Transit First Analysis of SEPTA Route 34

DELAWARE VALLEY
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REGIONAL
PLANNING COMMISSION

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APPENDIX A

Executive Summary

This study is the first conducted by DVRPC on behalf of the new Transit First Committee, jointly chaired by the City of Philadelphia and SEPTA. The purpose of this project is to explore the application of new planning and analysis techniques to route-level Transit First planning using one candidate Transit First route. For this project, the surface portion of Subway-Surface (trolley) Route 34—along Baltimore Avenue from the 40th Street trolley portal to the 61st Street loop—was selected for analysis. Transit signal priority (TSP) and various combinations of stop consolidation were tested using a microsimulation model. The results of this study will help deepen decision-makers' and stakeholders' understanding of the relationship between transit operations and rider experience.

The research and technical analyses conducted for this project provide meaningful recommendations for Route 34, and also shed light on questions with broad applicability for Transit First efforts throughout Philadelphia. Specifically,

- SEPTA's stop spacing standard for established service in urban areas (500 feet; roughly every block) is unusually narrow, but SEPTA's 1,000-foot standard for new service is in line with best practices.
- From the perspective of total passenger time savings (factoring access times as well as in-vehicle times), low/moderate levels of stop consolidation may be more effective than more aggressive levels of consolidation, particularly when combined with TSP.
- For future Transit First implementations, a more sophisticated TSP implementation (and/or consideration of far-side stops at a higher number of locations) can be expected to yield higher levels of running time savings from TSP.
- Travel time savings will result in increased ridership, all other things equal. A ridership gain in the AM peak of up to 200 riders can be achieved with the application of Transit First measures. Previous studies have shown that a 10% decrease in vehicle travel time will be associated with a 9% increase in line ridership (TCRP Report 95, January 2004).

Specific recommendations for Route 34

The medium consolidation scenario with TSP (removing seven of 22 stops each way) provides the best overall improvement by balancing vehicle and passenger time savings (Figures 10 and 11). It provides approximately the same travel time savings for passengers as the low consolidation scenario with TSP, but greater vehicle-time savings.

CHAPTER 1

Introduction

Purpose and Project Approach

The purpose of this project is to explore the application of new planning and analysis techniques to route-level Transit First planning using one candidate Transit First route. This effort will develop a framework and method through which future analyses for an ongoing Transit First program may be conducted in cooperation with the joint City-SEPTA Transit First Committee. For this project, the surface portion of Subway-Surface (trolley) Route 34—along Baltimore Avenue from the 40th Street trolley portal to the 61st Street loop—was selected for analysis. Various combinations of stop consolidation and transit signal priority (TSP) were tested using a microsimulation model. The results of this modeling will inform decision-makers about the relative impacts of improvement alternatives on trolley operations and the passenger experience.

Transit First Background

The Transit First program became City of Philadelphia policy through a 1989 mayoral executive order, and represents a coordinated citywide and route-level effort to improve surface transit operations through capital investments, operational changes, and better interagency coordination.

The August 1989 *Transit First Priority Routes* report, jointly published by the City of Philadelphia and SEPTA, describes the Transit First concept as follows:

> "Transit First is a cooperative venture between the City of Philadelphia and the Southeastern Pennsylvania Transportation Authority. The purpose of the Transit First program is to improve the quality of life in the city by providing ease of movement for transit patrons and secondarily for general traffic … The benefits of a Transit First program are considerable. First, transit times will be significantly improved. This alone has the potential of reducing transit operating costs, or, alternatively, allowing transit service levels to increase through the more efficient utilization of labor and equipment … All in all, the key elements of a Transit First program are already established in law; application of simple common sense, courtesy, and more rigorous enforcement are almost all that is necessary."

Practically speaking, the Transit First program includes:

- **Targeted capital improvements** (such as the traffic signal hardware necessary for transit vehicle signal priority treatments)
- **Changes in operating strategies** (such as a shift from every-block bus stops to every-second-block)
- **Better traffic law enforcement** where transit vehicle operations are impaired (such as where double-parked vehicles block transit routes)

This variety of strategies requires cooperation among a number of stakeholders, including SEPTA, the Philadelphia Streets Department, the Philadelphia Police Department, the Philadelphia City Planning Commission, and the Philadelphia Parking Authority, and also requires passenger and political buy-in to succeed.

To date, three route-level Transit First improvements have been implemented for the Route 10 and Route 15 trolleys, as well as the Route 52 bus. For a detailed history of Transit First and evaluation of these projects, see DVRPC publication no. 08066 (*Speeding Up SEPTA*, August 2008). That report was a result of one of the broad recommendations for SEPTA in the final report of the Governor's Transportation Funding and Reform Commission: to "reduce costs by improving average system speed" (e.g., to pursue strategies like Transit First that would improve cost effectiveness).

Transit First is consistent with this recommendation, and new leadership at the City of Philadelphia and SEPTA has expressed an intention to make the Transit First program a renewed part of transportation planning and investment in Philadelphia. DVRPC is an active partner in these efforts and provides technical expertise.

Microsimulation

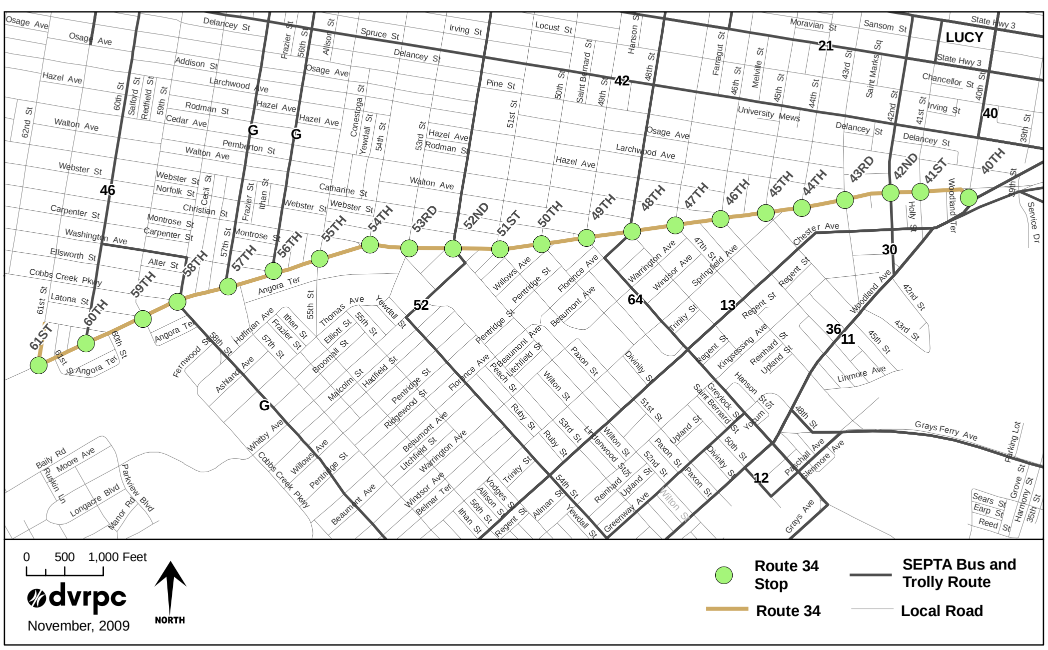
Traffic microsimulation is used to assess the effect of various changes to the transportation system at the finest level of detail. Microsimulation works by modeling the actions of every vehicle on the road at a sub-second basis. The main component is a car-following model which predicts whether a driver will speed up, slow down, or maintain speed. Simulated drivers make these decisions based on their desired speed and their environment, including the distance and speed of the vehicle in front of them, roadway geometry, desired route, and the status of upcoming traffic signals. There are also models for simulating passenger boarding and alighting on transit vehicles. Traffic microsimulation is a powerful predictive tool because both vehicle physics and driver behavior are modeled at an elementary level. The VISSIM microsimulation software package by PTV was used for this project.

Route 34

Alignment and Vehicles

The surface portion of the Route 34 trolley operates from the 40th Street trolley portal southwest along Baltimore Avenue to a loop at 61st Street. Service is frequent, with roughly 32 round trips during the AM peak, and three-minute headways during the heart of the peak (summer 2009 service was somewhat less frequent with five-minute minimum headways). The use of the tunnel to avoid congestion between University City and Center City, combined with frequent service, make the Route 34 an attractive travel option. The corridor has mostly residential uses with some commercial land uses fronting Baltimore Avenue. Institutional and commercial uses take prominence just as the line reaches the portal at 40th Street. Like each of the subway-surface “green line” trolley routes, the Route 34 service and reliability have been challenged recently with the full-time implementation of a new tunnel control system. That issue is not addressed in this study. Figure 1 illustrates Route 34’s surface routing and stops.

Figure 1: Route 34 Surface Routing and Stops



Source: DVRPC 2009

Figure 2: Route 34 Vehicle

Source: DVRPC 2009

Route 34's alignment along the surface portion of Baltimore Avenue consists of one lane of vehicle travel in each direction, flanked by a bicycle lane and typical on-street parallel parking. The trolleys operate in mixed traffic. There is a brief second travel lane in the westbound direction at the intersections of 54th Street, Christian Street, and Baltimore Avenue. Otherwise, there are no pocket lanes along Baltimore Avenue.

Route 34 currently stops at every numbered street. This results in **22 stops** between 40th Street, where the trolley exits the tunnel, and the terminus at 61st Street. **Average stop spacing is 550 feet**.

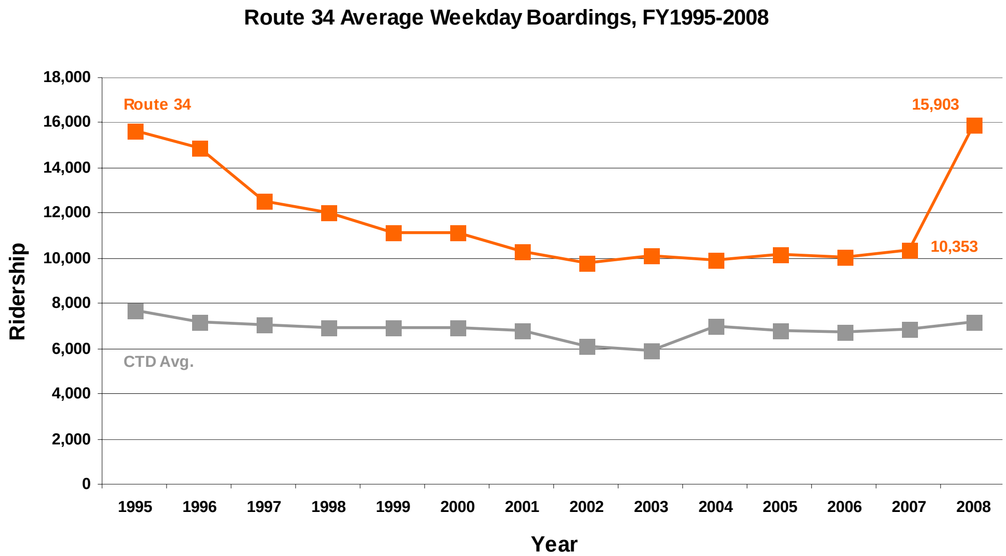
As illustrated in Figure 2, service on Route 34 is currently operated using single-ended Kawasaki LRVs purchased by SEPTA in the early 1980s. The vehicles have 51 seats and a practical capacity of approximately 85 to 90. The vehicles have double doors in the front for entry and exit and double doors in the mid-rear for exit (as well as entry at free-interchange subway stations). The vehicles have high floors, which require passengers to ascend three steps to enter.

Ridership Patterns

Weekday boardings in 2008 were roughly 16,000. Figure 3 summarizes Route 34 ridership over time relative to average ridership in SEPTA's City Transit Division (CTD). Note that these numbers reflect annual averages from SEPTA's Annual Service Plans and/or Route Operating Ratio reports. The significant spike in ridership reported between 2007 and 2008 was due in part to a change in the way that SEPTA accounts for revenue, and hence ridership, at City Hall station and other stations where turnstiles are shared by multiple subway lines. A portion of the revenue collected at the Market-Frankford Subway Elevated (MFSE) entrances—which are shared by the subway-surface routes—is now allocated to the trolley lines, whereas none had been allocated previously.

Initially, ridership data was collected by an individual employee, who counted boardings and alightings at each station. SEPTA upgraded its data collection devices in fiscal year 2009, and now ridership is tabulated by an automatic passenger counter (APC). These devices use a sensor and an on-board computer called an APC analyzer, which converts sensor information to alightings, boardings, current time, latitude, longitude, and vehicle number at each trolley stop. In the SEPTA fleet, trolleys and subways are well-equipped with the APC devices.

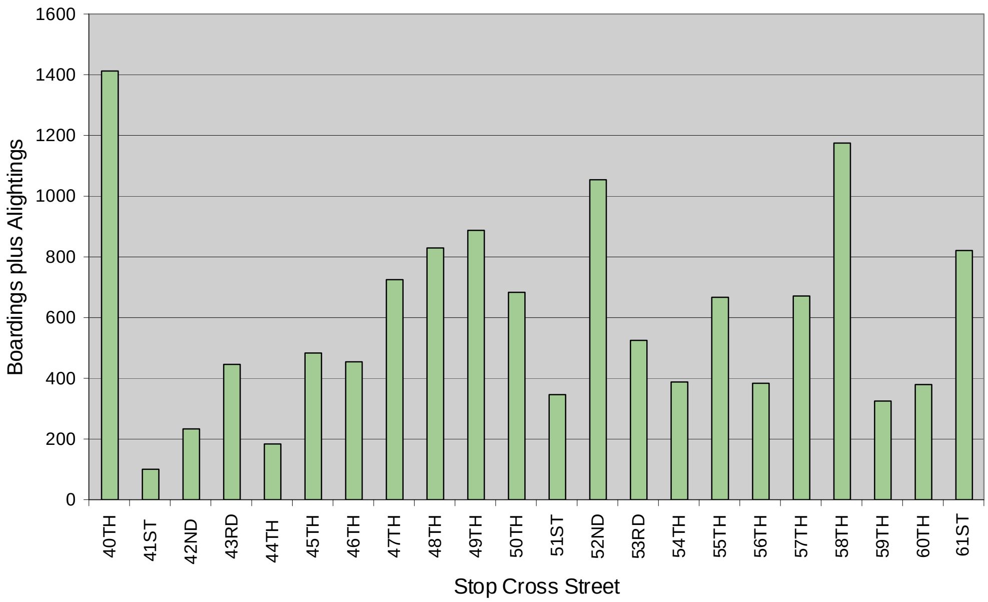
Figure 3: Route 34 Ridership Trends



Source: SEPTA 1996-2009

The data used for this project was collected over a four-month period during the winter and spring of 2009, using vehicles equipped with APC devices. Fifty-six days are included in the ridership analysis. The raw run-by-run APC data needed to be converted into a usable form before starting the analysis. First, the data was grouped into four distinct time periods for each direction along the route: AM peak (6am to 9am), midday (9am to 3pm), PM peak (3pm to 6pm), and evening (6pm to 6am). Next, the boards and alights were averaged for each station and multiplied by the number of unique vehicle trips during each time period (based on the SEPTA schedule). Finally, these averages were added together by direction. This calculation provided the average daily ridership activity at each stop along Route 34.

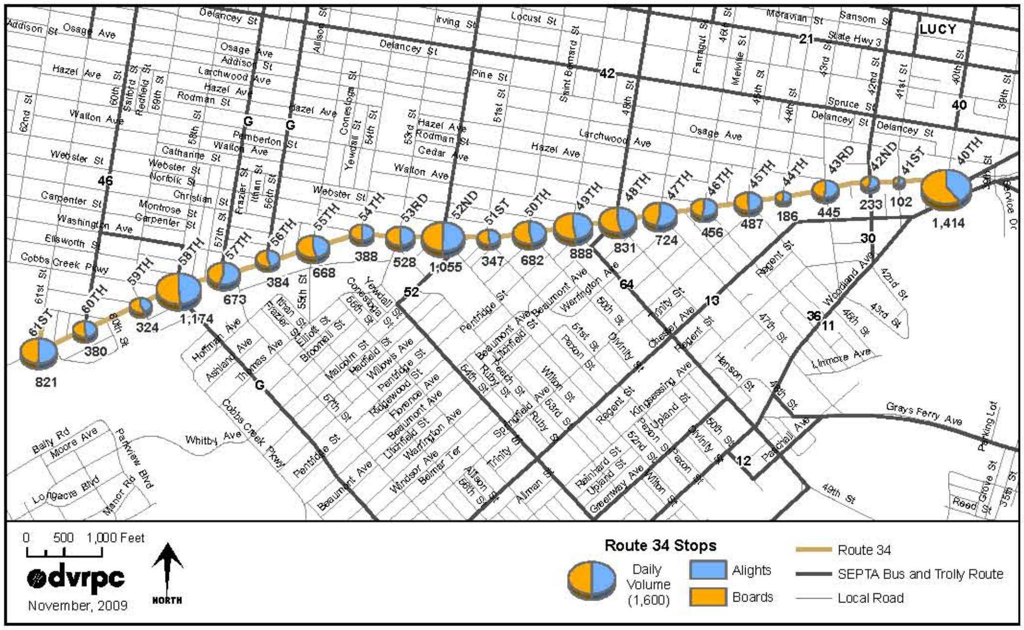
Figure 4: Rt. 34 Total Daily Station Activity - Winter/Spring 2009 APC Data



Source: SEPTA 2009

Figure 4 summarizes daily station activity for each stop, as calculated from the APC data. There are three stops that have significantly higher ridership than the others: 40th Street, 52nd Street, and 58th Street. There are numerous institutions located in the vicinity of 40th Street (Veterans Hospital, Penn Veterinary Hospital, and Presbyterian Hospital), which can help to account for the high ridership. The next spike in ridership is at 52nd Street, where there is a transfer to the heavily traveled Route 52 bus (Wynnefield/Bala), which provides access to Mercy Hospital. Additionally, both 40th Street and 52nd Street are commercial corridors. The most westerly spike in ridership is at 58th Street, where there are transfers to the Route 46 and G buses. The R3 Angora Regional Rail station is also nearby. To a lesser degree, 47th, 48th, and 49th streets also have notably higher ridership than other stops along the surface portion of Route 34.

Figure 5: Map of Route 34 Daily Station Activity from 2009 APC Data



Source: SEPTA 2009

Figure 5 summarizes average daily passenger activity for each stop, broken out by boards and alights. As Figures 4 and 5 indicate, ridership at the stops from 41st to 44th streets is relatively low. This may be due to the proximity of the 40th Street Portal, with its increased frequency of service due to the convergence of four trolley lines. The Market-Frankford El, Route 42 bus, and Route 13 trolley catchment areas also overlap with Route 34's likely catchment area along this eastern surface portion of the line.

Improvement Alternatives for Route 34

Various operational measures were tested in the VISSIM model to investigate their effectiveness in speeding up transit service and decreasing travel times for the Route 34 trolley. The two main measures tested were stop consolidation and transit signal priority (TSP). Each of these measures is described here.

Stop Consolidation

The trade-off between surface transit accessibility and efficiency is among the most widely discussed topics in the service planning arena, both internationally and within the Philadelphia transit community. This trade-off is most frequently discussed in the context of bus or trolley stop spacing. Put simply, **additional stops along a route make that route more accessible by walk-up riders, but cause the route to operate more slowly and less efficiently for riders already on the vehicle**. This impairs the transit service's efficiency and cost effectiveness and makes it less attractive to new riders. However, because waiting time is perceived much more negatively by passengers than in-vehicle time (regardless of how slow that vehicle is moving), removing or consolidating stops can be among the most controversial proposals that a transit agency can make.

SEPTA's service standards for established bus and trolley routes in urban areas call for a minimum stop spacing of 500 feet, or roughly one Philadelphia city block. Every-block stop spacing is the operating standard in the city. Efforts to consolidate stops along priority routes or corridors have comprised a significant component of the city's and SEPTA's Transit First efforts over the last two decades, with limited success (for more details on prior efforts, see *Speeding Up SEPTA*, July 2008, DVRPC publication no. 08066). SEPTA's service standards also acknowledge the desirability of wider stop spacing: **the minimum spacing for new routes in urban areas is 1,000 feet**, adjusted to account for major transfer points and attractors.

Objections to stop consolidation (such as those that hampered or sidelined prior Transit First projects in Philadelphia) relate first to accessibility and equity concerns, particularly for elderly or disabled riders, and second to fears that this perceived reduction in accessibility would cause riders to abandon the transit service. Recent evaluations of stop consolidation projects in Portland, published in the *Transportation Research Record* (TRR no.1971, 2006, pp 32-41), found that while anticipated running time savings were achieved, concerns that passengers might be lost proved unfounded. This same paper also highlights another factor: because passenger catchment or market areas for a given stop are variable and nonlinear (i.e., many patrons already approach from a “diagonal” direction and need to walk multiple blocks to access a stop), the actual reduction in accessibility from consolidation is often not as significant as is feared. The paper mentions a 1992 study conducted by New York’s Metropolitan Transit Authority, which found that **an increase in stop spacing of more than 40 percent reduced accessibility by only 12 percent**.

Although there is no single established “best practice” for stop spacing, Transit Cooperative Research Program (TCRP) Report 19 (1996) indicates that **typical stop spacing in CBDs and urban areas are roughly 600 and 750 feet, respectively**, with a wide range around these numbers. This highlights one fairly unique aspect of SEPTA’s stop spacing: whereas some other urban transit agencies have stop spacing as narrow as SEPTA’s within the CBD, most other agencies do not maintain this same spacing in adjacent urban neighborhoods.

The literature suggests an ongoing industry trend in recent years toward more widely spaced stops due to worsening and more pervasive traffic congestion, which severely impacts mixed traffic transit operations. Stops in San Francisco are already more widely spaced than in Philadelphia, and a new 2009 program aims for consolidation that would result in spacing of 800 to 1,000 feet, except where topography grades exceed 10 percent. In that context, **SEPTA’s 1,000-foot spacing standard for new routes is in line with emerging standards** for urban areas.

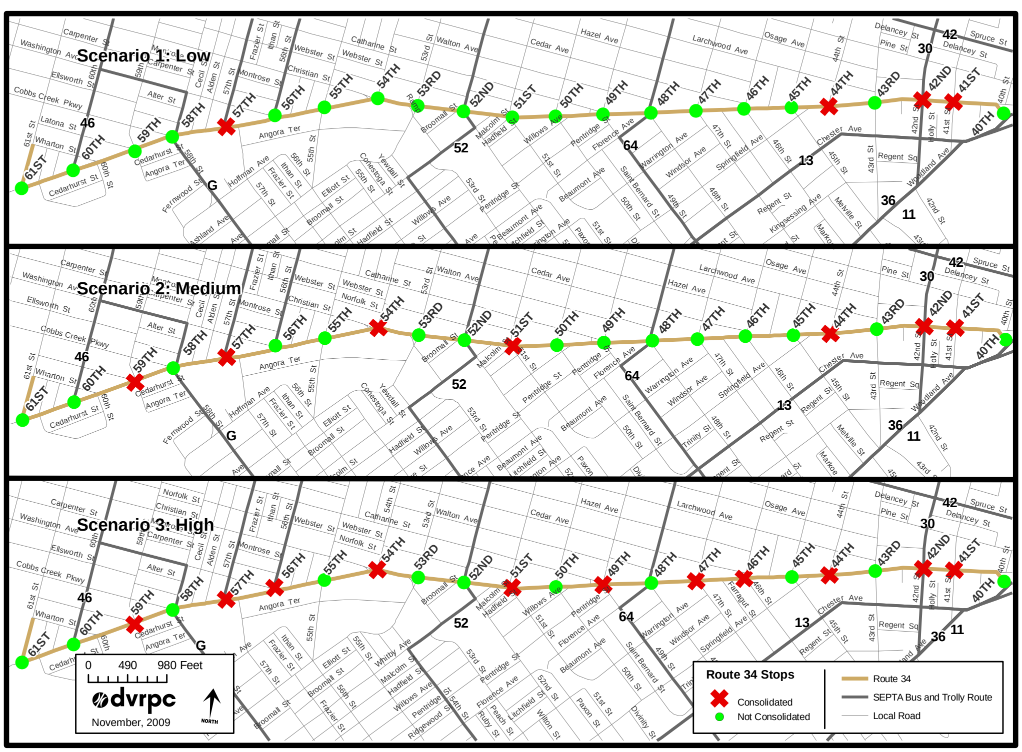
An understanding of transit vehicle travel delay is important to understanding how stop consolidation can improve transit performance. Transit vehicle time delay due to stopping is composed of two parts. The first part consists of the boarding and alighting time. This is the time that passengers spend getting on and off the vehicle. The amount of delay due to boarding and alighting depends on the number of passengers boarding and alighting at a particular stop, as well as the passenger boarding and alighting rates. The rates are determined by a number of factors, including the number and size of doors, fare payment mechanisms, and the presence or absence of level boarding. The other component of delay is the time to decelerate the vehicle to stop and then accelerate the vehicle back up to running speed.

Stop consolidation is the selective removal of stops along a transit line and is a strategy designed to decrease the delay from stopping. If passenger activity is simply shifted to adjacent stops, the total passenger boarding and alighting delay remains the same, but the time that would be taken to accelerate and stop at the consolidated stops is saved. Removing stops, therefore, increases transit operating speeds. Passengers whose stops are consolidated have to walk farther to reach a stop; on average half a block farther if moving from every-block spacing to every-other-block spacing. However, the extra walking time can be made up by in-vehicle time savings. **Stop consolidation can be particularly effective when low volume stops are eliminated**. This is because a transit vehicle incurs the same deceleration and acceleration delay whether one or many passengers board a vehicle. Stop consolidation will also enable some direct cost savings in the form of reduced wear and tear on transit vehicles and tracks from having to brake/accelerate less frequently, with somewhat reduced power consumption as a result.

DVRPC considers several factors when evaluating which stops should be consolidated. Stops with lower daily activity are more fruitful for consolidation than stops with relatively high ridership. This is especially true if adjacent stops have relatively high ridership. Block spacing is another factor in choosing stops to be consolidated; a stop is more readily removed where block spacing is relatively short along several consecutive blocks. Several stops spaced along Route 34 do not meet the previously mentioned SEPTA 500-foot standard, and none meet the 1,000-foot standard for new routes.

DVRPC developed three consolidation scenarios for Route 34 after considering these factors. The three scenarios are organized by aggressiveness: low, medium, and high. The low scenario reflects consolidation of only a few stops, while the high scenario consolidates many stops. The level of consolidation is also cumulative across the scenarios; that is, every stop consolidated under the low scenario is also consolidated under the medium and high scenarios. The three proposed consolidation scenarios are detailed in Figure 6 and Table 1.

Figure 6: Map of Stop Consolidation Scenarios



Source: DVRPC 2009

In the low consolidation scenario, the 41st Street, 42nd Street, and 44th Street stops are consolidated because of relatively low ridership and close proximity to the 40th Street Portal. The 43rd Street stop is not consolidated because of high ridership compared to neighboring stations and to ensure reasonable walking distances. The 57th Street stop is consolidated because of short block spacing. Some SEPTA and city staff have noted an operating condition at 42nd Street (relating to switchwork connecting Route 34 to the 40th Street subway diversion routing) which causes operators to slow or stop at this intersection in any case, particularly in the eastbound direction. While the Transit First scenarios that are modeled in this report propose removal of the 42nd Street stop, it might be prudent to substitute 43rd Street during implementation for this reason, unless the impact of this operating condition is expected to be lessened in the future.

For the medium consolidation scenario, the 51st Street, 54th Street, and 59th Street stops are consolidated due to low ridership compared to their neighbors. For the high consolidation scenario, several additional stops are removed to approximate an every-other-block operating pattern.

Table 1: Stops Consolidated by Scenario

Stops Consolidated in Each Scenario			
Stop	Low	Medium	High
40TH			
41ST	X	X	X
42ND	X	X	X
43RD			
44TH	X	X	X
45TH			
46TH			X
47TH			X
48TH			
49TH			X
50TH			
51ST		X	X
52ND			
53RD			
54TH		X	X
55TH			
56TH			X
57TH	X	X	X
58TH			
59TH		X	X
60TH			
61ST			

Source: DVRPC 2009

Transit Signal Priority

Delay from traffic signals can be a significant portion of overall travel time, especially with short intersection spacing. Transit signal priority (TSP) gives transit vehicles preferential treatment at signalized intersections along the route. TSP can take the form of either early or extended green phases, and is typically justified by the notion that transit vehicles carry many more people per vehicle than passenger automobiles on cross streets who might suffer additional delay.

TSP has various means of implementation. At a minimum, a signal controller requires some means to detect the approach of a transit vehicle. This can be accomplished in several ways, including hard-wired loops, GPS sensors, or optical sensors. A request for signal priority is then sent by the transit vehicle to the signal controller, which will grant priority if possible. Some systems also contain sensors to determine when the transit vehicle has cleared the intersection and hence cancel the call for priority. TSP is often found to work best with far-side transit stops, as this allows the transit vehicle to clear the intersection before stopping to load/unload passengers. As a result, the time it takes the transit vehicle to clear the intersection after being detected by the controller is more predictable. The major benefit of TSP for near-side stops, especially under moderately congested conditions, is the ability to clear the general traffic queue between a transit vehicle and the near-side stop. This allows the transit vehicle to only stop once, if at all, instead of twice – once behind the vehicle queue to reach the stop, and a second time while waiting to load/unload passengers.

As part of the Transit First projects for Routes 10, 15, and 52, SEPTA implemented TSP along all or a portion of those routes using optical sensor technology. Transit vehicles are equipped with an optical emitter, while curbside signal poles are equipped with corresponding detectors. Under the system implemented in Philadelphia, the optical emitter essentially acts as a powerful wide-beam flashlight. Under good conditions, **signal pole detectors typically sense an approaching transit vehicle when the vehicle is within 1,000 feet of the signal pole and has a clear line of sight**, illustrated in Figure 7, at which point a request for priority is placed with the signal controller. For Routes 10, 15, and 52, this triggers ten seconds of extended green time. The system has no method to detect whether a transit vehicle passes through the intersection before the extended green is complete, which would allow the request to be canceled or truncated, or whether a transit vehicle is delayed from reaching the intersection.

Figure 7: Optical Transit Signal Priority Implementation

Source: DVRPC 2009

Figure 7 also illustrates an interesting consequence of the emitter's 1,000-foot range in conjunction with 500-foot block lengths: **under certain conditions, a vehicle emitter can trigger two or even three optical receivers at once**. When combined with a rule in the system that will not permit a second green phase extension for a given signal within four minutes, this circumstance can limit the system's effectiveness.

For the Baltimore Avenue corridor, DVRPC simulated the operation of the same type of TSP system as has been used previously. This was done using the current stop configuration and under the three consolidation scenarios. Ideally, a custom delay should be built into the signal controller for each intersection based on the time between when a vehicle is detected and the time that it actually reaches the intersection under typical conditions. This level of operational optimization, however, was not within the scope of this study.

Stop Consolidation and Transit Signal Priority

As noted above, in addition to TSP and stop consolidation alone, this study also simulated several scenarios in which a combination of both stop consolidation and transit signal priority are deployed. This was done in order to test the combined effects of these two improvement strategies, as they have historically been under various Transit First route-level proposals. Eight scenarios, including the base case or "no build" scenario, were tested as part of this study, as summarized in Table 2.

Table 2: Simulation Scenarios

Route 34 Simulation Scenarios
Base Case
Stop Consolidation Low
Stop Consolidation Medium
Stop Consolidation High
Base Case plus TSP
Stop Consolidation Low plus TSP
Stop Consolidation Medium plus TSP
Stop Consolidation High plus TSP

Source: DVRPC 2009

CHAPTER 4

Model Description

For budget and time reasons, this project modeled each of the scenarios only during the AM peak period (6am to 9am) for eastbound and westbound operations. This chapter briefly describes the software system, model elements, and computational procedures used to model transit and traffic operations along the Baltimore Avenue corridor for this project. A more detailed description of the various steps used to build the model, as well as the inputs used, can be found in Appendix A.

Software System

DVRPC relied on the PTV Vision software suite for constructing the computer model used to evaluate the Transit First alternatives simulated as part of this study. The PTV Vision suite consists of two components: a macro-level demand forecasting package called VISUM and a micro-level traffic analysis simulator called VISSIM. PTV Vision was originally developed for the transit-rich European environment, where VISSIM has become the industry standard for traffic micro-simulation in recent years. VISUM is used to provide many of the inputs needed for VISSIM to run, including background levels of traffic, vehicle routing decisions, and basic roadway and intersection geometry. However, the DVRPC regional travel demand model was still in the process of being converted to VISUM at the time of this project, and consequently, only some of the VISSIM inputs were provided from the regional model (with others being provided by field counts).

Model Elements

Various data elements were required to apply VISSIM to the transit simulation along Baltimore Avenue. The elements of geometry, vehicular traffic, turning movements, transit vehicle data, passenger boarding and alighting data, and signal control are discussed here.

The basic geometry along Baltimore Avenue was taken from the VISUM regional travel model. Since the regional model does not include every street, all remaining numbered and side streets between 40th and 61st streets were manually added. The roadway geometry was adjusted both before and after exporting from VISUM to VISSIM in order to properly align with DVRPC's ortho-corrected aerial images.

Each intersecting street was modeled in VISSIM up to but not including the next intersection north and south of Baltimore Avenue.

Estimating the correct level of vehicular traffic is critical in order to accurately model transit operations for the Route 34 trolley. Both the overall level of traffic and turning movements at each intersection were determined by extensive traffic counts along Baltimore Avenue in January 2009. The counts are a mixture of automatic traffic recorder (ATR) volume counts, ATR classification counts, manual turning movement counts, and manual volume counts. Manual counts were needed along Baltimore Avenue and side streets that have trolley operations because rail traffic cuts the pneumatic tubes used for ATR counts. The various types of counts were processed, adjusted for consistency, and then aggregated into volumes to represent the AM peak time period from 6am to 9am. Midday counts (9am to 3pm) were also estimated, but no midday modeling was conducted due to time constraints. The vehicle inputs on the western and eastern edges of the modeled portion of Baltimore Avenue and on all intersecting streets were also added to the model.

Turning movements were determined from counts and adjusted for consistency in a similar manner, and average turning movements over the 6am to 9am period were then input to the model. These turning movements, for example, reflect the percentage of vehicles proceeding straight, left, or right at an intersection.

Classification counts were used to determine the percentage of each type of vehicle that operates along Baltimore Avenue. A simple model is used with only two types of vehicles for background traffic: automobiles and trucks, plus transit vehicles.

Transit vehicle data was provided by SEPTA. Important data includes maximum acceleration, deceleration, number and location of doors, and passenger capacity. Boarding and alighting rates (seconds per passenger) were estimated based on vehicle doors and geometry in conjunction with equations in the 2000 *Highway Capacity Manual* Chapter 27. Transit vehicle departure data was determined by calculating the average headway on the Route 34 trolley from the spring 2009 schedule.

Boarding, alighting, and occupancy data for each stop was determined from APC data collected during spring 2009. Boarding data was input into the model in the form of hourly arrival rates for the AM peak period (6am to 9am). Alighting was entered into the model as a percentage of vehicle occupants that depart at each stop. Because of some rounding issues in the VISSIM default alighting model, DVRPC implemented custom codes using Visual Basic for Applications (VBA) and VISSIM's open COM architecture. GPS location data within SEPTA's APC data sets was also used to determine transit vehicle travel time along the route, which was used to validate the model.

DVRPC obtained signal timing data from the City of Philadelphia. The signal timing plans were implemented in VISSIM using the ring-barrier controller (RBC).

All of the intersections in the study area along Baltimore Avenue currently use fixed coordinated signal systems operating on a 60 second cycle. The majority have a two-phase 40 second/20 second split in favor of traffic on Baltimore Avenue. TSP was modeled by placing transit vehicle detectors along the roadway 1,000 feet before each intersection, or closer if line of sight is blocked, and modifying the RBC controller for that intersection. This was done to simulate the reported range of the optical emitter/detector equipment.

Stop Consolidation Modeling

Several stops, as reflected in Table 1, were removed from the model for each of the stop consolidation scenarios. The activity at that stop (boarding and alighting) was then reassigned to adjacent stops. For each consolidated stop, passenger activity was reassigned based on proximity to adjacent stops, direction of desired travel during the AM peak period, the configuration of the street network, and surrounding land uses. In the low stop consolidation scenario, for example, 10 percent of the 57th Street passengers were reassigned to the 58th Street stop, and 90 percent to the 56th Street stop. The additional walking time to get to the new stop was then calculated based on the percentage of passengers shifting to each remaining stop, the extra distance that those passengers would be required to walk, and an average walking speed. This was used to calculate net passenger time savings for each scenario, which consists of an improvement in in-vehicle time minus extra walking time for passengers. It is important to note that the VISSIM model is not demand responsive. That is, the simulations assume that no passengers are lost due to their stops being consolidated, and no passengers are gained based on improvements in total travel time.

Ridership Response Calculation

Estimating traveler response to service modifications such as stop consolidation or TSP is difficult. The travel time improvements gained from stop consolidation and/or transit signal priority benefit some riders more than others, while still another group of riders are inconvenienced to a certain degree. The true transit service elasticity of demand for the Route 34 corridor is a function of many local conditions that are beyond the scope of this study to measure. The publication *TCRP Report 95: Travel Response to Transportation System Changes*; Chapter 9 - Transit Scheduling and Frequency (January 2004) documents the findings of four case studies that focused on rider response to service and scheduling changes. As a result of these case studies, the report estimates a transit service elasticity of 0.9. This means that a 10-percent decrease in passenger travel time will be associated with a nine percent increase in ridership. Figure 14 in this report applies this elasticity to the time savings calculated for the Route 34 build scenarios in order to estimate the ridership gains that could be expected.

Procedures

Each scenario was run in VISSIM for a four-hour period. During the first 30 minutes of simulation time, the model is ‘primed’ by loading very little traffic and no passengers into the network. This allows transit vehicles to enter the simulation and position themselves throughout the route. The simulation is then run for another 30 minutes with full vehicle and transit passenger boarding and alighting rates. These 30 minutes allow the system to come to a state of equilibrium. No output data is recorded during the first 60 minutes of simulation. The simulation then runs for another 180 minutes (reflecting the 6am to 9am morning peak period), during which data is recorded. Travel time sections are established in the VISSIM model to record the travel time for transit vehicles from each stop to the 40th Street portal for eastbound operations, and from each stop to 60th Street for westbound operations. Data for each transit vehicle in the simulation is fed into a Microsoft Access database for recording. Other data, such as the number of vehicles by type and transit vehicle occupancy, is also recorded in order to verify that the inputs to the model are correct.

Each scenario was run five separate times. VISSIM models many dynamics using stochastic processes. Items such as desired speed, acceleration rate, passenger arrivals at stations, and the number of people alighting from a transit vehicle are taken from probabilistic distributions. This is done by generating random numbers throughout the simulation and applying them to the various distributions used in the model. Two model runs will be identical if the random number generator uses the same starting point, referred to as a “random seed.” It is important to make sure that the results reflected in the model are a product of actual dynamics, and not by chance due to a peculiar set of random events. For this reason, the simulation for each scenario is run five times, each time with a different random seed. Measures such as transit vehicle travel time are averaged across all five runs to generate summary results.

Model Results

Model results are summarized in this chapter. The first section (model validation) demonstrates that the model accurately reproduces current conditions. Results from each of the build scenarios are then summarized.

Model Validation

Before a computer model is used to evaluate various transportation scenarios, it must first demonstrate a capacity to reasonably reproduce current conditions. This process is known as model validation. Validation is achieved by comparing some type of model result with data that has *not* been used to construct the model. The Route 34 model was validated using transit vehicle run time because travel time is one of the most significant outputs for Transit First planning. Travel time output from the model between 40th Street and 60th Street, both eastbound and westbound, was compared with APC data. 60th Street was used as a westbound time point landmark instead of 61st Street, because the time stamp on the APC data at 61st Street was found to be unreliable (possibly due to mixed passenger board/alighting activity at 61st Street and the 61st Street loop, which is technically not a stop). A comparison between measured and simulated travel time is shown in Table 3. It is important to note that both the modeled data and counted APC data have errors.

Table 3: Transit Travel Time Validation Data - AM Peak

Travel Time [min.]	Eastbound (60th to 40th)				Westbound (40th to 60th)			
	Model	APC Data	Difference	% Difference	Model	APC Data	Difference	% Difference
Average	16.7	16.0	-0.66	-4.1%	11.5	12.5	1.0	8.2%
Standard Deviation	6.1	6.8	0.79	11.5%	3.7	5.0	1.31	26.3%
Upper Limit	22.7	22.8	0.13	0.6%	15.1	17.3	2.2	12.8%
Lower Limit	10.6	9.1	-1.45	-15.9%	7.8	7.4	-0.4	-5.5%

Source: DVRPC 2009

The average simulated travel time for both the eastbound and westbound directions reasonably replicates measured data in that the simulated data in both directions is within 10 percent of measured data. The eastbound average simulated travel time is 4.1 percent higher than the measured travel time, while the westbound simulated travel time is 8.2 percent lower.

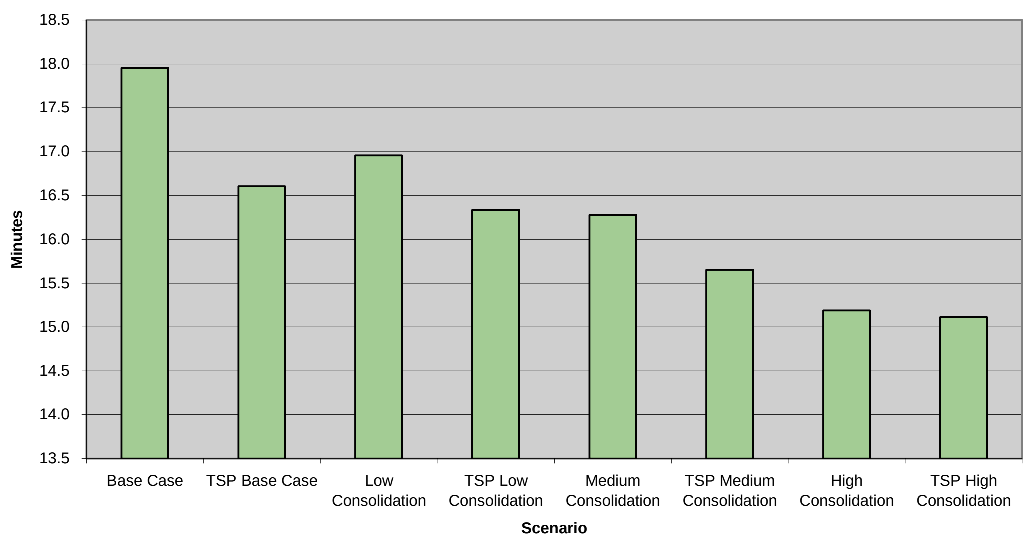
In addition to mean/average travel times, the ranges of travel time values were also compared. It is important for the model to adequately reproduce the variability present in the real system, especially in order to simulate phenomena such as vehicle bunching. In order to summarize overall variability, the standard deviation in travel times was calculated and then added to or subtracted from the average travel time to produce the upper and lower bounds, respectively. The standard deviations of the modeled travel times for the eastbound and westbound directions are close to, but less than, the standard deviation of the measured travel times. Part of the explanation for a higher level of variability in the measured results is that the model averages conditions over the peak period from 6am to 9am, while the measured results capture more of the run-by-run variation that occurs during this time period in both passenger loading and vehicular traffic. The measured data has lower minimum values and higher maximum values. Because of the higher level of variability in the measured results, the modeled upper and lower bounds are lower and higher, respectively, than the measured results.

Taken as a whole, the model is well validated against travel times in the eastbound direction and reasonably validated against travel times in the westbound direction. Given that the period modeled was the AM peak, it was most important for the eastbound direction to be simulated as accurately as possible.

Vehicle Travel Time

Transit vehicle travel time under each scenario was recorded during simulation. Figure 8 summarizes the eastbound AM peak travel time from the 61st Street loop to the 40th Street portal.

Figure 8: Transit Vehicle Travel Time, Eastbound AM Peak

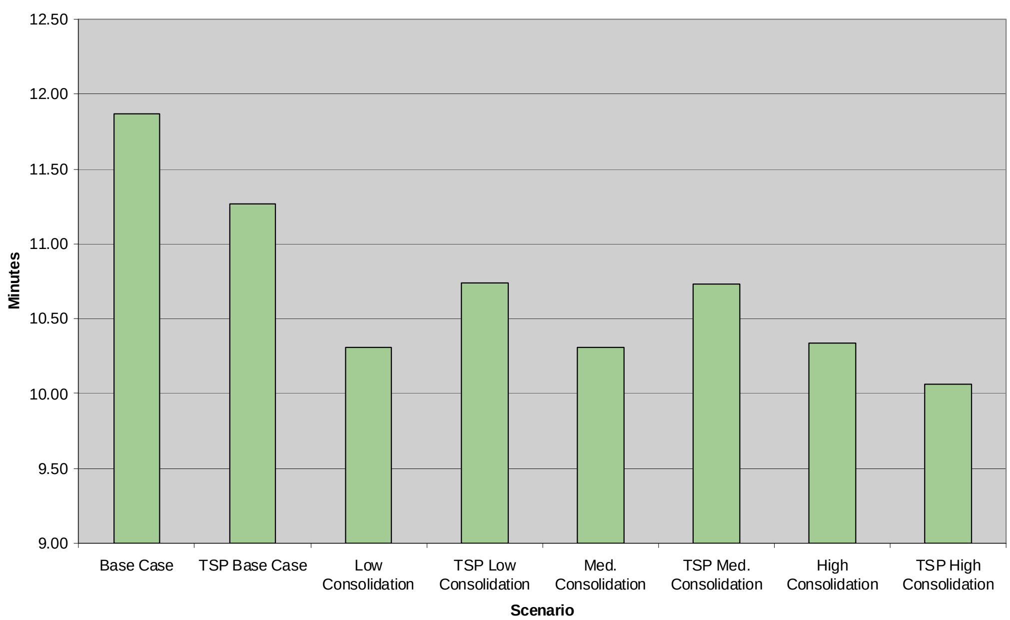


Source: DVRPC 2009

As would be expected, Figure 8 demonstrates a continual improvement in vehicle travel time as more stops are consolidated. The high consolidation scenario results in a decrease of almost three minutes (15 percent) in the travel time from 61st Street to 40th Street. The other stop consolidation scenarios exhibit less significant but still meaningful improvements in vehicle travel time (roughly two minutes and one minute for the medium and low scenarios, respectively).

Figure 8 also shows that TSP decreases eastbound vehicle travel time for each scenario. The TSP base case scenario (no stops consolidated) shows a vehicle run time improvement of almost 1.5 minutes (7.5 percent) from TSP alone. While TSP improves vehicle run times, the effect decreases as more stops are consolidated. The simple implementation of TSP technology is one possible cause. Signal priority for a given intersection is often triggered well before a transit vehicle has cleared the previous intersection. Consolidating stops changes the time that it takes a transit vehicle to travel the distance between where the TSP is triggered and the relevant intersection. Optimizing signal controller settings to ensure proper coordination is outside the scope of this study. Hopefully, such an exercise could improve TSP results under high stop consolidation scenarios.

Figure 9: Transit Vehicle Travel Time, Westbound AM Peak



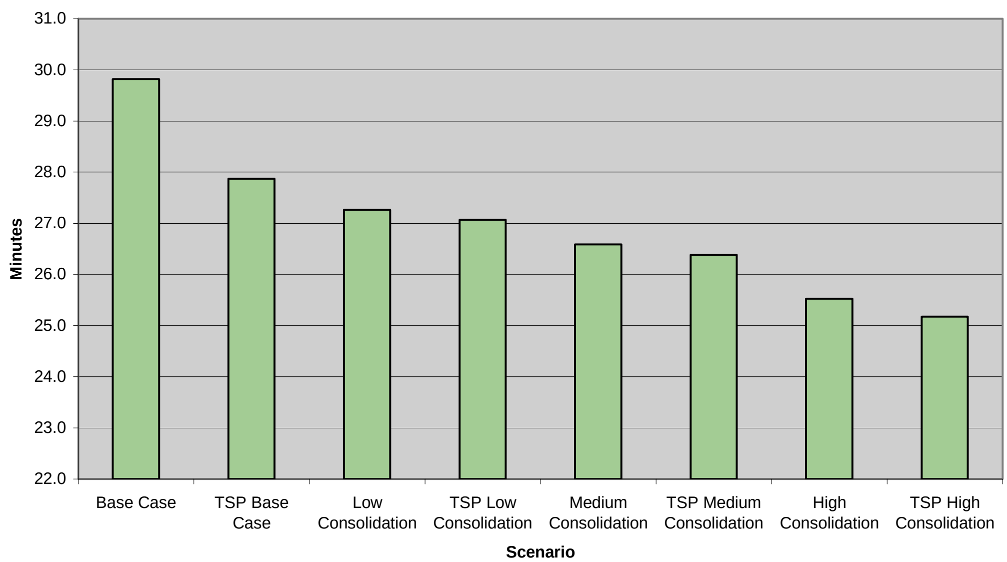
Source: DVRPC 2009

Figure 9 summarizes travel time for the westbound direction in the AM peak from the 40th Street portal to the 61st Street loop. This figure indicates an improvement in vehicle travel times on the westbound surface portion of Route 34 of about 1.5 minutes (5 percent) between the base case and each of the various stop consolidation scenarios. Aside from the TSP-only scenario, comparing the build scenarios does not show a marked difference in travel time between 40th Street and 61st Street. This is likely due to low westbound passenger volumes (and relatively low congestion) in the AM peak period.

The results for TSP, however, are less clear. There is just over half a minute of travel time saved by implementing TSP alone over the base case. The model, however, predicts a slight degradation in travel time of about 26 seconds when TSP is combined with either the low or medium consolidation scenarios over the corresponding scenarios without TSP. The model predicts a 16-second improvement in travel time by adding TSP to the high consolidation scenario. Possible explanations for this phenomenon include sub-optimal timing of the optically actuated TSP system currently under study, or simple "statistical noise," since under any stop consolidation scenario, the westbound trolley may already match general traffic speeds during the AM peak.

The combined vehicle surface running time (eastbound plus westbound) under the various scenarios is summarized in Figure 10 and Table 4.

Figure 10: Transit Vehicle Travel Time, Combined Directions AM Peak



Source: DVRPC 2009

Table 4: Vehicle Travel Time - Total and by Direction AM Peak

Total Vehicle Run Time (minutes)				
Scenario	Eastbound	Westbound	Combined Total	Total Savings
Base Case	18.0	11.9	29.8	-
TSP Base Case	16.6	11.3	27.9	1.9
Low Consolidation	17.0	10.3	27.3	2.6
TSP Low Consolidation	16.3	10.7	27.1	2.8
Medium Consolidation	16.3	10.3	26.6	3.2
TSP Medium Consolidation	15.7	10.7	26.4	3.4
High Consolidation	15.2	10.3	25.5	4.3
TSP High Consolidation	15.1	10.1	25.2	4.6

Source: DVRPC 2009

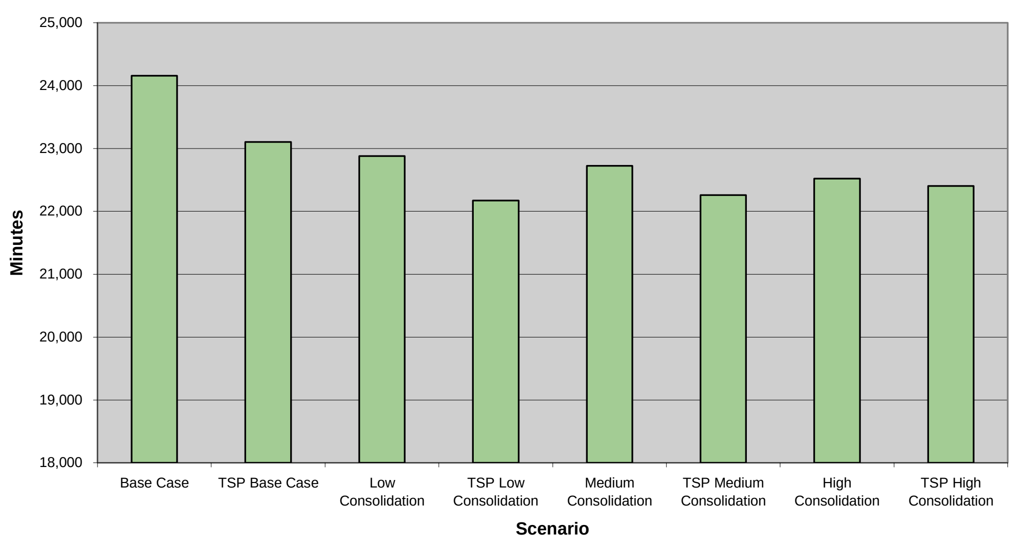
This table indicates a steady decrease in vehicle travel times when TSP or additional stop consolidation are implemented. The modeled travel time savings in the eastbound direction more than outweigh the idiosyncratic westbound results.

Travel time savings under the high consolidation scenarios (4.3 minutes without TSP and 4.6 minutes with TSP) are greater than the maximum peak headway of three minutes. The same is true for both medium consolidation scenarios. This suggests that if these strategies are pursued, SEPTA can expect to improve operating efficiencies by providing higher levels of service without adding a peak vehicle.

Passenger Travel Time

Any vehicle time savings through the use of TSP will also be realized by passengers. The same cannot necessarily be said of stop consolidation. Passengers who use stops that are not consolidated will realize the full gain in vehicle time savings. However, passengers whose stops are consolidated must walk some distance further in order to reach a non-consolidated stop. This extra travel time must be counted against any in-vehicle travel time benefit that passengers experience. The results of this analysis for the AM peak period eastbound direction are illustrated in Figure 11. The numbers in this figure are calculated by multiplying the travel time from each stop to the 40th Street portal by the number of passengers boarding at that stop. For stops that are consolidated, the travel time is calculated by adding the in-vehicle travel time plus any extra walk time required. For example, the 57th Street stop is consolidated in each of the scenarios. Passengers using this stop are reassigned to the 56th Street stop (90 percent of the passengers) and the 58th Street stop (10 percent of the passengers). Travel time for 57th Street passengers redirected to 56th Street is calculated by adding the in-vehicle time from 56th Street to the portal to the extra walk time required, and multiplying the sum by the number of passengers who were redirected to 56th Street.

Figure 11: Total Passenger Travel Time - Eastbound AM Peak



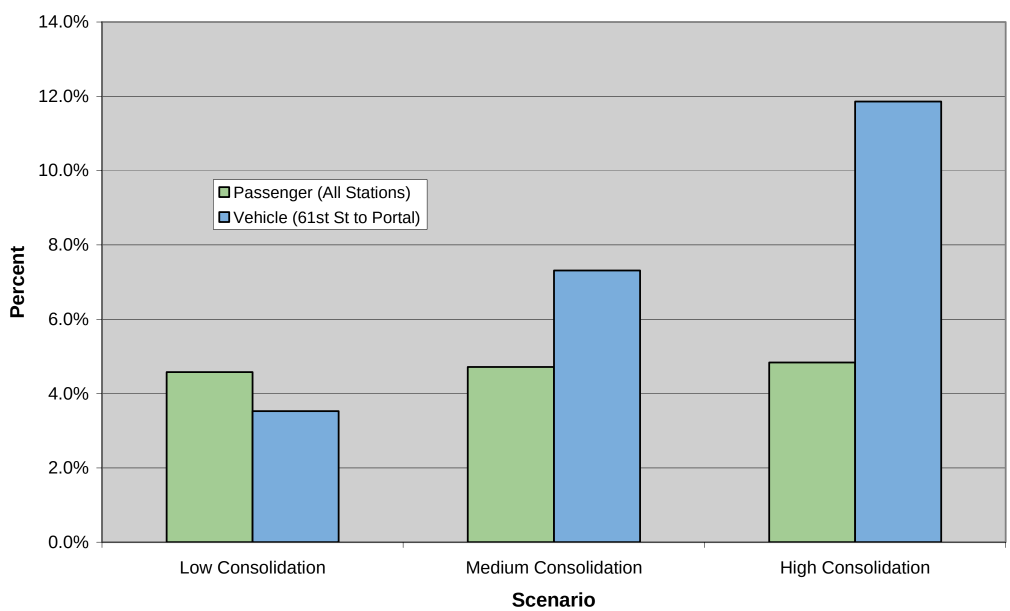
Source: DVRPC 2009

Figure 11 shows that TSP always improves passenger travel time over non-TSP scenarios. The pattern and magnitude of change between the scenarios is different, however, than the vehicle travel time savings. The TSP low consolidation and TSP medium consolidation scenarios have the best passenger travel time impacts. These two scenarios, with essentially identical aggregate passenger travel times, show an average passenger travel time savings of approximately eight percent. The savings under the high consolidation scenario are slightly muted (7 percent), due partly to the extra walking time incurred. The impact of TSP under the high consolidation scenario is also diminished as an artifact of the long optical sensor range. Stop consolidation leads to longer boarding times at remaining stations, and the simulation indicated that trolleys were losing their "window of opportunity" at forthcoming intersections (where a green phase extension has already been triggered as a result of the 1,000-foot range) while passengers boarded and alighted. This partially negated the advantages of TSP for the high consolidation scenario, which still shows a travel time benefit when compared to the low and medium consolidation scenarios without TSP. All of the scenarios show noteworthy improvements in travel time over the base case scenario.

Isolating passenger time savings from consolidation and TSP

The passenger time savings generated by the two improvement types proposed, stop consolidation and TSP, can be separated and compared. Figure 12 summarizes the benefits of stop consolidation from the perspective of both passenger time savings and vehicle time savings.

Figure 12: Time Savings from Stop Consolidation, Eastbound AM Peak



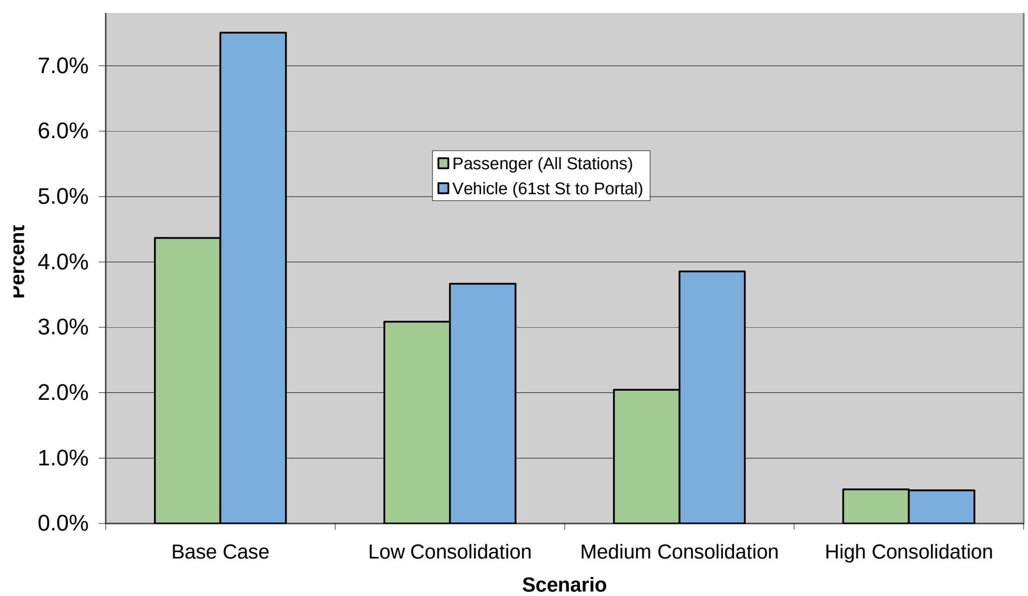
Source: DVRPC 2009

These results are calculated by averaging the TSP and non-TSP results for each scenario and comparing them to the average base case. Figure 12 shows that as more stops are consolidated, vehicle travel time steadily improves. The passenger travel time benefit, however, remains constant, at approximately 4.7 percent compared to the base case. This illustrates that the in-vehicle travel time savings that passengers experience is somewhat counterbalanced, as some passengers need to walk further distances to access the vehicle. The low, medium, and high consolidation scenarios are essentially neutral from a passenger's perspective. This shows that the biggest time benefit, from a passenger's perspective, comes from consolidating the lowest ridership stops.

Figure 13 summarizes the benefits of TSP from the perspective of both passenger and vehicle time savings. From either perspective, benefits (relative to consolidation-only scenarios) decrease as more stops are consolidated. This may be due to one or more of several factors, such as:

- Non-optimized implementation of TSP, as previously described;
- Near-side operating conditions do not allow transit vehicles to take full advantage of TSP, especially under increased boarding times at remaining stations due to consolidation.

Figure 13: Time Savings From TSP Over Non-TSP Scenarios, Eastbound AM Peak

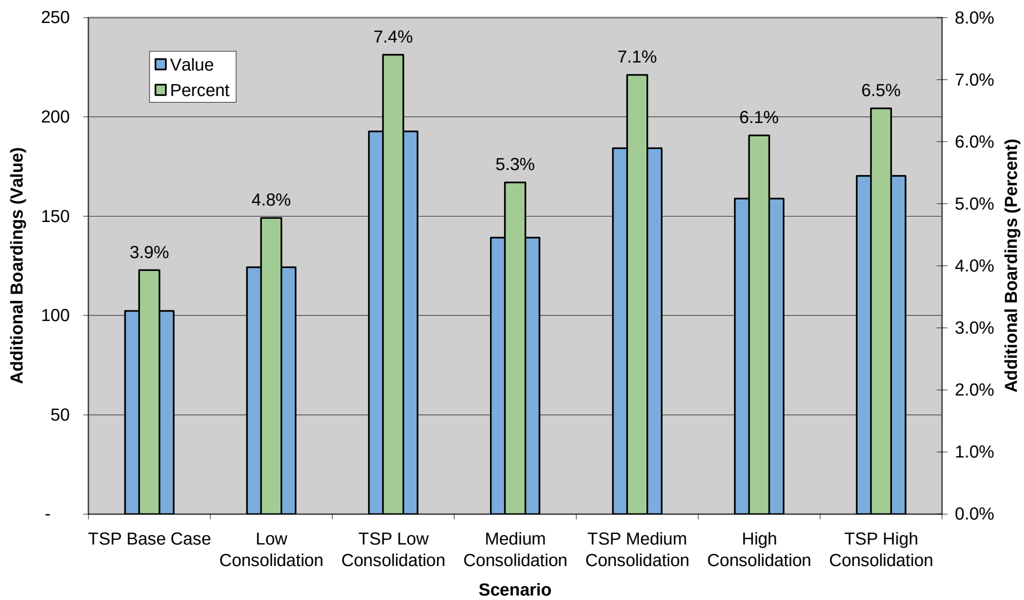


Source: DVRPC 2009

Estimated ridership impact

As described in Chapter 4, TCRP Report 95 indicated an elasticity of ridership with respect to travel time of 0.9. In other words, a 10 percent decrease in passenger travel time can be expected to lead to a nine-percent increase in riders. Figure 14 summarizes the results of a rider response calculation using this elasticity.

Figure 14: Estimated Additional Ridership Under Build Scenarios, Eastbound AM Peak



Source: DVRPC 2009

These ridership estimates reflect only the eastbound direction during the AM peak period. For this study, the smallest gains in ridership are estimated under the TSP base case scenario. Under that scenario, a 4.3-percent decrease in passenger travel time translates into approximately 100 additional boardings. The largest increase in ridership is estimated under the TSP low consolidation scenario, where an 8.2-percent decrease in passenger travel time translates into nearly 200 additional boardings.

Summary and Recommendations

This project accomplished two key objectives:

- The research and technical analyses conducted for this project provide meaningful recommendations for Route 34, and also shed light on questions with broad applicability for Transit First efforts throughout Philadelphia. Specifically:
    - SEPTA's stop spacing standard for established service in urban areas (500 feet; roughly every block) is narrower than typical standards of 750 to 1,000 feet for other cities. However, SEPTA's 1,000-foot standard for new service is in line with best practices.
    - From the perspective of total passenger time savings (factoring access times as well as in-vehicle times), low/moderate levels of stop consolidation may be more effective than more aggressive levels of consolidation, particularly when combined with TSP.
    - For future Transit First implementations, a more sophisticated TSP implementation (and/or consideration of far-side stops at a higher number of locations) can be expected to yield higher levels of running-time savings from TSP.
    - Travel-time savings will result in increased ridership, all other things equal. A ridership gain of up to 200 riders has been estimated here for the AM peak period with the application of Transit First measures. This is derived from previous studies, which have shown that a 10 percent decrease in vehicle travel time will be associated with a nine percent increase in line ridership (TCRP Report 95, January 2004).
- DVRPC staff refined and streamlined a method for conducting transit route or corridor microsimulation analyses for future projects. This method is already being applied to an analysis of SEPTA routes 104 and 120 along the West Chester Pike corridor, and will also be useful for future Transit First analyses in Philadelphia. In the future, this process will be made more efficient through greater use of traffic data from the DVRPC regional travel demand model (with manual counts as spot checks to refine model data).

Specific recommendations for Route 34

The analysis of various Transit First measures for Route 34 finds a clear benefit to both transit passengers and SEPTA operating speeds. Average passenger travel-time savings of seven to eight percent are observed when both stop consolidation and TSP are employed. Vehicle time savings of up to 4.6 minutes, or about 16 percent, are predicted by the simulation. This estimated time savings, greater than one peak headway for the spring schedule, is somewhat remarkable given the relatively short surface portion of the route on which these measures would be implemented. Further, it is likely that if these strategies were to be combined with signal optimization along the corridor (which was not modeled here), the benefits would be even more dramatic.

By pursuing these measures, SEPTA could reduce its operating costs while also improving travel times for passengers.[1] As SEPTA and city planners consider implementation scenarios for Route 34 through the Transit First committee, the analysis in this report suggests that, balancing vehicle and passenger time savings (Figures 10 and 11), **the medium consolidation scenario with TSP (removing seven of 22 inbound stops) provides the best overall improvement**. It provides nearly as much net time savings for passengers as the low consolidation scenario with TSP, but more vehicle-time savings.

[1] Note that this analysis was limited to the AM peak period; reasonably equivalent PM peak results are assumed for the opposite direction.

APPENDIX A

Appendix A. Model Construction Details

The PTV Vision software package, consisting of VISUM (macro-model) and VISSIM (microsimulator), was used for modeling the Baltimore Avenue corridor in this study. The modeling procedure is described in this appendix. The initial network editing was done using VISUM. All remaining work used VISSIM. The DVRPC highway network had previously been translated from the TRANPLAN format to VISUM at the beginning of the study. However, the full travel model had not yet been implemented in VISUM at that time. As a result, the full VISUM-VISSIM connection was not used in this study. Future studies will employ a modified version of this procedure, which takes advantage of the full VISUM-VISSIM connection, now that the full DVRPC travel demand model is implemented in VISUM.

Modeling Procedure

Network Preparation in VISUM

1. The 2000 version of the DVRPC highway network was used as a starting point to obtain basic geometry for the corridor intersections. A cut-out of the full network was made comprising only Baltimore Avenue from 40th Street to the Delaware County boundary, plus intersecting streets. Nodes were ortho-corrected using background aerial images, and additional side streets not present in the regional highway network were then added.

2. Three link types were defined. Baltimore Avenue and main intersecting streets were set to type "Major Urban Arterial." The other numbered intersecting streets were set to type "Minor Urban Arterial." Small intersecting side streets were set to type "Urban Collector." Nodes were edited in VISUM for lane geometry and "Use Lanes for VISSIM" was checked. Signal groups were also created for each intersection.

Export to VISSIM and Setup Network

3. The reduced and enhanced network file was exported to an *.anm file for importing into VISSIM. Route data was not included, as there was no valid assignment. This file was then imported into VISSIM.

4. The imported network had several problems. The network scale parameter in VISUM was fixed, the background image moved, and several streets had to be adjusted manually.

5. All intersections required adjustment to fix turning movement connectors, which initially had turning radii that were too small. Links were moved back and the splines for connectors were regenerated using additional points. In the future, changing the set-back parameter in VISUM may fix this problem.

6. Signal controllers for each intersection were set up using the RBC signal controller, which required extensive assistance from the PTV Hotline. Signal heads were inserted and connected to the signal controllers.

Add Auto Traffic

7. Vehicle speed distributions and vehicle mixes were added. Only two types of private vehicles were used: auto and truck. The mix was determined from classification counts. No data was available for auto speed distributions, so they were merely asserted (25 to 35 mph for autos, 20 to 30 mph for trucks).

8. Vehicle inputs were added for each entrance to the network. These were determined from counts that had been balanced. Turning movement percentages at each intersection were also added based on count data. All data (vehicle, transit, etc.) was for the 6 am to 9 am time period. Stochastic hourly volumes were initially used. This was changed to deterministic hourly volumes based on PTV advice in order to achieve consistency between model runs. This also assisted in verifying the inputs.

9. The simulation was run with auto traffic only. Errors were discovered and fixed with several conflict zones, particularly left turns from side streets.

Add Transit Components

10. Added transit stops using GIS layers of SEPTA stops as a guide. Several links required adjustment, as VISSIM prevents a stop from being placed across two links or connectors.

11. The transit lines were added. Examining both the schedule and APC data, it was determined that the layover time at the 61st Street loop could not be reliably modeled without excessive effort. As such, transit operations were modeled as two completely separate lines: 61st Street to the 40th Street portal and the 40th Street portal to 61st Street. Vehicles "disappear" after they have completed their run on the westbound portion of the line. New vehicles appear just as they are about to start an eastbound run.

12. Added boarding and alighting rates based on Traffic Check data. These were later replaced with APC data. Boarding rates are in terms of passengers per hour arriving at each stop. Alighting rates are based on the percentage of passengers on board a vehicle that disembark. Two problems exist with VISSIM's internal alighting calculation: it is deterministic, not simulated, and integer values are always rounded down. This meant that, in practice, most vehicles would never stop for a disembarking passenger. The internal VISSIM alighting calculation was replaced by an enhanced model implemented with a VBA script inside a Microsoft Excel workbook, which communicated with VISSIM using the open COM interface. Vehicle stop time at each station was determined from the surveyed boarding and alighting rates. Total vehicle dwell time was determined via the *Highway Capacity Manual* Chapter 27 and vehicle data. Figures of 4.2 seconds per boarding passenger and 1.5 seconds per alighting passenger were initially estimated. During calibration, this was changed to 7.7 and 1.9, respectively. A clearance time of two seconds was used. Vehicle occupancy was estimated at 85 passengers. This was calculated by examining the number of seats, the standing area, and reasonable figures for standing density, and also by examining the actual occupancy of trolleys based on traffic check data. Out of 299 vehicle runs in the traffic check data set, only four had peak occupancies over 85. Additionally, a dummy stop was added in the tunnel. This was per PTV instructions to add some variance in the model in terms of both headways at 40th Street and passenger loading. For all stops, the "skipping possible" box was checked.

Setup Data Collection and Run Model

13. Data collection points were added at two places in the middle of the corridor and at points on the eastern and western boundary of Baltimore Avenue. These were used to check vehicle flows and transit occupancies to ensure that data inputs were correctly entered. Travel-time sections were also added from every stop to the 40th Street portal. Two westbound travel-time sections were also added: 40th Street to 49th Street and 49th Street to 61st Street. These were used to measure the travel time of transit vehicles during a simulation run. Data on every transit vehicle for every travel-time section was set up to feed into a Microsoft Access database.

14. The full model was run with transit. After several runs where errors were corrected, the base case was rerun in order to validate transit run times. Several adjustments were made, including changes in boarding and alighting rates, substitution of a more detailed passenger alighting model, and changes to the trolley acceleration curves. For all runs of the model, five simulations were run with different random seeds. For the first 1,800 seconds (half an hour), trolleys would enter the system according to the schedule with little or no passenger or private auto volumes, to permit them to get into position without obstruction. For the next 1,800 seconds, full transit vehicle, auto, and passenger volumes were used in order to bring the system to a steady state, but with no data recorded. For

the remaining 10,800 seconds (three hours), the simulation ran with full inputs and data was collected.

15. Stop consolidation scenarios were run by removing selected stops. The passengers at the consolidated stops were redirected to adjacent stations according to which was closer and which stop was in the desired direction of travel.

16. Transit signal priority was implemented as ten seconds of extended green time. Detectors were placed either at 1,000 feet from each intersection, or at the nearest location with direct line of sight to the intersection, whichever was closer. No delay time was used between transit vehicle detection and the start of the priority phase. No check out detection was used, either, in order to mimic the existing optical detection technology.

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Abstract

The purpose of this project was to explore the application of new planning and analysis techniques to route-level Transit First planning using one candidate Transit First route. For this project, the surface portion of Subway-Surface (trolley) Route 34—along Baltimore Avenue from the 40th Street trolley portal to the 61st Street loop—was selected for analysis. Various combinations of stop consolidation and transit signal priority (TSP) were tested using a microsimulation model. Moderate levels of stop consolidation plus TSP were found to give the best combination of passenger and transit vehicle travel time savings. The results of this modeling will inform decision makers about the relative impacts of improvement alternatives on trolley operations and the passenger experience.

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