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Off peak Rail Transit Service Study – Importance for Auto Reduction and Peak Ridership Growth

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16. Abstract

In the past years, NJ TRANSIT added or enhanced off peak service on several lines, including the Pascack Valley line, the Montclair Boonton line, the Main and Bergen lines, and the Northeast Corridor line. As a result of these additions and enhancements, ridership has substantially increased on these lines. However, little is known about other effects of these additions and enhancements, such as the generation of revenue, reduction in vehicle miles traveled (VMT), and reduction in greenhouse gas (GHG) and other types of emissions. The primary objective of this research is to estimate these effects for the Pascack Valley line (PVL), where off peak service was added in October 2007. A secondary objective of the research is to examine the effect of parking constraints at station lots on PVL ridership.

This research involves a review of literature and practices, analyses of data from past NJ TRANSIT onboard surveys and other secondary sources, as well as extensive analyses of data from an onboard survey and two focus groups involving PVL passengers. The focus group participants clearly indicated that they benefited from the off peak service because of greater travel options and reliability of transit service. The onboard survey indicated that a large number of current PVL passengers drove to their destinations prior to the introduction of off peak service, while many others traveled to distant transit stations on other lines or ferry terminals. The reduction in VMT from these diversions is substantial. The reduction in the number of vehicle trips and VMT contributed to a significant reduction in the emission of GHG and other pollutants. Although the additional transit service modestly contributed to GHG emissions in the region, there was a net reduction in GHG from the off peak service because of the substantial reduction in automobile-generated emissions. This research also examined the effects of station parking constraints on PVL ridership. The analysis suggests that PVL ridership could be significantly higher in the absence of station parking restrictions.

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EXECUTIVE SUMMARY

At a time when New Jersey's highway network has become extremely congested in both peak and off peak hours and highway capacity expansion has virtually stalled because of limited resources and environmental concerns, NJ TRANSIT added new off peak and weekend service to its Pascack Valley line (PVL); added off peak service to its Montclair-Boonton line; and, added more off peak trains to the Northeast Corridor line and the Main and Bergen lines. These additions and enhancements of off peak service contributed to a significant increase in transit ridership on these lines and the commuter rail system as a whole. In theory the addition of off peak service has the potential to generate many benefits, including increase in both peak and off peak ridership; reduction in automobile trips; reduction in vehicle miles traveled; reduction in air pollution; and, increase in farebox revenue for NJ TRANSIT. However, no research had been conducted in the past to estimate these benefits from the off peak services added or enhanced by NJ TRANSIT. This research attempts to fill the gap in the existing knowledge base on the benefits of off peak service.

The primary objective of this research is to estimate the effects of off peak service by specifically focusing on the PVL, where off peak service was added in October 2007. In 2010, a total of seventeen PVL off peak trains were in operation. Between FY-06 and FY-09, PVL ridership increased by 18%, whereas systemwide ridership increased by only 9%. The effect of off peak transit for the PVL is assessed regarding ridership growth, generation of revenue, reduction of vehicle miles traveled (VMT), and reduction in emissions of Greenhouse gases (GHG) and other pollutants. Of particular importance to this research is the diversion of automobile users to transit as a result of the added off peak transit service. A secondary objective of the study is to examine the impact of station parking constraints on transit ridership.

In order to fulfill the objectives of the research, the following tasks were undertaken:

- A comprehensive review of literature pertaining to the benefits from new and enhanced transit service with a special emphasis on identifying methods for estimating the benefits was conducted.
- Focus groups involving PVL passengers to comprehend the perceived benefits from off peak service were conducted.
- An onboard survey of PVL passengers was designed and implemented to observe changes in travel patterns resulting from off peak service.
- An estimate was made of the increase in farebox revenue and reduction in automobile travel and emissions as a result of diversion of trips from other modes to transit after PVL off peak service was added.
- PVL survey data and past NJ TRANSIT survey data was analyzed to determine the effect of station parking constraints on transit ridership.

- Policy recommendations were made based on the analyses of estimation of benefits from off peak service and station parking constraints.

The literature review revealed that only a few studies have explicitly focused on the impacts of off peak transit service, though many studies have analyzed the impacts of new transit systems or routes. Studies on the Los Angeles, Chicago and Washington, DC transit systems noted substantial growth of ridership as a result of new and expanded service. The Chicago study noted significant diversion of automobile trips to transit when a new line was added to the city's commuter rail system. The review of studies on emissions reduction due to transit shows that such studies in the US context are rare, but a number of studies have been conducted in other countries such as Canada, Australia and Taiwan. Some of these studies found a substantial reduction of emissions due to public transit, but other studies found little or no reduction.

The two focus groups, involving PVL passengers, revealed several interesting facts about the participants' perceptions of off peak service and changes in travel patterns after off peak service was added. Most participants mentioned that they benefited from the off peak service and indicated that they used PVL service more often after off peak service was added. Many participants emphasized the importance of the Secaucus Junction Station, mentioning that the off peak service provided greater options to travel to Newark Airport and other destinations for social/recreational purposes. The participants who used PVL for work trips felt that off peak service provided greater flexibility to travel in emergencies during the middle of the day. Station parking was an important consideration for most participants in their decision to use PVL service. Some participants sought further increase in the number of trains and wanted an improvement in communication with passengers during emergencies and service disruptions.

One of the reasons for the overall scarcity of evidence on the benefits of off peak service is the lack of information on changes in travel patterns as a result of new service. To collect data on changes in travel patterns after off peak service was added to the PVL, an onboard survey was conducted in June 2010. The survey collected data from 1,431 passengers traveling in both directions by 24 trains throughout the day. Data were collected on many useful variables, including diversions from other modes to PVL; shifts between peak and off peak travel; and, perceptions about several service elements. The survey data were weighted to make them representative of overall PVL riders before analysis.

The analysis of survey data revealed significant changes in travel patterns by PVL passengers since off peak service was added. While 47% of the passengers did not make the PVL trip before off peak service was introduced, 24% used to make the transit trip by driving alone, 12% used to make the trip by bus, and 7% used to make the trip by another commuter rail line. This provides clear indication of significant diversions of trips from automobile to transit and a modest shift from other transit modes to the PVL. Close to 20% of the respondents reported starting to use off peak service and 5% reported making more peak period trips since off peak service was added to the PVL, indicating that off peak service contributes to both peak and off peak ridership growth.

Analysis of trip origins and destinations of passengers combined with station-to-station fares showed that, including trips to and from New York City and stations on other lines of NJ TRANSIT, the PVL passengers contributed $8.0 million to farebox revenue in the year 2010. When trips to and from New York City and stations on other NJ TRANSIT lines are excluded, PVL passengers generated $6.94 million in revenue, which is only 0.37% higher than NJ TRANSIT's own independent assessment of revenue from the line for 2010 ($6.92 million). Of the $8.0 million revenue generated from PVL passengers, approximately $3.1 million (38.2%) were generated from off peak trains and $2.1 million (26%) were generated from passengers who previously drove or carpooled to their destinations. Diversions from private buses also generated a substantial amount. Finally, the analysis of survey data showed that passengers who might divert to non-rail modes due to a potential reduction in off peak service generated $3.3 million annually. It indicates that as much as 41.7% in revenue loss may occur from a substantial reduction in off peak service. The important findings from the revenue analysis are summarized in Table 1.

Table 1 – Estimated Revenue by Source

Source	Annual Revenue (Dollars)	Percent of Total Revenue
NJ TRANSIT estimate of annual PVL revenue for 2010 (excludes trips from Secaucus Station to New York Penn Station and other NJ TRANSIT Stations)	$6,917,544	
Total annual revenue from PVL *excluding* trips between Secaucus Station and New York Penn Station and other NJ TRANSIT stations	$6,942,954	
Total annual revenue from PVL *including* trips between Secaucus Station and New York Penn Station and other NJ TRANSIT stations	$8,003,993	100.0%
(a) Annual revenue from off peak PVL trains	$3,055,491	38.2%
(b) Annual revenue from peak PVL trains	$4,948,502	61.8%
(c) Annual revenue from passengers who drove alone prior to off peak (drive alone only)	$1,972,631	24.6%
(d) Annual revenue from passengers who carpooled or drove alone prior to off peak (drive alone + carpool)	$2,055,468	25.7%
(e) Annual revenue from diversions from private buses (from Montvale, Park Ridge, Woodcliff Lake and Hillsdale stations)	$177,984	2.2%
(f) Potential annual **revenue loss** from passengers who might use non-rail mode if off peak service is reduced (including peak and off peak riders)	$3,337,810	41.7%

For the purpose of estimating reduction in VMT, the survey respondents who drove or carpooled to their destinations before off peak service was added were asked about their trip distance. VMT reduction was estimated by using these stated distances as well as network distances between trip origins and destinations. VMT reduction was also estimated for those who took trains on other commuter lines and ferry before off peak service was added to PVL. According to the estimates, weekday VMT was reduced between 12.4 and 14.6 million annually after off peak service was added to the PVL. Reduction in annual VMT from different sources is summarized in Table 2.

Table 2 – Reduction in VMT Due to Diversions from Other Modes

	VMT (Millions)
Using Network Distance	
VMT reduced due to diversions from driving and carpool	10.16
VMT reduced due to diversions from other commuter lines and ferry	2.26
Annual Weekday VMT Reduced	**12.42**
Using Stated Distance	
VMT reduced due to diversions from driving and carpool	12.31
VMT reduced due to diversions from other commuter lines and ferry	2.26
Annual Weekday VMT Reduced	**14.57**

Greenhouse gases include several components, including carbon dioxide (CO_2), methane (CH4), nitrous oxide (N_2O), and water vapor (H_2O). Since CO_2 is the most prevalent of the greenhouse gases, GHG is typically reported as CO_2 equivalent (CO_2E).Two methods were used to estimate GHG reduction due to diversions from other modes to PVL after off peak service was added: (a) the EPA method; and, the (b) NJ TRANSIT capital programming method. The estimates of GHG reduction by the two methods are provided in Table 3 for different assumptions on VMT and fuel consumption. The estimates by the NJ TRANSIT method have been provided *with* and *without* the land use and congestion effects.

Table 3 – Reduction in Annual GHG Due to Diversions from Other Modes

Assumed VMT Reduction (Millions)	**Assumed Average Mileage per Gallon of Fuel (MPG)**	**GHG reduced (CO_2E Metric Tons)**
The EPA Method		
12.42[a]	17.8[c]	6,233
12.42[a]	20.4[d]	5,430
14.57[b]	17.8[c]	7,316
14.57[b]	20.4[d]	6,373
THE NJ TRANSIT Method *with* Land Use and Congestion Effects		
12.42[a]	17.8[c]	8,694
12.42[a]	20.2[e]	7,751
14.57[b]	17.8[c]	10,204
14.57[b]	20.2[e]	9,097
THE NJ TRANSIT Method *without* Land Use and Congestion Effects		
12.42[a]	17.8[c]	6,429
12.42[a]	20.2[e]	5,655
14.57[b]	17.8[c]	7,546
14.57[b]	20.2[e]	6,638

[a]Network distance for drive alone and carpool passengers; [b]Stated distance for drive alone and carpool passengers; [c]Estimated from the 2008 Highway Statistics; [d] EPA national assumption; [e]NJ TRANSIT capital program assumption.

Although substantial reduction in GHG emissions occurred due to the diversion of trips from automobile and other modes to the PVL, the 17 PVL trains added in 2007 generated additional GHG emissions. The additional GHG emissions from the new PVL trains were estimated by several methods. The results are shown in Table 4. The first estimate in Table 4 is based on a methodology developed by the World Resources Institute (WRI), the second is based on a methodology that was used by NJ TRANSIT for its 2009 capital program, whereas the third is an estimate by VTC based on national data on passenger miles and energy consumption by commuter rail in the Transportation Energy Data Book (TEDB), 2011. Even if one accepts the most conservative estimates of additional GHG from off peak trains (2,067 MT CO_2E) and GHG savings due to diversions to PVL (5,430 MT CO_2E), the additional GHG generated by the off peak trains is only about 38% of the GHG reduced due to diversions from other modes to PVL.

Table 4 – Additional GHG Emission from PVL Off Peak Trains

Method	Annual CO_2E Estimate (Metric Tons)
WRI Method	2,067
NJT Capital Program Method	1,999
VTC Estimate Based on TEDB Data	1,762

In addition to reducing GHG, diversion of trips from other modes to PVL also reduced Volatile Organic Compound (VOC), Nitrogen Oxide (NOx) , Carbon Monoxide (CO), Fine Particles (PM2.5), and Sulfur Dioxide (SO_2). Reduction in these pollutants was estimated by using the NJAQONE model developed by Michael Baker Jr., Inc. for the New Jersey Department of Transportation. The reductions in annual VOC, NOx, CO, PM2.5, and SO_2 due to diversions to PVL from other modes were estimated to be 2,661 kg, 2,955 kg, 51,417 kg, 141 kg, and 87 kg, respectively.

The analysis of parking constraints also showed interesting results. First, among all NJ TRANSIT commuter rail lines, the proportion of passengers arriving at stations by automobiles is the highest for the PVL, and therefore availability of parking is more important for this line than other lines. According to the 2005 NJ TRANSIT onboard survey, 65% of the PVL passengers drove alone and parked, whereas for the other lines, the proportion varied between 34% and 57%. Second, among all lines, station parking restrictions are most severe at PVL stations. Thirteen of the 28 lots at the PVL stations do not allow non-resident parking, constituting 46% of the total lots and accounting for 38% of all parking spaces on this line. In addition to prohibiting non-residents from parking at station lots, lots at several stations on the PVL charge higher rates from non-residents and many municipalities prohibit on-street parking near stations. In the PVL onboard survey, 24% of the respondents cited non-resident parking restriction as a concern. Analysis showed that the passenger catchment area for stations is usually larger for those stations that do not impose restrictions on non-resident parking than those that do. This may be construed as an indication that station parking restrictions on non-residents deter potential riders from taking transit.

The most critical observations from this research are the following:

- Since off peak service was added to the PVL in 2007, total ridership has noticeably increased. Between FY-06, when off peak service was added, and FY-09, when this research began, average weekday trips on the line increased by 18%, from 6,000 to 7,075. Survey data indicates that the number of new riders has also substantially increased since that time. According to the 2010 PVL survey, 13.2% new users started using the PVL in 2008, and another 13.9% new users started in 2009. These percentages are significantly higher than the period before off peak service (2-7% each year).

- A substantial amount of trip diversions have occurred from automobile to the PVL since off peak service was added. According to the survey, 24.4% of the PVL passengers made the trip by driving alone and another 1.2% passengers carpooled prior to the off peak service.

- VMT, GHG and other emissions have decreased substantially because of the diversions. VMT decreased in the range of 12.4-14.6 million annually. According to the most conservative estimate, net GHG (CO_2E) decreased by 3,363 metric tons annually (38%).

- Off peak trains contribute substantially to the overall farebox revenue from the PVL. A total of $3.1 million or 38.2% of the PVL revenue is generated by the off peak service. A large proportion of the PVL revenue is generated from passengers who diverted from automobile (26%).

- Evidence is found that the attractiveness of peak period travel has also increased since off peak trains were added to the PVL. Survey data indicates that some increase in peak period ridership is attributable to greater travel options and flexibility for riders to travel at other time periods. Five percent of the survey respondents mentioned that they use more peak period trains because of off peak service. More importantly, 61% of the passengers who mentioned that they would consider diverting to non-rail modes if off peak service were reduced were peak period riders.

- Station parking is a significant issue for the PVL primarily because of non-resident parking restrictions imposed in many station lots owned by local municipalities. Non-resident parking is currently imposed on 13 of the 28 lots on the PVL, accounting for 38% of the parking spaces.

Based on the empirical observations, the following recommendations are made:

- The VMT and GHG benefits observed in this study clearly indicate that off peak service should be seriously considered whenever opportunities arise. The spreading of morning and afternoon peak periods for highway travelers over the years suggests that there will be more demand for off peak trains in the coming years.

- When decisions are made about increasing or decreasing the number of off peak trains, the effect of the change should be considered on both peak and off peak period ridership instead of only off peak ridership because off peak trains increase the overall attractiveness of a line, and thereby increases peak period ridership.

- On the basis of the focus groups and the survey questions on satisfaction with PVL service, it seems appropriate to increase the frequency of off peak trains and operate all off peak trains between Spring Valley and Hoboken instead of operating some trains between Hoboken and New Bridge Landing. To implement this recommendation, detailed analysis of costs and benefits as well as capacity constraints will be needed. A re-examination of additional passing sidings to allow enhanced off peak service frequency should be considered through more detailed analysis.

- Although this research indicates that the GHG reduction from off peak service far outweighs the additional emissions from the added trains, GHG emissions from trains can be further reduced by using alternative fuels.

- Issues relating to station parking constraints, especially non-resident parking restrictions at station lots, should be addressed. Alternative parking opportunities or low cost parking management improvements to allow increased non-resident access or off peak access should be further studied to improve ridership and assist municipalities in improving their operations. Other access modes, such as shuttles, may also be useful for certain stations.

- The focus group and the survey results provide support to NJ TRANSIT’s ongoing efforts to implement improved communication during service disruptions through the utilization of its Score CARD and customer satisfaction surveys. Improved communication is likely to result in greater ridership and passenger satisfaction in the long run.

INTRODUCTION

The increasing congestion on major New Jersey highways and trans-Hudson tunnels and bridges has made the conditions ideal for promoting commuter rail service. As a result of the extreme nature of congestion on highways during morning and afternoon peak periods, many automobile users have begun to travel during off peak periods, leading to a spreading of the conventional peak periods in both directions. In contrast to highway travel, commuter rail service in New Jersey has remained predominantly peak-oriented. Because of this focus on peak period service, certain components of the rail system, including the Hudson crossing, are currently operating at or near capacity. Under these circumstances, promotion of off peak commuter rail service has become a serious consideration for NJ TRANSIT.

During the last few years, NJ TRANSIT has added new off peak and weekend service to its Pascack Valley Line (PVL); added off peak service to its Montclair-Boonton Line; added more off peak trains on the Northeast Corridor Line (NEC) and the Main Line; and, the Bergen Line. These additions and enhancements of off peak service contributed to a significant increase in transit ridership on these lines and the commuter rail system as a whole. The addition or enhancement of off peak service has the potential to benefit transit agencies and society at large in several ways. Unfortunately, only a limited amount of research has been conducted nationally, and virtually no research has been conducted in New Jersey, to comprehend and estimate the benefits of new or enhanced off peak rail service.

The primary focus of this study is the PVL, where several off peak trains were put into operation in October 2007. A map of the PVL is presented in Figure 1, showing the station locations. While no trains operated from Spring Valley after the morning peak period in the inbound (New York or Hoboken bound) direction in the past, NJ TRANSIT added 7 new trains in this direction in October 2007 in an effort to promote off peak service. This increase in the number of trains in the inbound direction was accompanied by 6 new off peak trains in the outbound (Spring Valley bound) direction. By early 2010, NJ TRANSIT was operating 10 inbound and 13 outbound off peak trains, including early morning, midday, and evening hours.

In the years after off peak service was added to the PVL, ridership on the line increased substantially. Between FY 2006, when off peak service was added, and FY 2009, when this research began, average weekday trips on the PVL increased from 6,000 to 7,075 (an increase of approximately 18%). More importantly since off peak service was added, boardings increased in every station of the line, including the three stations in Rockland County, New York. However, besides the increase in ridership, very little was known until this research was conducted about the impacts of PVL off peak service. Identifying and estimating these impacts is important not only to evaluate the service itself, but also to draw inferences about the lines where off peak service was enhanced in recent years and to make policy decisions for future enhancement of off peak service on other lines.

Figure 1 – The Pascack Valley Line

Research Objectives

The general objective of this study is to identify and estimate the impacts of off peak commuter rail service in New Jersey by focusing on the case of the PVL. The specific objectives of the study are to:

- Document modal shifts, such as diversions from personal automobile to transit, and identify new riders resulting from improved off peak service on the PVL.

- Document how off peak service on PVL has affected passengers' use of both peak and off peak service, and examine how passengers changed their time of travel because of the off peak service.

- Document and quantify the benefits from PVL off peak service in terms of additional revenue generation as well as reductions in automobile trips and air pollution.

- Identify parking constraints at PVL station lots and determine its potential impact on rail ridership.

- Generalize the findings to the extent possible and assess how the observed results may affect transit planning, operations and investment decisions in the future.

LITERATURE REVIEW

A comprehensive literature review was conducted as a part of this research. The relevant literature was identified with key word searches in Google, Google Scholar, Transportation Research Information Services (TRIS) of the Transportation Research Board, Transportation Research Board Annual Meeting CD-ROMs, and the Rutgers University Library's online tools. The review consisted of academic publications as well as reports prepared by transportation agencies.

Consistent with the primary objective of the study, the literature review focused on the effects of new rail service on existing passengers, diversions from other modes, VMT reduction, reduction in air pollution, and generation of revenue. Literature was also reviewed on the benefits of reductions in air pollution from transportation. Because of the study's secondary objective of examining the effect on station parking constraints, literature on the effect of station parking was also reviewed. The reviewed literature is described in the following sections.

The Effect of Service Expansion on Transit Ridership and VMT

Numerous studies have explored the factors that affect transit ridership. However, only a few studies(1,2,3) have examined the relationship between off peak transit service and ridership. They have generally concluded that level of off peak service is directly associated with ridership volume. Compared to off peak service, there is much more evidence about the relationship between overall service expansion and ridership growth. For example, Jia(4) provides an account of rapid ridership growth for the Washington Metropolitan Area Transit Authority (WMATA) of Washington, DC, during a period of service expansion. The study attributes long-term ridership growth of the system to latent demand, new demand from developments near stations, and diversification of service, including the addition of off peak and weekend service. It concluded that the 750,000 daily passengers carried by the WMATA in 2008 can be translated to the equivalent of removing 350,000 vehicles from the region's roadways each day.

Using nationwide data from the National Transit Database, Polzin and Page(5) noted an association between service expansion and ridership growth for LRT systems. Mieger and Chu(6) observed that even the Metro Green Line of Los Angeles was able to generate a substantial ridership in spite of being written off as a failed project when it started. Peng, Dueker, Strathman, and Hopper(7) studied the impact of transit service improvement for the Tri-County Metropolitan Transportation District of Portland, Oregon, through a modeling effort. They concluded that the demand and supply of service are simultaneous. Transit ridership is affected by the level of service, but level of service is affected by ridership in the previous year.

A guidebook prepared for the Transit Cooperative Research Program (TCRP) H-32 project(8) provides some interesting facts about the relationship between service enhancement and ridership growth for transit systems. The study reported that service adjustment was the most common type of strategy used by transit agencies nationally, but only a small proportion used service expansion as a strategy. It appears from the data provided in the report that both service expansion and adjustment of headways were generally associated with growth in ridership.

Kain and Liu,[9] Labelle and Stuart,[10] and Dueker and Bianco[11] studied the impact of transit service expansion using different methodologies. From their study of the Houston and San Diego transit systems, Kain and Liu[9] concluded that the ridership increase for the two systems occurred due to significant increases in service, fare reductions, and growth of population and employment. Although the study shows that ridership growth was associated with service expansion, it is difficult to separate the effects of service increase from the effects of fare decrease and growth of population and employment. This example shows the difficulties in determining the independent effects of service expansion on ridership growth.

Labelle and Stuart[10] conducted a study that examined the effects of adding the Orange Line to the commuter rail system operated by the Chicago Area Transportation Authority. The study noted that the new line generated an average weekday ridership of 37,500 passengers within the first 12 months, raising transit ridership by 31% and increasing transit's mode share from 16.4% to 21.5% in the specific corridor. From an onboard survey of passengers, the study found that about 25% of the riders on the new line were automobile users before the line opened, whereas 63% of the riders were previously using buses and 11% were using other components of the rail system. The study attributed the substantial shift from buses to the new rail service to the reduction in travel time. Based on certain assumptions, the study estimated that as a result of the new line, 5,700 average weekday cold starts and 160,500 average weekday automobile vehicle kilometers (approximately 100,000 vehicle miles) were avoided.

While Labelle and Stuart[10] examined the shift in mode choice from automobile to transit, Dueker and Bianco[11] examined the effect of a new light rail corridor on automobile ownership in Portland, Oregon. The study found that, compared to a control corridor, automobile ownership changed very little along the segment of the new light rail corridor close to the city center, whereas it showed a slight decrease along the outer segment. In simple terms, there was a slight effect of the new line on automobile ownership in the outer areas, but there was little effect in the inner parts of the city. Based on their observations, the authors concluded that a discernible mode shift from auto to transit due to a new transit system can occur only in the long term. The study shows that the effect of transit service expansion or improvement on automobile ownership and use may be different in different parts of a region served by a rail line.

Although it is a common practice to attribute ridership growth and automobile diversions to VMT reduction, some studies have shown that the overall long-term impact of new transit service on regional VMT is difficult to estimate. The difficulty in translating new transit ridership to long-term VMT reduction arises from the fact that simultaneous changes may take place in other relevant factors. Yoh, Haas, and Taylor[12] highlighted the importance of population and employment growth as a factor potentially distorting the association between ridership growth and VMT. Pucher's[13] contention that ridership growth is associated with general economic conditions can be used to argue that directly converting ridership growth to VMT reduction overlooks the influence of regional economic growth. Similarly, from data presented by Polzin and Chu[14] it is evident that although ridership growth and VMT have an overall negative association, ridership growth is usually affected by economic upturns and downturns. Haire and Machemehl[15] and Lane[16] show that there is an association between changes in fuel price and transit ridership, and therefore automobile trip diversions to transit may not be solely attributable to a new or enhanced service at a time when fuel prices fluctuate significantly.

To summarize, the review of studies on transit service expansion, ridership growth, and diversion from other modes to expanded service provides a few insights. First, service expansion is usually associated with growth in ridership because of latent demand. Second, ridership growth may be associated with several external factors, including economic conditions and growth of employment and population, making it difficult to separate the effects of service expansion on ridership. Third, to a great extent, diversion from other modes, including buses and automobiles, is dependent on the travel time of the expanded rail service relative to the alternatives. Fourth, in places where rapid growth of ridership has been experienced (such as Washington, DC), diversification of service to off peak periods and growth of non-work trips have been important.

The Relationship between Transit and Air Quality

One of the reasons for an increasing emphasis on improving air quality is its impact on health. The World Health Organization[17] estimated that air pollution is one of the top ten causes of morbidity. The agency noted that air pollution, which mainly affects urban areas, is responsible for an estimated 460,000 lives lost annually. A study by Younger at al.[18] observes that exposure to air pollution is linked to various respiratory illnesses, cancer, birth defects, asthma, and fatigue. Due to a better understanding of the health impacts of air pollution, there is a growing concern about reducing air pollution produced by all sectors, including transportation.

Studies have shown that transportation is a major contributor to air pollution. According to a report[19] by the Cambridge Systematics, transportation contributes 28% of the total GHG emissions in the United States, second only to electricity generation (33%). To address the high GHG emission from the transportation sector, the study recommends a greater role of public transportation by means of expansion of service on existing routes, construction of new infrastructure, and fare subsidization.

The reason for the increasing emphasis on public transportation as a means to address GHG emissions is that VMT has increased significantly over the years because of increasing use of private vehicles. According to Bailey, Mokhtarian, and Little,[20] VMT increased from 1.5 trillion in 1982 to 3 trillion in 2006 despite a much slower growth of population. The same study also concludes that public transportation reduces gasoline consumption by 1.4 billion gallons and VMT by 102.2 billion per year. When the congestion relieved by transit is considered together with replaced auto trips and energy used by transit itself, transit saves 4.2 billion gallons of gasoline per year. The total effect of public transportation is a reduction of 37 million metric tons of GHG per year.

A report prepared by the Environmental Protection Agency[21] provides detailed information on the contribution of different modes of transportation to GHG. According to the report, passenger cars contribute 35% of all transportation sources, while light trucks contribute 27% and heavy-duty vehicles (including trucks and buses) contribute 19%. Rail contributes only 2% of the GHG emissions from transportation, but of this, 89% is caused by freight trains, while the remaining is generated by commuter rail, light rail, and intercity rail. Based on the study's observations, one can conveniently make a case for the expansion of commuter rail service to reduce GHG emissions.

The role of public transportation in reducing GHG has been emphasized in several studies published by the Transportation Research Board. TCRP Report 93, authored by Feigon, et al., [22] provides a detailed discussion on the role of transportation in reducing GHG emissions. It provides a detailed discussion on transit technology and land-use requirements for GHG-reduction strategies to be successful. One of the key conclusions of the report is that in order to successfully address GHG emissions, transit has to be able to attract a sufficient number of riders.

TCRP Report 20,[23] prepared by Cambridge Systematics and Apogee Research, covers a wide range of topics on benefits and costs of transit. In a section on transit's environmental impact, it mentions that an average single-passenger automobile produces a substantially larger volume of pollutants than a passenger mile of transit.

A report prepared by Davis and Hale of the SAIC Energy Solutions Operation[24] claims that if all current public transit riders used personal vehicles instead of transit, they would generate an additional 16.2 million metric tons of CO_2. The report mentions that an average private vehicle emits about 1.0 pound of CO_2 per mile, or 20 pounds for a 20-mile trip. Assuming an annual average of 12,000 miles and an average of 22.9 miles of travel per gallon, the study estimates that an automobile emits 4.6 metric tons of CO_2 per year (one metric ton=2,205 pounds).

A study by ICF Consulting[25] analyzed the effects of several potential transit strategies for reducing GHG emissions and energy use in New York State. However, the study did not consider rail service expansion as an alternative.

The American Public Transit Association[26] (APTA) also highlights the role of public transportation in reducing GHG and describes the methods for estimating GHG reductions at the agency level and project level. The agency-wide estimation considers emissions from transit vehicles and emissions avoided due to mode shift to transit, and the difference between the two is shown as net savings in emissions. For project-level estimation, it mentions the Federal Transit Administration's New Starts process for converting VMT reductions to GHG by applying standard emission factors.

Although a large number of studies have shown that reduction in VMT can reduce emissions and improve air quality, and public transportation produces significantly less pollutants than personal vehicles, only a handful of studies have empirically examined the impact of public transportation on air quality. Chen and Whalley[27] estimated that the opening of the Taipei Metro resulted in the reduction of tailpipe carbon monoxide by

9% to 13%. However, the study found no evidence of any reduction in ground-level ozone pollution. Nor did it find any evidence of automobile travelers adjusting their time or route of travel as a result of the new transit system. In another study, Hsu and Guo[28] examined the geographic distribution of air pollutants before and after the completion of the Taipei Metro. The air pollution distribution model developed in the study shows that pollutants are distributed more evenly over space after the completion of the transit system than before. That is, the areas with highest pollution were relieved whereas the areas with low pollution level remained fairly unaffected. Both studies indicate that the reduction of air pollutants from a transit system depends not only on the amount of diversion from automobile to transit, but also on the time of day when trips are made and the geographic areas where trips are diverted.

Geographic distribution of emissions over urban space was also studied by VendeWeghe and Kennedy[29] for the Toronto Census Metropolitan Area. They found that beyond the transit-intensive core of the city, private automobile emissions far surpassed emissions from residential operations. The study also shows that GHG emission per capita for auto users was several times greater than transit users (27.1 tons per capita for automobile user against 0.10 tons for transit user). Another study[30] for the Toronto area shows that CO_2 emissions per person mile from single occupancy vehicles is 13.5 times higher than Toronto's commuter rail system. Another Canadian study[31] concludes that the transit system in Vancouver, consisting of SkyTrain and electric trolley buses, is 100 times more efficient as private vehicles in terms of GHG emissions.

In a study for Sydney, Australia, Hensher[32] used a simulation model to predict the impact of different policy alternatives on GHG emissions. Only one rail-related alternative was considered, namely, reduction of fare by 50%. The model results show that the alternative would result in GHG reduction of only 0.42%, whereas doubling of bus service frequency would reduce GHG by 4.63%. Although the study shows that an increase in rail usage from reduced fare would only marginally reduce GHG emissions, since it does not consider increase of rail service, nothing can be concluded about the potential effect of such a strategy. Another Australian study[33] concluded that the key to reducing GHG emissions is promoting alternatives to the automobile, and expanding transit service is one of those alternatives. However, the study also concludes that such a strategy should also be accompanied by other strategies such as pricing of automobile travel.

The literature review shows evidence that public transit can reduce the emission of pollutants and improve air quality. However, the amount of reduction depends on several factors, including diversions from automobile, the region, the transit mode, assumptions, and the method of estimation. One of the difficulties in estimating net reduction in emissions is that new or expanded transit service also contributes to pollution. Although the studies by APTA[26], ICF Consulting[25], and SAIC Energy Solutions Operation[24] provide some useful information on methods and assumptions, there appears to be no consensus about the methods. Due to the difficulties involved, agencies such as the World Resources Institute[34] have developed emissions factors for transit modes by taking recourse to national data on fuel consumption and emission in Transportation Energy Consumption Data Book and other resources. However, application of these factors can only produce approximate emission estimates because different types of energy are consumed by different components of a commuter rail system. The same applies to NJ TRANSIT, where trains on different lines are operated by different types of energy.

The Relationship between Parking and Public Transit

A separate review of literature was undertaken pertaining to the objective of the study to examine the effect of station parking on transit ridership and passenger satisfaction. A number of studies have examined the effect of parking at or near stations as a means to promote transit ridership. In a study on the relationship between parking availability at stations and commuter rail ridership for the Chicago region, Merriman[(35)] found that each additional parking space generated between 0.6 to 2.2 additional riders, depending on the time of day. The study concluded that the net impact of parking at stations on system-wide boarding is positive and the expansion of station parking at capacity-constrained stations has positive net social benefits.

In a study on factors influencing light rail ridership in nine cities and 268 stations, Kuby et al.[(36)] also noted a positive association between parking spaces and transit ridership. Similarly, in a study for the Bay Area Rapid Transit (BART), Rodier et al.[(37)] found a positive association between monthly reserved paid parking spaces and transit ridership. A study for the San Francisco Bay Area by Cervero[(38)] showed mixed results; while one of the empirical models in the study found statistically significant positive association between parking spaces and station boardings, the relationship was statistically insignificant in another model.

Willson and Menotti[(39)] studied the combined effects of changes in parking supply and land development around stations for two stations of the BART system. The analysis for one of the stations showed that a decrease in parking spaces would significantly reduce the number of boardings. The study also showed that a combined land use-parking strategy could be more effective in generating additional boardings than a single-pronged parking strategy.

Shirgaokar and Deakin[(40)] conducted a detailed study of BART passengers using park-and-ride facilities. They found that almost all of the users were making commuting trips, driving alone to the facilities, and making long train trips to their destinations. A survey showed that even for the same number of parking spaces, the level of satisfaction varied among the respondents. It can be inferred from this finding that the effect of parking availability has a mixed or insignificant effect on riders' satisfaction in the area studied.

Station parking availability is likely to be associated not only with the volume of boardings, but also with customers' satisfaction with the transit system. In a study of rail passengers in the Netherlands, Givoni and Rietveld ([41]) found a small but significant positive association between parking capacity at stations and passenger satisfaction. However, in the study involving BART passengers referenced above, Shirgaokar and

Deakin[40] did not find any conclusive evidence about the relationship between station parking spaces at stations and passenger satisfaction.

It can be concluded from the review of literature on station parking and ridership that in most cases, there is a positive association between the two. Obviously, at stations where the demand for boardings is high, and stations that are primarily accessible by automobile, a few extra spaces can generate a significant number of additional riders. The relationship between station parking availability and passenger satisfaction appears to be less clear than the relationship between parking and ridership. While one of the studies found a noticeable link between the two, the other study found results to the contrary.

It may be noted that virtually all studies on the effect of station parking on ridership and passenger satisfaction exclusively focuses on current riders and excludes those who do not take transit because of parking constraints. To fully gauge the impact of station parking, it would be essential to survey populations that could have used transit but do not do so because of parking constraints. Obviously, such an effort would be more expensive than the conventional studies because of the need to collect data from a larger sample of population.

Summary and Discussion

The review of literature provides some important insights for addressing the two primary objectives of the study, namely, to assess the various impacts of off peak service and to examine the impact of station parking constraints. The key observations from the literature review are discussed below.

- First, the key findings from the review is that there is a reason to be concerned about the health impacts of air pollution caused by the transportation sector. Trying to reduce pollutants by promoting public transportation is a worthy strategy.

- Second, a number of studies have shown that public transportation can reduce air pollution because of reduced VMT caused by diversions from automobile. However, some studies have cautioned that the reduction is dependent on transit’s relative attractiveness compared to driving, and therefore the reduction in pollution from transit may not be substantial in some circumstances.

- Third, a few studies have presented methods for estimating reduction in air pollution, especially GHG, due to public transportation. However, only a few studies have empirically measured the air quality impacts of new or existing transit services, and most of these studies were conducted in countries other than the US. Studies on a new transit system in Taipei showed mixed results, but one of the studies found reduction in emissions in the city’s heavily travelled areas. Studies on existing systems in Vancouver and Toronto showed a positive impact of transit on air quality.

- Fourth, although several reports describe how transit's air quality benefits are to be estimated, obtaining pertinent data is not always easy. This is particularly the case regarding emissions from transit itself. While the EPA and other sources provide reasonably close parameter estimates for measuring emission from automobile diversions, obtaining emissions from transit is more difficult. Because of the difficulties in obtaining data, some organizations have used macro level data to obtain emission factors. However, application of such factors for a particular agency or commuter rail line can only provide crude approximation of emissions at best. To obtain a reasonably acceptable estimate, it is essential to obtain information on fuel consumption for the specific service studied.

- Fifth, regarding the relationship between station parking and transit ridership, almost all studies reviewed found a positive association. Although this positive association may be the result of a simultaneous relationship between the two, there is little or no evidence to suggest that station parking cannot increase transit ridership. The evidence found in the literature seems to suggest that station parking is important for lines such as the PVL, where a large proportion of riders arrive at the station by driving personal vehicles.

FOCUS GROUPS

One of the critical tasks of the study was to conduct focus groups involving passengers of the PVL. Two focus groups involving passengers from the New York Metropolitan Transit Authority's Metro North Line and PVL were conducted jointly by the Bloustein Center for Survey Research (BCSR) and the Alan M. Voorhees Transportation Center (VTC) on 8 and 9 June 2010. Metro North operates a few trains daily on the PVL and its passengers use the same route and service from Spring Valley to Secaucus Junction Station. The focus group effort had two primary objectives: (1) to obtain an in-depth understanding of the passengers' awareness, perceptions, and reaction to the off peak service introduced to the PVL, and (2) to inform the design and content of the onboard survey. Focus group participants engaged in a structured conversation that covered eight broad areas:

- Use of the PVL trains.
- Trips to and from rail stations.
- Parking at stations.
- Decision to use PVL trains.
- Awareness of the new service.
- Reaction to the new service.
- Assessment of service cuts and elimination of off peak tickets.
- Pretest of onboard questionnaires.

Recruiting Participants

The two focus groups were conducted at the Secaucus Junction Station. The site was selected because of the availability of a suitable facility and its accessibility to a large number of passengers. Several days prior to the focus groups, participants were recruited by trained recruiters at the Secaucus Junction and Hoboken Station. Index cards containing essential information about the focus groups were distributed among PVL and Metro North passengers with a request for interested passengers to contact the research team. Approximately 50 passengers contacted the research team, of which 21 participated in the two focus groups.

Undertaking the Focus Groups

The two focus groups were conducted by a trained moderator using a pre-tested topic guide. Notes were taken by supporting researchers and each focus group was audio recorded and transcribed. Prior to the focus groups, each participant filled out a questionnaire, answering basic questions on personal characteristics and usage of the PVL service. The socio-demographic characteristics of the participants, collected through the pre-focus group questionnaire, are presented in Table 5. At the conclusion of each focus group, participants were instructed to write down on index cards three most important topics related to the PVL.

Table 5 – Characteristics of the Focus Group Participants

	Focus Group #1 (June 8, 2010)	Focus Group #2 (June 9, 2010)	Total
Gender			
Male	50%	78%	62%
Female	50%	22%	38%
Ethnicity			
White Hispanic	8%	20%	14%
Black Hispanic	0%	10%	5%
White not Hispanic	75%	30%	55%
Black not Hispanic	8%	10%	9%
Asian	8%	20%	14%
Native American	0%	10%	5%
Household Income			
Less than $25,000	0%	0%	0%
$25,000 to less than $50,000	0%	0%	0%
$50,000 to less than $100,000	25%	22%	24%
$100,000 to less than $200,000	33%	67%	48%
$200,000 or more	42%	11%	29%
Level of Education			
Less than high school graduate	0%	0%	0%
High school graduate/GED	0%	0%	0%
Some college	17%	11%	14%
Two-year college degree	8%	11%	10%
Four-year college degree	42%	56%	48%
Graduate work, but no degree	8%	0%	5%
Graduate degree	25%	22%	24%
Household Language			
English	92%	89%	90%
Chinese/Mandarin	0%	11%	5%
Spanish	0%	0%	0%
Other	8%	0%	5%
Marital Status			
Single - Never Married	25%	44%	33%
Married / Civil Union	75%	56%	67%
Divorced	0%	0%	0%
Widowed	0%	0%	0%
Living with partner	0%	0%	0%
County of Residence			
Bergen	67%	78%	71%
Rockland	33%	22%	29%

Focus Group Analysis and Results

The audio recording from each focus group was transcribed professionally. The transcriptions served as the basis for the computer aided content analysis. Each transcription was imported into Atlas.ti, a qualitative data reduction and analysis program, to efficiently identify the themes evolving from the focus groups. In addition to the transcripts, information provided by the participants on index cards at the conclusion of each group was loaded into Atlas.ti.

The analysis of the focus groups was completed inductively by allowing themes to emerge from successive reading and coding of the focus group transcripts and data collected through index cards. These themes were used to code word groupings of any size as long as that word grouping represented a theme. During analysis, seven broad themes emerged. Further coding within each broad theme resulted in 20 additional themes, each contributing to the broader themes.

A straightforward coding scheme was developed for those themes that are easily identifiable. The process resulted in the following broad, over-arching themes:

- Assessment of service cuts
- Awareness of new service
- Decision to use PVL train
- Length of time using PVL trains
- Reaction to new service change
- Trips to and from PVL stations
- Use of PVL trains

The focus groups fulfilled their dual objectives of collecting insights on passengers' perceptions and pre-testing the onboard survey instrument. In addition to collecting in-depth information on the participants' awareness, perceptions and reaction to the off peak service, the focus groups provided information about the passengers' reaction to the recent changes in service and fare. The onboard survey instrument was tested in both focus groups. Based on participants' comments on the length of the survey, sequence of the questions, and wording of the questions, the instrument was subsequently revised before being deployed.

It was evident from the discussions that passengers made changes to their travel patterns as a result of the off peak service introduced in October 2007 to the PVL. It was mentioned by participants that the off peak service provided more flexibility to travel, particularly for return trips from work in New York.

Most participants used PVL service prior to the addition of midday and weekend service. However, the off peak service was appreciated almost universally by the participants. The off peak service was described as a "tremendous bonus" by one participant. A majority of the participants affirmed that since off peak service was added, they were driving less. Some mentioned that because of the off peak service, they could work until later in the evening or leave work earlier. Some noted that their friends/family also took off peak service for various non-work trips, including recreational activities in New York City. The option to travel by off peak trains to Newark Airport appeared to be a significant benefit to some participants.

A variety of reasons were cited by the participants for using the PVL trains. Some said PVL trains were easier to take than alternative modes, more relaxing, and less stressful.

It was emphasized that PVL offered a “smoother” ride than buses for trans-Hudson travel, even though the train trips were longer.

Although several participants mentioned making off peak trips, almost all participants used the PVL primarily to commute to and from work. About a third of the participants also used the line on weekends. Participants that were unaware of the off peak service took PVL in weekday peak periods for commuting purposes. Even peak-period commuters did see a high value of the off peak service. One participant mentioned: “The midday trains coming back home [are] great, too, because sometimes if you have a doctor’s appointment or something else, you don’t have to take a full day off from work in order to do those things; you could always go in late or come home early.”

The Atalas.ti analysis provides evidence that the PVL competes with, complements, and is complemented by other modes of transportation. It is evident from the transcripts that the word “bus” was mentioned as many as 67 times, and “drive” and “driving” were mentioned 70 times in the two focus groups. This confirms the study’s hypothesis that alternative and complementary modes are important for the PVL passengers. It can be hypothesized from the results that significant diversions from other modes to PVL might have occurred when off peak trains were added.

Most participants indicated that they required a transfer to/from the PVL from/to another train to arrive at their final destination. These passengers usually traveled to or from New York City by another train by transferring at Secaucus Junction. It can be inferred from the focus group discussion that the PVL contributes to ridership on other lines as well, especially to lines connecting Secaucus Junction and New York Penn Station.

The need for transfer between train lines made the Secaucus Junction Station focus of interest for many of the participants. The word “Secaucus” appeared a total of 72 times in the two focus groups. Not only did transferring at Secaucus allow quicker travel times for the majority of respondents, but it also facilitated easier car-free commuting to Newark Airport for some. The opening of the Secaucus Junction Station in 2003 was a major improvement for the PVL riders. In regards to service changes on the PVL, one respondent illustrated the importance of Secaucus Junction thus: “The major change is Secaucus. It made it more convenient to be able to pick up the MTA. Because prior to that, I would either take the PATH from Hoboken or take the PATH to World Trade Center, then walk two or three blocks and pick up the MTA there.”

A dominant theme of the focus groups was communication. Although the consensus was that PVL service was generally good, delays were a major cause of frustration. Sections of the PVL run on a single track, and so delays have the potential to be more extensive than those lines that run on multiple tracks. Many of the focus group participants expressed frustration at the lack of communication with PVL riders during the delays. While acknowledging the presence of message boards and public announcement systems, participants expressed frustration with their inadequacy.

Some participants mentioned that PVL trains occasionally left Secaucus Junction earlier than the scheduled time. Participants also noted that connecting trains often did not wait for passengers of delayed trains despite announcements being made that the connecting trains would depart past schedule to accommodate the passengers from the delayed trains. In addition, participants were frustrated by the cross-honoring system with PATH and NJ TRANSIT buses during service interruptions, as PATH officials and NJ TRANSIT bus operators often did not honor the PVL fare payment. One respondent summed up the main reason for the frustration thus: "… when there is a service interruption, it's usually not a small one on the Pascack Valley Line. It's huge…. It shuts it down like either all morning or all afternoon….It's never five, ten minutes or anything." Participants had two suggestions for improving the rider experience on the PVL: Better communication and more frequent service.

The fact that some of the off peak trains operate between Hoboken and New Bridge Landing instead of serving the entire route between Hoboken and Spring Valley frustrated many participants. As one participant mentioned, "I found that they're not frequent enough. I've tried to use the midday kind of trains coming back home, especially, and they don't all go all the way up…." Another participant expressed his frustration thus: "Like I got on one and got off at New Bridge Landing and I go, Okay, now what do I do? So I wait an hour for the next train, so it didn't help me at all." These participants advocated midday service in the entire route, noting that they otherwise had to transfer to a bus or wait for the next train that served the stations north of New Bridge Landing. These comments show that single-seat rides are important for off peak riders also.

The focus groups also showed evidence that station parking is important to many passengers. The Atlas.ti summary shows that the term "parking" was used 64 times during the two focus groups. It is not surprising because PVL passengers drive to boarding stations more than any other NJ TRANSIT lines. About half of the participants who drove mentioned paying for parking whereas the other half parked for free. Some passengers mentioned that shortage of parking close to stations restricted their ability to take preferred trains.

The recent elimination of two PVL trains appeared to have negatively affected the participants. Some participants mentioned that the elimination of the two trains prior to the focus groups made it harder to get to work. The elimination of off peak fares around that time received less attention from the participants than the loss of the two trains.

At the closing of the focus groups, the participants were encouraged to write down up to three suggestions based on their experience with the PVL service. This exercise showed that the two major themes were service frequency and communication. Of the 21 participants in the two focus groups, 9 suggested better communication and 9 suggested greater frequency of service. Despite some frustrations regarding service interruptions and communications break down, PVL service was generally regarded favorably by the focus group participants, which might account for the relatively low frequency of words such as, "frustrated," "infrequent," and "waiting" in the focus group transcripts.

Summary and Discussion

The focus groups clearly fulfilled their objectives. Almost all of the participants were aware of the fact that off peak and weekend services were added in October 2007. These participants expressed satisfaction with the off peak service, but suggested that frequency of trains should be increased and that the trains that currently run up to New Bridge Landing should run all the way up to Spring Valley.

Although most participants used PVL before the introduction of off peak and weekend service, it was evident from the focus groups their travel patterns had been affected by the new service. Many felt that they had greater flexibility to travel because of off peak service. They also felt comfort in knowing that midday trains were available if they needed to travel back home from work before peak period. Several participants mentioned driving less after off peak service was added, suggesting that diversions from automobile to PVL might be substantial. The two primary concerns of the participants were frequency of service and communication during service interruptions.

The focus groups provided support to the study's hypothesis that individuals make changes in their travel patterns because of new or enhanced off peak service. Participants repeatedly mentioned driving to stations, transferring to other trains, taking buses, thereby indicating that the PVL service is perceived by passengers as a component of the overall transportation system of the region.

While focus group observations cannot be construed as statistical evidence, the two focus groups provided in-depth information about the perceptions of the participants and the underlying reasons for those perceptions. Moreover, on the basis of the participants' comments on the draft survey questionnaire, some questions were simplified and minor changes were made in the sequence of the questions while preparing the final version.

SURVEY OF PVL PASSENGERS

The primary objective of this research – to measure VMT and GHG benefits from off peak transit – cannot be fulfilled with secondary data or data collected through the focus groups because detailed data are needed to determine changes in travel patterns over time. An onboard survey of PVL passengers was necessary to measure these benefits. A draft questionnaire for this survey was prepared by the research team in collaboration with NJ TRANSIT staff. The survey instrument underwent several revisions and was pre-tested at the two focus groups. On the basis of the pre-tests, revisions were made to the survey instrument in terms of substance and sequence of questions.

The final survey instrument included a total of 38 questions. The survey instrument included questions pertaining to changes in travel patterns after off peak service was added, access to boarding stations, perceptions about off peak service, trip origin and destination, trip purpose, mode of fare payment, station parking, satisfaction with service elements, and socioeconomic characteristics. The survey instrument was formatted to conform to conventional NJ TRANSIT surveys.

Implementation of the Survey, Data Entry, and Weighting

The onboard survey was conducted under the supervision of Rutgers University's Bloustein Center for Survey Research (BCSR) on 22, 23, 24, and 29 June 2010. Prior to the survey, a sampling strategy was prepared by BCSR staff in coordination with NJ TRANSIT staff to determine which trains would be surveyed. Accordingly, a total of 28 trains were identified for the survey, of which 12 were peak-period trains and 16 were off peak trains. Since the 28 trains included 4 trains that were surveyed twice (on different days), in reality a total of 24 trains were surveyed.

Data were collected by distributing and collecting questionnaires onboard the selected trains by investigators specially trained by the BCSR. Although most surveys were collected onboard, passengers were also given an opportunity to mail back the surveys if they so preferred. Including mail-back surveys, a total of 1438 surveys were received. Data from the surveys were converted to electronic format by BCSR staff. To ensure that there were no data-entry errors, the survey data were entered twice and compared for discrepancies. The variable names and codes were modified, as necessary, to conform to NJ TRANSIT's variable naming and coding conventions. Of the 1438 surveys collected, 1431 were found to be usable. The remaining seven surveys did not contain sufficient information to be included in the final data set.

The data collected through the surveys were weighted to conform to average weekday ridership. The weight variable was created on the basis of recorded station-to-station weekday trips – a method conventionally used by NJ TRANSIT. The weighting mechanism converted the 1431 surveys to 3897 one-way trips.

Data Analysis

The weighted onboard survey data were analyzed for various purposes. The analysis included frequency tables involving all survey questions and cross tabulation of selected variables. The summary statistics from these analyses were presented to the project sponsors in the form of a Task Report. Some basic statistics from the analysis are presented in the following sections. The data provided in the tables exclude those who did not respond to specific questions.

Demographic and Socioeconomic Characteristics

Selected demographic and socioeconomic characteristics of the survey respondents are presented in Table 6. It is evident from the table that a slightly larger proportion of men use the PVL than women. This is reflective of the fact that the line is used predominantly by persons commuting to and from work. Although women's participation in the labor force has steadily increased over several decades, in New Jersey and the nation as a whole, more men are employed than women. The age distribution of the passengers – specifically, a large proportion of working age population – is reflective of the use of the PVL predominantly for commuting purposes.

According to the survey results, 5.5% of the passengers are African American. Although this proportion is substantially smaller than the proportion for New Jersey as a whole, it is only slightly smaller than that for Bergen County, the County primarily served by the PVL, where 5.8% of the population is African American according to the 2005-09 American Community Survey (ACS) data. The proportion of Asian passengers in the survey (14.7%) is almost identical to the proportion of Asians in Bergen County (14.3%), but the proportion of Hispanic passengers (9.6%) is significantly smaller than the proportion of Bergen County Hispanic residents (14.5%).

Commuter rail users on average are economically better off than average persons. This is evident from the PVL survey also. Although Bergen County is one of the most affluent counties in the nation, the PVL passengers appear to be better off than the county's population at large. For example, according to the ACS, 7.1% of the county's households have an income below $15,000, whereas only 1.4% of the respondents have such low household income. Again, 20.6% of the respondents mention household incomes over $200,000, whereas the proportion of Bergen County households in that income level is only 11.7%. In sum, the PVL passengers are significantly more affluent than the population of New Jersey, and modestly more affluent than the residents of Bergen County.

Table 6 – Characteristics of the Survey Participants

Characteristic	Frequency[a]	Percent
Gender		
Male	2075	54.3%
Female	1743	45.7%
Total	3818	100.0%
Age		
18-24	413	10.8%
25-34	815	21.4%
35-44	855	22.4%
45-54	1041	27.2%
55-64	562	14.8%
65 or older	125	3.3%
Total	3811	100.0%
Race		
White	2716	74.7%
Black	200	5.5%
Asian	535	14.7%
Native American	22	0.6%
Other	162	4.5%
Total	3635	100.0%
Ethnicity		
Hispanic	354	9.6%
Non-Hispanic	3324	90.4%
Total	3678	100.0%
Language		
English	2848	76.7%
Non-English	864	23.3%
Total	3712	100.0%
Annual Household Income		
Under $15,000	45	1.4%
$15,000-$24,999	49	1.5%
$25,000-$34,999	64	1.9%
$35,000-$49,999	164	4.9%
$50,000-$74,999	342	10.3%
$75,000-$99,999	532	16.1%
$100,000-$149,999	851	25.7%
$150,000-$199,999	583	17.6%
$200,000-$249,999	375	11.3%
$250,000 or higher	309	9.3%
Total	3314	100.0%

[a] Weighted frequencies

Access Mode to Stations

Most NJ TRANSIT commuter rail passenger surveys include a question on access mode to boarding station. The distribution of access mode to station provides an indication of the areas and passengers served by a commuter rail line. For this particular study, the distribution is important for the analysis of parking constraints. As shown in Table 7, a vast majority of the passengers on the PVL use automobile to access boarding stations. While almost 52% of the survey respondents drove alone to stations, including passengers who carpooled or got dropped off at stations, 72% of the passengers used an automobile to access boarding stations.

Past surveys conducted by NJ TRANSIT show that among all commuter rail lines, automobile use to access boarding stations is most common for the PVL line. The high usage of automobile to access boarding stations on the PVL is reflective of the suburban atmosphere around most boarding stations, and also the relative affluence of the passengers. Because of the higher-than-average drive-alone trips to stations, station parking is more important for this line than other NJ TRANSIT commuter rail lines

Table 7 – Access Mode to Station for Survey Participants

Access Mode	Frequency[a]	Percent
Walk only	879	22.9%
Drive Alone	1988	51.8%
Carpooled and parked	58	1.5%
Passenger in carpool	176	4.6%
Car-drop off	554	14.4%
Bike	35	0.9%
Bus	33	0.9%
Another NJ TRANSIT Commuter Line	43	1.1%
PATH	17	0.4%
NYC Subway	14	0.4%
Hudson Bergen Light Rail	8	0.2%
Ferry	10	0.2%
Other	21	0.6%
Total	3836	100.0%

[a] Weighted frequencies

Trip Purpose

Trip purpose of passengers, recorded through the PVL onboard survey, is presented in Table 8. Throughout the day, more than 92% of the trips are made for commuting purposes, whereas only a very small proportion of trips are made for non-work purposes such as shopping, recreation, and personal business. The reason for the very high proportion of commuting trips is that the line is predominantly used by suburban residents to access jobs in New York City. Even during midday, almost two-thirds of the trips are made for commuting purposes, indicating that even after off peak service was introduced, the PVL's main function is to provide job access to workers living in predominantly suburban environments.

Table 8 – Trip Purpose of Survey Participants

Trip Purpose	All Day		Midday Off Peak	
	Frequency[a]	Percent	Frequency[a]	Percent
Work	3568	92.4%	396	64.6%
Company business	28	0.7%	22	3.6%
School	49	1.3%	27	4.4%
Shopping	5	0.1%	3	0.5%
Recreation	81	2.1%	68	11.1%
Personal business	85	2.2%	72	11.8%
Other	46	1.2%	25	4.1%
Total	3862	100.0%	613	100.0%

[a] Weighted frequencies

<u>Change in Travel Patterns</u>

Several questions were included in the PVL onboard survey regarding changes in travel patterns after off peak service was added to the line in October 2007. To measure the VMT and GHG benefits from off peak service, these changes are important. Responses to some of the highly relevant questions are discussed in the following sections.

New Users Before and After Off Peak Added

To gauge the increase in attractiveness of the PVL line over time, a question was included in the survey to inquire about the year in which passengers started using the PVL line trains. The results are shown in Table 9. As expected, the number of passengers beginning to use the PVL soared in 2008 and continued to remain high until the survey was conducted in June 2010. While only 2-7% passengers started using the PVL each year between 2000 and 2006, 13-14% new passengers started using the line each year between 2008 and 2010. The significant increase in new riders in the years 2008-10 is an indication that the off peak service was successful in increasing the attractiveness of the line to persons who were not previously using the PVL service.

Table 9 – Year Passengers Began to Use PVL

Year	Frequency[a]	Percent
Before 2000	889	23.3%
2000	118	3.1%
2001	115	3.0%
2002	58	1.5%
2003	112	2.9%
2004	172	4.5%
2005	220	5.8%
2006	269	7.0%
2007	341	8.9%
2008	503	13.2%
2009	529	13.9%
2010[b]	493	12.9%
Total	3819	100.0%

[a] Weighted frequencies
[b] Partial year, from January to June, 2010.

Travel Mode Before Off Peak Service

One of the variables necessary to measure VMT and GHG benefits is the diversion of trips from other modes to the PVL. It can be expected that the larger the diversion from other modes, especially automobile, the larger would be the reduction in VMT and GHG. To gauge the effect of PVL off peak service on changes in travel mode, the survey included a question inquiring how the passengers made the trip (i.e., the trip they were making when the survey was handed to them) before October 2007, when off peak service was added to the line. The responses to the question are summarized in Table 10.

Table 10 – Travel Mode By Passengers Prior to Off Peak Service

Prior Mode	Frequency[a]	Percent
Did not make the trip	1825	46.9%
Drove alone	952	24.4%
Carpooled	48	1.2%
Used bus	484	12.4%
Used another train	288	7.4%
Used PATH or ferry	148	3.8%
Used other mode	149	3.8%
Total	3894	100.0%

[a] Weighted frequencies

It is evident from the table that almost half the respondents did not make that particular trip before off peak service was added (although they might have made other trips using PVL). The table shows that 24.4% of the passengers made the trip by driving alone and another 1.2% passengers carpooled, indicating a substantial diversion from automobile to the PVL. At 12.4%, the diversion from buses to PVL was also substantial. Most of these diversions were from buses connecting Bergen and Rockland Counties to New York City via the George Washington Bridge. The 7.4% diversion from commuter rail occurred almost exclusively because of diversions from the Bergen County line, which runs parallel to the PVL several miles west.

Travel Time and Distance of Passengers Who Drove or Carpooled

Passengers who drove or carpooled before off peak service was added to the PVL were asked about their trip distance and travel time. The distribution of trip distance and trip duration of passengers are presented in Figure 2. It is evident that 74% of the trips on the PVL are 30 minutes or longer. The long duration is typical of commuting trips.

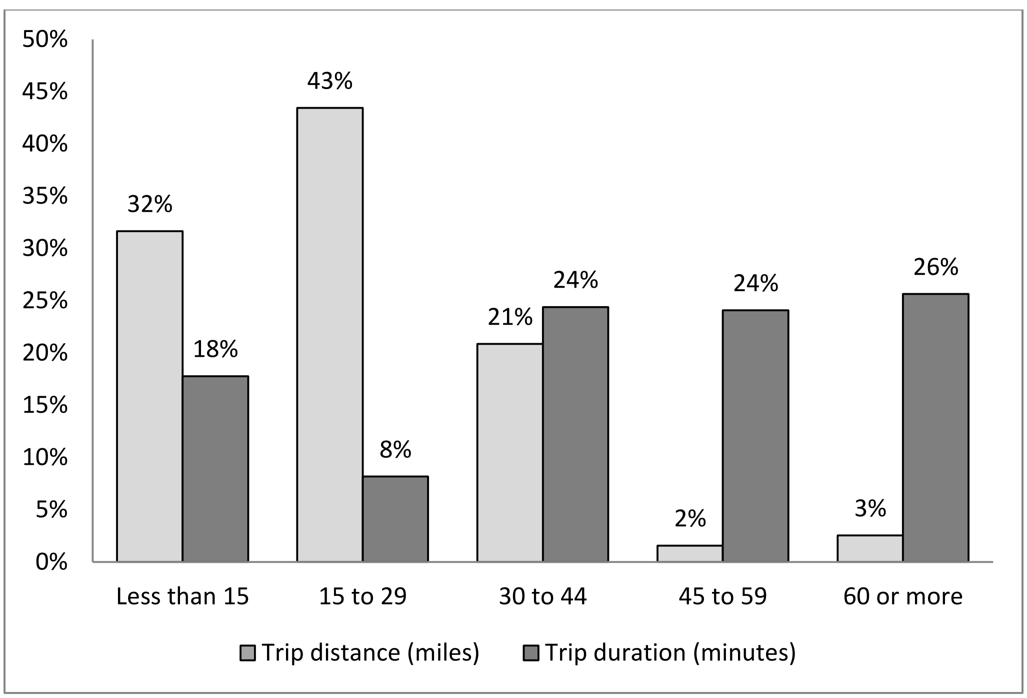

Figure 2 – Trip Distance and Duration of Passengers who Drove or Carpooled to Destination before PVL Off Peak Service

Change in PVL Use Patterns

Addition of trains in the off peak period is likely to alter travel patterns of passengers in many ways. To examine what kind of impact off peak PVL service had, the onboard survey included a question inquiring how passengers changed their travel patterns after off peak service was added in 2007. Multiple responses were allowed so that passengers had the opportunity to mention more than one change in travel pattern. The results are presented in Table 11. The responses indicate that off peak service has been able to draw additional passengers to the line. For example, almost 20% of the passengers surveyed indicated starting to use off peak service, whereas only 7.6% indicated never using off peak service. More importantly, the survey results show that 5.1% of the respondents used more peak period trains after off peak trains were added, indicating that off peak service can increase not only off peak ridership, but also peak ridership because of greater travel options and the knowledge that one could travel in off peak periods in case of emergencies. More trains in the off peak period also means that some passengers previously using peak-period trains would start using off peak trains. However, only 2% of the passengers mentioned making a switch from peak to off peak period, indicating that the loss of peak ridership is less only a small proportion of total gain in ridership.

Table 11 – Changes Made By PVL Passengers after Off Peak Service Added

Changes Made	Frequency[a]	Percent
Not changed	2079	48.81
Use more peak-period trains	216	5.06
Use less peak-period trains	84	1.97
Started using off peak trains	838	19.68
Never use off peak trains	323	7.58
Started using PVL after 2007	720	16.90
Total	4260	100.00

[a] Weighted frequencies

Reaction to Potential Reduction in PVL Off Peak Service

To determine how off peak service is valued by passengers, a question was included in the onboard survey to inquire how they would react to potential reduction in off peak service. The question was: "If train service were to be reduced on this line between 9:30 AM and 4 PM, or after 7 PM, how would your usage of the Pascack Valley Line be affected?" The results are presented in Table 12. While 31% of the respondents reported that they would make no changes in their travel pattern, others reported that they would travel differently. Close to 18% reported that they would continue to use PVL by simply switching the time of travel, while 15% reported that they would switch to bus. More importantly, close to 13% of the passengers reported that they would make the trip by driving. Although this proportion is smaller than the proportion of respondents who mentioned in response to another question that they used to make the trip by driving before off peak service was introduced, it is still a substantial proportion. The importance of the PVL off peak service is also evident from the fact that more than 5% of the passengers mentioned that they would no longer make the trip if off peak serviced was reduced. Overall, the responses clearly indicate that PVL passengers place a high value on the off peak service, and reduction of service will adversely affect a large number of passengers and increase automobile trips substantially.

Table 12 – Changes to be Made by PVL Passengers if Off Peak Service is Reduced

Changes to be made	Frequency[a]	Percent
No change	1502	30.9
Drive	612	12.6
Take earlier or later train	851	17.5
Switch from peak rail to bus	261	5.4
Switch from off peak rail to bus	487	10.0
Switch to a different peak line	150	3.1
Switch to a different off peak line	327	6.7
No longer make this trip	259	5.3
Other	405	8.3
Total	4854	100.0

[a] Weighted frequencies

Satisfaction with Service Elements

Customer satisfaction with service elements is important for transit agencies. All past NJ TRANSIT commuter rail surveys included questions on satisfaction. To examine how PVL passengers felt about service elements, a question was included in the survey that allowed passengers to use an 11-point scale to express their satisfaction, with 0 being not acceptable and 10 being excellent. The mean scores for different service elements from this survey are presented in Table 13.

Table 13 – Passenger Satisfaction with PVL Service Elements

Satisfaction with:	Mean Score[a]
Frequency of off peak service	4.56
Overall value of money	4.82
Announcements/information during service disruptions	4.89
Frequency of weekend service	4.95
Handling of service disruptions	4.98
Frequency of peak service	5.72
Overall satisfaction with NJ TRANSIT	5.84
Transferring to other trains or buses	5.86
Parking at boarding station	5.96
Trip time to destination	6.05
Boarding station	6.63

[a] Weighted scores

Satisfaction with boarding stations was found to be the highest among all service elements, followed by trip time. Considering that off peak service is relatively new to the line, one might expect a high satisfaction with such service. However, satisfaction with off peak service frequency was found to be the lowest. The reason may be that despite the novelty of the service, the frequency of off peak trains is lower than the frequency of peak period trains. In this context, it can be recalled that passengers in the two focus groups also expressed dissatisfaction with the low frequency of off peak trains. Also consistent with the focus groups, the satisfaction with the handling of service disruptions was lower than most other service elements. Somewhat surprisingly, the satisfaction with station parking is higher than most service elements. This issue is discussed further in the following section.

PARKING CONSTRAINTS

One of the major objectives of this research is to identify the effects of station parking constraints. This chapter summarizes the results from the analysis of station parking constraints. Although the primary focus of the analysis in this chapter is the PVL, data from several other NJ TRANSIT commuter rail lines are also presented for comparison. The data used in this chapter include a station parking inventory maintained by NJ TRANSIT, NJ TRANSIT onboard surveys conducted in 2005, and the 2010 PVL survey.

The parking data provided by NJ TRANSIT included a number of variables for station lots, including number of spaces, parking charges, parking restrictions, street-parking restrictions, lot ownership, and lot operators. The data set includes lot and parking space information for every year between 1990 and 2010, allowing analyses of changes over time in the number of lots and spaces at each station.

The 2005 NJ TRANSIT onboard survey data includes information on all commuter rail lines. Although the data set includes numerous variables on trip and passenger characteristics, only selected information has been used for analysis. Specifically, passengers' satisfaction with station parking and proportion of passengers driving to stations were analyzed in this chapter.

The 2010 PVL survey data helped to answer many questions regarding the impact of parking constraints on the PVL. The survey included specific questions on driving to stations, parking, and potential changes in travel patterns in response to hypothetical changes in station parking characteristics.

One of the important considerations of the parking analysis in this chapter is the impact of non-resident parking restrictions on transit ridership. The analyses in this chapter show that the PVL stations impose the most stringent restrictions on non-residents among all NJ TRANSIT commuter rail lines. The survey results show that a large proportion of current transit passengers would prefer to drive to stations if parking restrictions were lifted.

The analyses in this chapter also suggest that generally the catchment areas for stations are smaller when non-resident parking restrictions are present. This potentially indicates that because of non-resident parking restrictions, there may be a loss of rail ridership. However, the analyses in the report do not allow an estimation of the number of riders lost because of parking restrictions at stations.

Station Parking Capacity and Usage by Line

A total of 409 parking lots in 163 NJ TRANSIT commuter rail stations provide 63,228 parking spaces to the system's passengers. Lots on the Northeast Corridor (NEC) Line accounts for more than 1/3rd of all parking spaces, whereas the PVL lots account for only a little over 3% of the system's parking spaces. As shown in Table 14, the PVL includes 29 parking lots in 14 stations with a total capacity of 2097 spaces, of which

1514 are currently used by passengers. Only two lines, the Bergen County Line and the Gladstone Branch Line, have fewer parking spaces than the PVL.

Table 14 – Station Parking Lots, Capacity and Space Utilization by Line, 2010

Line Name	No. of Stations	No. of Parking Lots	Total Parking Capacity (Spaces)	Total Parking Spaces Used	Average Occupancy Rate of Lots[a]
Atlantic City Line	8	12	4335	3061	58%
Bergen County Line	14	16	1246	902	76%
Gladstone Branch	12	23	1753	1274	63%
Main Line	17	38	5576	3566	68%
Montclair-Boonton Line	23	42	4817	2845	49%
Morristown Line	19	59	6961	5623	80%
North Jersey Coast Line	20	68	8908	5944	63%
Northeast Corridor Line	17	76	22832	17492	69%
Pascack Valley Line	***14***	***29[b]***	***2097***	***1514***	***71%***
Raritan Valley Line	19	46	4703	3588	78%
Total	**163**	**409**	**63228**	**45809**	**NA**

[a] Note that the occupancy rates in the table are averages of occupancy rates separately calculated for specific lots, by station, by line.
[b] Includes Meadowland Sports Complex, for which data are not available.

The number of parking spaces for commuter rail lines is obviously related to the number of passengers they carry. For example, according to the NJ TRANSIT Quarterly Ridership Trend Analysis Report for the 1st Quarter of FY-2011, the NEC, with station parking amounting to almost 22,832 spaces, has an average weekday ridership of more than 112,200 trips, compared to only 6,650 trips for the PVL. However, despite having a smaller number of riders, parking supply at the PVL stations appears to be more constrained than most other lines. The average occupancy rate of the parking lots on the PVL is 71%, which is higher than all but three other lines, including the NEC. A reason for greater usage of the PVL lots is that, compared to the other lines, a far greater proportion of passengers using the line drive personal vehicles to access the boarding stations. As shown in Table 15, 65% of the PVL passengers drove alone and parked at the boarding station in 2005. When carpool and car drop-off passengers are added to the drive-alone passengers, automobile trips constituted 81% of the passengers that boarded in the PVL stations.

It may be noted by comparing the 2005 and 2010 PVL surveys that a smaller proportion of passengers drove to boarding station in 2010 than 2005. There are two potential reasons for this discrepancy. First, off peak service was not available in 2005, and second, the 2005 survey included only inbound (New York bound) passengers in the AM peak period, whereas the 2010 survey included passengers in both directions traveling at different times of the day.

Table 15 – Access Mode to Boarding Station by Line, 2005 NJ TRANSIT Survey

Line Name	Drove Alone And Parked	Carpool and Parked	Passenger in Carpool	Car Drop Off	Any Personal Vehicle	Other Modes
North Jersey Coast Line	56%	4%	1%	16%	77%	23%
Northeast Corridor Line	50%	4%	1%	17%	72%	28%
Raritan Valley Line	52%	3%	1%	17%	73%	27%
Montclair-Boonton Line	34%	2%	1%	15%	52%	48%
Morris & Essex Lines	43%	4%	1%	16%	64%	36%
Main/Bergen County Lines	57%	3%	1%	15%	76%	24%
Pascack Valley Line	***65%***	***4%***	***0%***	***12%***	***81%***	***19%***
All Lines	**50%**	**4%**	**1%**	**16%**	**71%**	**29%**

Comparison of Non-Resident Parking at Station Lots by Line

Transit ridership may be adversely affected when non-residents are not allowed to park at station lots or charged a higher parking fee. As shown in Table 16, non-resident parking is most severe at the PVL stations among all NJ TRANSIT commuter rail lines. Out of the 29 parking lots serving the 14 PVL stations, 13 (45%) do not allow parking to non-residents. The proportion of lots with non-resident parking restriction on the other lines is significantly lower, ranging from 0% for the Atlantic City Line to 20% for the Morristown Line.

Table 16 – Permission to Park at Station Lots by Non-Residents

Line Name	Allowed		Not Allowed		Total	
	No. of Lots	Percent	No. of Lots	Percent	No. of Lots	Percent
Atlantic City Line	12	100%	0	0%	12	100%
Bergen County Line	14	88%	2	13%	16	100%
Gladstone Branch	21	91%	2	9%	23	100%
Main Line	31	82%	7	18%	38	100%
Montclair-Boonton Line	40	95%	2	5%	42	100%
Morristown Line	47	80%	12	20%	59	100%
North Jersey Coast Line	67	99%	1	1%	68	100%
Northeast Corridor Line	74	97%	2	3%	76	100%
Pascack Valley Line	***16*** [a]	***55%***	***13***	***45%***	***29***	***100%***
Raritan Valley Line	43	93%	3	7%	46	100%
Total	**365**	**89%**	**44**	**11%**	**409**	**100%**

[a] Includes Meadowland Sports Complex, for which data are not available.

Comparison of Free Parking Lots by Line

The number of free station parking lots is another indicator of parking constraints. A comparison of free lots for residents and non-residents among the NJ TRANSIT commuter rail lines is shown in Table 17. On aggregate, free parking is most restricted on the Morristown line, followed by the NEC line. None of the 59 lots in the Morristown line allows free parking, irrespective of whether the users are residents or non-residents, whereas only 2 of the 76 lots on the NEC line offer free parking.

Although the PVL appears to be more generous than many other lines regarding aggregate free parking because 7 of the 29 lots allow free parking to passengers, stations on this line discriminate the most between residents and non-residents in providing free parking. Although the Morristown line is the most restrictive of all lines in terms of free parking lots, it does not discriminate between residents and non-residents. Similarly, only one lot on the NEC line that provides free parking to residents does not allow free parking to non-residents. On six lines, namely the Atlantic City line, the Bergen County line, the Gladstone Brach line, the NJ Coast line, Raritan Valley line, and the Morristown line, the number of free parking lots for non-residents is the same as the number of free parking lots for residents, meaning that no distinction is made between residents and non-residents in terms of free parking at station lots. The distinction between residents and non-residents in terms of free parking is minimal on the Main line (11 against 9), and the Montclair-Boonton line (18 against 17). The largest differential can be observed for the PVL, where seven lots are free for residents and only two are free for non-residents.

Table 17 – Free Parking Lots for Residents and Non-Residents

Line Name	Free for Residents		Free for Non-Residents		Percent Difference Between Resident and Non-Resident
	Free Lots	Percent	Free Lots	Percent	
Atlantic City Line	9	75%	9	75%	0%
Bergen County Line	3	19%	3	19%	0%
Gladstone Branch	6	26%	6	26%	0%
Main Line	11	29%	9	24%	5%
Montclair-Boonton Line	18	43%	17	40%	2%
Morristown Line	0	0%	0	0%	0%
North Jersey Coast Line	22	32%	22	32%	0%
Northeast Corridor Line	2	3%	1	1%	1%
Pascack Valley Line	***7***	***24%***	***2***	***7%***	***17%***
Raritan Valley Line	6	13%	6	13%	0%
Total	**84**	**21%**	**75**	**18%**	**0%**

Comparison of Satisfaction with Station Parking by Line

Satisfaction with station parking on the PVL can be compared with other lines to gauge the line's station parking constraints. In the 2005 NJ TRANSIT survey, passengers were asked about their satisfaction with a number of system elements, including station parking. Although the survey was conducted before off peak service was introduced to the PVL, it provides some interesting insights about parking constraints. The line-specific mean scores of satisfaction with station parking are provided in Table 18. It shows that the PVL passengers had the highest satisfaction with station parking among all surveyed lines. However, interpretation of satisfaction is difficult because of several reasons. For example, satisfaction may be related to the number of parking spaces and usage/occupancy rates. As it can be observed from Table 18, the lines with the highest ridership, namely, the NEC line and the Morris & Essex lines, have very low mean satisfaction score, but they also have very high parking usage/occupancy rate and a very low capacity to rider ratio. In contrast, the PVL has a lower usage rate and a high capacity to rider ratio. While a high occupancy rate and low capacity-to-rider ratio is generally associated with low satisfaction with parking, the Montclair-Boonton line is an exception, where the occupancy rate is low and capacity-to-rider ratio is high, but the satisfaction with parking is still low. This anomaly shows that passengers' satisfaction with parking may not always reflect the availability of parking. Although passengers are asked about their satisfaction with parking availability, their responses may be influenced by other factors, including the cost of parking and the nature of parking (e.g., permit versus daily parking).

Table 18 – Mean Satisfaction Score for Parking at Boarding Station, 2005 NJ TRANSIT Onboard Survey

NJ TRANSIT Train Line	Mean Satisfaction Score	Average Weekday Ridership, 2005	Average Occupancy Rate of Parking Lots, 2005	Total Capacity (Spaces), 2005	Capacity to Rider Ratio
Montclair/Boonton Line	4.77	12,050	0.59	4295	0.36
Northeast Corridor Line	4.94	99,150	0.86	19669	0.20
Morris & Essex Lines	5.23	48,500	0.84	8563	0.18
Raritan Valley Line	5.44	19,450	0.82	4605	0.24
North Jersey Coast Line	5.51	28,950	0.78	8205	0.28
Main/Bergen County	5.84	20,200	0.78	6129	0.30
Pascack Valley Line	5.91	5,550	0.79	1934	0.35

Note: Score 0 = Not acceptable; Score 10=Excellent

Parking at Specific PVL Stations

Comparison of station parking was made in the above sections between the PVL and other NJ TRANSIT lines. Due to the special emphasis of this study on the PVL, detailed data are provided in this section comparing parking at various stations of this particular line.

Lots, Capacity, and Usage at PVL Stations

The total number of parking lots, lots with non-resident parking restrictions, as well as lot capacity and usage at PVL stations are shown in Table 19. The data on New York's three Rockland County stations, namely, Spring Valley, Pearl River, and Nanuet are partial because the NJ TRANSIT parking inventory does not include data on those stations. Among the stations in New Jersey, the Oradell station has the most parking spaces, followed closely by New Bridge Landing. Of the 2097 total parking spaces at the New Jersey station lots, 795 (or 38%) are not available to non-residents.

Table 19 – Total Lots, Restricted Lots and Usage Rate at PVL Stations, 2010

Station[a]	Total No. of Lots	No. of Lots with Non-Resident Parking Restriction	Total Parking Capacity	Parking Capacity at Lots with Non-Resident Restriction	Parking Usage Rate
Spring Valley[b]	*3*	Not available	*207*	Not available	Not available
Pearl River[b]	*4*	Not available	*357*	Not available	Not available
Nanuet[c]	*3*	Not available	*226*	Not available	Not available
Emerson	3	2	102	64	.802
Anderson Street	1	0	50	0	.380
Teterboro	1	0	27	0	.630
Woodridge	1	0	118	0	.805
River Edge	2	2	101	101	.741
Westwood	3	2	198	96	.941
New Bridge Landing	2	0	291	0	.657
Essex St	2	0	236	0	.380
Hillsdale	4	0	267	0	.750
Oradell	3	3	299	299	.866
Woodcliff Lake	1	1	65	65	.831
Park Ridge	2	1	134	100	.722
Montvale	3	2	209	70	.493
All Stations	28[c]	13	2097[c]	795	NA

[a] Meadowland station not shown because data are not available
[b] Source: LAZ Parking (http://rrparking.com/parking_lots/31) and MTA Metro North
[c] Excludes Spring Valley, Pearl River and Nanuet lots

Ownership and Operation of Restricted Parking Lots

The owners and operators of the 13 parking lots at PVL stations with non-resident parking restriction are shown in Table 20. These restricted lots are located in Emerson, Montvale, Oradell, Park Ridge, River Edge, Westwood, and Woodcliff Lake stations and operated by the respective townships or boroughs. All 13 lots are owned by the respective municipalities. It may be noted that various restrictions, including no-parking and short-term parking, are imposed on street parking around all of the 13 lots that do not permit non-resident parking, indicating that it is difficult, if not impossible, for non-residents to drive and park at or near stations to ride a train at these stations. The only viable options for passengers living in other municipalities are to drive and park at private lots or take some other mode to the station.

Table 20 – Ownership and Operation of Station Lots with Non-Resident Parking Restriction

Station	Lot No.	Location	On-Street Parking	Owned By	Operated By
Emerson	03	Lincoln Blvd & Kinderkamack Rd	Short Term Limits	Municipality	Emerson Borough
Emerson	02	Palisade Ave	Short Term Limits	Municipality	Emerson Borough
Montvale	01	Railroad Ave	Short Term Limits	Municipality	Montvale Borough
Montvale	02	Grand Ave East	Short Term Limits	Municipality	Montvale Borough
Oradell	01	Oradell Ave & Maple Ave	No Parking	Municipality	Oradell Township
Oradell	02	Church St & Kinderkamack Rd	Various Restrictions	Municipality	Oradell Township
Oradell	03	Oradell Ave	No Parking	Municipality	Oradell Township
Park Ridge	01	Hawthorne Ave & Madison St	Short Term Limits	Municipality	Park Ridge Borough
River Edge	02	River Edge Rd & Center Ave	Various Restrictions	Municipality	River Edge Borough
River Edge	01	River Edge Rd	Various Restrictions	Municipality	River Edge Borough
Westwood	01	Park Ave & Madison Ave	Various Restrictions	Municipality	Westwood Borough
Westwood	02	Park Ave	Various Restrictions	Municipality	Westwood Borough
Woodcliff Lake	01	Woodcliff Ave & Broadway	No Parking	Municipality	Woodcliff Lake Borough

Comparison of Free Lots

Parking restrictions on non-residents can also be examined by comparing free parking spaces for residents and non-residents. Table 21 shows that residents can park for free in 7 of the 28 PVL lots, but non-residents can park for free in only two lots. Five lots that are free for residents are not free for non-residents.

It can be observed from Table 21 that two lots in Emerson and three lots in Oradell that allow free parking to residents do not allow non-residents to park at all. These five lots contain a total of 363 spaces. These lots are owned and operated by Emerson Borough and Oradell Township.

It is also noted that some pay-parking lots that allow parking to non-residents charge a higher rate from non-residents than residents. Three lots in Hillsdale and the Essex Street lot in Hackensack fall into this category. It is thus evident that non-residents are discouraged from driving and parking at many of the PVL stations by local municipalities by (a) imposing total parking prohibition, (b) limiting the number of free parking spaces, and (c) charging higher parking fee at stations from non-residents.

Table 21 – Comparison Free Lots for Residents and Non-Residents

Station	Lot No.	For Resident	For Non-Resident	Capacity (Total Spaces)	Used Spaces
Emerson	01	No Fee	No Fee	38	38
Emerson	02	No Fee	No Parking	20	9
Emerson	03	No Fee	No Parking	44	42
Montvale	03	No Fee	No Fee	139	84
Oradell	01	No Fee	No Parking	145	110
Oradell	02	No Fee	No Parking	134	119
Oradell	03	No Fee	No Parking	20	19

Analysis of Parking Data from 2010 PVL Survey

Several questions were included in the PVL onboard survey pertinent to the study's objective of examining the effect of station parking constraint. The first question inquired where the passengers parked at the boarding station. Only those passengers who drove or carpooled to stations answered this question. From the results presented in Table 22, it is evident that more than 60% of the passengers driving to boarding stations parked at station lots. Among those who parked at or near stations, approximately 49% reported parking free of charge, while the remaining passengers paid a parking charge using monthly, daily, or hourly rate.

Table 22 – Parking Location of PVL Passengers at Boarding Station

Parking Location	Frequency[a]	Percent
Station lot parking	1557	61.0
Parking lot near station	460	18.0
On Street Parking	366	14.3
Other	168	6.6
Total	**2551**	**100.0**

[a] Weighted frequencies

Potential Impact of Removing Parking Restriction

A multiple-response question was included in the 2010 PVL survey for passengers who did not park at or near stations, inquiring whether they would have driven to the boarding station if (a) station parking lots were available to non-residents, (b) more spaces were available at the station parking lot, (c) station parking costs were lower, and (d) additional daily parking were available. Table 23 shows the responses to this question. Since most PVL passengers drive to stations, these responses are indicative of potential increases in rail ridership. The numbers shown in the table are responses rather than respondents because passengers were allowed to select more than one response. The percentages in Table 23 are calculated for only those who did not drive to station.

It is evident from the table that between 21% and 35% of the non-drivers would have driven to the boarding station if conditions were more favorable to them. Lower parking cost appears to be the most attractive incentive to the passengers, as 35% of the passengers reported that they would have driven to the station if parking costs were lower. Availability of non-resident parking also appears to be highly attractive, as 27% of the respondents said they would drive to the station if non-residents were allowed to park.

It should be noted that the responses in Table 23 are from individuals who use PVL trains. The fact that they already use PVL trains is an indication that they have an acceptable means to travel to station (e.g., bus, walking, car drop off, etc.). The survey cannot inform how many potential users are currently avoiding the PVL service and using an alternative mode (e.g., automobile, bus, another rail line) to travel to their destination. On the basis of the responses by current PVL users about non-resident parking restriction, it appears reasonable to hypothesize that many potential PVL users are currently using other modes of transport to travel to their destination because of the restrictions.

Table 23 – Stated Propensity to Drive to Stations

Would have driven to boarding station if:	Weighted Responses	Percent
Station parking lots were available for non-residents	496	27%
More spaces were available at station lots	401	22%
Parking costs were lower	642	35%
Additional daily parking were available	384	21%

The data presented in Table 23 for the entire PVL were also analyzed for individual stations located in New Jersey to examine if there were any relationship between the proportion of restricted lots in stations and the passenger responses. Although sample sizes are small for some of the stations to draw reasonable inferences, for stations that had acceptable number of boardings, it is evident that passengers boarding at stations with the most stringent non-resident parking restrictions are far more likely to state that they would drive to station if non-resident parking restrictions were eliminated. A larger proportion of passengers boarding at River Edge, Oradell, Montvale, and Emerson – all with severe parking restrictions – mention that they would drive to the station if non-resident parking restrictions did not exist.

Non-Resident Parking Restriction and Driving Distance to Boarding Station

Mean driving distance to boarding station can provide an indication about the effect of parking constraints at stations. When station lots do not allow non-resident parking, passengers living beyond the municipal boundary can only park in private lots or on nearby streets (when permitted). This is likely to result in a shorter average driving distance between trip origin (e.g., home) and station for stations with severe non-resident parking restrictions. A shorter average driving distance between station and trip origin, in turn, indicates a smaller catchment area for a station, defined as the geographic area served by a station. All else being equal, a shorter catchment area may imply a loss of ridership.

Table 24 – Mean Driving Distance from Station to Trip Origin for Drivers

Station	Weighted Number of Drivers	Mean Distance between Trip Origin and to Boarding Station (miles)
Spring Valley	27	7.85
Nanuet	320	4.54
Pearl River	108	2.87
Montvale	86	3.41
Park Ridge	54	0.65
Woodcliff Lake	56	1.78
Hillsdale	143	2.19
Westwood	140	1.99
Emerson	78	1.59
Oradell	128	0.98
River Edge	157	1.58
New Bridge Landing	202	3.05
Anderson Street	57	1.46
Essex St	113	13.38
Teterboro	40	1.86
Woodridge	145	1.58
Total	1854	3.24

The mean driving distance of PVL passengers to boarding stations is shown by station in Table 24. The data shown in the table are for only those who drove to the boarding station because non-drivers are not likely to be directly affected by parking constraints. To compute the mean distances from stations, network distances were calculated between the trip origins (e.g., home address) and the boarding stations for each passenger using GIS applications. The data in Table 24 shows that the average driving distance between trip origin and stations for all drivers is 3.24 miles. In contrast, for stations where lots are open only to the residents (namely, River Edge, Oradell, and Woodcliff Lake), the average driving distance ranges between 0.98 and 1.78 miles. The average driving distance is also relatively short for Westwood and Emerson, where 2/3rd of the lots do not permit non-resident parking. However, the average driving distance for Montvale is higher than the average for all drivers. Although non-resident parking restriction is imposed in two of its three lots, these two lots contain only 70 of the 209 (or 33.5% of total) parking spaces at the station.

It should be noted that average driving distance between trip origin and boarding station may also be affected by factors other than non-resident parking restrictions. For example, if a station is located in a municipality with a very large geographic area, the average driving distance of passengers to the station may be long even if the station lots do not permit any non-resident parking. More rigorous analysis will be needed to fully understand how non-resident parking restriction affects the catchment area of stations.

Summary and Discussion

In this chapter, data from various sources were analyzed to examine the potential effects of station parking constraints. Comparisons were made between the various NJ TRANSIT lines, and also between stations on the PVL to understand the implications of the constraints. The analysis showed the following:

- Station parking is a serious concern for the PVL because a higher proportion of passengers drive to boarding stations on this line than any other NJ TRANSIT commuter rail line.

- Among all NJ TRANSIT commuter rail lines, non-resident parking restrictions are most severe at the PVL stations. Almost half (45%) of the lots on this line allow parking only to those who live within the municipality. A comparison of free parking, on-street parking, and parking charges also indicates that the PVL stations are the most restrictive to non-residents. One of the reasons for the severe restrictions on non-residents is that all station lots on the line are owned by local municipalities.

- The PVL survey indicates that many more passengers would have driven to their boarding station if non-resident parking restrictions were eliminated. The survey results show that passengers boarding at stations with severe restrictions are more likely to state that they would drive to the boarding station if non-resident parking restrictions were eliminated. However, parking cost appears to be a greater concern to current PVL passengers than non-resident parking.

- Analysis of PVL survey data also indicates that the catchment areas of stations with more severe non-resident parking restriction are generally smaller than the stations with less restriction. It may indicate that some potential PVL users are currently using other modes to travel to their destinations.

- Although the various analyses in this chapter suggest that there may be a loss of ridership because of non-resident parking restrictions, they do not reveal the volume of lost ridership. Survey of existing passengers cannot inform how much additional ridership could be generated by eliminating non-resident parking restrictions. For the estimation of lost ridership, data will also be needed from individuals who are currently using other modes to travel to their destinations. A household survey of residents in communities surrounding the stations could inform how many additional riders could be attracted to the PVL by eliminating non-resident parking restrictions.

FAREBOX REVENUE FROM PVL SERVICE

Analyses were undertaken pertinent to the study's objective of measuring revenue from PVL off peak service. In addition to total revenue, revenue estimates were made for time period and direction of trains, trips diverted from automobile, and trips diverted from private buses. Revenue estimates were also made for those who mentioned in the survey that they would divert to non-rail modes if off peak service were reduced. For the estimation of revenue, data from the PVL survey and station-to-station fare were integrated. Data on fare was collected from NJ TRANSIT. Although NJ TRANSIT rail fares increased substantially subsequent to the onboard survey conducted in June 2010, rates that were in place at the time of the survey were used for the estimation of revenue.

Method of Estimation

The following steps were involved in the estimation of revenue:

1) Weight the PVL survey respondents to make them representative of average weekday ridership on the basis of actual boardings.
2) Cross tabulate the weighted passengers by origin and destination stations and ticket type to obtain the number of riders between each pair of stations by ticket type.
3) Since most passengers transferring at Secaucus Junction state Secaucus as the deboarding station, convert the Secaucus riders into three categories (New York Penn Station, Secaucus, and stations on other NJ TRANSIT lines) on the basis of their final destination.
4) Obtain station-to-station fares for each ticket type by using zonal fare structure provided by NJ TRANSIT.
5) For each ticket type, multiply riders by fare between each origin-destination pair and multiply the products by factors provided by NJ TRANSIT to obtain annual revenue.

Thus, for origin station *i* and ticket type *t*, annual revenue R_{it} is given by:

$$R_{it} = A_t \sum_{j=1}^{m} P_{tij} F_{tij}$$

Total annual revenue for origin station *i* for all ticket types is given by:

$$R_i = \sum_{t=1}^{k} R_t$$

Total annual revenue for all origin stations is given by:

$$R = \sum_{i=1}^{n} R_i$$

Where, A_t is the annualization factor for ticket type t, P_{tij} is the number of weighted passengers or riders using ticket type t to travel from station i to station j, F_{tij} is the fare for riders using ticket type t traveling from station i to station j, m is the number of destination stations, k is the number of ticket types, and n is the number of origin stations. The annualization factors shown in Table 25 were used for each ticket type.

Table 25 – Factors Used to Annualize Revenue from Survey Data

Ticket Type	Annualization Factor
Monthly pass	12
Student monthly pass	12
Weekly pass	50
10-trip ticket	25
One way ticket	508
Off peak round trip	254
Peak round trip	254
Disability discounted	508
Senior discounted	508
Other	508

Total Revenue Generation

For the purpose of the analysis, trips were classified by period and direction: (a) peak period – peak direction; (b) peak period–off peak direction; and, (c) off peak period–both directions. Peak period–off peak direction and off peak period–both direction together constitute off peak period service.

The revenue generated by the methodology for peak and off peak period has been presented in Table 26 by ticket type. The unadjusted revenues are estimated directly from the survey. Since a small proportion of survey respondents did not provide all the necessary information for estimating revenue (e.g., ticket type), these revenue estimates were adjusted for the passengers with missing data. The total unadjusted annual revenue is estimated to be $7.73 million, whereas the adjusted revenue is $8.0 million. The adjusted revenue from peak period trains is $4.9 million, whereas the revenue from off peak trains (including trains running in off peak direction in peak period) is $3.1 million. Thus, according to the estimates, approximately 62% of the revenue from PVL is generated from peak period trains, while the remaining 38% is generated from off peak trains. The total adjusted annual revenue estimates by period and direction of train are shown in Table 27.

Table 26 – Estimated Farebox Revenue from PVL

Ticket Type	Peak Revenue (Dollars)	Off Peak Revenue (Dollars)	Total Revenue (Dollars)
Monthly	$3,796,810	$1,621,524	$5,418,334
Student	$11,556	$17,436	$28,992
Weekly	$84,338	$37,913	$122,250
10 Trip	$269,775	$121,288	$391,063
One way	$455,778	$718,820	$1,174,598
Off peak Round Trip	$12,700	$216,662	$229,362
Peak Round trip	$56,515	$75,184	$131,699
Disability	$0	$14,859	$14,859
Senior citizen	$137,541	$54,610	$192,151
Other	$9,652	$9,779	$19,431
Total Unadjusted Annual Revenue	$4,834,664	$2,888,074	$7,722,738
Total Adjusted Annual Revenue	$4,948,502	$3,055,491	$8,003,993

Table 27 – Estimated PVL Revenue by Period and Direction

Period	Total Revenue (Dollars)
Peak Period - Peak Direction	$4,948,502
Peak Period - Off Peak Direction	$1,642,441
Off Peak Period – Both Directions	$1,413,050
Total	$8,003,993

Comparison of Revenue Estimates with NJ TRANSIT's Estimates

During this research, NJ TRANSIT independently estimated farebox revenue using its own resources and methods. According to these estimates, the annual revenue from the PVL for the years 2008, 2009, and 2010 were $6.29 million, $6.79 million, and $6.92 million, respectively. The 2010 revenue estimate by NJ TRANSIT ($6.92 million) is significantly lower than the revenue estimated from survey data used by this research ($8.0 million). However, since NJ TRANSIT attributes the revenue from New York-bound passengers of the PVL who travel from Secaucus to New York City to other lines such as the NEC and New Jersey Coast line, these estimates do not fully represent the revenue generated from PVL passengers. When the New York bound trips are distributed between Secaucus and Hoboken stations based on survey responses, the total revenue from the PVL for the year 2010 decreases from $8.0 million to $6.94 million. (When the New York trips are attributed to Secaucus Junction Station only, the revenue decreases to $6.92 million, an amount almost identical to the revenue estimate by NJ TRANSIT for 2010.) Thus the difference between the NJ TRANSIT revenue estimates and the estimates generated by this research is only 0.37%. The minute difference between the two estimates validates the methodology used by this research for estimating farebox revenue.

Revenue Generation from Automobile Diversions

As shown in Table 10, a total of 952 passengers, or 24.4% of all passengers, reported that they drove alone to their destinations before off peak service was introduced to the PVL. The revenue generated from these passengers is presented in Table 28 by period and direction. As evident, $1.97 million (24.6% of total revenue) was generated from passengers who drove alone to their destination prior to off peak service. It may be noted that when carpool passengers are added, the total revenue from prior automobile users increases from $1.97 million to $2.06 million (25.8% of total).

Table 28 – Estimated Revenue from those who Drove Alone Before PVL Off Peak Service

Period and Direction	Passengers who Drove Before[a]	Annual Revenue (Dollars)
Peak Period – Peak Direction	592	$1,226,422
Peak Period – Off Peak Direction	192	$374,999
Off Peak Period – Both Directions	141	$315,264
Unadjusted Total	925	$1,916,684
Adjusted Total	952	$1,972,631

[a] Weighted response

Revenue Generation from Private Bus Passenger Diversions

Of the 3,897 daily passengers, 480 (12.3%) mentioned that prior to PVL off peak service they used buses to travel to their destinations. Out of the 480 passengers, 93 began their trips from Montvale, Park Ridge, Woodcliff Lake, or Hillsdale station – stations that are served by private bus carriers only. Of these passengers, 87% traveled to New York City or other places in New Jersey, whereas the remaining 13% made trips to places along the PVL. When the trips to New York City and other places in New Jersey are attributed to Secaucus Junction Station or Hoboken Station of the PVL, the annual revenue generated from these passengers amounts to $174,351. However, when the trips are attributed to the actual destinations (i.e., New York City), the estimated annual revenue from these passengers is $177,984. In sum, annual revenue in the range of $174,000-$178,000 was generated due to diversions from private buses serving the four stations after off peak service was added to the PVL.

Potential Revenue Loss from Off Peak Service Reduction

To examine the potential impact of reducing off peak service on ridership and revenue, a question was asked in the onboard survey, inquiring how the passengers would react if service were reduced between 9:30 AM and 4 PM and after 7 PM. The responses to the question are presented in Table 12 of this report. Of the 3897 passengers, many responded that they would take the PVL at another time or divert to another NJ TRANSIT commuter train. However, 1574 passengers (40%) responded that they would divert to automobile, bus, or other modes. Revenue generated from these 1574 passengers was estimated by taking into account their trip origins and destinations. These estimates are shown in Table 29 by period and direction.

Table 29 – Estimated Revenue from those who would Use Modes other than Commuter Rail if Off Peak Service were Reduced

Period and Direction	Passengers[a]	Annual Revenue (Dollars)
Peak period – Peak Direction	958	$1,993,912
Peak Period- Off Peak Direction	306	$636,705
Off Peak Period – Both Directions	310	$707,194
Total	1574	$3,337,810

[a] Weighted passengers

It is evident from Table 29 that a total of $3.3 million annual revenue is generated from the passengers who said that they would divert to non-rail modes. It is worth noting that even though the passengers were asked about a potential reduction in off peak trains, 958 passengers, or 61% of those who said they would divert to non-rail modes were peak period passengers. The revenue generated from these passengers is almost $2 million (25% of total revenue). This suggests that the reduction in off peak service may have a significant impact on revenue generated from peak period riders in addition to the revenue generated from off peak riders.

ESTIMATION OF VMT AND GHG SAVINGS FROM PVL OFF PEAK SERVICE

New or improved rail transit service is expected to reduce VMT and adverse air quality impacts of transportation by diverting trips from other modes to transit. This chapter provides the estimates of VMT and air quality benefits from PVL off peak service and describes the methodologies used. The primary data source for the analyses is the 2010 PVL onboard survey. VMT reduction was estimated by using responses from the survey, especially diversions from other modes to the PVL. The estimates of reduced VMT were used as input for the estimation of GHG and other types of emissions. Methods developed by NJ TRANSIT and the Environmental Protection Agency (EPA) were used for the estimation of GHG. The NJAQONE model, developed by Michael Baker J., Inc., for the NJDOT, was used to estimate other types of emissions benefits. For the estimation of VMT, GHG, other pollutants, spreadsheet models were developed.

Estimation of VMT Reduction

In the PVL onboard survey, respondents were asked how they used to make the trip before off peak service was introduced in October 2007. The distribution of responses to the question is shown in Table 10 of this report.

It is evident from Table 10 that close to 47% of the respondents did not make the trip prior to the introduction of off peak service. As the circumstances leading to these respondents' use of PVL service is not known, how their travel patterns affected VMT cannot be ascertained. Obviously the most critical for VMT reduction are those passengers who used to drive before PVL off peak service was introduced. Diversions from carpooling also contributed to VMT reduction, but to a smaller extent than driving alone because the vehicles they used carried multiple passengers. Those who diverted from another NJ TRANSIT commuter line, PATH, or ferry to PVL also contributed to VMT reduction because most passengers drive to rail stations and ferry terminals in New Jersey.

VMT Savings from Automobile Driving and Carpool Diversions

Regarding estimation of VMT reduction, a question was included in the PVL survey for the passengers who drove alone or carpooled, inquiring about the distance of the trip they used to make between their trip origin and final destination. The mean trip distances for trains departing at different times of the day are shown in the top row of Table 30. Since other surveys of transit passengers usually show that peak period trips are longer than off peak trips, it is somewhat surprising that the mean distance for off peak trains in the PVL survey is longer than peak trips. However, since the trip distances are not for all transit passengers, but for only those who used to drive or carpool before PVL off peak service, the discrepancy from the norm is possible.

A more significant issue with stated survey responses is that passengers may not know the exact distance of their trips. The problem may have been further exacerbated in the PVL survey by the fact that many users might have diverted from automobile to transit two or three years before the survey was conducted. Even if the respondents knew the exact trip distance from odometer reading when they used to drive, some of them might not remember it at the time of the survey, conducted a few years later.

Because of the difficulties in interpreting the stated survey distances, network distances between the trip origins and the final destinations were estimated using the ArcGIS Network Analyst. Network data from the Geographic Data Technology Inc., commonly known as GDT, was used to calculate distances between the geocoded origins and destinations of survey respondents. This method uses the shortest road network distance between the origin and destination. As this method does not consider traffic congestion or speed, it may underestimate trip length for those who travel longer than the minimum distance to avoid congestion and save time. The mean trip distances between trip origins and destinations estimated by this method are presented in the bottom row of Table 30.

Table 30 – Mean Distance between Trip Origin and Destination for those who Drove Alone or Carpooled before PVL Off peak Service

	Peak Period-Peak Direction	Peak Period-Off Peak Direction	Off Peak Period
Stated mean distance from PVL survey	23.0	26.1	30.5
Network mean distance using GDT	20.4	22.0	19.3

Table 31 – Annual One-Way Weekday VMT Saved from Driving and Carpool Diversions Using Network Distance and Stated Distance

	Peak Period-Peak Direction	Peak Period-Off Peak Direction	Off Peak Period	Total
Using Network Distance				
(A) Weekday Drive only VMT saved	12,066	4,532	2,974	19,572
(B) Weekday Carpool VMT	608	229	150	987
(C) Weekday Carpool VMT saved (B/2.33)[a]	261	98	64	424
(D) Total weekday VMT saved (A+C)	12,327	4,630	3,038	19,995
(E) Annual VMT saved (Weekday X 254)	**3,131,015**	**1,176,093**	**771,684**	**5,078,792**
Using Stated Distance				
(F) Weekday Drive only VMT	13,644	5,395	4,689	23,728
(G) Weekday Carpool VMT	688	272	236	1,196
(H) Weekday Carpool VMT saved (G/2.33)[a]	295	117	101	513
(I) Total weekday VMT saved (F+H)	13,939	5,512	4,790	24,241
(J) Annual VMT saved (Weekday X 254)	**3,540,550**	**1,399,993**	**1,216,764**	**6,157,307**

[a] Average occupancy of 2.33 persons used to convert carpool passengers' VMT based on NJ TRANSIT information.

There is no scientific method to determine whether stated distance or network distance is a closer approximation of actual trip distance. Since most users of the PVL are commuters, who usually perceive commuting as a burden, it is likely that the stated distances are somewhat inflated. On the other hand, since the GIS-based network distances do not consider those individuals who drove longer than the shortest distance to save travel time, the network-based distances are likely to be deflated. It is therefore reasonable to assume that the stated distances and network distances estimated by the two methods provide the range within which lies the actual trip distance of passengers who drove or carpooled prior to the introduction of the off peak service on the PVL. With this assumption, two estimates of VMT are provided for PVL passengers who diverted from driving and carpooling in Table 31. The VMT estimates provided in Table 31 are for one-way travel only. The annual VMT savings in both directions for automobile users are shown in Table 32.

Table 32 – Annual Two-Way Weekday VMT Saved from Driving and Carpool Diversions Using Network Distance and Stated Distance

	Outbound (Spring Valley bound)	Inbound (New York bound)	Total
Using Network Distance			
Peak period – Peak direction	1,176,093	3,131,015	4,307,108
Peak period – Off Peak direction	3,131,015	1,176,093	4,307,108
Off peak period	771,684	771,684	1,543,367
Annual Weekday VMT Saved	**5,078,792**	**5,078,792**	**10,157,583**
Using Stated Distance			
Peak period – Peak direction	1,399,993	3,540,550	4,940,543
Peak period – Off Peak direction	3,540,550	1,399,993	4,940,543
Off peak period	1,216,764	1,216,764	2,433,528
Annual Weekday VMT Saved	**6,157,307**	**6,157,307**	**12,314,614**

VMT Savings from Other Rail and PATH/Ferry Diversions

As shown in Table 10, in addition to those who diverted from driving and carpooling, many diverted to the PVL from other commuter rail lines (e.g., the Bergen County line) and PATH or ferry after off peak service was added. Since most passengers in New Jersey drive to rail stations and ferry terminals, additional VMT was potentially saved because of these diversions. As noted earlier, only the passengers who drove or carpooled to destination prior to PVL off peak service were asked about the travel distance between their trip origins and destinations because it has no relevance to VMT reduction for those who used another commuter rail line, PATH, or ferry. What is important for these passengers is the distance between their trip origins and the boarding stations or ferry terminals they used. To account for the miles they potentially drove, these passengers were asked which station or ferry terminal they used for boarding trains or ferry. This information was used to estimate network distances between the trip origins and boarding stations/terminals by using the GDT network database mentioned earlier. The estimated mean travel distances between the trip origins and non-PVL train stations and PATH/ferry terminals are shown in Table 33.

Table 33 – Mean Network Distance between Trip Origin and Non-PVL Stations and PATH/Ferry Terminals

	Peak Period-Peak Direction	Peak Period-Off Peak Direction	Off Peak Period
Non-PVL Commuter Rail Station	7.47	7.74	7.01
PATH/Ferry Terminal	16.47	11.63	16.95

The mean distance from trip origins to non-PVL stations is significantly shorter than the distance to PATH/ferry terminals. The reason is that almost all passengers who used another commuter rail line used the Bergen County line, which includes several stations in close proximity of the PVL. In contrast, there are only a few ferry terminals and they are located farther than the Bergen County line.

Table 34 – Annual One-Way Weekday VMT Saved from those who Previously Used Other Commuter Rail line or PATH/Ferry

	Peak Period-Peak Direction	Peak Period-Off Peak	Off Peak Period	Total
(A) Weekday VMT saved from other commuter line users	1,352	360	426	2,138
(B) Weekday VMT saved from other commuter line users	1,656	333	320	2,310
(C) Total weekday VMT saved (A+B)	3,008	694	747	4,448
(D) Annual VMT saved (Weekday X 254)	**764,049**	**176,186**	**189,636**	**1,129,870**

The annual one-way weekday VMT saved from diversions to PVL from other commuter rail lines and PATH/ferry is shown in Table 34. The figures shown in Table 34 are based on one-way travel. The total two-way VMT saved from these passengers is shown in Table 35. It may be noted that the total VMT savings from passengers previously using another rail line or PATH/ferry may be slightly overestimated because all passengers might not have driven to the station/terminal. Given the long average distance between trip origins and stations/terminals, few could be expected to walk, but there might have been a more significant number who carpooled.

The aggregate VMT savings from all sources, including passengers who previously drove to destination, carpooled to destination, or used automobile to access transit stations on other lines or ferry terminals, are presented in Table 36. Two sets of numbers are presented in the table, one set using network distances for drivers and carpool users, and the other set using stated distances. The combined VMT savings are the aggregate of the figures presented in Table 32 and Table 35.

Table 35 – Annual Two-Way Weekday VMT Saved from Those Who Previously Used Other Commuter Rail Line or PATH/Ferry

	Outbound (Spring Valley bound)	Inbound (New York bound)	Total
Peak period – Peak direction	176,186	764,049	940,234
Peak period – Off Peak direction	764,049	176,186	940,234
Off peak period	189,636	189,636	379,271
Annual Weekday VMT Saved	**1,129,870**	**1,129,870**	**2,259,740**

Table 36 – Aggregate Annual Weekday VMT Savings from Diversions from All Diversions

	Outbound (Spring Valley bound)	Inbound (New York bound)	Total
Using Network Distance			
Peak period – Peak direction	1,352,279	3,895,064	5,247,342
Peak period – Off Peak direction	3,895,064	1,352,279	5,247,342
Off peak period	961,320	961,320	1,922,638
Annual Weekday VMT Saved	**6,208,663**	**6,208,663**	**12,417,322**
Using Stated Distance			
Peak period – Peak direction	1,576,179	4,304,599	5,880,777
Peak period – Off Peak direction	4,304,599	1,576,179	5,880,777
Off peak period	1,406,400	1,406,400	2,812,799
Annual Weekday VMT Saved	**7,287,178**	**7,287,178**	**14,574,353**

As mentioned previously, the stated distances between trip origins and trip destinations may be longer than the actual distances travelled by the passengers, whereas the network distances may be shorter. When network distances are used for estimation, the annual VMT savings would be 12,417,322, but when stated distances are used, the savings would be 14,575,353, a difference of approximately 17%. The mean of the two estimates is 13,495,838. In sum, the total annual VMT savings from all diverted traffic since off peak transit service was added to the PVL is in the range of 12.4-14.6 million, but possibly somewhere close to 13.5 million.

GHG Savings from Diversions to PVL

Greenhouse gases (GHG) include several components, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O). Since CO_2 is the most prevalent of the greenhouse gases, GHG is typically reported as CO_2 equivalent (CO_2E).

The reason for the reduction of GHG from transit service is that automobiles generate a substantial amount of GHG, and therefore diversion of trips from automobile to transit is likely to reduce overall GHG emissions. According to the EPA, an automobile that is driven 11,720 miles annually generates about 5.1 metric tons of CO_2E.

For estimating reduction of GHG emissions from the PVL service, two methods were used. One of the methods is the APTA-based NJ TRANSIT model that is used for its annual capital programs, whereas the other model was developed by the EPA for estimating GHG from automobile use. Both models include VMT and gasoline consumption per mile (mpg) by automobiles as inputs. The basic difference between the NJTRANSIT model and the EPA model is that the former includes three additional variables, namely, GHG savings from land use changes, GHG savings from congestion reduction, and increase in emissions from additional transit service. When these three variables are excluded from the NJ TRANSIT model, its GHG estimate is within 4% of the GHG estimated by the EPA model. The two models used for the estimation of GHG are described below. Because of its simplicity, the EPA model is described first.

GHG Savings Estimation by the EPA Model

Only two input variables are required to estimate GHG by the EPA method: VMT and gasoline consumption (miles per gallon, or MPG). By assuming an annual VMT of 11,720 miles and gasoline consumption of 20.4 gallons per mile, the method is used to estimate an emission of 5.1 metric tons of CO_2E per year. Clearly, a vehicle with a greater annual VMT or a lower mileage per gallon will increase the GHG estimate.

It may be noted that the EPA uses 20.4 MPG as the average fuel consumption for an automobile to estimate GHG. The American Automobile Association (AAA) also uses 20.4 MPG as average fuel consumption standard. In contrast, for the estimation of GHG for its 2009 capital program, NJ TRANSIT used 20.2 MPG as average fuel consumption. Clearly, in a heavily urbanized state like New Jersey, gasoline consumption per mile is likely to be higher than the national average used/suggested by the EPA and AAA.

The 2008 Highway Statistics published by the Federal Highway Administration provides information that can be used to estimate miles per gallon of gasoline for the state of New Jersey. The report shows that a total of 4,142,285,000 gallons of gasoline are consumed, whereas a total 73,629,000,000 miles are driven in a year by private vehicles in the state. By dividing the latter by the former, one can obtain the average MPG, 17.77. This estimate is significantly lower than the average used by the EPA. The national average from the Highway Statistics is 22.88 MPG. Because of the congested travel conditions along the PVL, especially the trans-Hudson crossings, 17.77 MPG is a more realistic estimate of miles per gallon than 20.4. However, because of the uncertainties surrounding both estimates, GHG is estimated using both MPG rates.

Table 37 provides the estimates of GHG reduction from PVL by the EPA method by using different values of VMT and MPG. The VMT estimates are due to diversions to

PVL from all modes, including drive alone, carpool, other commuter rail line, and PATH/ferry trips.

Table 37 – Annual GHG Reduction Due to Diversions from All Modes to PVL by the EPA Method

Assumed VMT Reduction	Assumed Average Miles per Gallon (MPG)	GHG Reduced (CO_2E Metric Tons)
12,417,323[a]	17.77	6,233
12,417,323[a]	20.4	5,430
14,574,354[b]	17.77	7,316
14,574,354[b]	20.4	6,373

[a] Using network distance for drive alone and carpool passengers
[b] Using stated distance for drive alone and carpool passengers

GHG Savings Estimation by the NJ TRANSIT Model

For estimating GHG, NJ TRANSIT uses a model that is based on a methodology suggested by the APTA. Like the EPA model, it uses VMT and mileage per gallon of gasoline as two input variables, but in addition, it also integrates GHG savings from land use and congestion relief, and adds GHG emissions from additional transit service. The NJ TRANSIT model can be described as follows:

(1) Net CO_2E avoided = VMT CO_2E avoided + Land Use CO_2E avoided + Congestion CO_2E avoided - Additional CO_2E generated by transit.

(2) VMT CO_2E avoided = (Annual VMT saved/Miles per gallon gasoline used) X Metric Tons CO_2E per gallon of gasoline

Where,

Miles per gallon used by automobile=20.2
Metric Tons CO_2E per gallon of gasoline =0.0092

(3) Land Use CO_2E avoided = (Annual VMT saved/Average vehicle occupancy) X Emissions per passenger mile in Kg

Where,

Average vehicle occupancy=1.9
Emissions (kg) per passenger mile=0.436

(4) Congestion CO_2E avoided = VMT CO_2E avoided X Ratio of Congestion avoidance and Total avoidance

Where,
Ratio of Congestion avoidance and Total avoidance=0.22

(5) Additional CO_2E generated = Additional annual passenger miles X Metric tons CO_2E per passenger mile by fully loaded transit X Factor to convert kg to metric tons X Estimated percent of future growth that will not use existing infrastructure and therefore create additional energy consumption

Where,

Additional Annual passenger miles = 1.04 X Annual VMT saved
Metric tons CO_2E per passenger mile by fully loaded transit =0.00020633
Factor to convert kg to metric tons=1,000
Estimated percent of future growth that will not use existing infrastructure and therefore create additional energy consumption=0.75

Table 38 shows the GHG savings estimated by the NJ TRANSIT Model. The GHG savings are shown for different combinations of VMT savings and average vehicle mileage per gallon of gasoline. Since NJ TRANSIT used 20.2 MPG for the estimation of GHG for its capital program, the same rate was used instead of the EPA's estimate of 20.4 MPG. IN Table 38, the GHG estimates are shown with and without land use impacts, congestion impacts, and emissions from additional transit service.

Table 38 – Annual GHG Reduction Due to Diversions from All Modes to PVL by the NJ TRANSIT Method

Assumed VMT Reduction	Assumed Average Miles per Gallon (MPG)	GHG Reduced (CO_2E Metric Tons)
Estimated *with* land use, congestion, and additional transit service impacts		
12,417,323[a]	17.77	8,694
12,417,323[a]	20.2	7,751
14,574,354[b]	17.77	10,204
14,574,354[b]	20.2	9,097
Estimated *without* land use, congestion, and additional transit service impacts		
12,417,323[a]	17.77	6,429
12,417,323[a]	20.2	5,655
14,574,354[b]	17.77	7,546
14,574,354[b]	20.2	6,638

[a] Using network distance for drive alone and carpool passengers
[b] Using stated distance for drive alone and carpool passengers

Estimation of Reduction in other Emissions Using NJAQONE

The methods used so far generate only the savings in GHG emissions, consisting primarily of CO_2, but not the savings in other types of emissions. In air quality conformity analysis conducted by transportation agencies, it is fairly standard to estimate other types of pollutants, including Volatile Organic Compound (VOC), Nitrogen Oxide (NOx), Carbon Monoxide (CO), Fine Particles (PM2.5), and Sulfur Dioxide (SO_2). In order to estimate the reductions in these pollutants due to diversions to the PVL, the NJAQONE model, developed by Michael Baker Jr. Inc. for NJDOT, was used. This model uses Mobile 6.2 for estimating emissions.

The NJAQONE requires changes in VMT and vehicle trips (VT) as inputs. It requires VT to be distributed between work trips and non-work trips, and both VT and VMT to be distributed into four time periods. The model also considers characteristics of the study area, manufacture year of vehicles, project completion year, and analysis year. Year 2007 was used as the project completion date because off peak service was added to the PVL in that year. Year 2010 was used as the analysis year because the PVL survey was conducted during that year. Bergen County was used as the project site because most of the PVL runs through Bergen County. The inputs used for the NJAQONE model are provided in Table 39. The VT and VMT estimates were obtained from the PVL onboard survey.

Table 39 – NJAQONE Model Inputs for Diversions from other Modes to PVL

Variable	Estimate	Variable	Estimate
For Automobile and Carpool Trips		**For Other Line and PATH/Ferry Trips**	
Daily VMT change with network distance	-39,990	Daily VMT change	-8,896
Daily VMT change with stated distance	-48,482	Daily VMT change with stated distance	N/A
Work VT change	-1,807	Work VT change	-765
Nonwork VT change	-139	Nonwork VT change	-107
VT Split between Time of Day		**VT Split between Time of Day**	
AM Peak	42%	AM Peak	40%
Midday	8%	Midday	10%
PM Peak	42%	PM Peak	40%
Night	8%	Night	10%

Note: VT and VMT estimates are entered as negative numbers because they are reductions.

The results from the NJAQONE models for auto/carpool diversions and other line/ferry diversions are shown in Table 40. For auto/carpool diversions, two sets of outputs are presented because the VMT inputs are different (one estimated by using stated distances and the other estimated by using network distances). Since the stated distances are longer than the network distances, the estimates of emissions are higher for stated VMT than network VMT. The NJAQONE model allows estimation of pollutants for a year, as well as for an average summer day and an average winter day. The annual estimates as well as average summer day estimates of reduction in emissions from the NJAQONE model are presented in Table 40.

Table 40 – Reduction in Emissions from the NJAQONE Model

Analysis Period	Description	Emission Reduced (kg)				
		VOC	NOx	CO	PM2.5	SO_2
Annual	Auto/Carpool - Network VMT	2,660.84	2,954.76	51,417.30	140.87	87.18
Annual	Auto/Carpool - Stated VMT	3,122.00	3,553.91	58,915.92	165.27	102.31
Annual	Other Line/PATH/Ferry	687.73	682.14	14,687.18	37.20	23.00
Summer Day	Auto/Carpool - Network VMT	9.96	10.40	147.53	0.56	0.35
Summer Day	Auto/Carpool - Stated VMT	11.79	12.51	173.91	0.66	0.41
Summer Day	Other Line/PATH/Ferry	2.48	2.39	37.43	0.15	0.09

Estimation of GHG from Additional Off Peak Trains

Far fewer studies have been conducted on emissions from transit compared to automobiles. As a result, methods for estimating transit emissions have remained primarily ad hoc. APTA has provided a method to estimate GHG benefits from new transit projects. This method includes a component on GHG savings from diversions of automobile users to transit, and another component on additional GHG generation from new transit service. The overall GHG saving is the difference between the two. The APTA method uses transit passenger miles instead of transit vehicle miles for the estimation of additional GHG. In this method, transit passenger miles are computed on the basis of expected new trips, which in turn are estimated on the basis of projected diversions from other modes, especially automobile and carpool. NJ TRANSIT uses the APTA method for estimating GHG benefits from transit capital projects for its annual capital programs. For the agency's 2009 capital program, NJ TRANSIT used this method to estimate GHG savings from the ARC project and other capital projects involving commuter rail.

The World Resources Institute (WRI) also has devised a methodology for estimating GHG emissions from new commuter rail projects. This estimation method essentially involves application of an emissions factor. Based on data from the Transportation Energy Data Book (TEDB), WRI estimated that the GHG emissions factor for US commuter rail is 0.16 kg of CO_2 per passenger mile. A problem in applying this method is that the emissions factor is the same irrespective of the type of fuel used (diesel, electricity, etc.) by locomotives. The reason for the WRI providing one emissions factor for all transit fuel types combined could be that the TEDB publishes national fuel consumption data by commuter rail in BTU instead of fuel consumed (i.e., diesel gallons). Although BTU can be converted to diesel gallons, not all commuter rails use diesel. Without knowing what proportion of service is provided by different fuel types, it is difficult to make an accurate estimate of GHG by this method.

Both the APTA method and the WRI method use transit passenger mile instead of transit vehicle mile as an input. However, it is debatable whether passenger mile or vehicle mile is a better variable for the estimation of transit GHG. The popularity of transit passenger mile may be due to the convenience of translating automobile diversions to transit from a new transit service, and subsequently factoring the diverted trips to transit passenger mile. A simpler way to measure GHG emissions from transit is by using vehicle miles instead of passenger miles. However, this method requires the amount of fuel consumed per vehicle mile as an input. In the two following sections, GHG emissions from PVL have been estimated using several methods.

Estimation of PVL Off Peak GHG Using Transit Vehicle Miles

Between June 2007 and June 2010, 17 off peak trains were added to the PVL. Eight of these trains are from Spring Valley to Hoboken, one is from North Hackensack to Hoboken, seven are from Hoboken to Spring Valley, and one is from Hoboken to North Hackensack. The distance between Hoboken and Spring Valley is 30.4 miles, whereas the distance between Hoboken and Spring Valley is 15.1 miles. By applying the distances to the number of trains between each origin-destination pair, the total additional vehicle miles can be estimated as 486.2 for the 17 trains. Table 41 shows the details.

Table 41 – Increase in PVL Weekday and Annual Trains and Vehicle Miles

	To Hoboken from Spring Valley	To Hoboken from North Hackensack	From Hoboken to Spring Valley	From Hoboken to North Hackensack	Total
Increase in weekday number of trains	8	1	7	1	17
Additional weekday vehicle miles	243.2	15.1	212.8	15.1	486.2
Increase in annual number of trains	2032	254	1778	254	4420
Additional annual vehicle miles	61,773	3,835	54,051	3,835	123,495

Table 42 – National Commuter Rail Vehicle Miles and Diesel Consumption from the 2011 APTA Public Transportation Fact Book[42]

Variable	Estimates	Source
Commuter rail vehicle miles traveled (VMT)	343,500,000	Table 8
Percent of commuter rail that uses diesel	88.70%	Table 12
Commuter rail VMT by diesel (88.7% of total)[a]	304,684,500	
Diesel fuel used by commuter rail (gallon)	95,000,000	Table 15
Gallons per mile* (95,000,000/304,684,500)[a]	0.31	

[a] Estimated from the data provided

Various sources (e.g., TEDB, the US Energy Information Administration, and the SAIC report) indicate that the GHG emission from a gallon of diesel fuel by locomotives is approximately 22.2 pounds of CO_2E. However, data on actual fuel consumption by the PVL (total or per vehicle mile) is not available. Because of the unavailability of data, it was imperative to find national data. The 2011 APTA Public Transportation Fact Book[42] provides some information that can be used to estimate diesel consumption per mile by diesel locomotives (see Table 42). From the data provided in the Fact Book, it can be estimated that the gallons used per mile by a diesel locomotive is approximately 0.31.

In addition to the APTA Fact Book, the Transportation Energy Data Book[(43)] (TEDB) also provides useful national data on commuter rail. Data from this source is provided in Table 43. To use the TEDB data for estimating diesel consumption per mile, BTUs have to be converted to gallon of diesel. This conversion was done by using a conversation factor provided by the National Association of Fleet Administrators, or NAFA (see source below table). By using this method, the amount of diesel consumed per vehicle mile is estimated to be 0.71. This rate is more than twice that obtained from the data provided by the APTA Fact Book.

Table 43 – National Commuter Rail Statistics from the 2011 Transportation Energy Data Book[(43)]

Variable	Estimate[a]
Commuter rail vehicles	6,900
Commuter rail vehicle miles	344,000,000
Passenger miles	11,232,000,000
Load factor (Passengers/vehicle)	32.7
BTU per Vehicle mile	91,936
BTU per passenger mile	2812
Total Energy use (BTU)	31,600,000,000,000
BTU per gallon of diesel[b]	129,800
Diesel gallons per vehicle mile[c] (91,936/129,800)	0.71
Diesel gallons per passenger mile[c] (2812/129,800)	0.02166

[a] Estimates from Table 2.11 of the TEDB report
[b] Source: http://www.nafa.org/PrinterTemplate.cfm?Section=Energy_Equivalents
[c] Estimated from the data provided

Assuming that a gallon of diesel produces 22.2 pounds of CO_2E, and diesel locomotives consume 0.31 gallons of diesel per mile, it can be estimated that the 123,495 annual vehicle miles generated by the added PVL trains produce 386 metric tons of CO_2. In contrast, when it is assumed that diesel locomotives consume 0.71 gallons per mile, as estimated from the TEDB data, the total GHG emissions from the added trains appear to be 883 metric tons.

Estimation of PVL Off Peak GHG Using Transit Passenger Miles

The PVL survey provides basic information that can be used to estimate GHG using transit passenger miles. The station-to-station passenger volumes estimated from the survey were multiplied by the station-to-station distances (miles) to obtain the estimate of passenger miles for different periods of the day. The relevant data on input variables are presented in Table 44.

Table 44 – Input Variables for Estimating GHG based on Passenger Miles

Variable	Off Peak		Peak Period – Off Peak Direction	
	Weekday	Annual	Weekday	Annual
One-way weekday trips	597	151,638	760	193,040
Two-way weekday trips	1,194	303,276	1,520	386,080
One-way weekday passenger miles	10,665	2,708,986	14,762	3,749,639
Two way weekday passenger miles	21,331	5,417,972	29,525	7,499,279
Average trip length (mile)	17.86		19.42	
Diesel consumed per passenger mile[a]	0.02166		0.02166	
Load factor	51.60		51.60	
Total diesel consumed	117,375		162,464	

[a] Estimated from TEDB data (See Table 39 for source)

GHG estimates with passenger miles as input were obtained in three different ways: (a) by using the WRI method, (b) by using the NJ TRANSIT Capital Program method, and (c) by using TEDB data. The WRI method involves application of an emissions factor (0.16 kg or 0.35 pounds of CO_2 per passenger mile). The NJ TRANSIT method also involves application of an emissions factor (.000206331*0.75= 0.000154748 metric tons of CO_2 per passenger mile). To use TEDB data to estimate GHG emissions from passenger miles, it is necessary to obtain an estimate of diesel gallons per passenger mile and make an assumption about the load factor. As shown in Table 43, according to the TEDB data, an estimated 0.02166 gallons of diesel are used per passenger mile nationally by commuter rail. The same source shows that the national load factor for commuter rail is 32.7 (passengers per vehicle). A load factor of 52.3 was used for the estimation based on survey data. The GHG emissions from the three methods are presented in Table 45. The GHG estimates from the three methods are fairly similar.

Table 45 – GHG Estimates from PVL Off Peak Trains Using Passenger Miles

Method	Annual CO_2E Estimate (Metric Tons)
Using WRI Method	
Off Peak Period	867
Peak Period in Off Peak Direction	1,200
Total	**2,067**
Using NJT Capital Program Method	
Off Peak Period	838
Peak Period in Off Peak Direction	1,161
Total	**1,999**
Using TEBD Data on Passenger Miles	
Off Peak Period	739
Peak Period in Off Peak Direction	1023
Total	**1,762**

Comparison of GHG Estimates from Additional Transit and Diversions to PVL

A comparison of GHG saved from diversions to PVL and additional GHG emissions from PVL off peak trains are shown in Table 46. It is evident from the table that even the largest estimate of additional emission (the one based on the WRI method) is only 2,067 metric tons of CO_2E. This estimate is far smaller than the lowest estimate of GHG reduction due to diversions from other modes to the PVL (5,430 metric tons, by the EPA method). Even if one accepts the highest estimate of GHG emissions from additional trains and the lowest estimate of GHG reduction due to diversions to PVL, the net difference is a reduction of 3,363 metric tons of CO_2E. According to these estimates, the additional GHG generated by the additional PVL trains is about 38.1% of the GHG reduced from diversions to PVL, indicating a net GHG benefit of 61.9%. By the other estimates, the GHG reduction would be even larger.

Table 46 – Comparison of GHG Saved from Diversions to PVL and Additional Emissions from Off Peak Trains

	Annual CO_2E Estimate (Metric Tons)
GHG Saved from Diversions to PVL	
EPA method	5,430 – 7316
NJ TRANSIT Method without land use and congestion benefits	5,655 – 7,546
NJ TRANSIT Method with land use and congestion benefits	7,752 – 10,204
Additional GHG from Off Peak Trains	
WRI Method	2,067
NJT Capital Program Method	1,999
Using TEBD Data on Passenger Miles	1,762

SUMMARY OF THE RESEARCH FINDINGS AND RECOMMENDATIONS

Past studies have rarely examined the benefits of off peak commuter rail service. As a result, the value of off peak service to a transit system may not be fully comprehended. Due to the location patterns of jobs and workers and the rigid work hours of employees generally, commute trips peak in the morning and afternoon hours. Under the current circumstances, providing service in the two peak periods is the top priority for most transit agencies. Peak trains indeed serve more passengers than off peak trains in most regions, and therefore transit agencies often look at off peak trains whenever there is a need to reduce service because of financial constraints. However, this study shows that off peak service can be a valuable component of a transit system and add to the growth of overall ridership.

The addition of 17 off peak trains to the PVL in recent years provided a unique opportunity for this study to examine the consequences of off peak service. Understanding the impacts of off peak service is virtually impossible without knowing how passengers change their travel patterns after off peak service is added to a line. To gain information on these changes, this study collected primary data through focus groups and an onboard survey of PVL passengers.

The focus groups indicated that the PVL passengers are highly satisfied with the off peak service. The focus groups also indicated that passengers make changes in travel patterns as a result of new off peak service. Despite being satisfied with the opportunity and flexibility to travel in off peak periods, the focus group participants wanted even greater frequency of service in the off peak period. Some passengers were dissatisfied that not all off peak trains operated along the entire route from Spring Valley to Hoboken.

Data from NJ TRANSIT's quarterly reports show that average weekday ridership on the PVL increased substantially after off peak service was added to the line; from 6,000 in FY-2006 to 7,075 in FY-2009. The PVL survey data shows that new riders increased substantially more after off peak service was added (approximately 13% each year), compared to the year before off peak service was added (7%). Together, these two data sources indicate that PVL ridership has grown substantially after off peak service was added primarily because of the increasing attractiveness of the line to individuals who were not using the line before.

In addition to attracting new riders, the off peak service substantially reduced automobile volumes and miles by diverting automobile users to the PVL. The PVL survey showed that more than 25% of the passengers diverted from automobile and carpool to PVL after off peak service was introduced. Moreover, 5% of the respondents reported using peak period trains more often, indicating that the greater flexibility to choose trains made possible by off peak trains increased peak travel also. The study also showed that about 12% of the passengers diverted from buses and more than 7% diverted from other rail lines. These diversions are benefits to passengers because they are saving time by using the PVL instead of other transit options.

This research showed that the PVL passengers generate a total of $8.0 million in annual farebox revenue when their trips from Secaucus Junction to New York and other NJ TRANSIT stations are included. Of this revenue, $4.9 million is generated from peak period trains and $3.1 million (approximately 38% of total revenue) is generated from off peak trains. The analysis also shows that an estimated $2.1 million in revenue was generated from passengers who diverted from driving or carpool.

Substantial decrease in vehicle trips and vehicle miles can also be attributed to the PVL off peak service. According to the estimates, VMT decreased in the range of 12.4-14.6 million annually. Due to the decrease in VMT, emission of GHG also decreased substantially. Although additional GHG emissions resulted from the new off peak trains, this amount is far less than the emissions reduced by diversions from other modes. Other emissions, including Volatile Organic Compound (VOC), Nitrogen Oxide (NOx), Carbon Monoxide (CO), Fine Particles (PM2.5), and Sulfur Dioxide (SO_2) also decreased by large amounts.

Regarding station parking constraints, this research shows that it is a significant issue for the PVL, especially because of non-resident parking restrictions in many station lots. Among all NJ TRANSIT lines, non-resident parking restrictions are most severe at the PVL stations. This is a serious concern because proportionally more passengers drive to boarding stations on the PVL than the other lines. Although this research does not provide an estimate of lost ridership because of parking restrictions, analysis indicates that because of the restrictions, some potential PVL users are currently using other modes.

Based on the empirical observations, the following recommendations are made:

- The VMT and GHG benefits observed in this study clearly indicate that off peak service should be seriously considered whenever opportunities arise. The spreading of morning and afternoon peak periods for highway travelers over the years suggests that there will be more demand for off peak trains in the coming years.

- When decisions are made about increasing or decreasing the number of off peak trains, the effect of the change should be considered on both peak and off peak period ridership instead of only off peak ridership because off peak trains increase the overall attractiveness of a line, and thereby increases peak period ridership.

- On the basis of the focus groups and the survey questions on satisfaction with PVL service, it seems appropriate to increase the frequency of off peak trains and operate all off peak trains between Spring Valley and Hoboken instead of operating some trains between Hoboken and New Bridge Landing. However, to implement this recommendation, detailed cost-benefit analysis and analysis of capacity constraints will be needed. A re-examination of additional passing sidings to allow enhanced off peak service frequency should be considered through more detailed analysis.

- Although this research indicates that the GHG reduction from off peak service far outweighs the additional emissions from the added trains, GHG emissions from trains can be further reduced by using alternative fuels.

- Issues relating to station parking constraints, especially non-resident parking restrictions at station lots should be addressed. Alternative parking opportunities or low cost parking management improvements to allow increased non-resident access or off peak access should be further studied to improve ridership and assist municipalities in improving their operations. Other access modes, such as shuttles, may also be useful for certain stations.

- Finally, the focus group and the survey results provide support to NJ TRANSIT's ongoing efforts to implement improved communication during service disruptions through the utilization of its Score CARD and customer satisfaction surveys. Improved communication is likely to result in greater ridership in the long run.

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