307,732	24%
Region 3	22,140	7%	85,483	7%
Region 4 East	77,611	26%	154,513	12%
Region 5	72,006	24%	404,109	32%
Region 6	52,811	18%	224,653	18%
Total*	297,481	100%	1,264,315	100%

*Excludes pick-ups outside the 18 counties

Table 7 shows that the increase in pick-ups is likely to be the most in Region 4 East, followed by Region 5. The increase in Region 4 East can be anticipated because of rapid growth in all three constituent counties – Middlesex, Monmouth and Ocean. The increase in Region 5 can be expected primarily due to the increases in pick-ups in Morris County, Essex County, and Somerset County. Table 7 also shows that despite the significant increase in pick-ups in Region 4 East, Region 5 will continue to account for the most pick-ups by the year 2030, followed by Region 2 and Region 6, respectively.

The projected increase of Access Link trips in various counties has been shown in the form of a map in Figure 5. It clearly shows that the projected increases in pick-ups will be minimal in the southern counties, but substantial in the counties within Region 4 East. The map also shows where the share of pick-ups will increase and where the share will decrease. While the predominantly urban counties like Essex, Hudson, and Camden will lose share, the share will significantly increase in counties like Monmouth and Morris.

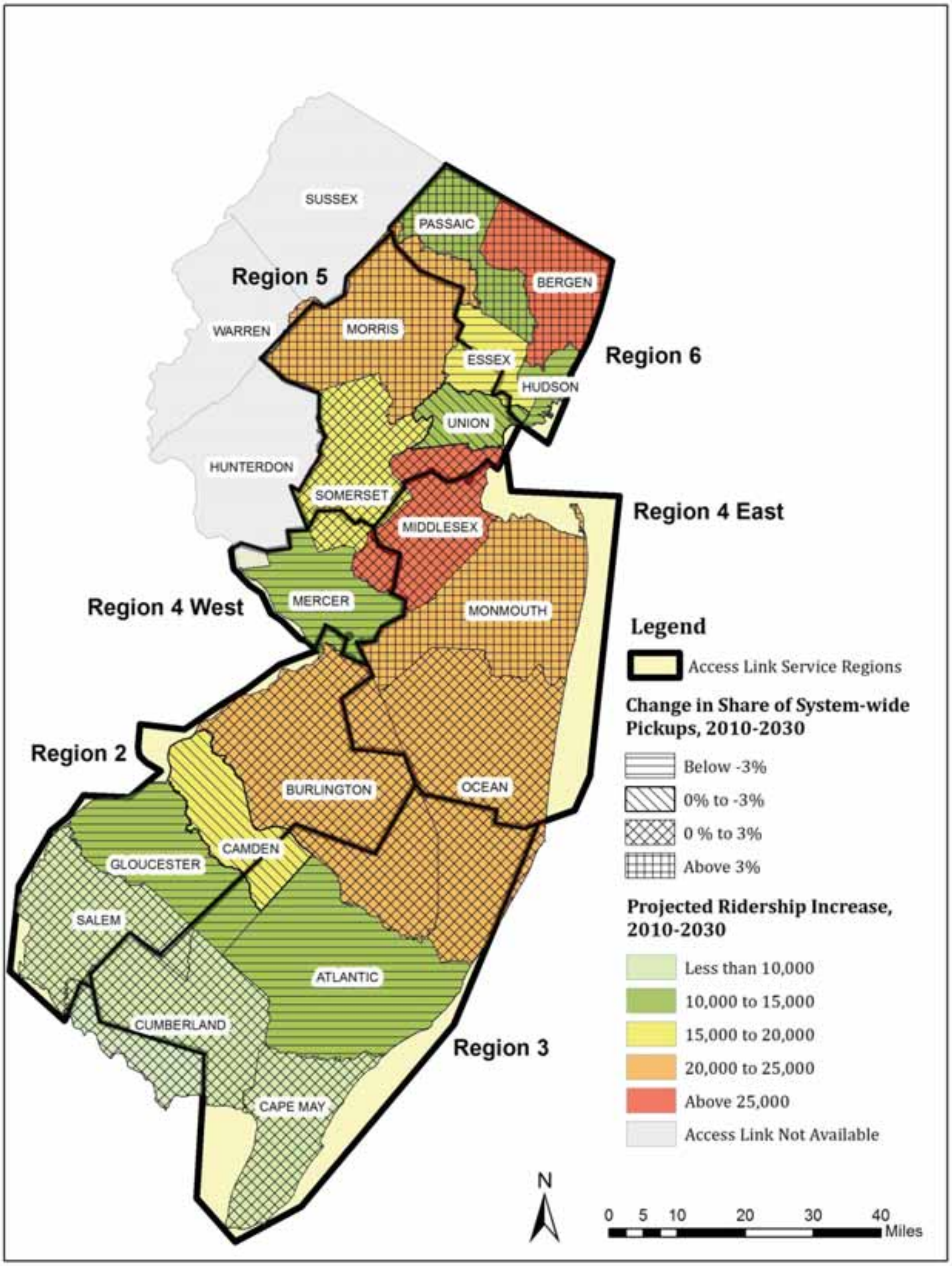


Figure 5. Projected Increase in Number of Access Link Pick-ups and Potential Changes in the Share of Pick-ups for Counties

ACCESS LINK SERVICE

According to the latest information provided by the National Transit Database, NJ TRANSIT operates a transit system consisting of commuter rail, light rail, buses, demand-response services, and vanpools in an area covering 3,353 square miles in New Jersey and the surrounding states, accommodating 267 million unlinked trips annually with a total of 4,411 vehicles. Access Link is a critical component of the region's transit system, serving the federally mandated ADA complementary transit service for customers with disability who are not able to use conventional transit services.

This section is composed of four subsections. First, cost data from other ADA paratransit services around the United States are summarized to establish a benchmark for comparison of Access Link as a whole and for each service region individually. Second, the existing service regions are described. Third, the ridership patterns within each service region are summarized. Fourth, the existing procedures for taking reservations and assigning service are described.

Benchmarking ADA Paratransit Costs

According to 2011 NTD data, the cost of providing ADA paratransit service in New Jersey exceeds the national average for paratransit service, as shown in

Table 8. Access Link is a large system that provides service in 5 service regions. The cost of providing this service exceeds that of other large paratransit services such as Houston's Metrolift ($2.47 per revenue mile) and Los Angeles' Access Services ($3.34 per revenue mile). In fact, similar to Access Link in New Jersey, the Los Angeles system also divides its coverage area into 5 geographic service regions (Figure 6). Although dividing the service area into regions makes operations more manageable, it can also lead to increased fleet requirements and transfers (Quadrifoglio and Shen, 2010). Identifying best practices for structuring service regions is an emerging research area which is of great importance to large paratransit operators such as Access Link. Part of the extended literature review that will be conducted in the beginning of the study will be to determine what lessons from other agencies may apply to Access Link in New Jersey.

Table 8 – Comparison Between Annual Costs of Access Link and National Average for ADA Paratransit Service, 2011

	National Average for ADA Paratransit Service	New Jersey ADA Paratransit Service
Operating Expenses per Vehicle Revenue Mile	$4.50	$5.60

Operating Expenses per Passenger Trip	$33.50	$58.90

Figure 6. Access Services (Los Angeles County) Service Area Divided into 5 Regions

One of the potential reasons for the high cost of providing paratransit service in New Jersey is traffic congestion. Congestion causes reliability problems leading to cost increases. According to the Texas Transportation Institute's 2011 Urban Mobility Report (Schrank et al., 2011), Northern New Jersey, where Access Link Region 5 is located, is one of the most congested parts of the country. According to this report, urban commuters in New Jersey suffer disproportionately higher delays than their counterparts in neighboring states. For example, New Jersey accounts for 27% of the total vehicles miles traveled within the New York-Newark metropolitan area, but it accounts for 46% of the delay. Similarly, New Jersey accounts for 17% of the vehicle miles traveled within the Philadelphia metropolitan area, but it accounts for 35% of the total delay. For Access Link, this excess delay translates to slower trips and less reliable travel times, which in turn lead to greater fleet and labor requirements.

In order to get a better idea about how the ADA paratransit service provided by NJ TRANSIT compares with other agencies, it is useful to look at each region individually. Since there is really no comparable system in the full Access Link service across the state, it is useful to compare the reported costs for each individual region compared with other ADA paratransit systems that have similar service area and annual ridership. Figure 7 shows a comparison of each service region with other ADA paratransit systems that serve similar coverage area and number of trips. The results are more useful for benchmarking Access Link against other services in the United States. Note that regions 4-west and 4-east are combined into a single region 4 for cost purposes, because this is how the cost data was provided.

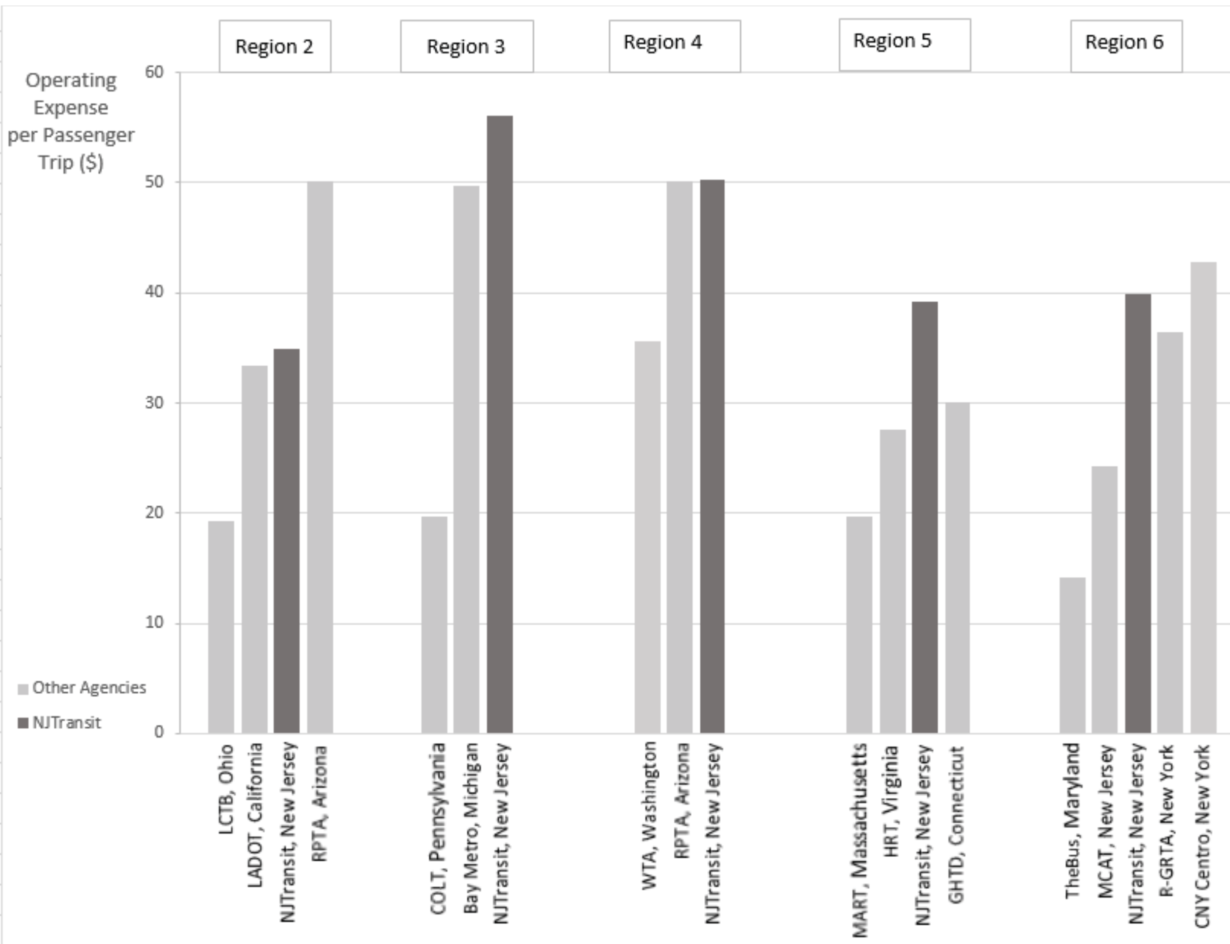


Figure 7. Comparison Between NJ TRANSIT Regions and Other Agencies

Access Link services have more operating costs per passenger trip compared to other similar agencies. This may be due in part to the geographic alignment of the regions, but high costs of land and labor also play a role. The operations and cost models developed as part of this research are designed to separate out these affects so that they can the effects of restructuring the Access Link services can be most accurately reflected.

Existing Service Regions

Access Link paratransit service is provided to eligible users making trips with origins and destinations that are within ¾ miles of local bus routes and within areas designated as *urban core*. We call this area where Access Link picks up and drops off passengers the *service coverage*, and a map of this area is shown in Figure 8. Since Access Link's service area spans most of the state of New Jersey, the operations have been broken down in to six overlapping *service regions*, each of which has a separate fleet of vehicles and garage facilities operated under contract. A map of the geographic extents of the service regions is shown in Figure 9. Note that in the figure, Region 1 represents Region 4-West and Region 4 represents Region 4-East. Areas labeled with more than one number are the overlapping parts of the regions.

A trip that originates and ends in the same region is served by a single vehicle. If a trip is destined for a different region than its origin, the customer will be served by at least two vehicles with a transfer at a designated point within the overlapping area between the region. A trip that originates and ends within the overlapping service region may be served by either region's fleet, depending on scheduling availability.

Since the size of the area over which trips are made is an important determinant of the required fleet size and cost of operations, this information is presented in Table 9. The geographic extent of the service regions only matters where changes affect the extent of the service area covered. Therefore, it is not important to worry about the size or extent of service regions in far reaching rural parts of the state where there is no fixed route bus service provided by NJ TRANSIT.

Existing Ridership by Region

By November 2011, Access Link had a total of 26,343 certified riders and 7,937 active riders. Its service has increased substantially over the years. In 2000, it operated only 134 vehicles, but by 2010 the total number of vehicles increased to 372. Between 2010 and 2011 alone, the number of certified riders and active riders increased by approximately 11%, while ridership increased by 9%. Between December 2009 and November 2011, monthly ridership of Access Link increased by almost 19% from 69,000 to 81,837. The steady trend of increasing ridership is shown in Figure 10, and this trend is expected to continue as the population of the region grows and ages.

Service is provided in each region by assigned contractors or service providers. Currently, ridership is the highest in Region 5 (34%), followed by Region 2 (26%), and Region 6 (18%). Ridership in each of the other three regions is less than half that of Region 6. Not surprisingly, the regions that include cities with a high level of local bus service have a larger number of customers and higher ridership compared to the other regions. However, recent growth in ridership and active riders has been significantly higher in Region 4-East, consisting of Middlesex, Monmouth and North Ocean Counties, compared to the other regions. Among the counties where service is available, most trips are made in Essex County and the least trips are made in Salem

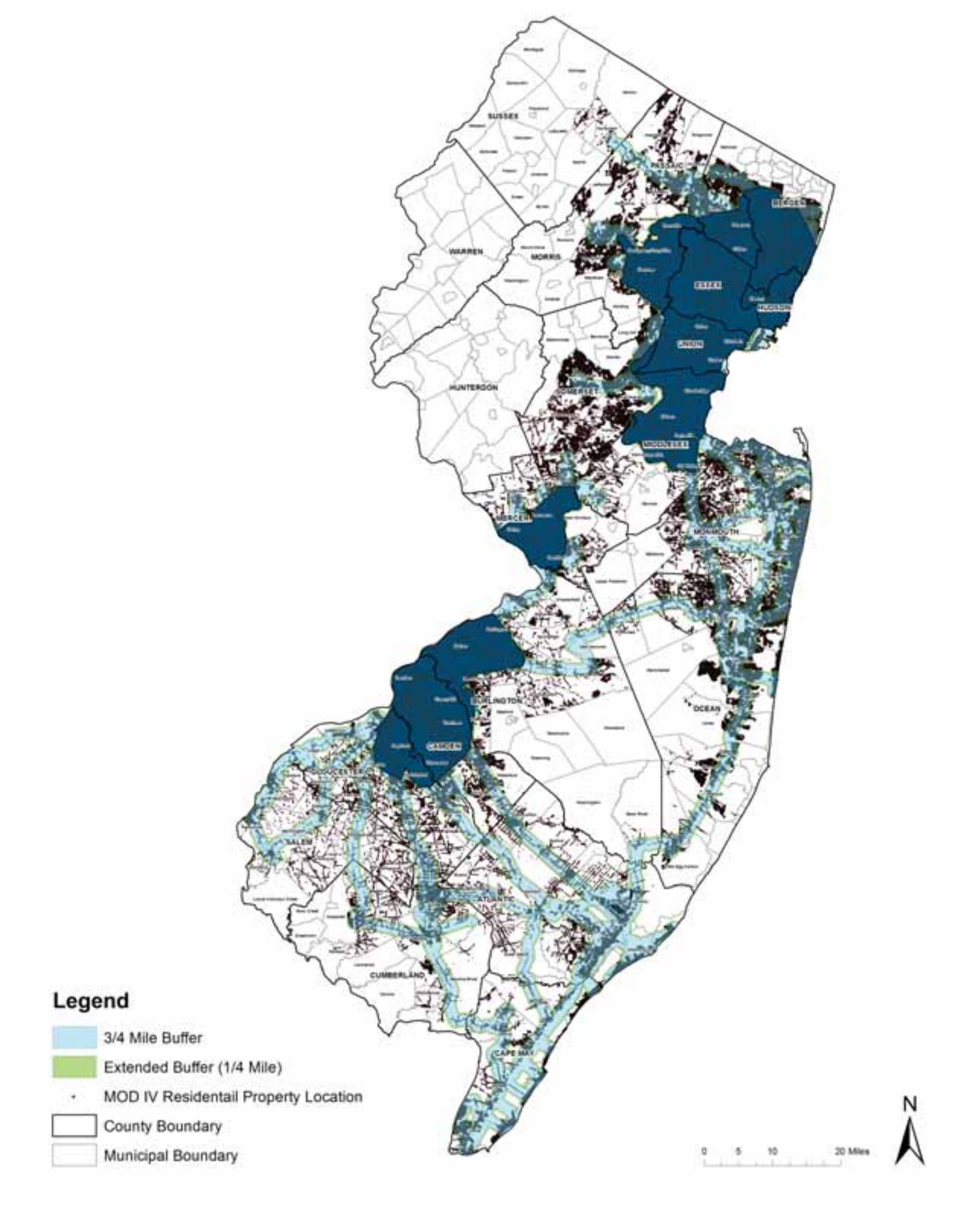


Figure 8. Existing Access Link Service Coverage in New Jersey

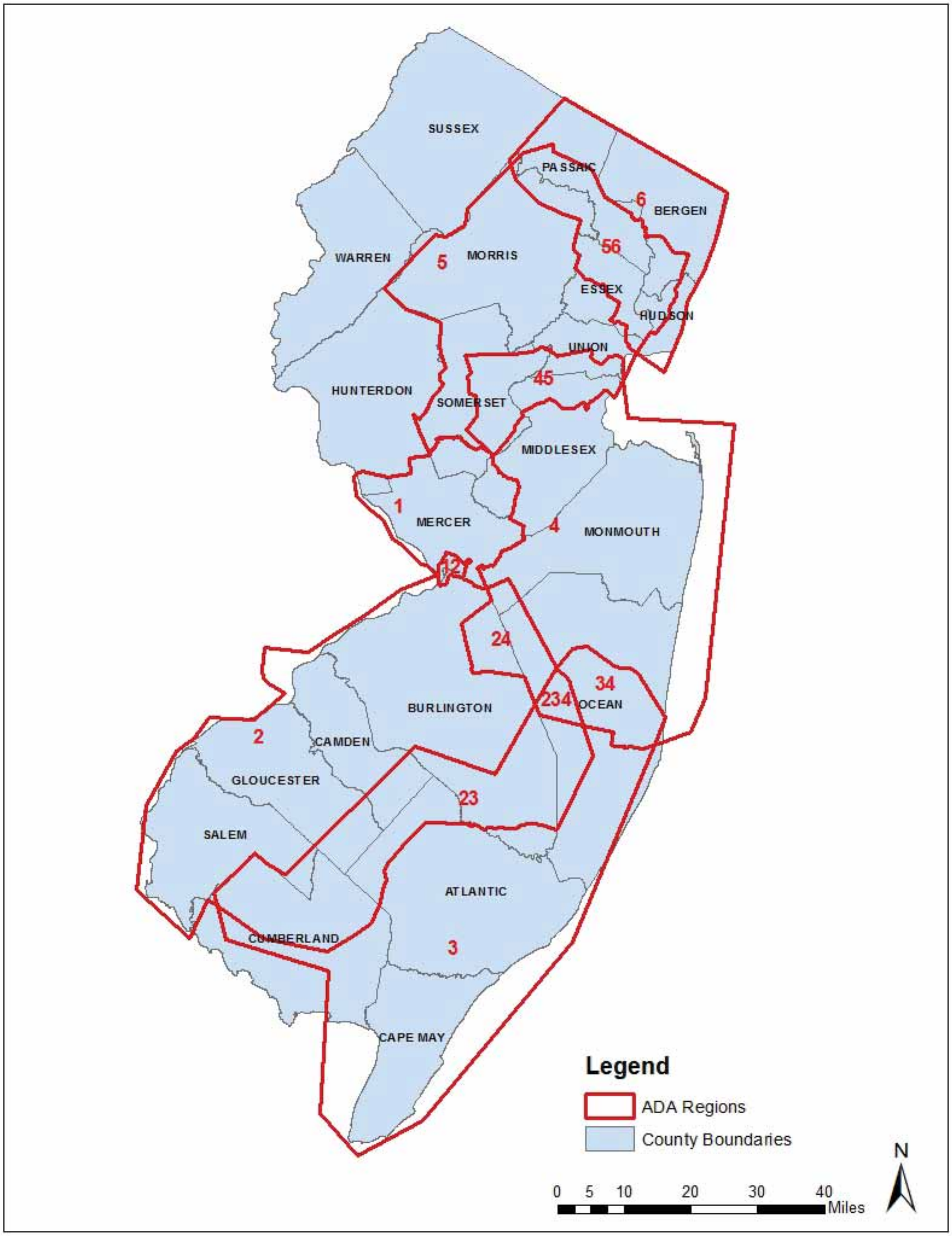


Figure 9. Existing Access Link Service Regions in New Jersey

Table 9 – Service Region and Service Coverage Areas

Region	Service Region (mi^2)	Service Coverage (mi^2)
Subregions		
1	326	118
2	1,413	505
3	1,445	389
4	1,248	390
5	683	210
6	344	121
12	13	11
23	706	121
24	135	26
34	144	23
45	208	110
56	307	243
234	35	0
Total	7,009	2,265
Region Totals		
Region 2	340	128
Region 3	2303	663
Region 4-East	2330	533
Region 4-West	1770	548
Region 5	1197	562
Region 6	651	363

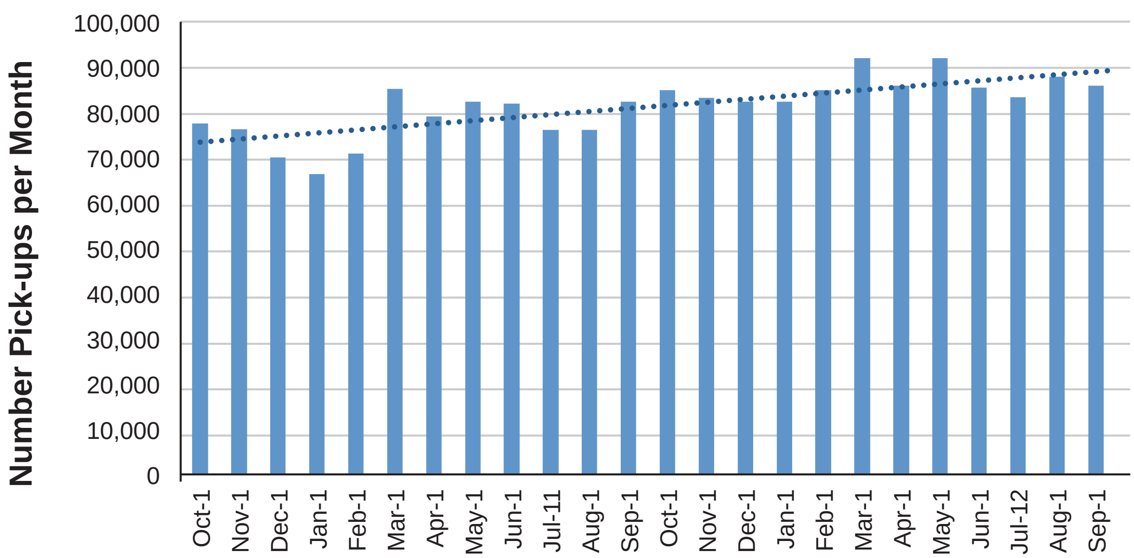


Figure 10. Aggregated Monthly Trips for All Regions

County. Table 10 and

Table 11 summarize the basic characteristics of the Access Link regions.

Access Link customers can reserve their trips in two ways: a subscription service exists to make multiple reservations for recurring trips, and a demand service is available for customers to reserve single trips. Figure 11 shows the relative number of reservations made in each of these categories by time of day. It is clear from the figure that subscription services are more peaked, and it this not surprising as many of these trips are for daily work, activity, or care arrangements. One way that the peaks differ from the common peak periods for general traffic (indicated by dashed boxes) is that the afternoon rush for Access Link service occurs earlier than the afternoon peak congestion on the roadways.

Another important observation from the figure is the displacement of the peaks in demand trips to just after the morning peak and just before the evening peaks of subscription services. There appears to be an effect that subscription services book up the capacity during the rush so that single demand trips must be displaced in time. It is likely that with additional vehicles in service, this peaked pattern would become even more pronounced.

The distribution of the demand over time is an important dimension to consider. The number of vehicles needed to serve the peak demand often determines the fleet size requirements. Since Access Link works by advanced reservation, there are times when the trips that are requested cannot be served at exactly the desired times. Figure 12 shows the relative peaking of Access Link demand by time of day in each region.

Table 10 – Service Area and Annual Ridership for Each Region

Region	Annual Ridership 2010	Annual Ridership 2011	Annual Ridership 2012
Region 2	249,141	259,560	284,247
Region 3	62,848	63,180	68,297
Region 4-East	70,013	79,092	85,169
Region 4-West	66,464	75,096	80,852
Region 5	309,643	330,972	381,511
Region 6	163,558	174,144	199,365

Table 11 – Access Link Clients and Ridership by Region, February 2013

Region	Monthly Ridership	Certified Clients	Active Clients
Region 2	22,905 (28%)	7,615 (25%)	2,075 (24%)
Region 3	5,123 (6%)	2,590 (9%)	629 (7%)
Region 4-East	6,991 (8%)	2,925 (10%)	858 (10%)
Region 4-West	5,662 (7%)	2,109 (7%)	479 (6%)
Region 5	28,669 (34%)	9,215 (31%)	3,019 (35%)
Region 6	13,897 (17%)	5,584 (19%)	1,596 (18%)
Total	83,247 (100%)	30,117 (100%)	8,699 (100%)

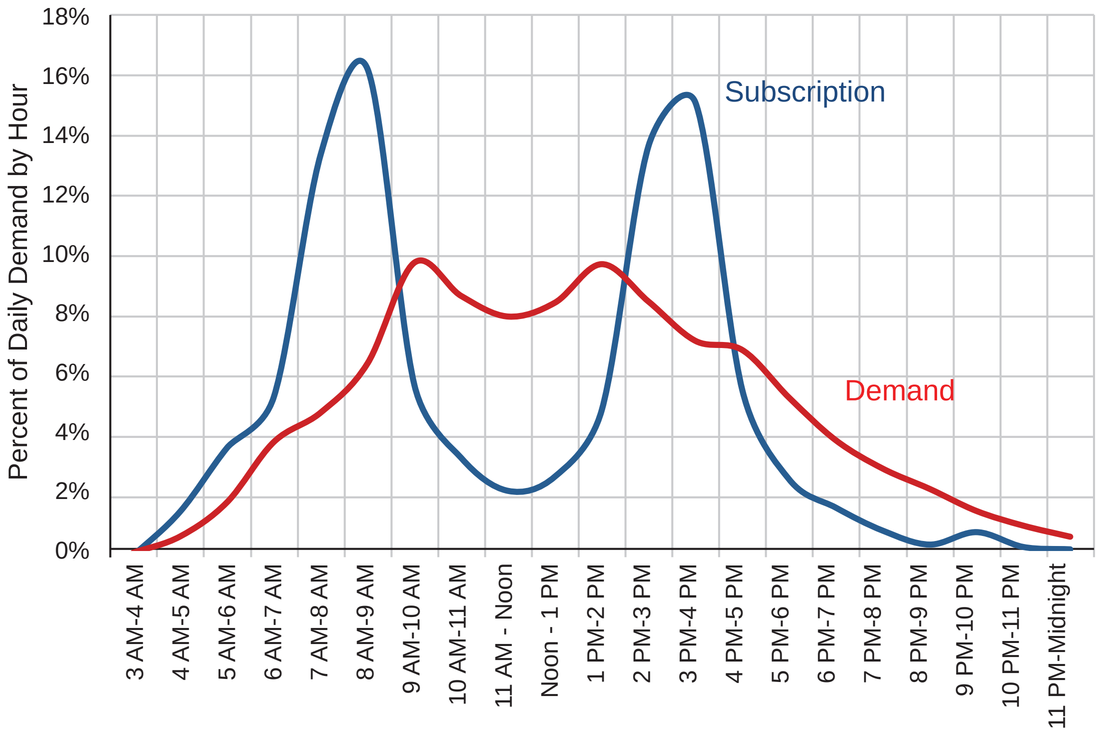


Figure 11. Percent of Daily Access Link Trips by Time of Day and Booking Type (October 2010 – September 2012)

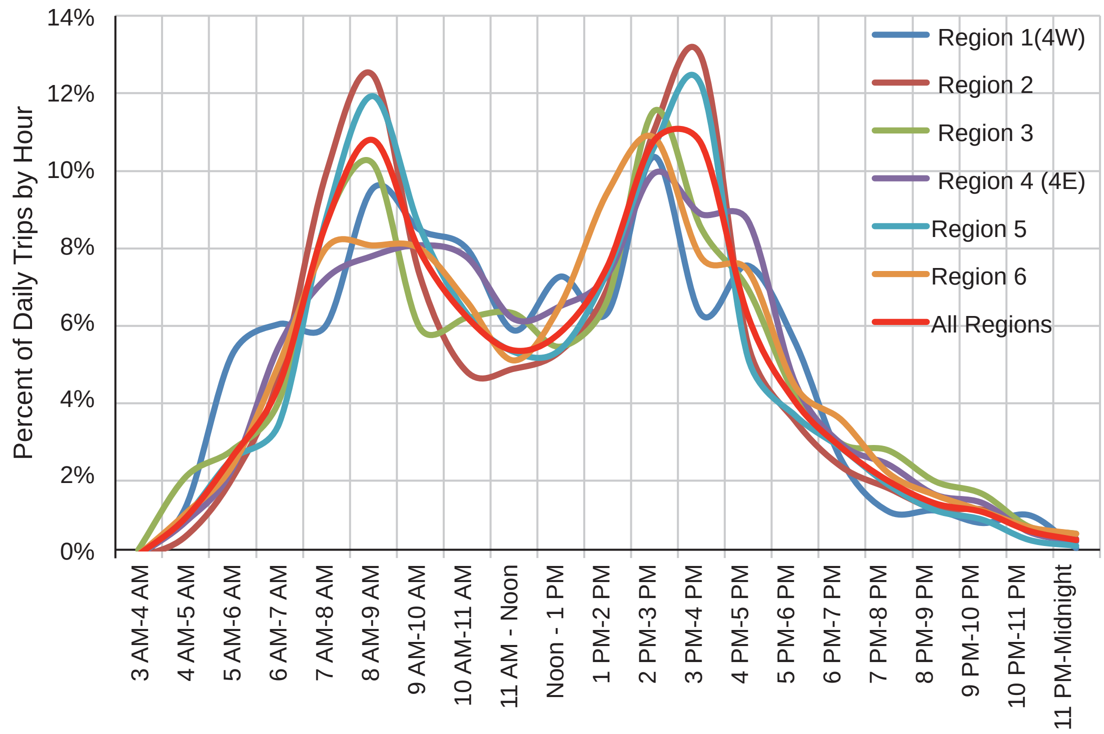


Figure 12. Percent of Daily Access Link Trips by Time of Day and Region (October 2010 – September 2012)

Regions 2 and 5, which are the most urban, exhibit the strongest peaks, but the phenomenon occurs everywhere. This variation in demand over time is significant, and as a result, the operations models that developed for this study consider this variation explicitly.

The spatial distribution of trips across the state is also important for understanding how regional alignments affect trip making and the need for transfers. Making use of the trip data at the level of Public Use Microdata Area (PUMA), an origin-destination table was developed to identify the linkages between different geographic regions. The goal for picking defining geographic service areas should be to pick boundaries that require the fewest number of transferring trips. The complete 70x70 matrix is useful for numerical analysis. Figure 13 shows the distribution of all trips longer than 8-minutes in the state with color-coded lines segments indicating the number of trips between each PUMA. Figure 14 shows a close-up of trips into and out of the urban core in northern New Jersey. The 8-minute threshold is used to show longer trips, which are more likely to cross the buffers where service areas overlap. The figures show clear clustering of trips in the north, central, and southern parts of the state. What is less clear is how to split the cluster in the north, because there are many crossing demand paths.

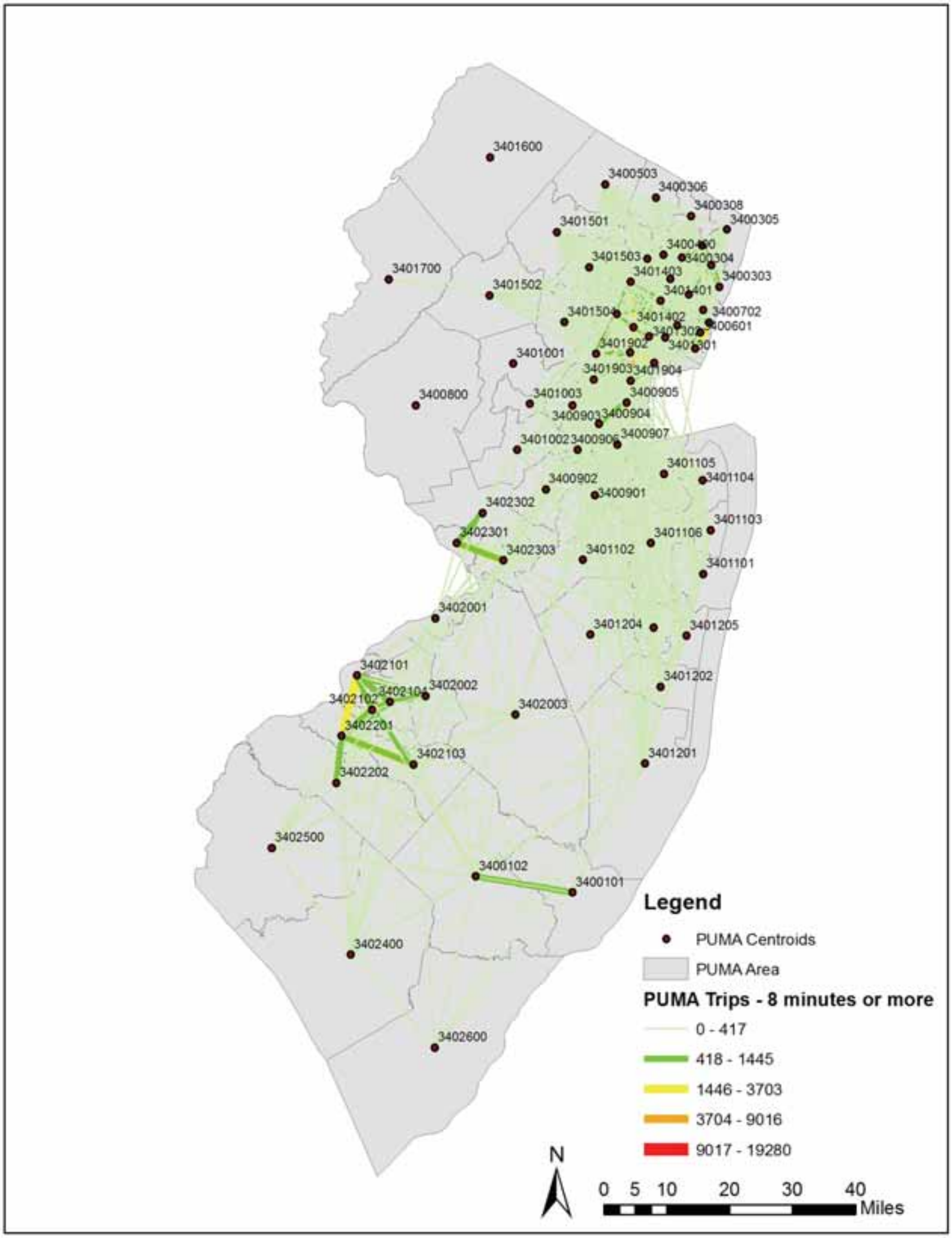


Figure 13. Access Link trips over 8 minutes long by PUMA pair.

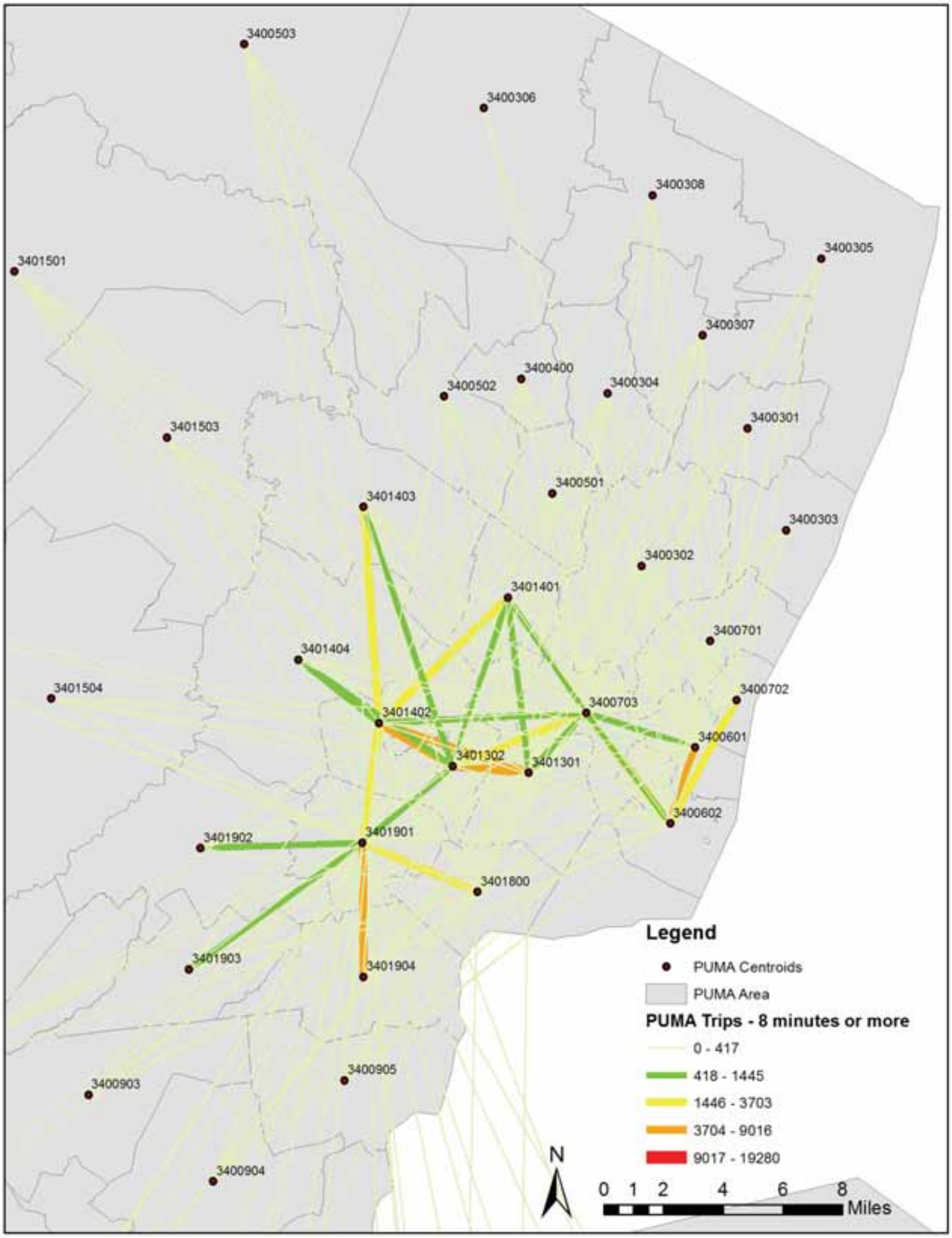


Figure 14. Close-up of Access Link Trips by PUMA Pair in Urban Core around Newark

Existing Operations

Access Link operates a demand responsive transit service in which routes are customized each day to serve an evolving demand of reserved trips. The paratransit service is realized by a fleet of vehicles operating on the streets, avenues, and highways of New Jersey. Although the data set of trip records does not include route information, it does provide with information about the sequence and locations of stops for each run. From this information, ArcGIS with Network Analyst was used to assign each segment to the shortest path on the real New Jersey road network. With additional data about road classifications and speed limits, these assigned routes were associated with estimated network travel times in addition to network travel distances. Table 12 shows a comparison of actual trip travel times and estimated network travel times for each region from a sample of data covering the month of September 2012. The comparison shows that Access Link vehicles spend much more time traveling between points in the network than the free flow speed would imply. A large part of this is due to traffic congestion. The magnitude of these travel times is an indicator of the necessity to use Access Link's experienced travel times as a basis for establishing travel speed estimates for modeling paratransit operations.

In order to account for the variations of operating speeds across the state, Trips have been matched to the real New Jersey road network using the Network Analyst tool with ESRI ArcGIS. The recorded travel time from pick-up to drop-off implies an average speed on the streets of the network. This average speed is an important input for the performance model, because traffic congestion slows down vehicles, requiring a larger fleet in order to maintain the same level of service. Figure 15 shows a map of the average travel time per mile of trips broken down by PUMA. There are 70 PUMAs in New Jersey that had at least one Access Link trip in the travel records, and the slower trip speeds are shown by red color while faster speeds are shown by green color.

Table 12 – Mean actual trip duration and estimated trip time and distance from Network Analyst, 2012

Region	Actual Minutes	Network Minutes	Network Miles
2	37.8	12.7	8.9
3	33.9	16.5	12.6
4-West	26.8	11.1	8.4
4-East	33.2	15.3	11.3
5	38.3	9.8	6.9
6	34.2	9.7	6.5
Total	**36.0**	**11.5**	**8.2**

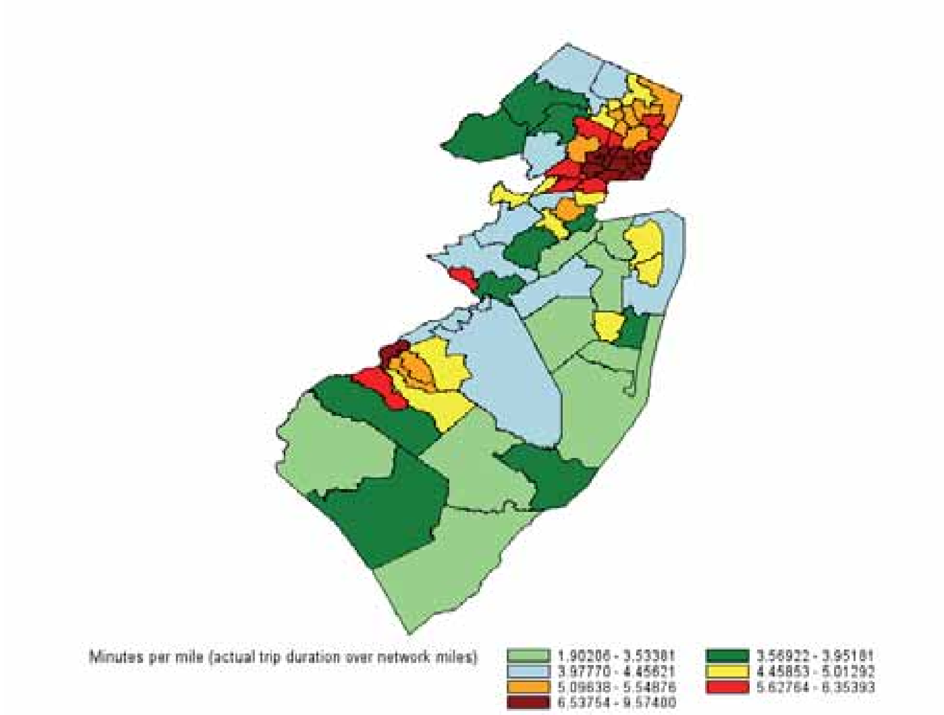


Figure 15. Average vehicle pace by PUMA (minutes/mile)

There is large variation in travel speeds across the state, and it is not surprising that the most congested areas are in the urban cores around Newark and Camden. For comparison, Table 13 shows assumed speeds used in the Trapeze booking system shows much less variation from region to region.

Table 13 – Vehicle Speed Used in Trapeze for Scheduling

Region	Average Speed (mph)
2	27
3	28
4-West	28
4-East	25
5	23
6	25

ACCESS LINK OPERATIONS AND COSTS

This section describes models and analysis of the system's performance and costs from the agency's perspective. Models are developed based on the physical operation of vehicles to pick up and drop off customers throughout the service regions. Parameters of these models are calibrated with existing operations and cost data. These calibrated models can then be used to estimate future performance and costs as demands change. Rather trying to predict specific routes, the approach focuses on the aggregate measures of performance and costs. Therefore, the problem is well suited for continuum approximation, and relatively straight-forward functions provide insights about how service should be structured.

Modeling Operations in a Single Zone

An analytical model that relates the rate that passengers are served by a demand responsive system to the fleet size, service area, and length of the service window for each pick-up is presented in Daganzo (1987). This model has been developed by approximate discrete passenger pick-ups and drop-offs as continuous values (i.e., using continuum approximation). The assumptions of model very nearly match the operating characteristics of an Access Link service region. An additional assumption that the vehicle keep approximately a constant number of passengers on board at all times by alternating pickups and drop-offs is made to facilitate developing a relatively simple mathematical form.

Estimating the Model of Vehicle Hours Traveled (VHT)

We would like to have a model of vehicle hours in operation (often called VHT), which will be correlated with the costs of vehicle operation that accrue with time, such as labor. This is easily estimated as the minimum fleet size required to serve an hour of demand, because these vehicles may be expected to operate for one hour each.

Daganzo's (1987) model has been developed to relate the required operating fleet size to the demand and region area. The original form is shown below, in which the rate that passengers are served by each individual vehicle are summed across the M vehicles in the fleet in order add up to the total regional demand.

$$\lambda = \sum_{i=1}^{M} \lambda_b^{(i)} = \sum_{i=1}^{M} \left[(b_1 + b_2) + \left(\frac{1}{\sqrt{N}} + \frac{1}{\sqrt{n_i}} \right) \frac{0.5r\sqrt{A}}{v} \right]^{-1} \qquad (1)$$

In this model, A is the coverage area, $\lambda_b^{(i)}$ is the rate at which bus i picks up customers, n_i is the number of passengers in bus i after a pickup, b_1 and b_2 is the boarding and alighting time respectively, v is the average speed of the vehicle excluding stops, N is the number of requests waiting to be served, and r is the travel factor that captures the circuity of the network. By assuming each vehicle has the same operating characteristics on average, (1) simplifies to the following result:

$$\lambda = M\left[(b_1 + b_2) + \left(\frac{1}{\sqrt{N}} + \frac{1}{\sqrt{n_i}}\right)\frac{0.5r\sqrt{A}}{v}\right]^{-1} \tag{2}$$

An important value of a model like this is that each parameter has a physical meaning. Therefore, many of the input values for the model can be measured or estimated in advance. Since the continuum model in (2) is derived from probability distributions and geometry, the specific functional form follows the correct physics of vehicle movement in demand responsive system. If such a model can be fitted to the data by changing only a small number of parameters, we can be confident that the specification accurately reflects the reality of Access Link's service.

Fortunately, many of the input variables can be measured or estimated directly from the set of Access Link trip data from October 2010 to September 2012. In fact, only the value of r must be fitted to the data using regression. The fleet size, demand rate, and average vehicle occupancy can all be measured directly. With a little manipulation of (2), the r value for each region may be estimated using the least square linear regression for the following model.

$$M - \lambda(b_1 + b_2) = r_{VHT}\frac{\frac{1}{2}\left(\frac{1}{\sqrt{N}} + \frac{1}{\sqrt{n}}\right)\lambda\sqrt{A}}{v} \tag{3}$$

For the regression, the independent variable is represented by the expression in (3) to the right of r_{VHT}, and the dependent variable is represented by the expression to the left of the equal sign.

Since the demand is not uniformly distributed in weekdays and weekends or even within a particular day, we have broken down the day into three hour time periods and have been done all the calculations once for a weekday and once for a weekend. However, the average duration of pickup and drop-off is assumed to be constant within each region.

The demand rate is the total number of trips per hour, which is calculated for each region based on the given dataset. Then, number of requests waiting to be served is estimated using little's formula in which $N = \lambda T$ where T is the time window. This in fact shows the ability of our model in reflecting the effect of time window, which is a measure of the quality of service.

Parameter M in the model, is the size of the fleet that is that is in operation. For each time period, the number of fleets in operation could be estimated by dividing the vehicle hours traveled by three hours. The vehicle hours traveled is the summation of trip durations, pickup and drop-off durations, stopping times, the times that vehicles are going empty to pick up the next customer, the times that vehicles are going empty from the depot to the first customer, and the times that vehicles are going empty from the last drop-off point to the depot.

The average speed of a vehicle is calculated by dividing the total vehicle miles driven by the total trip duration excluding waiting time. Since the total vehicle miles driven should be the actual distance that the vehicle is running through the network, it is estimated by multiplying the total straight line distance for each run of vehicle by the ratio of network distance to straight line distance which is calculated from consecutive trips. The network distance of the consecutive trips are available in the given dataset, and the straight line distance could be calculated using the longitude and latitude of pickup and drop-off points. For instance, the straight line distance from point 1 to point 2 is such as following:

$$x\ (mile) = 69.1(Longitude2 - Longitude1)\cos\left(\frac{Latitude1}{57.3}\right) \tag{4}$$

$$y\ (mile) = 69.1(Latitude2 - Latitude1) \tag{5}$$

$$Straight\ line\ distance\ (mile) = \sqrt{x^2 + y^2} \tag{6}$$

The model for VHT in an hour indexed by j is determined by solving (3) for M_j, using demand values for hour j.

$$VHT_j = M_j = \lambda_j \left[r_{VHT} \frac{\frac{1}{2}\left(\frac{1}{\sqrt{T\lambda_j}} + \frac{1}{\sqrt{n_j}}\right)\sqrt{A}}{v_j} - (b_1 + b_2) \right] \tag{7}$$

Although the model is flexible enough to allow all of the parameters to change each hour, we work with a model in which only the demand and traffic speed parameters are variable. We assume that the size of Access Link regions, the pick-up window T, the average vehicle occupancy, and the boarding and lighting times for the vehicles are constant over the course of the day.

Estimating the Model of Fleet Size

Although the model for estimating VHT is based on fleet size, for the purposes of this study we want to separate the estimate of the number of vehicles in operation each hour from the total size of the fleet that is required to serve the peak demand. The estimate for the minimum size of fleet that a region must have to serve the demand within the available time window is simply the maximum value of M_j over the course of the week:

$$M = \min_j \{M_j\} \tag{8}$$

Estimating the Model of Vehicle Miles Traveled (VMT)

Although the vehicle miles traveled (VMT) are highly correlated with VHT, we would like to have a separate performance model to estimate VMT for each region and be able to evaluate its correlation with the total annual cost of this system. This distinction is useful, because it allows us to separate the time that vehicles spend actively moving to reach or deliver passengers and the time that vehicles are idle while waiting for the next pickup.

Following from the same geometric assumptions on which the VMT model was developed, the expected distance between two points is

$$E(d) = \frac{1}{2} r \left(\frac{\sqrt{A}}{\sqrt{n}} \right). \quad (9)$$

The average distance traveled to connect λ points when λ is large would be $(\lambda - 1)E(d)$. But since $(\lambda - 1)$ would result in a negative value for the times of the day that the demand rate is low such as 12 AM to 6 AM, we have considered λ instead of $(\lambda - 1)$ in our model. This will slightly overestimate the distance traveled, but the error is small and the value of our decision variables would not change considerably with this assumption. Again, all variables are calculated using the given dataset and the r value is estimated using the least square linear regression model.

$$VMT_j = r_{VMT} \frac{1}{2} \left(\frac{1}{\sqrt{T\lambda_j}} + \frac{1}{\sqrt{n_j}} \right) \lambda_j \sqrt{A} \quad (10)$$

The VMT estimated from this model is the total vehicle miles driven within hour *j* which contains the distance traveled when passengers are onboard, the distance that the vehicles travel empty to pick up the next customer, the distance traveled when the vehicles are going empty from the depot to the first customer, and the distance traveled when the vehicles are going empty from the last drop-off point to the depot.

Operation Model Results

The regression model has been used to fit data for each of the six regions using data that is aggregated in 3-hour periods. The model is applied hour by hour during the day so that as demand increases, we can see how the operating costs increase. The peak fleet requirement over the course of the day is the fleet size that is required for the region. The model has been fitted in region to data points representing 3-hour intervals: 6am–9am, 9am–12pm, 12pm–3pm, 3pm–6pm, 6pm–9pm, 9pm–12am, 12am–3am, and 3am–6am. These data points and the fitted fleet size model are shown in Figure 16 for Region 3 and Figure 17 for Region 5 as a comparison. The horizontal axis represents the term that r is multiplied by in the equation above, which is a measure of the demand for travel (essentially, the trip rate multiplied by the average travel time required between consecutive vehicle stops). The vertical axis is $M - \lambda b$, which represents the number of occupied vehicles in circulation at any given moment. These figures do not

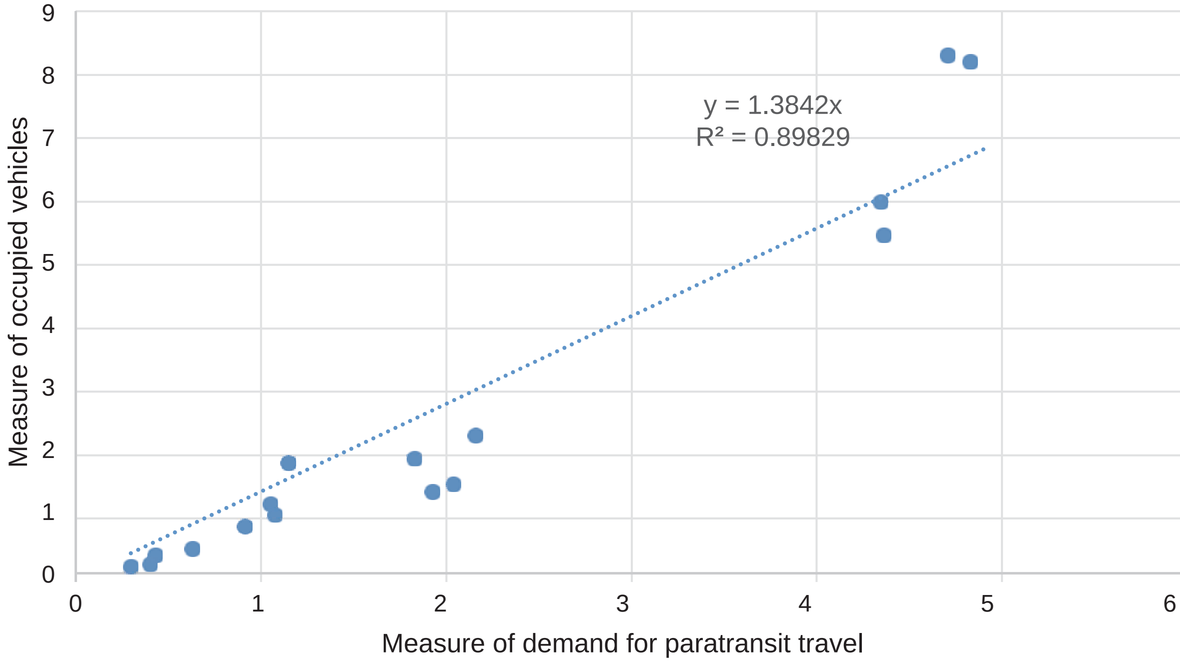


Figure 16. Fleet Size Model Fitting for Region 3

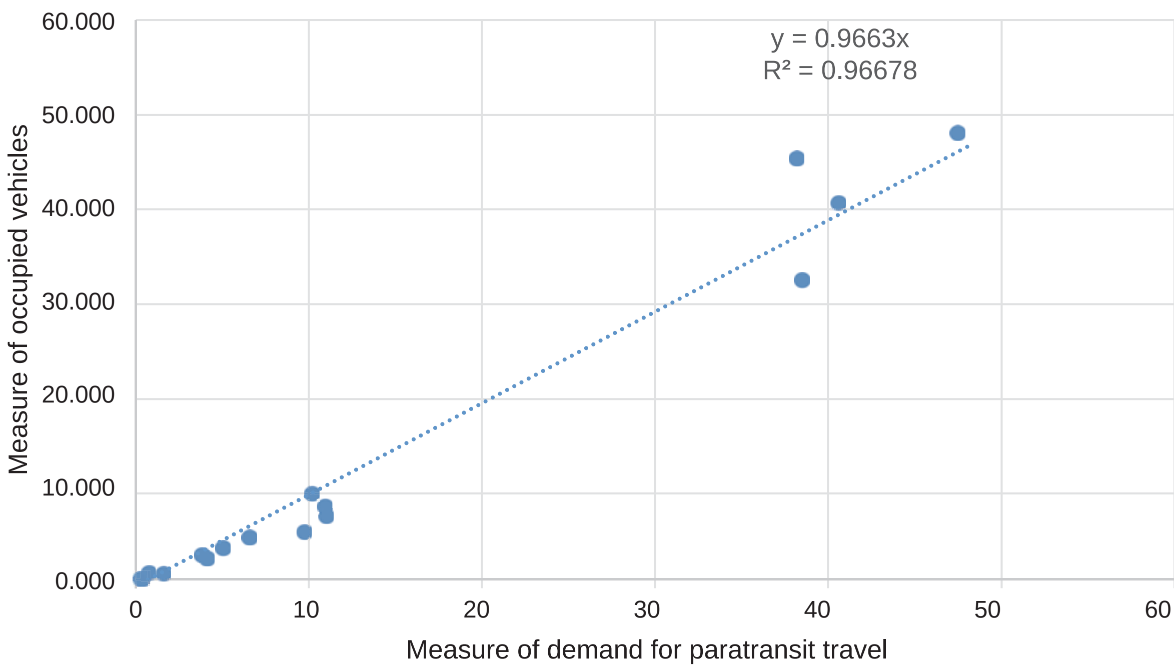


Figure 17. Fleet Size Model Fitting for Region 5

include empty vehicles that are deadheading or waiting, but these are also quantified by a similar model.

The slope of the line in the model is the fitted parameter r, which represents the required resources to serve the demand. The greater value of r in Region 3 is due to the dispersed pattern of trips that requires more resources per trip than Region 5. Table 14 represents the values of travel factor r that have been estimated for each region using the given dataset and the abovementioned models.

Table 14 – The r Values Estimated from the Models for each Region

Region	$\boldsymbol{r_{VHT}}$	$\boldsymbol{r_{VMT}}$	$\boldsymbol{r_{VHT}/r_{VMT}}$
Region 2	1.6471	0.8581	1.92
Region 3	2.2204	1.1924	1.86
Region 4-East	1.5807	0.9875	1.60
Region 4-West	4.0847	1.2489	3.27
Region 5	1.5671	0.8739	1.79
Region 6	1.6063	0.9462	1.70

The r_{VHT} value relates the demand, service area, traffic speed, and pickup window to the number of vehicle hours that must be operated (not counting the time spent stopped for loading and unloading). A greater value of r_{VHT} means that relatively more resources are being used to serve the demand. Similarly, the r_{VMT} value relates the demand, service area, and pickup window to the vehicle miles that must be traveled to carry the demand. If every vehicle hour that was not spent picking up and dropping off passengers was spent moving through road network at the average speed, the values would be equal (i.e., if there is no wasted time waiting, $r_{VHT} = r_{VMT}$). It is clear from Table 14 that $r_{VHT} \geq r_{VMT}$, and the difference reflects the amount of time that vehicles spend waiting with a driver being paid, but not distance being traversed to pick up or drop off a passenger.

To assess how much time is lost due to waiting and schedule inefficiencies, we can look at the ratio of r_{VHT}/r_{VMT}, which represents the extra vehicle hours that are reported beyond the theoretical minimum required to drive at the average speed of traffic between pick-up and drop-off points. It is not possible to entirely eliminate this waste, because demand is not strictly uniform in time or space. In order to serve all trips within the target pick-up window, some additional vehicles will be needed in the fleet, and there will be some time that they spend idling. The results in Table 14 suggest that most regions require 60–92% more vehicle hours than the theoretical minimum, but vehicles in Region 4 West appear to spend a far greater proportion of their time idling.

Another way to look at the model is to consider the more general relationships between the variables. The basic relationships are that in response to inputs of demand rate (trips per area per time), average trip length, region size (area), average vehicle speed, loss time for each pick-up and drop-off, and fleet size we estimate outputs of total vehicle miles operated, vehicle hours operated, and the size of service window required to meet the demand. The qualitative relationships between these values are summarized in Table 15.

Table 15 – Relationship between Model Inputs and Outputs

Input Change		Output Effect		
		Operating Miles	Operating Hours	Required Pick-up Window
Demand	↑	↑	↑	↑
Trip Length	↑	↑	↑	↑
Region Size	↑	↑	↑	↑
Vehicle Speed	↑	↑	↓	↓
Stop Time	↑	↓	↑	↑
Fleet Size	↑	↑	↑	↓

Modeling Operations in Multiple Zones

Extending the model to multiple regions is quite straightforward due to the way that Access Link handles transfer trips. If a trip origin and destination are within the same region, it is served by one vehicle as modeled in the single-zone section. If a trip requires a transfer, then it is essentially scheduled as two trips: a first trip from the origin to the transfer point, and a second trip from the transfer point to the destination. Therefore a transfer trip will appear as two trips in the model; one in each region. The total operations and cost of operating Access Link across the state of New Jersey is simply the sum of the totals across each of the regions. We prefer to estimate the performance and cost models separately within each region first and then sum them together rather than working with statewide averages because demand density and traffic conditions vary so much across the regions.

Modeling Costs Associated with Operations

The total annual cost data of the year 2010, 2011 and 2012 were used to estimate the relationship between the decision variables (i.e., VHT, VMT, and Fleet size) and the total service cost. Since the annual cost per each item of the total cost were only given for Region 2, we allocated this region’s cost pattern to all other 4 regions in order to have a detailed cost break down for each region. Unfortunately, the available annual cost data considered Region 4 East and Region 4 West combined so we also had to combine our estimated decision variables for our cost model for Region 4.

Having the cost break down of each region, we categorized the total service cost of each region into four classes. The revenue from fares is not included, because fares a calculated based on the equivalent bus transit fare for the trip, so the revenue is not expected to be affected by any restructuring of the service as long as the demand does not change.

Costs Related to VHT

The costs that increase with the hours of vehicle operation but not with the miles traveled are associated with VHT. These are primarily related to the labor force, because more vehicle hours require more scheduled hours for drivers and dispatchers.

- Stand-by Driver Cost
- Regional Bonus
- Liquidated Damage Cost
- Total Wages
- Fringe Cost
- Attendance Bonus
- Uniform Cost
- Recruitment/Background Checks
- Overhead Cost
- Profit

Costs Related to VMT

The costs that increase with the distance traveled are associated with VMT. These costs include fuel and maintenance that is associated with driving the vehicle.

- Fuel Cost
- C/L Mileage Cost
- Spare Parts Cost
- Supplies Cost
- Tires Cost
- Oil and Lubes Cost
- Body Repair Cost
- Outside Repair Cost
- Environment Cost
- Towing Cost
- Tolls

Costs Related to Fleet Size

The costs that are associated with fleet size are the costs associated with each vehicle regardless of how much it is driven. These include costs associated with vehicle registration and insurance as well as facilities costs.

- Additional Vehicle Cost
- Mentor Charges
- Vacant Positions Cost
- Coupons
- Facility Cost
- Taxes/Registration Cost
- Non-Driver Wages/Fringe Cost
- Vehicle Insurance Cost
- Communication System Cost
- Safety/Training Cost

Other Fixed Costs

The fourth category of costs consists of those that may not fit into any of the above categories and could be independent of VHT, VMT, and fleet size. In the modeling, these type of costs are considered to be equally divided between the other three cost categories which are related to our decision variables.

- Miscellaneous Expenses
- Other Charges/Deductions Cost
- Utilities Cost
- Professional Service Contract Cost
- Office Supplies Cost
- Employee Welfare Cost
- Travel Meetings Cost

The annual total for each type of cost and the percent of each region's total cost are presented in **Error! Reference source not found.**.

Using a least square regression model we find the relationship between each type of cost and the decision variables. For example, to model VHT costs, we fit a linear model to relate the observed VHT to the observed costs from that category. The components of the cost model are shown below.

$$VHT\ Cost = 14.345VHT + 890{,}636 \tag{11}$$

$$VMT\ Cost = 0.4595VMT + 236{,}326 \tag{12}$$

$$Fleet\ Cost = 37{,}880M + 653{,}069 \tag{13}$$

Table 16 – Total Annual Cost for Each Region, 2012

Region	Costs (% of Total) Related to VMT	Costs (% of Total) Related to Fleet size	Costs (% of Total) Related to VHT	Other Costs (% of Total)	Total costs
Region 2	$1,337,475 (14.3%)	$3,288,714 (35.1%)	$4,567,810 (48.7%)	$177,464 (1.9%)	$9,371,463
Region 3	$448,342 (12.3%)	$1,731,873 (47.5%)	$1,357,618 (37.2%)	$107,142 (2.9%)	$3,644,975
Region 4	$928,261 (12.2%)	$3,084,160 (40.5%)	$3,445,852 (45.2%)	$160,322 (2.1%)	$7,618,595
Region 5	$1,641,574 (12.2%)	$5,513,221 (41.0%)	$5,961,534 (44.3%)	$343,496 (2.6%)	$13,459,825
Region 6	$892,592 (12.7%)	$2,683,016 (38.2%)	$3,325,263 (47.3%)	$128,791 (1.8%)	$7,029,662

The total annual cost model is the summation of these three cost models such as following:

$$Cost = 14.345VHT + 0.4595VMT + 37{,}880M + 1{,}780{,}031 \quad (14)$$

It should be mentioned that the decision variables estimated from the performance model are not the annual values and they need to be converted to annual values in order to be applied as the inputs of the cost model.

The derived cost model is a unique function that is fitted for all regions. This generalization is useful, because it provide a basis to relate the variation in operating characteristics from region to region with the variation in costs, so hypothetical new service scenarios can be modeled and analyzed. However, the regional variation of costs is not reflected in this statewide model, so a calibration factor is introduced to bring each model estimate into alignment with the total costs in each region. By comparing the results of our cost model for the year 2012 and the cost data from NJ TRANSIT for the year 2012, we could examine the performance of our model and calibrate the model for the real conditions. The calibration factors suggested by comparing the model and the given data are summarized in

Table 17 below.

The calibration factor can be interpreted as the ratio of the costs in the region of interest to Access Link's overall average, controlling for the differing amount of VMT, VHT, and fleet size from region to region. This provides a sense of how costly the service is to provide in each region. The lowest cost region is in Region 3, and the highest costs are in Regions 4 and 5. It is likely that part of this difference is due to factors beyond NJ TRANSIT's control, such as variations in the prevailing wage rate and the cost of facilities.

Table 17 – Cost Calibration Factor in Each Region

Region	Calibration Factor
Region 2	0.97
Region 3	0.66
Region 4	1.07
Region 5	1.05
Region 6	0.87

COMPARISON OF GEOGRAPHIC ALIGNMENTS OF ACCESS LINK SERVICE

With the demand, operation, and cost models presented in previous sections, we have the tools to compare the existing Access Link operations to alternative alignments of the geographic regions. The following sections present expected changes in operating costs if the alignment of regions is not changed (i.e., status quo) or if the regions are realigned. Forecasts for the growth in Access Link demand are based on forecasted demographic changes in the state until year 2030. In all analysis scenarios, we assume that the basic operations and cost structure will relate vehicle hours, vehicle miles, and fleet size to costs in the same way that they are in 2012.

Status Quo

The first scenario is estimating the future conditions considering the population growth by year 2030 but without making any changes to the existing geographic alignment of the service regions. The demand estimate is based on the forecasted values from Table 7. Based on the future demand for Access Link pick-ups, we estimate that the demand increase will be spread over the different times if day in the same distribution as in 2012. Since the exact values of average boarding and alighting time, average speed, and the average number of people in the vehicle are not known for the future, these values are assumed to remain the same in the future. In order to maintain the same quality of service (i.e., to pick-up customers within 20 minutes of their scheduled trip time), the model is applied with only the demand parameter changed.

Since the new demands would not be uniformly distributed in the year, we have assumed that the new demands would be distributed in the same pattern that the current demand is distributed within each region. Therefore, the percentage of weekday trips and weekend trips and also the percentage of daily trips in each three hour time periods during the day are assumed to be constant for each region.

Based on the aforementioned assumptions in these two scenarios, the decision variables could be calculated with the new estimated demand and service area. By implementing these variables in the final cost model and applying the correlation factors one could have the total annual cost values and the cost of service per passenger. The costs for the existing service coverage and region alignment in 2012 are shown in

Table 18, and the forecasted costs for the same service coverage and regions in 2030 are shown in Table 19, along with the percent change from 2012 to 2030. The total increase in annual operating expenses for Access Link is expected to increase 19% by 2030 in response to an expected 32% increase in demand. Although total operating costs will increase, the denser demand will allow vehicles and supporting infrastructure to be used more intensely, so the operating cost per passenger is likely to decrease. These changes are shown for total cost in Figure 18 and for cost per pick-up in Figure 19.

Table 18 – Annual Operating Costs for Status Quo, ¾ Mile Buffer, 2012 Demand

Region	Demand (pax/year)	Coverage (mi²)	VHT	VMT	Fleet	Total Annual Cost	Cost/Pax
Region 2	252,340	663	175,305	1,888,959	52	$9,012,331	$35.72
Region 3	62,098	533	50,887	736,451	12	$3,478,683	$56.02
Region 4E	75,593	548	59,305	771,743	17	$7,406,106	$50.87
Region 4W	70,000	128	39,257	424,387	10		
Region 5	327,076	562	276,713	2,278,231	82	$12,972,655	$39.66
Region 6	168,160	363	126,687	1,150,456	37	$7,648,971	$45.49
Total	*955,267*		*728,154*	*7,250,227*	*210*	*$40,518,746*	*$42.42*

Table 19 – Annual Operating Costs for Status Quo, ¾ Mile Buffer, 2030 Demand

Region	Demand (pax/year)	Coverage (mi²)	VHT	VMT	Fleet	Total Annual Cost	Cost/Pax
Region 2	307,732	663	209,385	2,254,025	62	$10,427,147	$33.88
Region 3	85,483	533	66,351	957,751	15	$5,774,147	$67.55
Region 4E	154,513	548	110,645	1,425,854	33	$8,976,176	$37.04
Region 4W	87,824	128	47,436	512,696	12		
Region 5	404,109	562	335,520	2,757,959	99	$14,264,934	$35.30
Region 6	224,653	363	163,918	1,484,817	48	$8,854,370	$39.41
Total	*1,264,314*		*933,255*	*9,393,101*	*269*	*$48,296,774*	*$38.20*
% Change	*32%*	*0%*	*28%*	*30%*	*28%*	*19%*	*-10%*

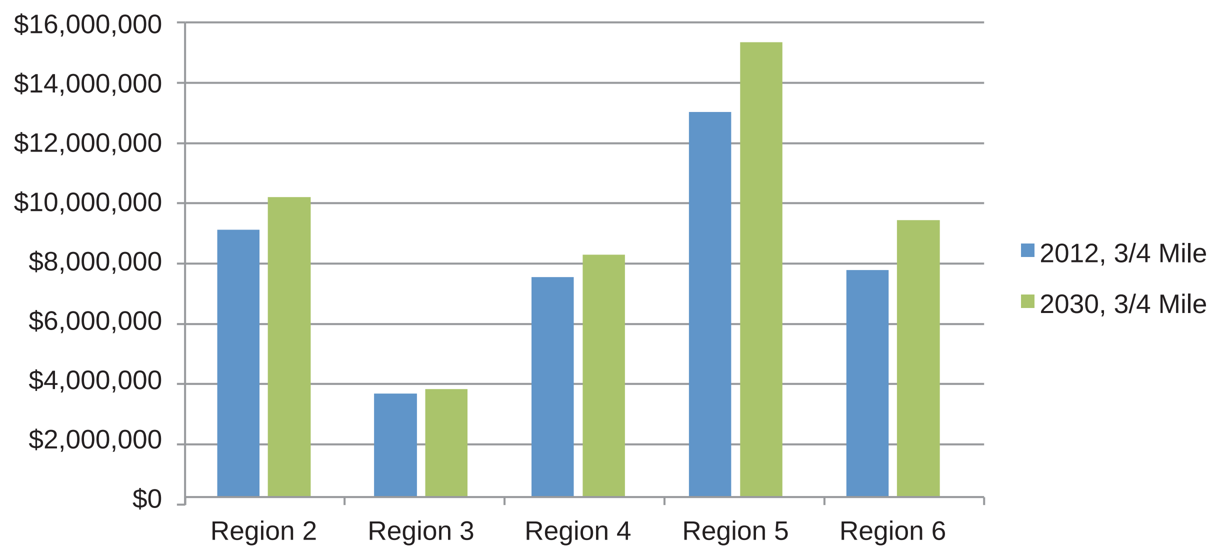


Figure 18. Total Annual Operating Cost by Region

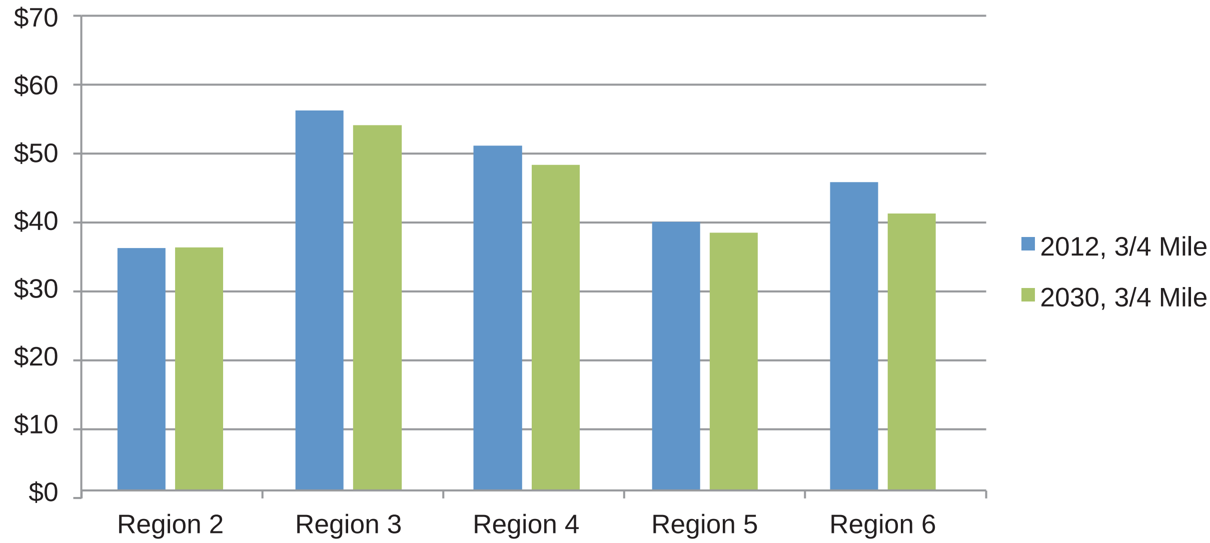
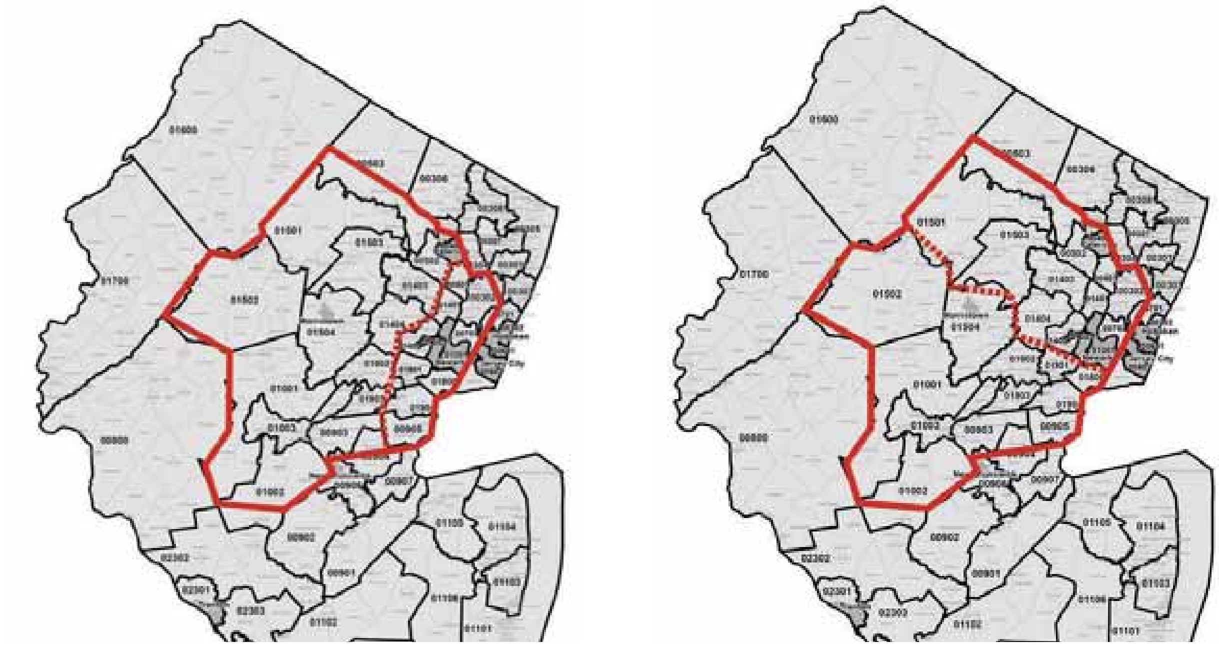


Figure 19. Operating Cost per Pick-up by Region.

Realigning Geographic Service Regions

As a preliminary investigation, the team constructed a set of PUMAs that nearly matches the extents of Region 5. We have then considered two possible cuts: to split the region into an east and west part; or to split the region into a north and south part. These are shown in Figure 20. The resulting origin-destination analysis resulted in a total number of trips within each part and between parts as shown in Table 20. In the upper left and lower right corners are the trips contained within each subregion. In the upper right and lower left are the trips that cross the boundaries illustrated. These provide some indication of where travel demand is going and how many trips would be force to transfer.

The insights from this preliminary analysis are that for different types of cuts there are different implications for the way that the system will work. Specifically, if the regions should remain geographically adjacent to one another and only overlap at borders to reduce transfers, then splitting regions in the urban core should be done in a radial manner (e.g., splitting into a north and south Region 5). This is because there is a large amount of traffic to and from the urban core, and relatively less traffic from suburb to suburb. Alternatively, if regions with a lot of overlapping area are acceptable, then it may make more sense to identify an eastern part of the region where many trips are destined, the demand rate is higher, and the traffic congestion is worse. Rather than making a distinct Region 5 east and west, we considered whether it makes more sense to keep region as it is, but to add a smaller, redundant region in the dense eastern parts of Essex and Union counties.



(a) Split into East & West (b) Split into North & South

Figure 20. Potential Ways to Split Region 5 into Two Regions.

Table 20 – Origin-Destination Trips by Subregion for Region 5

Orig. \ Dest.	East	West
East	378,984	104,629
West	101,128	161,162

Orig. \ Dest.	North	South
North	412,259	60,316
South	64,032	209,296

A second analysis is of the qualitative effects of splitting a region into smaller regions. This addresses the question of whether or not large service regions like Region 5 would be more efficiently served by multiple smaller regions. Splitting and large region into smaller regions introduces additional routing and scheduling constraints but makes each region a smaller operation to manage and oversee. We start by comparing two ways that a large region may be split into two smaller regions:

a) Split into two regions that overlap in the middle (Figure 21);
b) Add a new service region that completely overlaps part of the region (Figure 22).

The purpose of the analysis is to understand approximately how much area of the two regions should overlap. The percentage of the original regions area that is overlapping with the two new regions is denoted by ω.

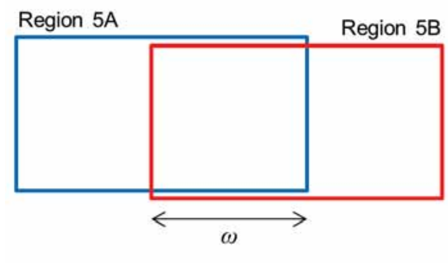


Figure 21. Concept for Splitting a Large Region in Similarly Sized Regions

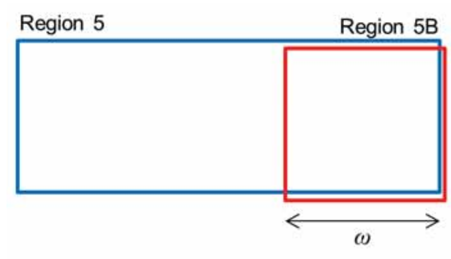


Figure 22. Concept for Splitting a Large Region into an Overlapping Subregion

Figure 23 shows how the total cost changes as a region with the demand and area of Region 5 is split into two regions. The assumption for this analysis is that the demand is uniformly distributed, which allows us to gain some insights about how regions should be split. Note that no matter how the region is split into two regions, the cost is greater than the current cost of operating Region 5 as a single region ($12,900,000 per year). There are two reasons for this increase in cost:

1) splitting a region effectively adds additional constraints to vehicle assignment optimization, which can only increase the total costs, and
2) adding regions introduces some additional fixed costs associated with managing the fleet and operations in the new service regions.

The figure shows that adding an overlapping sub-region is more efficient than two similarly-sized overlapping regions, regardless of the amount of overlap. This strategy of adding an overlapping region has an advantage for users and the operator of not introducing any additional transfers. This keeps the operating cost down and maintains high-quality service for the customers. For a symmetric region, the lowest cost is achieved when this new overlapping region covers 50% of the original area.

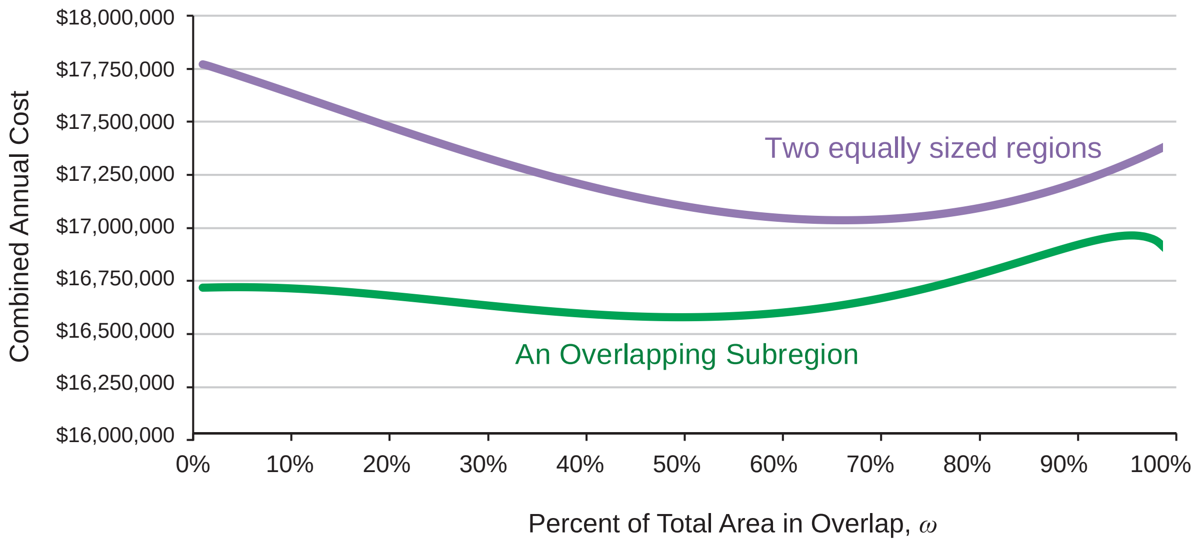


Figure 23. Operating Cost per Pick-up by Region

As an example of a geographic realignment of the service region considered for the study, a new overlapping region covering the busiest parts of Region 5 and 6 is analyzed. The assumption is that trips that have both their origin and destination within this new region will be served exclusively by its fleet. The fleets of Region 5 and 6 serve the remaining trips. An illustration of this scheme is shown in Figure 24. Note that no new transfers are introduced, and some transfers between Regions 5 and 6 are eliminated.

Using detailed origin-destination data at the level of PUMA regions, the number of pickups removed from the existing Region 5 and 6 counts can be calculated and reallocated to the new region. The effect of the realignment on costs is summarized in Table 24. Since the increase in costs is based on the statewide trends for cost per service region, some of the increase in cost may be mitigated by sharing garage and maintenance facilities. The predicted increase in costs can be interpreted as an upper bound on the increase that will result from adding additional service regions. Also shown in Table 24 is a cost estimate for a large region that would result if Region 5 and Region 6 were merged together. The model predicts that the larger region will be cheaper to operate, and this is for two reasons: 1) there are fewer fixed costs associated with the operations because they are consolidated to one, and 2) there is greater flexibility in the routing possibilities so the less constrained problem can be solved more efficiently. An additional benefit of merging regions is that the number of transfers reduced, so the number of pick-ups effectively drops and the users receive a one-ride trip.

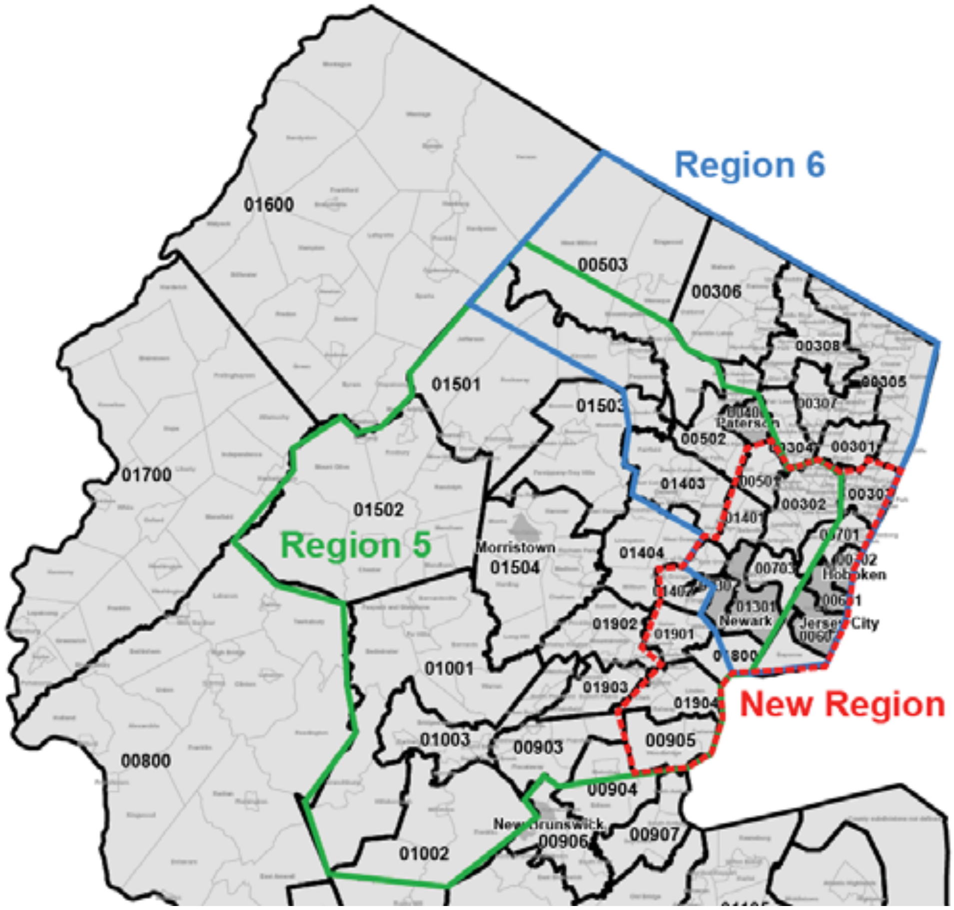


Figure 24. Geographic alignment with new overlapping region in Newark area

Table 21 – Comparison of Existing Geographic Alignments with Split and Merged Alternatives

Region	Parameter	Existing	New Region	Merged
Region 5	Annual Pick-ups	327,076	118,208	
	Service Area (mi^2)	562	562	
	Annual Cost	$12,972,642	$7,478,508	
Region 6	Annual Pick-ups	168,160	119,573	
	Service Area (mi^2)	363	363	
	Annual Cost	$7,648,971	$6,591,031	
New Region	Annual Pick-ups		238,079	475,860
	Service Area (mi^2)		229	684
	Annual Cost		$8,305,317	$18,017,490
Total Annual Cost		*$20,621,613*	*$22,374,856*	*$18,017,490*

CONCLUSIONS AND RECOMMENDATIONS

The following summary of findings and recommendations follow from the data and modeling evidence described in the previous sections. Although the goal of this project is primarily to address the geographic alignment and extent of service coverage for Access Link Service, this is all in an effort to make Access Link provide quality ADA paratransit service in an efficient way. Therefore, observations and recommendations that arose from the data but may not be directly related to the geographic alignment of regions are still included.

Vehicle Speeds

Finding: Vehicle speeds vary greatly by time-of-day and location. Access Link is currently using speed estimates that are applied to entire service regions and change a few times over the course of a day. In this project we made use of speed data at an aggregation level of 3 hour blocks. We have also shown that there is large spatial variation of speeds even at the PUMA level, so current estimates simplify the reality of variable traffic conditions.

Recommendation: Access Link may want to consider updating the speed profiles in the Trapeze software that is used for assigning trips and routing vehicles. Also consider that the distances that vehicle travel on the network is most closely related to the shortest network path, not a triangulation of point.

Forecasted Demand and Costs

Finding: Increased demand as New Jersey's population grows and ages will contribute to greater demands for ADA paratransit service, such as that provided by Access Link. Although total costs always go up with increased demand, paratransit operations exhibit economies of scale, so denser demand also tends to make the cost per passenger go down. This phenomenon is due to the increased sharing of vehicles that occurs in a dense environment so more trips can be fit onto each vehicle.

Recommendation: There is not much that can be done about the trend for growing ADA paratransit need unless there is coordination with other divisions of NJ Transit or other agencies. Understanding the benefits of denser demand for improving service efficiency could be useful for strategic planning. To the extent that opportunities exist to concentration service on centralized areas, this will be efficient. Perhaps other carriers can be contracted to serve some of the infrequent peripheral trips when they do happen.

Vehicle Occupancy

Finding: The distribution of vehicle occupancies is heavily weighted towards single occupant trips, and there is never a time when the average occupancy exceeds 2, so vehicles are mostly being used below their capacity.

Recommendation: Rather than trying to increase the capacity of each vehicle, it would be more effective to focus on keeping the right number of vehicles operating on the road. More vehicles on the road (even if they are small) increases the system's capacity. However, too many vehicles leads to excessive wasteful idling time which contributes to cost inefficiencies.

Efficiency of Each Region

Finding: The resources used to operate Access Link service (controlling for the amount of demand, speed of traffic, and size of region) varies as described by r factors. The most costly regions are not necessarily the least efficient when accounting for the fact that dispersed demand over large areas requires a lot of resources even for a well0run agency. It appears that most of the regions operate with similar levels of efficiency in this regard, except Region 4 West, which appears to have too many vehicle deployed for demand and region size being served.

Recommendation: In general, it is important to look for opportunities to reduce the deployment of resources where waste is occurring. One way to identify this waste is by comparing a regions performance to the modeled performance that was developed based on physical principles and calibrated using statewide data. In some cases there may be special circumstances that indicate waste where another explanation like severe traffic congestion could be to blame. In the case of Region 4 West, however, the traffic congestion and length of trips is shorter than is typical in more congested parts of the state like Region 5.

Cost Model

Finding: The cost data support a linear model of costs with respect to VHT, VMT, and Fleet Size. For all three types of costs, a linear relationship with a statistically significant intercept result, so there are non-negligible fixed costs associated with operating a region. These fixed cost components cause the cost function to exhibit economies of scale, so larger regions tend to have lower costs per trip.

Recommendation: Since it is not clear from the cost data that smaller regions will be more efficient than larger regions, the idea of splitting up large regions to improve efficiency may not be effective. In fact, the cost data suggest that Region 5, although large, is among the more efficient regions per pick-up. Perhaps some facilities and management components should be centralized and a few tasks like dispatching could be separated virtually but operate out of the same depot.

Transfers and Overlapping Regions

Finding: Transfer trips are costly for users as well as Access Link itself. This is because every transfer trip becomes at least 2-pickups involving 2 scheduled trips with stopping for pick-ups as well. Although transfers are not a very large part of the existing Access Link traffic, splitting large regions into smaller regions could make this a bigger problem, undercutting any potential gains in efficiency.

Recommendation: Avoid designing regional alignments that would require additional transfers to be made. It was shown in the previous analysis section that adding strictly duplicative service is better than splitting a large region into to smaller regions that have some overlap. If an important goal is to increase the number of regions (presumably to make each one smaller), then this should be done by adding overlapping regions that may even eliminate some current transfers. The models suggest that merging regions together would actually be more cost effective.

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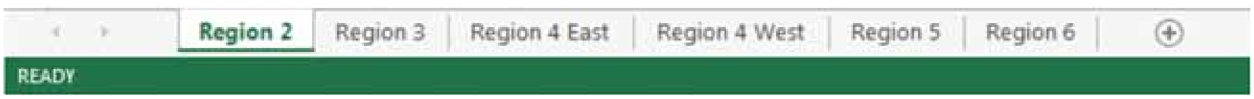
APPENDIX A. SPREADSHEET TOOL GUIDE

Access Link Service Region Analysis toolkit is a spreadsheet designed to help NJTransit to conduct comparative cost analysis. It provides simplified results for total vehicle hours traveled, vehicle miles traveled, fleet size, and annual cost of providing this service based on the models developed by the study and region's characteristics.

Step 1.

The toolkit consists of 6 sheets that represent the six regions of Access Link. The required information for the analysis of each region should be given to its own sheet. The specified sheet should be selected from the bottom left of the workbook.



Step 2.

There are three inputs required for the analysis of each region. Demand Rate, Time Window and Service Area should be given to the **Inputs** box of the worksheet.

a) Demand Rate is the annual number of ADA passengers that Access Link serves in the region. In other words, it is the total annual ridership in each region. Since the service is only provided between origins and destinations that are within a specified distance from the local bus routes, the demand rate would be the annual demand of region's service area. Although, when a part of the local bus route is shared between two different regions, the demand of that joint part should be equally divided between both regions.

b) Time Window is the duration that customers should expect to be picked up from their scheduled pick-up time. Currently Access Link operates with a 20 minutes time window which means that customers may be picked up 20 minutes before or after the scheduled pick-up time. This value should be given in minutes.

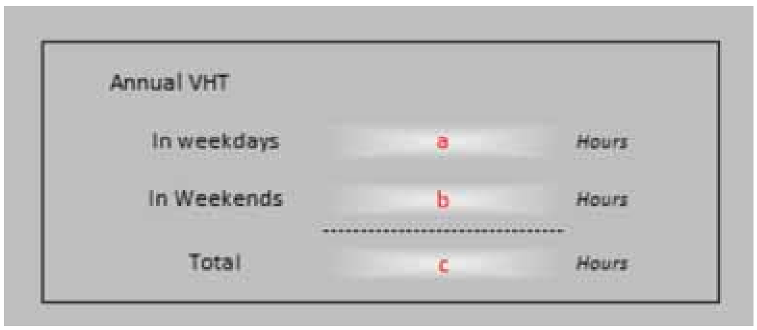
c) Service Area is the area that the service is actually provided in. Service is usually provided between origins and destinations that are within a specific distance of local bus routes which is referred to as the service area. Although, when a part of the local bus route is shared between two different regions, the joint part should be considered in the service area of both regions. This value should be given in square miles.

By entering the information required as inputs, the output values of the worksheet would be demonstrated. There are five boxes displayed in the **Outputs** section of the worksheet.

Step 3.

Box 1: Annual VHT

Annual VHT is the total hours that vehicles travel in a year which includes trip durations, pickup and drop-off durations, stopping times, the times that vehicles are going empty to pick up the next customer, the times that vehicles are going empty from the depot to the first customer, and the times that vehicles are going empty from the last drop-off point to the depot.



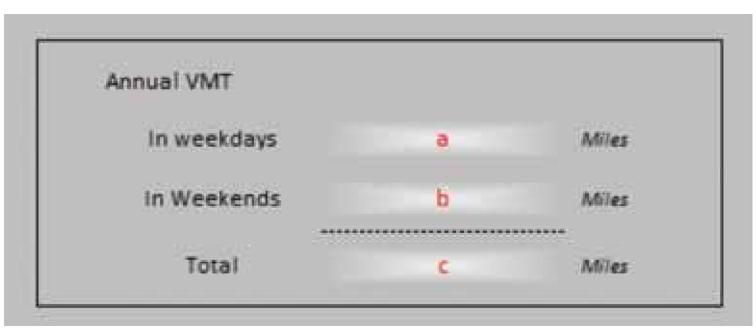
a) Annual VHT for weekdays is the annual value of VHT for Mondays through Fridays.

b) Annual VHT for weekends is the annual value of VHT for Saturdays and Sundays.

c) Total VHT is the total vehicle hours traveled in one year.

Box 2: Annual VMT

Annual VMT is the total miles that vehicles travel in a year including the distance traveled when passengers are onboard, the distance that the vehicles travel empty to pick up the next customer, the distance traveled when the vehicles are going empty from the depot to the first customer, and the distance traveled when the vehicles are going empty from the last drop-off point to the depot.



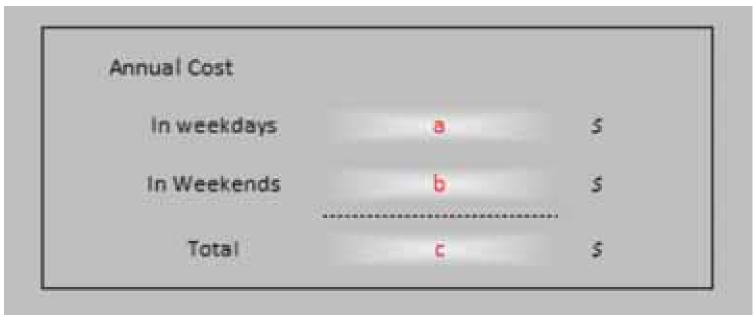
a) Annual VMT for weekdays is the annual value of VHT for Mondays through Fridays.

b) Annual VMT for weekends is the annual value of VHT for Saturdays and Sundays.

c) Total VMT is the total vehicle hours traveled in one year.

Box 3: Annual Cost

Annual Cost in each worksheet is the total cost of operating Access Link service in that region per year.



a) Annual cost for weekdays is the annual cost for Mondays through Fridays.

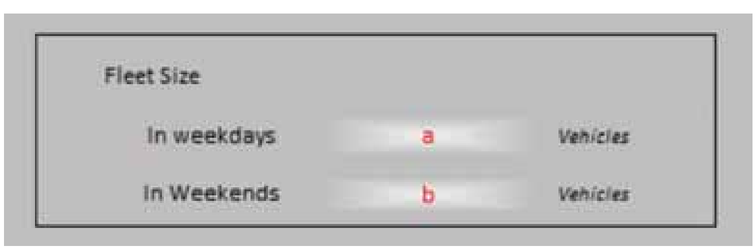
b) Annual cost for weekends is the annual cost for Saturdays and Sundays.

c) Total annual cost is the total cost of operating the service in one year.

Note: For Region 4 East and Region 4 West, Box 3 indicates the cost of operating the service in both regions. So in order to have the annual cost of Access Link Service for region 4, the inputs of both regions, region 4 east and region 4 west, should both be entered in their specified sheets.

Box 4: Fleet Size

Fleet Size is the number of vehicles Access Link Service needs to provide for each region.

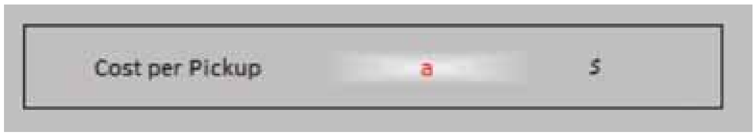


a) Fleet size for weekdays is the maximum number of vehicles that the agency needs to provide on Mondays through Fridays.

b) Fleet size for weekdays is the maximum number of vehicles that the agency needs to provide on Saturdays and Sundays.

Box 5: Cost per Pickup

Cost per Pickup is the cost of operating Access Link Service per trip.

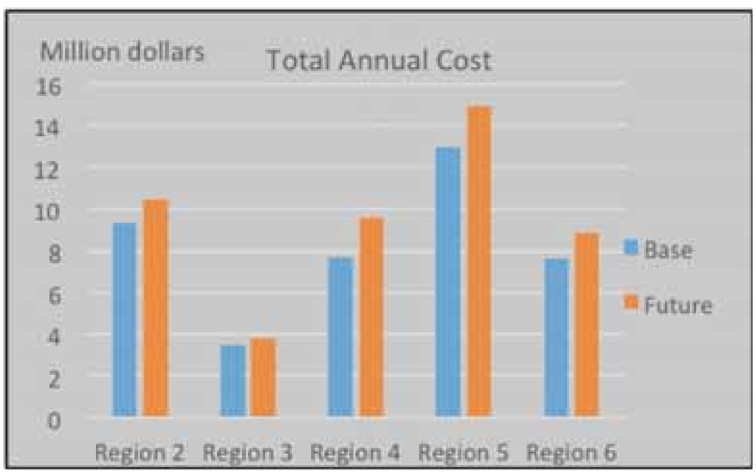


a) Cost per Pickup is the cost of operating Access Link Service per trip.

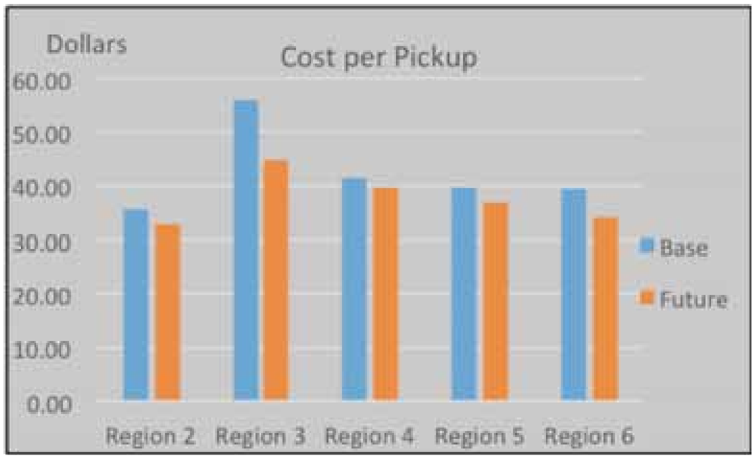
Note: Box 5 for Region 4 East and Region 4 West is the cost per passenger when they are considered as one region. So in order to have this output, the inputs of both regions should be entered in their specified sheets.

Box 6: Graphs

This section is located at the bottom right side of the **Outputs** of each worksheet. It provides graphs for better comparison of region's analysis. Before interpreting the graphs, you have to make sure that the inputs of all six worksheets are entered in their specified cells (Step 1 and Step 2). Then, the first graph summarizes the total annual cost of current situation with the base situation.



The second graph is shown by pushing Cost per Pickup Graph button (For more information check Button 3).



In both graphs, the orange bars represent the Future scenario which are the values entered in the six worksheets and the blue bars represent the Base scenario which is the default values of the Toolkit. These default values are the result of the analysis for the year 2012 which are available in six hidden worksheets called ORegion. (For more information check Hidden Worksheets).

The future scenario of the above sample graphs is related to the population growth for the year 2030.

Buttons

<u>Button 1: Show Assumptions/Hide Assumptions</u>

By clicking on this button, all the assumptions used in the analysis will be displayed and the button will automatically change name to *Hide Assumptions*. By clicking on the *Hide Assumptions* button, the assumptions will be hidden again.

The following figure presents the Assumptions box of region 2 displayed by clicking on the *Show Assumptions* button.

Assumptions

Daily Trip % Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
0.03	0.29	0.16	0.25	0.21	0.05	0.02	0.00

Daily Trip % Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
0.02	0.14	0.26	0.24	0.18	0.10	0.06	0.00

Speed (mile/hr) for Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
16.66	22.94	23.41	22.02	22.48	20.95	15.05	24.89

Speed (mile/hr) for Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
22.65	23.81	25.63	18.77	25.28	23.08	26.99	25.95

Average number of passengers in the vehicle for Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
1.21	1.93	1.26	1.67	2.10	1.15	1.40	1.05

Average number of passengers in the vehicle for Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
1.09	1.20	1.24	1.25	1.22	1.18	1.32	1.04

% Trip Weekday	% Trip Weekend
0.89	0.11

Average pick up and drop-off duration (hr)
0.06

rVHT	rVMT
1.647	0.858

Calibration Factor
0.9685

% Trip Weekday; % Trip Weekend

For each region, it is assumed that the annual demand is divided in to annual demand of weekdays and weekends by a certain percentage. This percentage is referred to as % Trip Weekday and % Trip Weekend.

% Trip Weekday	% Trip Weekend
0.89	0.11

Daily Trip % Weekdays; Daily Trip % Weekends

In order to be able to break down the daily trips to three hour time periods, the percentage of daily trips in each time period is assumed to be constant for weekdays and weekends within each region. These daily trip percentages are displayed in the assumptions called as *Daily Trip % Weekdays* and *Daily Trip % Weekends*.

Daily Trip % Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
0.03	0.29	0.16	0.25	0.21	0.05	0.02	0.00

Daily Trip % Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
0.02	0.14	0.26	0.24	0.18	0.10	0.06	0.00

Average Pickup and Drop-Off Duration (hr)

The average duration of pickup and drop-off is assumed to be constant within each region.

Average pick up and drop-off duration (hr)
0.06

Speed (mile/hr) for Weekdays; Speed (mile/hr) for Weekends

The average speed is assumed to be constant within each three hour time period in a weekday or a weekend.

Speed (mile/hr) for Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
16.66	22.94	23.41	22.02	22.48	20.95	15.05	24.89

Speed (mile/hr) for Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
22.65	23.81	25.63	18.77	25.28	23.08	26.99	25.95

Average Number of Passengers in the Vehicle for Weekdays; Average Number of Passengers in the Vehicle for Weekends

The average number of people in the bus is assumed to be constant within each three hour time period for a weekday or a weekend.

Average number of passengers in the vehicle for Weekdays							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
1.21	1.93	1.26	1.67	2.10	1.15	1.40	1.05

Average number of passengers in the vehicle for Weekends							
3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
1.09	1.20	1.24	1.25	1.22	1.18	1.32	1.04

r_{VHT}; r_{VMT}

The r values of the performance model are displayed for each region.

r_{VHT}	r_{VMT}
1.647	0.858

Calibration Factor

This value is estimated for each region based on a performance measure evaluation from the study. In order to have the real cost value, the value estimated from the cost model is multiplied by this factor.

Calibration Factor
0.9685

Button 2: More Details/Less Details

By clicking on this button, the results of the analysis will be displayed for a weekday and a weekend based on three hour time periods and the button will automatically change name to *Less Details*. By clicking on the *Less Details* button, the details will be hidden again.

The following figure presents the Advance box of region 2 displayed by clicking on the *More Details* button:

Advance

Weekdays

	3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
λ (trips/hr)	5.64	59.09	32.21	50.57	42.54	9.49	4.14	0.41
N	3.76	39.39	21.47	33.72	28.36	6.33	2.76	0.27
λ (b1+ b2)	0.35	3.66	2.00	3.14	2.64	0.59	0.26	0.03
0.5xλ (1/√N+1/√n)√A/	6.21	29.14	19.62	27.97	21.40	7.75	5.13	0.61
Fleet Size	10.58	51.67	34.31	49.20	37.88	13.35	8.70	1.03
VHT	31.73	155.00	102.92	147.61	113.64	40.05	26.11	3.08
VMT (per hour)	88.76	573.70	394.07	528.35	412.74	139.32	66.21	12.97

Weekends

	3-6 AM	6-9AM	9-12PM	12-3PM	3-6PM	6-9PM	9-12AM	12-3AM
λ (trips/hr)	0.64	3.71	6.79	6.34	4.73	2.57	1.47	0.12
N	0.43	2.48	4.52	4.22	3.15	1.71	0.98	0.08
λ (b1+ b2)	0.04	0.23	0.42	0.39	0.29	0.16	0.09	0.01
0.5xλ (1/√N+1/√n)√A/	0.91	3.11	4.66	6.01	3.54	2.41	1.32	0.27
Fleet Size	1.54	5.35	8.10	10.29	6.12	4.13	2.26	0.45
VHT	4.61	16.06	24.29	30.87	18.37	12.40	6.78	1.36
VMT (per hour)	17.66	63.56	102.49	96.76	76.76	47.79	30.51	6.03

The parameters in the Advance box can be found in the following table:

λ (trips/hr)	The total number of pick-ups per hour
N	Number of requests waiting to be served
Fleet Size	Number of vehicles in operation
$b_1 + b_2$	Average boarding and alighting time
n	Average number of people in the vehicle
v	Average speed of vehicles
VHT	The total vehicle hours traveled
VMT (per hour)	The total vehicle miles traveled per hour

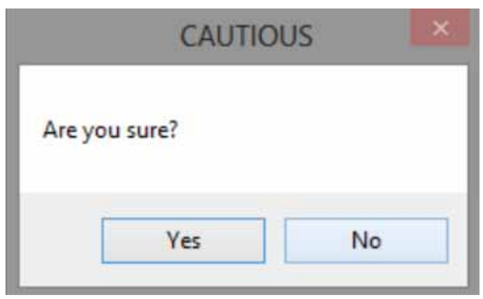
Button 3: Total Cost Graph/Cost per Pickup Graph

By clicking on this button, one of the graphs will be displayed in the **Outputs** box and the button will automatically change name to the other type of graph. If you click on the button again, the next graph will be displayed at the same place.

Button 4: Reset

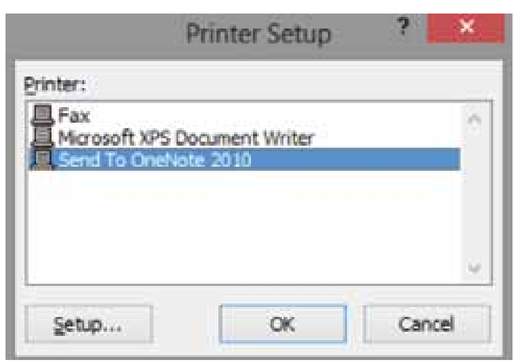
The reset button set the **Inputs** and **Assumptions** to their default values. These default values are the values for the analysis of the year 2012 which are available in six hidden worksheets called ORegion. (For more information check Hidden Worksheets).

By clicking on the *Reset* button, you will be asked if you are certain about making this change.



Button 5: Print Setup

By clicking on this button, different printer options become available. You can click on your desired printer option and click ok.



Button 6: Print

By clicking on this button, you can print the results of the analysis for all regions as a summary table and graphs. This table is available in a hidden worksheet called PrintR1. (For more information check Hidden Worksheets)

Hidden Worksheets

The workbook contains 8 hidden worksheets including six worksheets called ORegions, Graph Summary and PrintR1.

ORegions

The ORegions contain the analysis of regions for the base year 2012 which are considered as the default values. Therefore, the **Outputs** of ORegions are considered as the Base scenario of the graphs. If you want to change the **Inputs** and **Assumptions** of the Base scenario, you need to unhide these worksheets and make your changes. (For more information check Box 6)

The **Inputs** and **Assumptions** of these worksheets are also considered as the default values of the **Reset** button. (For more information check Button 4)

Graph Summary

This worksheet includes the data points of the two graphs provided in the **Outputs**. These data points are the result of the analysis from Regions and ORegions worksheets.

PrintR1

This worksheet contains the results of the analysis for all regions as a summary table and two graphs. It is actually a preview of the **Print** button. (See Button 6)n