

TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix A: Interstate Bus Network - Operational and Service Strategies

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Submitted by:



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# 1 Introduction

## 1.1 OVERVIEW

On October 22, 2015, the Port Authority of New York and New Jersey’s (PANYNJ) Board of Commissioners authorized a *Trans-Hudson Commuting Capacity Study* (the Capacity Study) to evaluate a range of strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand to 2040, to inform its deliberations on conceptual planning for replacement of the Port Authority Bus Terminal (PABT) (Table 1).

Table 1: Existing and Future PABT Demand

EXISTING (2011)	FUTURE (2040)
232,000 Daily Customers	337,000 Daily Customers (+45%)
7,800 Daily Buses	9,100 Daily Buses (+15%)
615 PM Peak Hour Buses	855 PM Peak Hour Buses (+40%)

Source: Midtown Bus Master Plan

The fundamental premise of the Capacity Study is that the transportation network that accommodates trans-Hudson commuter demand is an integrated *system*, as opposed to a series of stand-alone corridors, facilities, and services. Accordingly, the intended outcome of the Capacity Study is an updated overview of that system that takes into account potential investments in physical transportation infrastructure, operational changes to existing transit services, implementation of emerging technologies, and modifications to public policy – and the prospects for their implementation in the time frame for planning and implementing a PABT replacement project.

Concurrent with the Capacity Study, the PANYNJ has commissioned an *International Design + Deliverability Competition* (the D+D Competition) seeking concepts for a new PABT. A major objective of the Capacity Study is to provide insight to the D+D Competition by evaluating the range of alternative strategies for serving the trans-Hudson commuter market via bus and other modes, which will inform the determination of the appropriate capacity and configuration of the new PABT. The interim and final work products from the Capacity Study will inform the D+D Competition and the PANYNJ Board, which will select a preferred design concept for a new PABT this fall.

The purpose of this technical memorandum is to develop a range of potential bus operations/service, roadway network, technology and policy strategies that could inform the planning and design (capacity and configuration) of the new PABT. This document identifies and evaluates a series of strategies, including a comparison of benefits, impacts, and policy issues. The strategy development and assessment were informed by: the Midtown Bus Master Plan (MBMP) effort, meetings and technical discussions with PANYNJ and NJ TRANSIT staff, and a Capacity Study Expert Workshop held on April 14, 2016. The final section of this technical memorandum provides targeted findings, including identification of factors relevant to the D+D Competition process. Subsequent technical memoranda will consider multi-modal network strategies and workplace flexibility strategies to

either complement or serve as alternatives to the bus network strategies in this technical memorandum.

## 1.2 STRATEGY DEVELOPMENT AND GUIDING PRINCIPLES

The strategies defined in the Capacity Study comprise a range of bus operational and service scenarios to meet projected peak period trans-Hudson commuter demand in 2040. They include a combination of investments in transportation infrastructure, modifications to existing bus routes, implementation of emerging technologies, and changes to public policy. The strategies fall into two categories:

- Strategies that **increase/manage capacity along the Lincoln Tunnel corridor** to support a new PABT that accommodates forecasted peak demand as identified in the MBMP
- Strategies that **address overall Trans-Hudson demand** including the use of other modes/crossings

The review of previous work efforts, discussions with PANYNJ and NJ TRANSIT staff, and input from the Capacity Study Workshop attendees led to the definition of several guiding principles that framed the development and assessment of strategies.

- **Apply a systems approach** – The PABT is just one component of a trans-Hudson bus transportation system that extends from 8<sup>th</sup> Avenue in Manhattan to the New Jersey Turnpike five miles to the west and beyond. In order to handle future demand for trans-Hudson bus travel during peak hours, all elements of this system – the approaches to NJ Route 495 from the NJ Turnpike and Route 3, the ramps that make up the ‘teardrop’, the Exclusive Bus Lane (XBL) and other lanes of 495, the Helix, the toll plaza, the Lincoln Tunnel tubes, the ramps leading into PABT, the PABT itself, and locations for bus storage and staging on both sides of the river – function as a system and future improvements should be configured accordingly. Each element is currently functioning at or near its capacity during peak periods on the average weekday such that investments or policy changes that expand throughput capacity in one segment without addressing upstream and downstream effects will not have meaningful system-wide results. Reconstruction of the PABT with provisions to accommodate increased ridership should proceed in coordination with other capital, operational, and policy changes that will support improved performance of the system for travelers and the communities on the network.
- **There is significant latent demand for trans-Hudson bus travel** – All future planning must consider that the trans-Hudson bus system has built-in latent demand such that capacity or service improvements are quickly filled with increased passenger activity. In robust but capacity constrained travel markets like trans-Hudson transit, the concept of latent travel demand is key to understanding how commuters will react to changes on the network. Currently, bus service at the PABT is limited by operational constraints, and operators offer less service at the peak than their customers desire to consume. In this context, if strategies are employed that shift demand from PABT as a way to create new capacity at PABT for anticipated future growth, the reality

is that existing latent demand would fill any additional capacity. NJ TRANSIT has experienced evidence of this phenomenon on prior trans-Hudson projects. NJ TRANSIT staff has advised the study team that it would add more peak-period service from certain markets to the PABT today if capacity were available. It is also important to note that latent demand implies growth above and beyond the demand forecasts. A more detailed discussion of latent demand is included in Section 4.1 of this technical memorandum.

- **Short-term improvements are needed** – Projected ridership growth will continue to put more pressure on the interstate bus network long before the new PABT is available, sometime between 2025-2030. Daily customer demand at the PABT is forecast to increase 20% by 2020 and 30% by 2030, compared to the 2011 base year. Wherever practical, the involved agencies should develop and advance interim strategies identified here to relieve capacity bottlenecks along the Lincoln Tunnel corridor and the connecting roadway network, some of which may require significant planning and capital investment. As the same time, the bus strategies for shifting some demand from the PABT to other trans-Hudson crossings should be considered by the involved operators and transportation agencies, including pilot services to test strategies that may provide attractive alternatives for some commuters in the near-term and test their potential as long-term options to route trans-Hudson bus service via other parts of the regional transportation network.

## 2 Lincoln Tunnel Corridor/PABT Facility Strategies

The Lincoln Tunnel corridor includes a series of elements that work as an integrated system to deliver buses to and from the PABT: the PABT facility itself, roadway/ramps that connect the Lincoln Tunnel and the PABT, the Lincoln Tunnel, the toll plaza, the Lincoln Tunnel Helix, Route 495/XBL, regional highways (NJ Turnpike, Route 3) and local approaches to 495 (Figure 1).

Figure 1: Lincoln Tunnel Corridor System Elements



Source: Trans-Hudson Commuting Capacity Study; Lincoln Tunnel XBL Capacity Enhancement Feasibility Study; Lincoln Tunnel HOT Lane Feasibility Study

The bus system capacity into the PABT is a function of bus type, service frequency, operating characteristics of the approach roadways, the capacity of the Lincoln Tunnel, the capacity of the bus terminal to process buses, customer demand, and the capacity of outbound roadways. It is also worth noting that many non-PABT buses use this corridor, including New York City Transit (NYCT) and Academy express buses from Staten Island, and private operators from New Jersey and Pennsylvania that offer their customers the option of one-seat crosstown service as an alternative to stopping at the PABT. Current projections for growing usage of a reconstructed PABT show a likely

increase in customer demand of 45% between 2011 and 2040, which is expected to increase peak hour PM bus departures from 615 in that base year to 855 in 2040. Broadly speaking, matching passengers with buses for afternoon departures requires far more physical space than morning arrivals, so the ultimate capacity and configuration of a reconstructed passenger terminal is driven by number of departing buses and passengers to be accommodated during the busiest afternoon rush hour (i.e., the PM peak hour, 5:30-6:30PM).

The following sections describe potential bus operational and service strategies that could increase or manage capacity along the Lincoln Tunnel corridor to support a new PABT that fully accommodates this projected future demand. The strategies are bundled into two groupings: (1) improved corridor operations; and (2) improved facility operations.

The strategies aim to address challenges facing the corridor in both the AM and PM peak periods. There are different challenges in the AM and PM peak periods—including, but not limited to, capacity of the XBL in the AM peak period, and travel time reliability for empty buses dispatched from New Jersey to the PABT in the PM peak period—that warrant different solutions. For instance, adding a second XBL would improve bus throughput to the PABT in the AM peak period, but it would not improve the challenges related to real-time dispatching of west-of-Hudson buses to serve the PABT in the PM peak period. Accordingly, many of the strategies discussed in the following sections are complementary in that they aim to address different challenges along the corridor and within the PABT.

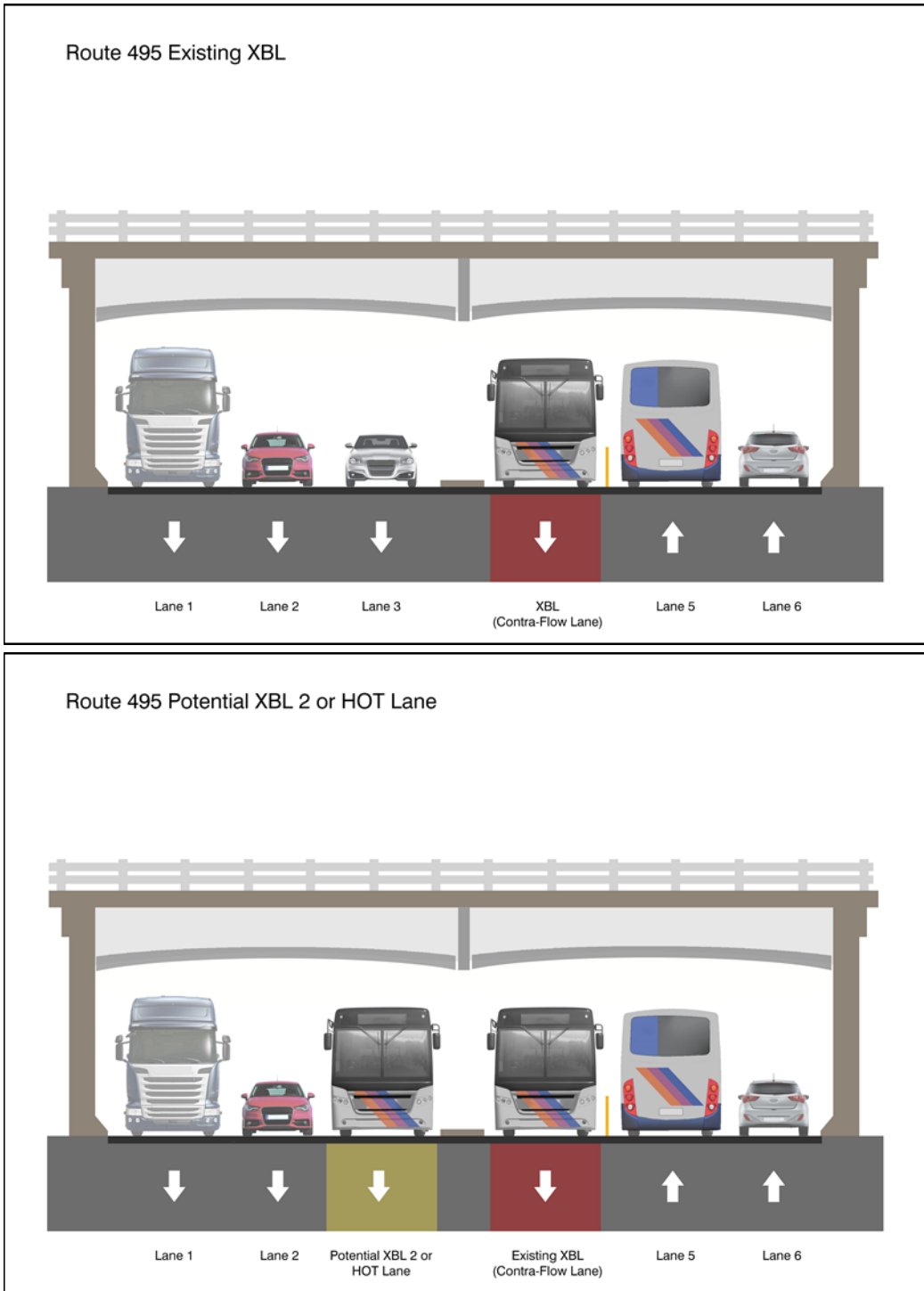
## 2.1 IMPROVED CORRIDOR OPERATIONS

The roadway network used to connect buses and other vehicles with the Lincoln Tunnel and local destinations in New Jersey is at or over its design capacity for a significant portion of the workday. Strategies to improve its capability to handle increasing bus volumes efficiently must address these constraints and balance the varied demands served by this critical corridor. The challenges include Route 495 itself, its connections to Route 3 and the NJ Turnpike, and local-access needs. Efforts to manage and prioritize the flow of buses and other traffic to and from the Lincoln Tunnel must be reconciled with growing volumes of local trips fueled by ongoing development along the corridor. Even with regard to the trans-Hudson bus flows, while the XBL feeds approximately 65,000 passengers along the Helix to the toll plaza and tunnel during the average morning rush (6-10 AM), approximately 30,000 more passengers travel on local bus routes that do not use Route 495 and instead access the tunnel from local streets that connect to the center ramp approach.

### 2.1.1 Second XBL or Route 495 HOT Lane

This strategy calls for adding either a second inbound XBL or a high-occupancy toll (HOT) lane on Route 495 to complement the existing inbound contra-flow XBL (Figure 2). The purpose of this strategy is to provide additional capacity for bus prioritization on Route 495, while also balancing overall vehicular demand with available capacity along the corridor. This strategy was examined in the *2006 Lincoln Tunnel XBL Capacity Enhancement Feasibility Study* and *2009 Lincoln Tunnel HOT Lane Feasibility Study*.

Figure 2: Route 495 Existing XBL and Potential XBL 2 or HOT Lane (Looking West, During AM Peak Period)



Source: Trans-Hudson Commuting Capacity Study; Lincoln Tunnel XBL Capacity Enhancement Feasibility Study; Lincoln Tunnel HOT Lane Feasibility Study

The 2009 study noted that, “the practical capacity of the XBL has been reached and periodically exceeded, with peak-hour volumes of 650 buses or more.” The 2.5 mile XBL is a critical link in the Lincoln Tunnel corridor, connecting the NJ Turnpike and Route 3 with the Lincoln Tunnel, which feeds the PABT. Given the combination of existing capacity constraints and projected future growth of PABT bus demand, the recent studies by the PANYNJ in 2006 and 2009 evaluated opportunities to enhance the capacity of the Route 495 XBL to accommodate additional buses.

The 2006 study suggested that a potentially feasible option for expanding bus prioritization along Route 495 during the morning rush would be to convert one of the three existing eastbound general purpose lanes to a second XBL. Other alternatives that were considered and eliminated from consideration due to a range of potential traffic and other environmental impacts included converting another westbound general purpose lane to function as a second contra-flow XBL or accommodating a second XBL by either widening Route 495 or constructing an elevated roadway for local traffic. The 2009 study advanced the previous work by noting that although a single XBL is not sufficient to service future bus demand, two such lanes offer more capacity than necessary, and identifying a preferred alternative that would enable full utilization of the second priority lane, thereby minimizing potential adverse traffic impacts along the corridor.

Specifically, the 2009 study proposed conversion of the left lane of eastbound Route 495 to a value-priced managed use lane (or HOT lane) in which buses could access the lane for free and other vehicles would also be permitted access for a variable charge. Based on travel demand projections, a second XBL would not be fully utilized by buses alone in the near-/mid-term, which would result in unused lane capacity along the already congested Route 495. This would exacerbate congestion upstream and also would impede access to local destinations along the route. A HOT lane would address this imbalance by imposing a charge on other vehicles to use the lane, and the price would be “changed dynamically to maintain free-flow conditions in the HOT lane.” The study noted that the pricing system could at times post “bus only” to restrict automobiles from accessing the HOT lane. In the long term, if growth in bus demand warrants exclusive use of the priority lane by buses, the HOT lane could be converted to a second XBL.

The 2009 study considered a total of eight alternatives for the HOT lane that varied based on access from the NJ Turnpike, pricing of carpools, and truck restrictions, but also shared a number of key assumptions. For instance, under all alternatives, vehicles on the Route 495 HOT lane would merge with additional high-occupancy traffic from the Center Ramp at the Lincoln Tunnel toll plaza and would use the right lane of the Lincoln Tunnel Center Tube. The study indicated that the need to merge with other traffic prior to entering the Lincoln Tunnel would be a “critical constraint to the maximum volume that can be accommodated in the HOT lane,” whereas the existing XBL connects Route 495 to the Lincoln Tunnel by way of a dedicated free-flow toll lane at the toll plaza. Accordingly, although the capacity of each lane of the Center Tube is assumed to be 1,200-1,400 vehicles per hour (depending on mix of vehicle types, and absent any connected vehicle technology), the capacity of the HOT lane may be lower because of the merge with other vehicles from the Center Ramp approach.

Other commonalities among the alternatives considered in the 2009 study included that all buses from Route 3 destined for the Lincoln Tunnel would use the HOT lane, while buses from the NJ Turnpike would continue to use the existing XBL and the left lane of the Lincoln Tunnel Center Tube. The study also acknowledged the PANYNJ's plan to implement all-electronic toll plaza operation at the Lincoln Tunnel.

The preferred alternative that emerged from the 2009 study included consideration for both a near-term solution—with no access improvements for NJ Turnpike traffic to access the proposed HOT lane—and a long-term solution, which would include extensive construction to enable direct access from the NJ Turnpike without the need to weave across Route 495.

Potential benefits associated with this strategy include increased capacity for bus prioritization along Route 495, improved travel time and reliability, and additional revenue generation for the PANYNJ (through collection of the HOT lane charge). Potential impacts associated with this strategy include diversion of auto traffic to other congested trans-Hudson crossings, additional delay in the remaining general purpose lanes, congestion at the NJ Turnpike approaches to Route 495 (because of the multiple-lane merge to access the potential HOT lane), and additional delay at the Lincoln Tunnel toll plaza. Public policy issues that would need to be addressed to advance this strategy include determination about the time of day for prioritization, number and location of access points to the lane, minimum desired speed to inform pricing for the lane, safeguarding local access and egress, and enforcement mechanisms. Other important considerations include timeframe for implementation and jurisdictional coordination, including a determination of agency responsibilities. Additionally, implementation of this strategy would include some ramping improvements with an associated capital cost.

It is important to note that the problem this strategy aims to address—insufficient AM peak hour capacity for bus flow into Manhattan—is also directly addressed in Section 2.1.3 regarding bus platooning (the ability to tightly group up a set number of buses essentially operating as a single unit). Indeed, these two strategies should be seen as alternate methods for achieving similar throughput goals. However, current demand projections do not appear to warrant the additional capacity that would result from both strategies being applied together. There are trade-offs associated with the two strategies. For instance, higher bus throughput in one lane rather than two has clear advantages for other eastbound vehicles, but a second lane would create a redundancy benefit that better technology cannot fully provide. For instance, in the case of a disabled bus or a glitch on an automated bus in a single lane, the entire operation could be compromised. With two lanes, however, some throughput could be maintained, and there could also be more flexibility in responding to the incident location.

**Conclusion: Demand currently approaches or exceeds capacity along the XBL, which provides prioritization for buses along Route 495 to access the Lincoln Tunnel enroute to the PABT. Implementation of a second XBL would improve AM operating conditions for buses, but it would not be fully utilized in the near-/mid-term and would degrade operating conditions for other vehicles remaining in the two general purpose lanes. Therefore, a HOT lane would be a better solution than a second XBL if lane utilization**



can be optimized. This corridor improvement can be accelerated for early implementation to address existing capacity constraints—which are projected to get worse in the future—for buses along Route 495, although implementation should be coordinated with measures to relieve bottlenecks to the Route 495 approaches (discussed in the next section). Additionally, whereas a second XBL would constrain automobile access, implementation of a HOT lane would enable continued use of the repurposed lane by some automobiles through payment of a variable charge. In the long term, the HOT lane could be converted to a second XBL if warranted based on projected growth in bus demand beyond 2040. A careful study of bus platooning technology should be undertaken to determine if the higher throughput needed to service an expanded PABT can be met without a second XBL or HOT lane.

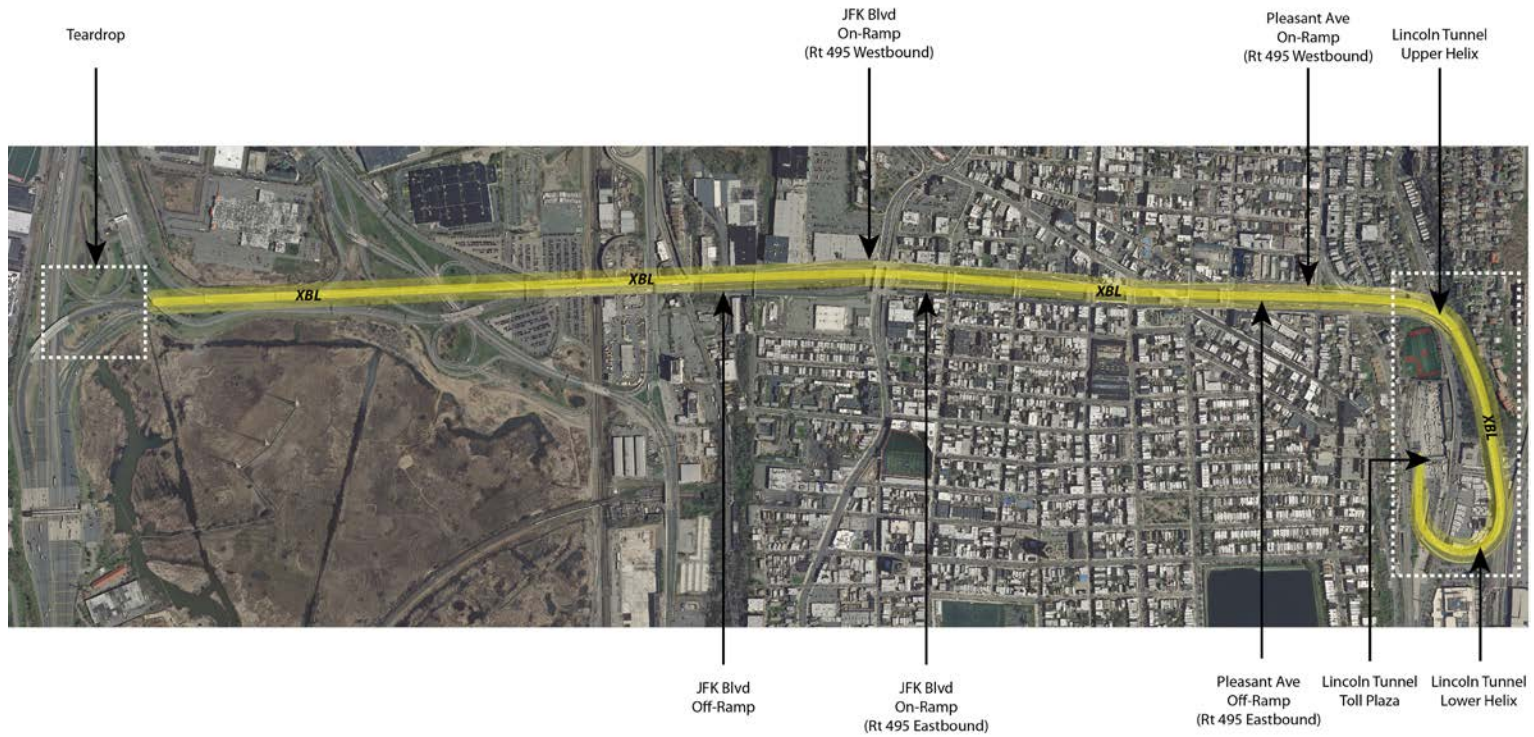
### 2.1.2 Enhanced Bus/HOV Priority Network

This strategy calls for improving bus/HOV priority within the existing Lincoln Tunnel corridor network, as well as adding bus/HOV priority on the major Route 495 approaches including Route 3 and the NJ Turnpike. The purpose of this strategy is to enhance the operation of the existing XBL and also supplement the XBL by providing additional bus prioritization farther upstream from the Lincoln Tunnel. Route 495 is shown on Figure 3. Corridor pinch points (from west to east) include NJ Turnpike Interchange 16E, the teardrop, protection of local access/egress at JFK Boulevard and Pleasant Avenue, and bus flow through the toll plaza.

This strategy builds upon ongoing studies and planned capital improvements by the PANYNJ. As part of the PABT Quality of Commute Program, the PANYNJ is advancing an initiative to improve incrementally bus prioritization at the approaches to the existing XBL. Specifically, the PANYNJ is proposing to realign the teardrop interchange that provides access to the XBL (Figure 4), which constrains the operational efficiency of the corridor due to pinch points in the merging area. The purpose of the proposed realignment is to provide additional length on the merging segment to increase the XBL throughput. Additional benefits of the proposed project include better alignment of the teardrop with the XBL, improved signage, and provision of a bus breakdown area and a protected area for PANYNJ police. The project is proposed for near-term implementation in coordination with the NJ Turnpike Authority.

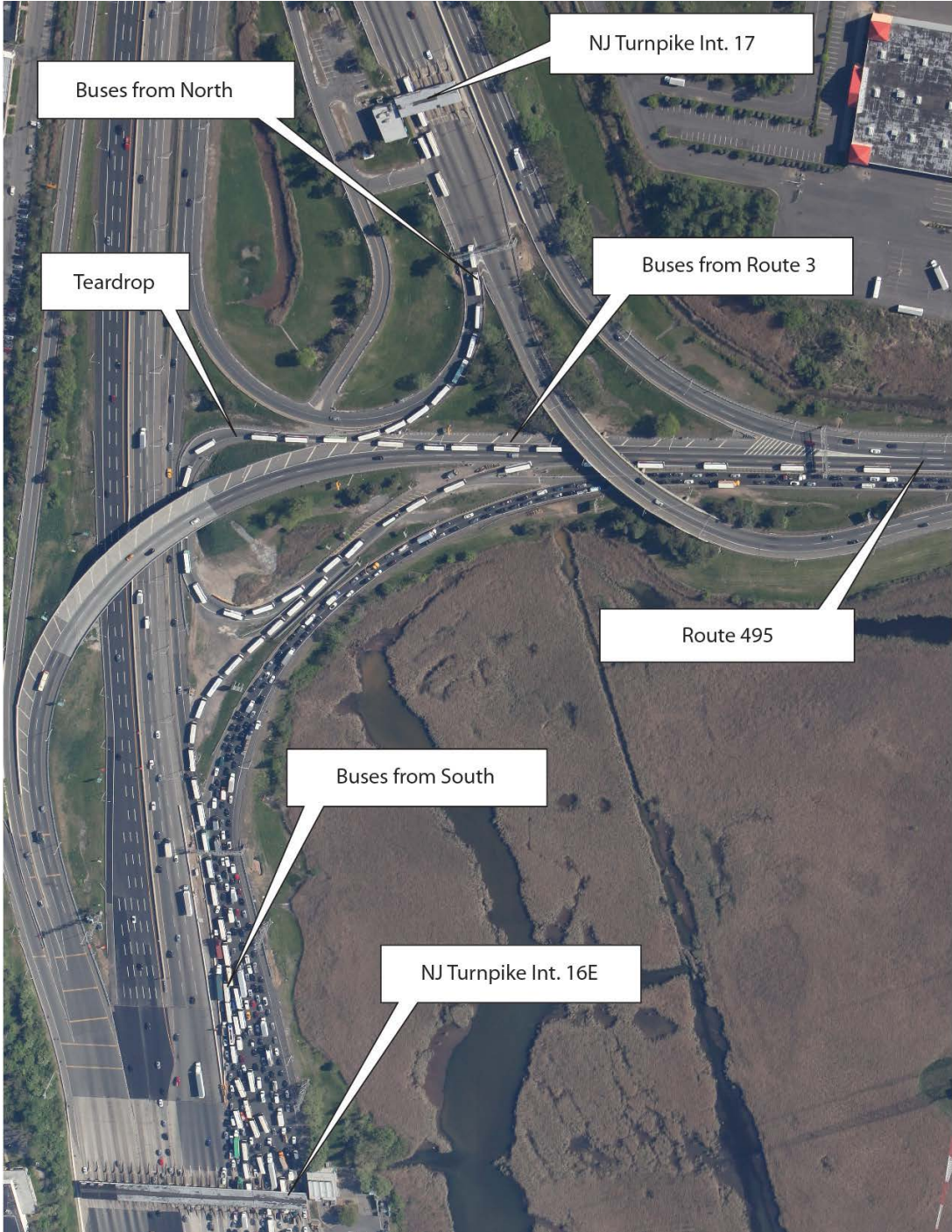
Nearby, another location that slows the efficient flow of buses toward the XBL is at the NJ Turnpike 16E interchange. Buses coming north on the Turnpike exit here in mixed traffic, navigating beyond the toll barrier in heavy peak-period volume toward a single lane that merges with buses coming through the teardrop. Identifying options to ease this bottleneck would improve reliability for this segment of the PABT-bound bus market.

Figure 3: Route 495



Source: Trans-Hudson Commuting Capacity Study

Figure 4: Teardrop Interchange



Source: Trans-Hudson Commuting Capacity Study



In addition to that effort, other potential actions could be taken to expand the priority network for buses that serve the trans-Hudson commuter market. Physical modifications to the teardrop to reduce merging conflicts would reduce delays at this bottleneck, providing more reliable travel time for buses and potentially reducing operating costs. Identifying capital resources for system enhancement projects like this is challenging as transportation agencies prioritize state-of-good-repair needs. Next steps for this initiative would be engaging the involved transportation agencies to discuss potential improvement options and scope a study including analysis of feasibility and impacts on travel times and overall traffic.

Public policy issues that would need to be addressed to advance this strategy include inter-agency coordination with the New Jersey Department of Transportation (NJDOT), the NJ Turnpike Authority, and municipalities with jurisdiction over local roadways that intersect the approaches to Route 495. Additionally, the evaluation of added bus prioritization options would need to consider the auto diversion factor. Specifically, while a reduction in the volume of private auto traffic during peak periods could provide significant benefits for bus operations, this strategy (and others that consider additional bus prioritization) would require more detailed analysis of impacts on general traffic and the resulting public policy implications (i.e., regional traffic, air quality, and transit-demand impacts).

It is also important to note that implementation of additional priority treatments along and at the approaches to Route 495 would need to maintain access for trips using this corridor that are oriented to local destinations in New Jersey. The New Jersey waterfront has experienced new development in recent years, and more growth is projected in the future, which underscores the need to preserve access to and from Route 495 for local trips that would not directly benefit from improved interstate bus service.

**Conclusion: The addition of bus prioritization at the Route 495 approaches could improve travel time, reliability, and operational efficiency of the Lincoln Tunnel corridor for trans-Hudson bus commuters. In conjunction with other Lincoln Tunnel corridor strategies, elements of this strategy could be accelerated for early implementation to address existing pinch points in the interstate transportation network that feeds the PABT. The full benefits of this strategy would likely only accrue if other strategies are advanced to improve capacity constraints along Route 495, within the Lincoln Tunnel, and at the PABT.**

### 2.1.3 Bus Platooning through Connected and Automated Vehicle Technologies

Emerging technologies can yield further improvements in capacity and flow beyond the high level of performance that drivers have sustained in the current intensive operation. Indeed, emerging technologies can safely and reliably assist drivers to enable existing lanes to serve many more buses and thus many more customers. Bus platoons refer to tightly spaced groups of buses, in this case enabled by connected technologies (such as systems for adjacent buses to communicate speed, distance, and braking information) and autonomous technologies (such as driver assist for lane keeping through driverless buses). There are already commercially available systems from passenger cars and trucks—as demonstrated in the April 2016 European Truck Platooning Challenge

(Figure 5)—that could be adapted to buses. Accordingly, near-term implementation within 10 years could potentially yield an increase in capacity of the XBL, as suggested by a collaboration of researchers at Princeton University and as discussed at the Capacity Study Workshop on April 14, 2016.

Figure 5: Route Successfully Completed by Truck Platoons from the April 2016 European Truck Platooning Challenge



Source: Arstechnica; EU Truck Platooning;

This strategy includes technology solutions such as Lane Keeping Assist, Blind Spot Warning (for drivers and pedestrians), Adaptive Cruise Control, Autonomous Emergency Braking, Collision Warning and Mitigation, and Obstacle Detection. Individually or in combination, most of these solutions exist today and can be implemented to immediately improve operations along the corridor. As discussed at the Capacity Study Workshop, and as noted in a presentation by Jerome Lutin and Alain Kornhauser at the 2014 Transportation Research Board Annual Meeting, some experts predict that the cost of installing these solutions could be recovered in as little as one to two years through reductions in casualty and liability claims alone.

A platoon could consist of two vehicles, or as many as four or five vehicles. A bus platoon would function as follows – As the vehicles “connect” into their platoon, their on-board computers would designate one vehicle as a lead and the others as followers. The key is that the lead bus would set the pace, the following buses would match their pace with shorter following distances, and—thanks to lane keeping and adaptive cruise controls—the platoon would maintain a steady trek down the corridor with consistent headway and speed. In the event the lead vehicle has to slow down, automatic braking technology in the follower vehicles could react quickly and efficiently to ensure the consistency and headway remains steady.

For the purposes of this strategy, the Phase 1 deployment would be limited to the XBL and Lincoln Tunnel where mixed vehicles are not present. Once there is more experience with bus platooning along the XBL, Phase 2 deployment could consider platoons in mixed traffic, such as in the off-peak direction.

The National Highway Traffic Safety Administration (NHTSA) defines five levels of automation from Level 0 (no automation) through 4 (the vehicle could drive unoccupied). The strategies currently being discussed for bus platooning are considered Level 2 - automation of at least two control functions designed to work in harmony when deployed together, such as Adaptive Cruise Control with Lane Keeping Assist. As the fleet begins to progress into Level 3 automation, there is limited self-driving available. It is in this case where it could be possible to begin implementation of connected and automated strategies to achieve solutions such as Cooperative Adaptive Cruise Control and Lane Keeping.

The combination of Lane Keeping with Cooperative Adaptive Cruise Control is the path to bus platooning along Route 495. This reveals the potential for increased capacity of the XBL. Under existing conditions, actual operation runs below its theoretical capacity due to a number of factors that both individually and collectively limit throughput in the corridor. These factors include: delays at merge points at both ends of the corridor; longer-than-necessary following distances; slow speeds due to sun glare; the need to take the XBL curve slowly because of narrow lane geometry; and occasional traffic collisions/breakdowns. Also, buses frequently dislodge the delineators that separate the XBL lane from the adjacent traffic lane leading to delays of 15 minutes or more due to disruptive collection and reset. Emerging technologies to automate certain functions and introduce more consistent headways could help to mitigate each of these factors and not only achieve the theoretical capacity, but potentially exceed it.

The primary benefits of connected/automated bus platooning are:

- Increasing XBL capacity, possibly to the point of avoiding or deferring creation of a second XBL lane or HOT lane (Section 2.1.1) to accommodate the projected bus demand. This is achieved through reducing bus headways and the variability in bus speeds.
- Reducing incidents of buses knocking XBL delineators out of place.

While there is always risk associated with implementing new technologies on machines as large as buses with human passengers, there are many steps to mitigate the risk. First, these technologies do not need to be developed from scratch for this application – there are limited real-world examples of many of the technologies described. As part of evaluation and program development, PANYNJ and NJ TRANSIT staff could visit such operators and companies for their first-hand experience. Piloting equipment on closed courses with local drivers would also be prudent. Many of these technologies are most reliable and yield the highest benefit when used within discrete stretches of managed roadways, which is consistent with the strategy as envisioned for the XBL and PABT. The buses would continue to operate with the driver in full control in their feeder areas and then transition to the connected/autonomous operation within the XBL and PABT.

From the transit operators' perspective, the comfort as well as the safety of bus passengers is another consideration in evaluating the application of these technologies in the intensive XBL/PABT environment. Vehicle weight, velocity, acceleration and deceleration rates matter. Availability of technology that can stop vehicles quickly may not be appropriate for passengers in the vehicle.

While bus platooning offers great promise to improve throughput along the Lincoln Tunnel corridor, it is important to qualify this optimism with an acknowledgement of the challenges associated with implementation. For instance, although many of the technologies necessary for bus platooning are already available or will be soon, the pathway for these technologies to be integrated into a system that can manage the needs of the Lincoln Tunnel corridor is less clear. Indeed, the complexity of the operating environment—including, but not limited to, the wide variety of bus agencies and companies that have buses currently using the XBL—poses a unique challenge for implementation along the Lincoln Tunnel corridor. Further policy development would be necessary to work out a safe and efficient transition as technologies proliferate through the fleet. At some time, to realize full benefit, certain technologies could become pre-requisites for use of the XBL, comparable to E-ZPass today.

Another important consideration is that buses can be in service for up to or more than a decade (depending on agency or operator), but computer technology becomes obsolete in 18 months to two years. Therefore, this strategy would require a plan not only for new installation, but for retrofit of existing inventory and plans for continuous measurement and updating. It is also important to note that agencies can have procurement practices that are so lengthy, there is risk that the technology could become obsolete by the time it is implemented.

One concern that has been raised is wind and suction effects from the connected buses traveling through the Lincoln Tunnel. However, there are several reasons why connected buses would not have the air flow concerns that would be present for trains in tunnels. The most advanced work in platooning is with trucks and it is based in part on reducing turbulent flows to improve fuel efficiency. By spacing vehicles closer together, each set only has turbulence after the final vehicle. Turbulence and pressure is not increased for the lead vehicle, rather, it just functions as a longer vehicle. The increased capacities projected for the XBL through bus platooning are due to shortening headways, not increasing speeds. Thus, even a bus going through the tunnel with no vehicles in front of it would not be pushing more air than the current unconnected vehicles. The project team followed up with a connected truck expert after the Workshop who concurred with these general principles and noted that he was not aware of any research into tunnel effects for connected trucks.

The need to move buses through the Lincoln Tunnel to the PABT led to the PANYNJ to establish the XBL, something that had not been done elsewhere. Continuing pressure to expand the passenger-handling capacity of the uniquely intensive Lincoln Tunnel corridor bus operation provides the impetus for PANYNJ once again to respond by introducing the additional innovation of bus platooning with its transit partners.

**Conclusion: The potential to increase bus throughput, safety, and reliability of the single XBL lane to meet forecasted demand levels is an extremely powerful incentive to**

**consider the deployment of connected vehicle (CV) technologies that will enable bus platooning in the near term, before completion of the PABT replacement effort. The complexity of the operating environment along the Lincoln Tunnel corridor poses a noteworthy challenge for implementation. Hurdles include availability of adequate funding, concurrence of multiple jurisdictions and bus operators, and coordination of retrofit and procurement cycles. However, the closed-loop nature of the XBL is a perfect location to test the viability and efficacy of bus platooning due to homogenous vehicle types and willing participants (bus companies interested in improving flow, safety, and reliability). Additionally, given the size and critical nature of the interstate bus network that feeds the PABT, as well as the marquee location of the PABT with respect to the Lincoln Tunnel portals, the PANYNJ is in a strong position to assume a leadership role in applying emerging technologies to support bus platooning. If proven reliable along the XBL, mixed-use traffic could be a future testing ground for limited platooning also, especially in helping to improve the throughput, safety, and reliability in reverse direction bus movements. However, any incremental implementation prior to completion of a new bus terminal would be conditioned on progress in managing traffic flow through the tunnel crossing and PABT operations.**

#### 2.1.4 Connected and Automated Bus Applications beyond Platooning

Although bus platooning is the application that most directly meets the need to increase capacity in the Lincoln Tunnel corridor, once the buses are outfitted with vehicle on-board units (OBU's), and roadways in and around the PABT are equipped with infrastructure roadside units (RSU's), there could be an opportunity to implement a number of future applications. CV applications are emerging that could include blind spot detection and advanced collision avoidance warning (based on conditions ahead of the vehicle). In mixed-traffic situations, these CV applications have safety, mobility, and liability benefits by reducing accidents and improving on-time dispatching performance. Additional CV applications include pedestrian detection and passing car detection to alert buses of cars pulling out around them.

As discussed at the Capacity Study Workshop, and as noted for the previous strategy, some experts predict that the cost of installing these solutions could be recovered in as little as one to two years through reductions in casualty and liability claims alone. The primary benefit of the connected and automated bus applications beyond platooning is safety. Secondary benefits include efficiency and liability.

Challenges associated with this strategy are similar to those associated with bus platooning, including the complexity of the operating environment, number of partners and operators involved, and the rapid cycling of technologies. Additionally, introducing these new technologies will take careful development and piloting prior to widespread roll-out. Nevertheless, the technology applications have great potential to improve operational efficiency and safety in the interstate bus network for trans-Hudson commuters.



**Conclusion:** The PANYNJ and NJ TRANSIT have both the need and the opportunity to be leaders in applying connected and autonomous technologies to buses, many of which could improve safety. While there are hurdles, recent advances in technology—including commercially available systems—mean that policy, perception, insurance, union, cost, and fleet turnover concerns are likely more limiting or slowing factors than the functioning of the technology itself.

#### 2.1.5 Increased Use of Higher-Capacity Buses

This strategy calls for expanded use of higher-capacity bus types—including double decker buses, articulated buses, and 45-foot coaches—by carriers that serve the PABT. The purpose of this strategy is to consider opportunities to run fewer trips on select high ridership routes through introduction of equipment that can carry more customers per vehicle than conventional transit buses. This is feasible only on certain routes where service and roadway infrastructure can accommodate these buses, as discussed below. The existing bus terminal cannot accommodate most double decker buses due to the limited vertical clearance within the terminal, and the facility’s geometry limits the ability to accommodate articulated buses. Even substituting 45-foot for 40-foot coaches affects bus operations within the terminal. Due in part to these structural limitations (in addition to capacity constraints), the existing PABT is also unable to accommodate several intercity bus carriers that use higher-capacity buses, such as Megabus, which currently serve curbside stops as opposed to gates within the PABT.

The design criteria outlined by the PANYNJ in the MBMP for a replacement bus terminal include accommodating taller and longer buses. This would function as a capacity management strategy because the use of higher-capacity buses with less frequent trips could reduce the number of vehicles along the congested Lincoln Tunnel corridor and within the PABT during peak periods, while still accommodating customer demand.

However, as noted in the design criteria, these benefits generally do not translate into reductions in the size of the replacement terminal, as articulated buses require additional platform areas and larger-capacity buses require more space for queuing the larger volumes of peak-period passengers each vehicle can carry. Some space savings may be possible in the future terminal through wider use of 45-foot coaches.

In conjunction with development of a new Midtown Bus Terminal, encouraging a long-term shift to higher-capacity buses is a potentially valuable strategy to improve service and efficiency of the interstate bus system as a whole. Increasing the average capacity of buses entering the PABT would allow for a reduction in the forecast increase in bus movements, and the benefits would cascade as total fleet size, operating costs, fuel consumption, and emissions would decline proportionally. In the long term, as PABT demand continues to grow, the use of higher-capacity buses could serve to accommodate more customers on the same number of buses (as a corollary to accommodating the same number of customers on fewer buses) than if the fleet only consisted of conventional transit vehicles.

However, it will take time and coordinated effort with west-of-Hudson partners to achieve meaningful benefits from bus-fleet changes. Higher-capacity buses are restricted on certain New Jersey roadways due to vertical clearance and axle weight constraints. Maintenance facilities would also need to either be substantially modified or constructed new to accommodate a new fleet. Finally, specifications would need to be developed and the new fleet would need to be procured. The potential application of this strategy in serving the trans-Hudson commuter market was examined during development of the MBMP as well as in the Capacity Study process.

**Double Decker Buses.** Given the real potential cost savings to bus operators from reduced fleet and driver requirements, it is likely that bus operators would generally be open to incorporating double decker coaches into their fleets where it is feasible and appropriate to do so. In the coming decades, significant growth is expected in intercity, long-distance commuter, and park-and-ride operations, and double decker buses are a logical choice for serving these markets. Major park-and-ride lots could be served in the future by double decker buses, but on many routes, these buses may not be practical, either because of the high number of stops (and the longer loading times associated with this fleet), the relatively low ridership, and/or roadway restrictions. A major re-orientation of bus networks toward more park-and-ride lots could have major consequences for local traffic. Corridors in which the use of double decker buses may be practical include Routes 3, 46, and 9.

A detailed feasibility and cost analysis of the potential for shifting to double decker buses on specific routes, while accounting for bridge clearances, axle weight restrictions, depot design, and route suitability, is beyond the scope of this study. However, a simple sketch exercise suggests that the conversion of appropriate routes from 45-foot coaches to double decker buses (bi-level coaches) could result in a net reduction of up to 25 PM nominal peak hour bus departures from the PABT. This is based on an assumption that only those routes that serve a very small number of stops would use double decker buses, including NJ TRANSIT and Academy routes that make 1-2 stops, and Pennsylvania bus companies' routes (which serve long-distance trips) that make 5-6 stops before starting the line haul portion of their routes. This conversion in bus fleet would provide a real benefit for bus circulation by reducing the number of PABT peak-hour buses, but would not provide a significant benefit with respect to terminal space requirements because of the need for longer boarding times and larger passenger queuing areas. The feasibility of this conversion in fleet type may be constrained by the considerations noted above regarding roadway and infrastructure limitations.

**Articulated Buses.** The MBMP developed bus terminal designs that were flexible enough to accommodate a higher share of articulated buses in the fleet. However, its bus activity forecasts assumed the continued use of articulated buses on routes where they are already present, but with no expansion of their use to new routes. This approach recognizes the real obstacles to greater use of articulated buses in some areas, including street geometry constraints, limited existing provisions for curb access, axle weight restrictions, and space constraints at legacy bus depots. Broader adoption of alternative vehicle types is a policy consideration, but one that requires the support of a coordinated infrastructure investment and revised service plan. This key qualifier reflects an earlier statement that the bus network must be considered as a system in which optimizing a new PABT also

involves other network investments/changes. Additionally, it is important to note that increased use of articulated buses would not significantly improve space productivity of the PABT. Articulated buses load passengers faster (i.e., less dwell time due to multiple doors), but they require longer bus slips and larger passenger queuing areas. Accordingly, as with double decker buses, this conversion in bus fleet would provide a real benefit for bus circulation by reducing the number of PABT peak-hour buses, but would not provide a significant benefit with respect to terminal space efficiency.

Nonetheless, significant population growth is expected in Hudson County and Eastern Bergen County, both of which have higher-density urban corridors that are a natural fit for articulated buses. Overall, the conversion of transit-style buses to articulated buses on appropriate routes could result in a potential net reduction of up to 35 PM nominal peak hour departures from the PABT. This is based on two assumptions: (1) that routes currently served by a mix of articulated and transit-style buses shift to a 100% articulated fleet (corresponding to a net reduction of approximately 15 PM peak hour bus departures); and (2) that routes currently served entirely by transit-style buses are converted to a 100% articulated fleet (corresponding to a net reduction of approximately 20 PM peak hour bus departures). This estimate does not account for constraints that must be overcome on the street network, depots, or other infrastructure. Because of the larger gates that these buses would require, there would be zero net change in bus demand equivalents used for terminal capacity planning purposes.

**45-Foot Coaches.** Another possible component of this strategy is expanded use of 45-foot coaches. The MBMP assumed that all 40-foot coaches in use by private operators would be phased out in favor of 45-foot models, but that NJ TRANSIT would continue to use 40-foot coaches for its own fleet due to space limitations at several of its older bus depots. Accordingly, the feasibility of shifting from 40-foot coaches to 45-foot coaches for NJ TRANSIT may be limited by land availability and infrastructure limitations at legacy bus depots, similar to the limitations associated with double decker and articulated buses noted above.

If pursued, the conversion in fleet for NJ TRANSIT from 40-foot coaches to 45-foot coaches on appropriate routes could result in a net reduction of up to 15 PM peak hour bus departures from the PABT. Unlike double decker and articulated buses, 45-foot coaches would provide a real benefit in terms of terminal space efficiency.

Overall, potential benefits associated with this strategy—assuming fewer bus trips—include newer vehicles that could be viewed favorably by customers, lower fuel consumption and emissions, and operating cost savings for bus operators (i.e., reduced fleet and driver requirements) on routes that are well matched for their physical characteristics. Increased use of higher-capacity buses could improve bus circulation by reducing the number of buses using the terminal access routes, ramps, and roadways, although—in the case of articulated buses and 45-foot coaches—the buses themselves are longer. Only the conversion of 40-foot coaches to 45-foot coaches yields space benefits for a future PABT, by providing a net reduction of up to 15 PM peak hour bus departures if impediments are overcome. The new PABT should be planned to accommodate significant numbers of all three types of larger vehicles.

Potential adverse impacts associated with this strategy include less frequent service for customers (since higher-capacity buses would result in fewer buses dedicated to the busier routes). There are several public policy issues that would need to be considered for this strategy, including coordination with NJDOT and the municipalities with roadway jurisdiction regarding vertical clearance and axle weight restrictions, infrastructure limitations at legacy bus depots, the potential need to special order double decker buses that meet the clearance restrictions in the Lincoln Tunnel, and ongoing coordination with NJ TRANSIT and other carriers regarding the feasibility of this strategy on different trans-Hudson bus routes. Significant capital investments may be needed to overcome these issues. Design criteria for the replacement terminal should incorporate sufficient waiting areas for the larger number of passengers. Additionally, as noted by the PANYNJ, a potential constraint associated with this strategy is the accumulation of passengers within gate areas during an operational disruption.

**Conclusion:** In terms of potential space-efficiency benefits for a new PABT, the increased use of 45-foot coaches has the potential to result in an estimated reduction of up to 15 PM peak hour bus departures from the PABT while still accommodating projected customer demand. Overall, maintaining design criteria for a new PABT that allows for use of double decker buses, articulated buses, and 45-foot coaches would enable the interstate bus system to accommodate the same customer demand using fewer vehicles. This is a long-term strategy that requires construction of a new PABT, as the existing PABT is unable to accommodate double decker buses or significantly more articulated buses. Although the utility of this strategy may be limited in the trans-Hudson commuter market, and significant capital investments may be required to upgrade west-of-Hudson roadways, bridges, and depots to accommodate these larger buses, it is still worthy of study and consideration from the perspective of the overall efficiency of the Lincoln Tunnel corridor as well as the PABT facility itself. Fleet mix is an important element of the PABT planning effort, both with respect to the capacity (total number of gates) and configuration (vertical clearance and gate layout) of the new terminal. The PABT planning effort should also consider the implications of additional passenger queuing and crowd management requirements for higher-capacity buses for routine operations as well as during service disruptions. Additional planning and coordination would be required with carriers that operate PABT commuter routes to confirm the potential reduction in peak hour bus demand associated with this strategy. However, due to the linear space required by articulated buses, and the additional loading time and queuing space needed for double decker buses, it cannot be concluded that potential shifts in fleet mix would allow for a smaller PABT, although the shift from 40-foot to 45-foot coaches could provide a real benefit in terms of terminal space efficiency. It is also important to note that this strategy could function to accommodate more customers as opposed to fewer buses. Specifically, rather than reduce the number of trips on high ridership routes in conjunction with the use of higher-capacity buses, it is possible that carriers could opt to run the same frequency of service to carry more passengers.

## 2.2 IMPROVED FACILITY OPERATIONS

### 2.2.1 Bus Staging and Storage

This strategy calls for development of a bus staging and storage facility in West Midtown to increase the operational efficiency of the PABT and the Lincoln Tunnel corridor overall. Direct access from a West Midtown bus staging and storage facility to the PABT would improve reliability and throughput, while reducing peak period demand along the Lincoln Tunnel corridor. *The Emerging Design + Deliverability Brief* stresses that, “A critical challenge to interstate bus operations is the scarcity of bus parking and staging capacity in West Midtown Manhattan,” and this strategy would directly address this shortcoming for the trans-Hudson bus commuter market.

One of the greatest challenges in operating a large transportation terminal is getting empty buses to the locations where customers board in a dependable manner. In a commuter terminal, operations are typically both heavily-peaked and have strong directional bias. Accordingly, in the morning, eastbound buses arrive at PABT with full customer loads. When buses depart PABT after initial offloading, some routes are in revenue service with reverse commuters headed back across the Hudson. Other buses, however, depart empty either to spend the midday period stored at a facility in New Jersey, or to go back to their New Jersey terminal to begin another eastbound revenue trip to PABT. The westbound buses that travel through the Lincoln Tunnel in the morning peak period face relatively few traffic constraints (compared to the evening peak), even with the removal of a westbound lane to accommodate the operation of the contra-flow XBL on Route 495.

In the evening peak, however, the situation is much more challenging. Every bus leaving the PABT must arrive at its assigned gate with sufficient time to board customers and depart on-time. Boarding time varies by route, but always requires at least several minutes. Some buses currently store during the day in Manhattan in the several blocks around the bus terminal, but a large number of buses spend the middle of the day in New Jersey.

At the PABT, it is necessary to time precisely the arrivals of empty buses from New Jersey. This is complicated by the fact that in the PM peak there are only two Lincoln Tunnel lanes available for eastbound traffic. Thus buses need to arrive at their gates on-time despite having no location to wait if they arrive early, and with no reliable method to predict eastbound congestion through the Lincoln Tunnel (although technology is being deployed to improve real-time traffic monitoring).

Insufficient daytime bus storage and staging capacity has multiple implications, including congestion within the PABT, congestion on New York City streets due to queues and diversions from the PABT, increased operational costs for bus operators, and decreased on-time performance and reliability for customers. These challenges collectively degrade bus operations and amount to a poor “quality of commute” for customers.

As part of the ongoing PABT Quality of Commute Program, which aims to improve current conditions at the existing PABT, the PANYNJ is currently converting two of its lots in Midtown West to serve as bus parking and staging areas. This is expected to result in operational improvements by providing improved access to the PABT and reducing queuing on local streets. Additionally, PABT/Lincoln

Tunnel Management have recently implemented an operational change whereby buses are directed to use a single inbound lane in the PM peak period, which has improved on-time performance and travel time reliability while reducing the number of buses arriving early at the PABT that must then circulate or park on local streets to await their departure time. Nevertheless, as affirmed by *The Emerging Design + Deliverability Brief*, “While new operating practices have reduced the frequency and duration of such diversions to manage heavy inbound bus demand, the balance of [PM] capacity and demand is fragile throughout the corridor.”

The PABT replacement planning effort has considered the possibility of developing a portion of the needed bus staging and storage capacity in New Jersey. During this Capacity Study process, PABT/Lincoln Tunnel management noted that staging in New Jersey would require proximity to the tunnel plaza and rigorous management of inbound Lincoln Tunnel lanes to ensure highly reliable dispatch of buses through the tunnel to their assigned gates. Although placing some bus staging and storage in New Jersey is certainly feasible, it inevitably leads to eastbound movement of empty buses in the Lincoln Tunnel during the PM rush. Since eastbound flows are limited to just two lanes during the PM rush, delays to eastbound traffic during this period are already substantial and are likely to grow worse. A policy of bus prioritization could improve the reliability of buses stored in New Jersey reaching their PABT gates at the appropriate times, but could exacerbate the already significant delays experienced by other vehicles trying to reach Manhattan during the PM rush.

As indicated in the MBMP planning effort, significant staging and storage capacity in Manhattan is important for efficient operation of the replacement terminal as well as the tunnel. Trans-Hudson buses stored on the west side of the Hudson River would have to travel empty from the PABT through the Lincoln Tunnel, and then travel empty back across the Hudson River to the PABT. This introduces unproductive bus miles and wastes fuel. The MBMP analysis also indicated that evening peak-period operation could not be supported fully without some staging and storage capacity in Manhattan.

A bus storage facility proximate to the PABT in West Midtown where buses could be warehoused and dispatched in real time would make a profound difference in the reliability of terminal operations. While trans-Hudson bus operators have stored many buses in the area over the past 20 years, much of this capacity has been lost to West Midtown development and Javits Center operations. There are three broad uses of such a facility. One function would be to store (park) buses that are not needed for midday service in Manhattan. These buses would not need to travel empty to New Jersey to be stored, only to return empty to Manhattan in the evening. If stored in West Midtown, buses would be “in place” for evening service. NYCT stores over 150 express buses for Staten Island and Queens services at Manhattan facilities during the midday period, and has done so for 20 years. Not only does this practice save payroll hours, fuel, and bus miles, but—most important—it helps to keep evening peak express bus service operating more reliably.

The second use would be as a location to stage (queue, sort, and ready for dispatch) buses for a short time, until space opens at their intended gate in the PABT. With real-time dispatch, the storage/staging facility would effectively function as an extension of the PABT. The third function would be as-needed as a customer facility. For instance, the lower floor of a staging and storage facility could be used for customer operations during major incidents, such as an extreme weather

event or a rail strike, and could potentially be permanently converted to a customer facility in the long term as demand grows beyond the 2040 projections.

If the staging and storage facility is sited close to both the current PABT location and the location of a new PABT, it should be constructed soon allowing for improvements in capacity and reliability at the current facility. Current thinking is that a storage/staging facility would be constructed over one of the portals of the Lincoln Tunnel. It would be highly desirable to accelerate the design and construction of this facility, as it would serve to increase the capacity of the current PABT complex. This is particularly important as demand is projected to continue to grow in the years before the new PABT will be built and operational. The design should be as flexible as possible to accommodate different bus types, and to allow for both static storage and for real-time dispatch. Although some ramps and approaches would likely need to be rebuilt as part of a new PABT project, the core of the building would remain and could have years of utility in the interim.

One of the fundamental “building blocks” of the MBMP was a bus staging and storage facility with connections to the PABT. Each of the concepts for a new PABT that were developed in the MBMP included accommodation for bus staging and storage. The MBMP did not establish a hard number of staging spaces required to serve the PABT commuter market, but concluded that the staging area would need to be flexible enough to handle a variety of configurations.

Potential benefits associated with this strategy include improved reliability of customer operations, reduced demand along the Lincoln Tunnel corridor, and increased near-term capacity of the existing PABT. Potential impacts associated with this strategy include loss of revenue potential for the PANYNJ associated with overbuild or high-rise development on the site for the staging/storage facility. However, one of the planning criteria in the MBMP was air rights development over either the bus terminal or staging/storage facility would be inherently difficult and costly. It is also worth noting that the properties at the portals may have limited development potential due to site constraints, security requirements, and—at Galvin Plaza—pedestrian access issues. Public policy issues that would be need to be addressed to advance this strategy include inter-agency coordination with the New York City Department of Transportation (NYCDOT) and the New York City Department of City Planning (NYCDCP), as well as coordination with local Community Boards.

**Conclusion: Bus staging and storage is one of the critical issues that can and must be addressed to improve the operational efficiency of the PABT, with consideration of early implementation. In addition to meeting and managing long-term projected demand at a new PABT, improved bus staging and storage can address current capacity constraints at the existing PABT and along the Lincoln Tunnel corridor. A bus staging and storage facility in West Midtown represents an essential component of the new PABT complex that would be amenable to modularity – the facility could have independent utility in the near-term, and could be integrated into a new PABT in the longer term. Further planning also should consider the option to develop some of the needed bus staging and storage capacity in New Jersey, at a close-in site with physical and operational provisions to assure reliable dispatch through the tunnel portal to the terminal. The October 22, 2015 PANYNJ Board resolution indicated that conceptual designs for a new**



**PABT developed in the D+D Competition should “allow for...sequential construction of key elements (including terminal facilities and bus-staging facilities) as estimates of future capacity needs are refined.” As such, the bus staging and storage facility should be accelerated as a first stage of the PABT replacement.**

### 2.2.2 ITS to Optimize Bus Dispatching and Circulation

As discussed in Sections 2.1.3 and 2.1.4, new technologies on buses and on the roadside offer a variety of emerging tools to improve efficiency and safety. This section covers Intelligent Transportation Systems (ITS) that focus more on the PABT itself, including throughput on the terminal’s ramps and merge points. The related topic of ITS to enable changes in gate assignment is covered in Section 2.2.3.

Better dispatching and circulation depends first and foremost on better awareness of vehicles. This strategy begins with improved deployment of sensors along the corridor (included in other strategies and described in more detail in the “Technology Implications & Opportunities” technical memorandum). Pinpoint locational awareness of all buses at all times is a necessity on both sides of the Hudson River. Projects are already underway to include better awareness inside the existing PABT through the use of E-ZPass readers as well as improvements in WiFi and GPS. Better awareness of vehicle location and conditions along the corridor as well as within the PABT would allow algorithms to more accurately predict arrival and departure times with improved precision, and would also enable other strategies such as enhanced travel information.

Once greater awareness of vehicle status and location has been achieved, the second element of this strategy is to include technology solutions to improve movement within the PABT. While there have been limited applications of such technology to buses so far, sensors and guidance systems are under development. As a proof of concept that would be available for near-term needs, it is worth noting that magnetic guidance for precision navigating and docking has been used by the Lane Transit District on revenue service in Eugene, Oregon (Figure 6). In that case, the guidance is used not only for Americans with Disabilities Act (ADA)-compliant docking of articulated multi-door low-floor buses, but to guide vehicles swiftly through narrow busways, across mixed-flow intersections, and along S-curves into and out of stations. It is expected that a non-invasive alternative would become available for design of the replacement PABT. Not only would non-invasive systems avoid disturbing the deck of a new facility, they would be more flexible to changes over time.



Figure 6: Example of Automated Steering and Precision Docking from Lane Transit District



Source: Lane Transit District; Jill Huang (UC Berkeley); YouTube

Great strides have been made in automated vehicle technologies for cars and for trucks that can drive on roads without infrastructure such as magnets. However, there are several reasons why the critical questions for the replacement PABT, such as the geometry of the ramps and number of levels, should not assume their availability and applicability. First, while the Google car has logged over one million miles, there are still significant technological hurdles for dealing with less than ideal driving conditions such as inclement weather. Also, these systems are currently, and understandably, very conservative. To achieve efficiencies within the bus terminal, buses would need to operate more efficiently than high-skilled and experienced professional drivers – not to drive conservatively. The path to the safe and efficient movement within the tight tolerances of the PABT is to leverage systems that integrate with the infrastructure for certain precision driving tasks.

Safe and smooth merging of buses within the proposed PABT's helical ramp system is required to enable projected peak period bus flows. Connected/automated vehicle technologies are required to achieve the throughputs assumed for the future PABT. That was the position of the MBMP and it was reinforced by this project team and the experts who participated in the Capacity Study Workshop on April 14, 2016.

As in-vehicle technology increases in availability—and as fleets begin to turn over or be rehabilitated—additional technology solutions such as lane keeping and precision movement and cooperative adaptive cruise control could guide buses more efficiently within the PABT as well as along the Lincoln Tunnel corridor, thereby reducing headways and improving overall flow. This would further increase the reliability of dispatching and estimated arrival/departure times.

The “game changer” for optimizing bus dispatching would be if fully driverless buses could make the buses virtually interchangeable. Under such a scenario, any bus, or perhaps any bus from the home garage, could serve the next route's departure. That would greatly simplify the operational side of dispatching, but its value would be offset in terms of inefficiencies regarding passenger queuing and loading. Another consideration to note is that while technology can be an enabler of optimized bus dispatching, technology is not necessarily the limiting factor with respect to the potential interoperability of buses. Indeed, even with fully driverless buses, there would be practical

limits due to varied locations of bus storage and other issues pertaining to the large numbers of bus carriers.

Even considering all of the technology advancements on the horizon for optimizing bus dispatching and circulation, given the complexities of a multi-level terminal serving so many different routes, it is not prudent to base design of a future terminal on a sustained average of more than 6 turns per hour per gate. That was the consensus of the participants in the Capacity Study Workshop, including among the technology experts. Nevertheless, technology can have a significant impact on facilitating the ramp movements and merges within the terminal.

The primary benefits of optimized bus dispatching and circulation are thus:

- Increasing precision and accuracy of dispatching buses. Until the time that a staging and storage facility is constructed in West Midtown (as suggested in Section 2.2.1), this strategy could optimize dispatching of empty buses from New Jersey to support reliable on-time departures from PABT without buses arriving early to use valuable space within the PABT or on NYC streets.
- Increasing safety and efficiency of bus circulation within the PABT with assistive technologies to smoothly, reliably, and swiftly move buses through the tight confines of the terminal, especially at merge points and within the helical ramps.

Leadership would be required on the part of the PANYNJ and NJ TRANSIT to evaluate, pilot, integrate, operate, and maintain the systems. Working together, they can address options for balancing investments in infrastructure and in-vehicle systems to achieve the most effective use of public resources in a rapidly evolving technological landscape. Eventually, the PANYNJ could consider how to mainstream the systems to other operators as well. In addition to explaining the benefits and leveraging the agreements for use of the PABT, some form of direct assistance or regulatory provision may also be necessary to bring about timely changes among many of the private operators.

**Conclusion: A robust bus and infrastructure sensor system within the PABT and on approaches is the foundation for connected and automated vehicle technologies to optimize bus dispatch and circulation. This will provide gains in efficiency and reliability, especially at merge points and within the helical ramps. These types of advances are assumed as part of the efficiencies transitioning from the PABT's current average of 4 bus turns per hour per gate to the 6 bus turns per hour per gate used in the MBMP. Many of these advances do not need to wait for the new PABT and could increase efficiencies within the next 10 years. However, technology is unlikely to make it possible to serve projected customer volumes with a terminal that has significantly fewer gates than envisioned in the MBMP.**

### 2.2.3 Enabling Various Adaptable Gate Assignment Strategies

Given the uncertainties around changing demand and changing technology over the lifespan of the current and future PABT, flexibility has been one of the recurring themes. The minor changes in design and addition of technology that enable, but do not mandate, a range of strategies related to gate assignment are likely a prudent investment. The PANYNJ would then have the flexibility to refine the most effective approach. There is a fundamental trade-off between providing flexibility to transit operators with respect to gate assignment and giving travelers advance notice. This is something that NJ TRANSIT has already experienced. Table 2 explains three major approaches (fully dynamic gate assignment, limited dynamic gate assignment, and flexible gate assignment) along with benefits and drawbacks to each.

Table 2: Overview of Various Adaptable Gate Assignment Strategies

	Fully Dynamic Gate Assignment	Limited Dynamic Gate Assignment	Flexible Gate Assignment
<b>Concept</b>	Underlying operation plan of gates changes everyday	Tool for managing incidents by as-needed changes within logical gate groupings	Facilitating changes of gate assignments to routes or carriers over the scale of months or years*
<b>Each route is assigned a typical gate</b>	No	Yes	Yes, but it can change over months or years*
<b>Gates are shared among operators</b>	Yes	Only limited situations, such as by long headway carriers	Allows changes over months or years*
<b>Routes would switch among floors</b>	Yes	No. Gates would be logically clustered.	Allows changes over months or years*
<b>Benefits</b>	More effective use of gates since buses do not need to wait for open gates	Mostly consistent for customers. More effective use of gates during disruptions.	More effective use of gates over time as needs change.*
<b>Concerns</b>	Customer inconvenience — uncertainty, waiting areas, walk time. Driver/operator confusion.	Potential customer inconvenience or confusion during disruptions.	Small potential for customer confusion.
<b>Enabling Technology</b>	Real time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators.	Real time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators.	Real time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators.

\* Also a policy decision to allow different weekend assignments, construction assignments, or other planned changes.

The limited dynamic gate assignment would be especially helpful when there are disruptions to bus flows, such as due to bad weather, incidents impeding buses from exiting the terminal, police activity, emergency maintenance, and disabled buses. Changes to typical gates would only be made when needed to mitigate those incidents.

To enable this flexibility, the dispatchers, operators, terminal operators, and passengers must all have clear information. Improved WiFi and GPS correction within the PABT would also increase the reliability and effectiveness of the current apps available from providers such as NJ TRANSIT. This could in turn increase usage and customer satisfaction, and also contribute to improved pedestrian movement within and around the PABT.

**Conclusion: Limited dynamic gate assignment and flexible gate assignment are promising operational strategies when used with enabling technology and within sound management practices, as a consideration in planning for the new Bus Terminal. However, fully dynamic gate assignment has operational and passenger concerns that outweigh potential advantages. Traveler information across a variety of sources is also essential to avoid degrading the customer experience as they re-route to their gates for occasional changes that minimize schedule disruption. However, no amount of technology can make the strategies work if the technology does not underpin a sound operational concept with experienced dispatchers and cooperative bus agencies and companies.**

## 3 Trans-Hudson Demand Strategies

To supplement the aforementioned strategies that increase/manage capacity along the Lincoln Tunnel corridor and within the PABT, this Capacity Study is also considering strategies that broadly address overall Trans-Hudson demand through the use of other crossings and/or modes. Subsequent work in the Capacity Study will include an assessment of multi-modal network strategies, and the following sections discuss trans-Hudson bus operational and service strategies that could potentially result in reduced utilization of the Lincoln Tunnel corridor and PABT by commuter buses.

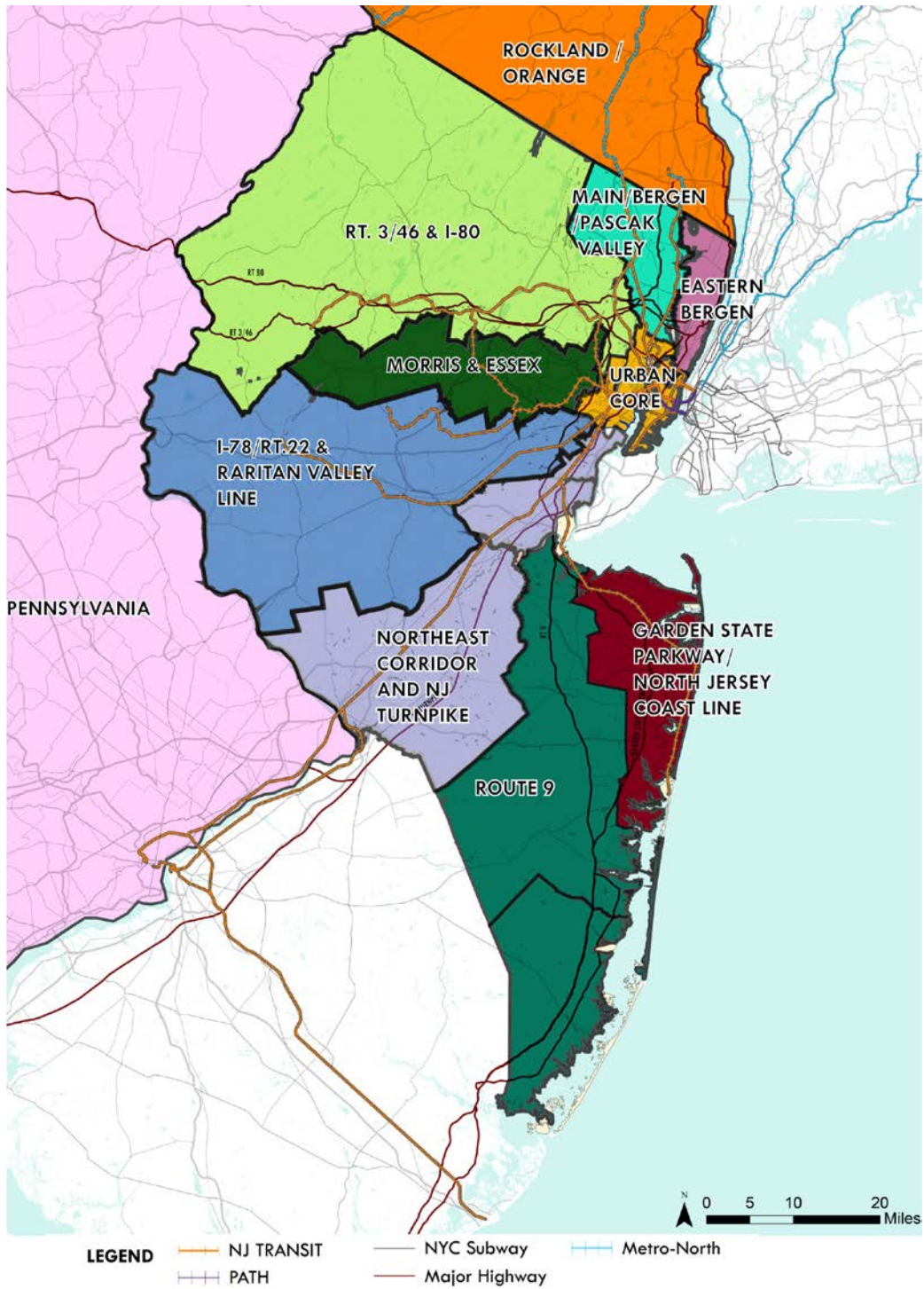
The strategy assessment includes identification of potential benefits, impacts, and public policy issues, as well as an estimate of the number of commuter buses that could potentially be diverted from the Lincoln Tunnel corridor and PABT. The findings section of this technical memorandum (Section 5) summarizes the implications of these strategies for the capacity and configuration of a new PABT to inform the D+D Competition.

Collectively, these strategies could result in a modest reduction of peak period demand along the Lincoln Tunnel corridor and at the PABT, so it is important not to overestimate the net impact of these strategies on the PABT demand forecast. Additionally, some concepts may have additional trans-Hudson commuting benefits beyond the scope of the PABT replacement, but that can further limit their modest potential to change the scale of a new PABT. For instance, new or improved bus service that uses Hudson River crossings other than the Lincoln Tunnel corridor could induce latent demand along the other crossings, thereby consuming some of the available capacity that would otherwise accommodate diverted customers from the PABT. Overall, while these strategies offer some promise with respect to reduction of peak period demand at the PABT, the potential reduction is not large.

### 3.1 EXPANDED BUS SERVICES THAT SHIFT BUSES AND DEMAND FROM PABT

The west-of-Hudson region can be divided into multiple trans-Hudson travel corridors (Figure 7) that have different modal orientations. As discussed in the following sections, the corridors also serve as an effective framework for identifying candidate bus routes that could be potentially be diverted from the Lincoln Tunnel corridor (and the PABT) to use other Hudson River crossings. This, in turn, could help to address overall trans-Hudson commuter demand in light of capacity constraints along the Lincoln Tunnel corridor. While incremental improvements can enhance bus operations and improve customer service, implementing lane prioritization for buses on additional corridors is unlikely unless volumes approach at least 200 buses per hour.

Figure 7: West-of-Hudson Trans-Hudson Travel Corridors



Source: Trans-Hudson Commuting Capacity Study, NJ TRANSIT



### 3.1.1 George Washington Bridge Bus Station

This strategy calls for leveraging the forthcoming completion of the GWBBS renovation by adding service to the attractive new terminal on a number of commuter bus routes that currently serve the PABT, and adjusting frequencies to the PABT in line with customer choices. The additional service to the GWBBS would correspond with increased use of the GWB instead of the Lincoln Tunnel to cross the Hudson River. Upon arrival at the GWBBS, customers could transfer to either the A subway line (via a direct connection), the 1 subway line (via an approximately 10-minute walk on city streets, although wayfinding to locate the station may pose challenges for customers), or a number of NYCT bus routes (via an approximately 1-minute walk) to access their final destination. To increase the attractiveness of the bus routes, this strategy could also include implementation of a range of transit priority measures and other improvements to enhance the customer experience. This strategy revisits assumptions based on a potential transportation demand management (TDM) measure that was associated with Concept 5 from the MBMP to reduce demand at a new PABT.

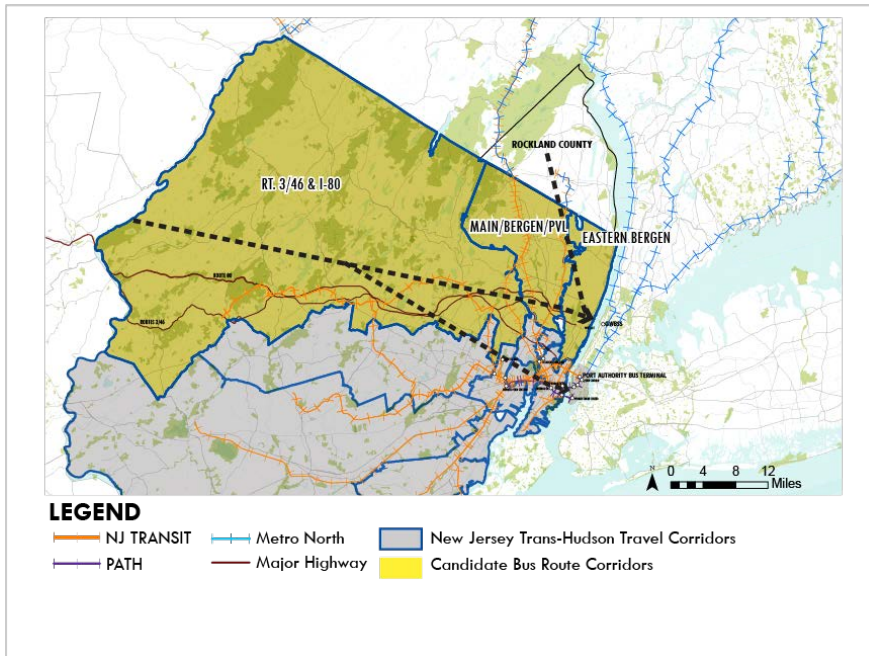
The GWBBS is well positioned to serve bus customers from points to the north and from along the I-80 corridor because of its location along I-95. Accordingly, candidate routes that could be considered for increased service to the GWBBS are those that originate in portions of the Eastern Bergen, Main/Bergen/PVL, and Route 3/46 & I-80 trans-Hudson travel corridors (Figure 8). Additionally, PABT commuter routes that originate in Rockland County could also be candidates for increased service to the GWBBS. Commuter bus routes that serve the GWBBS would likely be most appealing to PABT customers whose destination is north of 60<sup>th</sup> Street in Manhattan (or in the Bronx). From the GWBBS, customers traveling to the West Side would likely use the A or 1 subway lines, and customers traveling to the East Side would likely use the M98 NYCT bus route. The M98 is a peak-period limited-stop service which, after stopping adjacent to the GWBBS, operates non-stop on the Harlem River Drive and then operates southbound on Lexington Avenue and northbound on Third Avenue as far south as 67<sup>th</sup> Street. This is a fast and potentially attractive link for destinations on the Upper East Side such as Hunter College, Rockefeller University, Lenox Hill Hospital, the Hospital for Special Surgery, New York-Presbyterian Hospital, and the Memorial Sloan-Kettering Cancer Center, as well as the major employment center of Midtown East.

There are currently 13 commuter bus routes that serve the GWBBS, including seven NJ TRANSIT routes, two routes operated by Rockland Coaches, two by Saddle River Tours, and two operated by Spanish/Express Service. The GWBBS lost ridership for decades after opening, but has stabilized and started to make modest gains in the past five years. During this time, the market largely shifted from traditional carriers—including NJ TRANSIT and Coach USA—to jitney operators, which now carry roughly half the customers at the GWBBS, although the rising proportion of jitney riders may be indicative of more locally oriented trips rather than a Manhattan central business district (CBD) commuter market. It is possible that, over time, some current PABT customers could choose to change their commute if trans-Hudson travel via the GWB to the GWBBS is seen as an attractive option.

This could potentially be achieved by a combination of improved bus service, reduced fares, and a better terminal experience. One way to improve bus service to the GWBBS is to eliminate merges and conflicts at the bus slip under Lemoine Avenue and improve access from the bus slip to the toll

plaza, which could address an area where buses currently experience delays. This strategy could also include a reduced fare for the GWBBS bus services to encourage patronage and to avoid a fare penalty for transfer to NYCT. Nevertheless, nearly half of PABT customers already use the subway as their mode of access from the PABT to their destination, so the transfer at GWBBS could be comparable for some to their current travel experience. A better terminal experience at the GWBBS is imminent, as the ongoing station renovation is scheduled for completion in 2016. Sample renderings of the renovated GWBBS and station environs are shown on Figure 9.

Figure 8: Origins of Candidate Bus Routes to Serve the GWBBS



Source: Trans-Hudson Commuting Capacity Study

Figure 9: Renderings of Renovated GWBBS



Source: PANYNJ



The renovation will result in a reduction of bus gates at the GWBBS, but there will still be excess capacity such that the station could accommodate additional peak hour buses. According to the PANYNJ, upon completion of the renovation, the GWBBS will have 15 deep sawtooth gates available for commuter buses, in addition to two gates for long distance carriers and four mini bus gates for jitneys. Three of the 15 commuter bus gates will be needed to handle projected PM peak hour bus arrivals, so there will be 12 gates available for PM peak hour commuter bus departures. Based on a theoretical capacity of 4 bus departures/hour/deep sawtooth gate, the renovated GWBBS will have a capacity of 48 bus departures in the PM peak hour. There are 18 PM peak hour bus departures currently forecast for the GWBBS in 2040, and thus the station could accommodate an additional 30 PM peak hour departures. However, this strategy would not necessarily use all available excess capacity at the GWBBS; the number of additional buses that would serve the GWBBS would be informed by demand, as well as consideration for other opportunities such as improved transit connections in the future between Bergen and Westchester Counties or increased intercity service from the GWBBS.

The intent of this strategy is to expand the potential of the GWBBS as an attractive commuting option, and not to force PABT customers to change their travel patterns. As such, this strategy calls for two broad approaches. One action would improve the frequency and reliability of existing GWBBS services to make them more marketable. The second action would involve drawing more riders to the GWBBS by adding service to the renovated station on routes now serving PABT, in conjunction with modified service frequencies to the PABT to reflect customer choices. A potential pilot program could be instituted by one or more commuter bus carriers upon completion of the GWBBS renovation project.

Potential benefits associated with this strategy include demand shedding for the Lincoln Tunnel corridor and PABT, time savings for certain trans-Hudson commuters, and reduction in bus operating costs for certain routes. Additionally, in conjunction with technology strategies discussed previously (and expanded upon in the “Technology Implications & Opportunities” technical memorandum), increased use of the GWBBS could prove useful for real-time diversions of customers during major incidents along the Lincoln Tunnel corridor or at the PABT as a means to improve travel time reliability. For instance, it could be beneficial to provide customers with real-time information about delays at the PABT and the alternative of the GWBBS to enable a more seamless shift in commuting option. Furthermore, commuter bus carriers that serve the PABT could dispatch additional buses to the GWBBS as a diversion plan during major incidents.

Potential impacts associated with this strategy include additional congestion along the GWB and its approaches and reduction in bus operating revenue (if a fare reduction is offered and/or if ridership declines). Public policy issues that would need to be considered for this strategy include jurisdictional coordination regarding fare policy, improvements to NYCT subway and bus access, and improvements to the GWB approaches. The timing and marketing of this strategy should include coordination with NYCT as it continues to invest in improved facilities, subway service, and customer information.

**Conclusion:** Increased service to the renovated GWBBS, and a corresponding adjustment of service frequencies to the PABT, has the potential to result in a modest reduction of peak hour demand at the PABT. For purposes of a potential pilot program, an estimated 10 PM peak hour bus trips that currently serve the PABT could instead serve the GWBBS. This strategy aims to leverage the completion of an attractive new GWBBS by refreshing the routes that serve it, improving travel times, increasing service frequencies, and reducing fares to attract customers that currently use the PABT. If the potential pilot program is successful and viewed as an attractive option for trans-Hudson commuters, approximately 20 additional PM peak hour buses that currently serve the PABT could instead serve the GWBBS to use the remaining excess capacity, for a total of approximately 30 PM peak hour buses.

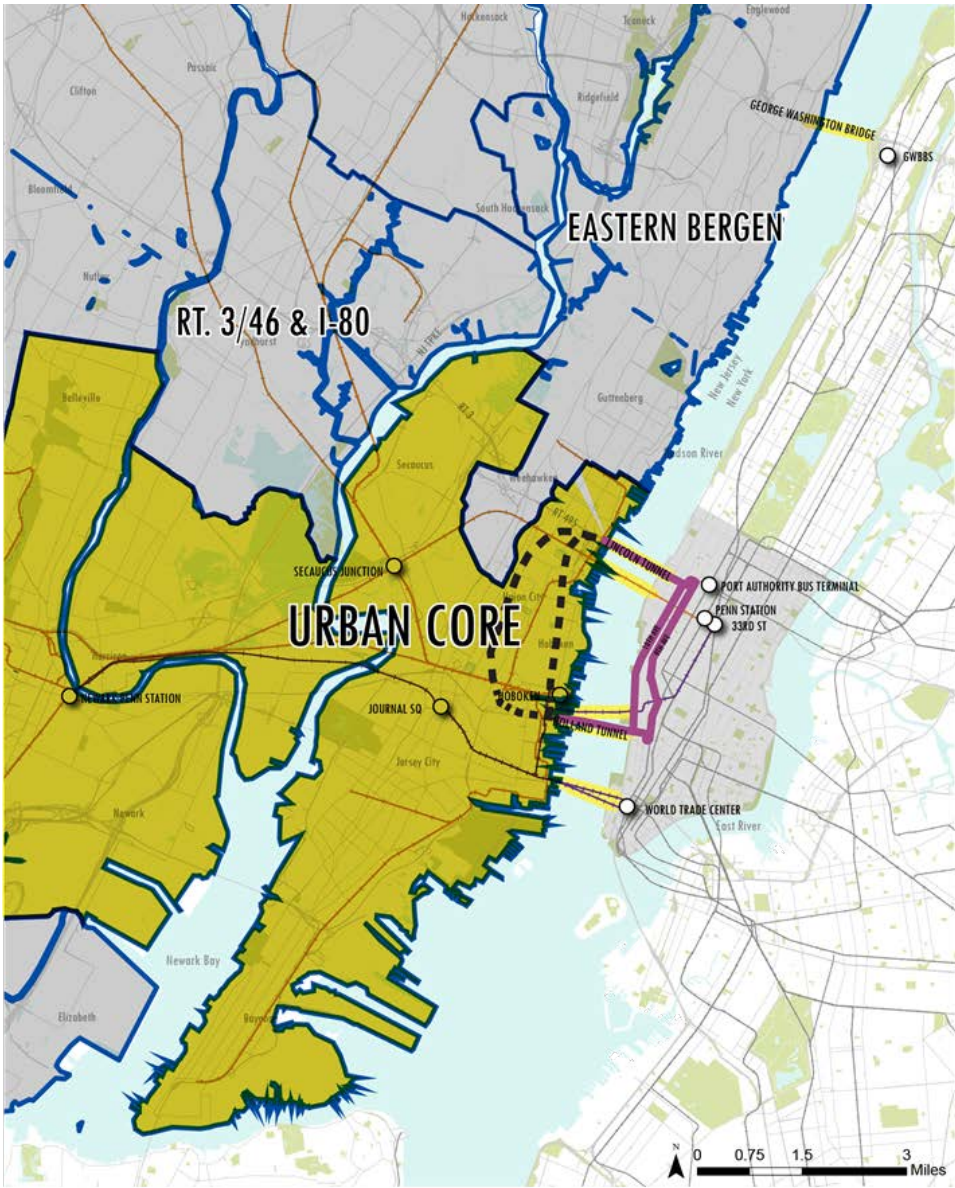
### 3.1.2 Holland Tunnel/Lincoln Tunnel Bus Loop

This strategy calls for implementing new variants on existing services such that select commuter bus routes would cross the Hudson River using the Lincoln Tunnel in one direction and the Holland Tunnel in the other direction, instead of using the Lincoln Tunnel for both inbound and outbound service. Rather than serve the PABT, the route variants would serve new on-street bus stops in Manhattan (with connections to NYCT subway and bus routes) that would be located near the emerging employment corridor on the far West Side between these crossings. This strategy validates and revisits assumptions based on a potential TDM measure that was associated with Concept 5 from the MBMP to reduce demand at a new PABT.

Candidate routes that could be considered for the loop operation are those that originate in the Urban Core New Jersey trans-Hudson travel corridor due to proximity to the Lincoln and Holland Tunnels (Figure 10). For instance, bus routes that serve Jersey City and the Hoboken waterfront could be candidate routes for the loop operation. Under this strategy, any commuter bus routes that use the loop operation would likely be most appealing to PABT customers whose destination is in Midtown West or Manhattan Valley, and specifically between the Lincoln and Holland Tunnels. For instance, the loop operation could effectively serve new employment destinations in/near Hudson Square, Hudson Yards, Chelsea, and Soho.

Similar to the GWBBS strategy, the intent of this strategy is to offer a submarket of trans-Hudson commuters an attractive new alternative for their journey to/from work, and not to force PABT customers to change their travel patterns. As such, this strategy does not call for re-routing all candidate bus routes, but rather to consider a potential pilot program that splits a select high-frequency candidate route such that certain trips would operate using the loop and other trips would continue serving the PABT.

Figure 10: Origins of Candidate Bus Routes for the Potential Lincoln Tunnel/Holland Tunnel Loop



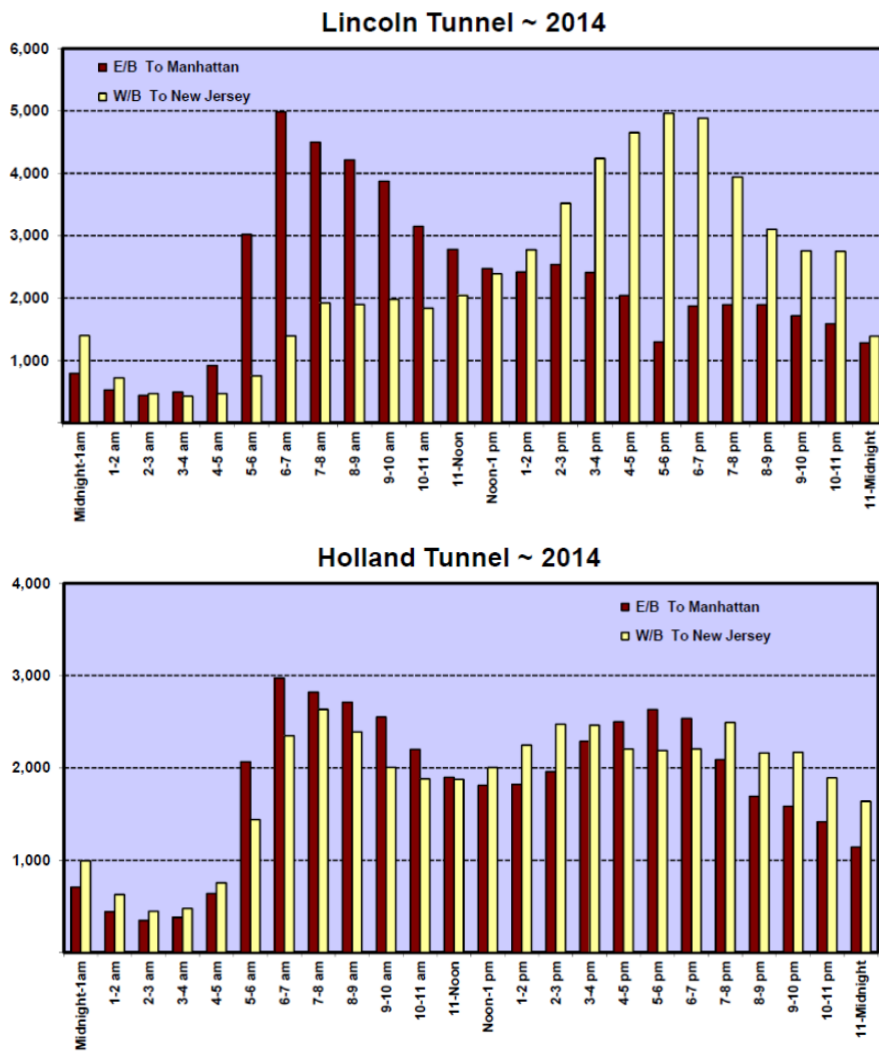
**LEGEND**

- NJ TRANSIT
- PATH
- NYC Subway
- Major Transit Stations
- Manhattan CBD
- New Jersey Trans-Hudson Travel Corridors
- Candidate Bus Route Corridors
- Holland Tunnel/Lincoln Tunnel Bus Loop

Source: Trans-Hudson Commuting Capacity Study

The loop operation would utilize both the Holland and Lincoln Tunnels, which could allow the routes to be adaptable to peak hour demand of the tunnels. Therefore, the bus routes that use the loop operation could operate either clockwise or counter-clockwise depending on traffic and available capacity of the tunnels and tunnel approaches (although customers will expect outbound routings to be consistent). Figure 11 shows the hourly vehicular volumes in the Lincoln and Holland Tunnels (based on 2014 data), which could inform the determination about the direction of travel for the loop operation. It should also be noted that, based on preliminary discussions with NJ TRANSIT during this Capacity Study process, it could be beneficial from a customer service perspective for the loops to be bi-directional at all times of day.

Figure 11: Hourly Vehicular Volumes in the Lincoln and Holland Tunnels (2014)



Source: NYC Bridge Traffic Report 2014

Within Manhattan, the buses could potentially operate on 9<sup>th</sup> or 10<sup>th</sup> Avenues (in the southbound or northbound direction, depending on the direction of the loop operation), as the intended purpose of this strategy is to directly serve workplaces and maximize connectivity to other transit options, which would not be fully accomplished if the buses were to operate on Route 9A.

Potential benefits associated with this strategy include demand shedding for the PABT (as well as the Lincoln Tunnel corridor in either the inbound or outbound direction, depending on the direction of the loop operation), as well as time savings, more direct service, and additional travel options for certain trans-Hudson commuters. This strategy would remove customers and buses from the PABT during the peak period by utilizing on-street bus stops instead of gates within the PABT. Potential impacts associated with this strategy include additional congestion along the Holland Tunnel and its approaches, as well as additional congestion within Manhattan on New York City streets. The loop operation is only a viable option if there is travel time reliability for the bus operators and customers. It could be possible to explore opportunities for implementation of transit priority measures within Manhattan, especially for outbound movements in the afternoon, to further reduce travel time and increase the attractiveness of the bus routes. Additionally, as discussed in the context of other strategies, roadway improvements and/or the expansion of existing bus prioritization at the New Jersey approaches to the tunnels could also improve travel time.

Public policy issues that would need to be considered for this strategy include integration with existing NYCT bus service as well as coordination with the NYCDOT in order to establish on-street bus stops within Manhattan. Though it is likely that the bus operator(s) could apply for a bus stop in New York City, infrastructure would still need to be put in place for customer boarding and alighting and to provide shelter from the elements. Coordination with local Community Boards and NYCDOT would also be critical to address potential concerns about adding additional bus traffic to an already congested road network.

**Conclusion: Implementation of a Lincoln Tunnel/Holland Tunnel loop operation as a variant of existing bus services, in conjunction with serving on-street bus stops instead of the PABT, has the potential to result in a modest reduction of peak hour demand along the Lincoln Tunnel corridor and at the PABT. For purposes of the potential pilot program, an estimated 10 peak hour bus trips could be diverted from the PABT to on-street bus stops. If the potential pilot program is successful and viewed as an attractive option for trans-Hudson commuters, additional variants of candidate route(s) could be implemented to use the loop operation, thereby diverting additional buses from the PABT.**

### 3.1.3 Increased Use of the Holland Tunnel for Direct Downtown Service

This strategy calls for implementing new variants on existing services such that select commuter bus routes would cross the Hudson River using the Holland Tunnel instead of the Lincoln Tunnel. Rather than serve the PABT, the route variants would serve on-street bus stops in Lower Manhattan that would be located near major employment centers.

The Holland Tunnel is well positioned to serve bus customers from points to the south because of its location relative to the Lincoln Tunnel. After Bergen and Hudson Counties, the largest PABT customer markets are Middlesex, Monmouth, and Ocean Counties to the south, and these markets present opportunities for increased use of the Holland Tunnel for trans-Hudson commuting. Accordingly, candidate routes that could be considered for this strategy are those that originate in the Route 9 and Garden State Parkway/North Jersey Coast Line trans-Hudson travel corridors (Figure 12). While there are relatively few candidate routes from these travel corridors, it could be possible to also consider candidate routes from Hudson County, which is a significant PABT commuter market. This strategy would likely be most appealing to current PABT customers whose destination is in Lower Manhattan.

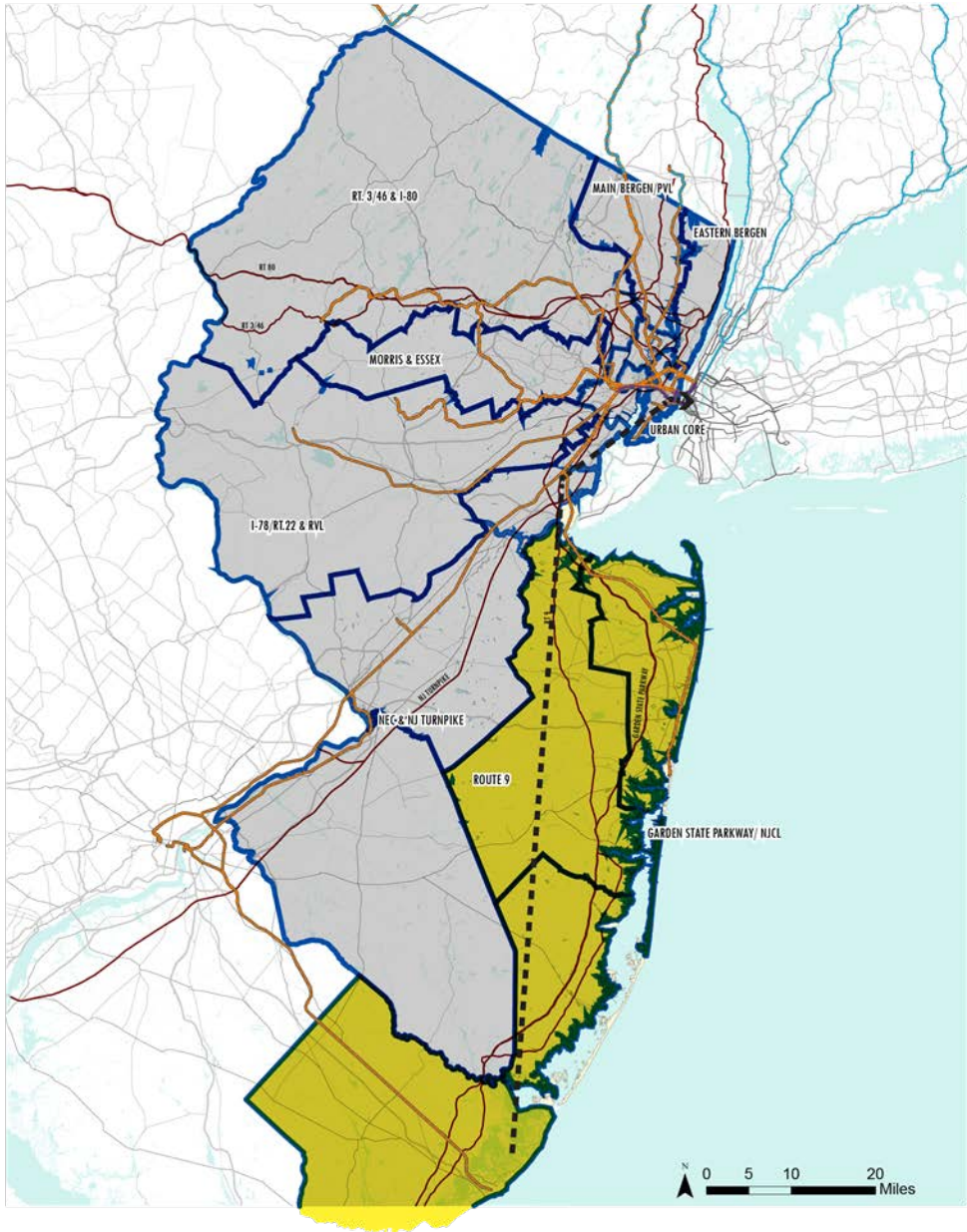
Similar to the other demand shift strategies, the intent of this strategy is to expand the potential of the Holland Tunnel as an attractive commuting option, and not to force PABT customers to change their travel patterns. As such, this strategy calls for modifying certain trips on candidate bus routes to serve Lower Manhattan using the Holland Tunnel, while other trips on the same routes would continue to serve the PABT. For instance, a potential pilot program could include implementing a route variant on two trips per hour for candidate routes, with the balance serving the PABT. Additionally, it could be possible to limit the Holland Tunnel service to the peak hours.

There are currently 14 commuter bus routes (plus several low-frequency intercity bus routes) that cross the Hudson River using the Holland Tunnel, most of which are operated by Academy Bus Lines. In addition to one NJ TRANSIT bus route (120 – Bayonne – Lower Manhattan), there are also individual bus routes operated by DeCamp Bus Lines, Lakeland Bus Lines, Suburban Transit, and Trans-Bridge Lines that currently use the Holland Tunnel to provide trans-Hudson service. There are two fairly robust clusters of activity in Lower Manhattan, each served in part by buses using the Holland Tunnel: (1) commuter routes that serve Wall Street and the Financial District, primarily along the Church Street/Broadway corridors; and (2) intercity routes that primarily serve Chinatown, which tend to be clustered around the Manhattan Bridge. Combined with the Staten Island express buses that serve the Financial District via the Battery Tunnel, the Church Street/Broadway corridor is close to saturated with buses during peak hours. In sum, trans-Hudson bus service to Lower Manhattan already exists and is well used, and its small size relative to the PABT is largely a function of market demand.

According to the 2014 Hub Bound Travel Data Report, only approximately 60 buses use the Holland Tunnel for outbound service in the PM peak hour, compared to approximately 680 buses that use the Lincoln Tunnel. This strategy aims to increase or add service via the Holland Tunnel to Lower Manhattan from potential markets that are currently underserved, thereby potentially helping to shed demand at the PABT. For example, commuter markets from Hudson County—which is a huge source of demand at the PABT—that are not well served by PATH, ferries, and NJ TRANSIT's Route 120 could be interested in bus service to the Financial District.



Figure 12: Origins of Candidate Bus Routes for Increased Use of the Holland Tunnel



- LEGEND**
- NJ TRANSIT
  - PATH
  - NYC Subway
  - Major Highway
  - Metro North
  - New Jersey Trans-Hudson Travel Corridors
  - Candidate Bus Route Corridors

Source: Trans-Hudson Commuting Capacity Study

In addition to historical restrictions on use of the Holland Tunnel by certain buses and carriers because of the narrow width of the tubes (compared to the Lincoln Tunnel), there are several potential reasons to explain the low utilization of the Holland Tunnel by the trans-Hudson bus market. These reasons could include—but are not necessarily limited to—capacity constraints and associated travel time unreliability within the Holland Tunnel and at its approaches, significant congestion within Manhattan south of Canal Street, the absence of customer amenities in Lower Manhattan, and restrictions on which carriers can operate and drop off/pick up customers on New York City streets.

The lack of bus priority in the outbound direction from Lower Manhattan to and through the Holland Tunnel is particularly significant as an impediment to reliable outbound PM bus operations. A bus priority solution has eluded combined staff efforts at the PANYNJ and NYCDOT for decades. In short, many of these actions have been evaluated in the past. Improved access from the north via Varick Street may be easier to achieve, but even if this action could be implemented, it would not improve travel times for Lower Manhattan commuters. Achieving a noteworthy improvement in bus priority and speed from Lower Manhattan through the Holland Tunnel would require real local support to enable the participating agencies to move forward.

This strategy aims to increase use of the Holland Tunnel by making this crossing a more attractive option for trans-Hudson bus commuters. For instance, expansion of the existing bus/HOV lane in Jersey City at the 12<sup>th</sup> Street approach to the Holland Tunnel may help improve bus access from immediately adjacent origins. Additional operational changes could be considered on 14<sup>th</sup> Street in Jersey City as well as the New Jersey Turnpike Newark Bay Extension to improve bus travel times. Furthermore, under this strategy, all Holland Tunnel buses could be outfitted with Traffic Signal Priority (TSP) equipment to take advantage of existing TSP on Water Street and other corridors within Manhattan, such as Church Street, where it could be implemented. On the approaches to the Holland Tunnel and through the tubes, eastbound bus priority could be considered during the AM peak period in order to take advantage of directional flow imbalances. In addition, bus priority or a queue bypass could be considered to speed westbound buses into the tunnel in the PM peak period. To further improve the customer experience, several stops in Lower Manhattan could be designated as primary boarding/alighting locations and could be prioritized for capital investment to add ticketing, real-time arrival displays, shelter from the elements, benches, and other customer amenities.

Potential benefits associated with this strategy include modest demand shedding for the Lincoln Tunnel corridor and PABT, time savings and cost savings for certain trans-Hudson commuters (with no need to transfer to the subway to get to Lower Manhattan), and reduction in bus operating costs for certain diverted routes. Potential impacts associated with this strategy include additional congestion along the Holland Tunnel and its approaches, as well as additional congestion within Manhattan on New York City streets. Impacts on bus operating costs could be neutral if time savings approaching the Holland Tunnel were to be off-set by additional travel time costs operating on New York City streets. Furthermore, from a customer's perspective, service to Lower Manhattan would be less frequent than service to the PABT under the potential pilot program associated with this strategy, which could limit the attractiveness of the service.

Public policy issues that would need to be considered for this strategy include but are not limited to those pertaining to the aforementioned Lincoln Tunnel/Holland Tunnel bus loop operation strategy. Coordination would also be necessary with NJDOT and the municipalities with roadway jurisdiction, as well as the bus operators, to identify suitable bus priority measures and stopping locations in New Jersey. Additional coordination would be necessary with NYCDOT and NYCT to establish reasonably unified routings for Lower Manhattan bus services and to establish fewer, but higher-quality bus stops. At a minimum, each stop should have a shelter with benches, real-time variable message signage (VMS) displays, and adequate space for customer queuing. Additionally, this strategy would ideally include a location for staging/storage of a small number of buses in Lower Manhattan.

**Conclusion:** Increased use of the Holland Tunnel to serve Lower Manhattan instead of the PABT has the potential to result in a modest reduction of peak hour demand at the PABT. For purposes of the potential pilot program, an estimated 20 PM peak hour bus trips could be diverted from the PABT to Lower Manhattan. If the potential pilot program is successful and viewed as an attractive option for trans-Hudson commuters, additional variants of candidate route(s) could be implemented to use the Holland Tunnel and serve Lower Manhattan. Similar to the Lincoln Tunnel/Holland Tunnel loop operation strategy, it is possible that capacity limitations of the Holland Tunnel and its approaches could be a constraint in fully realizing the potential demand shift from the Lincoln Tunnel corridor and PABT. Implementation of this strategy should consider opportunities to increase bus priority on both sides of the Hudson River, to the extent that such opportunities are operationally feasible. The success of this strategy is also dependent upon identification of new commuter markets that currently lack service to Lower Manhattan. There is no expectation that improving bus access into and out of Lower Manhattan through the Holland Tunnel is easy to achieve, but there are potential benefits to trans-Hudson commutation, so there could be value in further exploring these actions.

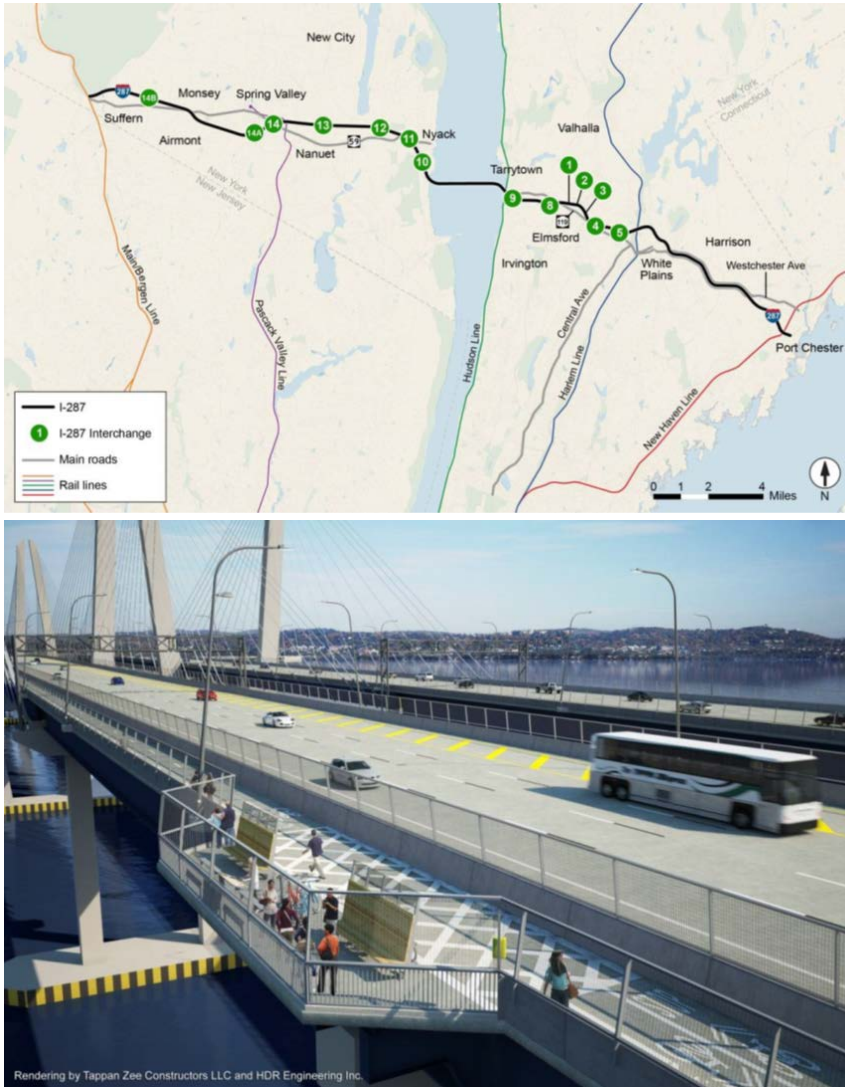
#### 3.1.4 Lower Hudson Transit Link/New NY Bridge (Tappan Zee Bridge Replacement)

This strategy calls for promoting the use of the planned enhanced commuter bus service across the New NY Bridge by trans-Hudson commuters, and a commensurate reduction in bus service to the PABT via the Lincoln Tunnel corridor. Rather than use commuter bus routes that serve the PABT, customers would use the planned enhanced commuter bus service across the New NY Bridge that would serve White Plains and Tarrytown, where customers could transfer to the Metro-North Railroad to access Midtown Manhattan.

Upon its scheduled completion in 2018, the New NY Bridge could serve Manhattan-bound trans-Hudson bus commuters from points to the north in New York along the I-287 corridor. As discussed in the MBMP, approximately 7% of customers on PABT commuter routes (approximately 6,500 customers) live in Orange or Rockland Counties or elsewhere in New York State, and these customers could be candidates for use of this strategy because of their residence location. However, the 7% figure should be qualified to note that some passengers are destined to West Side locations that

would not benefit from this strategy. Accordingly, this strategy would likely be most appealing to customers whose destination is in East Midtown. Figure 13 shows the I-287 corridor in Rockland and Westchester Counties, as well as a rendering of the New NY Bridge.

Figure 13: I-287 Corridor and Rendering of New NY Bridge



Source: New NY Bridge Mass Transit Task Force, Final Transit Recommendations

This strategy aims to leverage the planned enhanced commuter bus service that would connect Rockland and Westchester Counties by way of the New NY Bridge. The enhanced commuter bus service, which is anticipated to use double decker buses for added capacity, would connect Rockland County to White Plains on the Harlem Line and Tarrytown on the Hudson Line of the Metro-North Railroad. There are plans for a variety of bus priority measures along I-287 and the adjacent



arterial highways. The enhanced commuter bus service would make it more convenient for trans-Hudson commuters from points to the north in New York to ride Metro-North Railroad into Grand Central Terminal.

With marketing, fare integration, and schedule integration, this link has the potential to divert additional customers from Rockland and Orange Counties who currently ride PABT buses.

With respect to both fare and trip time, this strategy may not be competitive with continued use of PABT commuter bus services. A monthly pass (40-trip discounted commuter book) on Coach USA's Route 49—which connects points in Rockland County to the PABT—costs \$300, and a monthly pass on the Metro-North Railroad from White Plains to Grand Central Terminal costs \$259, which excludes the additional fare (not yet known) that would be required to use the enhanced commuter bus service from Rockland County to White Plains. Additionally, during the peak period, a commuter trip on Coach USA's Route 495 takes approximately one hour to travel to the PABT (from Spring Valley in Rockland County), while a trip to Grand Central Terminal using the proposed enhanced bus service from Spring Valley and a transfer to Metro-North Railroad at White Plains would take approximately 80 minutes (excluding transfer time). Accordingly, this strategy that includes a two-seat ride may cost more and/or take longer for a commuter than the existing bus service that offers a one-seat ride for commuters from Rockland County to the CBD. However, it may be an attractive option for PABT customers who work in East Midtown, many of whom already have a two-seat ride if they transfer to the subway to access their final destination. Additionally, a convenient connection to Metro-North Railroad east-of-Hudson service may provide more frequent and/or reliable service, with appeal to East Midtown workers.

Potential benefits associated with this strategy include modest demand shedding for the Lincoln Tunnel corridor and PABT, as well as possible time savings for certain trans-Hudson commuters (although it is important to note the possible shortcomings discussed above). Potential impacts associated with this strategy include one additional transfer for current PABT customers who walk to their work destination, loss of revenue for the PANYNJ if fewer buses use the PANYNJ-owned Hudson River crossings, and possible higher fares for the customers (compared to the commute to the PABT). Public policy issues that would need to be considered for this strategy include jurisdictional coordination regarding fare policy, marketing, and scheduling of service.

**Conclusion: The use of the planned enhanced bus service across the New NY Bridge by trans-Hudson commuters has the potential to result in a modest reduction of peak hour demand at the PABT. It is not unreasonable to anticipate that, over time, up to 1,000 daily commuters who currently use the PABT could switch to a transit link over the New NY Bridge. If this were to happen, it could reduce PABT demand by approximately 15-20 buses. However, since planning for transit over the new bridge is ongoing, it is premature to assign a number to the potential reduction in buses for use in planning the PABT replacement. Overall, this strategy may well be a viable alternative for some commuters from Rockland and Orange Counties to the East Side of Manhattan if the service along the New NY Bridge is sufficiently robust and total fare/trip time do not render it uncompetitive.**

## 4 Additional Considerations

### 4.1 INCENTIVE-BASED CAPACITY MANAGEMENT PROGRAMS VS. MANDATED VEHICULAR ACCESS POLICIES

The discussion of Lincoln Tunnel corridor/PABT strategies included consideration for a second XBL or HOT lane along Route 495 to support expanded bus prioritization (Section 2.1.1). Another possible way to achieve the operational goal of increased bus throughput into Manhattan during the AM peak period would be to prohibit use of the Lincoln Tunnel by Single Occupancy Vehicles (SOVs) during rush hour. This would reduce demand for car trips during the peak period, make additional capacity available for buses, and reduce travel time for carpools.

Limiting SOVs during rush hour could be expected to free up sufficient capacity in the Lincoln Tunnel to meet the projected AM throughput goal. However, this action would have greater ancillary effects on drivers than would the second XBL/HOT lane strategy. Creating capacity for buses using a HOT lane would allow drivers a choice: they could participate in a carpool<sup>1</sup> or pay a variable charge for a quicker trip, or opt for a slower, less costly trip. The ultimate choice would lie with each individual driver. The benefit of limiting SOVs could include a reduced infrastructure cost and faster implementation, but it relies on a potentially difficult public policy shift requiring extensive coordination and public outreach. It is noted that prohibiting SOVs during the AM rush hour may be a desirable policy choice, but it would have no greater benefit for buses than imposing a second XBL/HOT lane.

In sum, access to the Lincoln Tunnel for cars could be limited to HOVs during the morning rush hour, and doing so could be expected to generate sufficient capacity for buses to achieve the necessary throughput to serve an expanded XBL. However, this objective could also be met by adopting a second XBL/HOT lane in a way that still allows SOV access during the AM rush, and might also be met by using bus platooning (Section 2.1.3). Limiting travel of SOVs may be desirable from a policy point of view, but it provides no additional benefits for buses than could be achieved by other means.

### 4.2 IMPACT OF LATENT DEMAND

Latent demand is desire for transportation that goes unmet by the existing supply of transportation services. This latent demand generally cannot be observed, but can become real growth in passenger activity after transportation system capacity is increased. Generally, in a traditional

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<sup>1</sup> It should also be noted that the 2009 *Lincoln Tunnel HOT Lane Feasibility Study* considered whether HOVs would be able to access the HOT lane for free. The study recommended against this policy because of the expense and challenge associated with verification of HOV occupancy in light of the PANYNJ's possible migration to all-electronic tolling procedures.



planning process, if population remains the same and service characteristics like travel time and cost do not change, it is assumed that there would not be growth in passenger activity on the service. However, if a transit service is highly congested, then simply increasing service will induce additional travel even if the observable characteristics of the service do not change. On the trans-Hudson bus network, where service is limited at the peak by operational constraints, bus operators currently provide less service than their customers desire. For the PABT planning process, this means that latent demand could induce travel at the future terminal being considered by the PANYNJ beyond the projections of the travel demand models, which use ridership on existing services as a baseline input.

An example of this phenomenon is the impact to trans-Hudson travel when the Frank R. Lautenberg (FRL) Station in Secaucus opened in 2003. The FRL station allowed NJ TRANSIT customers on the Main, Pascack Valley and Bergen County lines—previously destined to Hoboken to transfer to PATH or ferry for service to Manhattan—to instead conveniently transfer for direct service to Penn Station New York (PSNY). NJ TRANSIT reconfigured a number of bus routes from Bergen County, with the expectation that customers would shift from bus to rail for this new service to PSNY. It was expected that several thousand commuters would make this choice, with the net result being higher use of PSNY and corresponding lower use of PABT. When the service changes were initiated, use of NJ TRANSIT rail increased as expected. However, use of PABT did not see a corresponding decrease. It is believed that this was due to latent demand – as seats were freed-up on buses headed to PABT by commuters choosing rail, others who had been using neither bus nor rail saw an opportunity. These might be people previously drove to New York or were not making the crossing at all.

This phenomenon has several implications for PABT reconstruction. First, if significant latent demand exists, it cannot be assumed that strategies to increase use of a mode or crossing other than the Lincoln Tunnel/PABT system will simply rebalance existing demand. The result could be more demand on the improved service or facility with little or no reduction in demand at PABT. Connected vehicle technology which would enable more buses to flow through the XBL and shared-vehicle technologies that allow customers to more easily connect to transit in New Jersey could also add to the attractiveness of the system and tap latent demand. Additionally, efforts to enable a smaller reconstructed bus terminal by handling demand at PABT more efficiently using design, storage and staging, or technology may not have the desired effect. Rather than the same commuters simply using a smaller but more efficient facility, new commuters could flock to the improved facility in even greater numbers than expected due to its new-found attractiveness and efficiency.

It is important to note that the ridership forecast prepared for the MBMP and used as an input to this Capacity Study does not fully account for the effects of latent demand. As noted in the MBMP Final Report Appendix B (*Bus & Passenger Activity Forecasts*), although the results of the ridership forecast are unconstrained by transit capacity, “The results [of the forecast] do not include the additional ridership induced by increased service frequencies due to agencies increasing their schedules to meet demand.” Additionally, the ridership model projects future demand based on base year ridership, and to the extent that the base year is not reflective of existing demand (due to capacity constraints), the future projections could underestimate likely demand. Indeed, NJ TRANSIT staff has advised the study team that it would add more peak-period service from certain

markets to the PABT today if capacity were available. Accordingly, latent demand implies growth above and beyond the demand forecasts.

In sum, latent demand could substantially reduce or offset any benefits obtained by shifting demand to other time periods or other modes. Due to growth from better service and a better terminal, a longer horizon year, and inevitable uncertainties, there may be the need for another (higher) forecast. Even if that number is not used for the design, it will be important to prepare a contingency plan for how the terminal might be expanded to accommodate more riders beyond the 2040 forecasts.

### 4.3 CUMULATIVE EFFECTS

Although the discussion in this technical memorandum so far has concentrated on strategies that could reduce peak hour bus demand to PABT (and/or increase the operational efficiency of the Lincoln Tunnel corridor/PABT facility), policy makers should be aware that there are as many factors that could increase demand for peak hour access to PABT as could reduce it. Some of the bus strategies described in this technical memorandum have potential to increase operating efficiency of the terminal itself in the PM peak beyond the six turns per gate per hour assumed for the MBMP. In particular, it may be possible to combine well-designed staging and storage in Manhattan with new bus tracking and dispatch technology to make more efficient use of bus gates and achieve the promised level of peak hour throughput with fewer gates. This opens the possibility to achieving desired performance with a smaller, less costly facility.

However, there are also reasons to be cautious. First and foremost, the Capacity Study team has found no other bus facility in the world that has implemented a comparable package of design and advanced technology solutions to use as a benchmark. Additionally, the nature of the PABT as a multilevel facility where vertical circulation is at least as important as horizontal circulation makes it different from most other large bus terminals. This is not a reason to shy away from aggressively pursuing these strategies. However, planners should recognize the uncertainties that limit the ability to accurately predict how effective they will ultimately prove to be.

Even if gate throughputs that are consistently higher than assumed for the MBMP can be achieved, there is reason to suspect that other factors may tend to work against any such gains. Several bus strategies described in this technical memorandum have the ability to reduce bus delays in addition to expanding bus throughput. During the AM peak, buses are delayed in several locations in gaining access to and transiting the Route 495 corridor/XBL, and several strategies have been proposed to reduce these delays. During the PM peak, buses are delayed getting to gates and, once loaded, in reaching the Lincoln Tunnel. These delays could be significantly reduced by the technology and staging/storage strategies discussed previously.

The net result would be both higher throughput and more reliable trip times for commuters (and perhaps even some time savings subject to traffic conditions elsewhere on their routes). Various plans have been proposed to increase capacity on the other main trans-Hudson transit crossings – PATH

trains and NJ TRANSIT rail – but in each case the likely outcome is higher throughput without much change in trip time for the average commuter. The cumulative result could be that bus travel becomes relatively more attractive than competing modes compared to today. Although there are a limited number of commuters who have the option to take either bus or rail due to route structure and other factors, nonetheless the result of improvements to the PABT system could be higher than anticipated demand.

#### 4.4 OTHER BUS NETWORK STRATEGIES CONSIDERED BUT NOT CARRIED FORWARD

This technical memorandum focuses on the most promising strategies to meet and manage existing and projected future trans-Hudson commuter demand. However, the list of strategies discussed in this technical memorandum is not exhaustive. Other strategies have been identified in prior trans-Hudson planning initiatives and/or during the Capacity Study process, but were deemed less promising than those outlined in this technical memorandum.

For instance, there is recurring interest in a **Westbound XBL**. The existing XBL facilitates efficient throughput for inbound buses to serve the PABT in the AM peak period, but there are no comparable provisions for bus priority in the outbound direction. However, the concept of a westbound XBL is difficult to justify because of the large number of exit points off Route 495, including Route 3 and both northbound and southbound NJ Turnpike. Whereas in the eastbound direction, these access points to Route 495 feed the Lincoln Tunnel, in the westbound direction, the situation is reversed, and the tunnel distributes traffic to a range of destinations. This presents a key operational constraint to the concept of a westbound XBL. Furthermore, the existing eastbound XBL was created in part to provide a bypass for buses to avoid the Lincoln Tunnel toll plaza, which is not an issue in the westbound direction. As such, this Capacity Study is not advancing a strategy that calls for the addition of a westbound XBL.

Another strategy that is not considered in this Capacity Study is the concept of spreading PABT buses across a number of **dedicated crosstown routes** in the Manhattan CBD (i.e., introducing a crosstown busway or bus boulevard) in lieu of a centralized bus terminal. The principal shortcoming, and indeed a fatal flaw of such an approach, is the challenge of turning buses around and providing layover space in East Midtown, especially for large volumes of buses. Another issue with this strategy would be the slow and highly variable bus travel time for crosstown operations. Even with the most effective bus priority treatments, crosstown bus speeds in Midtown would still be barely faster than walking, and there are concerns about the ability of west-of-Hudson buses to run crosstown and get back across the Hudson River with reliable running times during peak periods. Furthermore, the added congestion, emissions, fuel consumption, and bus miles could potentially result in adverse impacts to neighborhoods in Midtown. While some customers would be taken closer to their Manhattan destination, these customer benefits could also be offset by the introduction of on-street boarding. For all of these reasons, this strategy is not considered in this Capacity Study.

Other potential strategies were previously considered in the Capacity Study but not advanced for further evaluation based on feedback from PANYNJ staff. For instance, a strategy that was

previously identified but eliminated from consideration called for use of **elevators to facilitate bus storage**. Based on prior work, PANYNJ staff has considered this as not feasible for a commuter bus terminal.

There are also other potential strategies that have not been a focus of this Capacity Study to date but that nevertheless warrant recognition for their potential effect on the operational efficiency of Lincoln Tunnel corridor and/or the broader interstate transportation system. For instance, a potential strategy could call for **diverting current and future Staten Island-to-CBD bus demand** from the Lincoln Tunnel to the Staten Island Expressway (I-278) and the Battery Tunnel. Currently in the morning peak period, there are approximately 100 NYCT bus trips (X17J, X21, X22, X30, X31) that operate from Staten Island west over the Goethals Bridge, north along the NJ Turnpike, and back east across the Hudson River through the Lincoln Tunnel, taking advantage of the XBL. In the evening peak period, there are approximately 90 outbound trips through the Lincoln Tunnel. In addition, Academy Bus (X23, X24) operates approximately 32 inbound trips from Staten Island via the same path and approximately 28 companion outbound trips. These trips do not enter or use the PABT, but they add to bus volumes through the tunnel, and on Route 495 in both peaks.

The current Staten Island-Manhattan express-bus pattern reflects a balance between trips operating via New Jersey and through the I-278 bus priority corridor. Programmed improvements underway on the Verrazano-Narrows Bridge and the Gowanus Expressway in Brooklyn are expected to improve the performance of the bus-priority operation on I-278. Given the number of Staten Island buses operating on Route 495 and through the Lincoln Tunnel in peak hours, it could be beneficial to ask NYCT and Academy Bus if they would be amenable to re-evaluating operating practices to determine if the path via New Jersey is still the fastest and most dependable path. It may well be that circumstances have changed for certain routes, but the attractiveness of re-routing would likely depend on whether the enhanced managed use lane corridor on I-278 would offer those riders comparable or better travel times than the present route via New Jersey. However, it is worth noting that customers find these services very attractive, and may object if their route is redirected via a different path.

The technical memoranda for the Capacity Study will include additional analysis related to the most promising bus network strategies discussed in this technical memorandum (in addition to the strategies to be discussed in the “Multi-Modal Network Strategies” technical memorandum), as well as consideration for other strategies that may merit evaluation in the context of meeting and managing trans-Hudson commuter demand.

#### 4.5 LIFESPAN OF A NEW PABT BEYOND THE DESIGN YEAR 2040

As a matter of necessity, transportation planners must always select a future design year for the purpose of forecasting demand. For this technical memorandum, demand forecasts are made for 2040, 24 years in the future. This is consistent with standard practice in the transportation industry of forecasting demand 20-30 years into the future, and it represents the future year for which the most comprehensive data are available.

However, simply relying on forecasts for 2040 may not be ideal for PABT for several reasons.

First, it will take many years for a reconstructed PABT to be completed. Funding has yet to be secured and it is unknown how long this will take. In addition, design, engineering, environmental review and construction will all take time. A reasonable estimate for when a new facility might open could be 2025 at the earliest, and could stretch to 2030.

If a new facility is able to open in 2025, in the forecast year, 2040, it would be just 15 years old, well short of its actual useful life. If the often-used figure for a facility's useful life of 30 years is applied, the facility will not reach this age until 2055. However, a 30-year useful life is almost certainly too low for a facility of this kind. The south wing of the current facility opened 66 years ago; the north wing 37 years ago. Given the challenge currently facing the region as it considers renewing such a heavily used facility located in such a confined space, it is reasonable to expect that future policy makers will want to get every bit of utility possible out of a reconstructed PABT before renewing it yet again.

If planners were to assume a facility opening in 2025 and a 50-year useful life for a reconstructed PABT, an argument could be made for considering demand projections as far into the future as the year 2075 as being potentially relevant. Another perspective is to consider a potential 75-year design life (i.e., a horizon year of 2100), as would be assumed for a bridge.

Given the high level of uncertainty involved in projecting so far into the future, it may not be practical to generate and rely on numerical forecasts for 2075 or beyond. However, the real possibility that a reconstructed PABT may need to function for decades beyond the current 2040 horizon year suggests that policy makers should be wary of designing a facility that is strictly sized to meet only forecasted demand for 2040. Nevertheless, it should be noted that current PANYNJ forecasts assume that growth for the trans-Hudson commuting market will level-off significantly after 2040-2050, based on socioeconomic and demographic forecasts adopted by the region's two metropolitan planning organizations (i.e., New York Metropolitan Transportation Council (NYMTC) and North Jersey Transportation Planning Authority (NJTPA)). The NYCDCP similarly anticipates that population and employment growth in New York City will slow significantly after 2040.

In the PABT replacement planning effort, it is also important to consider the implications of the useful life of a new PABT in the context of the facility itself. For instance, PANYNJ staff has noted that it could be possible to rehabilitate the new PABT in phases (e.g., one helix at a time) and in perpetuity. Accordingly, future capital renewal of a new PABT must be considered in the design of the facility.

#### 4.6 IMPACTS OF SHIFTING THE NEW PABT FARTHER WEST/NEW 10<sup>TH</sup> AVE STATION

The existing PABT occupies the blocks between West 40<sup>th</sup> and West 42<sup>nd</sup> Streets and Eighth and Ninth Avenues in midtown Manhattan. The terminal provides direct connections to the Eighth Avenue A, C, and E subway lines and a passageway under 41<sup>st</sup> Street connects to Seventh Avenue 1, 2, 3, N, Q, R, S, and 7 subway lines.

The Port Authority Working Group concluded that the most promising approach to replacing the PABT would involve constructing a new bus terminal on available Port Authority-owned property one block west of the current structure, between Ninth and Eleventh Avenues. Under MBMP Concept 3, passenger gates would be relocated between Ninth and Eleventh Avenues, in order to allow the existing terminal to remain in operation throughout construction of the new bus terminal. Post-construction, the existing PABT site would be available for commercial development.

Shifting the new PABT one block farther west creates both challenges and opportunities. As noted in *The Emerging Design + Deliverability Brief* (Appendix A in the D+D Competition materials), approximately 50% of existing PABT's customers walk from the terminal and 40% use the subways to reach their final destination. More than half of PABT's customers are destined for Midtown Manhattan, east and north of the existing PABT. The shift of one city block would add approximately 6-7 minutes each way to customers' travel time for those who walk or access the subway.

The MBMP Peer Review conducted on November 16-18, 2015 identified several key issues including a major concern for increased walking distances and travel time as compared to the current facility. They noted that the pedestrian experience will need to be comfortable and efficient and that interim conditions are important as well as the long term.

The current No. 7 Extension to West 34th Street and 11th Avenue originally included provisions for a station at 10th Avenue. The current concept for providing this future station would include two side-platforms with connecting passageways. There would be two entrances: one at West 42nd Street between Dyer and 10th Avenues through the Related Companies' new mixed-use development, MiMa, and the second at 455 West 40th Street between Dyer and 10th Avenues. The conceptual design of the future station is currently being reviewed by NYCT. The proximity of this proposed station to the west side of a new PABT at 10th Avenue provides an opportunity to allow for convenient customer connections to the 7 Line to serve trips destined for Hudson Yards, East Midtown and Queens.

Overall, there is a significant travel time penalty as a result of shifting the new PABT farther west one city block. The design of the new PABT must take this into account and look for opportunities to create a more attractive experience for customers who are walking or transferring to the subway. Additionally, the planning process for the new terminal should investigate the benefits should the previously deferred construction of the No. 7 Line Extension 10th Avenue station go forward, especially with convenient pedestrian connections to a new PABT.

#### 4.7 INTERCITY BUS SERVICE ACCOMMODATION

Intercity bus operations have very different characteristics and demand from commuter buses and one argument is that they should not be included in a new PABT due to severe space limitations. Another side of the argument is that all bus operations should be unified in a new facility. This discussion will evaluate the pros and cons of the two courses of action.



Typically, commuter buses spend far less time at their gate than do intercity buses. Commuters, for the most part, understand the service pattern and how and where to board their bus. Intercity customers, however, need to allow more time for ticketing, to find their gate, confirm that they are on the correct bus and to stow baggage. Because intercity buses typically operate every several hours, customers strive to arrive early, to make sure that they do not miss their bus. Commuter buses typically operate much more frequently, so missing a bus is less of a concern. For these reasons, a proper waiting room is beneficial for intercity services.

This difference in behavior patterns means that, on average, gates dedicated to intercity service are not as intensively used as gates dedicated to commuter services. A commuter bus gate can be cycled every 10-15 minutes under most circumstances. Certain commuter routes, with simple fare collection and low-floor transit-style buses, could reliably cycle every 8 minutes. Intercity buses cycle 20 or 30 minutes for the reasons cited above. As a consequence, intercity bus gates are inherently less efficiently used. This then forces of question of whether there is room in a new PABT for intercity services.

It has also been proposed that intercity services would be not be permitted to depart the facility during the PM peak period. An advantage of moving intercity buses out of the terminal would be to free up additional space at the existing PABT for an expansion of commuter operations. While there is some logic to this approach from the view of the terminal operator, it creates issues for intercity customers and would severely constrain operations for the intercity operator. The comparison to rail operation is instructive. Amtrak does not load long-distance trains at Penn Station during the PM peak, because such trains take very long to load with many customers being assigned cabins, and to different rail cars for different destinations. Amtrak does, however, load regional trains during the PM peak period, because that is time that so many customers want to travel. It is not ideal to restrict intercity bus departures in the PM peak.

That said, there is no harm in offering incentives to intercity bus operators to shift some demand from the peak of the peak to less busy times. This would accomplish two complementary objectives. First, it would use scarce gate space in the PABT more effectively, and second, it would encourage intercity operators to stage departures at less congested times, thus speeding service for their customers.

If the decision is made to build a new free-standing intercity terminal, such a terminal could reasonably and feasibly be located away from the Lincoln Tunnel ramps complex. Intercity bus service thrives in locations throughout New York City that are not connected to bus priority infrastructure. Successful intercity bus service can be found throughout Midtown, around Hudson Yards, in Chinatown, and (including seasonal and casino routes) in neighborhoods throughout Manhattan and the other boroughs. Infrequent, lower volumes of intercity buses may be more compatible with on-street operations than high-frequency commuter services from a community impact/pedestrian safety perspective. Circulating on city streets, however, is bad for the quality of the service delivered to the customer and would increase operating costs for the carriers.

It is important to note that expenses associated with a separate facility for intercity buses would include both upfront capital costs and ongoing operating and maintenance costs. From the PANYNJ's

perspective, a new intercity facility would ideally be managed and operated by one or more of the carriers. However, if such an arrangement cannot be developed, management and operation of the facility would likely fall back to the PANYNJ, thereby leaving the PANYNJ with the added expense of managing two bus facilities in the place of one.

In order for a stand-alone intercity terminal to accommodate all of the carriers envisioned for it with only 35 gates, it will require some provision for bus layovers. Layover time is slack time independent of passenger boarding/alighting operations for driver rest and light interior cleaning of the bus. In the existing PABT, intercity operators tend to layover buses in passenger gates because no reliable alternative exists. However, off-site bus layovers are common in New York City by curbside carriers and in other cities around the world.

The MBMP envisioned that the staging/storage facility would also be used for intercity bus layovers. If a staging/storage facility is not completed when a new intercity terminal opens, some interim provision for layovers will need to be made for the new facility to be fully efficient.

Overall, intercity bus carriers have introduced low-cost travel options that are beneficial to and valued by the public. The MBMP anticipated a need to accommodate a few of the largest curbside operators in a new PABT, while other operators would continue to provide curbside service. The much-cited projection of 855 PM peak hour bus departures at a new PABT accounts for commuter buses and those intercity buses that currently serve the existing PABT. The projection does not include approximately 25 “additional Midtown-based intercity buses with sufficiently robust schedules and financial stability to be suitable as tenants in a future bus terminal”—as described in the MBMP Final Report Appendix B (*Bus & Passenger Activity Forecasts*)—but that currently provide curbside service. To accommodate these additional intercity buses, the bus demand at the new PABT in 2040 would be approximately 880 departures during the PM peak hour, whereas the demand would be approximately 820 departures during the PM peak hour if the PABT would not accommodate any intercity buses. The effort to right-size the PABT must consider whether intercity carriers will be accommodated in the new facility, and if so, whether some carriers would continue to provide curbside service.

## 5 Findings

The purpose of this technical memorandum is to investigate possible future strategies for trans-Hudson bus infrastructure and operations that could help optimize the capacity and configuration of a reconstructed Port Authority Bus Terminal (PABT).

While a new bus terminal will need to provide more room for bus customers on escalators, in waiting areas and along passageways, the crucial factor in modeling the ultimate capacity of a reconstructed facility will be the logistics of handling the buses themselves. Accordingly, analysis performed for this technical memorandum considered strategies that fall into two categories:

- Strategies that increase/manage capacity along the Lincoln Tunnel corridor
- Strategies that **address overall Trans-Hudson demand** including the use of other crossings (to be supplemented in the “Multi-Modal Network Strategies” technical memorandum by strategies that consider other modes)

The final number of gates needed at a reconstructed PABT, and thus the facility’s ultimate capacity and cost, is heavily influenced by the implications of these strategies with respect to meeting projected peak period trans-Hudson commuter demand.

Due to the timing and other parameters laid out at the beginning of the Capacity Study process, this technical memorandum’s findings are largely qualitative, and recommendations are made in several places suggesting where additional quantitative assessments are appropriate. It is important to note that, based upon the Port Authority of New York and New Jersey (PANYNJ) Board resolution of March 24, 2016, the analysis in this technical memorandum did not consider an option that would include construction of a bus terminal in New Jersey. However, the assessment included consideration of infrastructure improvements and operational initiatives in New Jersey important for reliable commuter service and containment of traffic impacts on both sides of the Hudson River.

Initial findings, which are revisited as appropriate in subsequent technical memoranda in the Capacity Study, are as follows.

1. **PABT is not a stand-alone facility; it is part of a system.** The bus terminal is just one component of a trans-Hudson bus transportation system extending from 8<sup>th</sup> Avenue in Manhattan all the way to the New Jersey Turnpike five miles to the west and beyond. To handle future demand, all parts of this system – the ‘teardrop’ and other approaches to Route 495, the Exclusive Bus Lane (XBL) and other lanes of Route 495, the Helix, the toll plaza, the Lincoln Tunnel tubes, the ramps leading into PABT, and locations for bus storage and staging on both sides of the Hudson River – must function as a system. Investments or policy changes that increase throughput in one segment without addressing upstream and downstream effects will not have the desired results.

Additionally, strategies are needed to address system-wide operational constraints for both the AM and PM peak periods.

- 2. Infrastructure and operations must be considered together.** Any future design for this integrated system must be grounded in a concept for how its individual parts will be operated. This includes factors from the size of buses to be used, where buses are staged and stored, and how buses move from storage to bus gates, to operation of the reversible lanes and the role technology will play in guiding bus movements. Proposals for facility design cannot be evaluated without understanding how they will be operated, and operational innovations cannot be implemented without supportive design. Each depends upon the other.
- 3. The infrastructure and operational plan for the future of the PABT must be arrived at through a process of collaboration.** The key facilities and procedures that make up the Lincoln Tunnel corridor/PABT system are in the hands of multiple government agencies and private operators spread across two states. As such, no single party can simply select a solution and implement it unilaterally. The future must be determined collaboratively, with each party clearly communicating its needs and priorities while respecting the needs and priorities of others. The ability of the interstate transportation system to accommodate projected commuter demand is dependent upon active cooperation and engaged working relationships across jurisdictional boundaries, including the City of New York, municipalities in New Jersey and agencies in both states. This includes collaboration with respect to bus staging and storage, pick-up/drop-off locations, roadway improvements, and implementation of additional bus prioritization.
- 4. Bus staging and storage is a critical issue that can and must be addressed in the short term.** A bus staging and storage facility in West Midtown represents an essential component of the new PABT complex in both the short and long term – such a facility could have independent utility in the near-term, and would be an important component of a new PABT in the longer term. A West Midtown bus staging and storage facility could result in improved reliability of customer operations, reduced demand along the Lincoln Tunnel corridor, and increased near-term capacity of the existing PABT, and thus should be accelerated as a first stage of the PABT replacement. During this Capacity Study process, PABT/Lincoln Tunnel management suggested that some—but not all—bus staging and storage should be accommodated in New Jersey, also noting that a facility in New Jersey would require proximity to the tunnel plaza and rigorous management of inbound Lincoln Tunnel lanes to ensure highly reliable dispatch of buses through the tunnel to their assigned gates. It would be advantageous to accommodate bus staging and storage on both sides of the Hudson River to promote balance in the interstate transportation network.
- 5. Strategies that accommodate trans-Hudson buses using other crossings, including the George Washington Bridge and the Holland Tunnel, have some potential to reduce demand at the PABT.** This technical memorandum has discussed three potential strategies that could siphon off some of the projected demand at the PABT by implementing new variants on existing commuter bus services from select trans-Hudson travel corridors. The route variants would use Hudson River crossings other than the Lincoln Tunnel as part of a pilot program. The technical memorandum also considers a strategy that calls for promoting the use of the planned enhanced

commuter bus service across the New NY Bridge by residents of Rockland and Orange Counties who currently use PABT bus routes. The intent of these strategies is to expand the potential of alternate Hudson River crossings as attractive commuting options, and not to force PABT customers to change their travel patterns. The preliminary assessment completed for this technical memorandum found that approximately 40 buses per hour could be diverted from the PABT when considering the potential cumulative effects of these pilot programs. This represents approximately 5% of the projected 855 PM peak hour bus departures at the PABT in 2040. If the pilot programs are successful and viewed as attractive options for trans-Hudson commuters, additional route variants could be implemented, which could result in a commensurate reduction in peak period demand at the PABT. Overall, while these strategies offer some promise with respect to reduction of peak period demand at the PABT, the potential reduction is not significant, and should not be overstated.

6. **Changes to the infrastructure and operations of Route 495 and points farther west in the New Jersey roadway network would have benefits to interstate bus operations and local traffic conditions preceding a reconstructed PABT, and would balance the capacity of the west-of-Hudson network with a new terminal designed to accommodate the 2040 demand forecast.** During the AM peak, buses are delayed in several locations in gaining access to and traversing the Lincoln Tunnel corridor. Demand currently approaches or exceeds capacity along the XBL, so capacity improvements for additional bus prioritization could productively be accelerated for early implementation to address existing capacity constraints. Over the longer term, without increases to the throughput capacity of this system, money spent on a higher capacity PABT will not generate the desired performance gains. It will almost certainly be necessary to either convert one general purpose inbound lane of Route 495 and the Lincoln Tunnel to a second XBL or combined XBL/HOT lane during the AM peak, or to implement bus platooning technology that will allow a significantly higher level of bus throughput in the current single dedicated XBL. Additionally, network improvements to support expanded and more efficient bus operations are also needed on the major Route 495 approaches, including Route 3 and the NJ Turnpike. Indeed, to support existing and projected future demand, there is a need to enhance the operation of the existing XBL and also supplement the XBL by providing additional bus prioritization farther upstream from the Lincoln Tunnel.
7. **Emerging technology to support bus platooning offers an opportunity for major performance improvements to the Route 495/Lincoln Tunnel system.** Implementation of bus platooning may be possible within 10 years and could significantly increase throughput of the existing XBL, assuming commensurate efficiencies are achievable crossing into Manhattan. Many of the technologies necessary for such a system are already available or will be soon. However, the pathway for these technologies to be integrated into a system that can manage the unique needs of the Route 495/Lincoln Tunnel corridor is less clear. The PANYNJ should seriously consider taking a lead role in setting out requirements for such a system and sponsoring the needed technology integration. A technology solution would have less effect on other users of Route 495 than dedicating a second bus lane during the morning rush, although a second priority lane would create a redundancy benefit that technology cannot fully provide.

- 8. Increased use of higher-capacity buses on routes with sufficient demand can improve the efficiency of the Lincoln Tunnel corridor and PABT, and should be seriously considered.** Some bus routes serving PABT carry very high volumes. On these routes, policy makers should seriously consider replacing conventional transit buses with higher-capacity double decker buses or articulated buses. Doing so could serve passenger demand with fewer bus movements, fewer bus gates, a smaller fleet, less fuel consumption, and lower operating costs, although it is possible that increased use of higher-capacity buses could function to accommodate more customers as opposed to fewer buses at the PABT. Ceiling height and other geometry issues limit the ability to use these vehicles in the terminal today, but the new terminal should be designed to accommodate the maximum reasonable usage of larger buses that could be possible given projections for customer demand. Although such a change to the bus fleet offers real promise, implementation would be complex. Many public agencies and private operators would be involved, height restrictions and axle loading standards on New Jersey roads would need to be addressed, as well as the size and configuration of bus garages and maintenance facilities. The key message for design of the new bus terminal is that uncertainty over future fleet mixes and service models require flexible designs and adaptable terminal configurations.
- 9. The combination of capacity management and demand management initiatives could potentially reduce the necessary capacity of a new PABT, if viable strategies are demonstrated during planning and project development.** This technical memorandum has outlined a range of strategies to manage capacity and improve the operational efficiency of the Lincoln Tunnel corridor/PABT facility, as well as strategies that address overall trans-Hudson demand. Collectively, these strategies—in concert with other multi-modal trans-Hudson strategies under consideration—could potentially reduce the capacity requirements of a new PABT. The PABT planning effort should consider the extent to which progress in advancing transit-service alternatives and demand management strategies could provide a sufficient and more cost-effective approach to a reconstructed PABT, while providing efficient terminal operation that also contains traffic impacts on the Lincoln Tunnel and surrounding streets. This is consistent with the objective to permit scalable and modular terminal solutions that may be phased over time. In turn, ongoing operational changes and potential projects that might divert some of the projected 2040 PABT demand will need to be assessed for their local impacts as well as transit service benefits.
- 10. Improvements at the PABT and along the Lincoln Tunnel corridor may actually increase demand for buses to use the PABT, underscoring the need for ongoing partnership efforts to improve bus-network efficiency and balance available interstate services across modes and corridors.** Reducing delays around the XBL and inside the PABT would generate both higher throughput and, crucially, more reliable end-to-end trip times for commuters (and perhaps even some time savings subject to traffic conditions elsewhere on their routes). This would likely occur in an environment where trip times on competing transit modes (PATH trains and NJ TRANSIT rail) hold steady even if investments to increase throughput capacity are made. The net result could be bus travel becoming relatively more attractive to commuters than competing modes. Although there are a limited number of commuters who have the option to take either bus or rail due to route structure and other factors, nonetheless the result could be demand for peak hour



bus access to the PABT that is actually higher than currently projected. This latent demand could cancel out the initial net reductions in peak-hour bus demand at the PABT from strategies to accommodate bus commuters via other crossings or improve the operational efficiency of the PABT.

- 11. There are as many factors that could increase demand for peak hour bus access to the PABT as could reduce it.** This statement was one of the primary conclusions of the participants in the April 14, 2016 experts' workshop undertaken as part of the Capacity Study. Although attendees generally agreed that many strategies were available to more efficiently manage the Lincoln Tunnel corridor/PABT system, there was a general consensus that policy makers should take seriously the possibility that projections for future bus demand as just as likely to be too low as too high. For instance, the uncertainty of achieving the full Gateway rail service expansion (discussed in the "Multi-Modal Network Strategies" technical memorandum) could increase future PABT bus demand. An additional consideration is that the travel time penalty of shifting the new PABT west could adversely impact ridership demand at the terminal.
- 12. A reconstructed PABT will likely need to accommodate growing demand well beyond the design year of 2040.** It will take many years for a new PABT to be designed, funded and built. For these reasons an opening date prior to 2025 seems unlikely. If this estimate is correct, in the forecast year of 2040 the new facility would be just 15 years old, well short of its actual useful life. In addition, future policy makers will likely want a reconstructed PABT to last longer than the 30 year life span considered standard for many infrastructure projects. The north wing of the current facility opened 37 years ago; the south wing, 66 years ago. The consequences of this could be significant: a new terminal opening in 2025 with a 50-year useful life would be called upon to accommodate growing demand until 2075. Nevertheless, it should be noted that current PANYNJ forecasts assume that growth for the trans-Hudson commuting market will level off significantly after 2040-2050, based on socioeconomic and demographic forecasts adopted by the region's two metropolitan planning organizations (i.e., New York Metropolitan Transportation Council (NYMTC) and North Jersey Transportation Planning Authority (NJTPA)). While it is not practical to produce exact demand forecasts as far out as 2075, the real possibility exists that a reconstructed PABT would need to function for decades beyond 2040. This suggests that policy makers should be wary of designing a facility that is strictly sized to meet only demand forecasted for 2040.
- 13. A policy decision must be made regarding accommodation of intercity bus service at a new PABT.** Today, some but not all intercity carriers that serve Midtown Manhattan enter the PABT, while others use on-street bus stops. This is due to a number of factors, including capacity constraints and structural limitations of the existing PABT. Operating characteristics for intercity buses are different from commuter buses, and there is a reasonable argument to be made that intercity buses should not be included in a new PABT due to the high cost of constructing a replacement facility large enough to serve both intercity and commuter buses. An argument can also be made to unify bus operations in a new facility. The much-cited projection of 855 PM peak hour bus departures at a new PABT accounts for commuter buses and those intercity buses that currently serve the existing PABT. The projection does not include approximately 25 additional Midtown-based intercity buses deemed to be suitable as tenants in a future bus

terminal but that currently provide curbside service. To accommodate these additional intercity buses, the bus demand at the new PABT in 2040 would be approximately 880 departures during the PM peak hour, whereas the demand would be approximately 820 departures during the PM peak hour if the PABT would not accommodate any intercity buses (based on demand projections in the MBMP Final Report Appendix B). The effort to right-size the PABT must consider whether intercity carriers will be accommodated in the new facility, and if so, whether some carriers would continue to provide curbside service.

Based on these findings, this technical memorandum reaches the following preliminary conclusions:

**Bus strategies are available to manage trans-Hudson travel in ways that could curb peak hour bus demand at PABT and process buses that do use the PABT more efficiently. Together, these approaches, if successful, open the possibility of a reconstructed facility that meets demand with fewer gates at a lower cost. Considering a terminal concept with less gate capacity than estimated to meet forecast demand would be feasible only if little or no accommodation for intercity buses is made in the new terminal, and the other bus network strategies considered in this technical memorandum—as well as the strategies to be considered in the “Multi-Modal Network Strategies” technical memorandum—are aggressively implemented and perform at the high end of available estimates.**

**However, factors are at work that may lead to levels of customer demand substantially higher than what is currently projected, and this would cause a facility with less than capacity required to support the project 2040 demand to exceed its design capacity relatively quickly. This countervailing pressure is further enhanced by the likelihood that a reconstructed terminal will be called upon to accommodate growing demand decades beyond the 2040 forecast year.**

**In sum, the authors have not found convincing evidence that the bus strategies considered in this technical memorandum can be relied upon to allow future demand for trans-Hudson bus travel to be accommodated at a bus terminal with substantially fewer gates than the full-build options presented in the MBMP. Some adjustments in capacity and scope may be possible but large reductions in the number of bus gates are not likely.**

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TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix B: Multi-Modal Network Strategies

September 2016

Version Final

Prepared for:

**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Submitted by:



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## ATTACHMENTS

Attachment: Ferry Analysis

# 1 Introduction

On October 22, 2015, the Port Authority of New York and New Jersey’s (PANYNJ) Board of Commissioners authorized a *Trans-Hudson Commuting Capacity Study* (the Capacity Study) to evaluate a range of strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand to 2040, to inform its deliberations on conceptual planning for replacement of the Port Authority Bus Terminal (PABT) (Table 2).

Table 1: Existing and Future PABT Demand

EXISTING (2011)	FUTURE (2040)
232,000 Daily Customers	337,000 Daily Customers (+45%)
7,800 Daily Buses	9,100 Daily Buses (+15%)
615 PM Peak Hour Buses	855 PM Peak Hour Buses (+40%)

Source: Midtown Bus Master Plan

The fundamental premise of the Capacity Study is that the transportation network that accommodates trans-Hudson commuter demand is an integrated *system*, as opposed to a series of stand-alone corridors, facilities, and services. Accordingly, the intended outcome of the Capacity Study is an updated overview of that system that takes into account potential investments in physical transportation infrastructure, operational changes to existing transit services, implementation of emerging technologies, and modifications to public policy – and the prospects for their implementation in the time frame for planning and implementing a PABT replacement project.

Concurrent with the Capacity Study, the PANYNJ has commissioned an *International Design + Deliverability Competition* (the D+D Competition) seeking concepts for a new PABT. A major objective of the Capacity Study is to provide insight to the D+D Competition by evaluating the range of alternative strategies for serving the trans-Hudson commuter market via bus and other modes, which will inform the determination of the appropriate capacity and configuration of the new PABT. The interim and final work products from the Capacity Study will inform the D+D Competition and the PANYNJ Board, which will select a preferred design concept for a new PABT this fall.

This technical memorandum evaluates a range of multi-modal network strategies/projects and their potential effect on projected trans-Hudson travel demand. The evaluation considers the extent to which these strategies may reduce demand on the constrained and congested elements of the trans-Hudson transportation network, with a focus on the Lincoln Tunnel corridor and PABT. The principal objectives of this technical memorandum are to assess the potential to add peak-period trans-Hudson capacity via other modes; their potential attractiveness to the trans-Hudson market; and the factors affecting the ability to implement these improvements in the time frame established for PABT redevelopment planning. The strategy development and assessment were informed by the Midtown Bus Master Plan (MBMP) effort and other previous plans and studies; meetings and technical discussions with PANYNJ and NJ TRANSIT staff; new research and operator interviews on commuter ferry services; and a Capacity Study Expert Workshop held on April 14, 2016. The final section of this technical memorandum provides targeted findings, including identification of factors relevant to the PABT replacement effort.

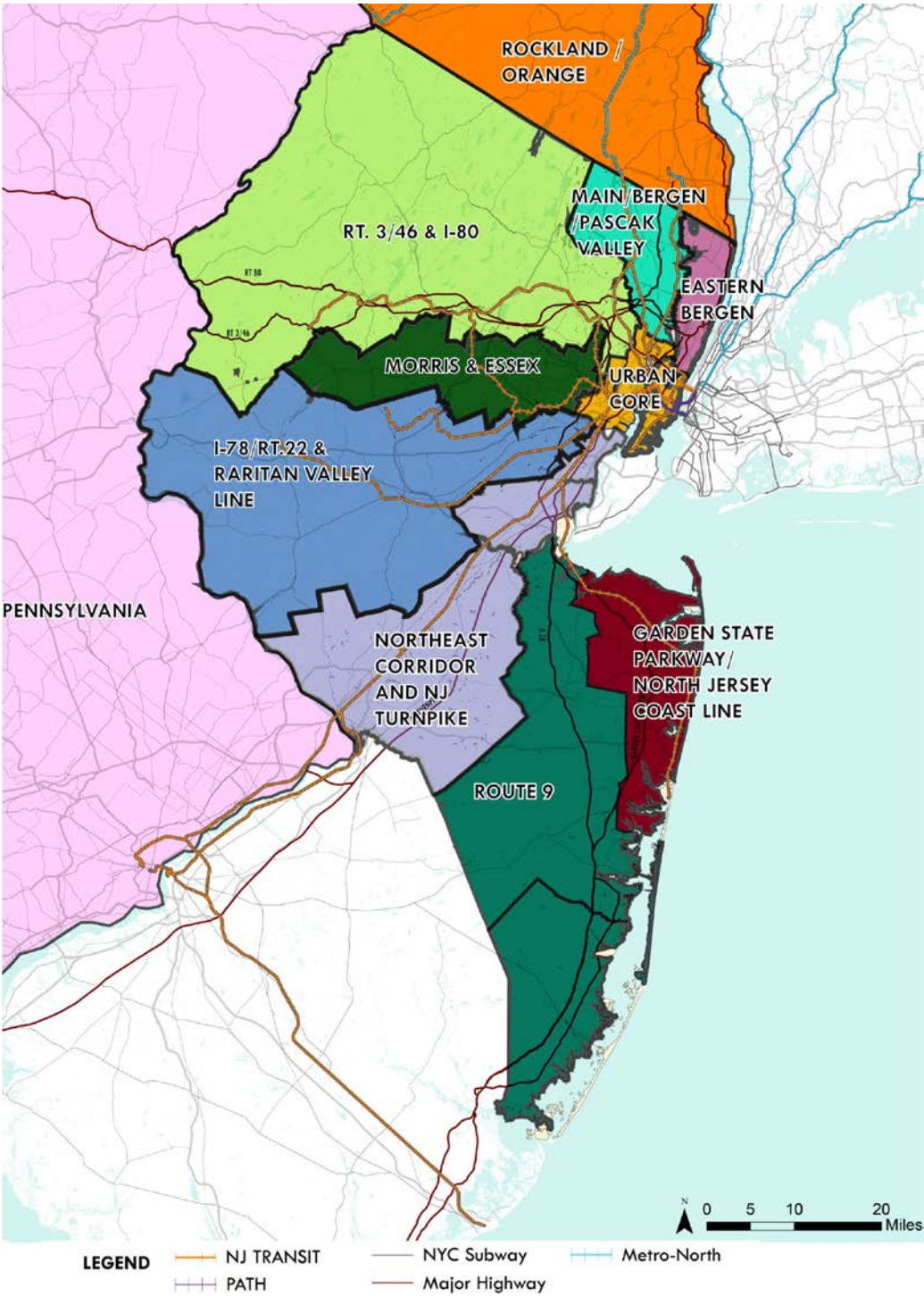
## 2 Multi-Modal Network Strategies

This technical memorandum builds upon and complements the work completed in the “Bus Network Operational/Service Strategies” technical memorandum. Whereas the bus network strategies aim to address trans-Hudson commuter demand through the use of other Hudson River crossings (besides the Lincoln Tunnel) for bus services, the multi-modal strategies discussed in this technical memorandum consider opportunities to balance demand across modes (with a focus on modes other than commuter bus).

There are several active projects in the region that could affect trans-Hudson travel. Indeed, the PANYNJ and other regional transportation agencies are currently advancing a number of initiatives related to the multi-modal interstate transportation network that could have implications for the trans-Hudson commuter market. Some of the initiatives are in the early planning stages, while others are further along in the project development process, ranging from design to construction.

The following sections discuss the multi-modal network strategies, including consideration for increased use of the Port Authority Trans Hudson (PATH) system, NJ TRANSIT commuter rail, ferries, and light rail by trans-Hudson commuters. The strategy assessment includes identification of potential benefits, impacts, and public policy issues associated with each strategy, as well as the potential for each strategy to result in peak period demand reduction along the Lincoln Tunnel corridor and at the PABT. Where applicable, the strategy assessment refers to specific trans-Hudson travel corridors (Figure 1) to identify the origins of trans-Hudson commuters for whom the respective strategy could potentially be an alternative to travel by bus via the Lincoln Tunnel and PABT. The strategies, in turn, could help to address overall trans-Hudson commuter demand in light of capacity constraints along the Lincoln Tunnel corridor.

Figure 1: West-of-Hudson Trans-Hudson Travel Corridors

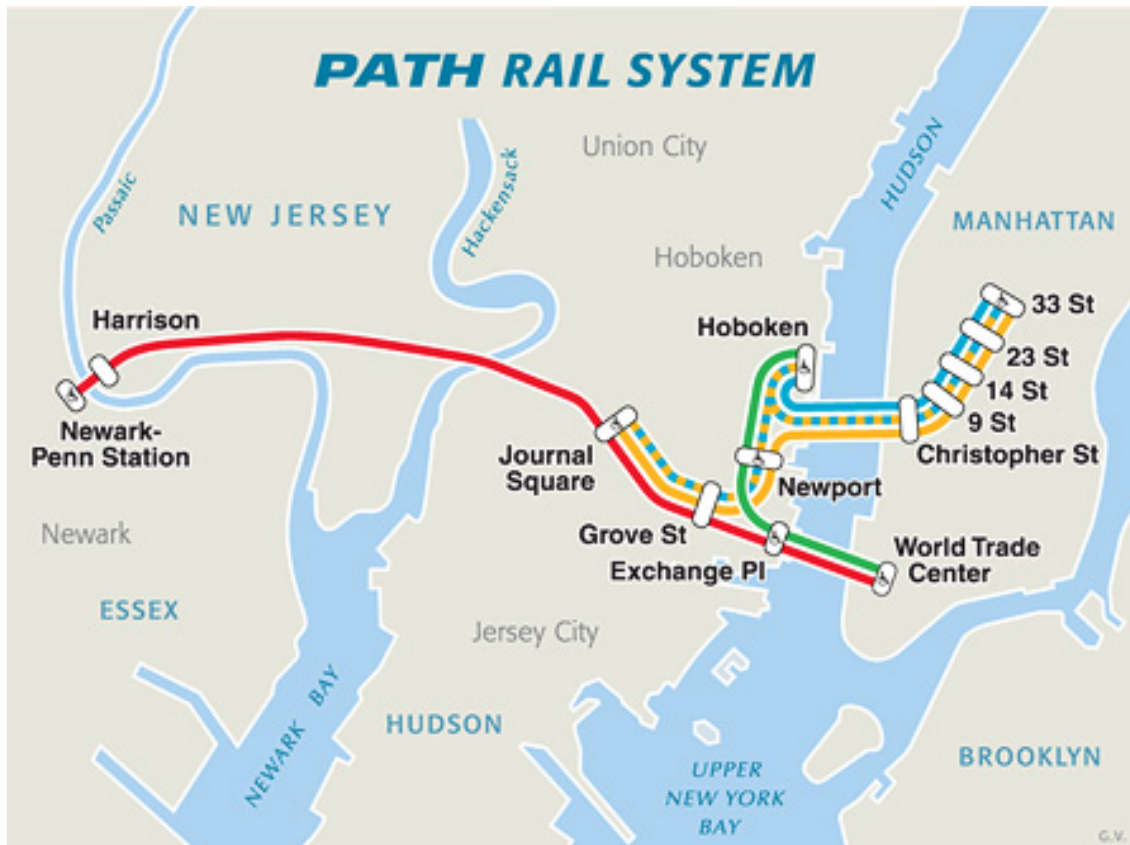


Source: Trans-Hudson Commuting Capacity Study, NJ TRANSIT

## 2.1 PATH SERVICE CAPACITY EXPANSION

This strategy calls for implementation of capital and operating improvements and policy changes to support expanded peak-period PATH service. The purpose of this strategy is to increase capacity along PATH lines for which peak hour demand approaches or exceeds capacity now or in the future. To demonstrate the need for this strategy, it is important to understand the existing and projected future demand outlook of the PATH system (Figure 2) by line.

Figure 2: PATH System



Source: PANYNJ

An April 2016 PANYNJ analysis of the PATH market and services described existing and projected future demand in comparison to capacity. For several PATH lines, peak demand occasionally if not regularly exceeds capacity under existing conditions, meaning that “passengers experience crush loading in excess of planning guidelines [110 passengers/car], or that passengers may not be able to board the first train that arrives and must queue on the platform.” Based on the expected effects



of other programmed transportation investments on PATH ridership, projected future trends in demand vary by PATH line:

- **Hoboken-33<sup>rd</sup> Street Line**

- Peak demand frequently exceeds capacity on this line today, but baseline projections indicate that pressure on this line will ease as some travel shifts to the downtown branch. In these baseline projections, peak demand is expected to exceed existing capacity in the 2030s, which points to the need to expand capacity in the long-term. Additionally, ridership on this line could grow faster than projected due to NJ TRANSIT capacity constraints under the Hudson River, a potential increase in NJ TRANSIT rail service frequency at Hoboken (refer to Section 2.6), and the potential extension of the Hudson-Bergen Light Rail (HBLR) system to Englewood as part of the Northern Branch Corridor Project (refer to Section 2.3).

- **Hoboken-WTC Line**

- At some point between 2020 and 2030, peak demand is expected to exceed existing capacity, which indicates a need for capacity expansion in the mid-term. As with the Hoboken-33<sup>rd</sup> Street Line, ridership could grow faster than projected depending on capacity shortfalls or network expansions on the NJ TRANSIT commuter rail or light rail systems.

- **Journal Square-33<sup>rd</sup> Street Line**

- Peak demand regularly exceeds capacity on this line today, but baseline projections indicate that pressure on this line will ease as some travel shifts to the downtown branch. Existing capacity is expected to be sufficient to accommodate demand beyond 2040. Therefore, capacity expansion is not expected to be necessary for this line based on current demand forecasts.

- **Newark-WTC Line**

- Due to improvements in the downtown transportation network, restoration of service on the 1 and W lines, and completion of the World Trade Center towers, passenger demand on this line is expected to grow rapidly. At some point between 2015 and 2020, peak demand on this line is expected to exceed existing capacity, which indicates a need for capacity expansion in the near-term. Demand is projected to continue to grow beyond 2020, reaching as much as 75% higher than 2015 levels by 2040. Ridership on this line could grow faster than projected due to the potential extension of the PATH system to Newark Liberty International Airport (EWR) (refer to Section 2.2).

To address the capacity constraints outlined above, this strategy includes two initiatives that are among those under consideration in ongoing development of the long-term PANYNJ Capital Program:

**1. PATH Signal System Replacement Program/Purchase of Additional Cars**

- This project includes the replacement of an outdated signal system with a computerized Automatic Train Control (ATC) System using Communications-Based Train Control (CBTC) technology. In addition to complying with Federal Railroad Administration (FRA) mandates for Positive Train Control (PTC), this project will also allow for increased capacity to meet growing ridership demand by permitting trains to operate safely in closer proximity to each other. Based on current demand projections, the additional capacity would likely be allocated to the Newark-WTC, Hoboken-WTC, and Hoboken-33<sup>rd</sup> Street Lines (Table 2) to address existing and projected future capacity constraints. The anticipated completion date for the signal replacement program is 2018. Increasing peak period service to take advantage of this additional capacity will require expansion of PATH railcar fleet (discussed below) by 50 cars.

Table 2: PATH Capacity Expansion Associated with the Signal System Replacement Program (CBTC) – Illustrative Service Plan

PATH Line	Existing Peak Capacity		Peak Capacity with CBTC	
	Trains per Hour	Headway	Trains per Hour	Headway
Hoboken-33 <sup>rd</sup> Street	9	7 minutes	10	6 minutes
Hoboken-WTC	10	6 minutes	13	5 minutes
Journal Square-33 <sup>rd</sup> Street	15	4 minutes	15	4 minutes
Newark-WTC	15	4 minutes	20	3 minutes

Source: PATH Capacity Analysis and Fleet Expansion, 12/15/2015

**2. PATH Newark-WTC 10-Car Program**

By the mid-2020s, the additional capacity that would be enabled by the Signal System Replacement Program is likely to be insufficient to fully accommodate projected demand on the Newark-WTC Line. Capacity on the Newark-WTC Line could be expanded by an additional 25% by enabling use of 10-car trains instead of 8-car trains on this line. Completion of the Newark-WTC 10-Car Program would require:

- Completion of the Harrison Station Replacement Project (under construction);
- Completion of Phase 2 of the Grove Street Station Capacity Enhancements and Station Modernization Project;
- The purchase of 48 additional railcars; and
- Several other projects that are not currently in the PANYNJ Capital Plan:
  - The Exchange Place Emergency Egress Project

- Newark Platform Improvements
- Extension of the Running Repair Shop

According to PANYNJ input during this Capacity Study, the 10-Car Program would likely not be operational until 2028 if approved today, given the design and construction timeline for the associated projects.

Furthermore, the viability of this capacity expansion would be endangered by a delay in purchasing the needed railcars, since it will no longer be feasible to purchase PA-5 railcars after the expiration of the PANYNJ's current railcar procurement contract.

Both the Signal System Replacement Program and the Newark-WTC 10-Car Program would require fleet expansion for the PATH system that is not currently programmed. At a cost of approximately \$2.5 million per car, it would cost approximately \$125 million (i.e., the purchase of 50 cars) to fully achieve capacity increases enabled by the Signal System Replacement Program. To fully achieve capacity increases enabled by the Newark-WTC 10-Car Program, it would cost an estimated \$189 million (beyond projects that are currently included in the PANYNJ Capital Plan), including the purchase of an additional 48 cars (for a total of 98 cars, when also considering the 50 cars for the Signal System Replacement Program) and completion of the other necessary capital projects. The estimated \$125 million and \$189 million are additive, such that it would cost an estimated \$314 million beyond currently programmed projects to fully achieve capacity increases enabled by both projects.

Looking farther ahead, another potential initiative is the Hoboken-WTC 8-Car Program, which would further increase capacity of this line (beyond the Signal System Replacement Program) by enabling use of 8-car trains instead of 7-car trains on this line. The increase in capacity would require reconfiguration of the tracks and platforms at Hoboken, as well as an expansion of the station box at Newport, with an estimated cost of \$550 million. This is not currently under consideration for the new capital program but may be warranted in the future based on projected demand.

Overall, potential benefits associated with expanded PATH peak period capacity include increased peak hour service frequency on the Hoboken-33<sup>rd</sup> Street, Hoboken-WTC, and Newark-WTC Lines. Another important consideration is that ridership may be higher than projected due to other investments (or lack thereof) in the regional interstate transportation network—including but not limited to the Gateway Program (refer to Section 3.2)—in which case the increase in capacity associated with this strategy may not be sufficient to fully accommodate demand. Public policy issues that would need to be considered for this strategy include the decision regarding whether (and when) to prioritize funding for the fleet expansion and other necessary investments not currently programmed in the PANYNJ Capital Plan.

It is important to note that it is unlikely that increasing PATH capacity would result in substantial peak hour demand reduction at the PABT. Although the PATH system and bus network provide complementary service between the Manhattan central business district (CBD) and certain trans-Hudson travel corridors (e.g., Urban Core, Morris and Essex), the two modes largely serve different

markets (as discussed in the “Summary of Previous Trans-Hudson Planning Work” technical memorandum). However, Hudson County is a noteworthy exception, as it is one of the largest PABT markets, despite the fact that PATH is the primary mode choice for residents who commute to the Manhattan CBD. There are parts of Hudson County where PATH and PABT bus service both are available, though some Manhattan-bound commuters choose the bus, likely due to considerations of travel time, ease of access, and other factors that influence mode choice. Nearly 20% of customers on PABT commuter routes reside in Hudson County (second only to Bergen County), yet there is direct competition between buses and PATH, particularly in Hoboken. For this reason, a failure to expand PATH system capacity to keep pace with demand would likely create significant new growth pressures at the PABT.

This is further highlighted by the fact that the travel demand forecasts prepared for the MBMP and used as an input in the Capacity Study reflect demand projections independent of capacity constraints, and in fact the No-Build condition assumed completion of the PATH service capacity expansion. Accordingly, the travel demand forecasts reflect a scenario in which anyone who would want to use PATH would be able to do so. This reinforces the premise that if a decision were made to forego investment in PATH such that capacity would be constrained, it is likely that PABT demand would be higher than projected, which underscores the relevance of this strategy in the context of the PABT replacement effort.

Nevertheless, while increasing PATH capacity would be an enormously beneficial investment, it would not change the capture area of PATH service. Additionally, the overall number of new commuters that could use PATH, even if new investments are made, is not large enough to significantly reduce PABT demand. Indeed, the potential future capacity of the PATH system after accounting for the aforementioned investments amounts to a small fraction of projected PABT demand. Accordingly, this strategy is unlikely to affect the necessary capacity and configuration of the new PABT.

**Conclusion:** This strategy includes two initiatives that would address existing and projected future capacity constraints on the PATH system. Individually and together, the two initiatives (fleet expansion for expanded service after completion of the Signal System Replacement Program and the Newark-WTC 10-Car Program) would enable increased capacity along PATH lines for which peak hour demand approaches or exceeds capacity and is projected to increase in the future. The purchase of additional PATH rail cars is necessary to fully realize the increased capacity enabled by the two initiatives. Additional capital projects that are not currently funded must also be completed to achieve the capacity increases made possible by the Newark-WTC 10-Car Program. It is not anticipated that this strategy would have a sizable effect on peak hour PABT demand because of the different markets served by the PATH system and bus network, but it should still be viewed as a priority in future updates to the PANYNJ Capital Plan to address capacity constraints for PATH commuters.

## 2.2 NEW INTERMODAL TRANSFER FACILITY AT PATH-NEC RAIL LINK STATION

This proposed project calls for extending PATH service to the Northeast Corridor (NEC) Rail Link Station at Newark Liberty International Airport (EWR), and creating a new intermodal transfer facility at this location. The current proposed scope includes consideration of the potential to leverage the PATH extension to the airport by adding bus service to the new intermodal transfer station at EWR on a number of commuter bus routes that currently serve the PABT, and adjusting frequencies to the PABT as appropriate to align with customer choices. By way of a transfer to the PATH system at the Rail Link Station, this new connection may offer additional trans-Hudson commuters the option of avoiding both the Lincoln Tunnel and PABT, although many commuters already take trans-Hudson buses directly to Wall Street or transfer from buses to PATH at downtown Newark. This concept revisits assumptions based on a potential transportation demand management (TDM) measure that was associated with Concept 5 from the MBMP to reduce demand at a new PABT.

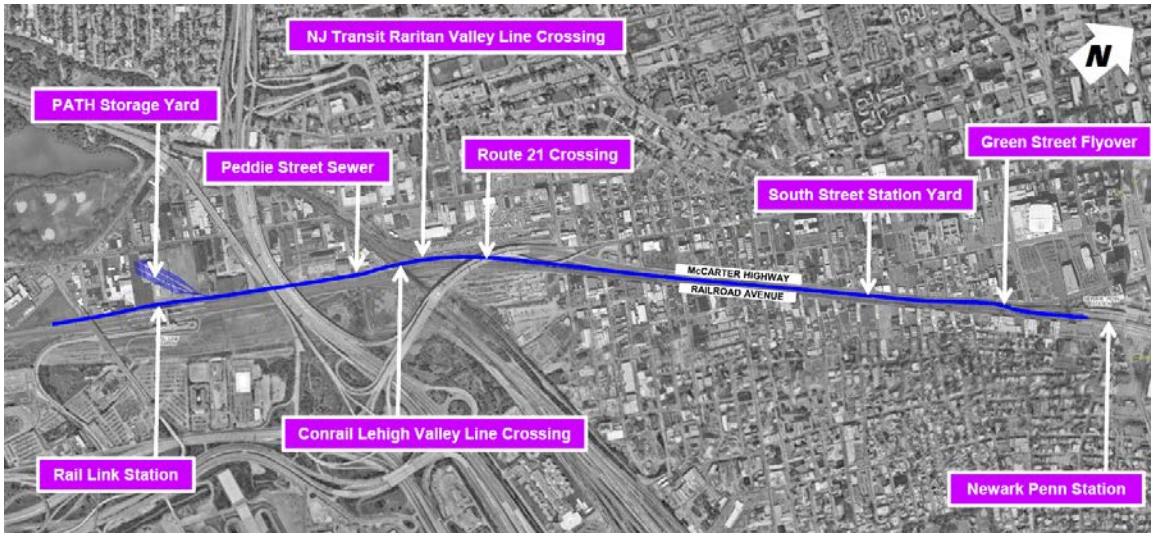
The PATH extension would provide new access to the Rail Link Station from surrounding communities, including Newark and Elizabeth. Additionally, the proposed project would also expand the reach of the PATH system, which could potentially create an additional travel option for certain trans-Hudson commuters. For instance, commuter bus routes that serve the Rail Link Station with a seamless connection to the Newark-WTC PATH Line may be appealing to current PABT customers whose destination is in Lower Manhattan and who live in portions of Union County, Middlesex County, and/or southern Essex County. However, based on preliminary feedback provided by NJ TRANSIT during the Capacity Study process, this proposed project may not have significant potential to divert PABT commuters. The potential attractiveness of this proposed project to serve the trans-Hudson market will not be known until the current ridership analysis and collaborative review with NJ TRANSIT are complete.

The scope of the PATH extension to NEC Rail Link Station includes the following elements:

- Construct rail infrastructure for elevated and at-grade track from Newark Penn Station to the Rail Link Station (Figure 3)
- Modifications at Newark Penn Station to accommodate bidirectional passenger flow as well as limited vertical circulation improvements
- Construct a new platform and associated station passenger infrastructure at the Rail Link Station with connections to the existing Rail Link Station
- Construct a rail storage yard near the Rail Link Station
- Investigate a Public-Private Partnership to construct a parking garage/multi-modal facility near the Rail Link Station for non-aviation commuters



Figure 3: PATH Extension to NEC Rail Link Station



Source: PANYNJ

The possibility of constructing a multi-modal facility near the Rail Link Station could have implications for how long-term trans-Hudson travel demand is accommodated across different modes and corridors in the interstate transportation system. The capacity of the potential multi-modal facility will be informed by the results of the ongoing ridership forecast. Under the baseline scenario, which includes no garage, the Rail Link Station could accommodate five bus bays, which is a function of the configuration of the site. As currently envisioned, the five bus bays under the baseline scenario would accommodate the local NJ TRANSIT bus routes that currently pass the Rail Link Station. Depending on projected demand, various garage configurations on an over-build of the site could result in additional bus bays at the Rail Link Station. These additional bus bays could potentially accommodate longer distance commuter bus routes that originate within a broader catchment area, including Union County, Middlesex County, and southern Essex County.

The PATH extension to the NEC Rail Link Station is currently in an early phase of planning, which includes conceptual design and environmental review in addition to ridership forecasting. According



to the current project schedule, which is subject to revision, construction is estimated to be completed in 2026, although funding is not yet secured for work after this first phase.

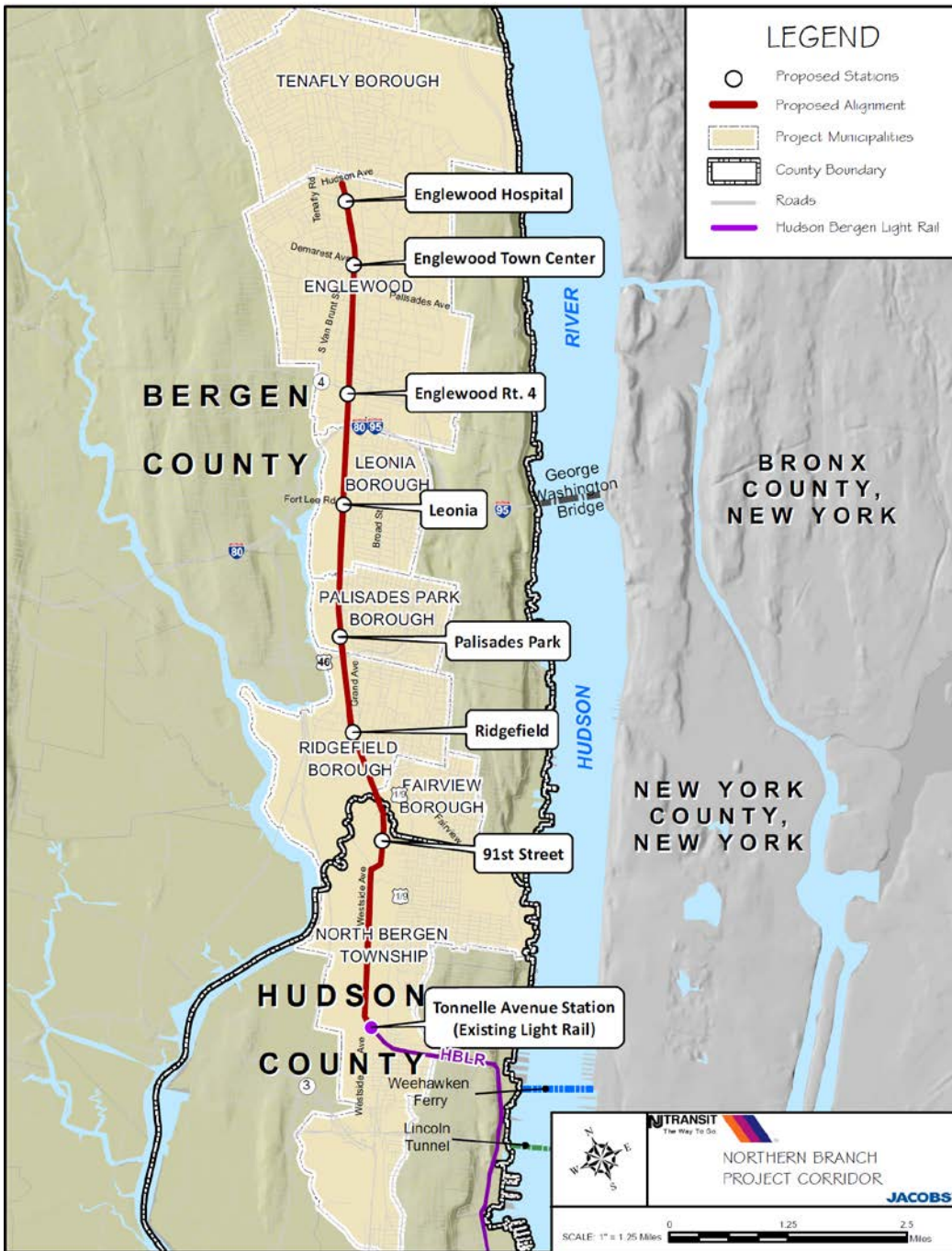
Benefits associated with this proposed project potentially include modest demand shedding for the Lincoln Tunnel corridor and PABT, travel time savings for certain trans-Hudson commuters (with no need to transfer to the subway to get to Lower Manhattan), and a reduction in bus operating costs for bus operators if certain candidate routes are truncated to terminate at the Rail Link Station instead of the PABT. Potential impacts associated with this proposed project include additional modal transfers for trans-Hudson commuters (the implications of which are discussed in Section 4.1) and congestion on the roadway network in the vicinity of the Rail Link Station (associated with potential increases in bus trips to and from the Rail Link Station). Additionally, while this proposed project could offer a new option for certain PABT customers, and might create more bus diversion to PATH, by itself it does not increase throughput capacity across the Hudson River. The Signal System Replacement Program and NWK-WTC 10-Car Program (discussed in the previous section) should be considered prerequisites to the Rail Link Station extension in order to ensure that the required peak capacity is available on the line.

**Conclusion:** In addition to improving regional access to and from EWR for airport passengers, as well as providing greater redundancy in the interstate transportation network, this proposed project would expand the reach of the PATH system, thereby potentially creating an additional travel option for certain trans-Hudson commuters. At this location, PATH service to and from Lower Manhattan could be an attractive option for some PABT customers who currently transfer to the subway upon arriving at the PABT. Accordingly, the PATH extension to the NEC Rail Link Station may have the potential to result in a modest reduction of peak hour demand at the PABT. However, since the ridership forecasting effort is ongoing, it is premature to assign a number to the potential reduction in buses for use in planning the PABT replacement. Additionally, since existing commuting options from New Jersey already include trans-Hudson bus service directly to Wall Street as well as bus-to-PATH service at downtown Newark, this proposed project may not play a substantive role in serving the trans-Hudson market. Based on a project briefing during the Capacity Study process, the initial focus is on bus routes serving the local market, followed by the analysis of potential attraction for current PABT-bound bus commuters.

### 2.3 HUDSON-BERGEN LIGHT RAIL TRANSIT EXTENSION

This strategy calls for implementing the proposed Northern Branch Corridor Project to extend existing Hudson-Bergen Light Rail (HBLR) service from North Bergen to Englewood (Figure 4). This strategy would offer certain commuters to Manhattan the option of using the HBLR to access either the Port Imperial Ferry Terminal or Hoboken Terminal and transfer to a trans-Hudson mode other than the bus (i.e., ferry at Port Imperial; ferry or PATH at Hoboken) to reach their destination. This would enable certain trans-Hudson commuters to avoid both the Lincoln Tunnel and PABT.

Figure 4: Proposed HBLR Northern Branch Corridor Project



Source: Northern Branch Corridor Project

Expanding the reach of the HBLR system, potentially could attract existing PABT customers from points to the north in the Eastern Bergen trans-Hudson travel corridor (refer to Figure 1). The strategy would likely be most effective in providing an alternative trans-Hudson commuting option to those who live within walking/biking distance of the proposed stations along the Northern Branch. It is not anticipated that this strategy would be appealing to those commuters who would have to travel by bus to the HBLR due to the additional transfer that would be required (in addition to the subsequent transfer to a trans-Hudson mode). Furthermore, this strategy would likely be most appealing to current PABT customers whose destination is in Lower Manhattan because it could eliminate the need for certain trans-Hudson commuters to transfer to the subway upon arriving in Manhattan.

The proposed Northern Branch Corridor Project would extend light rail service from the current northern terminus of the HBLR at Tonelle Avenue in North Bergen to the Englewood Hospital and Medical Center in Englewood. The project includes seven proposed stations along the proposed alignment in northern Hudson County and southeastern Bergen County. The preferred alternative from the Draft Environmental Impact Statement (DEIS) that was completed in 2011 included an extension of the HBLR farther north to Tenafly, and the alignment was refined based on comments received on the DEIS. As noted on the project website, the project as currently proposed “results in changes to the service plan and potential environmental and social impacts explored in the DEIS,” so the new alignment is the subject of a Supplemental DEIS.

The work completed in the DEIS offers insight into the potential attractiveness of the proposed project for trans-Hudson commuters, particularly because the DEIS includes estimated travel times from each proposed station to both the Port Imperial Ferry Terminal and Hoboken Terminal. Based on estimates in the DEIS, the travel time by light rail along the Northern Branch Corridor to Port Imperial would range from four minutes (from Tonelle Avenue) to 20 minutes (from Englewood Hospital), and travel time to Hoboken would range from 16 minutes (from Tonelle Avenue) to 32 minutes (from Englewood Hospital). From either Port Imperial or Hoboken, trans-Hudson commuters could transfer to another travel mode to complete their journey to work.

Potential benefits associated with this strategy include modest demand shedding for the Lincoln Tunnel corridor and PABT, as well as possible time savings for certain trans-Hudson commuters. Potential impacts associated with this strategy include additional modal transfers for trans-Hudson commuters (the implications of which are discussed in Section 4.1). It is also possible that this strategy could increase passenger demand on the PATH lines at Hoboken that connect the HBLR system with destinations in Manhattan. Additionally, although it is anticipated that trans-Hudson commuters would likely walk to the proposed HBLR stations, it is possible that the proposed HBLR extension could result in additional traffic congestion on the local west-of-Hudson road network that feeds the stations.

This strategy could pose an opportunity to use pricing to draw trans-Hudson commuters onto PATH instead of PABT-bound commuter bus routes. Commuters with NJ TRANSIT monthly and weekly rail passes are currently able to use their pass for any HBLR light rail trip at no additional charge during the period the pass is valid. Additionally, the Hudson Go Pass (discussed in the following section) allows HBLR customers to transfer at the Port Imperial Ferry Terminal to one of three NY Waterway

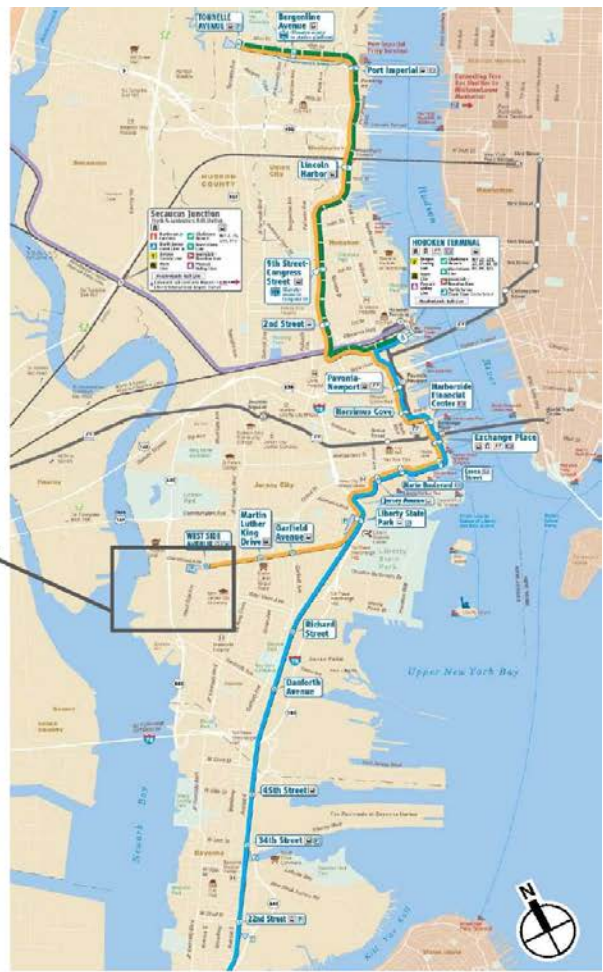
ferry routes to Manhattan. Fare reciprocity with the PATH system could further increase the attractiveness of this strategy as a potential trans-Hudson travel option.

It is also important to note that another HBLR project—the Route 440 Extension—is further along in the implementation process, as a Finding of No Significant Impact (FONSI) was released in 2014. The proposed Route 440 Extension would extend the HBLR system from the West Side Avenue Station approximately 0.7 miles west to a new station that will serve the planned Bayfront development in Jersey City near Culver Avenue, west of Route 440 (Figure 5). This project would provide a new transit option for commuters from the western waterfront of Jersey City, who could subsequently transfer to ferry or PATH to cross the Hudson River. However, similar to the proposed Northern Branch Corridor Project, the potential PABT demand reduction associated with the Route 440 Extension is not anticipated to be substantial, in part because the target neighborhood is not part of a major trans-Hudson bus corridor.

**Conclusion: This strategy considers the potential implications for the trans-Hudson commuter market of extending an intrastate transportation service in New Jersey. The proposed Northern Branch Corridor Project would extend existing HBLR service farther north to North Bergen, Ridgefield, Palisades Park, Leonia, and Englewood. This project would enable a new trans-Hudson commuting option for residents of northern Hudson County and southeastern Bergen County by means of a transfer to ferry or PATH. The proposed Route 440 Extension would have similar implications for residents along the western waterfront of Jersey City. The primary benefits of both extensions will be to significantly improve inter-county travel options within New Jersey. The potential PABT demand reduction associated with these projects is not anticipated to be considerable, and thus this strategy is unlikely to affect the necessary capacity or configuration of a new PABT.**



Figure 5: Proposed HBLR Route 440 Extension



Source: Route 440 Extension

## 2.4 EXPANDED BUS SERVICES TO PORT IMPERIAL FERRY TERMINAL

This strategy calls for implementing new variants on existing bus services such that select commuter bus routes would provide increased service to the Port Imperial Ferry Terminal in Weehawken. This would offer commuters the option of crossing the Hudson River by ferry instead of by bus, thereby avoiding both the Lincoln Tunnel and PABT. This strategy revisits assumptions based on a potential TDM measure that was associated with Concept 5 from the MBMP to reduce demand at a new PABT.

This strategy would likely be most effective in providing an alternative commuting option to heavily bus-dependent markets, as opposed to areas that are well served by commuter rail or PATH. Candidate bus routes that could be considered for this strategy are those that originate in portions of the Eastern Bergen trans-Hudson travel corridor (refer to Figure 1). Upon arriving at the Port Imperial Ferry Terminal, bus customers would transfer to Midtown or Lower Manhattan ferry service and subsequently either walk or transfer again to ferry shuttle buses to reach their final destinations. This strategy would likely be most appealing to current PABT customers whose destination is very close to the Hudson River in Midtown or in Lower Manhattan, and could also be appealing to those whose destination is in Midtown but beyond walking distance from the PABT. For current PABT customers whose destination is within walking distance of the bus terminal, this strategy would introduce two additional modal transfers to their commute (i.e., commuter bus to ferry, and ferry to shuttle bus). For other commuters, including those who transfer to either subway or bus upon arriving at the PABT, this strategy would only add one additional modal transfer to their commute.

Similar to the other PABT demand shift strategies, the intent of this strategy is to expand the potential of an alternative trans-Hudson commuting option, and not to force PABT customers to change their travel patterns. This strategy aims to draw more riders to the Port Imperial Ferry Terminal by adding service on routes now serving PABT, in conjunction with modified service frequencies to the PABT to reflect customer choices. As such, this strategy does not call for re-routing all candidate bus routes, but rather to consider a potential pilot program that splits select candidate routes such that certain trips would serve the Port Imperial Ferry Terminal and other trips would continue serving the PABT.

This strategy builds upon the ongoing partnership between NJ TRANSIT and NY Waterway to promote increased use of the ferry by trans-Hudson commuters through the new Hudson Go Pass (Figure 6). Launched in February 2016, the Hudson Go Pass allows customers on certain NJ TRANSIT buses (specifically, the 156R, 158, and 159R routes that serve the Palisade Avenue/River Road corridor) as well as HBLR customers to transfer at the Port Imperial Ferry Terminal to one of three NY Waterway ferry routes to Manhattan:

- An eight-minute ferry trip to Midtown/West 39th Street Midtown Ferry Terminal, where customers are offered a free transfer to one of several NY Waterway shuttle bus routes that meet every arriving ferry and provide connecting service to Midtown Manhattan
- A 16-minute ferry trip to the World Financial Center in Lower Manhattan
- An 18-minute ferry trip to Pier 11/Wall Street in Lower Manhattan



Figure 6: Hudson Go Pass

### One GO PASS for Bus, Light Rail & Ferry!



#### Free Manhattan Buses To Midtown Terminal



#### Free New Jersey Evening Bus Service



Source: PANYNJ

As noted on the Hudson Go Pass webpage (<http://www.nywaterway.com/HudsonGoPass.aspx>), the pass “provides great value, enabling customers to cost effectively avoid Lincoln Tunnel & bus terminal delays by seamlessly connecting with the Port Imperial Ferry.”

In complementing the ongoing efforts by NJ TRANSIT and NY Waterway, this strategy would provide additional bus service to the Port Imperial Ferry Terminal. The MBMP team identified a range of necessary site improvements at the ferry terminal (with an order-of-magnitude estimated cost of \$1 million) to accommodate additional bus service, including the provision of shallow sawtooth gates (by modifying street curbing/extending an existing bus loading zone) and the addition of bus shelters with customer amenities. Implementation of this strategy should include a detailed site planning exercise to determine necessary site improvements.

Potential benefits associated with this strategy include modest demand shedding for the Lincoln Tunnel corridor and PABT, time savings for certain trans-Hudson commuters (with no need to transfer to the subway to get to Lower Manhattan), and reduction in bus operating costs for certain diverted routes. Potential impacts associated with this strategy include additional modal transfers for trans-Hudson commuters (the implications of which are discussed in Section 4.1) and additional traffic congestion in Manhattan (if increased ferry ridership results in additional trips for NY Waterway shuttle buses) and/or New Jersey.

A key public policy issue that would need to be considered for this strategy is the need for coordination among service providers with respect to fare policy. Building upon the Hudson Go Pass, an integrated fare structure (including fare media) would help to market this strategy as an appealing alternative to PABT customers. Anecdotal information from the ferry operator suggests that there are less than 100 inbound and outbound weekday transfers between these buses or HBLR service and the ferry. Additionally, the issue of fare pricing sensitivity and the potential for ferry fare subsidies should be considered in advancing this strategy. This is discussed below with respect to the potential to decrease fares to incentivize additional ferry ridership.

**Conclusion:** Expanded bus services to the Port Imperial Ferry Terminal have the potential to result in a modest reduction of peak hour demand at the PABT. For purposes of a potential pilot program, an estimated 10 peak hour bus trips could be diverted from the PABT to the Port Imperial Ferry Terminal. If the potential pilot program is successful and viewed as an attractive option for trans-Hudson commuters, additional variants of candidate route(s) could be implemented to serve the Port Imperial Ferry Terminal, thereby diverting additional buses from the PABT. Under such a scenario, it could be worthwhile to consider an expansion of existing ferry services (building upon the strategy discussed in Section 2.5.1) as necessary to accommodate the additional ridership. The ridership potential of this strategy, which would complement the Hudson Go Pass, would likely be influenced by the introduction of additional modal transfers and the sensitivity to fare pricing for trans-Hudson commuters.

## 2.5 EXPANDED TRANS-HUDSON FERRY SERVICES

In addition to providing redundancy in the transportation system, ferries also offer promise in helping to address capacity constraints. As summarized in *The Profile of the Regional Interstate Transportation Network (RITN)* (Discussion Draft May 7, 2015):

Trans-Hudson ferries currently operate at only 25% of capacity in the AM peak hour, and provide the most easily deployable means for the region to add additional Trans-Hudson transit capacity when surges in demand run up against the constraints of the existing transit system.

As discussed in the following sections, this strategy calls for actions to expand the ridership potential of existing trans-Hudson ferry services as well as the addition of new ferry routes. Additional details are discussed in the Attachment.

### 2.5.1 Expansion of Ridership Potential for Existing Ferry Services

There are currently 18 ferry routes that serve the Hudson River commuter market operating between 12 New Jersey terminals and four Manhattan terminals. All of the privately-owned and operated ferry companies—New York Waterway (NYW), BillyBey Ferry, Seastreak, Hornblower, and Statue Cruises—are in public-private partnerships for use of public terminals, piers and/or property for parking as part of their business. Ferries provided an average of 28,000 weekday trans-Hudson trips in 2015, with ridership higher in the summer months than in the winter months. NJ TRANSIT estimates that ferry customers represent approximately 4% of current trans-Hudson commuters.

According to NJ TRANSIT's 2013 Trans-Hudson Ferry Survey, current ferry customers report a high level of satisfaction with their ferry commute and have higher-than-average incomes for trans-Hudson commuters. These customers place higher value on their time and are less price sensitive than other commuters, as ferries are typically not the least cost option. Incomes for ferry customers are much higher than bus customers. Whereas almost 83% of ferry rider households earned at least \$100,000 per year, just 39.5% of bus customer households reported income on that scale.

In addition to the prior strategy to expand bus service to the Port Imperial Ferry Terminal, additional actions to increase ridership potential on existing ferry routes may include increasing parking options at ferry terminals and decreasing fares of the existing services.

Interviews with the ferry companies were conducted during the Capacity Study to discuss these concepts. The interviews were used to supplement prior ferry research and modeling conducted for a regional passenger ferry study sponsored by the PANYNJ in conjunction with New York City agencies, NJ TRANSIT, and other partners. This updated assessment also drew on ongoing work for the North Jersey Transportation Planning Authority (NJTPA) to develop a transportation waterborne inventory, including potential sites for new ferry landings.

Two concepts that are not included in the discussion below are increasing frequency and decreasing in-vehicle time for existing ferry services. Ferries are already operating with significant excess capacity and therefore, on purely economic grounds, operators will not add additional service to

improve service frequency. Speeding up existing ferries is plausible from a purely operational standpoint, but even if fuel costs continue to decline, regulatory restrictions on ferry speeds make this infeasible. Boat speeds in New York State are not restricted when at least 100 feet from shore, however, wakes generated by boats are restricted and therefore the potential damage to shoreline facilities and anchored or docked vessels from wakes imposes strict limits on ferry operating speeds. Failing a drastic shift to vessels that can operate with higher speeds and lower wakes, there is little room for ferry operators to raise ridership by reducing in-vehicle time.

The discussion below focuses on the potential to increase parking options and decrease fares to incentivize additional ferry ridership on existing routes.

### ***2.5.1.1 Increasing Parking Options***

Increasing parking options at ferry terminals in New Jersey could have the effect of increasing ridership on ferry routes into Manhattan. This is particularly the case for the services offered from Monmouth County. For both the NYW ferry service from Belford and the Seastreak ferry service from the Atlantic Highlands, almost all ferry customers arrive at the terminals by car. According to the 2013 Trans-Hudson Ferry Survey, 90% of these customers drive and park, and 3% carpool or are dropped off.

Parking at these terminals is free and incorporated into the ferry fare. Currently, utilization of parking capacity ranges from 80% to 90% at these locations, based on interviews conducted with the ferry operators. Seastreak recently bought additional land near its terminal to accommodate another 300 cars for surface parking. Elevated parking garages have been discussed but are not anticipated to be financially viable and there are concerns that an elevated structure may block waterfront views and be deemed locally unacceptable. For the northern New Jersey ferry market, parking is less of a factor for ferry commuters as there is a higher percentage of commuters able to walk to the ferry terminals or take an intermodal connection through a shuttle, PATH, or HBLR. Paid parking for the northern New Jersey ferry market is available at Weehawken. However, 80% of this capacity is utilized currently and parking is not exclusive to ferry customers. There is no parking availability at Edgewater. Increasing parking availability is difficult at these locations and may increase local vehicle miles traveled (VMT) to drive to and from these terminals. These are recognized challenges to efforts at increasing ridership of ferry services at these locations.

For some commuters, bicycles may provide another means of accessing ferries for commutation between New Jersey and New York City. The NYW and Billybey routes allow bicycles on board for an additional \$1.00 per trip fee. Seastreak charges an additional \$2.50. Passengers pay no additional charge to bring bicycles on board for the Liberty Landing service. Bicycle parking is available for ferry passengers and other transit users at the intermodal Hoboken Terminal and at the PANYNJ's World Financial Center terminal in Manhattan, and at NYW's Weehawken and Midtown Manhattan terminals.

NYW reports an average of 200 weekday bicycle ticket sales on trans-Hudson ferry routes, 80% as single-trip purchases and 20% bought on a monthly ticket. Their data show nearly half of the

single-trip and monthly bicycle ticket purchases on the Paulus Hook-World Financial Center service alone. Seastreak and Liberty Landing report minimal usage of bicycles on their ferries.

#### **2.5.1.2 Decreasing Fares**

The City of New York recently has established a policy of decreasing fares as a key tool to increase ridership, starting with the East River ferry services. What makes the trans-Hudson ferry market different from the East River market is the number of intermodal connections typically required to make a commute from New Jersey to the Manhattan CBD. In NYCEDC's 2013 Citywide Ferry Study, it was clear that most of the existing and prospective new East River ferry customers are within a ½-mile walk radius to the respective ferry terminal. A primary threshold was within a ¼-mile walk radius and secondary market threshold was a ½-mile radius. Ridership largely came from new high-rise residential construction along the East River waterfront in Brooklyn and Queens, which are largely areas that were formerly industrially-zoned and far from the closest subway line.

On the trans-Hudson market, it appears that commuters evaluating their choice of mode are more sensitive to the length of their commute over the price of available options. In examining the elasticity of the ferry fares, a decrease in fares did not produce significant numbers of new ferry customers. Holding all other variables constant, it would take a large proportional decrease in the fare to attract a significant number of customers. One may deduce from this relationship that the ferry is not considered a good substitute for alternate modes of transport owing to both the fare relative to other modes and the transfers required to and from ferry landings on both sides of the Hudson River.

Also, as these services have been privately operated for some time, one can assume that the fares have been set to meet expenses and provide a profit and a return on capital for the operators. To lower ferry fares for the trans-Hudson services would present a difficult policy choice, as this would require a public operating subsidy for privately-operated services in lieu of investments to existing publicly-owned transit services that serve higher volumes of passengers generally from wider segments of the trans-Hudson market.

Moreover, based on interviews with ferry operators, there is a reluctance to lower fares to the extent that ferries would no longer be perceived as a premium service. For the Monmouth County services that are well subscribed, one operator noted that they have been asked by customers to increase prices rather than lower prices to limit demand for parking at the terminal. NYW, which operates with capacity on its routes from the northern market, also noted that their customers prefer the private crosstown shuttle over use of a public bus, and that they value the premium nature of the service. In sum, decreasing fares may not render significant diversion from bus to ferry, and this policy may not be acceptable to current ferry operators who have built a premium brand targeting high-income commuters.

#### **2.5.2 Addition of New Ferry Routes**

The introduction of new trans-Hudson ferry routes may draw additional ridership, some of which may be drawn from the existing PABT bus market. This assessment focused on three suggested routes representing a range of potential trans-Hudson ferry service enhancements. They include:

- South Amboy to Lower Manhattan
- Edgewater to West 125th Street – West Harlem Piers
- Hoboken to a new West 34th Street Ferry Terminal

The following is a preliminary investigation of these new routes.

#### ***2.5.2.1 South Amboy to Lower Manhattan***

In recent interviews with ferry operators and county planners as part of the NJTPA Waterborne Transportation Inventory Assessment, South Amboy was suggested as having potential to expand ferry ridership from Middlesex and Monmouth Counties. South Amboy is in Middlesex County on Raritan Bay and southwest of the southern tip of Staten Island. The waterfront site has good access to a regional road network off U.S. 9 where access to a new terminal would not require traffic to weave through a residential community.

A South Amboy to Lower Manhattan ferry route previously served the trans-Hudson market. This service was initiated in February 2002 to accommodate area commuters after the attacks of September 11, 2001. The service was discontinued in 2005 as high fuel costs combined with lower than expected ridership and dredging costs made the route uneconomical for the operator. The City of South Amboy plans to build a permanent ferry terminal as part of a larger waterfront development project. South Amboy also hosts a NJ TRANSIT commuter rail station.

South Amboy is at the northern tip of the Garden State Parkway/North Jersey Coast Line trans-Hudson travel corridor (refer to Figure 1). This travel corridor is forecasted by NJ TRANSIT to have an 11% bus market share for trans-Hudson trips in 2040, a 35% rail share, and an 8% ferry share, with the remainder commuting predominantly by auto. Though the public sector has provided infrastructure including ferry landings and terminals, trans-Hudson ferry service operations are unsubsidized by public agencies and consequently are a relatively expensive choice for daily commute and discretionary travel. For the Atlantic Highlands to Manhattan service, commuters may purchase discounted tickets in a 40-trip book at a cost of \$655 or \$16 for a one-way cost trip. By comparison, a monthly train pass from the South Amboy station to Penn Station New York is \$380 and would take one hour. A new ferry service from South Amboy, unlike at the Belford and Atlantic Highlands locations, would have to compete directly with the commuter rail option.

A ferry terminal at this location is also likely to be constrained by local adjoining vehicle parking capacity. Unlike many of the new East River ferry terminals being planned in the NYCEDC Citywide ferry expansion, a new South Amboy terminal is not currently being planned in conjunction with up-zoning for high-rise residential development. This option is unlikely to draw price-sensitive commuters from the bus market but may still be attractive to high-income commuters working in Lower Manhattan.



### 2.5.2.2 Edgewater to West 125<sup>th</sup> Street – West Harlem Pier



Source: NYW

NYW currently operates a trans-Hudson ferry service connecting the Edgewater ferry pier in Bergen County to the West Manhattan Ferry Terminal/Pier 79 at West 39<sup>th</sup> Street. Approximately 900 one-way trips are made daily on this route, according to recent ferry ridership reporting to NJ TRANSIT and the PANYNJ. There may be additional ferry opportunities in this commuter market as there is no direct rail competition to the ferry in eastern Bergen County. This market is also worth further exploring for potential peak PABT demand mitigation given the high percentage of bus customers commuting from this area.

A new ferry service from Edgewater directly to the newly constructed West Harlem Pier at West 125<sup>th</sup> Street in Manhattan has been suggested by officials in the Town of Edgewater to supplement the existing service to Pier 79. This route could offer a new option for trans-Hudson commuters to access Midtown Manhattan via a connection to the Broadway (No. 1) subway line, as opposed to the existing ferry route, which requires bus connections on congested streets on both sides of the Hudson River. The West Harlem Pier, which is newly constructed by NYCEDC, is a 6-minute, 1/3-mile walk to the 125<sup>th</sup> Street subway station on the No. 1 Line.

Capacity utilization of vessels on the existing ferry route from Edgewater to Pier 79 route is, like other ferry services, very light. Adding a new route from Edgewater to West 125<sup>th</sup> Street could therefore be feasible with existing vessels. It would cut several minutes to the trip over water (compared to the existing ferry route from Edgewater) but could also reduce travel time for commuters accessing destinations close to West 125<sup>th</sup> Street. An efficient connecting service to the subway would likely be a critical element for the success of this service, as the 1/3-mile walk to the subway, however short, may not appeal to all commuters.

An analysis of origin/destination locations of customers from the 2013 Trans-Hudson Ferry Survey indicates that only 4% of ferry customers take a subway to their final destination in Manhattan, and

that 61% of customers walk to their final destination. The average distances traveled for ferry customers by terminal are shown in Table 3. The overall average is 0.7 miles (or about a 15-minute walk at a speed of 3 miles per hour). The median distance is just 0.3 miles (or a 6-minute walk at 3 miles per hour).

Table 3: Average Distance to Final Destination by Landing for Ferry Customers

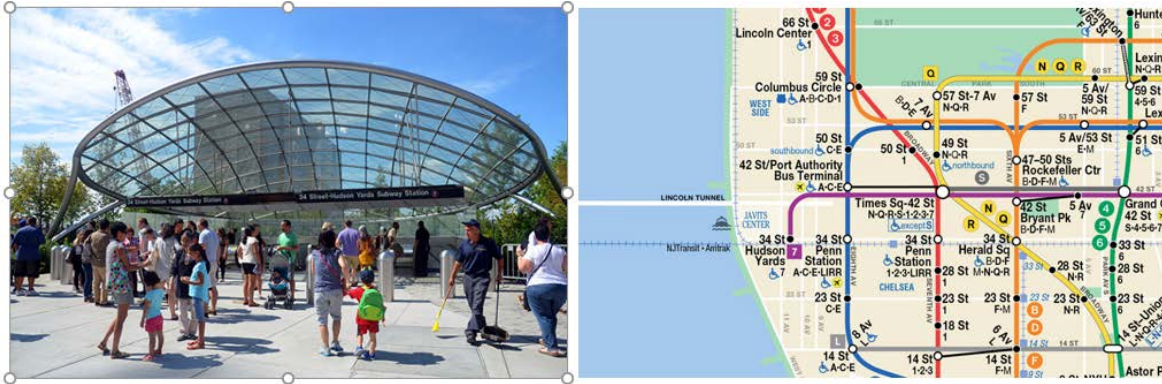
Destination Ferry Terminal	Average Distance in Miles	Observations
East 35th St.	1.64	76
Midtown West 39th St.	1.70	263
Pier 11/Wall St.	0.61	1,494
World Financial Center	0.50	939
<b>Overall</b>	<b>0.70</b>	<b>2,772</b>

Source: 2013 Trans-Hudson Ferry Survey; Cheng Solutions

According to the 2012 PANYNJ Interstate Bus Analysis, bus customers overwhelmingly walk (48.5%) or take a connecting subway (44.8%) to access their final destination. This suggests that ease of connecting services is important for bus customers using the PABT. On average, however, bus customers travel a significantly longer median distance (1.14 miles or a 23-minute walk) to reach their final destination than ferry customers. This suggests that having access to the connecting subway/bus service is a critical factor in the attractiveness of the bus to PABT.

Moreover, this may indicate that a new ferry service from Edgewater to the West 125<sup>th</sup> Street terminal may have limited appeal to most current ferry customers because of the small percentage of ferry customers that take the subway for a connection to their final destination (as noted above). However, this potential new route may eventually draw customers if the Port Imperial Ferry Terminal continues to experience greater roadway congestion as through traffic increases with organic population growth as well as greater waterfront residential development on River Road. The shorter water access trip from Edgewater to 125<sup>th</sup> Street may offer an upper Hudson ferry congestion relief valve should other options worsen in levels of service.

**2.5.2.3 Hoboken South to a New 34<sup>th</sup> Street Ferry Terminal**



Source: NYcurbed.com and MTA

Another potential new route is a ferry service operating between Hoboken and a new West 34<sup>th</sup> Street terminal to take advantage of the newly-opened 34<sup>th</sup> Street Hudson Yards subway station and proximity to the new Hudson Yards development. This potential route would provide service between the Hoboken/NJ TRANSIT Terminal and a new Manhattan ferry terminal at West 34<sup>th</sup> Street, south of the Lincoln Tunnel ventilation towers, as a replacement of the current West Midtown Terminal at Pier 79 at 39<sup>th</sup> Street. Currently, NYW operates services connecting the Hoboken/NJ TRANSIT Terminal with the ferry terminals at the World Financial Center and at Pier 11 Wall Street. The existing Hoboken to World Financial Center route is used by approximately 2,000 commuters daily and is the most intermodal of all trans-Hudson ferry routes.

The proposed route would enable commutation from six of NJ TRANSIT’s commuter rail lines as well as the Hoboken Terminal of the HBLR system to proximity with the subway system at Hudson Yards. For this market (including Hoboken and Jersey City), 35% of customers access the ferry in New Jersey via NJ TRANSIT rail, and 5% via HBLR, according to the 2013 Trans-Hudson Ferry Survey.

The opening of the No. 7 Line subway connection at Hudson Yards creates the possibility of a more efficient crosstown route for commuters than the existing terminal, which relies on NYW-operated crosstown buses to connect customers to their destination. This presents ridership opportunities for the proposed ferry route. The Hudson Yards development will also host additional office and commercial space that will present a draw for commuters.

Two primary public policy issues would need to be addressed to advance this proposed route:

- The existing terminal at 39<sup>th</sup> Street is only 12 years old and has extensive support facilities. According to NYW, its long-term operating agreement with NYCEDC to 2035 prohibits NYCEDC from building a competing terminal within 20 blocks of the 39<sup>th</sup> Street facility
- A new terminal will require agreement from the Hudson River Park Trust for an additional transportation facility within the park

Furthermore, the degree to which this route will substantially increase ridership, as opposed to shifting existing ridership from the current West Midtown Ferry Terminal, is subject to factors such as:

- Increased efficiency for intermodal transfers compared to the existing terminal that would shift the destination mode choice of customers who primarily take the crosstown NYW bus to the subway
- Expected growth of Hudson Yards development as a new location for office and retail-related commutation

### 2.5.3 Summary

While there is potential growth in ferry ridership that may be captured from the new routes examined above, it is unlikely that the ferry will draw enough customers from the bus commuter market to affect the sizing of a new PABT. The ferry offers a premium service for largely high-income commuters that is not likely to draw significant ridership from lower-income commuters. While ferries do not compete well in the number of customers compared with other modes in a head-to-head competition, ferries may offer flexibility to supplement other modes should those modes be capacity constrained. In the interviews conducted with ferry operators, it was clear that if any of the trans-Hudson rail tunnels and/or the PABT were to be unavailable for commuters, the market for ferries would be very different.

**Conclusion: Increasing parking options, decreasing fares, and/or adding new routes may increase ferry ridership. Additionally, maintaining bicycle access and assuring adequate bicycle parking capacity at ferry facilities on both sides of the Hudson River should be a consideration in future planning. However, it is unlikely that the increase in ferry customers would have sufficient mode diversion effects from buses that would affect the peak-period capacity of a new PABT. The commuter bus and ferry markets have a different customer base. There may not be significant numbers of inland bus customers that would find an additional intermodal connection with a ferry to be an attractive daily commutation choice given that bus customers already have longer commutes than current ferry customers. However, given the dynamic nature involved in estimating ridership among different modes, a stated preference survey should be completed for improved certainty of these effects. Ferries do offer flexible opportunities as interim commutation capacity should rail or bus capacity be constrained during the construction of improvements, as well as during any potential work outages due to labor issues. The ferry companies already have experience in working with public authorities on emergency transportation planning through leases of additional vessels and arrangements for shuttle connections at park-and-ride lots and locations such as Liberty State Park, which would be useful in planning PABT interim construction-related capacity.**

## 2.6 HOBOKEN TERMINAL RAIL EXPANSION

This strategy calls for implementation of capital and operating improvements to support expanded peak-period NJ TRANSIT commuter rail operations to and from Hoboken Terminal. The purpose of this strategy is to expand capacity at Hoboken Terminal to enable more frequent NJ TRANSIT commuter rail service.

As shown on Figure 7, five commuter rail lines serve Hoboken Terminal: the Pascack Valley Line; the Main-Bergen County Line; the Montclair-Boonton Line; the Morris & Essex Line; and the North Jersey Coast Line. In addition to its strategic role in the regional commuter rail network, Hoboken Terminal is also a major trans-Hudson transportation hub because it offers multi-modal connections between commuter rail, light rail, bus, ferry, and PATH services. Until new trans-Hudson rail capacity is completed, NJ TRANSIT's only option for increasing rail service in Northern New Jersey is to run additional trains to Hoboken Terminal.

The strategy to expand capacity at Hoboken Terminal builds upon the ongoing Long Slip Fill and Rail Enhancement project. The Long Slip project is one of several interrelated projects within the NJ TRANSIT Resilience Program that individually and collectively aim to improve system-wide resiliency. In response to the flooding of Hoboken Terminal and the adjacent Hoboken Yard associated with the surge created by Superstorm Sandy, NJ TRANSIT was awarded approximately \$146.5 million through the Federal Transit Administration's Emergency Relief Program to advance the Long Slip project, which will include construction of six new tracks on the filled Long Slip canal (Figure 8) to serve three high-level ADA-accessible boarding platforms. As noted on the NJ TRANSIT Resilience Program webpage, the project "will allow NJ TRANSIT to operate train service longer and recover more quickly from storm events." Although primarily a resiliency project, the construction of new tracks and platforms also creates an opportunity to increase commuter rail service frequency to and from Hoboken Terminal. However, major capital investments beyond the Long Slip project would be required to achieve the increased capacity at Hoboken Terminal, including—but not limited to—the Westbound Waterfront Connection Project.

The Westbound Waterfront Connection Project is included in the 2015 New Jersey State Rail Plan as one of a number of potential long-term projects "to improve service and expand capacity to meet future increases in demand." The project would create a grade-separated crossing at the Dock East interlocking to address an existing bottleneck in the commuter rail network. As discussed in the State Rail Plan, the existing bottleneck "severely [restricts] the number of trains that can be reliably operated today with current volumes, let alone trains to meet future growth." The Westbound Waterfront Connection Project would increase capacity along the Northeast Corridor for NJ TRANSIT commuter rail, but it is in the early planning stages and has no schedule or cost estimate at this time.







Figure 8: Long Slip Canal



Source: NJ Resilience Program

Overall, potential benefits associated with this strategy include increased peak period service frequency on multiple commuter rail lines to and from Hoboken Terminal. There are also significant benefits associated with this strategy beyond the primary focus of the Capacity Study, most notably with respect to system redundancy. During emergency situations, NJ TRANSIT trains can be diverted into and out of Hoboken Terminal. As such, the expanded capacity at Hoboken Terminal enabled by this strategy would reinforce the role of this intermodal hub as a critical node in the interstate transportation system.

Comparable to the PATH capacity expansion strategy, it is unlikely that this strategy would result in any substantial peak hour demand reduction at the PABT, because NJ TRANSIT capacity expansion would primarily benefit existing commuter rail customers as opposed to attracting PABT customers. Due to the locations of NJ TRANSIT stations in New Jersey, there is only modest overlap among likely NJ TRANSIT rail customers and likely PABT customers. As discussed in the “Summary of Previous Trans-Hudson Planning Work” technical memorandum, despite the fact that the two modes are complementary and interdependent, the interstate bus network serves commuter markets that are

not well served by rail transit. For instance, this strategy would not benefit heavily bus-dependent trans-Hudson travel corridors, such as Eastern Bergen or Route 9.

It is possible that this strategy could result in increased trans-Hudson travel by PATH or ferry from Hoboken to Manhattan above projected volumes. As noted in *The Profile of the Regional Interstate Transportation Network*, “it would be in the region’s interest to keep options open for future capacity expansion on [the Hoboken-WTC PATH Line] by ensuring the redevelopment of Hoboken Terminal...provides space to accommodate [the Hoboken-WTC 8-Car Program]” (refer to Section 2.1). Accordingly, it is important to acknowledge the potential policy implications of this strategy with respect to levels of peak period demand requiring additional trans-Hudson capacity via other modes.

**Conclusion:** This strategy includes multiple initiatives—including the Long Slip and Westbound Waterfront Connection projects—that would collectively increase commuter rail capacity at Hoboken Terminal. Construction of six new tracks on the filled Long Slip canal is an enabling project, but it is insufficient to realize the potential increase in peak period frequency on NJ TRANSIT commuter rail lines that serve Hoboken Terminal. The Westbound Waterfront Connection Project, which is not currently active and has no timetable for implementation, is an example of a major capital investment that is necessary to unlock the capacity increase enabled by the Long Slip project. It is not anticipated that this strategy would have a sizable effect on peak hour PABT demand because of the different markets served by the NJ TRANSIT system and bus network, but it could potentially result in increased trans-Hudson travel by PATH or ferry beyond current ridership forecasts. Nevertheless, this strategy is critical to the NJ TRANSIT system because Hoboken Terminal is a strategic asset and an important safety valve in the interstate transportation network, providing opportunities to not only accommodate growth in travel demand but also—through the Long Slip project—enable rapid recovery of transit services following an extreme weather event.

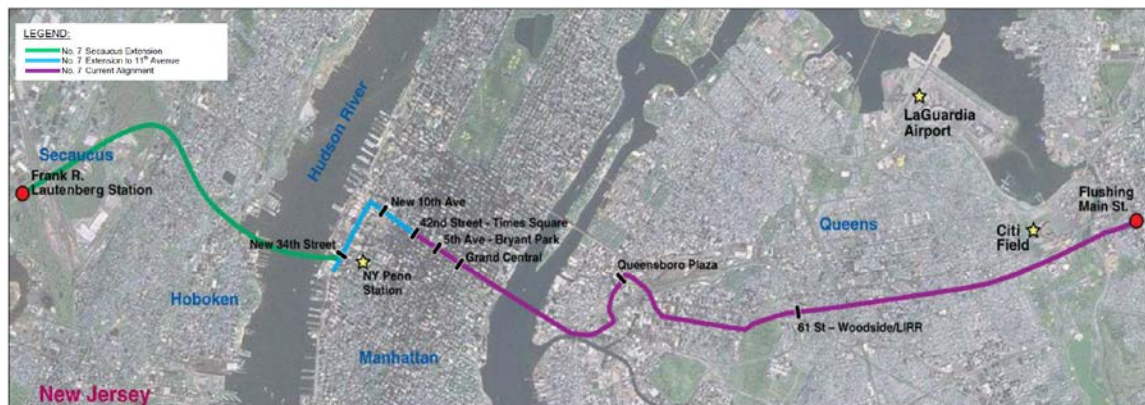
## 3 New Trans-Hudson Rail Transit Infrastructure

### 3.1 NO. 7 LINE EXTENSION TO SECAUCUS

In 2013, the Mayor's Office of the City of New York issued the No. 7 Line Secaucus Extension Feasibility Analysis Final Report, which evaluated options for extending the Metropolitan Transportation Authority's (MTA) No. 7 Line from West Midtown to the Frank R. Lautenberg (FRL) station in Secaucus with a new bus transfer facility. The project proposed a new two-track tunnel under the Hudson River, two tracks south of the existing Northeast Corridor, a new No. 7 Line/bus terminal adjacent to FRL, and the construction of the previously deferred No. 7 Line station at 10<sup>th</sup> Avenue (Figure 9). The project would provide cross-Midtown distribution by linking Secaucus with West Midtown, East Midtown, and Queens. As proposed, the potential project would include a two-story, 60-bay bus facility at the FRL station, which would be designed to serve 250 buses in the peak hour, including approximately 200 interstate buses that were previously destined for the PABT. As such, implementation of this potential project could reduce peak hour PABT bus demand in 2040 by approximately 25% below projected levels. However, even if this were to occur, peak hour bus demand at PABT in 2040 would still be at or above current levels, which suggests that a reconstructed PABT would need to offer at least as much capacity as the current facility.

The study determined that the project was technically feasible and could be justified from a ridership perspective. However, several key institutional issues were identified, including availability of funding, operational and labor-union considerations, zoning, and land acquisition. Next steps would include closer examination of the business case for the project, as well as investigation of operational concerns and required improvements to existing Manhattan stations. Currently, the MTA does not support further development of this concept amid other demands on its system. No funding has been identified for further phases of analysis.

Figure 9: Potential Trans-Hudson Capacity Expansion: No. 7 Line Secaucus Extension



Source: *No. 7 Line Secaucus Extension Feasibility Analysis Final Report*

Despite this project’s potential to shift a significant number of PABT buses, the obstacles bring to question whether this project has any potential to move forward. Although it could reduce the need for peak hour bus capacity at PABT in 2040 by a significant amount, a reconstructed facility with at least as much capacity as PABT offers today would still be needed. The resulting savings from a smaller reconstructed PABT would be much less than the cost of the No. 7 Line extension project. The net cost of pursuing both projects would be higher than a reconstructed and expanded PABT. The potential of this project to allow a reduction in the peak-period demand a new PABT would need to serve, would depend on the region’s ability to implement the subway extension as well as the new PABT and long-term expansion of commuter and intercity rail capacity.

### 3.2 GATEWAY PROGRAM/NEC FUTURE

As currently conceived, the Gateway Program (Figure 10) will include the addition of a new two-track Hudson River tunnel, expanding the existing mainline to four tracks between Newark and New York Penn Station (PSNY), replacement of the Sawtooth Bridge, a new Portal Bridge, loop tracks at Secaucus, and expansion of PSNY, with new tracks, platforms, and concourses. Some specific projects contained in the Gateway Program are related to current state of good repair conditions while others relate to increased train capacity.

Figure 10: Potential Trans-Hudson Capacity Expansion: Gateway Program of Projects



Source: Amtrak

It has been determined that certain specific projects will be advanced immediately given their independent utility and criticality to maintaining the current level of rail service on the Northeast Corridor between New Jersey and New York. To this end, work is now underway to complete an Environmental Impact Statement (EIS) for the Hudson Tunnel Project. Previously, an EIS was prepared for the Portal Bridge project and a Record of Decision was issued by the Federal Railroad Administration. The federal government and the states of New York and New Jersey have committed to cost sharing and a governance structure for the program, but actual construction funds have not yet been obtained for the Hudson Tunnel Project. Once the design and construction of the new tunnel is complete, the existing tunnel will need to be taken out of service one tube at a time for rehabilitation. The tunnel rehabilitation will need to be completed, and Penn Station will need to be expanded with new tracks and platforms, before increased morning and evening peak period rail service can be implemented.

There is a range of possible outcomes and timeframes for the resolution of the trans-Hudson transportation capacity shortfall over the long-term. While bridge replacements are well-defined, the exact alignment of the new tunnel and associated track connections in New Jersey and on the west side of PSNY are still being finalized, and the expansion of PSNY and potential additional tunnel and track connections require further study and decision-making. These decisions could substantially affect when new capacity for trans-Hudson travel becomes available. Construction of the full Gateway Program could enable as much as a doubling of capacity for NJ TRANSIT rail trains during peak travel times, but for the reasons described above, significant capacity increases will not likely occur until some years beyond 2025.

The Federal Railroad Administration (FRA), as part of the NEC FUTURE initiative, is in the process of defining a long-term vision and initial first phase investment plan for the entire Northeast Corridor. While the FRA has not yet selected a Preferred Alternative or defined future service levels and patterns, the representative service plans from the NEC FUTURE Tier 1 Draft Environmental Impact Statement offer insight into the range of possible outcomes. NEC FUTURE Alternative 1 and Alternative 2 both add two new tracks under the Hudson River for a total of four Hudson River tracks, as proposed in the Gateway Program. Alternative 2 also assumes two new tracks under the East River, expanded track capacity in New Jersey, and additional train storage east of the East River and in New Jersey at locations not yet determined. NEC FUTURE Alternative 3 adds another pair of Hudson River rail tracks over and above what is contemplated for Gateway (six total Hudson River tracks), as well as the additional track capacity and train storage.

The NEC FUTURE travel demand model forecasts that travel between New Jersey and New York will far exceed what the trains alone can deliver. Thus, even with the considerable increases in rail service, demand for trans-Hudson bus services remain strong and will grow substantially. This reflects both the anticipated strong growth in overall demand for trans-Hudson travel and the inherent strength of the bus market, particularly in the corridors where rail service does not exist or is constrained (i.e., Route 9 corridor, Eastern Bergen County, NJ Route 3/US Route 46 corridor). Based on the Bus Passenger and Operations Forecast developed for the MBMP (and as documented in MBMP Appendix B), a full build scenario for the trans-Hudson rail network—that would double NJ TRANSIT capacity and create a one-seat ride to Manhattan from the Main/Bergen/Port Jervis and



Pascack Valley Lines—would only result in a 7.5% decline in PABT peak hour passenger demand, compared to the No-Build condition in 2040. For the same level of expanded rail service, the Access to the Region's Core (ARC) Final Environmental Impact Statement (FEIS) analysis estimated only a 4% reduction in PABT demand, although it is important to note that the ARC analysis considered daily trips (as opposed to peak hour passengers) for a horizon year of 2030 (as opposed to 2040). The NEC FUTURE Interregional Model forecasts a reduction of 6%-8% in daily intercity bus demand (for the overall intercity bus market within the NEC FUTURE study area) associated with the Action Alternatives in 2040.

The summary documentation of the Bus & Passenger Activity Forecasts completed for the MBMP Appendix B includes instructive details to explain the modest reduction in projected demand at the PABT associated with significant expansion of trans-Hudson rail capacity. Specifically, the document notes that “for most customers, the primary effect of the Gateway project would be to provide more capacity, not change the time or convenience of rail service. From any given location in New Jersey, the relative tradeoffs between rail and bus will remain unchanged by the expansion in rail service.” Indeed, although there is some overlap between the west-of-Hudson rail and bus networks, the two modes largely serve different markets for trans-Hudson commuting. Accordingly, while increasing commuter rail capacity would be an enormously beneficial investment, it would not change the capture area of the commuter rail service, thereby resulting in only a modest change in projected PABT demand.

However, the MBMP Appendix B also indicates that “a significant increase in trans-Hudson rail capacity could induce transit operators to make changes to bus service,” such as re-routing some routes to terminate at Secaucus Junction and discontinuing direct service into Manhattan, which could potentially result in “significant additional reduction in demand at the bus terminal.” The forecasts cited above assume no such modifications to bus service. Furthermore, the potential effects of commuter rail capacity expansion cannot be viewed in isolation from the rest of the interstate transportation network, including but not limited to the role of the PATH system in addressing future projected trans-Hudson travel (discussed in Section 2.1).



## 4 Additional Considerations

### 4.1 POLICY IMPLICATIONS OF MODE TRANSFERS AND PRICING

The assessment of Trans-Hudson modal strategies leads to the discussion of how transfers and pricing may impact customer decision making. There have been a significant number of studies evaluating the cost and impacts of ridership associated with transfers within and between transit modes. Transfers are a common occurrence in public transportation systems, especially in large multimodal networks, or between distinct operating services. For example, approximately 42% of the bus passengers entering the PABT today transfer to the subway, and approximately 52% of commuter rail passengers at PSNY transfer to/from the subway (with another 18% transferring to/from the bus, based on the 2006 Moynihan Station FEIS). According to a 2007 American Public Transportation Association (APTA) report (*A Profile of Public Transportation Passenger Demographics and Travel Characteristics Reported in On-Board Surveys*), 40% of public transportation trips in the United States include at least one transfer, with 29.3% including one transfer, 8.4% including two transfers, and 2.3% including three or more transfers.

From a policy standpoint, the transfer penalty is a fundamental issue, and is a key factor in the determination of overall ridership demand. Nearly all forecasting procedures assume that the impact of transfer time is greater than just the simple time spent changing from one route (or service) to another. For instance, the Federal forecasting models add 5 minutes of time for each transfer above and beyond the actual time required to transfer between routes.

It is important to consider, however, that future trans-Hudson travel decisions may depend on other factors, in addition to equivalent travel time:

- In cases where the system is near its person-hauling capacity, travelers may elect to avoid the crowded no-transfer option in favor of the less crowded option that involves a transfer.
- Technology is quickly evolving and the accuracy and timeliness of transit information available to the customer would promote the use of alternative routes/modes/transfers.
- Unified ticketing technology across multiple trans-Hudson modes/agencies would also promote the use of alternative routes/modes/transfers.
- Providing opportunities for flexibility and convenience may also promote the use of alternative modes (i.e., creating park-and-ride options that allow customers to use bus and rail interchangeably; providing amenities at park-and-ride locations such as dry cleaners, auto repair, pharmacy; etc.)
- Pricing strategies that promote the use of alternative modes.

Key to understanding and shaping the future of trans-Hudson technology/ticketing/pricing/transfer options is (1) establishing regional transit agency collaborative working groups to explore and institute technology and coordination options; and (2) engaging customers through outreach and surveys to test transfer options and pricing strategies. These next steps could become a focus of future research or pilot pricing initiatives.

## 5 Findings

This is the second of two technical memoranda that assess strategies for serving future trans-Hudson travel demand. For each technical memorandum, the primary goal is to determine if a particular strategy will accommodate sufficient demand to allow meaningful reductions in the size and cost of a reconstructed PABT. The “Bus Network Operational/Service Strategies” technical memorandum looks at strategies involving improvements to and reconfiguration of bus service; this technical memorandum looks at all other trans-Hudson modes of travel.

The strategies presented here cover a wide range, from large investments such as the Gateway Program for new Hudson River rail tunnels, to more incremental improvements such as improvements to trans-Hudson ferry service. Given the wide range of scope and cost of these strategies, expected effects on the potential size and scope of a reconstructed PABT also cover a wide range.

On the high end, one strategy – the No. 7 Line Extension to Secaucus – would have a large effect on future PABT bus demand, larger than any other strategy considered in this technical memorandum or in the “Bus Network Operational/Service Strategies” technical memorandum. This one project could reduce demand for buses to access the PABT by as much as 25% below projected levels in 2040, and could justify a reconstructed bus terminal that is both substantially smaller and significantly less expensive than currently projected.

These benefits would come at a substantial cost. A preliminary assessment of the No. 7 Line Extension to Secaucus estimated cost at or around \$10 billion, an amount far greater than the likely cost reductions it would allow by enabling a reduction in capacity of a replacement Midtown Bus Terminal. Although the project may be worth pursuing for many reasons, it would not represent a net reduction in the cost of infrastructure to serve the trans-Hudson market. It also would bring its own set of construction and physical and operational impacts as well as benefits on both sides of the Hudson River, and an additional financing challenge over and above the various trans-Hudson projects already on the region’s agenda, most driven by a combination of state-of-good-repair imperatives as well as capacity-expansion opportunities.

At this writing, the No. 7 Extension shows no signs of advancing through the transportation planning and funding process. However, should this change, it could significantly affect the design of a constructed PABT, but for the moment it must be seen as more an idea than a plan.

Other strategies considered in this technical memorandum have much smaller effects on future demand for buses to access the PABT. Extension of the Hudson-Bergen Light Rail and improvements to trans-Hudson ferry service have been discussed for many years and would offer many benefits to the region, but cannot be expected to have significant effects on future PABT bus demand.

Improvements that increase both the reach and capacity of the PATH rail system fall somewhere in the middle. The PATH system offers a high quality trans-Hudson option to New Jersey commuters in certain markets, and improvements to the system could increase this value over time. These improvements—longer trains, more frequent service, and an extension to Newark Liberty Airport—offer many benefits, but their effect on future demand for buses to access the PABT would be modest. This is largely because the specific locations served by PATH are not markets that generate significant bus travel to PABT (with the notable exception of Hudson County). Improved PATH service would benefit these communities but would leave bus demand largely unaffected.

This highlights an important issue for policy makers in both states, though not directly related to the PABT: The primary effects of the trans-Hudson bus strategies assessed in the “Bus Network Operational/Service Strategies” technical memorandum would be on bus commuters and the infrastructure that serves them. As such, decisions of whether to implement these strategies can be made based largely on their effects on PABT and the larger bus system. This is not the case for the strategies assessed in this element of the Commuting Capacity Study. It is important to understand the effects that improvements to the PATH system would have on PABT, for example, but it does not follow that decisions about these investments should be made based on their effects on the bus system. In fact, for many strategies assessed in this technical memorandum, the effects on the bus system and PABT are minor and ancillary compared to other effects, and as a result, a decision of whether to pursue the project should be based mostly on these other factors.

There is no trans-Hudson initiative for which this is more true than the Gateway Program. It is the most costly strategy considered in this technical memorandum or in the “Bus Network Operational/Service Strategies” technical memorandum by a wide margin, and it can be argued that its effects would be the most far reaching. One of these effects would be a modest reduction in future demand for buses to access PABT, likely a percentage reduction in the mid-single digits. The reasons for this relatively modest effect are similar to those cited for improvements to the PATH system. Gateway would significantly increase the capacity of NJ TRANSIT trains to carry passengers into Manhattan, but this effect would be felt mostly in communities with NJ TRANSIT rail stations. These communities are on the whole not major generators of bus demand, and so the diversion effect from improved NJ TRANSIT rail service would not be large.

However, effects on bus demand and the PABT reconstruction are not the reasons to either pursue or not pursue Gateway. It would affect the region in many ways—through improved resilience, higher capacity commuter rail service, and better connections up and down the Northeast Corridor—and as a project it should rise or fall based on these factors.

Future investment to substantially increase trans-Hudson capacity over and above what is delivered by the Gateway Program could have multiple forms and likely will require a multimodal investment strategy: greatly increased bus service and with increased capacity and efficiency on the Lincoln

Tunnel Corridor and in a replacement bus terminal, extension of a NYCT subway line to New Jersey,<sup>1</sup> and/or even more commuter rail service. Growth in ferry service is possible, but would be insufficient to meet the totality of projected 2040 demand on its own. Either of the potential rail investments – subway or regional rail – would divert some but not all trans-Hudson bus trips and would reduce peak-period demand for interstate bus service to and from Manhattan, but the need would still exist for a substantial bus terminal. Expanding PATH peak-period service is possible through additional car purchases and other potential capital improvements in New Jersey, though these may be needed to serve growth from local Hudson County markets as well as transfers from other modes at Hoboken Terminal and Newark Penn Station. Ferries can provide some supplemental capacity, with limited potential to divert bus commuters with inland origins.

The estimated diversionary effects of the strategies outlined in this technical memorandum that have the potential to reduce peak hour PABT demand (and for which the potential PABT reduction is quantified) are summarized in Table 4. It is important to note that the effects are not necessarily additive—and thus the cumulative effects cannot be inferred—because there could be overlap between the potential bus diversions associated with the respective strategies. Additional strategies specific to the interstate bus network that could divert demand from the PABT are discussed in the “Bus Network Operational/Service Strategies” technical memorandum.

Table 4: Summary of Potential PABT Bus Diversions from Applicable Strategies

Strategy	Potential PABT Diversions (Number of Peak Hour Buses)
Expanded Bus Services to Port Imperial Ferry Terminal	10
Expanded Trans-Hudson Ferry Services	10-20
Gateway	50-60
No. 7 Line Extension to Secaucus	200

Source: Trans-Hudson Community Capacity Study; MBMP; No. 7 Line Secaucus Extension Feasibility Analysis Final Report

In summary, even when policy makers are successful in advancing the Gateway Program to construction and if NJ TRANSIT is able to double rail service into PSNY, it is not expected that the Gateway Program alone will meaningfully reduce demand at PABT. Demand for trans-Hudson transit service is expected to grow by 30% or more by 2040, which will fully utilize all of the capacity created by the Gateway Program and require investment in even more additional capacity. Increasing and improving bus service to PABT, made possible by a reconstructed terminal, is necessary to meet growing trans-Hudson demand prior to 2040. The well-developed network of bus routes and services feeding PABT has proven to be a convenient, productive, and competitive means of trans-Hudson transit service, and will remain a critical asset for travelers. This is especially the case in areas of northern and central New Jersey where rail service is unavailable or constrained.

<sup>1</sup> This assumes adequate institutional support is found in both states and especially within the MTA to pursue such a proposal, and that such an extension can be proven to provide adequate benefits, especially in addressing projected future travel demand.

Finally, it is important that any strategies to reduce projected demand at PABT in the forecast year of 2040 be considered in light of the likely useful life of a reconstructed PABT regardless of the size and configuration that are selected. This issue was addressed in the findings of the “Bus Network Operational/Service Strategies” technical memorandum and apply equally here, and are presented here verbatim:

It will take many years for a new PABT to be designed, funded and built. For these reasons an opening date prior to 2025 seems unlikely. If this estimate is correct, in the forecast year of 2040 the new facility would be just 15 years old, well short of its actual useful life. In addition, future policy makers will likely want a reconstructed PABT to last longer than the 30 year life span considered standard for many infrastructure projects. The north wing of the current facility opened 37 years ago; the south wing, 66 years ago. The consequences of this could be significant: a new terminal opening in 2025 with a 50-year useful life would be called upon to accommodate growing demand until 2075. While it is not practical to produce exact demand forecasts as far out as 2075, the real possibility exists that a reconstructed PABT would need to function for decades beyond 2040. This suggests that policy makers should be wary of designing a facility that is strictly sized to meet only demand forecasted for 2040.

Based on these findings, this technical memorandum reaches the following tentative conclusions:

The non-bus strategies assessed in this technical memorandum could have some effect on the appropriate future size of a reconstructed PABT, but the only strategy that could lead to a significant size and cost reduction – the No. 7 Line Extension – is unlikely to be implemented in the foreseeable future. Improvements to PATH service and incremental improvements to ferry service and light rail in New Jersey may be worth pursuing on their own merits, but would not meaningfully change the parameters for PABT reconstruction. The Gateway Program may be the most important transportation investment for the region currently being planned, but its effect on bus demand at a reconstructed PABT would be modest.

These factors, together with need for a reconstructed PABT to accommodate trans-Hudson bus demand well beyond the 2040 forecast year, lead the authors to conclude that the non-bus trans-Hudson strategies assessed in this technical memorandum do not provide a basis to reduce the current projected capacity at full build-out of a reconstructed PABT.

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TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix B Attachment: Ferry Analysis

September 2016

Version Final

Prepared for:

**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Submitted by:



CHENG SOLUTIONS LLC

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# 1 Introduction

## 1.1 OVERVIEW

There are currently 18 ferry routes that serve the Hudson River commuter market operating between 12 New Jersey terminals and four Manhattan terminals. All of the privately-owned and operated ferry companies – New York Waterway (NYW), BillyBey Ferry, Seastreak, Hornblower, and Statue Cruises – are in public-private partnerships for use of public terminals, piers and/or property for parking as part of their business. Ferries provided an average of 28,000 weekday trans-Hudson trips in 2015, with ridership higher in the summer months than in the winter months. NJ TRANSIT estimates that ferry riders represent approximately 4% of current trans-Hudson commutes.

According to NJ TRANSIT's 2013 ferry passenger survey, current ferry customers report a high level of satisfaction with their ferry commute, and have higher-than-average incomes compared to trans-Hudson commuters overall. Given that ferries are not the lowest cost option available, one can deduce that these customers place greater monetary value on their time and are not as price sensitive as other commuters.

Strategies that have been frequently discussed to expand ferry ridership, similar to other modal strategies, are largely centered upon:

- Increasing parking options at ferry terminals;
- Decreasing fares on existing services; and,
- Providing new ferry routes to capture additional market.

This report addresses the extent to which these strategies would likely cause bus commuters to shift to ferry commutation in numbers sufficient to affect peak period usage of a new PABT. Following an analysis of the effects of additional parking, the report discusses the potential impact of reduced fares on existing services and the likely market for three new routes (proposed as part of the North Jersey Transportation Planning Authority's (NJTPA) *Waterborne Resources Transportation Inventory*) on ferry and bus ridership. *The report presents an estimate of potential ridership that may be diverted specifically from bus to ferry.*

Specifically, this report assesses the degree to which current trans-Hudson bus commuters may be significantly diverted to the ferry mode and how this would affect the design capacity of a new redeveloped Port Authority Bus Terminal (PABT). It is not a market analysis or a ridership study. Finally, it is important to note that this report relies heavily on ferry elasticity calculations provided by the 2011 Port Authority of New York and New Jersey (PANYNJ) *Interagency Study of Regional Private Passenger Ferry Services in the New York Metropolitan Area*. Interviews with ferry operators also were conducted to provide current and additional perspectives for this analysis.

## 2 Ridership Analysis on Current Routes

### 2.1 PARKING

Increasing parking options at ferry terminals in New Jersey could have the effect of increasing overall ridership on a few ferry routes into Manhattan. This is particularly the case in the services offered from Monmouth County. For both the NYW ferry service from Belford and the Seastreak ferry service from the Atlantic Highlands, almost all ferry customers arrive at the terminals by car. According to the 2013 Trans-Hudson Ferry Survey, 90% of these customers drive and park, and 3% carpool or are dropped off. Parking at these terminals is free but incorporated into the ferry fare. Currently, parking utilization ranges from 80% to 90% of capacity at these locations, based on interviews conducted with the ferry operators. Seastreak recently bought additional land near its terminal to accommodate another 300 cars for surface parking. Elevated parking garages have been discussed but are not anticipated to be financially viable. There also are concerns that an elevated structure could block waterfront views and therefore not be deemed acceptable to the public.

For the northern New Jersey ferry market, parking is less critical for ferry commuters since a higher percentage of commuters are able to walk to the ferry terminals or take an intermodal connection through a shuttle, Port Authority Trans-Hudson (PATH), or Hudson-Bergen Light Rail (HBLR). Paid parking for the northern New Jersey ferry market is available at Weehawken, however, capacity is at 80% and parking is not exclusive to ferry customers. There is no parking availability at Edgewater. Increasing parking at these locations would be difficult and would increase local vehicle miles traveled (VMT) at the terminals. Hence, this could be a challenging public project to implement in order to increase ridership.

Increasing parking does not address the diversion of *bus commuters* to the ferry mode as most bus customers walk to their bus stop. This is important because parking is often cited as a key issue for ferry ridership expansion. However, it is not relevant for the specific research question of this effort as it relates to PABT redevelopment.

For some commuters, bicycles may provide another means of accessing ferries for commutation between New Jersey and New York City. The NYW and Billybey routes allow bicycles on board for an additional \$1.00 per trip fee. Seastreak charges an additional \$2.50. Passengers pay no additional charge to bring bicycles on board for the Liberty Landing service. Bicycle parking is available for ferry passengers and other transit users at the intermodal Hoboken Terminal and at the PANYNJ's World Financial Center terminal in Manhattan, and at NYW's Weehawken and Midtown Manhattan terminals.

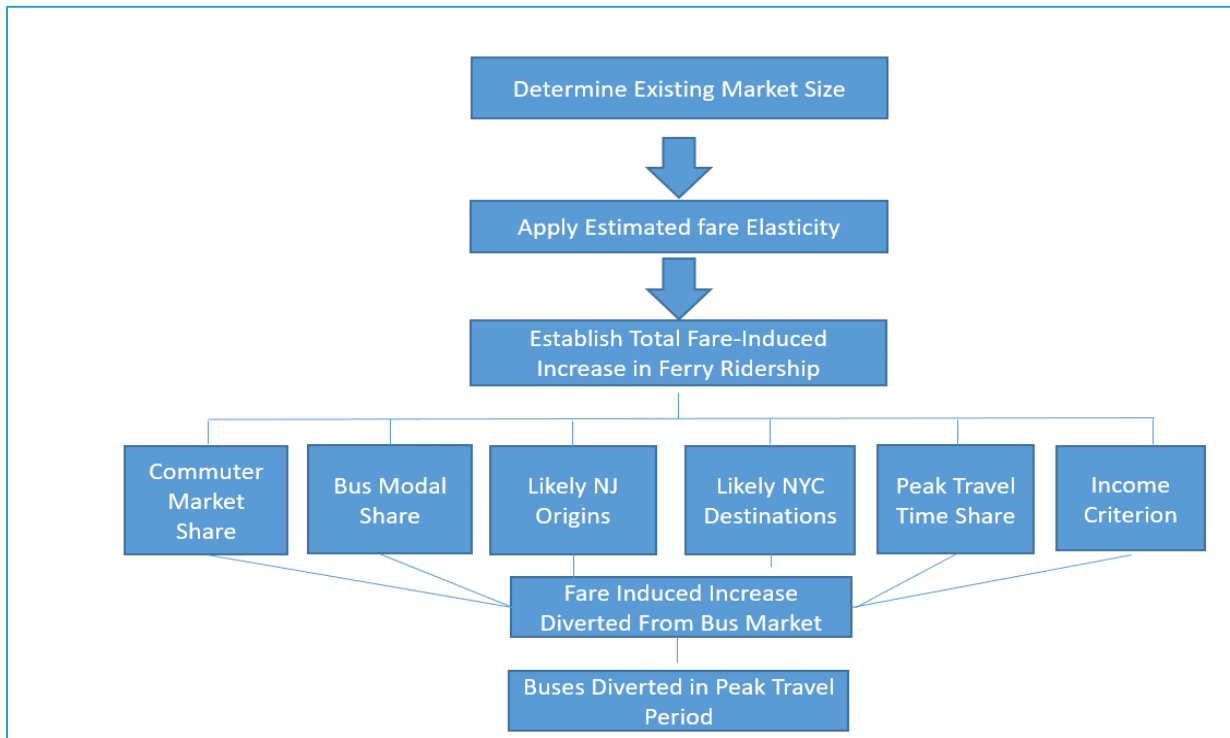
NYW reports an average of 200 weekday bicycle ticket sales on trans-Hudson ferry routes, 80% as single-trip purchases and 20% bought on a monthly ticket. Their data show nearly half of the single-trip and monthly bicycle ticket purchases on the Paulus Hook-World Financial Center service alone. Seastreak and Liberty Landing report minimal usage of bicycles on their ferries.



### 3 Increasing Ridership on Current Routes

Though the public sector has provided infrastructure including ferry landings and terminals, trans-Hudson ferry service operations are unsubsidized by public agencies and consequently are a relatively expensive choice for daily commute and discretionary travel. Moreover, because landside connections are limited, the geographic (eastbound) market tends to be confined to the immediate areas surrounding the waterfront landings, and Manhattan-bound commuters are heavily comprised of residents who live within or near these neighborhoods. In addition, once a ferry customer arrives at a landing in Manhattan, limited shuttle service to ultimate destinations presents another barrier for riders. Unless the Manhattan landing is within walking distance (on par with a train, bus or subway service) to the ultimate destination, there is little incentive to opt for a ferry when there are other more convenient and significantly less costly alternatives available. In order to entice more ferry riders, issues of fare, overall transport costs (including value of time) and ease of access must be addressed (Figure 1).

Figure 1: Existing Routes Methodology Flowchart



Source: Cheng Solutions, 2016

The impact of the fare on ferry ridership can be calculated by estimating the price elasticity of demand. Using either revealed or stated preference data, researchers can estimate the percentage change in ridership for a given percentage change in the fare. A recent effort using both types of data was completed in 2011 by a team of consultants for the PANYNJ, in collaboration with partner agencies in both states. The *Interagency Study of Regional Private Passenger Ferry Services in the New York Metropolitan Area* provided a forecast of ferry ridership driven by fares (defined as daily rates and converted to real values using the consumer price index), employment in the finance industry, regional unemployment, and housing starts. Since the data was monthly, there are controls for seasonality as well as service interruptions due to weather or other phenomena. The econometric model constructed with these data yielded an estimated (short-term) fare elasticity of -0.27. It was assumed that the elasticity does not vary with the level of the fare. In other words, the response of riders to fare changes is the same across all plausible values of the fare. In most cases this is a reasonable assumption since fare levels will seldom vary more than 10% up or down in real terms. The specification of the model enabled the researchers to estimate a short-term elasticity only. Short term responses to fare increases are likely to be smaller than the longer term response since riders cannot usually make an immediate transition from one mode to another in response to a change in fare. For many reasons, riders would initially experience some duration of inertia.

The interpretation of the elasticity estimated in the PANYNJ report is as follows. Holding all other variables constant, a 10.0% increase in the fare will reduce ridership by 2.7%. Similarly, a 10.0% decrease in the fare will generate a 2.7% increase in ridership, all else being equal. At this level, the estimated elasticity is similar to estimates for other forms of transit. Over the past thirty years, estimates of transit elasticities have ranged from -0.2 to -0.5 in the short term, to between -0.6 and 0.9 over the long run. It is reasonable to assume a larger long-run elasticity for the trans-Hudson market even if its exact level is unknown.

Stated preference<sup>1</sup> survey data collected for the study, including socioeconomic characteristics of riders and transport market attributes such as in-vehicle time, out-of-vehicle time, and headway, provided further confirmation of the ferry fare elasticity. This data was used to develop an econometric mode choice model designed to gauge general interest in ferry transport relative to other modes. The mode choice model generated an estimated short-run elasticity of ridership with respect to fare of -0.24, almost precisely on par with the results of analyzing the revealed preference data within the same study. Thus according to the stated preference data, a 10.0% change in the fare would result in a 2.4% change in ridership in the opposite direction. Again this comports well with previous transit studies undertaken in recent decades.

The estimated elasticities derived from both the revealed and the stated preference data are considered inelastic because they are less than 1.0 in absolute value. This means that the proportional change in ridership is less than the proportional change in the fare. Therefore, holding

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<sup>1</sup> Stated preference data is different from revealed preference data in that it refers to a survey technique that extracts from respondents their views and preferences under a hypothetical set of circumstances and product attributes. In transportation research, survey respondents may be shown a list of modal attributes including fares, in-vehicle transit time, access time etc. then asked to choose which is the most attractive to them.

all other variables constant, it would take a large proportional decrease in the fare to attract a significant number of riders. One may deduce from this relationship that the ferry mode is not considered an equal substitute to alternate modes of transport, owing to both the fare relative to other modes and the difficulty of ferry landing access on both the east and west sides of the Hudson. Trans-Hudson ferry service can in fact be characterized as a “premium service” that is differentiated along price and service attributes:

Two policy implications of this analysis are:

- On existing routes, holding all other variables constant, even large decreases in the fare will go largely unheeded by the traveling public; and
- The main considerations for new routes should be reducing the cost of access and/or taking advantage of population densities in relatively high-income areas.

### 3.1 HEADWAY

Transit service frequency is called headway. Previous studies<sup>2</sup> reveal an elasticity of ridership to headway of -0.50, such that—on average—a 10.0% increase in headway (reduction in service frequency) cuts ridership by 5.0%, all else being equal. In the PANYNJ report, the impact of headway on ferry riders was derived via the stated preference survey component. The elasticity of ferry riders with respect to headway was found to be -0.62, which is relatively high in light of average estimates in the literature. It indicates that a 10.0% increase in headway will generate a 6.2% decrease in ferry riders, all else being equal. This may be at least partially explained by the wide availability of substitute transport modes and the relatively high value of time of Manhattan-bound New Jersey customers. Commuters can make the switch to an alternative mode with relative ease should the ferry headway increase. But the relationship, as in the case of all elasticities, is symmetric. Thus a 10.0% decrease in ferry headway will generate a 6.2% increase in ridership. The fact that commuters are relatively more sensitive to headway than to fares again reflects the region’s relatively high wages and value of time.

The difference between headway and fare elasticities may be an important policy consideration. According to the stated preference results, more riders are generated per unit decrease in headway than per unit decrease in the fare. In fact, holding all other variables constant, a decrease in headway will generate more riders than an equal percentage increase in the fare. However, there are limitations on the ability of providers to reduce headway. Ferries are already operating with significant excess capacity. Consequently, on purely financial grounds, providers are not likely to add additional capacity to improve service frequency. Speeding up existing ferries may be another alternative from a purely operational standpoint. However, even if fuel costs continue to decline, regulatory restrictions on ferry speeds make this impossible.

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<sup>2</sup> See Littman, Todd “Transit Price Elasticities and Cross-Elasticities” *Journal of Public Transportation*, Vol. 7, No. 2, 2004 (pp. 38

### 3.2 IN-VEHICLE TRANSIT TIME

The final key point to consider is the responsiveness of ridership to changes in in-vehicle time. The stated preference survey results from the PANYNJ report showed that the elasticity of ridership to in-vehicle time, specifically the time in-transit from origin ferry landing to destination ferry landing is -0.24. This is identical to the stated preference fare elasticity. Thus a 10.0% increase in transit time aboard the vessel will reduce ridership by 2.4%, all else being equal. Such an increase in operational speeds would also reduce headway, potentially eliminating the need for an increase in the number of ferryboats while deriving the ridership benefits of the relatively high headway elasticity. However, given the current regulatory environment raising operational speeds is infeasible. Boat speeds in New York State are not restricted when at least 100 feet from shore. However, wakes generated by boats are restricted. The potential damage to shoreline facilities and anchored or docked vessels from excessive ferry wakes has resulted in strict limits on ferry operating speeds. Failing a drastic change in boat design to vehicles that can operate at higher speeds with lower wakes, there is little room for ferry operators to raise ridership by reducing in-vehicle time.

### 3.3 QUANTITATIVE RESULTS - FARE ELASTICITY EFFECTS

In order to gauge how ridership might respond to various fare changes, we applied the estimated ferry fare elasticities discussed above to ferry ridership data provided by the PANYNJ.<sup>3</sup> The objective of this exercise was to determine how many commuters may be diverted from the bus to the ferry should the fare differential between the two modes narrow. The analysis was conducted for 15 ferry routes operating between New Jersey and Manhattan. The Rockland County service was not included, as it is too small to be statistically relevant. For purposes of this study, the bus market includes only those riders accessing the PABT in midtown. Riders accessing the terminal at the George Washington Bridge or any other destinations outside of the PABT are not included.

In order to arrive at final estimates, we have made several research-based assumptions about the relevant market. These include the share of commuters currently taking the bus, the share of trips occurring in the peak travel period, the share of bus riders whose ultimate destination is in close proximity to the Manhattan ferry landings, and the share of bus riders whose household income is on par with typical ferry riders. The peak month of July was chosen as the base for ridership. A quantitative description of these assumptions is displayed in Table 1. We did not empirically address inland connection issues such as bus, shuttle, jitney, private auto drop-off/park and sail, or other means of access to the New Jersey-side landings.

The analysis proceeded in steps and was designed to generate an estimate by ferry route of peak daily bus diversions. The first step was to generate changes in peak month ferry ridership by simulating the effects of reduced fares. Next we converted this to additional ferry riders per day during the peak month. We subsequently applied our research-based assumptions about the bus

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<sup>3</sup> Staff at PANYNJ provided Cheng Solutions with monthly one-way ferry ridership across all trans-Hudson routes from January 2014 through April 2016

commuter market to estimate the number of additional riders that will divert to the ferry from the bus, as opposed to from rail and autos.

Table 1: Bus Rider Market Assumptions

Origin-Destination	% County of Bus Users	% Bus Share	% Commuting	% of Bus Riders Traveling to Area	% of Peak Month	% Peak Period Trips	% in Ferry Income Class
Hoboken-Pier 11	64.7	36.3	79.6	15.7	10.1	17.7	47.2
Hoboken-World Financial Center (WFC)	64.7	36.3	79.6	2.8	10.1	17.7	47.2
Paulus Hook-Pier 79	64.7	36.3	79.6	9.3	10.1	17.7	47.2
Paulus Hook-WFC	64.7	36.3	79.6	2.8	10.1	17.7	47.2
Port Liberte-Pier 11	64.7	36.3	79.6	15.7	10.1	17.7	47.2
Liberty Harbor-Pier 11	64.7	36.3	79.6	15.7	10.1	17.7	47.2
Paulus Hook-Pier 11	64.7	36.3	79.6	15.7	10.1	17.7	47.2
Weehawken-Pier 79	64.7	36.3	79.6	9.3	10.1	17.7	47.2
Weehawken-Hoboken N-WFC	64.7	36.3	79.6	2.8	10.1	17.7	47.2
Hoboken North-Pier 79	64.7	36.3	79.6	9.3	10.1	17.7	47.2
Weehawken-Pier 11	64.7	36.3	79.6	15.7	10.1	17.7	47.2
Lincoln Harbor-Pier 79	64.7	36.3	79.6	9.3	10.1	17.7	47.2
Edgewater-Pier 79	23.9	36.3	79.6	9.3	10.1	17.7	47.2
Belford-Pier 11	19.7	36.3	79.6	15.7	10.1	17.7	47.2
Atlantic Highlands-Pier 11	19.7	36.3	79.6	15.7	10.1	17.7	47.2
Atlantic Highlands-E 34 <sup>th</sup> St	19.7	36.3	79.6	15.0	10.1	17.7	47.2

Source: Cheng Solutions, 2016

We control for the likely origin and destination of ferry riders, the share of trips made during the peak month and hour, the current modal share of buses in the overall Manhattan commutation market (to ensure that it is only bus riders who are relevant switchers), and finally, bus rider income. Average bus capacity adjusted for capacity utilization is given as 58.5 seats per bus. The results for fare reductions of 10%, 20% and 50% are displayed in Table 2. Given our assumptions as stated, there is virtually no diversion from buses to the ferry even with a 50% discount on the fare.

Table 2: Potential Bus Diversion in Peak Travel Hour

Origin-Destination	10% Fare Reduction		20% Fare Reduction		30% Fare Reduction	
	Diverted PABT Riders	Diverted PABT Buses	Diverted PABT Riders	Diverted PABT Buses	Diverted PABT Riders	Diverted PABT Buses
Hoboken-Pier 11	4	0	8	0	19	0
Hoboken-WFC	1	0	1	0	3	0
Paulus Hook-Pier 79	0	0	1	0	2	0
Paulus Hook-WFC	1	0	2	0	4	0
Port Liberte-Pier11	0	0	1	0	2	0
Liberty Harbor-Pier11	1	0	2	0	4	0
Paulus Hook-Pier 11	2	0	5	0	12	0
Weehawken-Pier79	5	0	11	0	27	0
Weehawken-Hoboken N-WFC	0	0	0	0	1	0
Hoboken North-Pier 79	2	0	4	0	10	0
Weehawken-Pier 11	1	0	3	0	7	0
Lincoln Harbor-Pier 79	2	0	3	0	8	0
Edgewater-Pier 79	0	0	1	0	1	0
Belford-Pier 11	1	0	2	0	4	0
Atlantic Highlands-Pier 11	1	0	2	0	4	0
Atlantic Highlands-E 34 <sup>th</sup> St	1	0	1	0	3	0
<b>Totals</b>	<b>22</b>	<b>0</b>	<b>45</b>	<b>0</b>	<b>112</b>	<b>0</b>

Source: Cheng Solutions, 2016

### 3.4 DIFFERENCE BETWEEN TRANS-HUDSON AND EAST RIVER FERRY MARKETS

There have been public policy discussions calling for decreasing fares as a key tool to increase ferry ridership, particularly in context of growth in the New York City (NYC) East River ferry market. What makes the trans-Hudson ferry market different from the East River market is the number of intermodal connections typically required to make a commute from New Jersey to the Manhattan CBD. In New York City Economic Development Corporation’s (NYCEDC) 2013 Citywide Ferry Study, it was clear that most of the existing and prospective new East River ferry customers are within a ½-mile walk radius to the respective ferry terminal. A primary threshold was within a ¼-mile walk radius and secondary market threshold was a ½-mile radius. Ridership largely came from new high-rise residential construction along the East River waterfront in Brooklyn and Queens, which are largely areas that were formerly industrially-zoned and far from the closest subway line.

On the trans-Hudson market, it appears that commuters evaluating their choice of mode are more sensitive to the length of their commute over the price of available options. In examining the elasticity



of the ferry fares, a decrease in fares did not produce significant numbers of new ferry customers. Holding all other variables constant, it would take a large proportional decrease in the fare to attract a significant number of customers.

Also, as these services have been privately operated for some time, one can assume that the fares have been set to meet expenses and provide a profit and a return on capital for the operators. To lower prices as a public policy would present a policy challenge as this would require a public subsidy for privately-operated services. Implementation of such a policy in lieu of investments to existing publicly-owned transit services could present challenges given the limited numbers of customers that would be served, many of them in high-income brackets versus bus commuters living further inland and away from the ferry terminals.

Finally, based on interviews with ferry operators, there is a reluctance to lower fares to the extent that ferries would no longer be perceived as a premium service. For the Monmouth County services that are well subscribed, one operator noted that they have been asked by customers to increase prices rather than lower prices to limit demand for parking at the terminal. NYW, which operates with capacity on its routes from the northern market, also noted that their customers prefer the private crosstown shuttle over use of a public bus, and that they value the premium nature of the service. In sum, decreasing fares may not render significant diversion from bus to ferry, and this policy may not be acceptable to current ferry operators who have built a premium brand targeting high-income commuters.

## 4 Ridership Analysis on Potential New Routes

New ferry terminal locations have often been discussed, most recently as part of NJTPA's *Waterborne Resources Transportation Inventory* (currently underway). The goal of that effort, which is being undertaken for future planning purposes, is to evaluate sites in terms of their prospective for ferry or waterborne freight use.

Three new routes that have the potential to divert bus commuters to the ferry have been identified. These include Edgewater – 125th Street West Harlem Piers, Hoboken – New West 34th Street Ferry Terminal, and South Amboy – Manhattan to Pier 11, World Financial Center (WFC) and East 34th Street.

- **Edgewater to West Harlem 125th Street.** While there is an existing NYW stop in Edgewater NJ, the possibility of a new route directly to the pier at West 125th Street is proposed in response to a new pier. From the new pier, it is a 6-minute walk to the subway station on the #1 train line, which provides connections to midtown and downtown. This route may also provide an opportunity to alleviate vehicular congestion at the Weehawken and midtown ferry terminals.
- **Hoboken/NJ TRANSIT to a new West 34th Street terminal.** This route would take advantage of the newly opened 34th Street Hudson Yards No. 7 subway station. It would pair the Hoboken South ferry terminal and a new Manhattan ferry terminal at West 34th Street, south of the Lincoln Tunnel ventilation towers. The new terminal would serve as a replacement for the current West Midtown Terminal at Pier 79 at 39th Street. Currently, NYW operates services connecting the Hoboken South/NJ TRANSIT Terminal with the ferry terminals at the World Financial Center and at Pier 11 Wall Street. Pairing Hoboken South with the proposed route opens up commutation with six NJ TRANSIT's commuter rail lines, as well as the Hoboken terminal of the HBLR system to New York City Transit's (NYCT) No. 7 subway station at Hudson Yards.
- **South Amboy to Manhattan.** This potential new route was identified for two reasons. First, South Amboy was the terminus site of a prior successful commuter ferry operation to NYC. Second, both the Belford and Atlantic Highlands ferries are beginning to experience saturation as the availability of surface parking is proving to be a constraint to further growth. There is parking availability at Perth Amboy. Additionally, there is no other appropriate growth option in Monmouth County with the exception of the Perth Amboy.

Evaluating these potential new services entail the following steps. The team used US Census Journey-To-Work to determine total trans-Hudson commuter market size (includes relevant New Jersey counties and Rockland and Orange Counties in New York State). To estimate the total number of bus riders with potential to divert to the ferry, we applied the same bus modal share as was used in the 2011 Interagency Study. Commuter survey data provided by the NJTPA and the PANYNJ was utilized to ascertain commuting patterns and socioeconomic attributes of ferry riders and determine the extent to which bus user characteristics match those of ferry users. Bus riders who

present a similar profile are considered eligible to switch to the ferry. For example, we eliminate potential bus riders whose share of expenditures out of household income would exceed that for current ferry riders.<sup>4</sup> Another condition relates to geographic commutation patterns. For instance, any bus commuter that lives within walking distance of their bus stop is eliminated from the potential market as it is unlikely that they would surrender that convenience for additional travel to a ferry landing.

Once the relevant market set was established, the ferry fare elasticity was applied to various price differentials that bus riders could face to access the ferry. An elasticity of -0.24 was used, based on the previously mentioned 2011 Interagency Study.<sup>5</sup>

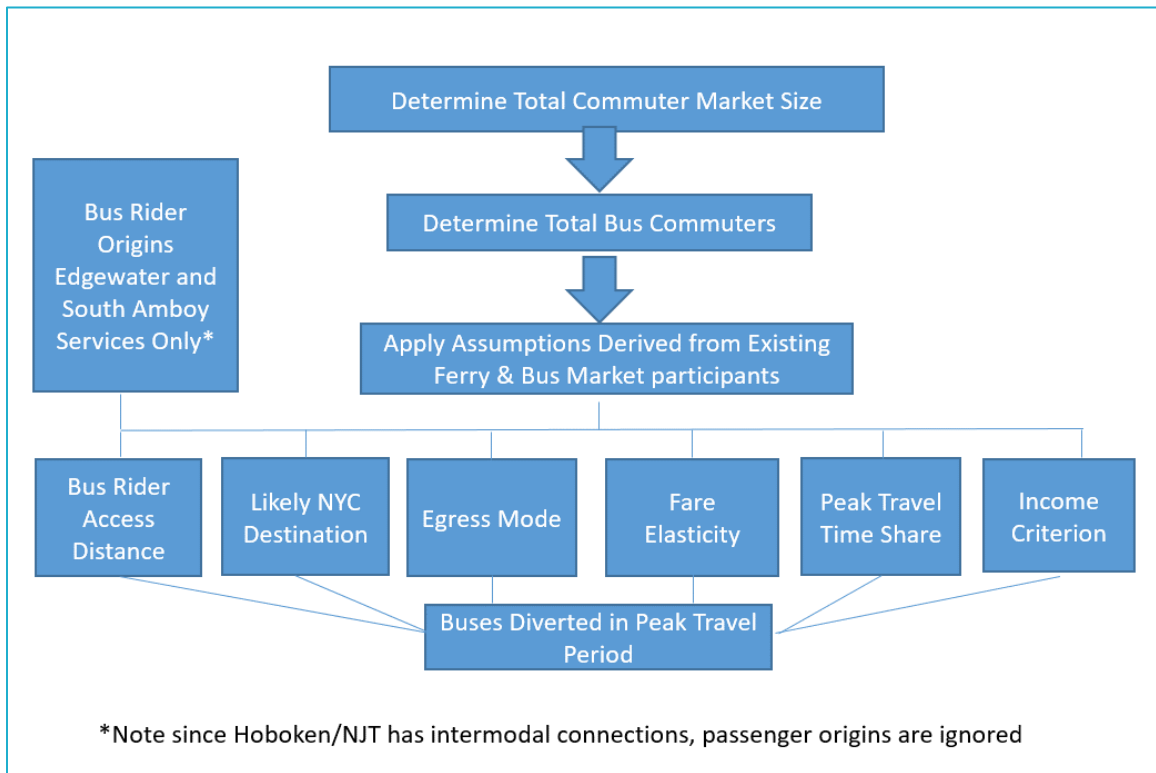
It is important to note that the elasticity utilized was estimated for current ferry riders and may not be the best fit for current bus riders. The elasticity for a bus rider is likely to be higher since they are more likely to consider substitute modes of transport such as rail or car pool. Ferry riders enjoy a “premium service” and are unlikely to view alternate modes as comparable substitutes. Thus their elasticity with respect to fare is likely to be significantly lower. It would be preferable to have an elasticity of ridership specific to bus riders to provide a more accurate gauge of modal switching behavior. This could be estimated via a stated preference survey of trans-Hudson commuters. However, for the purposes of estimating modal switch for this effort, we applied the existing elasticities from prior efforts. The analysis for each service is described below, and Figure 2 provides a comprehensive outline of the process.

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<sup>4</sup> Examination of ferry ridership survey data indicated that on average, ferry commuters spend roughly 2% of their annual household income on commutation.

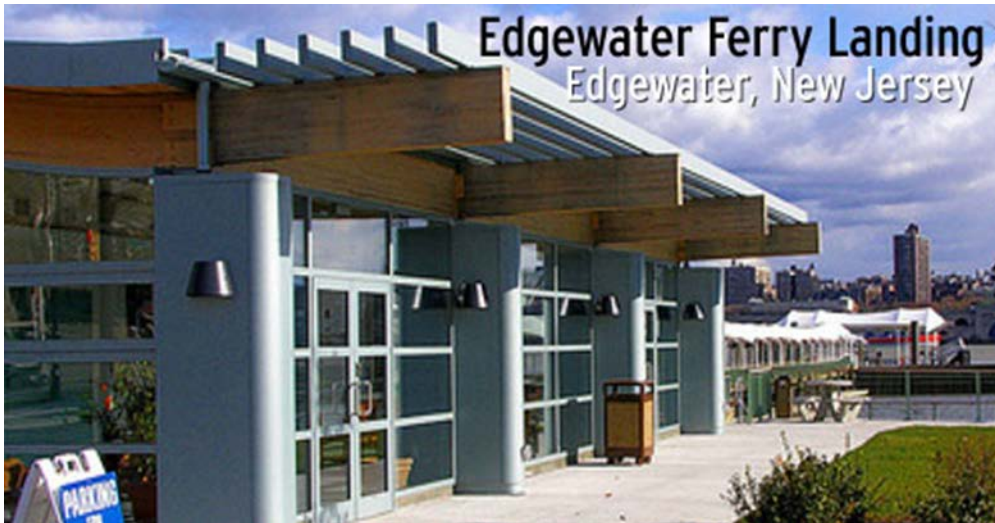
<sup>5</sup> We chose to use the Stated Preference derived -0.24 over the revealed preference study estimate of -0.27 as the latter applies only to current ferry riders while the former incorporates the preferences of all trans-Hudson commuters.

Figure 2: New Routes Methodology Flowchart



Source: Cheng Solutions, 2016

#### 4.1 EDGEWATER – WEST 125TH STREET



Source: NYW

NYW currently operates a trans-Hudson ferry service connecting the Edgewater ferry pier in Bergen County to the West Manhattan Ferry Terminal/Pier 79 at West 39<sup>th</sup> Street. Approximately 900 one-way trips are made daily on this route, according to recent ferry ridership reporting to NJ TRANSIT and the PANYNJ. There may be additional ferry opportunities in this commuter market as there is no direct rail competition to the ferry in eastern Bergen County. This market is also worth further exploring for potential peak PABT demand mitigation given the high percentage of bus customers commuting from this area.

A new ferry service from Edgewater directly to the newly constructed West Harlem Pier at West 125<sup>th</sup> Street in Manhattan has been suggested by officials in the Town of Edgewater to supplement the existing service to Pier 79. This route could offer a new option for trans-Hudson commuters to access Midtown Manhattan via a connection to the Broadway (No. 1) subway line, as opposed to the existing ferry route, which requires bus connections on congested streets on both sides of the Hudson River. The West Harlem Pier, which is newly constructed by NYCEDC, is a 6-minute, 1/3-mile walk to the 125<sup>th</sup> Street subway station on the No. 1 Line.

Capacity utilization of vessels on the existing ferry route from Edgewater to Pier 79 is, like other ferry services, very light. Adding a new route from Edgewater to West 125<sup>th</sup> Street could therefore be feasible with existing vessels. It would cut several minutes off the trip over water (compared to the existing ferry route from Edgewater) and also could reduce travel time for commuters accessing destinations close to West 125<sup>th</sup> Street. An efficient connecting service to the subway would likely be a critical element for success of this service, as the 1/3-mile walk to the subway, however short, may not appeal to all commuters.

A new ferry service from Edgewater would predominantly attract Manhattan-bound commuters from Bergen County in New Jersey and possibly Rockland County in New York. Access times for commuters from counties south of Bergen would likely be prohibitive relative to other transportation options. This assumption is supported by NJ TRANSIT's origin and destination survey data for the Edgewater-Pier 79 route. Nearly all of the survey respondents commuting on the ferry to Manhattan from Edgewater began their trip in Bergen County, and 72% started in Edgewater itself. See Table 3 for a breakdown of the point of origin for the Edgewater-West 39th St Ferry passengers.

In addition to point of origin constraints, the current Edgewater – West 39th Street service is limited by a lack of intermodal connections at the destination terminal. There are no convenient connections to the NYC transit system from the 39th Street terminal, although commuters journeying to areas outside this immediate area are able to take an operator-provided bus service closer to their ultimate destination. As a result, this service is convenient primarily for commuters who work within walking distance of Pier 79 in Midtown Manhattan. Indeed, the current customer base for this service is predominantly composed of such commuters.

Table 4 breaks down the ultimate destinations of the Edgewater ferry passengers. It shows that 45.8% of riders end their trip in the Manhattan neighborhoods of Midtown, Chelsea or Clinton; 39.3% end up in the Gramercy Park, Murray Hill neighborhoods. Edgewater ferry passengers heading downtown were 8.5% of the sample and uptown commuters were 5.4% of the sample.

Table 3: Edgewater Ferry Passenger Origins

Origin County	Origin City	Origin State	Observations	Percent
Bergen	Cliffside Park	NJ	7	3.5
Bergen	Dumont	NJ	1	0.5
Bergen	Edgewater	NJ	142	71.7
Bergen	Englewood	NJ	1	0.5
Bergen	Englewood Cliffs	NJ	2	1.0
Bergen	Fort Lee	NJ	35	17.7
Bergen	Leonia	NJ	2	1.0
Bergen	Park Ridge	NJ	1	0.5
Bergen	River Vale	NJ	1	0.5
Bergen	Teaneck	NJ	1	0.5
Bergen	Tenafly	NJ	1	0.5
Hudson	Weehawken	NJ	1	0.5
Rockland	New York	NY	1	0.5
Rockland	Tappan	NY	1	0.5
Union	Union City	NJ	1	0.5
<b>Totals</b>			198	112

Source: NJ TRANSIT Ferry Customer Study Report, June 2014 Final Report



Proximity to the NYC subway system would be the major advantage for an Edgewater service to the landing at 125th Street - presumably West Harlem Piers - over the current service to West 39th Street. West Harlem Piers lies only 0.3 miles from a NYC subway connection at 125th Street and Broadway, a six-minute walk at an approximate speed of three miles per hour. It is conceivable that such a connection would expand the market to include Bergen County commuters traveling to anywhere in Manhattan and the remaining four boroughs. However, this service would be most convenient and therefore attractive to commuters whose ultimate destination is anywhere on the Westside of Manhattan, Upper Manhattan, Inwood, Midtown and even as far south as Lower Manhattan, the financial district and downtown Brooklyn.

It is not clear, however, that commuters currently taking the bus to the PABT and ending their trip in Midtown or other areas via walking or easy connections to NYCT would find much advantage in switching to a more expensive ferry to 125th Street. Such a service would put these commuters further from their ultimate destinations and would require walking another 0.3 miles for an additional connection to the NYC subway. Perhaps as importantly, relative to the bus, the Edgewater – 125th Street service would likely require additional access time to the Edgewater landing from points in New Jersey as there are currently no parking facilities in Edgewater. Hence, park-and-ride commuters would require a shuttle bus connection once in the area. This would add significantly to the total travel time. By comparison, according to the NJ TRANSIT Ferry O&D survey data, the median distance the Bergen County bus commuter travels to their bus stop is just 0.4 miles, about a 10-minute walk.

Table 4: Edgewater Ferry Passenger Ultimate Destinations

Destination Borough	Destination Area	Observations	Percent
Brooklyn	Sunset Park	1	0.6
Manhattan	Central Harlem	1	0.6
Manhattan	East Harlem	2	1.2
Manhattan	Gramercy Park and Murray Hill	66	39.2
Manhattan	Greenwich Village and Soho	8	4.8
Manhattan	Lower East Side	3	1.8
Manhattan	Lower Manhattan/Financial District	3	1.8
Manhattan	Midtown, Chelsea, and Clinton	77	45.8
Manhattan	Upper East Side	4	2.4
Manhattan	Upper West Side	2	1.2
Queens	Northwest Queens	1	0.6
<b>Totals</b>		<b>168</b>	<b>100.0</b>

Source: PANYNJ Ferry Rider Origin and Destination Survey

Given the foregoing, it is reasonable to eliminate all Bergen County bus commuters whose ultimate destination is Midtown New York from the potential Edgewater – 125th Street ferry market, as

Midtown is generally within walking distance of the PABT and to abandon it for the ferry would require a NYC subway ride. Further, since parking in Edgewater is a major constraint, the majority of passengers for a new ferry service would most likely be drawn almost exclusively from the town of Edgewater and the bordering towns of Fort Lee and Cliffside, each of which constitutes 71.7%, 17.7% and 3.5%, respectively, of current ferry riders from Edgewater.

Finally, it is unlikely, given the NYC subway shuttle connection to Grand Central Station, that bus commuters originating from the above three towns who are currently accessing points on the East Side including, the Upper East Side, Murray Hill, Gramercy Park, the East Village and the Lower East Side, would consider switching to the ferry at 125th Street, since it lands much further away from their ultimate destination. Therefore, the pool of potential Edgewater-125th St ferry riders that can reasonably be extracted from the Bergen County bus commutation market is confined to bus commuters who begin their trip in Edgewater, Fort Lee and Cliffside and end their commute in Upper Manhattan and the Bronx, the Upper West Side, Lower Manhattan and downtown Brooklyn.

#### 4.1.1 Origin Market

According to the US Census Journey to Work dataset, the total size of the market for commuters from Bergen County to NYC is 80,002 people. Multiplying by an estimated bus modal share of 36.3%<sup>6</sup> leaves 29,041 Bergen-NYC bus commuters. The potential market is adjusted further by considering only commuters originating in the towns of Edgewater, Fort Lee and Cliffside Park, which according to the NJ TRANSIT Bus Origin and Destination survey data, aggregates to 19.6%. Therefore, based on point of origin, the total size of the bus market that could conceivably switch to an Edgewater – 125th Street ferry service is 5,694 persons.

#### 4.1.2 Ultimate NYC Destination

The share of bus commuters from the relevant three-town Bergen County market (Edgewater, Fort Lee and Cliffside Park) traveling to Upper Manhattan and the Bronx, the Upper West Side, Lower Manhattan/Financial District and downtown Brooklyn amounts to 8.5%. Table 5 summarizes the ultimate destinations. Controlling for origin and ultimate destination pares the potential market for converted bus-to-ferry to 484 new riders.

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<sup>6</sup> This figure is provided in the 2011 Interagency Study of Regional Private Passenger Ferry Services in the New York Metropolitan Area.

Table 5: Edgewater, Fort Lee and Cliffside Park Bus Commuter Ultimate NYC Destinations

Locale	Observations	Percent
Borough Park	2	0.2
Bushwick and Williamsburg	2	0.2
Central Bronx	1	0.1
Central Brooklyn	2	0.2
Central Harlem	5	0.5
East Harlem	4	0.4
Flatbush	1	0.1
Gramercy Park and Murray Hill	228	23.9
Greenpoint	2	0.2
Greenwich Village and Soho	38	4.0
Inwood and Washington Heights	1	0.1
Lower East Side	24	2.5
Lower Manhattan/Financial District	52	5.5
Manhattan	120	12.6
Midtown, Chelsea and Clinton	384	40.3
North Queens	4	0.4
Northwest Brooklyn	3	0.3
Northwest Queens	15	1.6
Outer Borough	1	0.1
Outside	10	1.1
Southeast Bronx	1	0.1
Southwest Queens	1	0.1
Sunset Park	1	0.1
Upper East Side	24	2.5
Upper West Side	11	1.2
West Central Queens	1	0.1
West Queens	6	0.6
Unknown	7	0.7
<b>Totals</b>	<b>952</b>	<b>100.0</b>

Source: NJ TRANSIT Bus Origin &amp; Destination Survey

### 4.1.3 Income Constraint

In keeping with an assumption that annual transportation outlays should be no more than 2% of total household income, we estimate that 39.7% of current bus commuters in the Edgewater, Fort Lee and Cliffside Park market meet this criterion (see Table 6).<sup>7</sup> This reduces the potential Edgewater-125<sup>th</sup> St ferry market to 193 riders. We arrive at this share by assuming that the monthly ferry fare from Edgewater to 125th Street will be the same as the current fare from Edgewater to Midtown West 39th Street, or \$231.50. This amounts to \$2,778 on an annualized basis. Therefore, to meet the 2% criterion, a commuter must have an annual household income of \$138,900. Unfortunately, the income categories given in the NJ TRANSIT Bus survey are not sufficiently granular, forcing us to settle on the figure of \$100,000 per year. Nonetheless, this comports well with previous research conducted for the PANYNJ<sup>8</sup> that found a positive relationship between ferry ridership and household income of at least \$100,000 per year

Table 6: Edgewater, Fort Lee and Cliffside Park Bus Commuter Income

Household Income	Observations	Percent
Under \$15,000	31	3.9
\$15,000-\$24,999	32	4.1
\$25,000-\$34,999	28	3.5
\$35,000-\$49,999	76	9.6
\$50,000-\$74,999	171	21.6
\$75,000-\$99,999	138	17.5
\$100,000-\$149,999	175	22.2
\$150,000 and Over	139	17.6
<b>Totals</b>	<b>790</b>	<b>100.0</b>

Source: NJ TRANSIT Bus Origin & Destination Survey

### 4.1.4 Peak Period

According to the PANYNJ, 21.6% of trans-Hudson total bus arrivals, including both NJ TRANSIT and other commuter buses, occur during the peak period, defined as between 7-8 AM.<sup>9</sup> Further adjusting the pool of new ferry commuters to include only peak period travelers reduces the total number from 193 to just 42 potential ferry riders who are likely to be diverted from bus service to PABT.

<sup>7</sup> A 2% share of household income would roughly align with expenditures of current trans-Hudson ferry riders, based on an analysis of ferry rider characteristics documented in the 2014 NJ TRANSIT Ferry Customer Study Report.

<sup>8</sup> See 2011 Interagency Study Of Regional Private Passenger Ferry Services in the New York Metropolitan Area.

<sup>9</sup> See PANYNY “Midtown Bus Master Plan Bus & Passenger Activity Forecasts” Prepared By Planning & Regional Development Department August 1, 2013, Revised January 5, 2016

#### 4.1.5 Fare Elasticity

Interviews with ferry operators (see Appendix A) strongly suggest that fares will not be reduced unless a public agency commits to a significant subsidy. The effect of fares on potential ridership is therefore derived based on current fares, applying an elasticity of  $-0.24$ <sup>10</sup> - the same parameters as were used for existing markets in the 2011 *Interagency Study of Regional Private Passenger Ferry Services in the New York Metropolitan Area*. The use of current fares will constitute the “base case.” In order to gauge how ridership may be affected should a subsidy be offered, the ferry fare was subsequently simulated to fall by 10%, 20% and 50%, respectively. The elasticity is applied to the percent differential in monthly fares. Table 7 displays the results for each level of market size and fare reduction. Note that at a 50% reduction in ferry fare, the differential between the ferry and bus fares becomes negative such that ferry ridership increases.

Table 7: Ferry Ridership Edgewater-West 125<sup>th</sup> Street – Varying Fare Scenarios<sup>11</sup>

Fare Scenario	Percent Reduction in Ridership from Final Market Estimate	Ridership	Peak Period Buses Diverted
Base Case Ridership	15.2	35	0.6
Reduced Fare – 10%	11.0	37	0.6
Reduced Fare – 20%	6.8	39	0.7
Reduced Fare – 50%	-5.9	88	1.5

Source: Cheng Solutions

#### 4.1.6 Final Estimates

Using the above qualifications on the market in the base case produces 35 ferry passengers per day. At a capacity of 58.5 persons per bus, this amounts to less than one bus diverted per day in the peak period. A 50% reduction in the ferry fare results in 88 new ferry commuters. This amounts to 1.5 peak-period buses diverted per day, or two buses when rounding to the highest integer.

<sup>10</sup> This falls in the inelastic range such that an increase in the fare would result in a less than proportional decrease in ridership. But this elasticity was measured by examining current ferry riders who demand a premium service and do not see other modes as appropriate substitutes. Thus given their need for a premium luxury service they are a more “captive” market. Bus riders, on the other hand are not in the same mindset. Their fare elasticity, as a consequence is likely to be significantly higher as they consider the bus and rail as substitutes. Thus a small increase in prices is liable to yield a much larger proportionate decrease in ridership. Knowing the elasticity for a broader market is not possible given the current information set, the Interagency Study level of  $-0.24$  was applied, with the caveat that in reality, this figure is likely to be significantly higher.

<sup>11</sup> At a 50% fare reduction, the number of eligible riders increases as exponentially more of them can achieve the 2% of income constraint. In the case of Edgewater – 125<sup>th</sup> Street, the income constraint falls to \$50,000 per year for which 78.9% of bus riders can satisfy

## 4.2 HOBOKEN – 34TH STREET



Source: NYcurbed.com and MTA

A second possible ferry service is one that connects the terminal at Hoboken South / NJ TRANSIT to a new terminal at 34th Street on the West Side of Manhattan at Hudson Yards. NYW currently runs a service from the Hoboken NJ TRANSIT terminal to both Pier 11/Wall Street and to the World Financial Center. NYW also runs a service from Hoboken North to Midtown West 39th Street. It is assumed that the new terminal at Hudson Yards will replace the Midtown West 39th Street terminal, but not change the travel behavior for those already traveling there from Hoboken North. The analysis is therefore confined to the potential ridership from the Hoboken/ NJ TRANSIT terminal to Hudson Yards.

The primary advantage for the Hudson Yards/34th Street terminal will be connecting service to the MTA via the new No. 7 Line subway extension and the M34 Select Bus Service. Moreover, Hudson Yards will be an attractive destination for commuters in its own right as planned office and retail development in the area proceeds.

### 4.2.1 Access to New Jersey Sites

The Hoboken/NJ TRANSIT Terminal offers no free parking. Paid parking is available, but it is expensive and for many commuters currently crossing the Hudson by bus would be cost prohibitive. Moreover, it has insufficient capacity. There are instead several mass transit connections to the terminal including NJ TRANSIT trains and buses, light rail service, private buses (Academy) and the PATH train.

Because of its connections to mass transit, the customer base at the Hoboken/NJ TRANSIT ferry terminal is far more geographically diverse than its Hoboken North counterpart. Whereas almost all of the Hoboken North commuters (work trips only) arrive there from Hudson County, only 35.9% of commuters using Hoboken/NJ TRANSIT begin their trip in Hudson County. The remainders were composed of Bergen County commuters (24.3%), followed by Essex County (13.4%), Union County (5.4%), Morris County (5.0%), Passaic County (4.8%) and Rockland and Orange Counties in New York (5.2%).

Just under 19% of commuters at this terminal walked; 63.4% took NJ TRANSIT and 3.5% arrived via the Hudson-Bergen light rail. Only 4.1% took a NJ TRANSIT bus; 2.3% took some other bus, and only 3.0% drove and parked.

Table 8 and Table 9 make clear that the market for trans-Hudson ferry commutation at the Hoboken/NJ TRANSIT terminal extends from Hoboken itself to anywhere in New Jersey and New York State where NJ TRANSIT provides service either via rail or bus. Therefore, the geographic market is defined as bus commuters travelling to NYC from nine counties west of the Hudson River – seven in New Jersey and two in New York. Counties that accounted for less than 2% of the commuter ridership were excluded as being outliers.

Table 8: Ferry Commuter Origins at Hoboken/NJ TRANSIT Ferry Terminal

County	Observations	Percent
Bergen	203	24.3
Essex	112	13.4
Gloucester	4	0.5
Hudson	298	35.6
Hunterdon	1	0.1
Middlesex	4	0.5
Monmouth	15	1.8
Montgomery	2	0.2
Morris	42	5.0
Orange	26	3.1
Pennsylvania	1	0.1
Passaic	40	4.8
Rockland	19	2.3
Somerset	18	2.2
Sullivan	1	0.1
Sussex	3	0.4
Ulster	1	0.1
Union	45	5.4
Warren	1	0.1
<b>Total</b>	<b>836</b>	<b>100.0</b>

Source: NJ TRANSIT Ferry Customer Study Report, June 2014 Final Report



Table 9: Ferry Access Mode at Hoboken/NJ TRANSIT Ferry Terminal

Access Mode	Observations	Percent
Auto/Drive & Park	28	3.0
Bicycle	10	1.1
Carpooled/Dropped Off	23	2.5
Hudson-Bergen Light Rail	32	3.5
NJ TRANSIT Bus	38	4.1
NJ TRANSIT Rail	584	63.4
Other	1	0.1
Other Bus	21	2.3
Taxi	12	1.3
Walk Only	172	18.7
<b>Total</b>	<b>921</b>	<b>100.0</b>

Source: NJ TRANSIT Ferry Customer Study Report, June 2014 Final Report

The total commuter market for these nine counties is given by the US Census Journey to Work data and is displayed in Table 10.

Table 10: Workers Journeying to NYC by Key Market County

County	Commuters	Percent
Bergen	80,002	25.6
Essex	41,106	13.2
Hudson	91,971	29.5
Morris	13,495	4.3
Orange	17,207	5.5
Passaic	12,510	4.0
Rockland	24,408	7.8
Somerset	8,399	2.7
Union	22,982	7.4
<b>Total</b>	<b>312,080</b>	<b>100.0</b>

Source: US Census Journey to Work 2013

From the 2011 Interagency Study the trans-Hudson bus mode share is 36.3%. This is a broad estimate that in all likelihood varies significantly by county depending upon the distance, speed and most importantly availability of a bus service. Nevertheless, the application of this mode share to the total commuter market yields 113,285 potential trans-Hudson bus commuters eligible to switch to the proposed ferry service.

#### 4.2.2 Access Modes

According to the NJ TRANSIT Bus Origin and Destination Survey data, the overwhelming majority of bus commuters (82.6%) walk to their bus stop at median distance of 0.40 miles (Table 11).<sup>12</sup> At a speed of three miles per hour, that is about a 10-minute walk.

It is doubtful that bus commuters would prefer to abandon that convenience for longer access time to the ferry landing at Hoboken/NJ TRANSIT, particularly if they must access their final NYC destination via another ride on public transit. This significantly reduces the market potential for the ferry to comprise only those who drive and park. The reasoning is that since they are already driving and parking, it can be assumed that they are more likely to have the financial means to drive and then pay for parking facilities at the Hoboken/NJ TRANSIT terminal. The application of the share of commuters using private autos or carpools (13.6%) for bus access reduces the potential market to 15,401 riders.

Table 11: Access Modes at NJ TRANSIT Bus Commuters

Access (to NJ TRANSIT) Mode	Observations	Percent
Another Bus/Shuttle	32	1.1
Bike	1	0.0
Carpooled/Dropped Off	67	2.3
Drove Car and Parked	388	13.6
Jitney/Van	1	0.0
Light Rail	4	0.1
NJ TRANSIT Train	1	0.0
PATH	1	0.0
Taxi	2	0.1
Walked	2,357	82.6
<b>Total</b>	<b>2,854</b>	<b>100.0</b>

Source: NJ TRANSIT Bus Origin and Destination Survey

#### 4.2.3 Egress Modes

Table 12 provides the egress modes of bus commuters arriving at the PABT from the aforementioned key market area to NYC. As in the case of the proposed service from Edgewater – 125th Street, it is assumed that NJ TRANSIT bus riders who work within walking distance to the PABT are unlikely to switch to a ferry for which they would have to take a NYC subway from Hudson Yards to their final destination. However, NJ TRANSIT bus riders who access the PABT then connect to NYCT may consider a ferry if the transit connection could either be eliminated or significantly eased. Therefore,

<sup>12</sup> Distances for each leg of the commuter's journey were not given directly in the survey data, however, map coordinates were given. Cheng Solutions used these coordinates to access the Google maps distance matrix to derive exact walking and driving distances. Travel times were imputed from distance and mode.

we include as potential riders those commuters currently using the subway or bus to access their final destination (46.1%) from the PABT. This reduces the potential market to 7,092 persons.

Table 12: Egress Modes of Bus Commuters Arriving at the PABT

Egress Mode	Observations	Percent
Another Bus/Shuttle	11	0.2
Bike	3	0.0
Carpooled/Dropped Off	11	0.2
Drove Car and Parked	13	0.2
Jitney/Van	7	0.1
NJ TRANSIT Train	1	0.0
NYC Bus	256	3.8
Other	6	0.1
PATH	1	0.0
Subway	2,846	42.3
Taxi	38	0.6
Walked	3,543	52.6
<b>Total</b>	<b>6,736</b>	<b>100.0</b>

Source: NJ TRANSIT Bus Origin and Destination Survey

#### 4.2.4 Ultimate NYC Destination

A service from Hoboken/NJ TRANSIT to Hudson Yards offers no advantage for commuters ending their trip in Lower Manhattan, as there is already a service from Hoboken/NJ TRANSIT to Pier 11 and to the WFC. Hudson Yards would be attractive for those remaining strictly in Midtown/Clinton/Chelsea, and could plausibly pick up some commuters traveling to Gramercy/Murray Hill as long as the No. 7 Line extension is available. The number of commuters traveling to Midtown and Gramercy/Murray Hill accounts for 64.6% of the sample. The application of this share leaves 4,583 commuters in the market.

#### 4.2.5 Income Constraint

With respect to income, the same principle applied to the Edgewater – 125th Street service is applied here as well. Assuming the ferry fare charged on the Hoboken North to Lower Manhattan service prevails for service to Hudson Yards, the total annual fare is \$2,748. Under the aforementioned 2% assumption, this means that to be eligible to switch to a ferry service, the bus commuter household income must be at least \$137,400. Because of the lack of granularity in the NJ TRANSIT Bus data, the cut off for income was again placed at \$100,000 per year. The data show that 44.4% of bus commuters meet this criterion (Table 13) and are therefore included in the final potential market. We stress that this is an optimistic estimate. Not all commuters earning above \$100,000/year will make the switch, but it is from this group that the ferry will likely draw most of its riders. After application of the income constraint, the size of the market falls to 2,036.

Table 13: NJ TRANSIT Bus Commuter Household Income (Key 9-County Market)

Income	Observations	Percent
Under \$15,000	110	1.8
\$15,000-\$24,999	151	2.5
\$25,000-\$34,999	250	4.1
\$35,000-\$49,999	551	9.1
\$50,000-\$74,999	1,216	20.1
\$75,000-\$99,999	1,078	17.9
\$100,000-\$149,999	1,273	21.1
\$150,000 and Over	1,410	23.3
<b>Totals</b>	<b>6,039</b>	<b>100.0</b>

Source: NJ TRANSIT Bus Origin and Destination Survey

#### 4.2.6 Peak Period

As in the case of Edgewater – 125th Street, we include the PANYNJ’s peak period hour of 7-8 AM only, which accounts for 21.6% of trans-Hudson bus arrivals. After application of this share the Hoboken/NJ TRANSIT – Hudson Yards ferry commuter market falls to 441 riders.

#### 4.2.7 Price Elasticity

Finally, the issue of pricing and price sensitivity must be addressed. While there is currently a public discussion about reducing ferry fares via public subsidy, for purposes of this study, price sensitivity is considered at present rates. As with the potential Edgewater – 125th Street service, we applied a ferry fare elasticity of -0.24 to the likely differential between the monthly ferry and bus fares. Since average fares are not given in the bus survey data, we calculate the difference between the monthly bus fare to NYC from the Hoboken/NJ TRANSIT terminal (\$107) and the monthly ferry fare to Pier 11/WFC from the same terminal (\$229). Application of the elasticity to this price differential reduces the potential diversion of bus riders to the ferry to 305 riders per day.

#### 4.2.8 Final Estimates

The above qualifications yield a base case of 305 trans-Hudson bus passengers per day that could plausibly make the switch to a ferry service in the peak period. At a capacity of 58.5 persons per bus, this amounts to 5.2 buses (6 after rounding) diverted per day in the peak period. As was stressed earlier, this is an optimistic estimate. It will be reduced if, among other factors, not all potential bus riders that meet the income criterion actually make the switch and/or the elasticity of ridership with respect to fare is higher than what was given in previous literature. Both scenarios are extremely likely. For example, if only 50% of those meeting the income constraint actually make the switch, the number of buses diverted falls to 3. If we assume the elasticity is double what has been used here as well as assuming only 50% of our income class make the switch, the number of diverted riders falls to 2. The model can accommodate variations in all other variables discussed in this analysis as well. Table 14 shows results for varied ferry fare reductions according to proposals for existing services.

Table 14: Ferry Ridership Hoboken-NJ TRANSIT – West 34<sup>th</sup> Street Under Varying Fare Scenarios

Fare Scenario	Percent Reduction In Ridership from Final Market Estimate	Peak Period Ridership	Peak Period Buses Diverted
Base Case – No Change	27.4	320	5.5
Riders at 10% Reduced Fare	22.2	343	5.9
Riders at 20% Reduced Fare	17.1	365	6.2
Riders at 50% Reduced Fare	-1.7	804	13.7

Source: Cheng Solutions

Note that because 82.4% of the nine-county bus commuters meet the income requirement when ferry fares are reduced by 50%, and ridership climbs to 804.

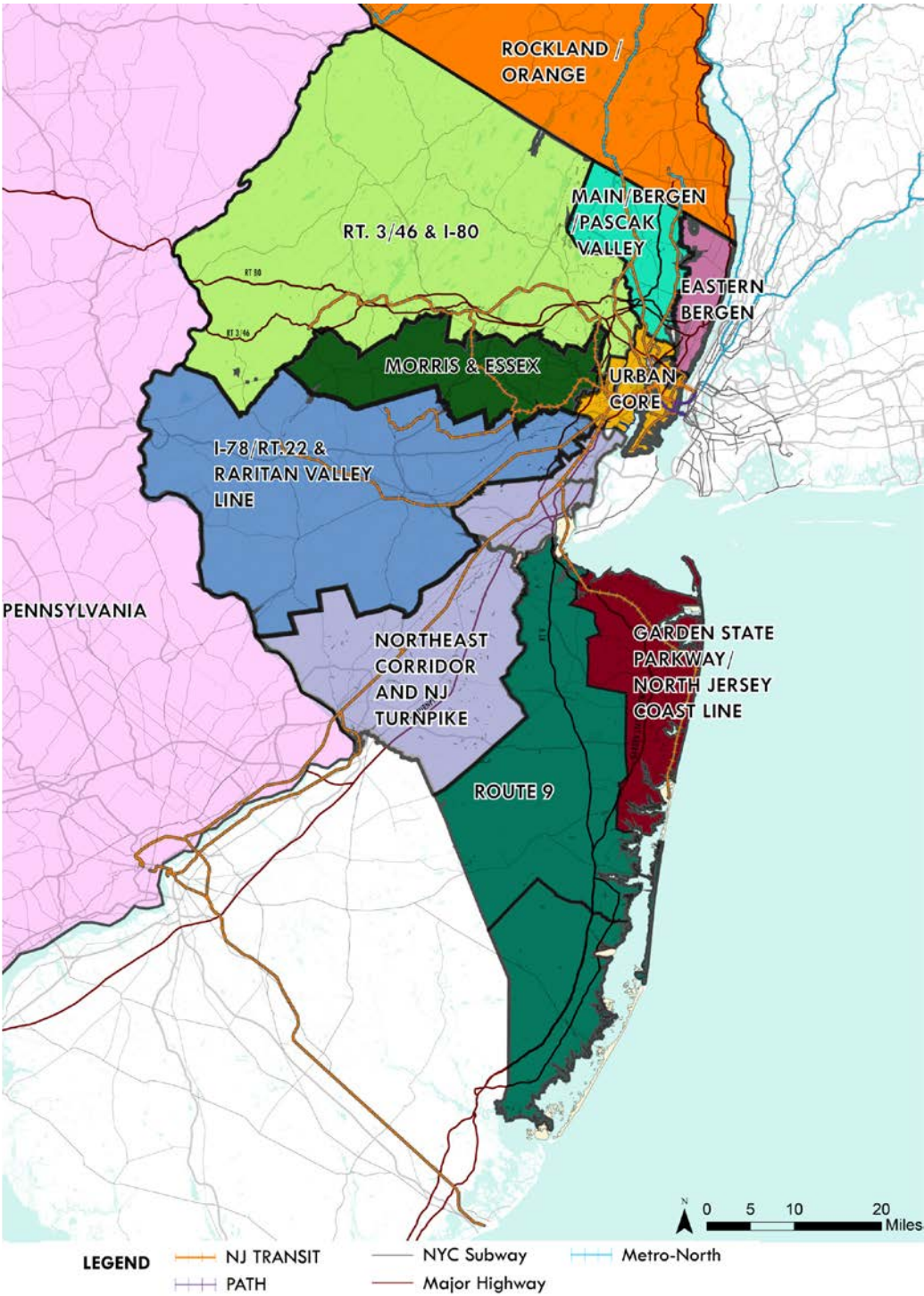
### 4.3 SOUTH AMBOY – MANHATTAN

Also under consideration for expansion is a potential new ferry service from South Amboy, New Jersey to Pier 11/Wall Street, World Financial Center and East 34<sup>th</sup> Street. In recent interviews with ferry operators and county planners as part of the *NJTPA Waterborne Transportation Inventory Assessment*, South Amboy was suggested as having potential to expand ferry ridership from Middlesex and Monmouth Counties. South Amboy is in Middlesex County on Raritan Bay and southwest of the southern tip of Staten Island. The waterfront site has good access to a regional road network off U.S. 9 where access to a new terminal would not require traffic to weave through a residential community.

A South Amboy to Lower Manhattan ferry route previously served the trans-Hudson market. This service was initiated in February 2002 to accommodate area commuters after the attacks of September 11, 2001. The service was discontinued in 2005 as high fuel costs combined with lower than expected ridership and dredging costs made the route uneconomical for the operator. The City of South Amboy plans to build a permanent ferry terminal as part of a larger waterfront development project. South Amboy also hosts a NJ TRANSIT commuter rail station.

South Amboy is at the northern tip of the Garden State Parkway/North Jersey Coast Line trans-Hudson travel corridor (refer to Figure 3). This travel corridor is forecasted by NJ TRANSIT to have an 11% bus market share for trans-Hudson trips in 2040, a 35% rail share, and an 8% ferry share, with the remainder commuting predominantly by auto. An unsubsidized ferry service is expensive compared to the public-sector transit alternatives in this market. For the Atlantic Highlands to Manhattan service, commuters may purchase discounted tickets in a 40-trip book at a cost of \$655 or \$16 for a one-way cost trip. By comparison, a monthly train pass from the South Amboy station to Penn Station New York is \$380 and would take one hour. A new ferry service from South Amboy, unlike at the Belford and Atlantic Highlands locations, would have to compete directly with the commuter rail option.

Figure 3: West-of-Hudson Trans-Hudson Travel Corridors



Source: Trans-Hudson Commuting Capacity Study, NJ TRANSIT

A ferry terminal at this location is also likely to be constrained by local adjoining vehicle parking capacity. Unlike many of the new East River ferry terminals being planned in the NYCEDC Citywide ferry expansion, a new South Amboy terminal is not currently being planned in conjunction with up-zoning for high-rise residential development. This option is unlikely to draw price-sensitive commuters from the bus market but may still be attractive to high-income commuters working in Lower Manhattan.

#### 4.3.1 New Jersey Market

We consider only commuters from Middlesex County as potential South Amboy customers. First, there is already a ferry service from Atlantic Highlands as well as Belford in Monmouth County, which suggests that any Monmouth County commuters with a propensity to ride the ferry would already be doing so. This logic would exclude all counties south of Monmouth as well including Ocean and Burlington Counties. It is also unlikely that many customers will be drawn from north of South Amboy since access to this proposed service would entail traveling away from the ultimate destination. Mercer County just to the west is possible but commuters from this market would be required to drive a significant distance for access to South Amboy as there are no NJ TRANSIT bus services between these counties. Thus from the US Census Journey-To-Work data, the total number of commuters to NYC from Middlesex County is 39,224.

As in the cases of Edgewater – 125th Street and Hoboken/NJ TRANSIT – West 34th Street, we apply a trans-Hudson bus mode share of 36.3%. The total estimated potential number of trans-Hudson bus commuters eligible to switch to divert to ferry service is therefore 14,238.

#### 4.3.2 Access Modes

In the NJ TRANSIT Bus Origin and Destination survey data set there are relatively few observations of bus riders from Middlesex County (16) traveling to Manhattan for work purposes. Eleven out of the 16 drove and parked for NJ TRANSIT access. By applying the same logic that commuters currently walking to the NJ TRANSIT bus stop are unlikely to abandon that convenience, we consider only commuters (68.8%) who drive and park to catch their bus. The potential market therefore falls to 9,789.

#### 4.3.3 Egress Modes and Ultimate Destination

The proposed South Amboy – Manhattan service would land at Pier 11/ Wall Street, WFC and East 35th Street terminals. Thus Middlesex bus commuters (40%) accessing Lower Manhattan and Gramercy/Murray Hill were considered. Midtown commuters are likely to prefer to stay on the bus since for much of Midtown, East 35th Street is not within easy walking distance. The number of riders is pared down to 3,916.

#### 4.3.4 Income Constraint

With respect to the income constraint, the same principles as the Edgewater – 125th Street service and the Hoboken – 34th Street service were applied. However, the ferry fare, listed by Seastreak's current service from Monmouth County is significantly more expensive (\$655/month) than the



Hoboken and Edgewater services. Annualized to the fare is \$7,860 which if our 2% condition holds, would require a household income of at least \$393,000. The bus rider household income statistics only capture income of \$150,000 and up. We therefore use the share (13.3%) earning at least \$150,000. This condition leaves 522 potential riders.

#### 4.3.5 Peak Period

Application of the peak period share of buses further pares this market down to 113 riders.

#### 4.3.6 Price Elasticity

Using the same pricing and price sensitivity methodology as Edgewater and Hoboken services yields the results shown below. We assume a ferry fare of \$655 per month and a monthly bus fare of \$267 per month.

Like the cases of Edgewater – 125th Street and Hoboken/NJ TRANSIT – Hudson Yards, reducing the ferry fare by 50% raises the share of bus riders who meet the income constraint.

#### 4.3.7 Final Estimates

Under the base case of no change in ferry fares, the above qualifications yield 69 passengers per day that would potentially make the switch to a ferry service from the bus. At a capacity of 58.5 persons per bus, this amounts to 1.2 buses (2 after rounding up) diverted per day in the peak period (Table 15).

Table 15: Ferry Ridership South Amboy-Pier 11/Wall Street – East 34<sup>th</sup> Street Under Varying Fare Scenarios

Fare Scenario	Percent Reduction from Final Market Estimate	Ridership	Peak Period Buses Diverted
Base Case Ridership	39.2	69	1.2
Reduced Fare – 10%	32.6	76	1.3
Reduced Fare – 20%	26.0	84	1.4
Reduced Fare – 50%	-6.1	106	1.8

Source: Cheng Solutions

## 5 Proposed Routes Summary

Based on the analysis of available data, opportunities to greatly increase ferry ridership directly from the pool of bus commuters on the three proposed routes appear limited. While the new ferry routes may offer better options for a niche commuting (high-income) public, absent drastic degradations in the level of service of competing modes, they appear to have limited impact on the peak-period bus commutation market. We attribute this primarily to the more onerous intermodal connections required by the ferry and a large difference in the household incomes of ferry riders compared to bus riders.

Table 16 provides a summary of diverted bus riders various fare levels. Note again that this analysis is specific to examining the degree to which ferries will draw only from bus commuters. The extent to which commuters using any other mode would switch is not relevant for the current exercise. Hence this analysis should not be viewed as a total ridership analysis or market analysis regarding the viability of these new routes.

Table 16: Summary Bus to Ferry Riders All Proposed Services

Fare Scenario	Ridership	Peak Period Buses Diverted
Base Case — No Change	424	7.3
Riders at 10% Reduced Fare	456	7.8
Riders at 20% Reduced Fare	488	8.3
Riders at 50% Reduced Fare	998	17.1

Source: Cheng Solutions

## 6 Conclusions

Increasing parking options, decreasing fares, and/or adding new routes may increase ferry ridership. Additionally, maintaining bicycle access and assuring adequate bicycle parking capacity at ferry facilities on both sides of the Hudson River should be a consideration in future planning. However, it is unlikely that the increase in ferry customers would have sufficient mode diversion effects from buses to affect the peak-period design capacity of a new PABT. The commuter bus and ferry markets have different customer bases. There may not be significant inland bus customers that would find an additional intermodal connection with a ferry to be an attractive daily commutation choice given that bus customers already have longer commutes than current ferry customers.

However, given the dynamic nature involved in estimating ridership among different modes, a stated preference survey should be completed for improved certainty of these results. Ferries do offer flexible opportunities as interim commutation capacity should rail or bus capacity be constrained during the construction of improvements, as well as during any potential outages due to labor or storm events. The ferry companies already have experience in working with public authorities on emergency transportation planning through leases of additional vessels and arrangements for shuttle connections at park-and-ride lots and locations such as Liberty State Park, which would be useful in planning PABT interim construction-related capacity.

### 6.1 NEXT STEPS

This analysis was done for the sole purpose of addressing the larger planning question of whether ferry ridership can increase to levels that may merit design changes for a redeveloped PABT. This analysis is not meant to assess the market feasibility of new ferry routes from a commercial perspective or whether ferries deserve increased governmental support. Ferries have demonstrated themselves to be an important component of a network for transportation resiliency and may have positive attributes that are not addressed by this effort.

Additional studies, such as a comprehensive mode choice model using either stated preference or revealed preference survey data would be required particularly since levels-of-service among the other modes have changed since the 2011 Interagency Study was completed. The ferry and bus origin and destination data used in this study is a good beginning to a more comprehensive modal choice analysis. To complete a trans-Hudson mode choice analysis, similar information for rail customers and commuters who drive and park or car pool would be required. This would enable an analyst to more accurately gauge the relationships between mode choice and travel time, travel costs including the fare, modal attributes and the socio-demographics of the commuting public. These relationships would be quantified such that estimates of ridership could be extracted under simulated changes in any of the critical variables. For instance, the user of the final mode could determine how ferry ridership might change if bus fares increased or bus services changed either for the better or for the worse.

## 7 Interviews with Trans-Hudson Ferry Operators

As part of the Trans-Hudson Commuting Capacity Study, to help inform an analysis on the potential of the ferry mode to manage trans-Hudson and PABT peak demand, Cheng Solutions solicited feedback from current ferry operators. Feedback was solicited through phone interviews with senior executives of current ferry companies, including Hornblower (interview conducted 6/9/16), NYW (interview conducted 6/13/16), and Seastreak (interview conducted 6/17/16). Each phone interview lasted approximately one hour. A list of questions—included below—was provided to the interviewees in advance of the phone interview.

Representatives from these organizations were asked to comment on the following topics:

- Overall ferry market and constraints
- Inland connections to the ferry terminal
- Service cost issues
- Potential areas for expansion

Not every interviewee was able to respond to every question nor was every question covered given the specific organization's business model and/or the allotted time for the interview. This document provides a summary of the feedback.

### 7.1 SUMMARY

Major common themes that emerged from the interviews include:

- All operators cited insufficient parking as a constraint towards growing their ridership in all or some of their routes. However, the operator with this as their most pronounced constraint is Seastreak, as the bulk of their customers arrive at their Atlantic Highlands terminal via car. Parking adversely affects the opportunity to grow ridership for NYW for their Belford service, but their service is diversified with other locations where riders access the ferry by walking or various transit modes.
- Fare reduction is not seen as a desirable strategy to grow ferry ridership. Operators do not expect to gain ridership with decreasing fares, but rather expect to lose money. The operators of trans-Hudson ferry service see their ferries as offering a high-quality service to a clientele that is seeking a premium service over public transit, in contrast to the NYCEDC's East River ferry system. There is a concern that reducing prices, even for a trial period or to accommodate commuters stranded from a rail transit strike, may have the undesirable effect of driving away loyal customers that are inconvenienced by a surge in demand. However, public partnerships

are welcomed in the development of landside facilities such as parking and terminals as well as in the provision of grants to assist with upgrading vessels to meet stricter governmental air quality regulations.

- Liberty State Park (LSP) may offer potential to accommodate greater ferry ridership. Both Hornblower and NYW mentioned greater use of LSP as a park-and-sail lot to increase ferry ridership. Hornblower noted that the current pricing policy of \$7 per day, which is the same seven days per week, deters commuter use. It was suggested that LSP could lower its price to park during weekdays to encourage ferry commutation.
- All operators cited their emergency contingency plans with NJ TRANSIT as a template for potential pilot projects. While ferries are currently a premium transit service, all operators noted that if the commuter rail and/or bus infrastructure were to be significantly impaired, the demand for ferries would exceed their current capacity. Their emergency contingency plans, which entail leasing additional vessels and implementing shuttles from various parking lots, could be used to increase ferry capacity.

## 7.2 INTERVIEW QUESTIONS

The following preamble and list of questions were prepared to guide the interviews with the ferry operators:

The PANYNJ is evaluating the potential effect on projected trans-Hudson travel demand as it relates to the redevelopment of the Port Authority Bus Terminal (PABT). Specifically, the Trans-Hudson team is assessing the potential to balance demand across modes and corridors. The expansion of existing trans-Hudson ferry services and/or addition of new routes, including landside connections on both sides of the Hudson River, is being examined for its potential role in balancing trans-Hudson travel demand.

### The Ferry Market

1. Is there any defined catchment area (in terms of radial distance) around landings that can be reasonably designated as the geographic market?
2. Are there any points in time when operators have noticed a spike in ridership not related to seasonal conditions? E.g., does ridership materially increase when NYC tolls increase?

### Inland Connections and Access

3. How critical are transport connections for your ferry riders? Should such connections to transport hubs not be available what would be the impact on ridership?
4. Is the current capacity of connecting services adequate? Are customers satisfied with such connections or are there things that can be done to improve them? What might be the impact of such improvements on ferry ridership?

5. How important are parking facilities at your NJ ferry landings? What percentage of ferry riders drive and park at or close to the landings as opposed to accessing them via public transport? Is current parking capacity adequate? Will expansion be required in the near future?

#### **Service Costs**

6. Do you see any potential increase in ridership if ferries shared a common fare platform with the transit agencies (e.g. Orca card in Seattle, Octopus card in Hong Kong)? NJ TRANSIT has the MyTix app.
7. How do you regard the future for operating and fixed costs? E.g., what is the outlook for fuel, labor, maintenance, insurance and other costs?
8. Have you evaluated decreasing fares to increase ridership to a revenue neutral level?
9. Does the size of the current system limit efficiency? That is, if the system were expanded, would operators experience improvement in operating efficiency, i.e., better capacity utilization?
10. Do public policy initiatives play any role in determining the economic viability of a ferry service? E.g., are there tax policies and/or business incentives that are in force now or in the past that have had an impact (positive or negative) on service viability?

#### **Potential for Expansion**

11. What do you see as opportunities to increase ferry ridership?
12. Which mode of transport is considered the biggest competitor to ferry service? Bus, rail or private auto? In other words, if ferry service were to expand, which mode of transport would the expansion be primarily drawing riders from? What percent might come from the bus?
13. What is the role of terminals in increasing and maintaining ridership?
14. How would you think your ridership would change if one or two of the Penn Station rail tunnels would be unavailable for a year or two while improvements are being made?
15. How would you think your ridership would change if the PABT would be unavailable for a year or two during construction?
16. What pilot projects make sense to serve commuters as an interim mode during down time when infrastructure has to be maintained or rebuilt (rail station and/or PABT)?

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TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix C: Technology Implications and Opportunities

September 2016

Version Final

Prepared for:

**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Submitted by:



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## ABBREVIATIONS

ACC	Adaptive Cruise Control
AOC	Agency Operations Center
ATCMTD	Advanced Transportation and Congestion Management Technologies Deployment
AV	Automated Vehicle
AVL	Automatic Vehicle Location
CMAQ	Congestion Mitigation and Air Quality
CSW	Curve Speed Warning
CV	Connected Vehicle
DGPS	Differential Global Positioning Systems
DMS	Dynamic Message Sign
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
EEBL	Emergency Electronic Brake Lights
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FOIA	Freedom of Information Act
FTA	Federal Transit Administration
GCRTA	Greater Cleveland Regional Transit Authority
GPS	Global Positioning Systems
GWBBS	George Washington Bridge Bus Station
HOT	High-Occupancy Toll
HOV	High-Occupancy Vehicle
HSIP	Highway Safety Improvement Program
IHS	Insurance Institute of Highway Safety
ITS	Intelligent Transportation Systems
MOU	Memoranda of Understanding
MPH	Miles Per Hour
MTA	Metropolitan Transportation Authority
MUL	Managed Use Lanes
MVTA	Minnesota Valley Transit Authority
NHTSA	National Highway Traffic Safety Administration
NJDOT	New Jersey Department of Transportation
OBU	On-Board Units
PABT	Port Authority Bus Terminal
PANYNJ	Port Authority of New York and New Jersey
PATH	Port Authority Trans Hudson
PCW	Pedestrian in Signalized Crosswalk Warning
PMC	Program Management Committee
RFI	Request for Information
RFID	Radio Frequency Identification
RSE	Roadside Equipment



RSU .....Roadside Units  
SOV .....Single-Occupancy Vehicles  
SPaT.....Signal Phase and Timing  
TNC.....Transportation Network Companies  
TSPW.....Transit Bus Stop Pedestrian Warning  
USDOT .....US Department of Transportation  
VMS .....Variable Message Signs  
VMT ..... Vehicle Miles Traveled

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# 1 Introduction

On October 22, 2015, the Port Authority of New York and New Jersey's (PANYNJ) Board of Commissioners authorized a *Trans-Hudson Commuting Capacity Study* (the Capacity Study) to evaluate a range of strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand to 2040, to inform its deliberations on conceptual planning for replacement of the Port Authority Bus Terminal (PABT) (Table 1).

Table 1: Existing and Future PABT Demand

EXISTING (2011)	FUTURE (2040)
232,000 Daily Customers	337,000 Daily Customers (+45%)
7,800 Daily Buses	9,100 Daily Buses (+15%)
615 PM Peak Hour Buses	855 PM Peak Hour Buses (+40%)

The fundamental premise of the Capacity Study is that the transportation network that accommodates trans-Hudson commuter demand is an integrated *system*, as opposed to a series of stand-alone corridors, facilities, and services. Accordingly, the intended outcome of the Capacity Study is an updated overview of that system that takes into account potential investments in physical transportation infrastructure, operational changes to existing transit services, implementation of emerging technologies, and modifications to public policy – and the prospects for their implementation in the time frame for planning and implementing a PABT replacement project.

Concurrent with the Capacity Study, the PANYNJ has commissioned an *International Design + Deliverability Competition* (the D+D Competition) seeking concepts for a new PABT. A major objective of the Capacity Study is to provide insight to the D+D Competition by evaluating the range of alternative strategies for serving the trans-Hudson commuter market via bus and other modes, which will inform the determination of the appropriate capacity and configuration of the new PABT. The interim and final work products from the Capacity Study will inform the D+D Competition and the PANYNJ Board, which will select a preferred design concept for a new PABT this fall.

This technical memorandum focuses primarily on technology factors. Technology is a broadly defined term that can refer to an even broader set of issues and strategies. For the purposes of this report, the study team has focused on technologies that influence the demand and operation of the Lincoln Tunnel corridor and PABT, as well as those technologies that enable other operational or policy strategies that are considered important to the overall functionality of this crossing.

This report begins by presenting information on technology trends affecting transportation patterns. While it is difficult to predict how social acceptance of technology trends will impact all aspects of transportation, there is enough evidence to at least present concepts for consideration and potential technology-based strategies for the PANYNJ to use for meeting its growing needs. The sections that follow outline and expand on those strategies, providing greater detail on their make-up, prioritization (e.g., near term), and risk/opportunity profile.

Technology alone will not solve the demand and capacity issues, but combined with policy and operational approaches, technology will play an important role in addressing many of the components necessary for the entire Lincoln Tunnel corridor and the PABT itself to serve passenger demands.

## 2 Influence of Technology Trends on Travel Behavior and Trans-Hudson/PABT Demand

When planning for the future needs of trans-Hudson/PABT customers, it is important to understand how trends in technology outside of the PANYNJ's control will influence travel behavior and demand at PABT. Technology trends are already affecting aspects of transportation and will continue to offer agencies and private service providers new tools for serving their customers. Technology will change quickly and this will lead to changes in traveler behavior. Some changes will be as predicted but others will not. There are competing trends, including some that could reduce travel demand and others that could contribute to increased travel demand.

However, there are some fundamental physical constraints in the interstate transportation network that dictate a different impact of some of these trends on PABT needs than on bus transit in other cities. The Route 495 Exclusive Bus Lane (XBL) and current PABT are unparalleled facilities for serving tremendous commuter demand through the Lincoln Tunnel to and from the dense Midtown Manhattan area. Given the well-documented projected growth in residential units in northern New Jersey and employment in Midtown, transportation demand will continue to increase. The technology trends and applications described in the following sections will help to optimize trans-Hudson travel, but will not remove the need for large vehicles in the XBL (with high passenger densities) and a multi-level facility in Manhattan connected to the tunnel for passenger waiting, loading, and unloading. The high land values, significant pedestrian volumes, and densely congested grid roadway network in Manhattan will continue for the foreseeable future. Over the time horizon of the proposed PABT, even with changes in technology, the PABT will be an essential part of the region's economic vitality.

The unique demands of the Lincoln Tunnel corridor have prompted the PANYNJ to innovate, beginning with the Bus Terminal itself. Opened in 1950, it consolidated multiple operators using separate Manhattan facilities into a unified terminal. The PABT offered direct, grade-separated bus movements between the Lincoln Tunnel and a multi-level facility with direct connections to the subway system. Implementation of the XBL in 1970 represented another innovation, prioritizing bus service in allocating limited roadway capacity.

As demand continues to grow, the PANYNJ, NJ TRANSIT, and other partners will have a continued need to lead the industry in innovation. Advances in connected and automated technologies in cars and trucks offer resources and applications to bus fleets. However, leadership by public agencies will be necessary to overcome the challenge in deploying new technologies presented by the number of bus operators using the corridor and the PABT, including varying fleet procurement cycles and funding constraints. Successful implementation of these innovations in the Lincoln Tunnel corridor and PABT will require a significant advance in the level of coordinated policymaking and investment that may take years to achieve. That effort should begin in the near term, as various technological advances are or will become realistically available over time, from some that could be applied

while the current PABT is still in operation to others that will become available after opening of the proposed new PABT. Further growth in demand beyond the 2040 planning horizon may require application of technologies that will not be available until after 2040.

## 2.1 THE FUTURE IS MOBILITY AS A SERVICE, NOT TRANSIT VERSUS CAR

Over the planning horizon for the new PABT, there will be an acceleration of the existing shift from rigid mode choices to the concept of “mobility as a service” in much of the metropolitan area. Under mobility as a service, people do not procure mobility by simply purchasing their own car or transit pass; instead, they assemble trips across various modes and purchasing options to meet changing daily needs. The use of personal technology to conveniently assess and select those options has been a game changer that is enabling the acceleration of the shift toward mobility as a service. In addition, and particularly for urban residents, owning a car is less desirable as there are more technology enhanced options that are reasonably priced and flexible. Easy access and readily accessible information are evident in the rapid adaptation of services such as Uber as well as bike share and transit for various portions of each trip. Transit agencies become one part of a more fluid set of transportation choices made among a variety of private sector and public sector providers.

Mobility as a service is an example of technology enabling a change in behavior rather than changing the transportation equipment or service itself (i.e., the cars, buses, bikes, and trains). Mobility as a service will certainly influence transit usage patterns for the PABT and vehicular demand on the non-XBL lanes of Route 495 and the Lincoln Tunnel. Three of the developing sectors within mobility as a service are the following:

- **Transportation Network Companies (TNC)** – Services such as Uber or Lyft that currently focus on linking people driving their personal vehicles to customers ordering rides-on-demand through their smartphones.
- **Rideshare** – A smart-phone-enabled upgrade to the carpooling concept where the vehicle and driver are requested on demand.
- **Car share & Bike share** – Shared lease or technology-driven temporary car or bike usage (e.g., ZipCar or CitiBike) allows the same car or bicycle to be used by multiple individuals. Before the end of the PABT planning period, the study team anticipates driverless vehicles advancing the car-share philosophy by moving themselves between requests for on-demand personal transportation. This would allow the same car to serve many more trips per day instead of being parked, thereby reducing costs.

Each concept is described further below, including possible impacts to demand.

TNCs, rideshare, car share, and bike share all rely heavily on technology—real-time information flow among the transportation mode providers and the customers to provide efficiency and convenience. Under mobility as a service, the providers become more integrated with all modes of transportation, further breaking down barriers to shifting modes within a trip or across a traveler’s

monthly journeys. Thus, while many of the providers are private companies, public transit has the opportunity to integrate with mobility as a service to continue to serve existing customers with changing needs and to capture new customers by providing an appealing mobility option. Two areas for the transit agencies to consider are mobility service apps and open payment systems with account-based ticketing:

- Mobility service apps are in their infancy and will grow more powerful over time. They will be able to provide integrated real-time information on mobility options across operators, including relative speed and cost, and will coordinate reservations and payments across these operators. This will enable public transit agencies to more effectively interface with TNCs, rideshare, and vehicle share. When there are disruptions of service and/or the system is congested, these services can also advise/incentivize customers to travel off-peak or via an alternate route. These technologies could help transit agencies manage peak demand better, and could attract more customers in off-peak periods.
- Open payment systems and account-based ticketing for public transit will allow universal access to transportation services with a single fare media, centralized management of accounts, and innovative “smart” fare structures that reduce the risk of ticket purchasing. Toll payment systems, parking payment systems, etc. could also integrate as well with these technologies.

While there are many competing trends within mobility as a service, it is still anticipated that this concept itself will contribute a small net increase in bus demand at the PABT and other trans-Hudson transit services relative to demand without the growth of mobility as a service, at least in the midterm. Mobility as a service is expected to initially be more complementary to transit than competitive with it, especially since the physical capacity constraints for the interstate transportation network will continue to favor high-density modes such as buses and trains as the region’s population continues to grow. Mobility as a service would not significantly change the projected overall increases in passengers and buses reported in Table 1.

Some examples of mobility as a service are already manifesting locally. For example, NJ TRANSIT has reported that at some train stations where car parking lots are fully utilized, there have been increases in ridership due to TNCs providing first-/last-mile connections between homes and the stations. The long-term understanding of how mobility as a service may ultimately influence demand is still unclear as the technology continues to evolve, but its growing integration with modal choices by consumers will continue to be one of many factors determining demand for transit services.

### 2.1.1 Transportation Network Companies (TNC)

The rapid growth of TNCs like Uber and Lyft have changed the transportation landscape of many large metropolitan areas. While similar in outcome to use of taxi cabs, the method and operation are significantly different, thanks to technology that allows users to simply pull out their mobile smartphone and get curb-to-curb service arranged with a payment account. The rapid growth of TNCs has created an opportunity for some by providing first-/last-mile connections for transit usage – but it has also changed the commuting pattern for some who may not use transit at all as a result.



### 2.1.2 Rideshare

Technology has transformed ridesharing, a concept that has been around for decades. The rise of electronic “bulletin boards” where multi-occupant passengers are sought (e.g., eRideshare.com) has helped to breathe life back into basic carpooling, which saw an overall decline in the previous decade. And thanks to a customer-fueled desire to save a few dollars, many TNCs are also now beginning to recognize the value of ridesharing as a component of their services – additional stops or minor rerouting to pick up additional passengers and reduce the overall cost to the individual. Ridesharing through TNCs has a profound impact on demand and could one day spell the elimination of sparsely utilized transit routes and/or increase in demand for popular high-volume routes.

### 2.1.3 Car Share and Bike Share

The interest shown by TNCs in autonomous-vehicle companies proves their interest in moving from independent drivers using their personal vehicles for many trips per day to fleets of driverless vehicles providing the service. Two steps in that direction were recently announced by Uber: a \$300 million alliance with Volvo, and intent to offer rides to the public in Pittsburgh using autonomous vehicles with back-up human drivers in late summer/early fall 2016. With dedicated vehicles for car sharing, using existing operators like ZipCar or car2go, the opportunity to use vehicles at any time without the cost of a driver may further reduce the cost of the service, making it an even more attractive option. As with rideshare, it could further support first/last mile-to-transit trunk lines or divert demand completely away from some transit routes. Furthermore, if “next-generation park-n-ride” facilities evolve into “mobility hubs,” there would be an even greater possibility of car sharing services becoming first/last mile tools.

Car manufacturers are also investing in car share starting with conventional vehicles. Examples include Daimler’s car2go, BMW’s DriveNow and ReachNow, Volkswagen’s Quicar, and Ford’s Getaround. The technology enhancements include smartphone apps for finding and reserving vehicles as well as for keyless entry. This type of car share can offer not only reduced cost over private ownership but also the potential to access various types of cars at any point of the day in convenient locations. The first-/last-mile potential can complement transit, such as if someone takes transit to work then occasionally picks up a large vehicle for the trip home that includes a shopping trip or taking children to evening activities.

Bike sharing is another area in which technology has enabled a transportation resource that is dramatically affecting travel choices and patterns. While the bike sharing concept has existed since the 1960s in Europe, the operators of those free or coin-operated systems often suffered from theft and the users suffered the uncertainty of having bikes when needed. When technology was integrated into the systems, they proliferated. The first modern bike sharing system in the United States was in Tulsa, Oklahoma, in 2007. Less than a decade later, there are 60 modern bike sharing programs functioning in North America with another 15 planned (<http://bikeshare.com/map/>). Much of the success of the modern systems stems from using technology for membership-based usage (reducing theft by increasing accountability) and technology for tracking bike locations (useful for the customer to know where bikes and docking stations are available, as well as useful for the

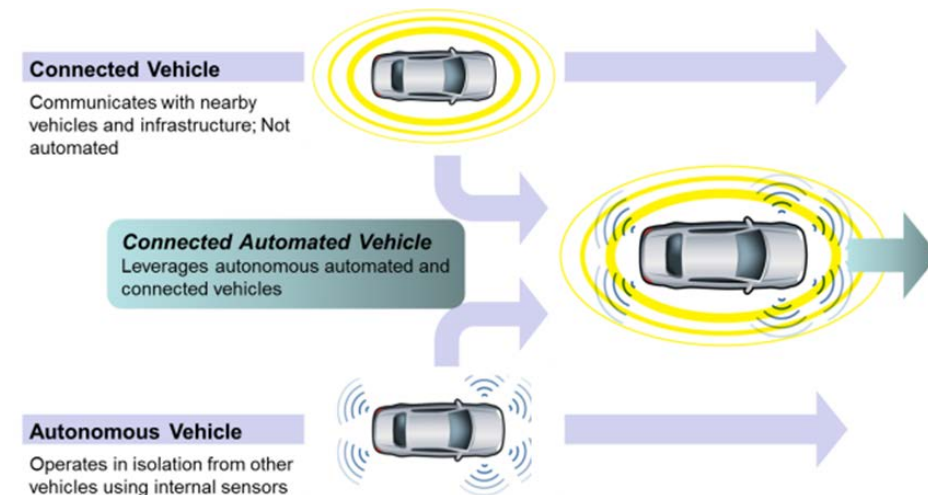
operator for redistributing bikes and planning service expansions). A smartphone app gives users real-time access to bike and dock availability.

This is part of the appeal of CitiBike in New York City, which was launched in May 2013 and by December 2015 served over 15 million trips. By the end of 2017, CitiBike plans to have 12,000 bikes and over 700 stations, further increasing its impact on New York City travel. Additionally, CitiBike has locations in Jersey City, and there is a Hudson Bike Share program in Hoboken. The significant growth in bike share programs, both east and west of the Hudson River, proves the transformative effect that the access to information and sharing can have on how people use a well-established device, in this case a bike.

## 2.2 CONNECTED, AUTONOMOUS, AND AUTOMATED VEHICLES

Decades of research leveraging advances in computing power, sensors, and communication have led to many emerging technologies that are fundamentally changing how vehicles interact with each other, their environments, and human drivers. Figure 1 introduces three major terms and illustrates how connected vehicle (CV) and autonomous-vehicle technology can function independently, and that combining both into connected and automated vehicles (AV) provides the optimum benefits.

Figure 1: Overview of Connected, Autonomous, and Automated Vehicle Terminology



Source: US Department of Transportation

The emergence of CV technology opens the possibility of significant safety, mobility, and environmental benefits. The National Highway Traffic Safety Administration (NHTSA) has estimated that CV technology could prevent 83% of all light-vehicle crashes and 72% of all heavy-truck crashes annually – a leap forward unlike any previous technological advancements in the past 50 years. As a result, NHTSA is in the process of initiating a Notice of Proposed Rulemaking (NPRM) that will mandate the inclusion of dedicated short-range communications (DSRC) in all new passenger

vehicles in the not-too-distant future. Some automakers are already preparing for the implementation ahead of the regulation, and after-market suppliers are also beginning to ramp up technology for deployment once the demand begins to spike. A separate NPRM for heavy trucks and buses is anticipated soon after the passenger car notice, and as a result, several manufacturers are already making plans to deploy.

The basic CV system is based on connectivity between and among vehicles, the infrastructure, and other devices such as mobile smartphones. Depending on one’s communication needs (i.e., the application to be enabled), that communication system can include a number of different technology solutions including cellular wireless 4G/LTE, satellite, and DSRC at 5.9GHz. Some applications may require infrastructure roadside units, most would require vehicle on-board units, and all require some form of back-haul communication system that brings data to/from a central command back-office network server (either directly or most often through the cloud). See Figure 2 for an RSU with DSRC.

Figure 2: Example of Dedicated Short-Range Communications Roadside Unit Installed at Signalized Intersection



Source: WSP | Parsons Brinckerhoff

Applications can utilize communication that is vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), or vehicle-to-anything (V2X) such as a mobile device or cellphone used by a pedestrian or bicyclist (see Figure 3 for illustrative examples). The US Department of Transportation (USDOT) has been researching potential applications for nearly a decade, and extensive testing and development have been done on a number of them. Some applications provide safety benefits, some provide mobility and access benefits, some provide environmental benefits, and many provide multiple layers of benefits. Although these applications and benefits are being readied for actual use, it is important to acknowledge that a communication system may exist that opens the door to future applications not yet imagined.

Figure 3: Example Connected Vehicle Systems and Applications



Source: WSP | Parsons Brinckerhoff

At the same time that vehicle connectivity is being actively researched and developed, a number of technological advancements have led to autonomous or driverless vehicle development. The job of driving is made up of hundreds of different tasks, and manufacturers of automobiles and heavy vehicles are increasingly finding ways to automate them. Passenger cars today now come with lane-keeping assist, automatic parking capability, advanced brake assist, and adaptive cruise control features. Technology companies like Google and Apple are quickly advancing the state of software development to assemble their own automated vehicles as well, relying heavily on global positioning systems (GPS) and on-board vehicle sensors like LIDAR to map the environment surrounding the vehicle in real time and therefore provide a driverless capability. The “Google Car” has logged more than one million miles and several vehicles are now being tested in real traffic conditions in four separate states.

NHTSA has classified vehicle automation into five levels, with level 0 being no automation and level 4 being fully driverless automation. By definition, autonomous means stand-alone, although USDOT has made it clear that the optimum benefits are realized when connected and autonomous technology are combined into what is being called an Automated Vehicle (AV). Additionally, new guidance is expected from NHTSA in late 2016 that further outlines the USDOT’s stance on AVs, along with recommended government actions at the federal, state, and local levels.

Connected, autonomous, and AV developments are happening quickly, and during the lifespan of the replacement PABT it is impossible to accurately predict how they will impact the many different aspects of personal mobility. For the purposes of this report, however, the study team assumes that there will be a range of implications for trans-Hudson transportation related to the Lincoln Tunnel corridor capacity and PABT utilization, including but not limited to the following:

- Current autonomous applications, such as lane keeping combined with adaptive cruise control for autonomous driving in congested conditions, tend to be much more conservative than human drivers. This leads to increased spacing between vehicles. While there is a clear safety benefit, there is also a capacity decrease that could become significant as the percentage of vehicles with such technology increases. The AV's promise of increasing capacity will be realized only once there is a high percentage of vehicles using vehicle-to-vehicle communication coupled with autonomous driving that enables vehicles to safely drive closer together and at higher speeds.
- Completely driverless vehicles could theoretically lead to an increase in demand for single-occupant (SOV) vehicle trips. The opportunity to sleep, work, exercise, or relax instead of actively driving will make the time spent commuting more productive than if driving or taking public transit, even if more time is spent in traffic. This improvement in the quality of time spent traveling could also offset some other trends based in part on avoiding the travel, such as working remotely and shopping online.
- Individually owned driverless vehicles could also add to travel demand if they reverse commute without any occupants to home or to cheaper parking outside Manhattan. The individually owned driverless vehicles may also create demand by being sent on errands by their owners, such as picking up groceries and dry cleaning.
- As described in the previous sections, the impact of driverless vehicles on PABT demand hinges on the interplay of two opposing trends:
  - Increased use of trunk transit service into PABT, as trips from home access the trunk transit stops/stations by means of shared ride and/or vehicle services (assuming that physical Trans-Hudson capacity constraints and pricing still make the trunk transit service attractive)
  - Decreased use of trunk transit service into PABT due to significant volume diverted to single-occupancy or shared driverless vehicles

The net balance between these trends will be influenced by a number of factors including public policy, quality of service on the overall transportation system, and the many unique characteristics of the New York-New Jersey metropolitan region.

As the technology evolves and proliferates, PANYNJ and other operating agencies will need to evaluate and consider policies that can affect the use of such technologies within their jurisdictions, prohibiting or mandating features, perhaps on a lane-by-lane basis (Figure 4). Research is underway at the federal level to actually model and analyze the potential impacts (benefits and disbenefits) of separating vehicles operated by computers from vehicles driven by humans. Also, AVs without occupants could pay different tolls or be prioritized below occupied vehicles. Vehicle occupancy status could be verified through CV technologies, or by using a switchable version of an E-ZPass tag as is currently used for differentially tolled high-occupancy vehicle (HOV) lanes in other parts of the country. Enforcement would be similar to current visual observation, the rapidly-improving video processing technologies, or through CV technologies. Limited Lincoln Tunnel corridor capacity will require agencies to consider both fairness and public good when setting policies under

their control. Many jurisdictions will be faced with the challenge of managing the transition from human driven vehicles to a mixed fleet to computer operated vehicles.

The facets of connected, autonomous, and AV technologies that the PANYNJ and bus operators can leverage directly for Lincoln Tunnel corridor capacity enhancements are defined as strategies in various portions of Sections 4, 5, and 6. They include deploying the infrastructure side of the CVs as well as adapting autonomous, connected, and AV technologies to buses.

Figure 4: Possible Separation of Fully Automated and Partially Automated Vehicles



Source: WSP | Parsons Brinckerhoff

### 2.3 REMOTE WORKSITES

Commuting to/from concentrated employment centers on a set workday schedule (i.e., traditional 9am – 5pm office hours) is no longer a given. Advanced computing and telecommunication technology has enabled the growth of telecommuting (working remotely at one’s home or at a gathering place remote from an office). However, even though telecommuting has become more common, the growth in the practice appears to be leveling off in recent years according to Gallup’s annual work and education poll.

This Commuting Capacity Study will also examine the potential to further reduce trans-Hudson peak-period demand through expanded adoption of workplace flexibility by employers in the region (included in the “Travel Demand Management Options” technical memorandum). These opportunities could include a combination of voluntary programs that encourage participation and mandatory programs (such as those in Washington State) that require actions to address peak-period commuting. While workplace flexibility strategies could reduce trans-Hudson demand during the peak of the peak period, they would neither eliminate nor lessen the need for significant capital investment on both sides of the Hudson River to address capacity constraints.



There is no conclusive trend data about whether the portion of the labor force taking advantage of flexible hours and telecommuting will substantially change over time. Nonetheless, it is now a permanent part of the labor market, and telecommuting has played an important role in short-term situations such as pre-planned major events, significant weather events, or large-scale construction projects that reduce capacity in the short term. Commuters have demonstrated the ability to rely on telecommuting in those instances, which has reduced demand and in some cases has been effective in managing the impacts of extraordinary events. Historically, these instances have been only of short duration, as individuals return to their daily commuting patterns once the anomaly has cleared, but they demonstrate that telecommuting can influence trip-making by workers.

The Hudson River crossings are also unique in that a large number of individuals entering or exiting New York City are doing so for non-work trips: theater and shopping, dining and entertainment, tourism and socializing are types of non-work trips that comprise a significant amount of demand on any given day. Studies differ on their extent – some suggest that an unusually high percentage of trips into Manhattan are for non-work, while others show it to be lower than the national average. Regardless of the specific number, non-work trips cannot be accomplished by telecommuting and presumably will continue.

## 2.4 MODE CHOICE/TRAVEL TIME

Technology has enabled the commuter or visitor to consider a broader set of travel planning tools. Whereas in the past a traveler might simply get on the road and deal with congestion, in many instances they now have avenues for gathering data and making an informed decision whether or not to alter their mode choice, departure time, or in some instances the decision to make the trip. Travel information technology will continue to grow as more-accurate and real-time data is collected, further enabling the individual to make informed decisions.

Improved travel information and real-time arrival/departure information could induce new demand to use the PABT during peak periods. On routes where commuters might have multiple travel options, improved information may lead them to choose the bus over other options. One challenge is to make sure that NJ TRANSIT is not the only bus operator that provides enhanced travel information, but rather that all the other carriers do as well, thereby ensuring that improved access to data is not unique to a location or route.

## 2.5 IMPACT OF SOCIAL MEDIA

Technology has introduced one of the most prolific (and accidental) travel planning tools: social media (Figure 5 and Figure 6). Commuters or travelers can monitor real-time conditions through social media – information about accidents, congestion, reliability, or general volumes can be garnered simply by monitoring the crowd-sourced feedback from other commuters and travelers. Since this is not controlled by the operating agency (except in cases where the agency uses social media to broadcast specific information) there is an inherent unknown outcome in behavior change,



specifically regarding whether individuals will alter their mode choice, route choice, departure time, or decision to travel.

Figure 5: Recent Twitter Feed from NJ TRANSIT



Source: Twitter

Figure 6: Recent Customer Twitter Feed Regarding Lincoln Tunnel Traffic



Source: Twitter

## 2.6 TRAVEL INFORMATION

The availability of real-time traveler information has increased dramatically over the past decade due to advanced technologies able to detect, analyze, and disseminate traffic and transit conditions. The traditional information mainstays of radio and TV traffic broadcasts are being supplemented in many places with travel websites, real-time roadside and “next-bus” displays, personalized e-mail, text, social media alerts, and in-vehicle real-time systems. Detailed and up-to-the-minute information helps manage commutes in real-time, but it can also change when, where, and how people travel.

### 2.6.1 Travel Information – Rising Expectations

In an increasingly connected society, consumers are accustomed to on-demand, accurate information. The tolerance for anything not up-to-the-minute has virtually evaporated with the amount of data and information now available in all of the “vertical information markets.” Vertical information markets are defined as news, sports, weather, business, traffic/transit, etc. Customers have availability of information at any time in each of the vertical markets and the rapid growth of personal communication devices (smartphones) only has served to increase their expectations.

In addition to availability of information, consumers expect high accessibility to services such as travel planning tools and mobile purchasing applications. For example, the MyTix program has become very popular among NJ TRANSIT customers, as evidenced on Customer Satisfaction Surveys. In a September 2015 press release, NJ TRANSIT reported that “Payment Options” received the highest scores from customers using their MyTix app, with a 7.3 on a 0 to 10-point scale. At that time, customers already had used the MyTix app to establish more than 600,000 accounts and purchase more than 8 million tickets.

### 2.6.2 Travel Information – Impact on Demand

Traveler information is transforming the way transportation professionals can manage travel demand. In the past, managing demand meant switching commuters over long term from driving alone to carpooling, transit, or having them avoid the commute altogether by telecommuting. Today, travel management strategies have broadened to include influencing the timing, destination, and route of a trip, not just the choice of transportation mode. Such changes are much more likely to be short-term, spur-of-the-moment decisions made just before a trip takes place or even enroute.

Traveler information is also relevant for much more than helping commuters navigate rush hour. Managing commuter travel is still a major concern in most metropolitan areas, but managing travel for local and long distance trips taken for social and recreational purposes, around planned special events, in poor weather, in emergency situations, and in rural areas is also important. Freight transportation is another part of the mix, particularly in certain travel corridors and near border crossings, ports, and concentrations of manufacturing and distribution facilities.

## 3 Near-Term Opportunities for Improved Operations

### 3.1 IMPROVED SENSOR DEPLOYMENT TO ENHANCE AWARENESS OF VEHICLE LOCATION

#### 3.1.1 Motivating Needs

The starting point for any optimization problem in a transportation network is situational awareness. Traffic congestion cannot be improved if accurate real-time measures of speed, volume, and capacity are not available. Traffic safety cannot be improved without real-time knowledge of sudden changes in conditions. Bus arrival/departure information cannot be provided to customers if information on the location and operating conditions of buses is not available. Situational awareness can open the door to a wide range of applications that benefit the PANYNJ, bus operators, and other users of the interstate transportation network, whether they are in nearby passenger vehicles, other modes of transportation, or otherwise affected by the operations of the Lincoln Tunnel corridor or the PABT.

Technology is available and in use today by the PANYNJ and bus operators to help provide additional situational awareness. However, there is an immediate opportunity to enhance the depth, accuracy, and timeliness of data to further enable applications intended to optimize operations along the Lincoln Tunnel corridor and inside the PABT itself.

#### 3.1.2 Opportunities, Benefits, and Risks

A combination of vehicle-based and infrastructure-based sensors and strategies will yield the most accurate, reliable, and thorough database of real-time conditions. A number of tools and strategies are already in place along the Lincoln Tunnel corridor and in the PABT – this is not starting from scratch. In some instances, the concepts discussed in this report may already be planned or are being implemented.

##### **3.1.2.1 Radio Frequency Identification**

E-ZPass readers use radio frequency identification (RFID) to collect tolls. Additional readers, which anonymize the tags' owners, have been deployed throughout the region to detect travel time. They are the basis of travel times on Variable Message Signs, among other uses. Readers deployed along Route 495, in the Lincoln Tunnel, and in the PABT represent an immediate opportunity to increase situational awareness.

Specific to bus operations, there is an opportunity to expand the collection of information by increased deployment of the E-ZPass readers, and to maintain individual bus identification. This would enable “tracking” specific buses from the moment they enter the geographic boundaries of

the network. Knowing the specific position of a specific bus along the Lincoln Tunnel corridor and within the PABT is paramount to improving operations, travel information for customers, and overall system optimization. Increasing the number of readers inside the PABT will also counteract any problems or concerns with GPS antenna occlusion that might be precluding operators from providing more real-time arrival/departure information for customers.

Tags and readers are existing technology, and simply expanding the deployment of readers and enhancing the data analysis specific to buses will provide an immediate boost in data and situational awareness. In addition, archival E-ZPass data can also be used to analyze dwell times for specific operators, traffic flow at entrances/exits to the PABT on different floors, and general adherence to schedules. There is a project underway by the PANYNJ to install additional readers to develop software to interface with the bus data.

### **3.1.2.2 Video Analytics**

Although E-ZPass readers are an immediate opportunity using an already deployed solution, there are additional technological strategies that can and should be considered to improve situational awareness which also utilize/leverage existing technology. One such technology is video analytics.

Video surveillance supplemented with video analytics (Figure 7) is a useful tool to increase the accuracy of data on vehicle movements from the moment a vehicle enters Route 495 until it reaches the PABT ramps – and further until it docks for loading/unloading, followed by its return trip out of the building, through the tunnel, and west along Route 495. Using video analytics allows for dual-purpose video surveillance (traffic operations and security), and is a good supplement to in-vehicle tools that might be enhanced through GPS correction and improved WiFi.

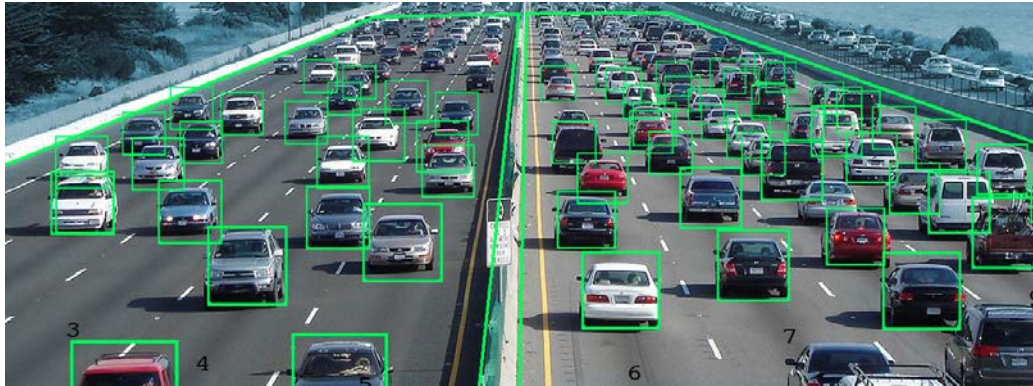
Video analytics can supplement existing tools that provide speed and overall situational awareness by providing more detailed metrics such as volume, lane occupancy, vehicle classification, level of service, incident detection, wrong-way detection, and even pedestrian detection. A recent presentation from the New Jersey Institute of Technology suggests a 20-30% improvement in travel time and improved incident detection time through the use of video analytics.<sup>1</sup>

Video surveillance along the Lincoln Tunnel corridor, within the tunnel, and in the PABT is relatively dense. An analysis could be performed to determine if any gaps exist, but in general there is a tremendous amount of video surveillance equipment already in place. Additional computing and operational strategies could be added to the existing system to leverage all of this video coverage and provide additional metrics. If changes in operational strategies are considered in the future—such as additional reversible lanes, active traffic management, or queue detection—the data collected via video analytics would already be in place to support such operational measures.

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<sup>1</sup> Video Analytics Systems for Effective Traffic Management, Lazar Spasovic, Ph.D. Dept. of Civil and Environmental Engineering New Jersey Institute of Technology, The 15th Annual NJDOT Research Showcase October 2013, [http://cait.rutgers.edu/system/files/u11/2013-Spasovic\\_0.pdf](http://cait.rutgers.edu/system/files/u11/2013-Spasovic_0.pdf)

Figure 7: Sample Output using Video Analytics



Source: TrafficVision, a Division of OmniBond

### 3.1.2.3 Automatic Vehicle Location (AVL)

NJ TRANSIT has been actively deploying automatic vehicle location (AVL) throughout their bus fleets and is still in the early stages of working through integration and quality issues. The vendor (Clever Devices) has a full suite of applications to provide computer aided dispatch, real-time travel information, and passenger information for operational purposes—all of it made possible by real-time location information transmitted via cellular device. The system currently transmits data every 1–4 minutes, but eventually it is specified to operate at 30-second transmission intervals, providing thorough data for a wide variety of potential applications. For location accuracy, the system utilizes GPS as the primary source and odometer readings as a secondary refinement. Data is transmitted to a central processing server and then redistributed for NJ TRANSIT's MyBus mobile app, NJ TRANSIT's MyBusNow website tool, or on-site dispatch field personnel to utilize for operational purposes.

In addition to speed and location (latitude/longitude), the Clever Devices system has the capability to broadcast passenger loading information, such that on-site dispatchers can know the number of passengers coming into the PABT and theoretically could divert to alternate disembarking locations based on person-throughput instead of just vehicle-throughput.

NJ TRANSIT has also installed WiFi inside the PABT to enable their dispatch personnel to have real-time AVL information on their tablets—and for passenger use as well. However, this addition could also enable enhanced indoor positioning systems to better monitor vehicle location inside the terminal building where GPS is not effective.

### 3.1.3 Policy Considerations

Collecting more timely and accurate information enables positive outcomes: increased safety, efficiency, reliability, and environmental stewardship. The above recommendations in general do not change current postures on data collection; they merely expand upon them.

The E-ZPass information remains anonymized for general traffic and only bus operators opt-in to the specific identifiable data. The PANYNJ would presumably have written Memorandums of Understanding concerning the use and archival of such data, but could include this opt-in posture as a condition of gate access for operators. While some applications can be completed without real-time access (e.g., analysis of dwell times, periodic review of level of service), traffic management and real-time bus operations are enhanced by receiving the data in real-time.

Video analytics do not specifically identify drivers or operators, but provide similar data already gathered through the use of inductive loops. Likewise, the AVL data would be opt-in by each bus operator, and could be a condition of gate access.

The federal Freedom of Information Act (FOIA) passed in 1967 is designed to give citizens access to federal records supporting their right to know about the functioning of the government. Since FOIA applies only to federal records, FOIA itself does not apply to data collected along the corridor in question. However, all 50 states and the District of Columbia have public record laws with a similar intent. The PANYNJ's Public Records Access Policy stipulates that records shall be released to the public unless they are exempt from disclosure under both the New York Freedom of Information Law and the New Jersey Open Public Records Act.

#### 3.1.4 Possible Path to Implementation

The aforementioned systems are available today—considered “off-the-shelf” technology and in use in many different parts of the country and elsewhere around the world. Development is minimized, planning can be advanced, and implementation would not be far behind.

These solutions are also eligible for a number of different federal funding opportunities, including grant programs such as the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) or Transportation Investment Generating Economic Recovery (TIGER) programs; more traditional funding sources such as Highway Safety Improvement Program (HSIP) or Congestion Mitigation and Air Quality Program (CMAQ); or the recently revised Surface Transportation Block Grant Program.

## 3.2 PUBLICLY AVAILABLE TRAVEL INFORMATION

### 3.2.1 Motivating Needs

If situational awareness is the foundation of optimization, then distributing that knowledge to users of the network is the next step. Providing accurate real-time information to customers can and will have a profound impact on their use of the transportation system as well as their overall satisfaction and willingness to follow recommended actions.

### 3.2.2 Opportunities, Benefits, and Risks

A combination of fixed and mobile tools can be utilized to gather information on the current transportation network by users. Whether it comes from TV and radio, from overhead dynamic message signs, or hand-held mobile devices, the information needs to be reliable.

#### 3.2.2.1 Traffic Conditions

Average speed, estimated travel time, accident information, and/or planned lane closures are all valuable pieces of information that are regularly conveyed to roadway users today. Once additional data collection tools and strategies are in place, it could be possible to enhance the reliability, depth, and timeliness of such information. Numerous studies have been conducted over the years that quantify the benefits of travel information, including a relatively recent survey from the Washington State Department of Transportation (DOT) indicating that 84% of users found the information useful and 95% saying the Department should continue to collect the information.<sup>2</sup>

PANYNJ incident and construction information is collected by the Agency Operations Center (AOC) and entered into the regional information clearinghouse system, the Transportation Operations Coordinating Committee's (TRANSCOM) OpenReach. Peer agencies input their information as well. Transit has historically been underrepresented, but increasing transit participation is a current focus area for TRANSCOM. Information in OpenReach is distributed to the public through a variety of means, including the 511NY and 511NJ traveler information systems accessed through a voice recognition phone line, customized text messages, customized e-mail, a webpage, and on Twitter. The TRANSCOM information is also available as a data stream for interested parties for integration into mobile phone apps and websites. Upon the request of PANYNJ facilities, the AOC also contributes real-time traffic alerts to customers who have signed up for PA-Alerts. PA-Alert messages are also posted on the PANYNJ's website, and traffic conditions can also be posted on dynamic message signs along roadway corridors. The PANYNJ can request messages on regional partner signs when there is value reaching customers before they would view a PANYNJ-owned dynamic message sign.

#### 3.2.2.2 Bus Arrival/Departure

NJ TRANSIT's MyBus mobile app (and accompanying MyBusNow web tool) rely on information from existing operations. As NJ TRANSIT improves the operation of their AVL system, it intends to introduce more real-time information and integrate with currently schedule-oriented information. Newark Penn Station currently has screens with gate information in its bus lanes. The PABT has touch-screen displays with schedule information for multiple carriers.

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<sup>2</sup> *Survey of the public's use of WSDOT's traveler information services, January 2013*, Research Office Washington State DOT, published in the *US Department of Transportation Benefit-Cost Database*, <http://www.itsbenefits.its.dot.gov/ITS/benecost.nsf/ID/00D69153B125ABB985257B7B0071729B?OpenDocument&Query=Home>



For transit, today's 511NY and 511NJ includes primarily static (construction) information, but with improved sensor deployment there is the opportunity to provide more real-time operational information.

### **3.2.2.3 Trip Planning**

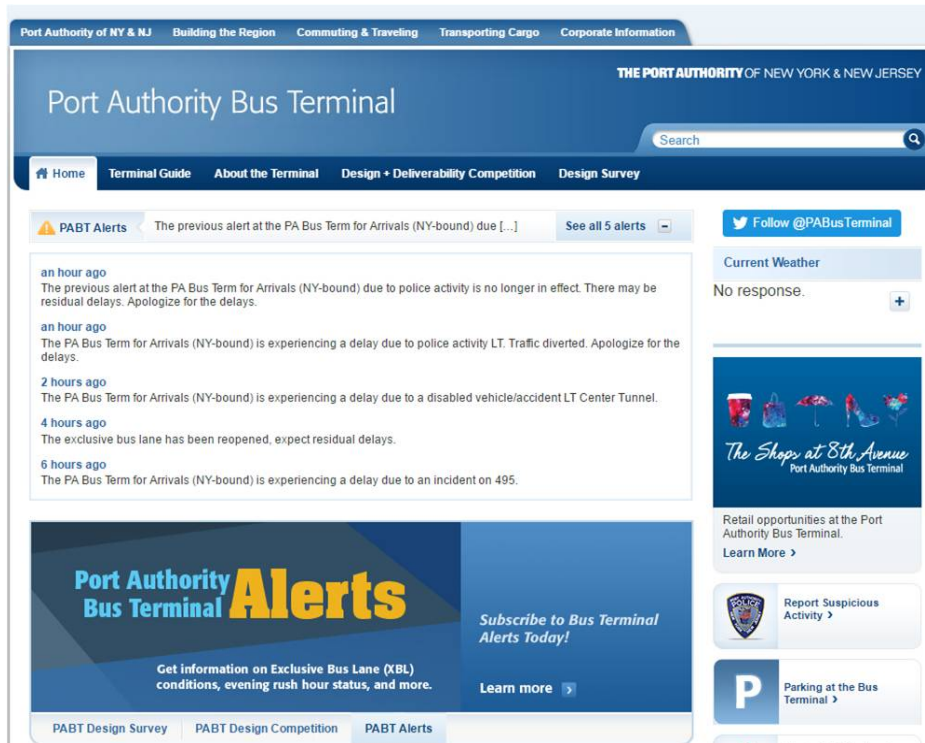
The availability of reliable real-time information and robust archived information enables more broad-reaching travel and trip-planning tools. The ability to influence time of departure, mode choice, route choice, or even the decision on whether or not to travel can be enhanced with additional data. NJ TRANSIT's website has a trip-planning tool that incorporates both bus and rail (as well as walking). Future applications could be developed by third party vendors (either under contract to an agency or more likely independent of an agency) that include private automobiles, ridesharing, car sharing, and meeting co-workers at a place other than their typical office.

The precedent already exists to suggest drivers avoid coming downtown during times of crisis or major weather events. NJ TRANSIT, the Port Authority Trans Hudson (PATH), private bus carriers, and ferries will cross-honor tickets when there are serious enough disruptions. There is also an active practice for providing trip planning tools and alerts on the PANYNJ's own website (Figure 8). Various traveler information sources could be expanded to provide mode-choice recommendations during certain time periods based on real-time information or on historic data.

Trip planning will not be universally available for all passengers, depending on their specific bus operator, time of departure, or destination. Also, due to bus storage and dispatch some travel information may be available with smaller lead time than others. For example, for trips that originate at the PABT, a bus may not be assigned to the specific route and run until it is within the PABT. AVL information associated with that bus before it is assigned is therefore not useful for communicating real-time information to passengers, such as a display of how many minutes until the bus arrives. However, the AVL information is useful for dispatchers and the flexibility of bus assignment improves on-time performance for the customers.

In general, the opportunity to provide *any* level of information is better than the alternative of *no* information, and improved collection of location information will enable the execution of that philosophy.

Figure 8: PANYNJ Website with Real-Time Travel Information Alerts



Source: PANYNJ

### 3.2.3 State of Enabling Technologies

There are many different possible approaches to providing enhanced travel information, including:

- Dynamic message signs and interactive screens/kiosks both inside and outside the facility to broadcast arrival and departure times for pedestrians to view. This could include increasing the real-time content displayed via the recently installed touch-screen information centers at the PABT. Prominent electronic signage at each gate with upcoming bus departures is also helpful.
- XML feeds that can be utilized by various travel apps on mobile devices or on travel information websites provided by the private sector (e.g., Google Transit). It has been proven that when data is available, developers will utilize it. For the New York region, operating agencies in New York State, New York City, the PANYNJ, and the state of New Jersey enter real-time information into the TRANSCOM OpenReach system. TRANSCOM is a coalition of 16 transportation and public safety agencies in the New York-New Jersey-Connecticut metropolitan region created in 1986 to provide a cooperative, coordinated approach to regional transportation management. TRANSCOM OpenReach fuses the geocoded information and distributes it through a variety of channels, including an XML feed with approximately 300 commercial and academic subscribers. The TRANSCOM data is also the backbone of the 511NY and 511NJ traveler information

systems, which each include phone lines, websites, mobile applications, Twitter feeds, and traveler-customizable alerts.

- Provision of travel information through agency-operated websites and/or through an application—using the same data feed released to the public and creating an agency or facility distribution channel. For roadway information, there is a definite trend away from agency distribution platforms in favor of feeds for use by third parties. However, there are a number of fundamental differences between roadway and transit information that have led to a more robust set of agency-developed transit distribution channels. The Metropolitan Transportation Authority (MTA) uses a hybrid, listing on its website’s App Gallery (<http://web.mta.info/apps/>) eight of its own apps, 36 officially licensed apps, and 47 other apps that leverage MTA data. This fosters innovation and creativity while also providing core information that is credible.
- Audio information delivered through the phone, such as 511. Depending on the location the call is made from, the caller may be connected to the New York State Department of Transportation’s (NYSDOT) 511 system or New Jersey Department of Transportation’s (NJDOT) 511 system. This is already available for travelers with a heavy emphasis on highway usage, but this strategy includes introducing additional bus information for users who wish to dial in. Once the data is made available to the 511 system, any alerts or anomalies can also be broadcast out via the 511 social media linkage (Twitter).

### 3.2.4 Policy Considerations

The PANYNJ and the region already have a robust open-access traveler information program: the provision of real-time travel information and trip-planning tools are existing practices, as is the emphasis on customer service. The areas that would most need policy development are expanded cross-honoring and providing recommendations for change in mode. While such flexibility is definitely a benefit to travelers, there are practical and revenue concerns among agencies that have to be worked out.

The emphasis in this report is on leveraging the current system to fill in gaps and enhance the services provided, including in support of resiliency. For example, the PANYNJ is working with Google and Waze to integrate verified information, including precise times of restrictions and closures of major bridges and critical roads.

## 3.3 ACTIVE BUS SYSTEM MANAGEMENT

### 3.3.1 Motivating Needs

The efficiency of the PABT depends on the ability of multiple bus operators to work in concert and find the optimum balance of scheduling, management, customer access/awareness, and conditions beyond their control such as weather or special events. One important measure of this efficiency that NJ TRANSIT monitors closely is on-time performance. While the PANYNJ itself does not control most of the short-term factors behind the operations, they can be the ideal foundational platform for bus operators to rally around and lean on for help in improving coordination, cooperation, and

communication. The PANYNJ also has some leverage with the bus operators in its facility, both through established working relationships and through the facility lease agreements.

### 3.3.2 Opportunities, Benefits, and Risks

The real-time collection of information as suggested in Section 3.1 would result in an improved database of conditions important to every bus operator with a gate within the PABT. Every bus and/or operator should contribute data (e.g., AVL, schedule), and every bus and/or operator should have access to data (e.g., real-time traffic information). As noted in the previous discussion about travel information, it is realistic to assume that this will not happen all at once, and some bus operators (and as a result their passengers) may not have equal levels of information and in a timely manner. The philosophical intent is to aim for the maximum possible and recognize that any improvement will provide value to the customer and overall operation. Since the state of data management among some carriers is currently lacking, it is a challenge for the PANYNJ to implement useful passenger information systems across carriers. Investments in technology and ongoing cooperation from bus carriers to provide current arrival/departure information is encouraged.

Since NJ TRANSIT is the largest bus operator at the PABT, its operations provide an excellent launching point for recommended procedures and technology for other bus operators to consider. If every bus entering the network (beginning with Route 495 and proceeding all the way to the PABT) is equipped with technology that both transmits and receives real-time data, then the opportunity exists to maximize and coordinate operations independent of the logo on the side of the bus. Improved situational awareness will allow for improved precision of operations. Not only will customers benefit, but the bus operators will also benefit through fuel savings and more efficient utilization of bus and operator time.

This report does not advocate that PANYNJ personnel be directly engaged in the dispatching or operating of individual bus lines—instead the PANYNJ would provide a common technical and institutional platform for operators. As discussed in greater detail in Section 6.1, this report also does not advocate a fully dynamic gate assignment. This is considered to be unrealistic for passenger access in a facility the size and scope of the PABT. Most fully dynamic systems, such as those found in the Netherlands, service much smaller footprints, number of passengers, number of buses, and number of bus operators. However, some elements of dynamic gate assignment may prove attractive at the PABT—during major events, emergencies, weather incidents, etc. The flexibility could be considered in smaller segments such as within an operator’s area or small groups of operators, rather than as a complete top-floor to bottom-floor dynamic flexibility. (See Section 6.1 for additional discussion of various adaptable gate assignment strategies.)

### 3.3.3 Policy Considerations

Policy considerations include potential incentives the PANYNJ could use to encourage adoption of relevant bus technologies (for users of the PABT, Lincoln Tunnel, or XBL), as well as the potential for the PANYNJ to eventually require use of AVL and management technologies as a prerequisite for use of the XBL and/or Lincoln Tunnel. These questions should also consider fairness to the wide variety of bus operators, especially for those that only occasionally use the XBL and/or Lincoln Tunnel.

The PANYNJ should explore whether current legislation presents impediments to implementation today, and if so, what steps could be taken to overcome the issues.

#### 3.3.4 Possible Path to Implementation

The PANYNJ could host a web-based platform for all AVL and traffic data that impacts the XBL, Lincoln Tunnel, and PABT. Every bus operator who utilizes the network would contribute data and could retrieve it. This platform would not be a public-facing travel information site, but rather an internal operations-focused database of information which could be utilized with appropriate policies and written agreements to engage in multi-operator coordination, collaboration, and communication toward more efficient use of the PABT, especially during peak periods, adverse weather, special events, crashes, and other disruptions.

Regular gatherings of operations personnel to discuss improvements in operations would serve as a foundation to such activities—to ensure that the technology is driven by operations personnel and that its interface is focused on the demands of real-time bus operations, especially during the most chaotic and unpredictable periods.

## 4 Connected & Automated Corridor Applications

### 4.1 BUS PLATOONING FOR IMPROVED CORRIDOR OPERATION

#### 4.1.1 Motivating Needs

The XBL on Route 495 moves a tremendous volume of people using just a single eastbound lane during the AM peak hours. However, the XBL and Lincoln Tunnel are operating at peak capacity, a capacity limited in part by driver comfort for speed and following-distance. Demand projections point to an increasing volume of buses in the future, exceeding current single lane capacity before too long. Without changes, the XBL and Lincoln Tunnel could become the bottleneck in the bus system before a new PABT is constructed.

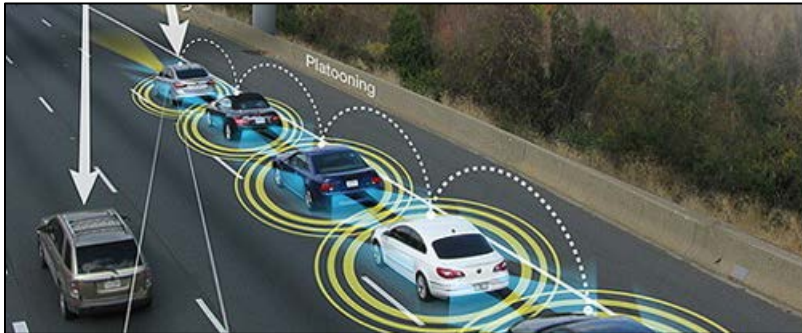
#### 4.1.2 Opportunities, Benefits, and Risks

Options for increasing the number of buses moving through the Lincoln Tunnel corridor include:

- **Creating a second XBL:** Creating a second bus-only lane would provide an immediate increase in bus capacity, but taking the lane from either direction of existing traffic would have extreme negative consequences to the remaining traffic lanes, given projections for significant continued growth in local (non-New York) traffic along Route 495. The resulting congestion would create fairness and equity issues since much of the traffic on Route 495 is not bound for New York.
- **Creating a high-occupancy toll (HOT) lane:** This lane would complement the existing XBL by designating a lane primarily for buses that would “sell” excess capacity to vehicles other than buses with prices set (perhaps dynamically) depending on demand versus real-time capacity such that there would not be enough added vehicles to slow the lane. This could reduce excess congestion on the remaining eastbound lanes. However, that approach still would result in a net reduction of capacity along Route 495 for vehicles other than buses. There are also weave and merge concerns, and potential safety concerns with an increased mix in vehicle types, sizes, and speeds.
- **Connected & Automated bus technology to increase effective capacity of the existing XBL:** Using various combinations of in-vehicle and roadside equipment would allow buses to safely travel closer together and reduce shock waves thereby increasing capacity of the existing XBL lane. The consensus of experts convened at the Capacity Study Workshop on April 14, 2016 as well as others is that recent advances in C/AV technology, including for buses, automobiles, and trucks, make the bus platooning option feasible within 10 years – a vast improvement over the alternatives that could be detrimental to other vehicle types in the corridor as well as detrimental to the PANYNJ’s revenue stream.

Grouping vehicles into platoons is a method of increasing the capacity of roads. Platoons decrease the distances between cars or trucks using electronic coupling (Figure 9).

Figure 9: Illustration of Passenger Car Platooning



Source: [www.driverlesstransportation.com](http://www.driverlesstransportation.com) newsletter

Adaptive Cruise Control (ACC) is commercially available by auto manufacturers, but that does not achieve platooning – it only allows the vehicle with the ACC to maintain a consistent following-distance from the vehicle in front of it. ACC will not achieve small enough headways to increase capacity. Cooperative ACC adds a CV component in which vehicles communicate with each other for functionality such as nearly simultaneous braking, which makes very short headways safe. Whether or not bus platooning for the XBL needs to further advance to include V2I as well depends on the type of benefits necessary and other potential constraints, such as the physical tolerances for the buses within the XBL and Lincoln Tunnel.

Bus platoons could increase capacity on two fronts – reducing individual spacing between buses (so more buses can fit in the system at one time) and reducing shockwaves that cause chain-reaction slowdowns through the line of buses. There is some related research on the potential impacts in these areas.

A paper by Dr. Jerome Lutin (retired NJ TRANSIT Senior Director of Statewide and Regional Planning) and Dr. Alain Kornhauser (Chair of Princeton Autonomous Vehicle Engineering)<sup>3</sup> included an examination of the theoretical capacity increases of the XBL available through reducing the space between buses, assuming all buses use connected technology. The results are shown in Table 2 below. The base condition is five seconds between buses, which yields a theoretical maximum flow of 720 buses per hour. PANYNJ staff report that the observed maximum flow through the XBL is not quite that high and that it was reduced further after bus widths increased from 96" wide to 102" wide. The impact of width illustrates one aspect of driver confidence and thus spacing and speed. Another factor is disturbances in the bus flow, such as when a tentative driver drives slowly, holding up traffic. These disturbances also cause shock waves slowing buses behind even after the slow driver regains speed or exits the system. Still, the table illustrates how even a small decrease in spacing can have a large effect on capacity. As will be discussed further, the theoretical upper limits far exceed the projected need or even the capacity of the PABT and surrounding street network.

<sup>3</sup> Lutin, Jerome M. and Kornhauser, Alain L., "Application of Autonomous Driving to Transit – Functional Capabilities for Safety and Capacity", July 22, 2013, presented at the 2014 Annual Meeting of the Transportation Research Board.



Table 2: Potential Increased Capacity at the XBL through Decreased Spacing between Buses

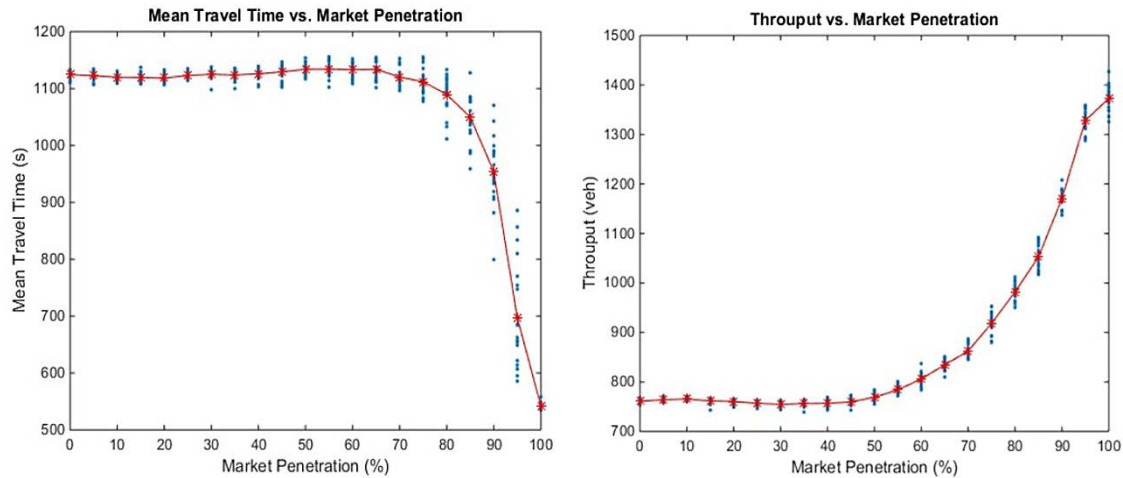
Average Interval Between Buses (seconds)	Average Distance Between Buses (feet)	Buses per Hour
5 (Base)	212	720
4	150	900
3	109	1,200
2	47	1,800
1	6	3,600

Source: Lutin, Jerome M. and Kornhauser, Alain L., “Application of Autonomous Driving to Transit – Functional Capabilities for Safety and Capacity”, July 22, 2013, presented at the 2014 Annual Meeting of the Transportation Research Board.

Since CVs will be an increasing percentage of the vehicle fleet over time, there has been research interest in the penetration of the technologies necessary for meaningful benefits to traffic flow. Research from the University of Oregon includes microsimulation of a single lane of traffic through a constriction in flow.<sup>4</sup> That scenario is akin to a shock wave caused by a slow bus. By observing the queues and travel times at different percentages of CVs, the influence could be observed. In the simulation, with no CVs, a queue quickly grew behind the constriction. With 100% CVs, the vehicles smoothly arranged themselves closer together and there was virtually no queue. When the penetration was high enough, platoons could be observed that efficiently moved groups of vehicles through the constriction reducing the average amount of queuing. Figure 10 shows the exponential benefits in the traffic flow at high penetration levels for two traffic flow measures. For the constriction being modeled, connected passenger cars could significantly reduce delay, but market penetration needed to exceed approximately 80% for significant gains. For throughput, minimum penetration for significant impact was approximately 70%.

<sup>4</sup> Wang, Dr. Haizhong; Mostafizi, Alireza; Dong, Shangjia (Oregon State University) webinar – “Network-Wide Impacts of Connected Vehicles on Mobility”, presented June 16, 2016, and hosted by the USDOT ITS Joint Program Office Talking Technology and Transportation (T3) webinar series.

Figure 10: Relation of Mean Travel Time and Throughput to Market Penetration of Connected Vehicle Adaptive Cooperative Cruise Control in One-Lane Simulation through a Constriction



Source: Wang, Dr. Haizhong; Mostafizi, Alireza; Dong, Shangjia (Oregon State University) webinar – “Network-Wide Impacts of Connected Vehicles on Mobility”, presented June 16, 2016 and hosted by the USDOT ITS Joint Program Office Talking Technology and Transportation (T3) webinar series.

Current projections for PABT demand include an increase from approximately 630 buses to 810 buses in the AM peak hour between 2011/12 and 2040.<sup>5</sup> Although not all buses in the XBL go to the PABT, the corresponding increase in demand through the XBL could be accommodated by a modest average reduction in distances between buses combined with small increases in driver speed, reduction in slowdowns through lane-keeping, and small increases in throughput through limiting the effects of shock waves. Since the maximum theoretical capacity improvements are not needed for all of these improvements to meet projected demand, it is likely that a high penetration of CV equipment, but not a mandate for 100% compliance, may be sufficient to meet demand and provide some resiliency benefits. For example, an average reduction in headway of only 1.5 seconds yields a theoretical XBL throughput of 900 buses per hour—well above the forecast need of 810 in the 2040 AM peak hour. Equipping only the NJ TRANSIT fleet with C/AV technology would help meet the 70% C/AV market penetration that seems to be critical mass for significant impact. Increasing the number of buses per hour dramatically increases the potential person-throughput of the Lincoln Tunnel corridor. Using an average headway of 5.5 seconds that corresponds to the throughput of 650 buses per hour, a one-second reduction would result in up to 8,000 additional passengers being processed within the peak travel hour, and an additional one-second reduction would bring the number up to approximately 21,000.

Along with the potential capacity increase, the lane-departure warning and lane-keeping systems have a significant potential to reduce accidents even when the buses are not platooning. This not only will improve the operation of the XBL and Lincoln Tunnel for the PANYNJ, but will reduce liability and insurance costs for NJ TRANSIT. In addition, improved lane keeping will reduce the number of lane delineators that get knocked down on a regular basis, which has a direct cost benefit to the

<sup>5</sup> Midtown Bus Master Plan, Tables 2-3 and 2-7

PANYNJ due to reduced time spent by maintenance personnel retrieving and replacing them. There is also a worker safety benefit of not having to replace the lane delineators during peak periods when multiple delineators get knocked out and have to be replaced immediately in order to maintain safe contra-flow operation of the XBL.

Implementing new technologies often comes with risks, and those that deal with the safety of passenger transit vehicles are serious. Paramount are safety risks—systems need to safeguard the well-being of drivers and passengers on equipped vehicles as well as the safety of those in other vehicles. There are also system development and implementation risks, from not having stakeholder buy-in to not having successful software development.

To help manage these project risks, both the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) require Intelligent Transportation Systems (ITS) projects that it funds to follow the Systems Engineering process. Federal grant funding is certainly a possibility for a connected bus program developed by the PANYNJ. Even if the development was not required to follow Systems Engineering, it is a proven method for reducing project risk that should be considered. Section 4.1.6 on the possible path to implementation includes additional discussion on ways to mitigate the risks.

While developing a bus platooning program would be a significant undertaking, given the projected increase in demand for trans-Hudson travelers to the PABT, there are no simple solutions. In order to move travelers, the entire Lincoln Tunnel corridor system, including the PABT ramps and gates as well as storage, all must function harmoniously. Since Route 495 and the Lincoln Tunnel are already constrained and face increasing demands, options that require use of an additional lane are problematic on several fronts. Moving more bus passengers through the existing XBL is preferable should it be feasible. As described in the following sections, it will be feasible if the PANYNJ, NJ TRANSIT, and eventually other bus operators commit to the leadership and investment. The PANYNJ has risen to its unique challenges with innovative solutions before, with the XBL being a prime example.

#### 4.1.3 State of Enabling Technologies

The proliferation of software innovation leveraging inexpensive computing power, sensors, and communications has already started transforming the driving experience. While there is no vendor selling a complete connected bus system and no known transit agencies piloting the reduced bus spacing application, there are closely related proven technologies from automobiles, snowplows, trucks, and buses that have led experts considering the PANYNJ's needs to believe that the needed system could be developed and implemented within the next 10 years.

For passenger vehicles, profit and safety have been strong motivators as companies develop commercially available systems to bring a market advantage. These include autonomous (adaptive) cruise control, front and side collision warning, and autonomous emergency braking. As an example of success, the Insurance Institute of Highway Safety reported that the 2010 Volvo XC60 SUVs with autonomous braking had 33% fewer bodily injury claims, 15% fewer property damage claims, and

20% fewer collision claims.<sup>6</sup> The warning systems and systems in which the vehicle takes an automatic action, such as emergency braking, continue to proliferate across models of new vehicles.

For trucks, fuel savings have driven the development of connected truck systems. When trucks platoon at precise spacing, air turbulence is reduced and thus fuel can be saved. These systems are closer to the bus application needed for the XBL than to the passenger vehicle autonomous cruise control in a very important way—the trucks use communication to cooperate with each other. This cooperation is what would safely enable the close vehicle spacing need to increase XBL capacity. Autonomous cruise control systems and autonomous braking on passenger vehicles currently still rely on sensing the vehicle immediately ahead. With CVs, the need for a sudden stop is instantly transferred from the lead vehicle to the following vehicles for more coordinated braking, a necessity when buses are closer together. The viability of truck platooning has been demonstrated, most recently through the 2016 European Truck Platooning Challenge in which automated trucks from six different manufacturers drove on various public roads from across Europe to convene in the Netherlands (see Figure 11).<sup>7</sup>

Figure 11: Route Successfully Completed by Truck Platoons from the April 2016 European Truck Platooning Challenge



Source: Arstechnica; EU Truck Platooning

<sup>6</sup> Glenn, Alex “Do Automatic Braking Systems Save Lives?” esurance Blog, May 9, 2013 accessed June 7, 2016 <http://blog.esurance.com/do-automatic-braking-systems-save-lives/#.V2Vg6vkrKM8>

<sup>7</sup> European Tuck Platooning Challenge 2016 (report), April 2016, file:///C:/Users/swindlerk/Desktop/Storybook%20European%20Truck%20Platooning%20Challenge%202016.pdf

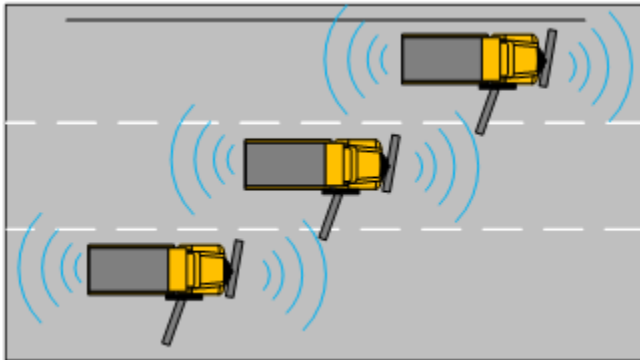
A platoon could consist of two vehicles, or as many as four or five vehicles. A bus platoon would function as follows—as the vehicles “connect” into their platoon, their on-board computers would designate one vehicle as a lead and the others as followers. The key is that the lead bus would set the pace, the following buses would match their pace with smaller distance between buses, and—thanks to lane-keeping and adaptive cruise controls—the platoon would maintain a steady trek down the corridor with consistent headway and speed. In the event the lead vehicle has to slow down, automatic braking technology in the follower vehicles could react quickly and efficiently to ensure headways remain steady.

Some of the current advanced transit bus applications have grown out of the work completed by the University of Minnesota ITS Institute for connected (gang) snow plows (Figure 12). In gang snow plowing, a series of snow plows move in the same direction along the roadway in a tight formation to push snow across multiple lanes into the shoulder. The trailing snow plow(s) can have reduced visibility from snow disturbed by the lead plow. This situation, and the general need to maintain knowledge of the road edge while plowing snow, prompted the development of CV systems using differential global positioning systems, geospatial databases (digital maps), vehicle-to-vehicle electronic communication, radar, a laser scanner, a driver interface, and steering, brake, and throttle control.<sup>8</sup> The following snow plow precisely knows its own location, the location of the lead plow, and the offset the user has specified between the following plow relative to the lead plow (both distance ahead and to the side). The lead plow is driven by an active driver. The second plow remains under the supervision of the driver, but while the system is active, the sophisticated software operates the following plow’s steering, gas, and break to automatically follow the lead vehicle. The system was successfully piloted in 2002 on public Minnesota roads. The system was installed on two snow plows and two airport rescue and fire firefighting vehicles in Alaska in 2003. Due to the success of that implementation, the State of Alaska ordered three new driver-assist systems and two upgrade kits in 2011. While this system relies on GPS, which is not available within the Lincoln Tunnel, additional discussions described below indicate that alternate technologies for vehicle location necessary for guidance would be available.

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<sup>8</sup> GGPS-Based Gang Plowing, Final Report, Report No. MN/RD-2005-18, Minnesota Department of Transportation, April 2005. <http://www.Irrb.org/media/reports/200518.pdf>

Figure 12: Minnesota DOT Diagram of Connected Gang Snow Plows



Source: Minnesota DOT

The next major advance was also through the University of Minnesota ITS Institute. Transit agency staff had heard about the snow plowing project and expressed interest based on one of their own needs. Minneapolis, Minnesota has a successful bus rapid transit system that includes 300 miles of highway shoulder that are open to use by buses only, anytime the travel lane speeds drop below 35 miles per hour (MPH). While the system functions fairly well under normal conditions, the agency noticed that during inclement weather, including rain and snow, bus operators were less comfortable on the shoulders so stayed in normal traffic lanes. Bus commuters began to expect that their bus travel times would increase when the weather forecast was poor, so they switched to driving their own cars for the day, further exacerbating traffic already extra slow due to the weather conditions. The transit agency posited that a system to help operators feel confident in safely using the shoulder lanes in a wider range of weather conditions would help not only the bus commuters, but the vehicles in the rest of the lanes as well.

The University of Minnesota ITS Institute and the Minnesota Valley Transit Authority (MVTA) developed a driver-assist system in 2010 and retrofitted 10 buses. The system included lane keeping assistance, lane-departure warning, forward collision awareness, side collision awareness, and a driver interface. The driver interface included a heads-up display superimposing the lane edge with the driver's view, a screen showing vehicles alongside the bus, a seat that could vibrate to indicate lane departure, and steering feedback to either indicate lane departure (to a driver with hands on the wheel) or steer the bus itself. Tests showed that the system was successful and the buses have continued to operate with the system ever since. The left frame of Figure 13 shows the view through the heads-up display, including the virtual shoulder line superimposed on the actual lane line. On the far left is part of the dynamic display showing vehicles to the side of the bus. The right side of the figure shows that the video is taken while driving in freeway traffic with the driver's hands off the wheel.

Figure 13: Screen Capture from video from MTVA Driver-Assist System Showing Heads-Up Display and Autonomous Steering for Lane Keeping



Source: Courtesy Craig Shankwitz, MTS Systems, unpublished

The MVTA experience also showed that with the lane-keeping system, drivers felt comfortable driving on average about 3 mph faster.<sup>9</sup> That kind of increase in confidence could counteract the reductions in throughput observed at the XBL when buses widened from 96" to 102".

The MVTA, along with a company called MTS Systems with a key staff member from the University of Minnesota ITS Institute, were awarded a \$1.8 million grant in 2015 through the FTA's Innovative Safety, Resiliency, and All-Hazards Emergency Response and Recovery Demonstration program. That year, the program issued a total of \$29 million in grant funding. The MVTA project is currently underway as the next phase of system development. Using lessons learned from the initial deployment and newer technology, the current project will retrofit the technology into 11 additional buses and retrofit the original 10 buses all with the current generation of the system. Based on driver feedback, one of the lessons learned was that more targeted displays to the drivers are more effective. The 2016 generation of the system will replace the heads-up display with LEDs on the windshield frame that indicate drift toward the lane edges. Both generations use commercial off-the-shelf automotive components, sensors, and communications technology.

The bus assist grant also includes an outreach task, and the recipients expressed an interest/willingness to speak with interested individuals at the PANYNJ, NJ TRANSIT, and others. One of the experts at the April 14, 2016 Capacity Study Workshop (Dr. Lutin, the retired NJ TRANSIT Director of Statewide and Regional Planning) has been working with Craig Shankwitz, formerly of the University of Minnesota ITS Institute and now with MTS, on these issues for many years. Discussing the XBL needs with Mr. Shankwitz, the Capacity Study team learned that the systems used in the snow plow and bus projects, especially the base software, could be adapted. Concerning the lack of GPS in the Lincoln Tunnel, Mr. Shankwitz suggested that RFID tags could be mounted to the tunnel wall itself (or along the tunnel and in the PABT) for sensors on the bus to read

<sup>9</sup> Cedar Avenue Driver Assist System Evaluation Report, Federal Transit Administration (FTA) Report No. 0010, prepared by Brian Pessaro and Caleb Van Nostrand, National Bus Rapid Transit Institute, December 2011. <https://www.transit.dot.gov/research-innovation/cedar-avenue-driver-assist-system-evaluation-report-fta-report-0010>



for precise offset from walls and as a basis for identifying distance along the corridor. Dedicated short range communications (DSRC), similar to WiFi, will also support bus tracking and guidance within the XBL and PABT.

Precise GPS is currently the most expensive piece of hardware on the connected bus, potentially costing around \$10,000 per bus. However, GPS 3 is on the horizon within the next 10 years and would drop the price to around \$100 per bus. Google has invested heavily in pairing GPS 3 with the lidar-based mapping, done as part of collecting Streetview images, as a platform for operating its autonomous vehicles. The second most expensive investment per bus cost is the labor to retrofit the buses with the various systems. Labor costs will decrease as optimal configurations for each bus model are developed and technicians become more efficient at installation. Costs will further decrease once the equipment is mature enough to be installed directly by the bus manufacturer at time of purchase.

The expenditures for equipment and software to enable the connected bus platooning application would overlap significantly with applications that increase safety and reduce claims paid by the transit agency for crashes. One way to consider the financial implications of the uncertain costs and collision benefits would be to analyze a range of costs and percentage reduction in claims. This approach was taken by Dr. Lutin and Dr. Kornhauser in a 2013 research paper. The cost range began with the collision avoidance system sold by Mercedes for automobiles (\$2,800) and extended up to five times that price (\$14,000). Percent reductions in claims ranged from 10% to 90%. Looking at 35 different scenarios, only three that were combinations of low reductions in claims and high costs did not find the application to be cost effective over the life of the bus. Furthermore, “for the midrange scenarios, with 50% of claims reduction and a cost three times the base price, installation cost would be recouped in 3.5 years.”<sup>10</sup>

Although the connected snow plows and the bus lane keeping assistance are not the exact applications that the PANYNJ and bus operators in the XBL/Lincoln Tunnel would utilize, the former is a proof of concept of the connected fleet vehicles and the latter is a proof of concept of retrofitting driver assist systems into transit buses. Combining these concepts with the automated cruise control advances in passenger cars and the connected bus platooning, the technological capabilities are in reach to realize a connected bus system to increase capacity by allowing buses to move closer together.

#### 4.1.4 Policy Considerations

Key policy issues to be addressed include:

- What incentives might the PANYNJ use to encourage adoption of connected bus technologies for users of the XBL/Lincoln Tunnel?

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<sup>10</sup> Lutin, Jerome M and Kornhauser, Alain L, “Application of Autonomous Driving to Transit – Functional Capabilities for Safety and Capacity”, July 22, 2013 presented at the 2014 Annual Meeting of the Transportation Research Board

- At what point might the PANYNJ make use of connected bus technologies a prerequisite for use of the XBL/Lincoln Tunnel?
- What steps can be taken to ensure fairness to the variety of bus operators that use the XBL/Lincoln Tunnel, including the practicality of passing on costs, especially in cases when buses only occasionally use the XBL/Lincoln Tunnel?
- What steps can be taken to protect the PANYNJ and bus operators from legal challenges? The bus-on-shoulder lane-keeping system in Minnesota has been in revenue service on 11 buses for six years without any legal problems, mostly because the driver is still in control and ultimately responsible. Similarly, driver warning and driver assist technology in passenger vehicles such as ACC and lane keeping have not been legally challenged. However, a rigorous investigation of legal and liability issues, combined with outreach to bus operators, would be prudent.
- Would these systems be supported by professional bus drivers and their unions, or would these systems be perceived as threats? Based on discussions with experts at the Capacity Study Workshop on April 14, 2016, the advent of fully autonomous passenger vehicles will precede driverless buses.
- What roles would the PANYNJ, NJ TRANSIT, and other partner agencies and operators play in implementing this innovation? How would the PANYNJ assign resources and mobilize the cooperation necessary to lead development of connected bus implementation as an early champion and to oversee ongoing efforts? Initial activities would include public education, consensus building, grant writing, piloting, performance management, and other tasks described more fully in Section 4.1.6.

Connected bus technology is significantly more complex than requiring E-ZPass in the XBL. However, there are parallels in the PANYNJ's obligation to optimize the performance of scarce trans-Hudson capacity by leveraging its control over specialized lanes. Policy development is a crucial underpinning for a successful program.

#### 4.1.5 Operational Considerations

Connected bus systems are a technological tool for operations. The tool needs to be designed to integrate into the exceptionally complex bus system. Although a significant undertaking, the magnitude of the needs and limitations in options should prompt the PANYNJ to rise to the challenge. Some of the known operational challenges will be:

- **Mixed flow (equipped and non-equipped buses)** – An existing, observed problem in the XBL is that a single slow bus can cause buses behind it to slow, either for prolonged time or as a ripple through the line of buses. To achieve peak performance, the entire line of buses should be interconnected. However, it is not realistic to equip all possible buses that might use the XBL with the technology. At best, the percentage of buses will gradually increase in the typical fleet that use the PABT. Incremental benefits to operational efficiency could be achieved through equipping some buses with the necessary technology to enable formation of small platoons. For instance, in each instance of a two-bus platoon, the total space those two buses occupy would

be less since they would travel closer together, and these savings would add up. The equipping of buses should keep pace with the demand for bus capacity. The theoretical upper limit of capacity based on buses extremely closely spaced will exceed the capacity of the proposed PABT and the surrounding street network.

- **Mixed flow (equipped buses and cars)** – Outside of the AM peak period along the XBL, buses will primarily be operating in mixed flow with passenger cars. Eventually, passenger cars may be equipped to connect to buses, but that is beyond the influence of the PANYNJ. Until then, the capacity-adding capabilities of equipped connected buses will be minimal in mixed flow lanes, except stretches of lanes where there are groups of buses without passenger cars or other vehicles in between (e.g., in the PM peak period in the Lincoln Tunnel because, as discussed in the “Bus Network Operational/Service Strategies” technical memorandum, PABT/Lincoln Tunnel Management have recently implemented an operational change whereby buses are directed to use a single eastbound lane during this period).
- **Protocols for the formation of bus platoons** – A connecting zone would potentially be located just east of the teardrop merge points. The connections would occur at a speed to avoid creating disturbances in the bus flow. Truck platoon formations occur with in-vehicle displays indicating to drivers the position of nearby candidate vehicles and prompting verbal coordination to initiate the link. Protocols would also be necessary for disbanding platoons.
- **Driver interface** – As demonstrated in the original bus-on-shoulder deployment in Minnesota, providing clear and targeted information to drivers can be more useful than a complicated display with extraneous detail, even when potentially using a heads-up display.
- **Troubleshooting and maintenance** – Even though the connected bus system would be designed to be inherently reliable, the components are likely to have shorter functional lifespans than the buses themselves, either due to hardware failure or obsolescence. The connected bus system would share hardware and software with related applications, such as collision avoidance, but this would add an additional high-tech system to maintain. The Minnesota lane-keeping and collision avoidance program demonstrated an equipment damage concern. The location of radar equipment was moved from the front corner of the bus to behind the wheel to be in an area less prone to damage.

#### 4.1.6 Possible Path to Implementation

Developing a bus platooning program is a complicated undertaking with risks in several areas. The unique geographic considerations that led the PANYNJ to make the visionary leap to institute the XBL also underpin why the PANYNJ is the right agency to take this all-important first step in bus platooning. This initiative presents technical, operational, and policy challenges. One method for addressing them is to implement a Bus Platooning Pilot Program. The purpose of such a pilot program would be to demonstrate the viability of the technology, estimate benefits in various scenarios, and establish the path necessary for full implementation.

By starting with a pilot program, the PANYNJ would also be able to realize a number of other opportunities including the establishment of key relationships among agency experts, the further

exploration of next-generation technology, and the installation of technology that will have benefits far beyond the Lincoln Tunnel corridor. The Bus Platooning Pilot Program also has the potential to bring additional public attention and demonstrate the innovative posture of all the agencies involved. It has the potential to be replicated in other parts of the region as well as the country, and because this is such a ground-breaking initiative, involvement and support from the USDOT should be actively sought.

Based on a systems engineering approach and adapting some elements of “A Research Roadmap for Substantially, Improving Safety for Transit Buses through Autonomous Braking Assistance for Operators,”<sup>11</sup> the following steps provide a potential framework for the PANYNJ to launch a Bus Platooning Pilot Program:

1. Identify a PANYNJ Champion to lead the effort and establish the Program Management Committee (PMC) members from PANYNJ, NJ TRANSIT, and NJDOT. This effort also should include New York’s MTA (which operates some commuter express buses from Staten Island via the XBL).
2. Work with internal staff and/or consultant staff to further flesh out the scope of the program, and determine what (if any) long-term support might be needed from internal or consultant staff. Develop a high-level concept of operations for the pilot program, recognizing that changes might occur as a result of the Request for Information (RFI) to be released. As part of this exploration, it will be necessary to identify any policies, laws, or operational procedures that might need to be adjusted to accommodate the pilot program.
3. Prepare and release an RFI to garner feedback from the industry on potential technology solutions and/or to solicit potential partners that want to be a part of the effort. Review input from the RFI with the PMC and relevant technical staff from each agency.
4. Work again with internal staff and/or consultant staff to further refine the scope of the program, make any changes to the high-level concept of operations, and affect any changes needed in policies, laws, or operational procedures.
5. If necessary, seek federal funding opportunities through various grant programs.
6. Carry out the pilot program as scoped, achieving the stated program goals and garnering a number of valuable lessons learned and documents generated.
7. Consider next steps beyond the pilot program to garner the full suite of benefits that are estimated.

For this Bus Platooning Pilot Program, the PANYNJ has a unique opportunity to demonstrate and evaluate multiple scenarios of connected and automated technology: longitudinal control by itself

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<sup>11</sup> Lutin, Dr. Jerome M., Senior Director of Statewide and Regional Planning, NJ TRANSIT (Retired), and Kornhauser, Dr. Alain L., Faculty Chair, Princeton University Autonomous Vehicle Engineering, et al.), A Research Roadmap for Substantially, Improving Safety for Transit Buses through Autonomous Braking Assistance for Operators, Submitted to the Transportation Research Board August 1, 2015, Revised November 9, 2015, Paper 16-1246,

(accelerator and brake pedals controlled by system, steering by the driver), longitudinal control with the addition of lane-departure warnings (the driver is still steering but now has additional guidance), and longitudinal control with latitudinal control (automated acceleration, braking, and steering). Lessons learned from the pilot will help to determine an optimal approach for future deployment on a much larger scale.

Note that during this pilot program, drivers would always be expected to stay engaged with the driving task and ready to take over the control at any moment. Drivers would receive extensive training on the aspects of the technology and are an important component of the pilot program's success.

One path that is exceedingly unlikely to succeed is to wait for another transit agency, a bus manufacturer, or another company to independently develop an off-the-shelf connected and automated bus solution that would address XBL/Lincoln Tunnel/PABT needs. Other transit agencies simply do not have the bus volumes funneled through single lanes without bus stops or turns. Bus manufacturers and other companies do not have the incentive to develop such systems without a specific customer request. Therefore, the PANYNJ should provide overall leadership to work with NJ TRANSIT and concerned agencies and operators to develop a programmatic and collaborative approach to this complex challenge. Since the base technologies exist and the development steps take time, the sooner the PANYNJ and its partners can embark on realization of a connected bus program, the more likely it will be in place to meet growing commuter demand, best manage and allocate capacity along the Lincoln Tunnel corridor, and support efficient operation of a potential new Midtown Bus Terminal.

## 4.2 OTHER CONNECTED & AUTOMATED BUS APPLICATIONS

### 4.2.1 Motivating Needs

Applications that utilize connected and automated technology are rapidly advancing from research to practical deployment. The USDOT has been researching potential CV applications for nearly a decade, and extensive testing and development have been done on a number of such applications. Some applications provide safety benefits, some provide mobility and access benefits, some provide environmental benefits, and many provide multiple layers of benefits. Although these applications and benefits are being readied for actual use, it is important to acknowledge that a communication system may exist that opens the door to future applications not yet imagined.

Meanwhile, automobile, truck, and bus manufacturers have been rapidly developing advanced driver-assist tools and AV technologies that further enhance the safe operation of their vehicles. Advanced braking, lane-keeping assistance, and various driver warning systems all utilize on-board sensors and/or connectivity to provide the driver with more information and in some instances enhance operation of certain driving tasks.

These additional applications and benefits are important to consider because they are value-added benefits beyond the planned use in platooning as described in the previous section. Many hardware,

software, and communications components would serve bus platooning and other applications. Although bus platooning would be used initially only in the Lincoln Tunnel corridor, many of these other applications could provide benefits along other portions of interstate bus routes. Identifying methods to model these non-XBL/PABT benefits for bus operators could help make the case for early adoption.

#### 4.2.2 Opportunities & Benefits

The Safety Pilot Model Deployment project in Ann Arbor, Michigan tested a number of CV applications focused primarily on safety as part of their Transit Safety Retrofit Project.<sup>12</sup> This effort used retrofitted transit buses to test three basic safety applications and two transit-specific applications.

The basic safety applications in the Safety Pilot Model Deployment included:

- **Forward Collision Warning (FCW):** Warns a bus driver if there is a risk of a collision with a vehicle in front of the bus. This V2V app was tested throughout the model deployment geographic area on buses, but similar research has been ongoing with cars and trucks. A representative graphic for FCW is shown in Figure 14.
- **Emergency Electronic Brake Lights:** Warns a bus driver when there is a hard-braking event in the lane ahead of the bus (which may be several vehicles in front of the bus), or in an adjacent lane. This application is designed to address chain-reaction collisions.
- **Curve Speed Warning (CSW):** Warns a bus driver if the bus is approaching a curve too quickly for safe navigation. This feature relies on roadside equipment and therefore is only available at designated locations.

Figure 14: Forward Collision Warning



Source: Volvo Bus

<sup>12</sup> Transit Safety Retrofit Package Development, Final Report, US Department of Transportation, July 2014, [http://ntl.bts.gov/lib/54000/54500/54592/FHWA-JPO-14-142\\_v1.pdf](http://ntl.bts.gov/lib/54000/54500/54592/FHWA-JPO-14-142_v1.pdf)

The Safety Pilot Model Deployment project also developed and tested the following transit-specific applications:

- **Vehicle Turning Right in Front of Bus Warning (VTRW):** Warns a bus driver when another vehicle is passing on the left and turning in front of the bus, either to re-enter the right-hand lane or to complete a right turn in front of the bus, as a bus is leaving a bus stop. This situation often occurs when a bus stop is located prior to an intersection and the bus is stopped in the right lane at the bus stop loading and unloading passengers. Another vehicle traveling behind the bus (and planning to turn right at the intersection) is unsure of the bus's dwell time. As a result, the other vehicle passes the bus on its left and attempts to make a right turn at the intersection. If the bus is pulling away from the bus stop at the same time the other vehicle is turning, there is a potential for a collision. This V2V app was tested at 17 bus stops in the model deployment geographic area.
- **Pedestrian in Signalized Crosswalk Warning (PCW):** Warns a bus driver if the vehicle is about to collide with a pedestrian in a crosswalk while making a left or right turn at a signalized intersection. The app relies on roadside equipment for transmission of traffic signal phase and timing (SPaT) as well as the static physical geometry of the intersection. The SPaT message contains pedestrian presence and detection data objects. Figure 15 includes a description of the system design and operation.

Results from the pilot project were valuable inputs for making improvements to the applications, further advancing their development, and readying them for real-world deployment. It is important to note that even in the early stages, the applications produced important safety benefits such as faster driver reaction time for FCW, CSW, and feedback from the drivers that the alerts were easy to understand and use.<sup>13</sup> Each agency will need to decide which applications are applicable to their own needs and within their own policies.

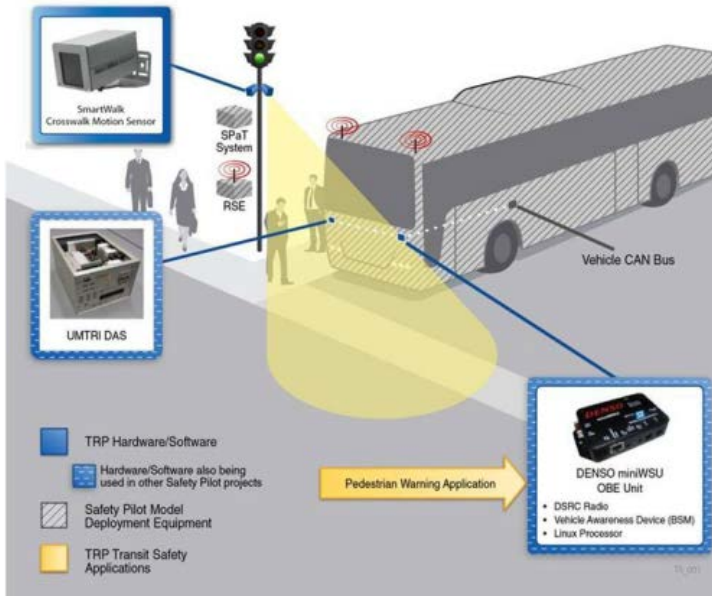
Coupling the advancements in CV application research with advancements in AV development opens the window to an even greater return on investment, such as by adding advanced brake assist to FCW, adding lane-keeping assistance to lane-departure warning, and adding automated braking to pedestrian warning. The possibilities are limitless. Many automakers are already instituting such pairings of technology in real-world vehicles today, and their proliferation to trucks and buses are just around the corner. This all points to an exciting future in connected and AV technology.

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<sup>13</sup> Independent Evaluation of the Transit Retrofit Package Safety Applications, US Department of Transportation, February 2014, [http://ntl.bts.gov/lib/54000/54800/54839/FHWA-JPO-14-175\\_v1.pdf](http://ntl.bts.gov/lib/54000/54800/54839/FHWA-JPO-14-175_v1.pdf)



Figure 15: Pedestrian in Crosswalk Warning



Source: US Department of Transportation

#### 4.2.3 State of Enabling Technologies

Since the Ann Arbor Safety Pilot Model Deployment test that first included transit applications, a number of additional CV research efforts have been undertaken by the USDOT covering more than a dozen applications which impact transit as outlined in Table 3.

Table 3: Transit Related Connected Vehicle Pilot Tests and Research

Application	Pilot Test
<ul style="list-style-type: none"> <li>● Connection Protection (T-CONNECT): increase the likelihood that a traveler makes a successful transfer</li> <li>● Dynamic Transit Operations (T-DISP): provide both real-time trip-planning information and demand-responsive transportation access</li> <li>● Dynamic Ridesharing (D-RIDE): provide access to a ridesharing network for travelers by communicating needs (passengers) or available space (drivers)</li> </ul>	<p>Proof of concept demonstration and testing in Fall 2014 in Orlando, FL</p> <p>Demonstration from March to December 2014 in Columbus, OH testing T-CONNECT and trip-planning component of T-DISP</p>
<ul style="list-style-type: none"> <li>● Interactive Transit Station Information System (ITSIS)</li> </ul>	<p>California Partnerships for Advanced Transit and Highways (PATH) Santa Clara Valley Transportation Authority (VTA) – Routes 22 &amp; 522</p>
<ul style="list-style-type: none"> <li>● Transit Bus Stop Pedestrian Warning Application                             <ul style="list-style-type: none"> <li>○ Alerts pedestrians of buses approaching and departing stop (V2I &amp; V2I2P)</li> <li>○ Alerts bus drivers of pedestrians in roadway (I2V)</li> <li>○ Alerts passengers alighting from buses about approaching motor vehicles (V2I)</li> </ul> </li> </ul>	<p>Greater Cleveland Regional Transit Authority (GCRTA), Operations expected December 2016 – June 2017</p>
<ul style="list-style-type: none"> <li>● Urban Bus Ops Safety Platform                             <ul style="list-style-type: none"> <li>○ Enhanced Pedestrian Crossing Warning (E-PCW)</li> <li>○ Enhanced Vehicle Turning Right in Front of Bus Warning (EVTRW)</li> <li>○ Rear Camera Integration</li> <li>○ Improved pedestrian detection sensing technology</li> <li>○ Improved locational accuracy technology</li> </ul> </li> </ul>	<p>Greater Cleveland Regional Transit Authority (GCRTA), Operations expected December 2016 – June 2017</p>

Source: Transit Connected Vehicle (CV) Research Projects Update, US DOT presentation at the APTA Fare Collection & Revenue Conference, April 2016, <https://www.apta.com/mc/revenue/presentations/Presentations/Transit%20Connected%20Vehicle%20CV%20Research%20Projects%20Update%20-%20Tim%20Weisenberger.pdf>

#### 4.2.4 Policy Considerations

C/AV technology and solutions represent a step-change in ITS deployment, operations, maintenance, and policy/planning. The tremendous increase in data and new technological systems will require coordination within the PANYNJ (and among the various bus operators) concerning issues such as data privacy, data security, data sharing, multi-agency coordination, and interoperability. At this time, no significant policy changes are required, but new policies considered in conjunction with the platooning application discussed previously would also apply here.

### 4.3 LIFESPAN OF VEHICLE FLEET AND RETROFIT VERSUS NEW MODELS

Transit operators wrestle with issues surrounding the lifespan of their vehicles on a daily basis. The rapid evolution and attractiveness of alternative-fuel vehicles has sped up the pace of replacement somewhat (due to the large return on investment), but the FTA still estimates that the typical life of a vehicle is up to 12 years. Given the tremendous cost of vehicles, the need to maintain some consistency in fleet (for maintenance and driver training purposes), and the need to maintain a certain level of spare vehicles (many operating at 10-12% spare availability), the opportunity to spend significant additional funds on new technology is typically measured with great care. The installation of “one-off” ideas and applications is acceptable for experimentation, but any serious deployment of new technology is usually considered at the fleet-wide level for purposes of maintenance and training.

This sets up a natural conflict: long lifespan of vehicles, minimal differences for maintenance and training, and the preference for larger-scale deployments of new technologies (which takes time) in contrast with the extremely nimble evolution of technology which has an average leading-edge lifespan of typically no more than 18 months and in many instances requires specialized maintenance and training. This inherent conflict has parallels to other transitional issues that have confronted operators, most notably the transition from diesel to alternative fuels. The lessons learned from that transition support the premise that management and organizational culture change will be required to implement new technological developments. The acceptance and utilization of new technology brings benefits such as cost savings, revenue increases, customer experience improvements, safety benefits, liability reductions, and mobility enhancements. Those benefits are worth the initial capital investment and the acceptance that software upgrades and application improvements may occur multiple times during the lifespan of the vehicle—it is not a one-and-done installation.

## 5 PABT Connected & Automated Bus Opportunities

### 5.1 BUS GUIDANCE TECHNOLOGY (PRECISION GUIDANCE & PRECISION DOCKING)

#### 5.1.1 Motivating Needs

The premium cost of space in Midtown Manhattan has led to constricted spaces for bus movement within the PABT itself and on its ramps and the surrounding street network, particularly at the Eighth Avenue end of the building. The future PABT will also face constraints, especially at the helix ramps between floors. The professional bus drivers are extremely skilled, but vehicle speeds are necessarily low and marks on walls and columns within the PABT bear testimony to occasional miscalculations. A steady, reliable, and safe flow of vehicles, no matter the experience level of the driver, is important to the smooth operation of the system. This would be especially true for the helix ramps in the future PABT.

#### 5.1.2 Opportunities, Benefits, and Risks

Technology brings an opportunity for more precise docking and vehicle movement within the PABT. The level of automated movement throughout the PABT could be linked to a system for driverless or enhanced operation from the moment the bus enters the facility. For example, the RFID tags in the Lincoln Tunnel to facilitate bus platooning are also a form of precision bus guidance that could be extended within the PABT itself.

Precision docking and movement systems allow the driver to operate autonomously in the PABT, and to park or dock the vehicle in an exact location. Automated guidance and steering within the PABT would allow for more efficient movement in confined spaces, tight curves, or problem spots within the PABT (e.g., tight turns such as at the Eighth Avenue end of the building). For docking, it is primarily used to ensure that the vehicle aligns precisely with the platform edge at bus stops, providing for a minimal gap between the platform edge and the doors, which facilitates smooth, safe, and efficient boarding/alighting.

Magnetic devices embedded in pavement, discussed in the next section, have the drawback of disrupting the road surface and building floor. With more advanced systems available, the magnetic solution is not recommended for the PABT. Rather, it is presented to show the in-service viability of using sensor-based technology to safely and precisely guide buses that are in revenue service.

#### 5.1.3 State of Enabling Technologies

There are already many non-ITS technologies to assist precision docking. The most basic technology is the Kassel Kerb, which allows the wheel of the vehicle to make contact with the edge so the driver has the sensory feedback to correctly position the vehicle. However, the curb is curved and does not

cause tire damage nor does the edge of the vehicle scrape against the platform. Kassel Kerbs are found throughout Europe and in England. Another common “low-tech” docking guidance is a small lateral guide wheel attached to the steering arm. When this comes in contact with the curbing, it steers the vehicles along the required alignment. This is found in parts of Europe and Australia.

Current technology-supported precision docking and movement (Figure 16 and Figure 17) consists of two main technology types:

- Optical guidance, where the travel path is marked out on the roadway and is ‘read’ by an optical sensor located at the front of the vehicle. (Rouen France; Las Vegas, NV)
- Magnetic sensors, where a loop/wire or permanent magnet guidance studs are embedded on the roadway along the path to be followed. Sensors on the undercarriage of the vehicle detect the loop/studs and guide the bus along the alignment. (Lane County/AC Transit)

With sensor and guidance technologies evolving rapidly, a recommendation for a certain type of system for the current or future PABT would be premature. This section outlines the practicality of technology to improve fine vehicle movement. Two technologies to consider if the PANYNJ is interested in a near-term pilot program to improve operations of the existing PABT are discussed.

In both cases, the sensor technology is integrated with the steering system of the vehicle. The primary advantages of precision docking and movement systems are to:

- Ensure efficient movement of vehicles throughout the PABT
- Address problem spots for vehicle movement within the PABT
- Ensure that vehicles dock precisely every time
- Facilitate faster boarding and alighting, thus increasing both vehicle and passenger throughput at stations
- Improve the accessibility for people with mobility challenges
- Facilitate tighter design, and in some occasions enable a design solution that could not be reliably achieved without such support
- Reduce the burden on drivers to make precise docking maneuvers

Figure 16: Optical Guidance for Precision Docking and Movement



Source: Rouen, France

Figure 17: Example of Automated Steering and Precision Docking from Lane Transit District



Source: Lane Transit District; Jill Huang (UC Berkeley); YouTube

#### 5.1.4 Policy Considerations

Questions to guide policy discussions would include:

- What incentives could the PANYNJ use to encourage adoption of relevant bus technologies for users of the PABT?
- At what point could the PANYNJ require the use of precision docking and movement technologies as a prerequisite for use of the facility?
- Are there any liability issues?

These are big questions that should also consider fairness to the wide variety of bus operators – especially for those that only occasionally use the PABT.

### 5.1.5 Possible Path to Implementation

A simplified path to implementation includes researching current and emerging technologies in more depth (including speaking with agencies currently using the technology and companies providing it), arranging a pilot at an offsite location, conducting a pilot within the PABT, and subsequently encouraging wider adoption. Many of the steps in Section 4.1.6 (regarding the possible path to implementation for bus platooning) could also be adapted here.

## 5.2 CONNECTED & AUTOMATED BUS MERGING TECHNOLOGY

### 5.2.1 Motivating Needs

A longer-term possibility of connected and automated technology is the opportunity to implement bus merging technology. An outgrowth of collaborative ACC, merging technology is not yet close to market but has been hypothesized as a future application of CV communications and AV operation. There are multiple locations along the Lincoln Tunnel corridor where enhanced merging technology could improve the overall flow of the corridor and reduce the possibility of accidents. For example, there are multiple bus merge points within a portion of the XBL called the “teardrop” where the streams of buses from the NJ Turnpike northbound, the NJ Turnpike southbound, and Route 3 eastbound combine to enter the single XBL lane on Route 495. In addition, there are locations where buses not in the XBL—but still traveling through the Lincoln Tunnel—must merge with buses that were in the XBL as they enter the ramps for the PABT. Whether the merging technology occurs with driver involvement or in a fully automated driving capacity depends on the maturity of the technology, the location of the merge, and the potential mix of traffic that exists.

### 5.2.2 Opportunities, Benefits, and Risks

One application would utilize CV technology for lane change advisories, providing alerts to vehicles in a mainline to change lanes and thereby open up capacity in the merge lane on-ramp. This application has been modeled in a project by the University of Virginia, and the results demonstrated that this approach holds significant potential in improving freeway operations.<sup>14</sup> However, the improvement achieved through this algorithm is limited in that it provides only a lane changing advisory to mainline vehicles, rather than disseminating appropriate control messages (accelerate, decelerate, and change lanes) to all three vehicles involved (i.e., leading and lagging mainline vehicles and a ramp vehicle).

Another application would utilize C/AV technology for merge control, accomplished by an algorithm that determines an appropriate control strategy for all vehicles involved in a merging conflict and provides corresponding advisory messages and/or control actions to create adequate gaps for

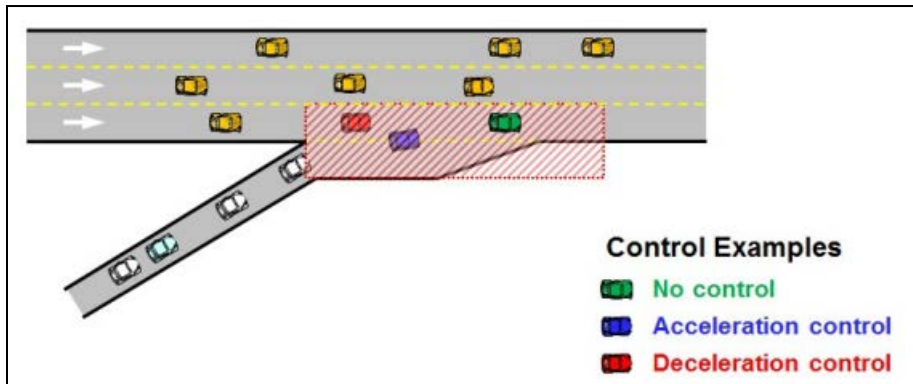
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<sup>14</sup> A Prototype Freeway Merging Control Algorithm Under a Connected Vehicle Environment, January 2014, Hyungjun Park, Shize Su, and Brian L. Smith, the University of Virginia.  
[https://www.researchgate.net/publication/283352128\\_A\\_Prototype\\_Freeway\\_Merging\\_Control\\_Algorithm\\_Under\\_a\\_Connected\\_Vehicle\\_Environment](https://www.researchgate.net/publication/283352128_A_Prototype_Freeway_Merging_Control_Algorithm_Under_a_Connected_Vehicle_Environment)



smoother merging operation. This algorithm is proactive in that it determines and implements a control strategy to “actively” create a gap rather than “passively” waiting for a gap to become available. Figure 18 shows a graphic representation of the vehicles involved in the merge operation and the types of control required to successfully execute the action.

Figure 18: Concept of Freeway Merging Control Algorithm



Source: University of Virginia

According to an evaluation conducted by the University of Virginia using a VISSIM simulation of an actual freeway network, the proposed algorithm has significant potential to improve freeway operations. In an ideal situation, with a 100% market penetration rate of CV technology and a 100% advisory compliance rate, the proposed algorithm increased vehicle miles traveled by 6.3% and average speeds by 42.2%, while reducing total delay times by 54.6% for the whole network.

### 5.2.3 State of Enabling Technologies

C/AV merging applications remain in the research stage, and thus there is not a significant body of knowledge on the subject at this time. USDOT has an active research program underway to examine lane change advisory, merge control, and gap responsive on-ramp signals utilizing CV technology in conjunction with ramp metering.<sup>15</sup> USDOT is considering additional simulations using a driving simulator to assess the receptivity of people to advice or control actions taken in response to the concept of operations. Success could eventually lead to testing a prototype on a closed course to identify further technical questions, assess human factors issues, and to support technology transfer activities.

### 5.2.4 Policy Considerations

Since this is an ongoing research program, the PANYNJ should continue to monitor its development, and should also encourage the federal research programs to incorporate bus vehicles and technology, especially for the cases of multiple streams of buses merging together (rather than an on-ramp situation). While connected and autonomous vehicles are ultimately expected to optimize

<sup>15</sup> Advanced Freeway Merge Assistance: Harnessing the Potential of Connected Vehicles, US Department of Transportation, 2014, <http://www.fhwa.dot.gov/advancedresearch/pubs/14045/14045.pdf>

merging and other aspects of driving, those advances would happen well after implementation of bus platooning and the bus safety features previously described. To address the PANYNJ's needs to smooth merging, a more custom solution that utilizes precision bus guidance, accurate knowledge of precise bus locations, and direct messaging to drivers may be the more advantageous policy direction, especially for the operation on the helix ramps.

## 6 Additional Technology-Enabled Operational Opportunities

### 6.1 ADAPTABLE GATE ASSIGNMENT STRATEGIES

Given the uncertainties around changing demand and technology over the lifespan of the current and future PABT, ensuring flexibility has been one of the recurring themes in this Capacity Study. Minor changes in design and addition of technology that enable, but do not mandate, a range of strategies related to gate assignment is likely a prudent investment. The PANYNJ would have the flexibility to refine the most effective approach, including different usages for different types of carriers.

As discussed below, there are practical impediments to some strategies that would offset potential benefits. In addition, it should be noted that limited dynamic gate assignment actually can be a low-tech implementation. It would require sufficient passenger waiting areas, a few stanchions, and staff to sort passengers into appropriate queues directing them to the right gate. While more labor intensive than would be desired for a long-term solution, it would be useful for pilots, during periods of unusual incidents, and as an interim or short-term improvement.

Table 4 defines three different types of gate assignment strategies: fully dynamic; limited dynamic; and flexible. There is not an industry standard for these terms, but they are used consistently within this Capacity Study according to the descriptions in the table.

#### 6.1.1 Motivating Needs

Flexibility in gate assignments, potentially both in the short and long terms, is a tool for the PABT to optimize utilization of limited gates.

#### 6.1.2 Opportunities, Benefits, and Risks

As experienced in the current PABT, different types of carriers have different usage patterns for their gates. Due to fundamental differences between high-volume commuter lines and less frequent intercity travel, usage patterns lead to some gates backing up, being used for short-term storage, or remaining empty.

A fully dynamic gate assignment system would bring the highest level of flexibility in bus operations. As each bus arrives, it would be routed to the next open gate, minimizing bus waiting times. However, in a large complex bus terminal, such as the PABT, the full flexibility afforded to bus operators provides a negative tradeoff to passengers as they would be directed to different gates each day for their bus and on short notice. In addition, a fully dynamic gate assignment would require a common waiting area, which likely could not be accommodated in the multi-level PABT.

Table 4: Overview of Various Adaptable Gate Assignment Strategies

	Fully Dynamic Gate Assignment	Limited Dynamic Gate Assignment	Flexible Gate Assignment
<b>Concept</b>	Underlying operation plan of gates changes everyday	Tool for managing incidents by as-needed changes within logical gate groupings	Facilitating changes of gate assignments to routes or carriers over the scale of months or years*
<b>Each route is assigned a typical gate</b>	No	Yes	Yes, but it can change over months or years*
<b>Gates are shared among operators</b>	Yes	Only limited situations, such as by long headway carriers	Allows changes over months or years*
<b>Routes would switch among floors</b>	Yes	No; gates would be logically clustered	Allows changes over months or years*
<b>Benefits</b>	More effective use of gates since buses do not need to wait for open gates	Mostly consistent for customers; More effective use of gates during disruptions	More effective use of gates over time as needs change*
<b>Concerns</b>	Customer inconvenience — uncertainty, waiting areas, walk time; Driver/operator confusion.	Potential customer inconvenience or confusion during disruptions	Small potential for customer confusion
<b>Enabling Technology</b>	Real-time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators	Real-time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators	Real-time bus locations, dynamic signage for customers, traveler information, dynamic signage and communication to bus operators
<b>Recommended?</b>	No	Yes	Yes

\* Also a policy decision to allow different weekend assignments, construction assignments, or other planned changes.

The fully dynamic gate assignment concept highlights trade-offs between providing flexibility to transit operators with respect to gate assignment and giving travelers advance notice to find their gates. The following gate assignment concepts are designed to give some flexibility to bus operators while still offering a high quality customer experience.

Limited dynamic gate assignment has typical gates for all departures, but allows changes to be made on days where there are unusual conditions, such as inclement weather leading to many empty buses not arriving to the PABT on schedule. Departure gates would not be expected to change between floors. In extreme cases of problems with the Lincoln Tunnel or PABT itself, such as if portions of the PABT had to be closed for a police investigation, some bus operations could shift to the George Washington Bridge Bus Station (GWBBS). When these reassignments are robustly communicated to travelers, this type of flexibility is recommended.

Flexible gate assignment uses dynamic signage to enable the reassignment of typical gates used for departures without replacing printed signage. It allows gate assignments to be easily modified to match changes in bus schedules or to temporarily reassign departures due to PABT construction. This type of flexibility is also recommended for the PABT.

### 6.1.3 State of Enabling Technologies

The enabling technologies for each of the adaptable gate assignment types are essentially the same: real-time bus locations; dynamic signage for customers; traveler information; and dynamic signage and communication to bus operators. The differences in the gate assignment types are the circumstances that trigger gate assignment changes. Investing in the hardware and software to enable adaptable gate assignment will give the PABT and the bus operators a valuable tool for flexibility. The technologies already exist in the market; they just need to be applied to the PABT and integrated with the local traveler information systems.

### 6.1.4 Policy & Operational Considerations

To reap some of the benefits of limited dynamic gate assignment to increase gate utilization, certain bus operators with infrequent departures would likely need to share gates. This may require a change to the lease terms of the bus operators.

The PANYNJ and bus operators would have to agree to the parameters of the limited dynamic gate assignment as well. The possible rerouting between PABT and GWBBS during major events would also require a policy decision and operational plans both for the PABT and GWBBS.

Furthermore, crowd and queue management is a major concern for limited dynamic gate assignment in the current PABT on floors where queuing space is limited and passenger volumes are high.

### 6.1.5 Possible Path to Implementation

For the existing PABT, retrofitting all gates with dynamic signage is probably not prudent. However, it may be a worthwhile investment in areas of the PABT that would most likely benefit from the flexibility afforded by limited dynamic gate assignment. After working with operational staff to determine a candidate group of gates, a pilot program could be initiated and subsequently expanded to any other areas with a strong need for the flexibility. In the new PABT, appropriate dynamic signage at all gates is recommended.

## 6.2 FLEXIBLE MOBILE TICKETING

A resilient transportation system offers travelers the flexibility to switch modes during disruptions. For example, NJ TRANSIT and PATH have an agreement for cross-honoring tickets during serious disruptions. Implementation of a cross-honoring system in a more precise and less labor intensive manner would make it available for more situations. Policy issues such as fare revenue reciprocity would need to be addressed, but technology would enable the options that policy allows and operations support. Some policy issues are strictly within agencies; for instance, NJ TRANSIT allows

flex between bus and train under specified conditions, possibly with an incremental fare option. Other policy issues would be between agencies for exceptions to support resiliency and possibly for a unified regional fare payment and ticketing system for everyday use. As customers expect more convenient service and more seamless transfers across modes and agencies, unified mobile ticketing is a way to meet expectations and draw more people out of SOVs. NJ TRANSIT, as a leader in mobile ticketing, would be a strong asset in regional discussions.

### 6.3 IMPACTS ON REVERSE-DIRECTION CAPACITY

Travel information and traffic management are also important in the reverse direction during the peak periods (outbound in the morning, inbound in the afternoon). In addition to passenger car traffic, empty and revenue buses rely on the reverse trip for getting back to staging points or ongoing pick-up and drop-off points. Travelers and non-commuting traffic need access to New York City for entertainment and shopping, while freight movement occurs at all times of day. Technology plays a role in the reverse commute just as importantly as it does during the peak-period directional commute.

Technology utilized for traffic management including queue warning, ramp metering, shoulder running, and other active traffic management solutions should be considered for reverse-direction implementation as well. Additionally, technology for travel information including extensive availability of reverse-direction data is important for those non-commuter trips that currently are running on routes at or above current capacity.

### 6.4 MANAGED USE LANES

For managed use lanes (MUL) concepts—such as a time-of-day hard shoulder on the NJ Turnpike southbound for buses, a second XBL, or a HOT lane—proven hardware and software technologies are available to safely enable these operations. For example, there is currently dynamic hard shoulder use on the NJ Turnpike Newark Bay-Hudson County Extension. A second XBL would use similar lane use control signals to those currently in place. As discussed below, HOT lanes use a combination of lane use control signals with dynamic signage indicating pricing and other vehicle restrictions.

Another technology component uses toll-tag readers that switch between fare class modes when there is differential pricing. These “flex transponders” allow users to indicate multiple occupants in a vehicle under conditions where a price differential exists between HOVs and single-occupancy vehicles (SOVs). Some managed lane deployments do not charge a toll for HOVs and the transponder has a specific switch for HOV mode. However, they may allow SOVs to also use the facility in toll-paying mode to have the toll automatically debited from the driver’s account. Figure 19 shows a few existing variations.

The MUL concepts use commercial-off-the-shelf electronic signage along with typical ITS communications. The associated software is also readily available.

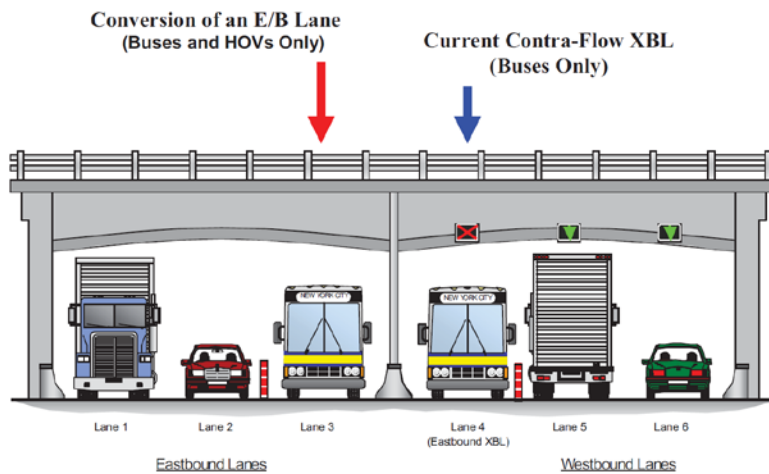
Figure 19: Composite of Switchable Toll-Tag Readers from WSDOT, VDOT, and CalTrans



### 6.4.1 Technology to Enable a Second XBL

If the strategy of adding a second inbound XBL on Route 495 is pursued, technology would be an important enabler for real-time conversion (Figure 20) and to help reduce the overall impact to other traffic. Under one potential scenario, the Lincoln Tunnel center tube far lane from the catwalk could be converted to an inbound dedicated bus lane to accommodate the second XBL. This action could be time based or flexible based on real-time volumes (i.e., convert only if volumes exceed a certain threshold). As a key part of this strategy, enhanced travel information would be required upstream to notify passenger vehicles that the center tube was being converted and to consider alternate crossings or be prepared for congestion ahead. Active traffic management tools could be considered along Route 495 to improve end-of-queue warning and overall flow through the tunnel’s south tube, and in the opposite direction to improve flow for empty buses and reverse commutes. For this strategy the technology is an enabler, not a driver.

Figure 20: Reversible Lane Signals for Contra-Flow XBL



Source: Lincoln Tunnel Exclusive Bus Lane – Capacity Enhancement Feasibility Study



### 6.4.2 Technology to Enable Route 495 HOT Lane

Another operational strategy for consideration is the creation of a HOT lane on Route 495, consisting of a value-priced managed lane in which buses and qualified HOVs could access the lane for free and low-occupancy automobiles would also be permitted access for a fee. The pricing for the HOT lanes could be fixed time-of-day or could be variable based on volume and congestion. The ability to accommodate transit priority vehicles and some additional volume in a flexibly managed lane is important in the Lincoln Tunnel corridor to use available capacity most efficiently and to maintain accessibility to local destinations along the corridor.

Technology is a key enabler of HOT lane implementation, including signage, barriers, enforcement, and real-time pricing implementation (Figure 21). Upstream dynamic message signs would be used to communicate current pricing. When there is a different price for high-occupancy vehicles within the HOT lane, it is also necessary to have a toll tag with a switch to indicate if the car is claiming HOV status for the particular trip or not. Vehicle occupancy enforcement technology is also evolving and becoming market-ready, to assist in enforcement of violators thereby reducing SOVs present in the lanes when not paying the SOV price. With this strategy there would be a mixed-use operation with buses and automobiles sharing the lanes, and the use of CV blind spot warning and object detection on buses would be a viable consideration to reduce the probability of car-bus accidents.

Figure 21: Technology and Signage Utilized for HOT Lane Operations in Washington



Source: Washington State DOT

The suite of technologies described in the preceding paragraph is typical of HOT lanes. The sign in Figure 21 is from the Washington State Department of Transportation State Route 167 HOT Lane available in the Seattle area. HOT lanes have been in operation in the United States since 2005, and there are currently more than a dozen cities with HOT lanes. Other examples of HOT lane systems in the United States include the Los Angeles area, the Miami area, and near the District of Columbia in Virginia.

### 6.4.3 Technology to Enable Expanded Bus/HOV Priority Network

Adding bus/HOV priority on the major Route 495 approaches including the NJ Turnpike and Route 3 has also been considered as an operational change. The technology required to enable this strategy is similar to the HOT lane strategy, with the key exception being that toll collection technology is not needed. Beyond that, however, much of the signage, enforcement, and travel information necessary to implement this strategy is available.

## 7 Conclusion

This technical memorandum has discussed the utilization of new technologies to improve throughput and efficiency of existing facilities and to enhance commuter choice, as well as approaches for communicating real-time information to meet rising customer expectations. The discussion highlights technologies that *influence* the demand and operation of the Lincoln Tunnel corridor and PABT, as well as those technologies that *enable* other operational or policy strategies that are considered important to the overall functionality of the corridor. A major focus of the report is the opportunity to apply a range of connected and AV technologies to improve the operational efficiency of the Lincoln Tunnel corridor and the PABT.

Indeed, implementation of technology innovations can help achieve the proposed increase in peak-period bus flow through the Lincoln Tunnel corridor. A bus terminal designed to accommodate more buses during the busiest times of day will be limited by the current capacity of the Lincoln Tunnel corridor to deliver buses across the Hudson River. Two methods of increasing bus throughput along the corridor, and specifically into Manhattan during the AM peak period, have been studied: dedicating a second lane to buses (either as a second XBL or a HOT lane); and increasing throughput in the existing XBL using technology-enabled bus platooning.

Of these two options, the technology solution would have fewer negative spillover effects on other users of Route 495 and the Lincoln Tunnel and would therefore be preferable. The technology that would enable such a system is just emerging, and the XBL/Lincoln Tunnel could be the first place it is implemented. Accordingly, the PANYNJ, working with NJ TRANSIT and other partners, will need to take a leadership role in designing, developing, and implementing a bus platooning system that meets its needs. This report has suggested a possible path to implementation for a Bus Platooning Pilot Program for the Lincoln Tunnel corridor. Such work can and should begin as soon as possible to test performance and optimize effectiveness before a new PABT opens, and to benefit commuters sooner rather than later.

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TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix D: Summary of Capacity Study Workshop

September 2016

Version Final

Prepared for:

**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Submitted by:



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## ATTACHMENT

Attachment 1: PowerPoint Presentation from 4/14/16 Expert Workshop



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# 1 Overview of Workshop

Parsons Brinckerhoff conducted a one-day workshop of industry experts to inform the ongoing *Trans-Hudson Commuting Capacity Study* (the Study). The Board of Commissioners of the Port Authority of New York and New Jersey (PANYNJ) authorized the Study to evaluate a range of strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand to 2040, to inform its deliberations on conceptual planning for replacement of the Port Authority Bus Terminal (PABT).



The purpose of the workshop was to convene a combination of local, national, and international industry leaders in Transportation Operations and Infrastructure, Public Policy, and Technology Factors (for operations and customer service), to evaluate advantages, disadvantages, and trade-offs of different strategies to address trans-Hudson capacity issues.

The agenda for the workshop included:

- Introductions
- Project Background
- Workshop Objectives
- Break-out Groups
  - Transportation
  - Technology
  - Policy
- Group Reports/Integration
- Summary/Next Steps

The following sections identify the workshop attendees/participants and summarize the substantive elements of the workshop in bullet-point form. Comments made during the workshop by the invited experts are summarized in this document and do not necessarily reflect consensus of the workshop participants, nor is their inclusion herein an indication of their factual accuracy.

## 2 Attendees/Participants

- Invited Experts:
  - Rohit T. Aggarwala, Adjunct Professor, Columbia University's School of International and Public Affairs; Sidewalk Labs; Co-Chair of the Regional Plan Association's Fourth Regional Plan
  - Richard Bishop, Principal and International Vehicle Automation Expert, Bishop Consulting
  - Gerry Bogacz, Director of Planning, New York Metropolitan Transportation Council
  - Candace Brakewood, Assistant Professor of Civil Engineering, City College of New York
  - Walter Cherwony, Independent Contractor (Bus Operations Planning)
  - Jeremy Colangelo-Bryan, Chief Planner, Capital Planning & Programs, NJ TRANSIT
  - Emil Frankel, Interim President and CEO, Eno Center For Transportation
  - Jerome Lutin, Independent Consultant (Connected Vehicle Technologies)
  - Alan Maiman, Deputy General Manager, Bus Service Planning, NJ TRANSIT
  - Dennis Martin, Interim Executive Director, NJ TRANSIT
  - Mary K. Murphy, Executive Director, North Jersey Transportation Planning Authority
  - Ken Philmus (via webinar), Senior Vice President, Transportation Solutions Group, Xerox Services (former General Manager/PABT and Director of PANYNJ Tunnels, Bridges, and Terminals Dept.)
  - Michael Replogle, Deputy Commissioner for Policy, New York City Department of Transportation
  - Richard Roberts, Chief, NEC and Trans-Hudson Projects, NJ TRANSIT
  - Jack Schmidt, Director, Transportation Planning Division, New York City Department of City Planning
  - Karen White, Assistant Director of Statistical and Economic Analysis, Bureau of Transportation Statistics, USDOT
  - Rae Zimmerman, Professor of Planning and Public Administration, NYU Robert F. Wagner Graduate School of Public Service
  - Jeff Zupan, Senior Fellow, Transportation, Regional Plan Association
- Port Authority of New York and New Jersey (PANYNJ):
  - All-Day Participants
    - Rizwan Baig, Assistant Chief Traffic Engineer
    - Guillermo Benavides, Traffic Engineering
    - David Caruth, Traffic Engineering
    - Diannae Ehler, General Manager of the PABT and Lincoln Tunnel
    - Todd Goldman, Planning Department
    - Mark Muriello, Tunnels, Bridges and Terminals (TB&T) Deputy Director

- Kristine O’Brien, Vice Chairman’s Office
- Jose Rivera, Chief Traffic Engineer
- Mark Schaff, Assistant General Manager of the PABT
- Lou Venech, Gen. Mgr. Regional Transportation Policy Development, Planning Department
- Closing Summary/Next Steps Participants
  - Nicole Crifo, Sr. Advisor to the Chairman
  - Patrick Foye, Executive Director
  - Cedric Fulton, TB&T Director
  - David Garten, Vice Chairman’s Office
  - Portia Henry, Chairman’s Office
  - Patricia Hurley, Chairman’s Office
  - Michael Kraft, Major Projects Office
  - John Ma, Chief of Staff to the Executive Director
  - Lillian Valenti, Procurement Director
- WSP | Parsons Brinckerhoff Team:
  - John Porcari, Project Manager
  - Nicole Bucich, Deputy Project Manager
  - Roy Kienitz
  - Gabriela Kappes
  - Steve Kuciemba
  - Theodore Orosz
  - Maxwell Sokol
  - Kathleen Swindler
  - Victor Teglas
  - Matthew Woodhouse

### 3 Project Background

- Commuting Capacity Study Project Manager L. Venech opened the workshop and provided background context for the invited experts
  - The PANYNJ Midtown Bus Master Plan (MBMP) was completed in 2015 and highlighted key challenges pertaining to the PABT, including the limited remaining useful life, capacity constraints, and functional obsolescence
  - Concurrent with this Commuting Capacity Study, the PANYNJ has commissioned an *International Design + Deliverability Competition* (the “D+D Competition”) seeking concepts for a new PABT
  - A major objective of the Capacity Study is to provide insight to the D+D Competition by evaluating the range of alternative strategies for serving the trans-Hudson commuter market via bus and other modes, which will inform the determination of the appropriate capacity and configuration of the new PABT
    - This workshop will help to identify priority strategies and probe uncertainties
- Following the opening remarks, J. Porcari, M. Sokol, R. Kienitz, and N. Bucich presented background information about the trans-Hudson commuter network, including historic trends, existing conditions, and projected future conditions
  - The presentation summarized information from the following documents that L. Venech shared with the invited experts in advance of the workshop:
    - The Emerging Design + Deliverability Brief from the D+D Competition (“Appendix A”)
    - Draft Profile of the Regional Interstate Transportation Network (PANYNJ)
    - Draft NJ TRANSIT Presentation, Trans-Hudson Market Dynamics at-a-glance: A Customer’s Perspective
  - The presentation focused on commuter demand and summarized existing and emerging capacity constraints across a range of modes and transportation facilities, including the Route 495 Exclusive Bus Lane (XBL), the Lincoln Tunnel and Helix, the PABT, the Port Authority Trans-Hudson (PATH) system, and NJ TRANSIT/Amtrak
  - The presentation included an overview of trans-Hudson plans and projects by PANYNJ and others, as well as potential future projects that could add trans-Hudson capacity (i.e., XBL capacity enhancement, Gateway, and the No. 7 Line extension to Secaucus)



## 4 Workshop Objectives

- L. Venech summarized the workshop objectives:
  - Identify major transportation network components for the effective operation of a PABT replacement to be located in West Midtown
  - Probe relevant future workplace and regional travel trends
  - Assess prospects for other transportation investments with potential effect on PABT demand
- N. Bucich outlined two overarching questions to be discussed by the workshop participants in break-out groups, with a third question that varied by group:
  - (1) What are the key uncertainties affecting future trans-Hudson travel?
  - (2) What are the key interdependencies?
  - (3 – Transportation break-out group): What service and infrastructure options will best accommodate demand?
  - (3 – Technology break-out group): What are the most promising technology options?
  - (3 – Policy break-out group): What are the major policy challenges?
- To provide additional background context for the workshop participants, N. Bucich summarized the strategies defined to date in this Study that aim to meet projected peak period trans-Hudson commuter demand in 2040
  - The strategies fall into two categories:
    - Strategies that increase/manage capacity along the Lincoln Tunnel corridor, including improved corridor operations and improved PABT facility operations
    - Strategies that address overall Trans-Hudson demand, including expanded bus services that use other crossings as well as multi-modal network strategies
  - The strategies include a combination of investments in transportation infrastructure, modifications to existing bus routes, implementation of emerging technologies, and changes to public policy. Accordingly, the break-out groups for the workshop correspond to Transportation (including both infrastructure and operations), Technology, and Policy

Following the overview of the workshop objectives, an open discussion among the workshop participants, PANYNJ staff, and the Parsons Brinckerhoff team touched upon a number of issues raised during the Project Background presentation. Here is a summary of comments made and questions raised during the discussion.

- Lincoln Tunnel Helix Replacement:
  - The project will not increase capacity, but will widen the traffic lanes and improve the safety of the XBL
  - The project will not preclude future consideration of capacity enhancements
  - Capacity enhancements on the Lincoln Tunnel approaches could exacerbate as opposed to mitigate capacity constraints at the PABT, unless system improvements proceeded in balance

- Gateway:
  - The Portal Bridge project has received a Record of Decision and is cleared to proceed, subject to funding
  - The project received Transportation Infrastructure Generating Economic Recovery (TIGER) funds in late 2015 to begin pre-construction activities
  - The Gateway program must consider the design of the new Penn Station South in addition to the tunnels under the Hudson River, as the new station is a major factor that will inform the extent to which Gateway will increase peak-period rail service capacity
- PABT:
  - Due to current capacity constraints at the existing facility, NJ TRANSIT cannot add more bus service to meet additional demand
  - The MBMP called for a flexible PABT design to accommodate a range of vehicle types
  - The existing PABT is currently averaging four turns per gate per hour, which is below the global best practice of six turns per gate per hour for a facility of this type
- XBL:
  - Prior PANYNJ studies that evaluated opportunities to enhance the capacity of the XBL (either by adding a second XBL or a high-occupancy toll (HOT) lane) were focused on the Route 495 corridor and did not explicitly consider PABT constraints
  - The prior studies did not extend far enough north or south to assess potential impacts to the NJ Turnpike and Route 3
  - A second XBL could work from an operational standpoint but would need to be a managed use lane in order to balance demand with capacity
  - When the existing XBL is in operation, Route 495 in the westbound direction drops to one lane at Route 3, creating a major bottleneck
    - Will this be addressed by the viaduct replacement to be completed by the New Jersey Department of Transportation (NJDOT)?
- Potential future No. 7 Line Extension to Secaucus:
  - The extension would create major pedestrian issues at Grand Central Terminal due to capacity constraints



## 5 Break-Out Groups and Group Reports/Integration

The invited experts were divided into three break-out groups—Transportation, Technology, and Policy—to address the three discussion questions outlined above. PANYNJ staff attended each of the break-out sessions. Members of the Parsons Brinckerhoff team facilitated and took notes during each of the break-out group sessions. Each break-out group drafted PowerPoint slides that were subsequently added back into the main presentation with all workshop participants. All workshop participants re-convened in the main workshop room, and one or more members from each break-out group led the report-back for discussion by the full group, summarized below:

### 5.1 TRANSPORTATION BREAK-OUT GROUP

- What are the key uncertainties affecting future trans-Hudson travel?
  - What will be the composition of the bus fleet (conventional transit buses vs. higher-capacity buses, including articulated buses and double decker buses)?
    - This will depend on the routes and markets that are served and the demand for service to the PABT
    - Fuel types for buses can also affect the new facility, as some fuel sources may require on-site recharge/refuel
  - How much bus staging is needed, and where will it be located?
    - Bus staging dictates the need for gates and the utilization of those gates
      - If buses can arrive at the PABT just in time to start their run, they are able to provide reliable service for customers
      - If buses are not staged near the PABT, there is greater uncertainty in their travel time from the staging area to the PABT, creating the potential for negative impacts to gate utilization and on-time performance
    - Regional highways can be managed to prioritize the movement of buses, thereby improving bus reliability
  - What improvements can be made to bus loading/unloading to improve the number of gate turns per hour?
  - Should the new PABT be built to meet intercity bus demand?
  - Commuting characteristics and work styles may shift over time, which cannot be fully predicted
  - Trans-Hudson rail capacity and the timing of capital improvements are major uncertainties that could have a significant impact on demand at the PABT; however, it is a unique challenge to accurately forecast the remaining life of Amtrak’s North River Tunnels, the opening of the proposed new Gateway Tunnels with expanded station facilities in Manhattan, and the completion of other major trans-Hudson capital projects
- What are the key interdependencies?

- There is no silver bullet solution to address trans-Hudson demand and capacity issues; a mosaic of complementary strategies is needed
  - A systems approach—one that considers all strategies together and includes active collaboration among the pertinent agencies and municipalities—is essential
- The desired capacity of the PABT replacement will be informed by demand throughout the multi-modal trans-Hudson transportation network
  - Although the strategies under consideration in this study could shave demand at the PABT, there could also be significant latent demand in the trans-Hudson market that could be generated by new PABT and bus system improvements
- New pricing strategies could influence demand along the Lincoln Tunnel corridor and at the PABT
- The timing of capital improvements/rail capacity enhancements could influence shifts in demand between trans-Hudson modes
- What service and infrastructure options will best accommodate demand?
  - Ferries
    - Ferries are most promising for origins/destinations within walking distance from the landing/terminal
    - NJ TRANSIT is carrying out a combination ticket program, allowing customers to transfer between buses and ferries using a single ticket
    - Would a new ferry terminal close to the No. 7 Line at 34<sup>th</sup> Street and 10<sup>th</sup> Avenue help to address some trans-Hudson commuter demand?
    - Ferry service from points north of the Tappan Zee Bridge to Midtown Manhattan could potentially reduce the number of buses traveling from Rockland County to the PABT
  - George Washington Bridge Bus Station (GWBBS)
    - It could be possible to divert some PABT-destined buses from Bergen, Orange and Rockland Counties to the GWBBS, and once at the GWBBS, customers could transfer to the subway
      - The A Train from GWBBS is a long ride and does not connect to Midtown East, thus making it a less attractive route for commuters accustomed to the PABT
  - New NY Bridge (Tappan Zee Bridge Replacement)
    - A dedicated bus lane on the new bridge could provide Bus Rapid Transit (BRT) connections from Orange and Rockland Counties to Metro-North Railroad stations on the Hudson and Harlem lines; customers could then transfer to Metro-North Railroad to access Grand Central Terminal
  - Northern Branch Corridor Extension
    - The extension of Hudson-Bergen Light Rail into northeastern Bergen County could provide a modest reduction in bus traffic to PABT as commuters could travel to Hoboken and transfer to PATH in order to access Midtown Manhattan
    - The potential impact on the PABT is dependent in part on pricing and inter-agency coordination
- There are some limited opportunities—along some corridors in the inbound direction—for existing bus routes that are not at capacity to serve additional customers

- NJ TRANSIT rail has capacity to accommodate more customers outbound during the PM peak
  - This raises the possibility of some commuters traveling by bus for the inbound trip and traveling by rail for the outbound trip
- Potential long-term “game changers” include the No. 7 Line Extension to Secaucus (although this project is not currently under consideration by regional transit authorities) and potential intensification of commuter rail service and the possibility of extension into new territory beyond the Gateway Program
  - However, there is also a need to address near- and mid-term projected growth in trans-Hudson demand (before the new PABT is constructed)
- Miscellaneous comments/questions:
  - NJ TRANSIT buses are unable to operate at the posted speed limit along certain routes due to highway design and regulations that do not permit buses to operate on the shoulders of State roads in New Jersey
  - At the existing PABT, the term “loading positions” is used in place of gates so as to differentiate between sawtooth gates and platforms, which have different throughput capabilities
  - There is a need for a convenient cross-town bus service (distributor route) to connect the new PABT and ferries to East Midtown locations
  - Will the new PABT include car parking?
    - This could be a potential revenue source to address PABT operating costs
    - However, car parking would use space that could otherwise be used for bus staging and storage
  - Planning for the PABT replacement assumes six turns per gate per hour
  - The height of new PABT is limited to seven levels total and five levels for bus operations
  - Additional amenities and customer technologies should be made available for bus commuters to “level the playing field” with respect to the relative attractiveness of rail
  - The proposed location of the new PABT is sub-optimal because it is farther from commuters’ destinations

## 5.2 TECHNOLOGY BREAK-OUT GROUP

- What are the key uncertainties affecting future trans-Hudson travel?
  - How quickly can new technologies be applied? For instance, what is the timeframe for full automation (of buses and all vehicles) in comparison to the timeframe for the PABT replacement?
  - Connected and Automated Vehicle technologies are advancing rapidly and are likely to be available for deployment in the time frame for completion of a PABT redevelopment project with corresponding Lincoln Tunnel corridor improvements
    - Note that legal/administrative issues with automation are likely more challenging than the technical issues
  - Technology advances that improve the customer experience could increase demand for the PABT

- How could widespread adoption of car/rideshare and other external factors (telecommuting, etc.) affect trans-Hudson commuter demand?
- What are the key interdependencies?
  - Corridor and facility improvements
    - Improvements along the Route 495 corridor must complement improvements within the PABT
- What are the most promising technology options?
  - Along the Route 495 corridor:
    - Near- and mid-term: Platooning of buses and the introduction of automated cruise control and lane-keeping technology for buses along the existing XBL could reduce bus headways, thereby not only helping to achieve the theoretical capacity, but potentially exceed it
      - As an alternative, a second XBL/HOT Lane could dramatically increase bus capacity along the corridor in the inbound peak, but it would be necessary to allow toll-paying cars to use the lane in order to maximize efficiency
  - Within the PABT:
    - Near-term: locating buses in real-time, which is already underway and offers both operational and customer benefits
      - Additionally, NJ TRANSIT offers a MyBus app that provides real-time bus locations, arrival times, and information about delays
        - The app is effective in New Jersey but less so in New York because there is no GPS reception inside the PABT, and thus the arrival times and bus locations cannot update in real-time
    - Mid-term: automation for efficient circulation (e.g., magnetic guidance for precision docking)
    - Long-term: connected and automated buses for merging, especially at the helixes
- Miscellaneous comments/questions:
  - The ability to apply vehicle technology must consider the bus procurement cycle
  - Can technology increase the productivity of gates at the PABT?
    - Technology can maximize efficiency, but there is no technology solution to fully address the human element of passenger loading/unloading
  - Staging buses on both sides of the Hudson River allows for an effective response if the Lincoln Tunnel is shut down and alternate measures need to be put in place
    - Would it be possible to store buses on a barge on the Hudson River in New York?
      - This could address the need to stage buses in Manhattan while not consuming expensive real estate
    - Autonomous buses would not need to return to a depot because there would be no driver

### 5.3 POLICY BREAK-OUT GROUP

- What are the key uncertainties affecting future trans-Hudson travel?
  - Locations of population growth and travel demand growth
  - Infrastructure lifespan (e.g., PABT, North River Amtrak Tunnels, etc.)
  - Inter-agency cooperation (e.g., among PANYNJ, NJ TRANSIT, NJDOT, NJ Turnpike Authority, the City of New York, etc.)
- What are the key interdependencies?
  - Inter-governmental cooperation to plan and finance trans-Hudson projects
  - Development of East Midtown and its impact on travel demand patterns
  - The operation of the Lincoln Tunnel and the connecting roadway system
- What are the major policy challenges?
  - A principal policy challenge relates to pricing and imposing lane restrictions
    - It could be possible to better manage single-occupancy vehicles (SOVs) in the system by using pricing to encourage commuters to shift to mass transit or to shift travel to other times
      - A second XBL along Route 495 would likely need to be a HOT/managed use lane in order to be effective as there is not (yet) enough bus traffic in the AM peak period to fill all of the capacity of an additional bus lane
      - In considering future modifications to the operation of the Route 495, it would be important to avoid impeding access to local destinations or for reverse peak travel along the corridor
      - There could be political resistance to imposing pricing strategies because motorists in the region already face high costs
    - Differential pricing for curbside as opposed to terminal off-loading could potentially incentivize behavior change among PABT commuters
  - Other policy challenges include:
    - Identifying and securing funding sources to pay for improvements
    - Predicting long-term travel demand by route and mode
    - Coordinating transportation and technology improvements in order to ensure that the improvements are complementary
    - Bus staging/storage, including predicting bus travel time from staging areas in New Jersey to the PABT
- Miscellaneous comments/questions
  - If the PABT is moved farther west, it would be necessary to construct the No. 7 Line station at 34<sup>th</sup> Street and 10<sup>th</sup> Avenue
  - Current travel patterns are shaped by the supply of available transportation services, and it would be unsound to justify planning decisions based solely on existing supply

- The PABT replacement effort should be viewed as part of a comprehensive regional vision for the interstate transportation network
- There are ways to model customer preferences during the planning process; NJ TRANSIT has a strong and active interface with its customers
- It would be important to compare the relative emissions levels of different transportation investments
- Is it possible to provide additional incentives for trucks to use the interstate transportation network during overnight hours?
- Could long-distance buses be an additional revenue source for the PABT?
- NJ TRANSIT has a dispatcher stationed at the Lincoln Tunnel operations center to assist with flow into PABT, which is indicative of the strong working relationship between NJ TRANSIT and PANYNJ
- Private bus operators often contribute to PABT inefficiencies as they do not turn gates as often and are more vulnerable to service disruptions
- New York City is hampered by a state law that prevents localities from charging more than a base price for bus registration

## 6 Summary/Next Steps

Following the reports of the break-out groups, the invited experts, PANYNJ staff, and the Parsons Brinckerhoff team compiled a slide of “Key Takeaways” to guide a discussion with PANYNJ Executive Management who joined for the last hour of the workshop. Consistent themes emerged from the break-out groups that reinforced the overall charge of this Study. The full workshop presentation, including the “Key Takeaways” slide, is included as an Attachment.

- Summary of key takeaways:
  - There is no single investment or strategy that will reduce the need for a modern, flexible bus terminal
    - Rail service expansion (Gateway) is important but unlikely to significantly impact the level of demand to be served by the bus network overall
  - Improved trans-Hudson services may reveal additional latent demand
    - Additionally, technology that enhances the PABT customer experience could increase demand
  - There is a need for modularity and flexibility in future designs for a new PABT to address uncertainties, with elements that have independent utility
    - Bus staging/storage should be prioritized
  - Strategies are needed to address near-term demand increases
    - Incremental strategies that are not capital intensive (e.g., pilot programs) should be pursued
    - Technology holds promise in the near-term
  - A replacement PABT that accommodates future demand requires other actions and investments in both states
    - Actions are necessary to improve throughput along the Lincoln Tunnel corridor
    - This requires a systems approach for improvements that includes highways, toll facilities, etc.
      - To handle future demand for trans-Hudson bus travel during peak hours, PANYNJ and partner agencies must configure all infrastructure and operational elements supporting interstate bus services to function as a system, including the approaches to Route 495 from the NJ Turnpike and Route 3, the ramps that make up the “teardrop,” the XBL and other lanes of 495, the Helix, the toll plaza, the Lincoln Tunnel tubes, the ramps leading into PABT, the PABT itself, and locations for bus storage and staging on both sides of the river
  - The implications of moving the new PABT farther west must be considered, and the customer perspective must be taken into account in planning for the future of the interstate transportation network
- Additional comments at the conclusion of the workshop:
  - Resiliency is an important consideration, and the bus network provides redundancy to the rail network



- However, bus and rail serve different markets because of the relative availability of the rail network
  - Nevertheless, modal dependencies are not immutable and are subject to change over time based on available travel options
- Along the Lincoln Tunnel corridor, more bus throughput at current pricing and less auto throughput at current pricing would be deleterious financially for the PANYNJ (on top of the current operating deficit of the PABT)
  - Would commuters be willing to pay more for a one-seat ride into Midtown?
    - It would be necessary to consider Title VI (Environmental Justice) before imposing any changes to pricing
- Will commuting habits change as it becomes more difficult to access the existing PABT?
- The Gateway Program and the PABT replacement will likely move forward simultaneously, and it will be necessary to address inter-organizational governance and funding issues
- The new PABT must fit into the community and take into account walk circulation and transit access to the 8<sup>th</sup> Ave Subway and cross-town bus at 42<sup>nd</sup> Street
- Environmental issues associated with the different trans-Hudson strategies warrant greater attention moving forward
- There should be follow-up discussion about how the workshop findings and the Study overall inform the D+D Competition and reflect the 14 objectives of the Competition

L. Venech and J. Porcari ended the workshop by thanking the participants and outlining next steps, including the preparation of summary documentation from the workshop.

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# Trans-Hudson Commuting Capacity Study

## EXPERT WORKSHOP

April 14, 2016



Presented to

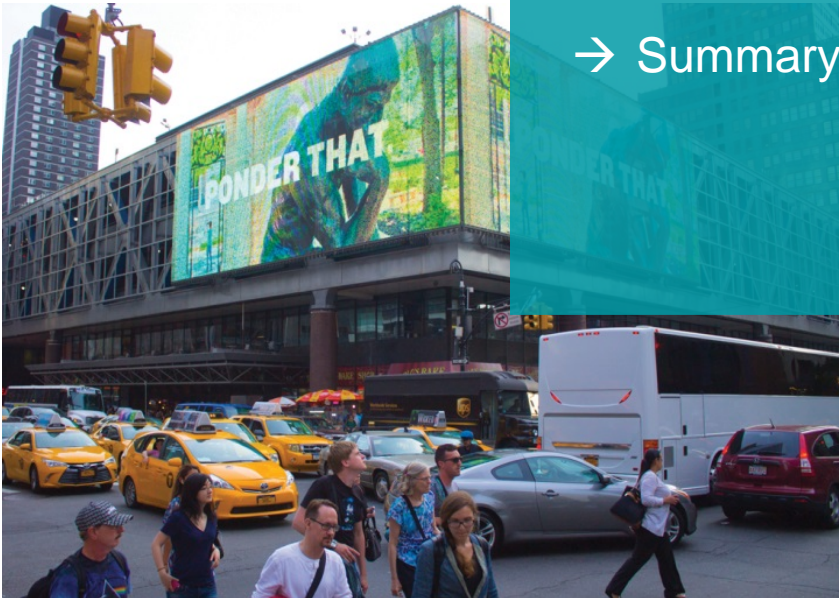
**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Presented by

**PARSONS**  
**BRINCKERHOFF**

# Agenda

- Introductions 9:00-9:30am
- Project Background 9:30-10:30am
- Workshop Objectives 10:30-11am
- Break-out Groups/Lunch 11:00am-1pm
- Break 1:00-1:30pm
- Group Reports/Integration 1:30-3:30pm
- Summary/Next Steps 3:30-4:30pm



# Project Background

*PABT Replacement/Trans-Hudson Network  
Challenges*



# Why are we here?



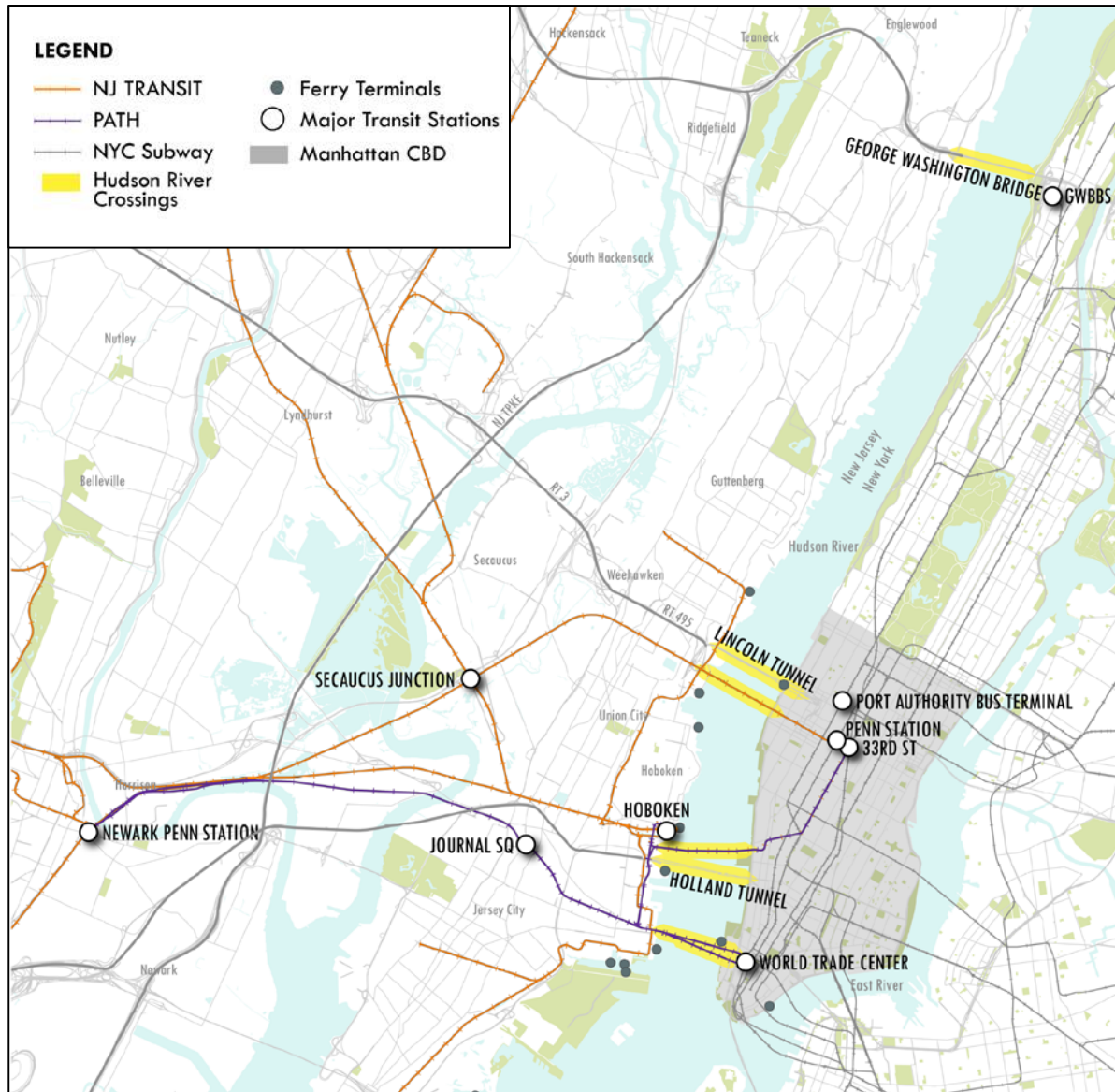
- PANYNJ Midtown Bus Master Plan completed 2015
  - *Structure's remaining useful life 15-25 years*
  - *Lacks capacity to serve growing forecast demand*
  - *Functionally obsolete due to advent of larger, heavier buses*
- Board weighing project concept for Fall 2016 decision
  - *Replacement options challenging and expensive*
  - *Design and Deliverability Competition underway*
  - *Commuting Capacity Study to provide Regional Context*



# Why are we here?

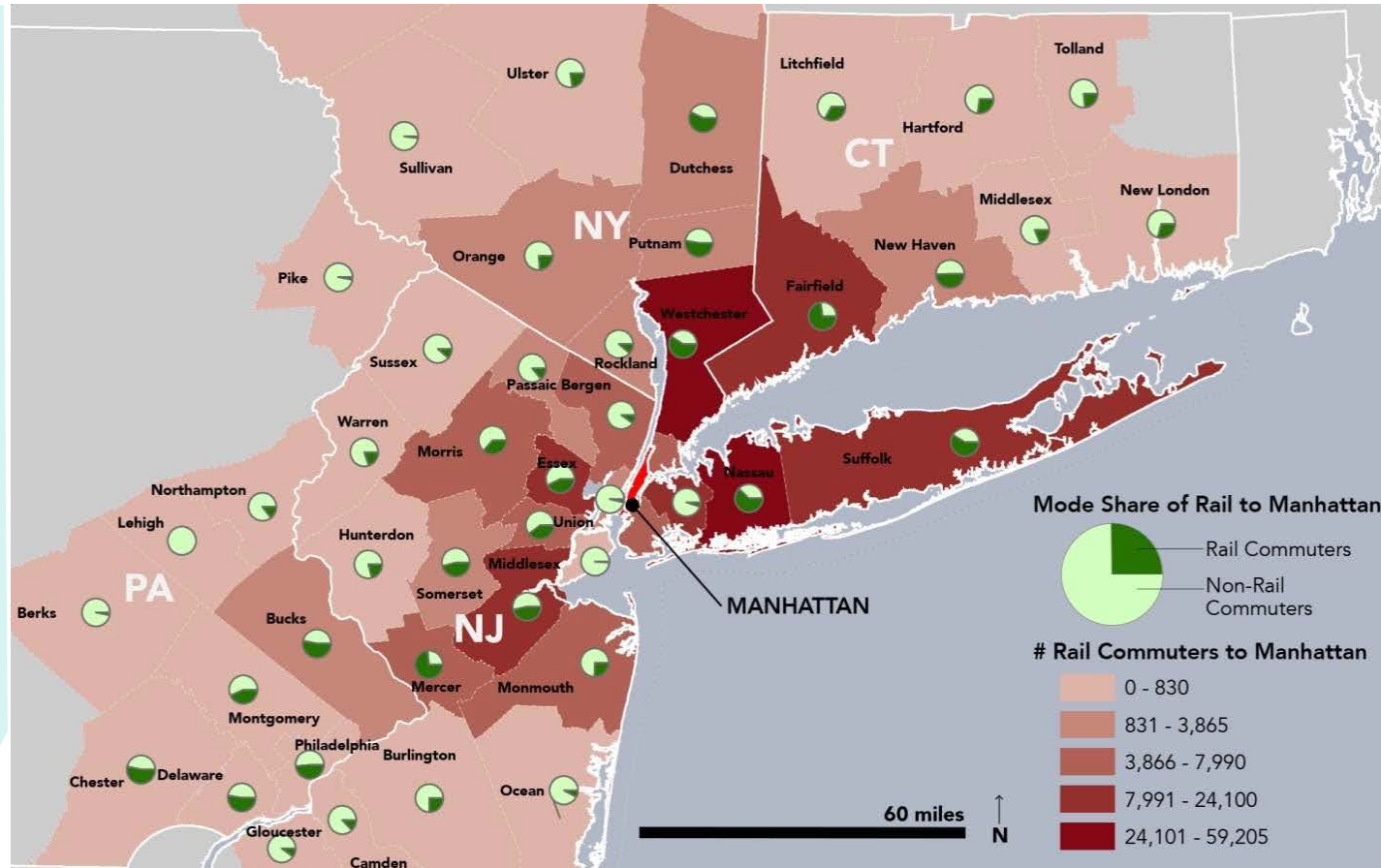
- Capacity Study to identify and evaluate strategies to address trans-Hudson demand and capacity
  - Strategies that increase **capacity** to support a new PABT that accommodates full future peak period demand
  - Strategies that address overall Trans-Hudson **demand** including the use of other modes/crossings
- Develop a package of strategies to achieve optimal benefits
  - Transportation (physical and operational)
  - Technology
  - Policy
- Informs the Design and Deliverability competition
- Transportation leaders' Workshop to identify priority strategies, probe uncertainties

# Trans-Hudson Commuter Network



# Mode Share of Rail by Origin for Trans-Hudson Commuters to Manhattan

→ Counties with robust existing rail service have a larger rail mode share than counties that lack frequent / direct rail service to Manhattan

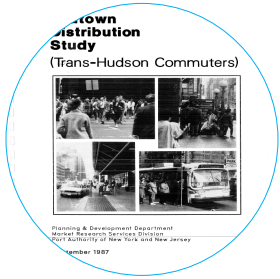


Source: Trans-Hudson Summit, Amtrak presentation (2015)

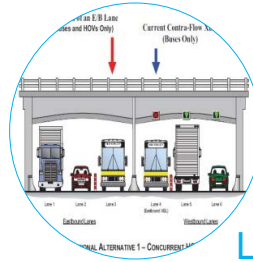
# Trans-Hudson Planning History

Trans-Hudson Network Task Force

Trans-Hudson Summit



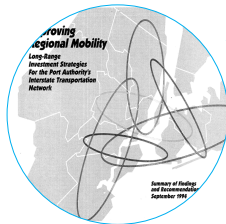
Lincoln Tunnel XBL Capacity Enhancement Feasibility Study



Lincoln Tunnel HOT Lane Feasibility Study



PATH Alternatives Study



Trans-Hudson Interstate Network Analysis

Variable pricing at PA Crossings

ARC FEIS;  
Amtrak NEC Master Plan

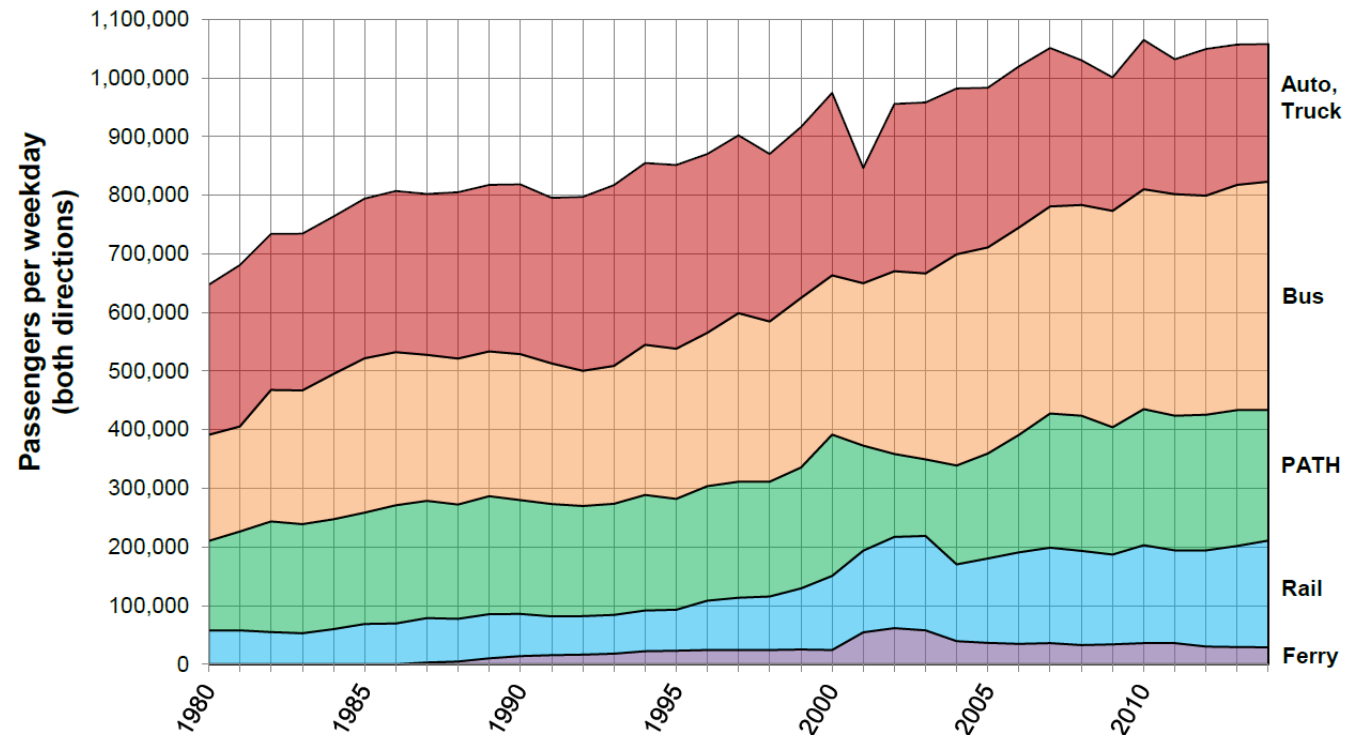


Midtown Bus Master Plan  
PABT D&D Competition  
NEC FUTURE  
Hudson Tunnel/Gateway  
Penn Station NY Redevelopment  
PATH WTC Hub

# Historic Trends in Trans-Hudson Travel by Mode

→ Substantial growth in Trans-Hudson travel to/from Manhattan CBD since 1980

- 110% growth in weekday travel by public transit
- 8% decline in weekday travel by automobile

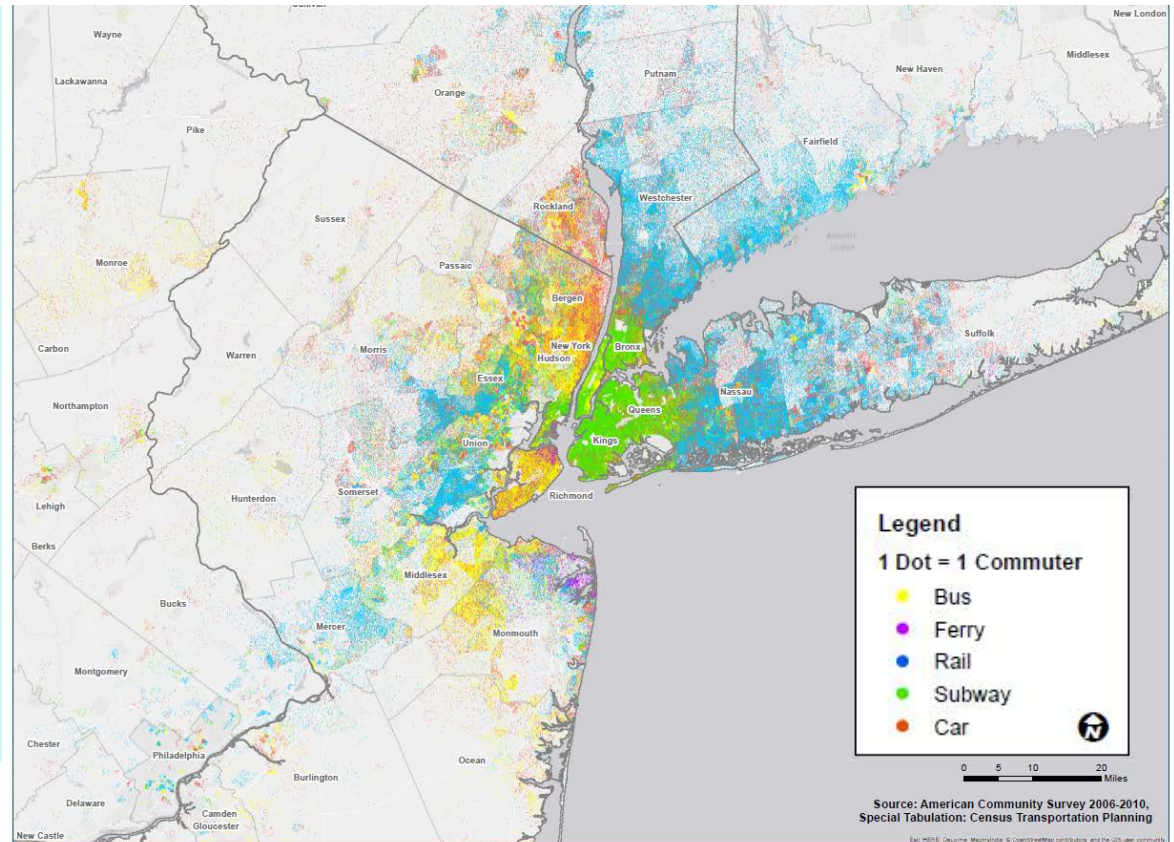


Source: PANYNJ



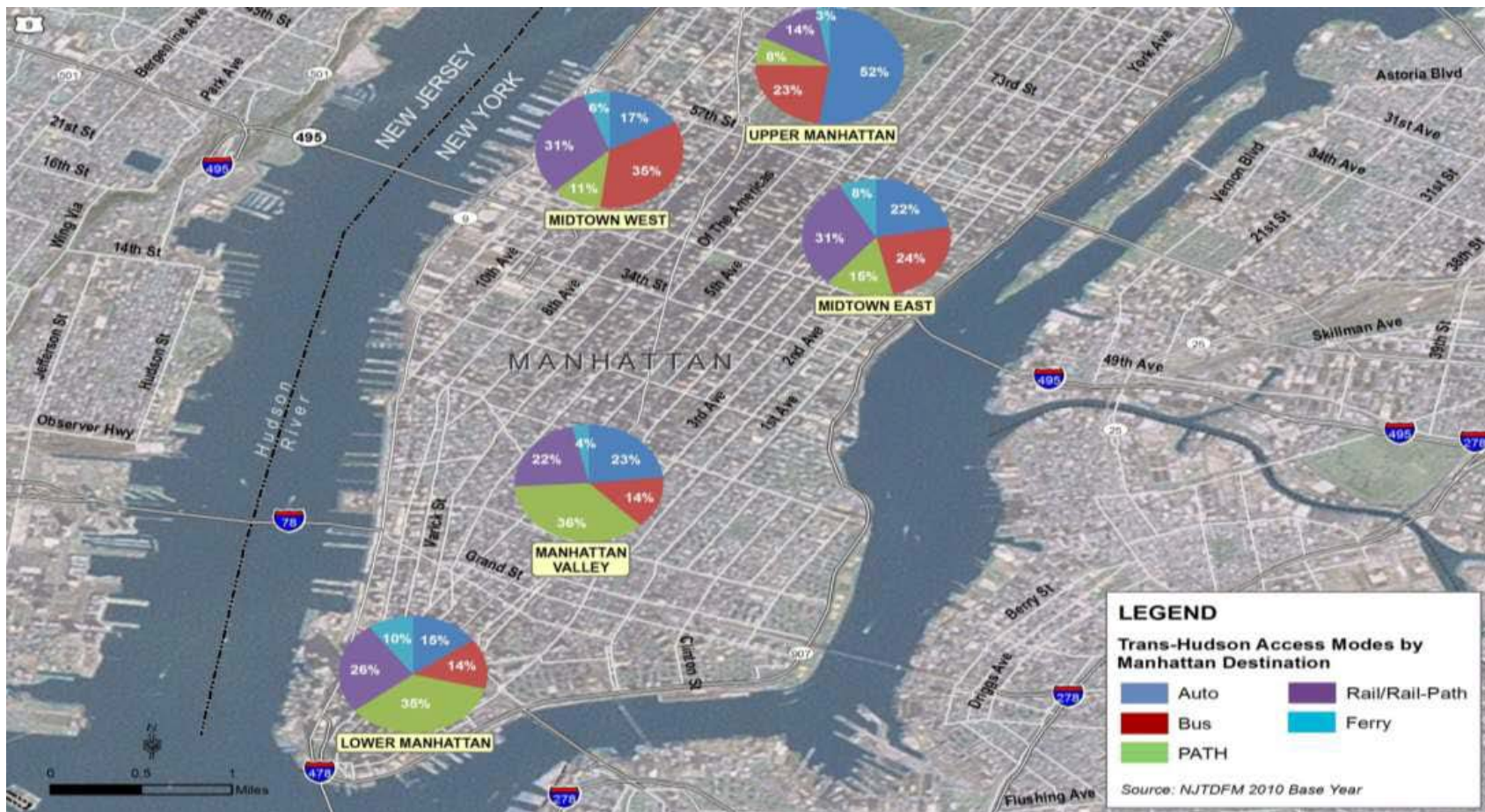
# Mode Split by Origin for Trans-Hudson Commuters to Manhattan

- More than 40% of Trans-Hudson commuters who work in Manhattan live in Hudson or Bergen Counties
- Commuter mode choice differs by County of origin



Source: PANYNJ

# Mode Split by Destination for Trans-Hudson Commuters to Manhattan

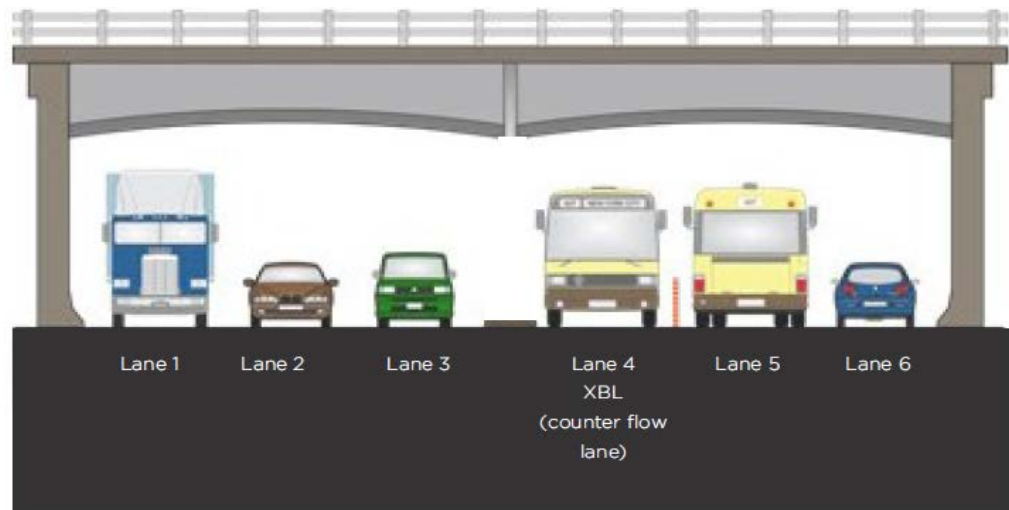
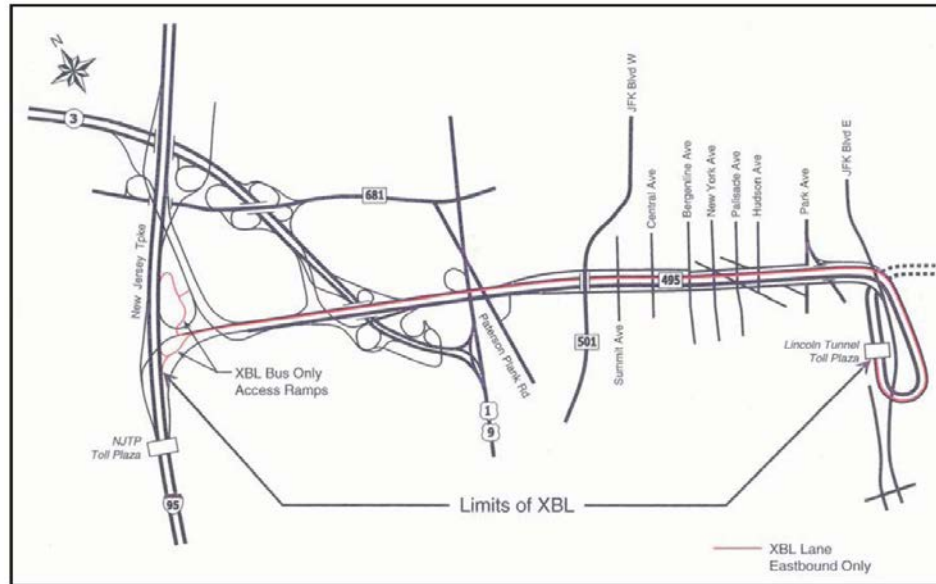


Source: Trans-Hudson Summit, NJ TRANSIT (2015)



# Lincoln Tunnel Bus Efficiency and Throughput

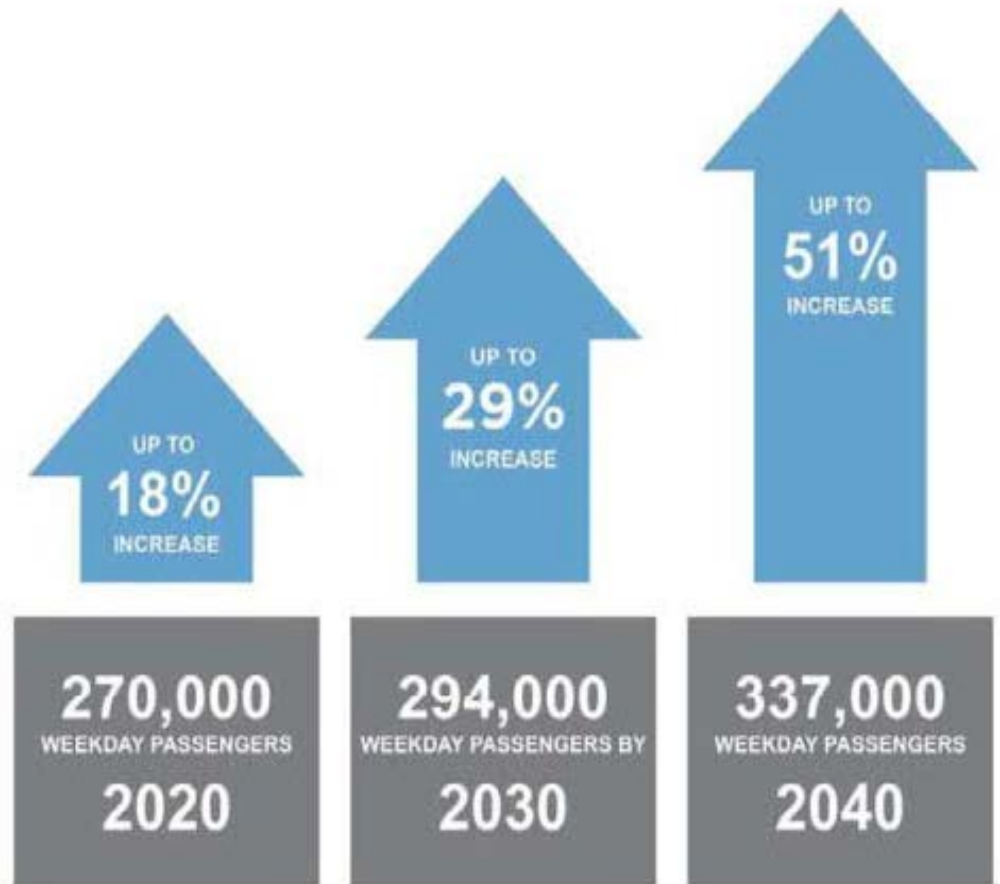
- Lincoln Tunnel: buses comprise 20% of vehicles and carry 90% of passengers in the peak hour
- Route 495 Exclusive Bus Lane (XBL) + bus prioritization at Lincoln Tunnel portals + dedicated bus lane within the Lincoln Tunnel



Source: Lincoln Tunnel Exclusive Bus Lane (XBL) – Capacity Enhancement Feasibility Study; MBMP Final Report

# Existing (2011) and Future PABT Demand

- 232,200 daily passengers
- 7,800 daily buses
- 26,400 peak hour passengers (5 - 6 pm)
- 615 peak hour buses (5 - 6 pm)



Source: MBMP

9,080 daily buses  
855 peak hour buses

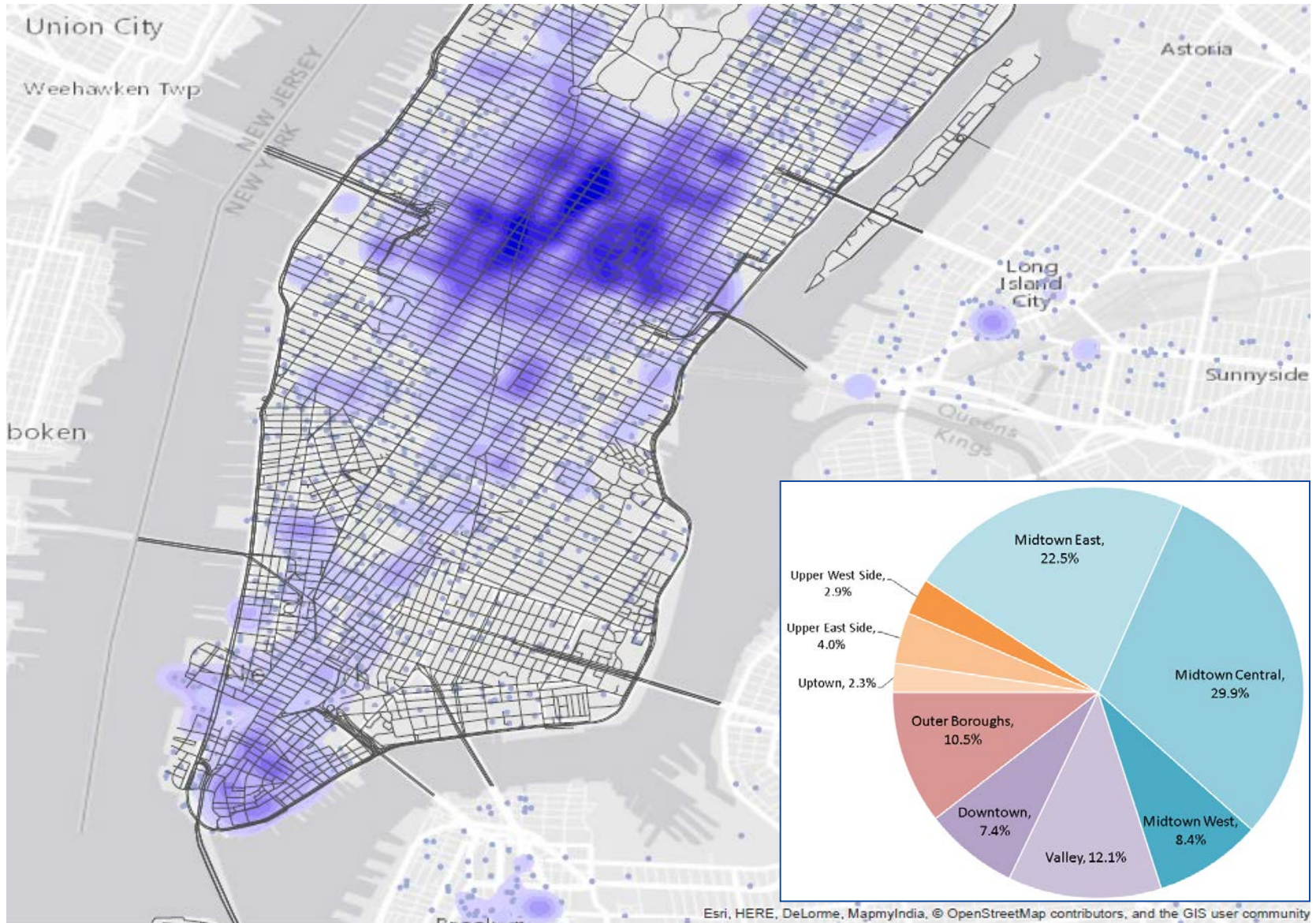
# Residence Locations for Customers on PABT Commuter Routes

Residence Location	Number of Passengers	Percent of Passengers
Bergen County	27,514	28.3%
Hudson County	17,742	18.2%
Essex & Union Counties	10,986	11.3%
Passaic County	6,889	7.1%
Middlesex, Monmouth, Ocean Counties	12,061	12.4%
Other New Jersey	5,705	5.9%
New York City	7,084	7.3%
Orange, Rockland & Other NYS	6,506	6.7%
Other Locations	2,856	2.9%



Source: MBMP Final Report

# NYC Origins/Destinations for PABT Commuter Routes

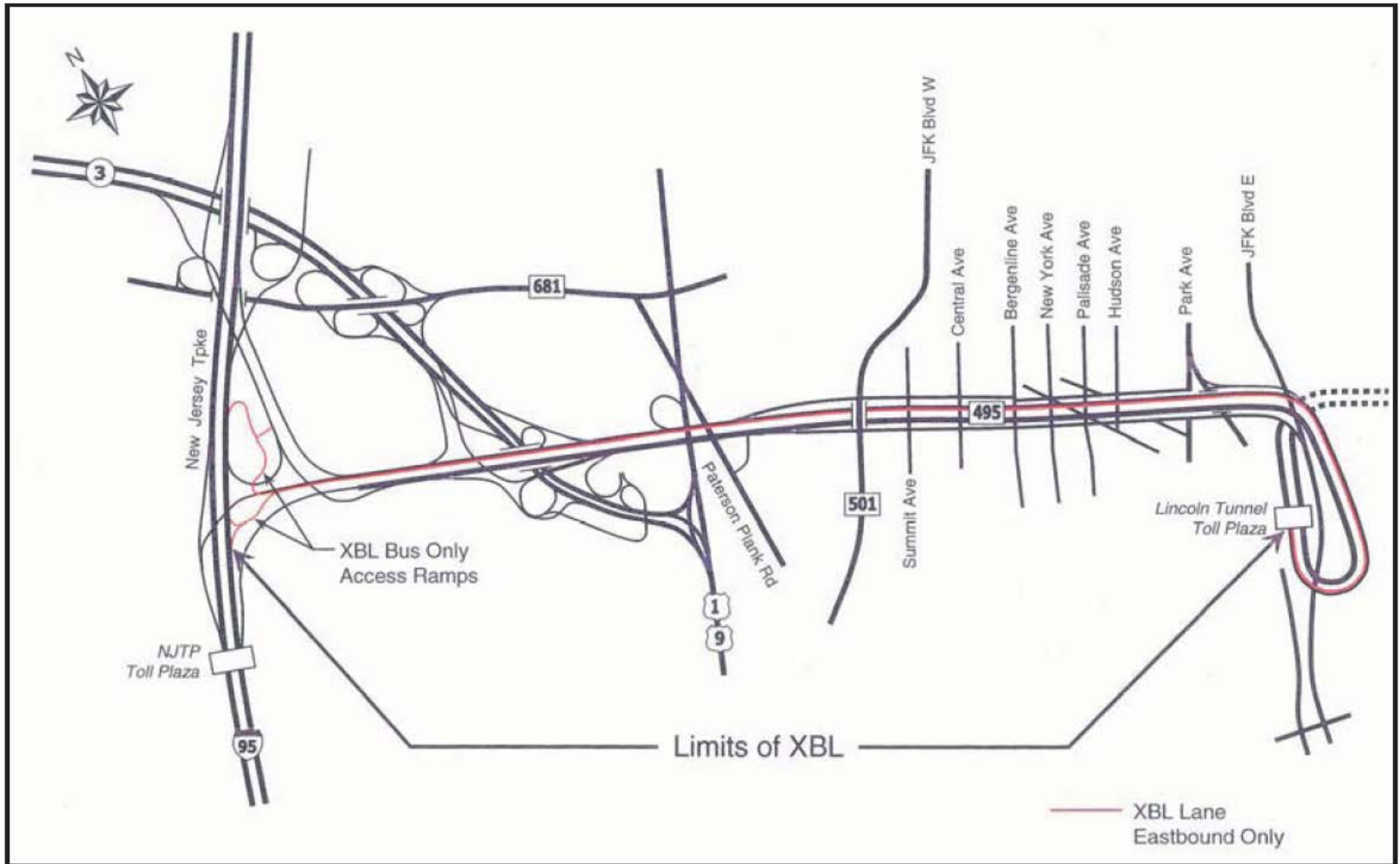


Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Source: PANYNJ



# Capacity Constraints: Route 495 XBL



Source: Lincoln Tunnel XBL - Capacity Enhancement Feasibility Study (2006);  
Lincoln Tunnel HOT Lane Feasibility Study (2009);  
PANYNJ Lincoln Tunnel XBL webpage

# Capacity Constraints: Lincoln Tunnel and Helix

- Current configuration of Lincoln Tunnel lacks capacity to support full-time operation of priority lanes for buses
- During peak periods, traffic volumes on the Helix are constrained by the capacity of the Tunnel



Source: PABT D+D Competition, Appendix A (2016)  
Lincoln Tunnel HOT Lane Feasibility Study (2009)  
Profile of the RITN (2015)

# Capacity Constraints: PABT

- Passenger demand exceeds capacity in both AM and PM
- Desired service expansion deferred due to lack of capacity
- Operations impeded by insufficient and dwindling daytime bus storage and staging capacity
- Bus queues periodically spill over onto NYC streets



Source: MBMP Final Report (2016)  
PANYNJ webpage for PABT



# Capacity Constraints: PATH



Source: PANYNJ PATH webpage

# Capacity Constraints: NJ TRANSIT/Amtrak

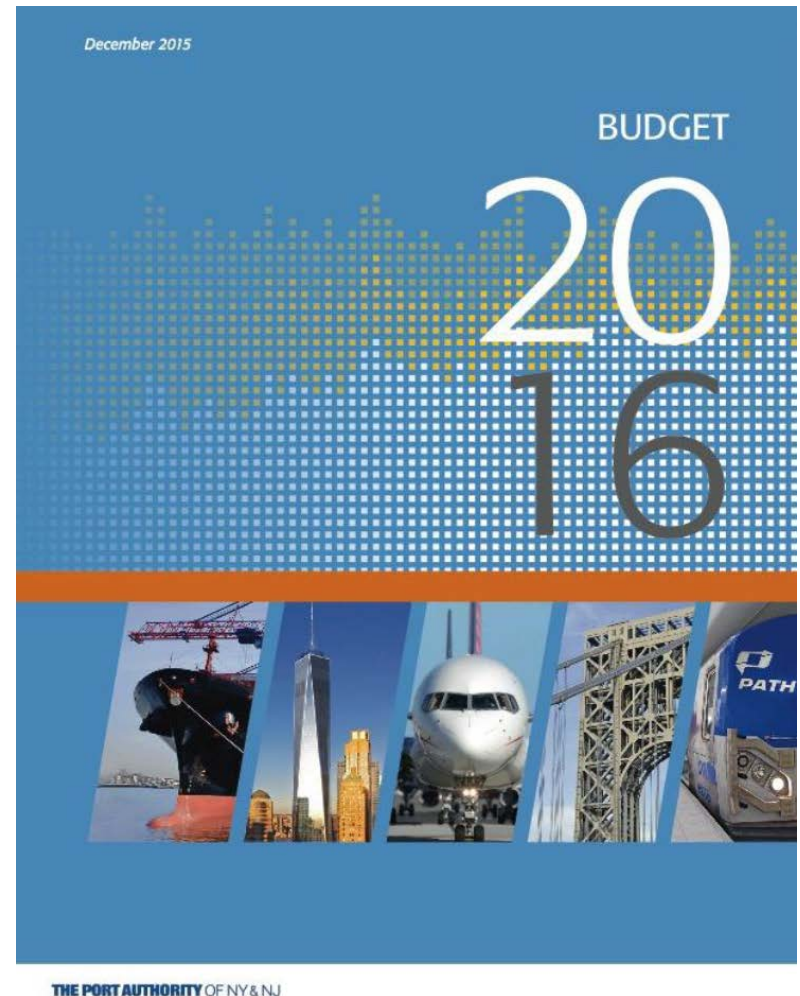
- NJ TRANSIT ridership growth over the past 25 years has consumed nearly all available capacity between Newark and New York City
- Risk loss of 75% of peak period capacity if Amtrak tunnels close in turn for rehab before Hudson Tunnel Project
- Penn Station NY lacks track and platform capacity to expand weekday peak service



Source: NJ TRANSIT; Profile of the RITN (2015); NEC Commission

# PANYNJ Trans-Hudson Plans and Projects

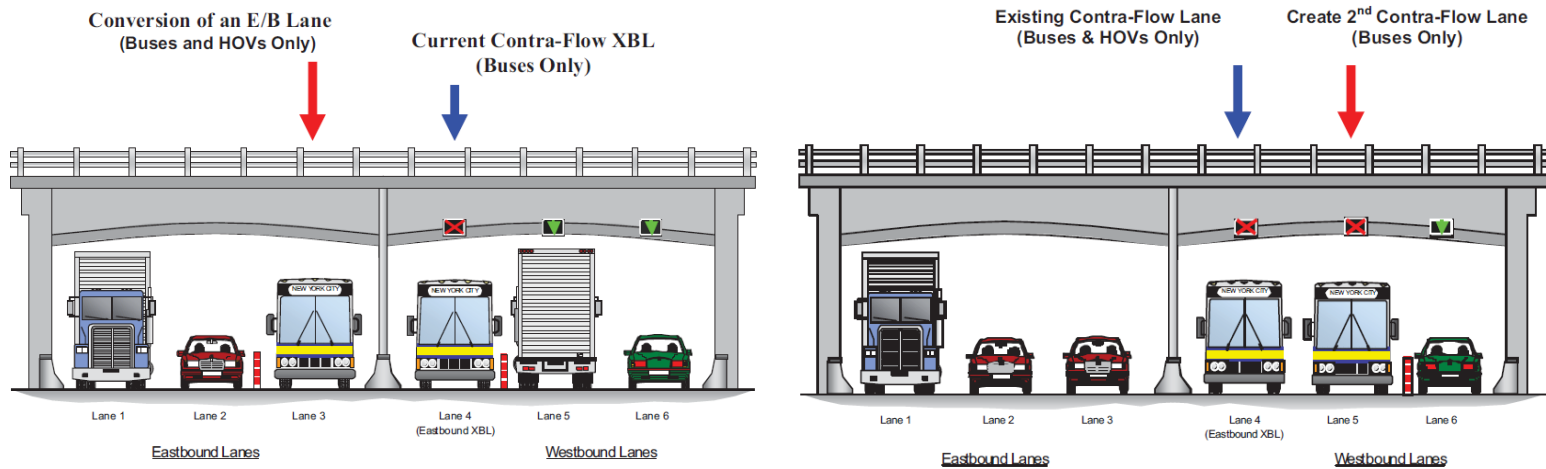
- Planned replacement of Lincoln Tunnel Helix (2020>)
- PABT Interim “Quality of Commute” Improvements
- Longer Trains on PATH-WTC service (w/ pending station improvements)
- Modernization of GWB Bus Station (2016)
- Potential ferry service expansion



# Potential Projects Adding Trans-Hudson Capacity

## *XBL Capacity Enhancement*

- Lincoln Tunnel HOT Lane or second XBL
  - Multiple operational and physical alternatives
- Ensure full utilization and balance demand with capacity



Source: Lincoln Tunnel XBL Capacity Enhancement Feasibility Study (2006)  
Lincoln Tunnel HOT Lane Feasibility Study (2009)

# Potential Passenger Rail Service Expansion GATEWAY

- Requires initial Hudson Tunnel Repair Project, without new capacity
- NEC, Gateway alternatives add 43-100% more peak-hour NJT capacity
- ARC full-build estimated 4% reduction in PABT demand



Source: Amtrak, Gateway Fact Sheet, Spring 2015



# Potential Projects Adding Trans-Hudson Capacity

## *NO. 7 LINE SECAUCUS EXTENSION (NYC Study)*

- Extension to Secaucus Junction w/ bus terminal serving 200+ buses diverted from PABT; reduced PABT demand 25-35%
- Provides cross-Midtown distribution
- Not supported by regional transit authorities



Source: No. 7 Line Extension Feasibility Draft Final Report, August 2011

# Workshop Objectives



# Workshop Objectives

- Assume a West Midtown replacement terminal
- Identify major network components for its effective operation
- Probe relevant future workplace and regional travel trends
- Assess prospects for other transportation investments with potential effect on PABT demand

# Workshop Objectives – Key Questions to be Answered



- What are the key uncertainties affecting future Trans-Hudson travel?
- What are the key interdependencies?
- Transportation: What service and infrastructure options will best accommodate demand?
- Technology: What are the most promising technology options?
- Policy: What are the major policy challenges?

# Strategies



- Strategies that increase **capacity** to support a new PABT that accommodates full future peak period demand
  - Lincoln Tunnel corridor strategies
  - PABT strategies
- Strategies that address overall Trans-Hudson **demand** including the use of other modes/crossings
  - Bus operational and service strategies
  - Multi-modal network strategies

# Lincoln Tunnel Corridor/PABT Strategies

- Improved corridor operations
  - Second XBL/HOT Lane
  - Expanded bus/HOV priority network
  - Connected/autonomous bus platooning
- Other West-of-Hudson infrastructure/bus network improvements
- Improved facility operations
  - ITS to optimize bus dispatching and circulation
  - Dynamic gate assignment with improved traveler information
- Bus staging and storage options

# Multi-Modal Trans-Hudson Network Strategies

- Expanded bus services
  - George Washington Bridge Bus Station
  - Holland Tunnel
  - Port Imperial Ferry Terminal
  - New NY Bridge (Tappan Zee Replacement)
- PATH Service Capacity Expansion
- New intermodal transfer facilities
  - North Bergen Park and Ride with BRT shuttle service
  - Park & Ride/Bus at PATH-EWR/Rail Link Station
- Expanded NJ TRANSIT (Gateway) rail service
- Hudson-Bergen Light Rail Transit Extension
- 7 Line extension to Secaucus
- Lincoln Tunnel/Holland Tunnel NJ-NYC Bus Loop
- Expanded Trans-Hudson ferry services
- Traveler incentives

# Break Out Groups

# Break Out Groups

<b>Transportation (Training Rooms 2313A/B)</b>	<b>Technology (Conference Room 251)</b>	<b>Policy (Conference Room 235)</b>
<p>Gerry Bogacz Walter Cherwony Jeremy Colangelo-Bryan Mary K. Murphy Richard Roberts Jack Schmidt Jeff Zupan Karen White</p>	<p>Richard Bishop Candace Brakewood Jerome Lutin Alan Maiman Ken Philmus (via webinar)</p>	<p>Rohit Aggarwala Emil Frankel Nancy Kete Dennis Martin Michael Replogle William Wheeler Rae Zimmerman</p>



# General Instructions

- Each break out group responsible for answering key questions and reporting back
  - Nominate group member(s) to lead report-back
  - Fill-in slides throughout break out session

# Group Reports/Integration

# TRANSPORTATION



→ What are the key uncertainties affecting future Trans-Hudson travel?

- Vehicle characteristics and fuel type
- Bus staging and storage – where and how much
- Meeting intercity bus demand – total and by time of day
- Managing the highway system for bus priority
- Rail capacity / timing of capital improvements
- Characteristics of commuting and workstyles
- Goods movement

# TRANSPORTATION

→ What are the key interdependencies?

- Size of PABT vs. expansion of rail facilities and services
- Demand on multi-modal network
- Pricing
- Timing of major capital investments

# TRANSPORTATION

- What service and infrastructure options will best accommodate demand?
  - No silver bullet
    - Many options could have modest benefit
  - Potential game changers:
    - No. 7 Line Extension
    - Intensification/extension of commuter rail service (beyond Gateway)
    - Key caveats:
      - Not currently on the table
      - Fails to address short-/mid-term projected growth in trans-Hudson demand (before new PABT)

# TECHNOLOGY



- What are the key uncertainties affecting future Trans-Hudson travel?
  - Timing of full automation [bus and all vehicles] vs PABT 2040 time frame
  - Technology advances that improve customer experience will increase demand for bus terminal
  - Changes to demand based on external factors such as widespread adoption of car or ride share
  - **Future is not transit vs. car – is mobility as a service across modes enabled by personal technology with public partners in the mix**

*Note: Some national trends will not apply here due to Trans-Hudson physical limitations*

# TECHNOLOGY

- What are the key interdependencies?
  - Have to do corridor (platooning instead of taking another lane, even as HOT) **and** facility improvements



# TECHNOLOGY

→ What are the most promising technology options?

- **495/XBL Corridor**

- **Near/Mid term:** Use platooning/ automated cruise control/ lane-keeping teardrop into PABT to reduce headway to 3 sec → increasing theoretical buses per hour to PABT from 720 to 1200
- **Long term:** Connected and automated for merging

# TECHNOLOGY

→ What are the most promising technology options?

- **Within PABT Facility**

- **Near Term** (*in process*) Locating buses in real-time (operational and customer)
- **Mid Term:** Automation for efficient movement within terminal – ex. magnetic guidance for precision docking; docking
- **Long term:** Connected and automated for merging, especially the helixes

# TECHNOLOGY

→ What are the most promising technology options?

- *Even if implementing all of these, won't dramatically reduce demand. Might shift at margins. Could increase demand due to enhanced customer experience.*
- **Demand**
  - Mode shift
  - Transportation network companies
  - Connected passengers
  - Real-time communications

# POLICY



- What are the key uncertainties affecting future Trans-Hudson travel?
  - Population growth location
  - Travel demand location
  - Infrastructure lifespan
  - Inter-Agency cooperation

# POLICY

- What are the key interdependencies?
  - Inter-Governmental Cooperation
  - Development of East Midtown
  - Tunnel operations and road system
- What are the major policy challenges?
  - Pricing and Lane Restriction/Reconfiguration
  - Funding
  - Predicting Travel Demand
  - Coordinating transportation and ITS improvements

# Summary/Next Steps

# Key Takeaways

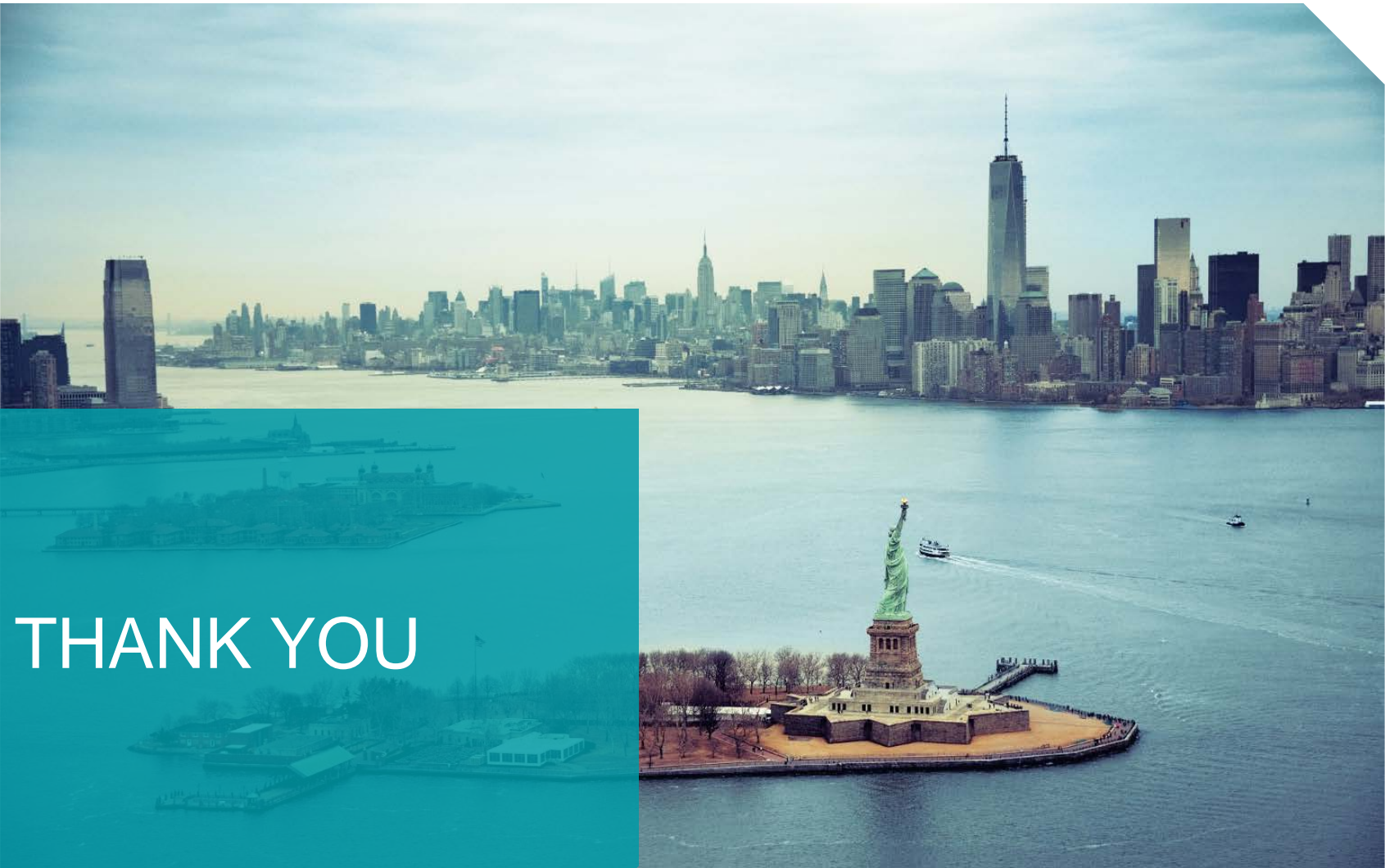
- There is **no silver bullet** that will reduce the size of the PABT
  - Gateway will not substantially alter demand at PABT
- There are as many options that increase demand as those that will reduce demand
  - Additional capacity will be filled by **latent demand**
- Need for **future modularity/flexible designs** is key to address uncertainties, with elements that have independent utility
- Develop options to address short-term demand increases (pilot programs)
  - Incremental strategies – not capital intensive
  - Technology will be available in the short-term and should be advanced sooner rather than later
- A PABT that accommodates future demand requires other actions and investments
- Moving the new PABT further west – need to build 10<sup>th</sup> Ave station
- Need to consider the customer perspective



# Next Steps



- Summarize workshop feedback and distribute workshop materials
- Complete comment card
- Follow-up webinar in June 2016



THANK YOU

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TRANS-HUDSON COMMUTING CAPACITY STUDY

# Appendix E: Travel Demand Management Options

September 2016

Version Final

Prepared for:

**THE PORT AUTHORITY**  
OF NEW YORK & NEW JERSEY

Submitted by:



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# 1 Introduction

## 1.1 OVERVIEW

On October 22, 2015, the Port Authority of New York and New Jersey’s (PANYNJ) Board of Commissioners authorized a *Trans-Hudson Commuting Capacity Study* (the Capacity Study) to evaluate a range of strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand to 2040, to inform its deliberations on conceptual planning for replacement of the Port Authority Bus Terminal (PABT) (Table 1).

Table 1: Existing and Future PABT Demand

EXISTING (2011)	FUTURE (2040)
232,000 Daily Customers	337,000 Daily Customers (+45%)
7,800 Daily Buses	9,100 Daily Buses (+15%)
615 PM Peak Hour Buses	855 PM Peak Hour Buses (+40%)

Source: Midtown Bus Master Plan

The fundamental premise of the Capacity Study is that the transportation network that accommodates trans-Hudson commuter demand is an integrated *system*, as opposed to a series of stand-alone corridors, facilities, and services. Accordingly, the intended outcome of the Capacity Study is an updated overview of that system that takes into account potential investments in physical transportation infrastructure, operational changes to existing transit services, implementation of emerging technologies, and modifications to public policy—and the prospects for their implementation in the time frame for planning and implementing a PABT replacement project.

Concurrent with the Capacity Study, the PANYNJ has commissioned an *International Design + Deliverability Competition* (the D+D Competition) seeking concepts for a new PABT. A major objective of the Capacity Study is to provide insight to the D+D Competition by evaluating the range of alternative strategies for serving the trans-Hudson commuter market via bus and other modes, which will inform the determination of the appropriate capacity and configuration of the new PABT. The interim and final work products from the Capacity Study will inform the D+D Competition and the PANYNJ Board, which will select a preferred design concept for a new PABT this fall.

The purpose of this technical memorandum is to research the potential to reduce trans-Hudson peak-period demand through expanded adoption of workplace flexibility by employers in the Manhattan central business district (CBD). It builds on earlier work conducted by the PANYNJ’s Planning and Regional Development Department (“Managing Peak Transit Demand into the Manhattan CBD,” dated November 10, 2015). Initial research documented historical knowledge on workplace flexibility in Manhattan. Data sources are listed in Section 7 of this technical memorandum. Searches were conducted within the following groups:

- Business groups and associations
- Flexible working groups and associations

- Flexible working recruitment organizations
- Human resources groups and associations
- Local and State government bodies

This research included a targeted survey effort to evaluate employer perspectives. Manhattan employers were contacted to ascertain their present views and considerations for the future concerning the adoption of workplace flexibility; present extent of adoption of workplace flexibility; expected extent of future adoption; and key issues affecting the future adoption of workplace flexibility. The technical memorandum also cites examples of cost incentives that have been used to influence commuters' behaviors is also documented.

Workplace flexibility is a term that defines an arrangement an employer has with an employee to work flexibly with regard to their work hours, work location and/or work methods.

## 2 Trends and Drivers for Increasing Travel Demand Flexibility

### 2.1 TECHNOLOGY ENHANCEMENTS

Technology has now reached a point where most home-based internet connections are as good as those in offices, and improvements in mobile technology mean that most technological obstacles to employees working away from the office have been overcome.

Video conferencing and chat & share software options are now plentiful, alleviating much of the need for meetings to be held in a central location. While technology cannot always replace the human connection, Skype, Google Hangouts, and many others provide a virtual platform for people to communicate and collaborate. Cloud-based software and storage can be accessed from anywhere with any device, making it easier and more secure to work from out of the office.

### 2.2 RATIONALIZATION OF PROPERTY COSTS

Organizations are now more likely to be looking for ways to save costs. Property costs tend to be the third-highest cost for most businesses (behind people and technology), so organizations are now more open to introduce measures that will help them rationalize their property portfolio. Many employers, including most notably the federal government, have sought to promote flexible workplace arrangements for certain categories of employees as a strategy for reducing their real estate footprints.

### 2.3 DEMOGRAPHIC SHIFTS

Generational influences will start to shift attitudes toward a more flexible way of working. Many Baby Boomers (those born between 1946 and 1964) are reaching retirement age, but cannot afford to retire and still have skills and talents that organizations require. Baby Boomers who are looking to remain in the workplace without the full burden of the daily commute increasingly view telework and variable hours as viable options.

Millennials (those born between 1980 and 2000) will soon be the largest generational group in the workplace and will bring new attitudes to where and when they work. By 2020, Millennials will make up 50 percent of the workforce, and by 2025 will comprise 75 percent. Millennials are open to flexible work arrangements. However, many also like to congregate in the workplace so they can gain knowledge from their colleagues. As their influence and knowledge grows, the need to come into the office may decrease.

Millennials are the first generation to have grown up with a significant level of comfort and familiarity with mobile technology, and may ultimately show a greater willingness to adopt workplace flexibility.

## 2.4 EMPLOYMENT SHIFTS

A recent Business Insider article estimated that some 35 percent of workers in the U.S. are “contingent” (i.e., freelance, temporary, part-time and contractors), and that figure is expected to rise to 40 percent or 50 percent, by 2020. The members of the Millennial generation are expected to change careers at least 10 times before the age of 40, while solo businesses are already popping up at the rate of about half a million a year. Many of these people are highly mobile and often do not work from an office. Meanwhile, more than 70 percent of workers in the U.S. report that they are not engaged at work and would consider starting a solo business, which often involves a flexible work schedule.

## 2.5 MORE OPEN HUMAN RESOURCES ATTITUDES

Attraction and retention of the best staff is a crucial issue that all businesses face. Key skilled staff are now in short supply in most industries, so the more incentives and benefits organizations can offer, the better chance they may have in attracting and retaining the best staff. Allowing employees more choice as to when and where they work is viewed as a key benefit.

## 2.6 WORK-LIFE BALANCE

With time-consuming and crowded commutes followed by long work hours, many people are finding it harder to balance their work and home lives. Flexible and compressed work schedules can help improve the health and welfare of workers by helping them achieve a better balance between work and family lives. These kinds of work schedules can also improve employee retention through more satisfactory work arrangements and can promote greater workforce participation among parents and other caregivers.

## 3 Workplace Flexibility

The topic of workplace flexibility interests the government and the business community for a wide range of reasons:

- Improves the general welfare of the workforce
- Improves conditions for women in the workplace
- Increases the attractiveness of particular employers in a competitive environment
- Reduces employer real estate costs

This analysis addresses the potential for workplace flexibility to reduce peak commuting into Manhattan's CBD, with a focus on employers of office workers.

It is important to understand that some jobs cannot adopt workplace flexibility. Examples of sectors where flexible work arrangements are generally not feasible include retail, transportation and warehousing, health and social assistance, accommodation and food services, education, and construction—although many of these jobs are not in the CBD or already follow non-peak commuting schedules. The remaining employees are in industries that could adopt workplace flexibility, although even within these more favorable industries, only certain job categories or occupations can take advantage of workplace flexibility while others such as operations or client-facing services cannot.

To consider the impact that workplace flexibility could have on commuter demand, it is essential to define the different types of workplace flexibility and understand how each type could have a different impact.

### 3.1 TELECOMMUTING/TELEWORK

Telecommuting (or teleworking, as it is sometimes known) describes employees who occasionally work from home rather than from a central office. This type of workplace flexibility is particularly appropriate for tasks that involve information management, such as research, accounting, editing, software development, and design. It also lends itself to knowledge workers. Major advances in technology, communication tools, and video-conference capability now facilitate collaboration and meetings between employees within and outside the physical workplace.

There are several types of telecommuters. Ad hoc telecommuters work from home only when there is a need to do so. Some contracted telecommuters will work from home for one to two days a month—others one to two days a week. A smaller group will not work from an office at all and will be permanently based at home.

Ad hoc telecommuting and contracted telecommuters who work from home for one to two days a month will have only a small impact on peak-flow traffic. However, contracted telecommuters who work from home for one to two days a week will have a more significant impact on peak-flow traffic.

More workers now say they have telecommuted more than in the past; however, telecommuting remains much more the exception than the rule (Table 2). Workers in the U.S. reportedly telecommute from home on average about two days per month. Nine percent of workers indicate that they telecommute more than 10 workdays a month, which means they spend at least half of all workdays in a typical month working from home.

Table 2: Number of Workdays Typically Telecommute Rather Than Go to Office

	All Workers %	Workers who have ever telecommuted %
No days	72	23
One to two days	9	23
Three to five days	8	22
Six to 10 days	2	6
More than 10 days	9	24
Mean number of days	2.3	6.4
Median number of days	0	3

Source: Gallup, Aug 5-9, 2015 (based on employed adults)

Telecommuting is much more common among certain demographics and tends to be done more by those who have had more formal education, those who are in the upper-income bracket, and those who have white-collar professions.

The impact that workplace flexibility has on productivity has always been debated. Most Americans believe workers who work remotely are just as productive as those who work in a business office. This belief has grown to 58 percent—up from 47 percent the first time Gallup asked the question in 1995. However, the percentage of people who believe that telecommuters are *more* productive than those who work in an office has dropped from 28 percent to 16 percent. Overall, telecommuters are perceived to be at least as effective as those who work in offices.

Even though telecommuting has become more common, the growth in the practice appears to have started to level off in recent years, according to Gallup’s annual work and education poll. It is unclear how much more prevalent telecommuting can become because it is only feasible for workers who primarily work in offices using a computer to perform most of their work duties.



The federal government, one of the largest employers in the United States, has particularly strong policies promoting telecommuting. Under the Telework Enhancement Act of 2010 and predecessor legislation, federal agencies have been aggressively promoting telework as part of a broad strategy to reduce facilities costs. As a result of these efforts, telecommuting by federal employees has increased by over 400 percent since 2005.

According to the *2014 Status of Telework in the Federal Government Report to Congress*, positive trends in eligibility and participation in telework include:

- Telework eligibility increased from 33 percent of all employees in 2011 to 45 percent of all employees in 2013.
- September telework participation remained relatively stable over time: 23 percent of eligible employees teleworked in September 2011 and 21 to 23 percent of eligible employees teleworked in September 2013 (depending on the subset of agencies).
- Fiscal-year telework participation increased from 29 percent of eligible employees in 2012 to 39 percent of eligible employees in 2013, reflecting increased use of situational telework.
- February telework participation was higher compared to September participation, with 23 percent of eligible employees teleworking in September 2013 and 26 percent of eligible employees teleworking in February 2014. The higher participation most likely reflects the impact of weather-related agency closures and delays as well as use by teleworkers of agency flexibilities such as unscheduled telework or unscheduled leave on days where the office is open but the Office of Personnel Management (OPM) makes an announcement triggering the use of such flexibilities.

### 3.2 WORKING FROM SATELLITE OFFICES/CO-WORKING HUBS

A more recent flexible working development is allowing staff to work from a satellite office located closer to where they live, alleviating the need to commute longer distances all the time into the principal office. Neighborhood work centers can provide office services to a variety of businesses, giving employees the connections and facilities they need to carry out their work. Satellite offices can be useful for those employees whose home life does not lend itself to telework. Co-working hubs are increasingly opening in suburban communities, and are usually designed to accommodate those employees who do not have an office location.

Employees who are able to use satellite offices for more than one to two days a week could have a substantial impact on decreasing peak-period commuter demand. Although growing in popularity, the use of satellite offices, is still in its infancy. Worries about data security have often stopped organizations from looking at this as a viable option.

**Example: Suburban Co-Working in the Greater Chicago Area**

Much of the literature on the trends in co-working focus on activity hubs in CBDs of cities. However, there is an emerging phenomenon of suburban co-working that aims to “provide urban-style amenities to the suburbs,” as described by the business development coordinator for a village in the Greater Chicago Area and quoted in a recent *Arlington Heights Patch* article. The metropolitan area that surrounds Chicago is poised to see an increase in suburban co-working opportunities, as the company 25N Coworking will soon open its second location in the region, which will offer flexible workplaces outside the central city. In 2015, 25N Coworking won the Mayor’s Choice Award from the City of Geneva, also in the Greater Chicago Area, to recognize the positive impact on the local economy generated by the co-working space the company introduced in that municipality. As discussed in a recent article from the inaugural edition of *Workplace Magazine* (“25N Ignites the Suburban Coworking Movement”), location is an important consideration for suburban co-working arrangements, and “As [co-working] becomes an integrated part of work culture everywhere, suburban [co-working] will become part of the new normal.” Two relevant factors cited in the article with respect to location include transit accessibility and time savings associated with a modified commute. The west-of-Hudson suburbs in New York City could benefit from expanded co-working opportunities in part because of the robust multimodal transit network and the potential time savings for commuters who could travel to and from their jobs without having to traverse one of the congested Hudson River crossings.

### 3.3 VARIABLE WORKING HOURS

Some organizations still require their staff to work set core hours, which can vary, but are usually 9:00 AM to 5:00 PM. However, the following variable or alternative working hours are possible:

- Flextime work offers employees flexibility their daily work schedules. For example, rather than all employees working 9:00 AM to 5:00 PM, some might work 8:00 AM to 4:00 PM, and others 10:00 AM to 6:00 PM.
- Compressed work weeks allow employees to work fewer days but longer hours per day. Examples include four 10-hour days each week (4/40), or 9-hour days with one day off every two weeks (9/80). This was a popular form of variable hours; however, it has recently lost ground to more flexible options.
- Staggered shifts are designed to reduce the number of employees arriving and leaving a worksite at one time. For example, some shifts may be 8:00 AM to 4:30 PM; 8:30 AM to 5:00 PM or 9:00 AM to 5:30 PM. This has a similar effect on traffic as flextime, but does not give individual employees as much control over their schedules.
- Agile work (work anywhere) suits employees that have varied work schedules and whose job will allow them autonomy as to when and where they work.

Variable working hours help only to reduce peak commuting but increase shoulder commuting on either side of the peak. However, this option seems to be more acceptable to the majority of employers than telecommuting.

As summarized in the TDM Encyclopedia (prepared by the Victoria Transport Policy Institute), prior research has demonstrated that flextime or variable working hours can have the effect of reducing peak-period congestion, can increase the attractiveness of ridesharing and transit use, and can result in a reduction in commute time of an average of seven minutes per day. However, other research points to the need for those who telecommute having to make additional business trips from their home base.

Based on an analysis of Census Bureau data by Global Workplace Analytics, 3.7 million employees, or about 2.5 percent of the non-self-employed workforce, now work from home at least half the time. This share has more than doubled since 2005. The NY/NJ metropolitan region has somewhat lower rates of telecommuting than the national average.

***Example: The Port Authority and the Downtown-Lower Manhattan Association***

When the original World Trade Center (WTC) was under construction, the PANYNJ and the Downtown-Lower Manhattan Association undertook an initiative to accommodate additional commuters on the existing transit system associated with the projected 120,000 jobs created by the WTC and other projects in Lower Manhattan. In April 1970, the two agencies sponsored a Staggered Work Hours Project as a pilot program with a corresponding advertising campaign to encourage flexible work schedules. The first three months' results were deemed a success, with participation by 45 of the area's top employers and 50,000 employees. Peak passenger volumes at PATH's downtown terminal and three major subway stations dropped in the ensuing months and years. By April 1974, approximately 200,000 employees throughout Manhattan (working for approximately 400 employers) were using staggered work hours, and in 1975, the City of New York introduced staggered work hours for approximately 13,000 employees in downtown Manhattan.

### 3.4 BENEFITS OF IMPLEMENTING WORKPLACE FLEXIBILITY

Many employees highly value workplace flexibility, which can increase their productivity and job satisfaction. Workplace flexibility can also help employees meet their home life commitments, reduce commuting time and stress, and work when they are most productive. One survey discussed in the TDM Encyclopedia found that 68 percent of employees would like to have flexible work hours, and 53 percent would participate in a compressed workweek.

The benefits of workplace flexibility include reduced traffic congestion and transit crowding and other benefits to employees. Workplace flexibility allows commuters to match their work schedules with transit and rideshare schedules, which can significantly increase the feasibility of using these modes. Compressed work weeks reduce commute travel, although total vehicle or transit travel

impacts may be modest if employees have to make additional business-related trips from their home.

Workplace flexibility can help achieve organizations' equity objectives. Many economically and physically disadvantaged workers (e.g., single parents and people with physical disabilities) place a particularly high value on optional flexible working opportunities.

Because they are important to workers, these policies help businesses attract and retain the best talent. One study tracked the impact of announcements regarding new work-life balance policies by Fortune 500 companies and found that companies' stock prices rose 0.36 percent on the days following announcements. This suggests that investors believe companies implementing such policies are profitable investments. A comprehensive study of 700 firms in the U.S. and Europe conducted by business management researchers found that work-life balance policies are positively associated with good management.

Employers can benefit too; with more employees using the office less, there may be an option to rationalize the property portfolio helping to cut costs.

### 3.5 CHALLENGES WHEN IMPLEMENTING WORKPLACE FLEXIBILITY

Many organizations have or are looking to introduce agile working programs into their businesses as a way to reduce property costs. The introduction of "hot desking" and "hoteling" options, where staff don't own desks but share them to maximize utilization, are now commonplace. However, teleworking and variable work hours have been slower to become mainstream.

Even with flexible working strategies in place, top and middle management can often resist allowing teleworking and variable hours working to become accessible to the majority of staff. This can be seen by the main demographic (high-income professionals) who have work flexibility.

As the Gallup data in Table 3 shows, most employees who telecommute are college-graduate white-collar professionals who have annual household incomes of \$75,000 or more. They are also in the older age bracket with an average age of 49. This shows that the majority of telecommuters have the autonomy to work where and when they like.

Table 3: Ever Telecommute — by Education, Income and Job Type

	% Yes
College graduate	55
Non-college graduate	26
Annual household income \$75,000 or more	52
Annual household income less than \$75,000	26
White-collar profession	44
Blue-collar profession	16

Source: Gallup, Aug 5-9, 2015 (based on employed adults)

Note: White-collar professions are those categorized as being executive/managerial, a professional specialty, technical, sales, or administrative.

Human nature can also keep people tied to their desks. During times of uncertainty and recession, statistics show that building occupancy and utilization tend to increase by as much as 15 percent. People worried about losing their jobs want to be seen working in the office. There is also a correlation between telework and lack of promotion prospects. This fact may not deter the Baby Boomers (born between 1946 and 1964) who are finishing their later years of work, but will potentially affect Millennials’ (born between 1980 and 2000) and Generation X-ers’ (born between 1965 and 1979) attitude to telework.

Telework can face institutional and technical barriers. Telework requires changing organizational and management practices. It may also increase equipment costs by requiring the purchase of laptops and mobile devices instead of desk-based PCs. There may also be increased costs to supply internet access and security services. Cost issues can also include increased administrative and management responsibilities; many managers find it more difficult to evaluate an employee productivity when they work remotely. Workplace flexibility may reduce staff coverage and interaction, and may make meetings more difficult to schedule. Findings from one study indicate that compressed work weeks may reduce productivity since employees become less productive at the end of a long day.

Labor organizations sometimes oppose telework programs because they are concerned about negative impacts on vulnerable employees. Some of the more specialized residential communities where residents rent their homes under specific agreements are not always happy about people working from home, which may make telecommuting more difficult.

In 2013, Yahoo CEO Marissa Mayer changed the company policy to stop all workers from working flexibly. The reason given for the change in policy was the need generate a more creative and innovative team approach. Collaboration and innovation are often cited by corporations as the main reason for not making workplace flexibility more accessible. However, Yahoo’s policy is in the minority since an increasing number of employers allow workers the flexibility to do their job remotely if it is feasible for them to do so. More American workers report telecommuting than in three prior Gallup surveys. Nevertheless, the growth of the practice appears to be slowing.

## 4 Employer Surveys

The Parsons Brinckerhoff Team initiated a comprehensive effort to evaluate employer perspectives. The team made contact with a number of large Manhattan employers to ascertain their present and future views concerning the present adoption of workplace flexibility, the expected future adoption of workplace flexibility, and key issues to the future adoption of workplace flexibility.

The team contacted the employers in the following industries:

- Engineering
- Government
- Banking
- Media
- Fashion
- Education
- Technology
- Marketing/Advertising
- Medical
- Legal

While the survey effort targeted a cross-section of two dozen major employers with significant numbers of Manhattan-based workers, responses were limited due to the reluctance of some employers to provide the information and other reasons. Complete responses from six organizations reflected strong interest in the subject from diverse respondents, suggesting the value of developing alternative approaches for eliciting employer participation.

### 4.1 SURVEY RESULTS

#### 4.1.1 Questions and Answers

**Question 1:** What percentage of staff in your organization working in Manhattan between 59th St. and the Battery already work flexibly, would you expect to be working flexibly in 2021 (in 5 years) and would you expect to be working flexibly in 2026 (in ten years)?

Table 4: Percentage of staff who work or telecommute for 1 to 2 days per week

Year	Highest %	Lowest %	Average %	% Increase over 2016
2016	85%	5%	26%	N/A
2021	95%	15%	38%	12%
2026	95%	20%	42%	16%

Table 5: Percentage of staff who work or telecommute for more than 3 days per week

Year	Highest %	Lowest %	Average %	% Increase over 2016
2016	40%	1%	15%	N/A
2021	50%	2%	20%	5%
2026	50%	5%	24%	9%

Table 6: Percentage of staff with alternative work schedules traveling outside peak commuting times

Year	Highest %	Lowest %	Average %	% Increase over 2016
2016	75%	5%	28%	N/A
2021	90%	5%	36%	8%
2026	95%	5%	40%	12%

**Question 2:** Does the organization allow staff to use satellite offices and if so what percentage of staff in your organization working in Manhattan between 59th St. and the Battery presently work from satellite offices for more than 1 day a week, will work from satellite offices in five years' time and will work from satellite offices in ten years' time?

Table 7: Percentage of staff who use satellite offices for more than 1 day per week

Year	Highest %	Lowest %	Average %	% Increase over 2016
2016	15%	0%	8%	N/A
2021	45%	0%	18%	9%
2026	30%	0%	18%	10%



**Question 3:** Are there any other trends that you see affecting your staff's need to commute at peak times in the future?

Responses received:

- No trends
- Upgrading of aging road infrastructure may put pressure on alternative transport options.
- Increased availability of alternative public transport at more diverse off-peak times.
- Commuter rail lines need expanding they are crowded and expensive.
- Healthcare and maternity needs
- Changes in technology

**Question 4:** What are the main issues that are stopping more staff from working flexibly and consequently reducing their peak time travel?

Responses received:

- The majority of employees already take advantage of our alternate work schedules.
- Public nature of work requires face-to-face interaction.
- Requirement of teams to work together
- The need for support staff to be in at the same time as lawyers and the need for lawyers to collaborate together.
- There is still a face time culture and many employees are support staff and need to be in at certain times.

**Question 5:** From an organizational point of view, what public policy incentives if implemented would help your organization to allow more of your staff to work more flexibly in the future?

Responses received:

- None as alternate work schedules are available to all our employees.
- Traveler incentives would also benefit the organization.
- Technology upgrades and additional funding for training.
- Transit programs, tax incentives for organization on real estate
- None

- Financial / tax incentives would be beneficial; however, the Corporation would consider joining in a city-wide campaign to promote more flexibility

**Question 6:** In your opinion, what workplace incentives if implemented would help staff work more flexibly in the future?

- Financial incentives would help
- Free addressing of workplace by organizations
- Management training
- None
- Financial

**Question 7:** Do you have any additional thoughts or comments?

- Employees coming to the office and working with their teams and leaders will always be an effective collaboration. I do not see the workplace going away but rather changing from a 1:1 requirement of persons to seats to a more flexible ratio.
- 30 percent of staff feel they would not be comfortable working more flexibly as it is not the right time in their careers
- As a major employer in the area we would be happy to be involved in encouraging our management and staff to take a more active role in working flexibly.

Overall, telecommuting for 1 to 2 days a week (26 percent) and alternative work schedules (28 percent) were the two most popular types of workplace flexibility. They also show the greatest estimated increase with telecommuting 1 to 2 days a week increasing by 12 percent over 5 years and 15.5 percent over 10 years. Estimated increases for alternative working schedules were less dramatic with 9 percent over 5 years and 9.5 percent over 10 years.

Alternative work schedules were only slightly more popular than telecommuting for 1 to 2 days a week.

Telecommuting for 3 days or more was less popular with 15 percent uptake. There was also less of an increase predicted with a 5 percent increase estimated over 5 years and a 9 percent estimated increase over 10 years.

The use of satellite offices was the least popular, with only an 8 percent uptake and a 9 percent increase estimated over 5 years and a 9.5 percent estimated over 10 years. The small increase shown between the 5- and 10-year figures may in turn be due to more staff telecommuting and using alternative work schedules.

**What do these figures reveal about the impact that flexible working will have on peak-period commuter travel demand?**

Telecommuting for 1 to 2 days a week is the second most popular type of flexible working but shows the biggest estimated increase over 5- and 10-year periods. This in itself does not help reduce peak-time traffic since many people will take Monday or Friday as their days to telecommute. This will reduce peak demand on Monday and Friday but will not have as much effect on Tuesday, Wednesday, and Thursday traffic.

Telecommuting for 3 days offers a more balanced reduction of peak traffic; however, the estimated future uptake is significantly less, showing a 5 percent and 9 percent increase over 5- and 10-year periods.

Alternative work schedules (the most popular type of workplace flexibility) directly affect peak traffic by moving some trips into pre- or post-peak times. It is also the easiest for organizations to manage and does not significantly affect collaboration in the workplace. However, it does not have the same effect on work-life balance as telecommuting.

It must be noted that the statistics here are individual opinions from a small number of employers in Manhattan and are qualitative and inadequate as a basis for wider projection of attitudes and trends. The statistics do offer insight into potential receptiveness by employers and their workers to flexible working initiatives.

Significant variation exists in the estimates as the highest, lowest, and average figures show. Adoption of these policies depends on an organization's culture, management style, technology infrastructure, and staff with jobs that will not allow them to work more flexibly.

Given the limited number of employers willing or able to provide information in response to the survey, it is difficult to estimate the percentage of workers below 60th Street who are in jobs where policy could dictate their commute patterns and how that percentage may change. From the data received, the variety among organizations is significant, with one public-sector organization saying that its workplace flexibility policies are open to all, and another saying that at least 40 percent of its staff could not participate due to the nature of their jobs. One private-sector organization stated that the company's culture of face-to-face collaboration significantly reduced the percentage of potential participation. There does not seem to be any existing data that would shed more light on this topic.

#### 4.1.2 Findings

Without complete research on the new changes in workplace flexibility, it is difficult to offer clear guidance as to the level of peak-period reduction in commuter demand that could be expected by the introduction of such a program. Most existing research emphasizes that without additional study, it is difficult to estimate how much further the peak could be reduced in New York City with greater incentives or mandates.

However, there are some clues from the data available that allow deeper consideration of potential scenarios.

Several large corporations with staff in Manhattan have flexible working initiatives in place, which could indicate that reasonable numbers of staff may work flexibly. The adoption of these initiatives however is often disappointing. For instance, staff may not be comfortable working more flexibly if they perceive it as not the right time in their careers. Additionally, working from home could have an adverse effect on opportunities for promotion. Organizational culture, management style, and technology infrastructure can lead to significantly lower rates of adoption of flexible work initiatives. Moreover, many workers have jobs that do not allow them to work more flexibly, due to the nature of their work. A coordinated program of mandatory, voluntary, and incentive-based initiatives could increase the uptake of workplace flexibility over the longer term.

With Millennials soon be the largest generational group in the workplace, their attitudes to working flexibly and mobile technology will potentially increase the uptake of flexible work programs. The Millennial attitude to environmental issues also could carry over to viewing flexible work schedules as more environmentally sensitive.

Even though telecommuting has become more common, the growth in the practice appears to have started to level off according to the annual Gallup poll cited previously. Statistics in the U.S. show that 9 percent of employees telecommute from home rather than go into the office on average about two days per month. Telecommuting is much more common among certain demographics and tends to be done more by those who have had more formal education, those who are in the upper-income bracket, and those who have white-collar professions. To succeed in developing a sustainable flexible work program, efforts to expand these benefits to other demographics must be examined.

Even with flexible working strategies in place, upper and middle managers may resist allowing teleworking and variable working hours to become accessible to the majority of staff. This can be seen by the main demographic (high-income professionals) who work flexibly.

Adoption of variable working hours is the easiest and most popular form of workplace flexibility, but it will only help to reduce peak-period demand and will increase shoulder peak-period demand on either side of the peak hour.

Cost incentives instead of disincentives seem to work better and are more popular. Singapore MRT's "free early bird rider program"—which was implemented in June 2013 offering free travel—showed that about 7 percent of commuters have shifted out of the morning peak period.

As described in the next section, using gamification as an incentive to make changes in commute behaviors is still in its infancy, but offers new opportunities. Section 5 describes a new pilot program initiated this spring by the Bay Area Rapid Transit (BART) system in San Francisco and successful incentive programs implemented in Asia and Europe.

The *Managing Peak Transit Demand into the Manhattan CBD* document rightly states that employer-based programs can be effective at influencing commuting behavior, even when employee participation is voluntary. However, more is needed to open up flexibility to all demographics and especially to train middle management how to manage employees remotely. Public policy can also be effective at inducing employers to implement these programs. Price increases used as a deterrent to peak-flow commuting may not be an effective option since the high cost of commuting in this region has not deterred commuters who appear to be relatively insensitive to price.

In summary, options for promotion of workplace flexibility measures include the following:

- Encourage employers to further expand upon any flexible working strategies they may already have in place—possibly offering incentives to them to do so—and offer training opportunities to help managers manage from a distance.
- Change the default attitude from “work statically from the office unless considered able to be more flexible” to “work flexibly unless your presence is essential in the office.”
- Encourage management to develop the organization’s ability to collaborate and communicate virtually so as to decrease the need for teams to collaborate face-to-face all the time.
- Encourage employees to change their commute behaviors with financial incentives to travel out of rush hours and make their travel more inclusive using gamification.
- Look at additional incentives like sponsored breakfast deals.
- Promote—especially through social media—constant embedding and timely feedback and reviewing will be needed to keep the program relevant and moving forward.

## 5 Incentives to Shift Individual Behavior

Flexibility for workers to shift their commuting hours is a prerequisite for promoting this strategy to alleviate the crunch of peak-hour demand, but it may not by itself be sufficient to get commuters to change their travel patterns. After all, there are many factors outside of the workplace that incentivize commuters to conform to the most popular travel times, including family considerations, greater frequency of peak-period transit service, and even after-work entertainment options. Once workplace and work schedule flexibility is available, additional direct incentives to commuters can be effective at achieving shifts in travel behavior. These can be generalized price incentives, or more-targeted and creative types of incentives.

### 5.1 PRICE INCENTIVES

A global survey found that employees tend use about 15 percent of their disposable income for commuting costs, so they appreciate any incentives to cut that cost. Comparable numbers for Manhattan are not readily available. There are a number of options for incentivizing commuters to travel during off-peak times:

- Free or reduced prices for traveling outside the peak-flow times
- Higher prices for those who travel during peak times

Peak-period fare surcharges, or off-peak discounts, are not often used in the United States. Only five of the 50 largest transit providers in the United States charge peak-period fare surcharges or offer off-peak discounts: Long Island Rail Road, Metro-North Railroad, Washington, D.C. Metro, King County (Seattle) Metro Transit, and Minneapolis/St. Paul Metro Transit. Two examples follow, including one example from the United States and an international example.

#### **Example: Washington, D.C. Metro**

Facing increasingly crowded rail cars during peak periods with little ability to lengthen trains or decrease headways, the Washington Metropolitan Transit Authority “Metro” introduced a “peak-of-the-peak” fare surcharge. Introduced in 2010, the \$0.20 surcharge was added to trips taken between 7:30 and 9:00 am and between 4:30 and 6:00 pm with the intention of encouraging customers to take trips outside of the peak periods for a lower cost. The program was eliminated in 2012 with the introduction of a new fare increase. One of the primary reasons for the elimination of the “peak-of-the-peak” surcharge was to simplify Metro’s fare charts. Under the “peak-of-the-peak” fare structure, customers were forced to navigate a distance-based fare for 91 stations that was charged at six different rates: SmarTrip Card off-the-peak, SmarTrip Card peak, SmarTrip Card peak-of-the-peak, paper farecard off-peak, paper farecard peak and paper farecard peak-of-the-peak.

**Example: Mass Rapid Transit (MRT) Free Early Bird Program, Singapore**

One of the best examples of incentive-based transit programs is the Singapore MRT's "free early bird rider program," which was implemented in June 2013. The program offers free travel to commuters who travel through high-traffic stations before 7:45 AM on weekdays. The program is for commuters using the MRT, the city's crowded subway system. Commuters pay nothing if they exit at one of 16 heavily used MRT stations in the city core by 7:45 AM on weekdays. The number has subsequently been increased to 18 stations from its inception. Commuters who exit at one of these stations between 7:45 AM and 8 AM received a slight discount. There is a requirement for MRT to run additional off-peak trains to accommodate the change. MRT officials worked with large employers in the area to promote the use of flexible work schedules.

Results have been impressive; 36,000 people exited at one of the 16 core stations between 7:00 and 8:00 AM on weekdays, compared to 99,500 who got off at the same places between 8:00 and 9:00 AM, which is a peak/off-peak ratio of nearly 2.8 to 1. Ridership was nearly as high in the 15 minutes before 9:00 AM as it was in the whole hour before 8.

Data from the project study showed that about 7 percent of commuters have shifted out of the morning peak period since the introduction of Free Pre-Peak Travel. The ratio of morning peak (8:00 AM-9:00 AM) to pre-peak (7:00 AM-8:00 AM) travel (based on commuters exiting from the designated stations) has fallen from 2.7 to 2.1. Capacity during the pre-peak period remains adequate.

In a Singapore Land Transportation Authority (LTA) survey conducted in September 2013, the majority of commuters who shifted their travel to the pre-peak period did so because of the free travel or discounted fares. Ninety-five percent of respondents said they would continue traveling early. For those who had not shifted, two out of three said it was because they do not have flexible work arrangements.

All of the public agencies located within the catchment area supported the LTA's Free Pre-Peak Travel Scheme, and allowed their staff to report for work as early as 7:00 AM, where the nature of their work allowed for it. In a survey conducted in July 2013, 8 percent of public officers working in the city area at the time changed their work timings and commuted before the morning peak hours.

The LTA also embarked on a series of activities to promote pre-peak travel. The LTA arranged for sponsored breakfast vouchers, which were distributed to early commuters at selected city stations on certain days in May. Commuters who exit these stations before 7.45 AM will each receive a breakfast voucher while supplies last. The LTA continued to conduct other promotional activities at various stations.

The city has extended the program, which was originally supposed to end in June 2014.



## 5.2 GAMIFICATION INCENTIVES

Gamification is defined as the application of game mechanisms and design techniques to motivate and engage people to change their behavior in targeted ways. When designed correctly, games have proven to be very successful in engaging people and motivating them to change their behaviors, develop new skills, or solve problems. Games are currently being applied to customer engagement, employee performance, training and education, innovation management, personal development, sustainability, and health and wellness projects.

The following are some of the projects already in use:

- Nike built the Nike+ platform to engage fitness enthusiasts to take their workouts to the next level, and uses games to help employees run through possible scenarios for futurecasting.
- Khan Academy uses games to enhance the learning experience for students.
- Quirky uses games to crowdsource ideas from inventors for product development.
- The Recyclebank app gives points for recycling.
- EVOKE, an award-winning game that gives players missions to help solve problems related to human rights and climate change.
- A mock stock market in the United Kingdom brought new ideas that spread throughout the government's largest federal agency.
- Officials in one Florida county government agency are planning a suite of gamified systems that will change their approach to community outreach.
- Delta Airline is offering a series of giveaways that uses Delta's Twitter, Instagram hashtag #DeltaGoFridays, and a new Slack bot to give overworked New Yorkers plane tickets, Mets and Yankees tickets, The New York Spectacular at Radio City tickets, and other reasons to take the day off.
- Accenture, a business services company, set up a system that used pedometers to measure the number of footsteps more than 3,000 employees took each day, encouraging them to walk more for better health. The campaign, called "Steptacular," included a social network component and a web-based game to add a random element to the incentives; it handed out \$238,000 in rewards.

Today's video game producers are sophisticated and use psychology and neurochemistry to determine what motivates players and keeps them coming back. Gamification is still in its infancy; however, the development of mobile devices, wireless technology, wearables, sensors, big data and cloud computing have made it more affordable and scalable in recent years.

Research firm Gartner predicted that "by 2015, 40 percent of Global 1000 organizations will use gamification as the primary mechanism to transform business operations." Gamification—whether

by using something as simple as virtual badges or as complex as an entire game—offers a framework for encouraging desirable behavior.

There are a number of examples of gamification being used to help commuters and to promote greener driving practices.

***Example: Bangalore, India***

One of the lead innovators in this field has been Balaji Prabhakar, Professor of Electrical Engineering and Computer Science at Stanford University. Based on his work, Bangalore, India, conducted a trial in 2008-2009. When participating commuters traveled outside rush hour, their odds of winning a weekly raffle that paid up to \$240 improved. Results showed pre-peak travel doubling and morning travel times declining as a result. The incentives system worked incredibly well. Roughly 14,000 locals were given the chance to commute outside peak hours; every time they did, they improved their odds of winning a weekly raffle that paid out prizes ranging from \$10 to \$240. Over the course of the pilot, commuter traveling pre-rush hour doubled, and the average morning commute time of all bus riders fell from 71 to 54 minutes.

***Example: Stanford University, Congestion and Parking Relief Incentives***

Using a \$3 million research grant from the U.S. Department of Transportation, Stanford deployed a new system in 2012 designed by Dr. Balaji Prabhakar. Called Capri (Congestion and Parking Relief Incentives), it allows people driving to the notoriously traffic-clogged campus to enter a daily lottery, with a chance to win up to an extra \$50 in their paycheck, just by shifting their commute to off-peak times. The program has proved so popular that it is to be expanded soon to also cover parking. The Stanford experiment adds a social network component to the lottery, in effect making it a game where friends can observe one another's "good" behavior. The researchers say this tends to reinforce changes in behavior and individual commitment.

***Example: BART gamification pilot, San Francisco***

Dr. Balaji Prabhakar has now started a company, Urban Engines, which develops a range of data fusion projects for agencies looking to manage urban congestion. Bay Area Rapid Transit (BART) and Urban Engines launched a six-month pilot program in early 2016, involving 25,000 commuters to try to alleviate rush-hour overcrowding. The program is called BART Perks, and travelers are incentivized, using mini-games and monetary rewards, to avoid traveling between 7:00 AM and 8:30 AM and take the train one hour earlier or one hour later. The participants will have their trips tracked using their electronic transportation cards. They will be rewarded with points according to their efforts. Points can also be earned by involving friends and family in the program. The points can then be redeemed for small rebates, small cash rewards, or even gambled in games like a virtual roulette or snakes and ladders. Commuters can win up to \$100 in those mini-games. The scheme has been set up specifically to persuade people to change their commuting behaviors.

The success of BART Perks will depend on whether major employers agree to offer their workers flexible hours, as well as the specifics of the agency's reward system. Results as to the success of the pilot are not yet available. The PANYNJ will revisit the pilot as part of its ongoing trans-Hudson network management efforts.

**Example: Waze**

Waze, a popular GPS-based navigation app, incorporates crowdsourcing and gamification. The application is based on the idea that commuters know their road the best and have valuable information to share with others. Game mechanics encourage drivers to head to roads that need mapping and report on road conditions, traffic, and hazards. Points and leaderboards encourage drivers to engage with one another and compete to report. Rather than get distracted to socialize while driving, Waze gets people to socialize in order to drive more efficiently.

**Example: From5To4 web-based tool, Europe**

From5To4 is web-based tool that combines personal and group incentives for employees into an attractive game. It aims to reduce the energy impact of commuter and business trips by providing a "Commuter Challenge" competition. From5T4 is seen as a game-changer, introducing new trends in social media and gamification into the field of mobility management. From5To4 encourages employees to change their travel behavior and use sustainable modes for at least 20 percent of their travel to work trips. This is possible if they work and travel smart. A digital coach, the personal obligation to fill in travel choices, and team coherence are strong incentives. Peer pressure, competition, and small awards help people to stay motivated. Recent implementations in 10 sites reaching over 1,000 employees show an average drop in car-use during rush hour of 21 percent.

In one specific case (Municipality of Eindhoven, 60 contestants), the participants reduced car trips by 27 percent, biked 5.8 kilometers (3.6 miles) more per week per average participant, and drove 6.25 kilometers (3.88 miles) less per week.

## 6 Conclusion

This technical memorandum complements the other work in the Capacity Study by considering opportunities to *reduce* overall trans-Hudson peak-period travel demand. In conjunction with other strategies for meeting and managing the anticipated increases in trans-Hudson commuter demand, broader adoption of workplace flexibility by employers in the region could “reshape” or “flatten” the peak period. The means to promote travel demand management by employers could include offering employees additional options to telecommute, work at satellite offices/co-working hubs, and/or have an alternative work schedule/variable working hours. Additionally, public policy can promote travel demand management by providing incentives for commuters to travel outside the peak period.

One of the key findings in the Capacity Study is that expanded adoption of flexible work schedules warrants further investigation as a strategy to ease “peak of the peak” pressure on the trans-Hudson network. Trans-Hudson infrastructure and services are straining under current levels commuter of demand, and significant expansion in capacity of the bus, rail, and PATH services are years in the future. As both a near-term and potentially long-term strategy, wider adoption of flexible work schedules, telecommuting, and other strategies by employers in the Manhattan CBD could help maintain acceptable service levels and moderate the peak-hour targets for additional commuter capacity on the interstate bus system and other modes. Research and limited surveying performed for the Capacity Study suggest there may be sufficient potential benefits to warrant a more comprehensive effort in cooperation with the City of New York, Manhattan employers, and partner agencies.

## 7 Data Sources

This overview builds on earlier work conducted by the PANYNJ's Planning and Regional Development Department ("Managing Peak Transit Demand into the Manhattan CBD," dated November 10, 2015). Additional sources included:

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### Additional Resources

- Association for Commuter Transportation (ACT) Telework/Alternative Work Arrangements (AWA) Council (<http://actweb.org/act-councils/teleworkawa-council/>)
- Global Workplace Analytics (<http://globalworkplaceanalytics.com/resources>)
- Mobile Work Exchange (<http://www.mobileworkexchange.com/>)
- Society of human resource management (<https://www.shrm.org/>)
- Telework Coalition (<http://www.telcoa.org/>)
- Telework Research Network (<http://undress4success.com/research/>)
- University of South Florida, National TDM and Telework Clearinghouse (<http://www.nctr.usf.edu/clearinghouse/>)
- World at Work (<https://www.worldatwork.org/adimLink?id=79123>)