ROUTE 15 TROLLEY MODERNIZATION

OPERATIONS ANALYSIS FOR EASTERN GIRARD AVENUE

JUNE 2019

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

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DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

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SEPTA is preparing to replace its trolley fleet with accessible light rail vehicles. This project tests the travel time effects of new trolleys on Route 15 using a microsimulation model. We estimate that replacing trolleys with curbside-lane-running buses (build scenario 1) would yield either a travel time penalty, or a very slight benefit for transit riders, depending on the interventions made. We find that modern trolleys can offer significant travel time savings within the study area (build scenario 2), and even greater travel time savings when prioritized in a dedicated right-of-way (as in build scenario 3).

Microsimulation results:
Girard Avenue between Broad Street and Frankford Avenue

				Average, Both Directions, Both Periods		
				Travel Time	Δ Time	Δ Percent
Existing Conditions	0.a	Near-side Stops	Trolleys Only	11:41.7		
			All Other Vehicles	5:56.0		
Curbside Bus	1.a	Near-Side Stops	Buses Only	12:51.7	+ 01:10.0	+ 10.0%
			All Other Vehicles	6:40.8	+ 00:10.5	+ 2.7%
	1.b	Far-Side Stops	Buses Only	12:33.7	+ 00:52.0	+ 7.4%
			All Other Vehicles	6:37.8	+ 00:07.5	+ 1.9%
	1.c	Near-Side Stops with Stop Consolidation	Buses Only	11:45.8	+00:04.2	+ 0.6%
			All Other Vehicles	6:32.6	+ 00:02.3	+ 0.6%
	1.d	Far-Side Stops with Stop Consolidation	Buses Only	11:24.4	- 00:17.2	-2.5%
			All Other Vehicles	6:36.9	+ 00:06.6	+ 1.7%
Basic Trolley Modernization	2.a	Near-Side Stops	Trolleys Only	10:51.8	- 00:49.9	-7.1%
			All Other Vehicles	6:27.1	- 00:03.2	-0.8%
	2.b	Near-Side Stops with Stop Consolidation	Trolleys Only	9:47.4	- 01:54.3	-16.3%
			All Other Vehicles	6:24.7	- 00:05.6	-1.4%
Premium Trolley Modernization	3.a	Far-Side Stops	Trolleys Only	10:24.5	- 01:17.1	-11.0%
			All Other Vehicles	7:44.9	+ 01:14.6	+ 19.1%
	3.b	Far-Side Stops with Signal Optimizations	Trolleys Only	9:57.6	- 01:44.1	-14.8%
			All Other Vehicles	6:47.6	+ 00:17.3	+ 4.4%
	3.c	Far-Side Stops with Stop Consolidation	Trolleys Only	9:52.0	- 01:49.7	-15.6%
			All Other Vehicles	7:45.5	+ 01:15.2	+ 19.3%
	3.d	Far-Side Stops with Stop Consolidation and Signal Optimizations	Trolleys Only	9:22.1	- 02:19.5	-19.9%
			All Other Vehicles	6:39.9	+ 00:09.6	+ 2.5%

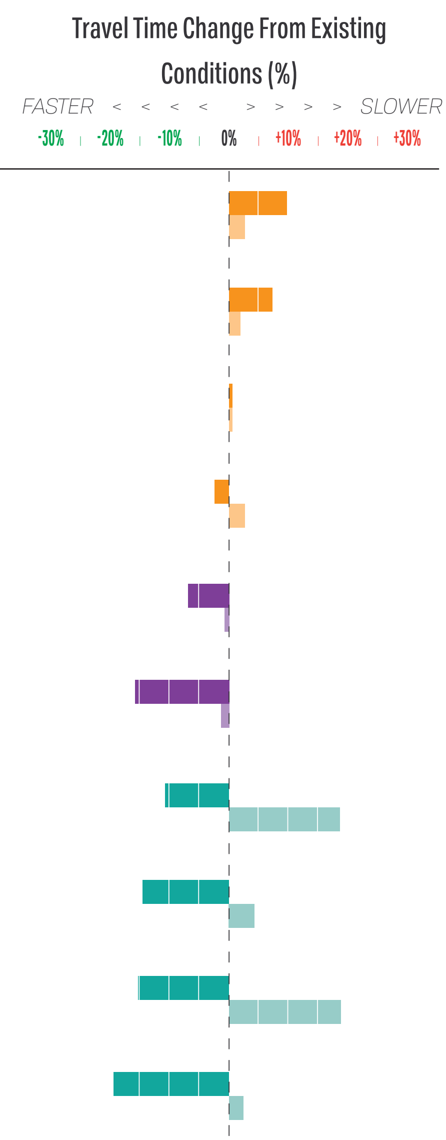


Table 1: Executive summary results

Figure 1: A typical existing Route 15 station

Figure 2: A graphic rendering of a modernized Route 15 station

Project Background

SEPTA is preparing for a once-in-a-generation replacement of its trolley fleet. The existing trolley vehicles have surpassed their expected useful lifespans, and, in replacing these vehicles, SEPTA will be required to comply with the Americans with Disabilities Act (ADA).

Major changes to trolleys and the streets they operate on are needed to achieve ADA compliance. New trolleys are functionally different from today's SEPTA fleet, and will trigger changes to the streetscape, stations, and maintenance facilities. Every modernized trolley stop, for instance, will require a station platform that allows for near-level boarding, and is wide enough to accommodate a wheelchair.

Beyond legal compliance, new trolleys offer opportunities to improve operational performance and passenger experience. New vehicles have lower floors and passenger-deployed wheelchair ramps, allowing faster boarding and alighting for all. When paired with policy changes, such as low-friction fare payment, multi-door boarding, transit signal prioritization (TSP), and stop consolidation, these features can speed up service for SEPTA passengers overall, and reduce congestion for other vehicles.

This report investigates opportunities to improve operational performance on SEPTA Route 15, a trolley route that runs east-west across Philadelphia, primarily along Girard Avenue. The DVRPC project team performed a VISSIM microsimulation analysis to test changes in travel time under three build scenarios for the portion of Route 15 between Frankford Avenue and Broad Street. This segment is unlike most of the streets with SEPTA trolley routes because it features multiple travel lanes in each direction. This study examines whether there are opportunities to improve operational performance in the context of Trolley Modernization that are unique to this cross-section.

Specifically, the microsimulation model tested two Trolley Modernization build scenarios: Basic Trolley Modernization which introduces modern vehicles and policies with minimal changes to the roadway, and Premium Trolley Modernization, which introduces modern vehicles and prioritizes transit by creating a trolley-only right-of-way. The model also tested a third build scenario, Curbside Bus Service, which replaces trolleys with standard SEPTA buses. This scenario was introduced at the steering committee's request to test a contingency in which Route 15's restored historic trolleys were to fail mechanically before Trolley Modernization.

Previous Work

This analysis builds upon DVRPC's earlier work providing planning support for Trolley Modernization. The 2017 *Modern Trolley Station Design Guide* (www.dvrpc.org/Products/15014/) presented conceptual designs for modern, accessible stations that will be compatible with SEPTA's new trolley fleet. That report developed station designs specifically for multi-lane cross-sections on Girard Avenue, which became the basis for two of this project's build scenarios.

The 2016 *Analysis of Modernization Scenarios for SEPTA Route 34* (www.dvrpc.org/Products/15005/) used a VISSIM microsimulation to identify travel time reduction opportunities related to modern trolley vehicle characteristics, including multi-door boarding, boarding for passengers with disabilities, and transit signal priority. That project's findings became assumptions for this report.

In short, this project applies designs from the *Modern Trolley Station Design Guide* using a similar methodology to that of the *Analysis of Modernization Scenarios for SEPTA Route 34*.

ADA Compliance

Trolley Modernization's core design requirement is to comply with the ADA's accessibility requirements. Route 15's cross-section and existing stations are unlike those of SEPTA's five other Philadelphia trolley routes, presenting different ADA-compliance challenges.

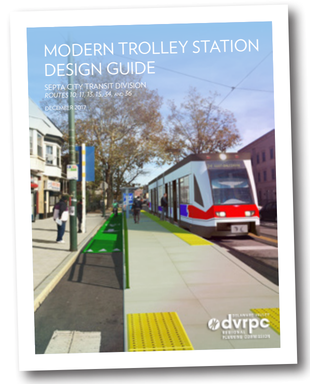


Figure 3: *Modern Trolley Station Design Guide*

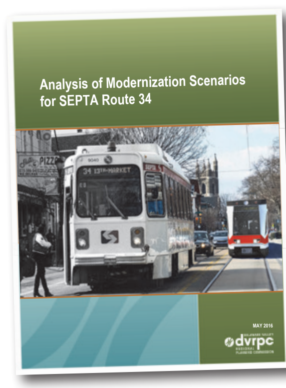


Figure 4: *Analysis of Modernization Scenarios for SEPTA Route 34*

Figure 5: Typical existing station platform

Currently, Route 15's PCC-II vehicles feature a retrofitted wheelchair lift at the vehicle's rear door. This lift requires the trolley operator to leave the vehicle controls, and manually operate the lift—a process that often takes longer than two minutes, even when the lift functions correctly.[1] This time penalty disincentivizes people with disabilities from using Route 15.

Transit systems that use modern vehicles typically address this problem with a combination of new vehicle technology and policy changes. Low vehicle floors and passenger-deployed ramps allow for a passenger in a wheelchair (or with a stroller or shopping cart) to board or alight in about 25 or 20 seconds, respectively. When transit agencies allow multi-door boarding and low-friction fare payment methods, such as a proof-of-payment system, all other passengers are able to swiftly board or alight without delaying a passenger using a ramp.

Route 15's existing stops are not ADA-compliant, even if they are served by ADA-compliant vehicles. At 63–69" wide, the existing platforms do not meet the U.S. Access Board's *ADA Standards for Transportation Facilities* §810.2.2, which mandates a 96" by 60" clear area for accessible boarding and alighting. These standards apply to both trolleys and buses, meaning that no matter what type of vehicle serves Route 15, the existing platforms require significant investment to meet legal requirements.

1 See Appendix B of the 2016 *Analysis of Modernization Scenarios for SEPTA Route 34* for a detailed discussion of accessible boarding strategies, including on Route 15 and on peer transit systems.

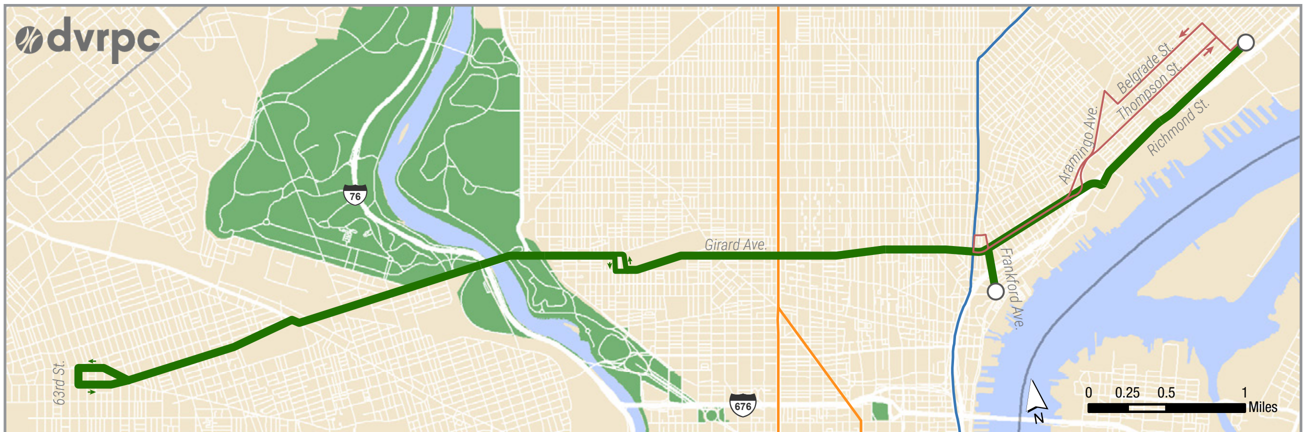


Figure 6: Route 15 map

Route Profile

Route 15 travels through North Philadelphia and the northern portion of West Philadelphia. The route begins, at its western end, at 63rd Street & Girard Avenue in the Haddington neighborhood, and travels east to Frankford and Delaware Avenues in the Fishtown neighborhood.

Route 15 connects several dense urban communities to Fairmount Park and other recreational attractions, such as the Philadelphia Zoo. As a crosstown route, it intersects with numerous north-south bus routes, as well as Trolley Route 10, the Broad Street Line and the Market-Frankford Line.

Since 2012, the portion of the route east of Frankford Avenue has been served by buses, as Route 15B, due to PennDOT's ongoing reconstruction of I-95, which required temporarily removing the wire that supplies Route 15's electrical power on Richmond Street.

	Period	Frequency (Mins.)
Weekday	Peak (AM | PM)	9 | 10
	Base	15
	Early Evening	15
	Late Night	30
Saturday	AM | PM	20 | 15
	Base	15
	Early Evening	20
	Late Night	30
Sunday	AM | PM	20 | 15
	Base	15
	Early Evening	20
	Late Night	30

One-way Route Miles	9.4
Average Daily Weekday Ridership	8,120
On-time Performance	69%
Weekday Operating Hours	24

Table 2: Route 15 operating statistics
Source: SEPTA Route Statistics, 2017

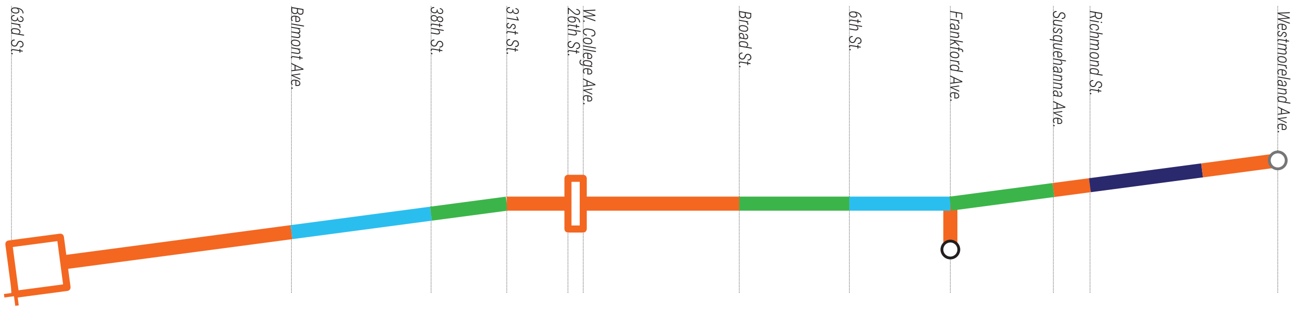


Figure 7: Route 15 typical cross-section diagram

Typical Cross-Sections

Route 15 operates in roadway cross-sections that are atypical from SEPTA's five other city trolley routes. Notably, Route 15 operates on a multi-lane roadway, Girard Avenue, for much of its route alignment.

There are two multi-lane segments of Route 15. The stretch between Belmont Avenue and 31st Street, primarily in West Philadelphia, mostly features trolleys in mixed traffic (see *Figure* 9). Between 38th and 31st Streets, trolleys run in dedicated lanes, though vehicular left turns are permitted from trolley lanes (see *Figure* 10). The lack of a physical barrier between the trolley right-of-way and general traffic reduces compliance by private vehicles. This segment suffers from traffic congestion related to the Interstate 76 on-ramps between 34th and 38th Streets.

The second multi-lane cross-section runs between Broad Street and Susquehanna Avenue. Trolley-only right-of-way exists between Broad and 6th Streets, and again between Frankford and Susquehanna Avenues. The segment between Broad Street and Frankford Avenue is the focus of this project's microsimulation analysis.

The recently rebuilt section of Richmond Street, near the eastern end of Route 15, features two trolley/vehicular mixed-traffic lanes, two bicycle lanes, and a center turn lane (see *Figure* 11). The rest of Route 15 runs in mixed traffic on streets that are typically one travel lane per direction, and a parking lane immediately adjacent to each travel lane (see *Figure* 8).

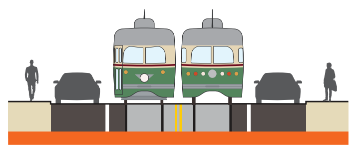


Figure 8: Typical cross-section A

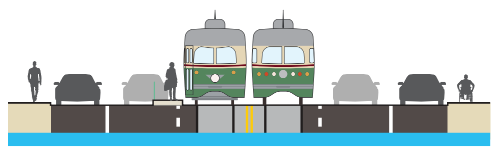


Figure 9: Typical cross-section B

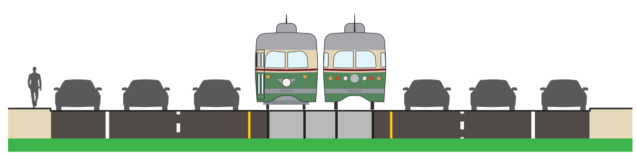


Figure 10: Typical cross-section C

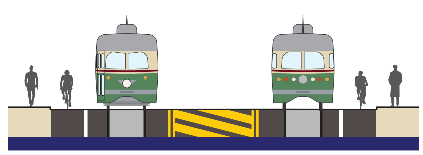


Figure 11: Typical cross-section D

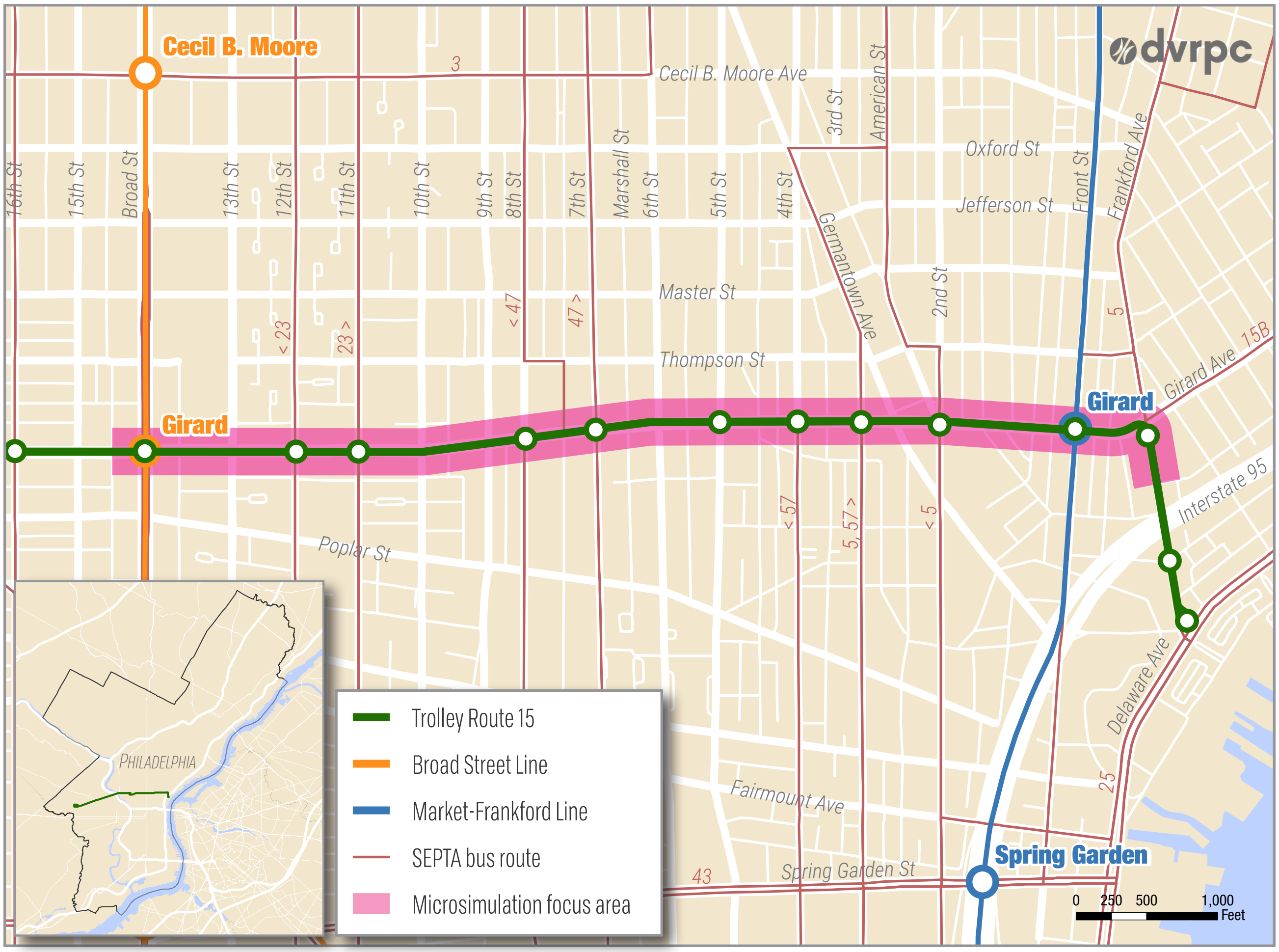


Figure 12: Study area map

Study Area

This project's microsimulation analysis focuses on an approximately 1.5-mile segment of Route 15 from Broad Street to Frankford Avenue. This segment was selected because it features trolleys running on a street with multiple travel lanes.

Wider roadways present more opportunities to improve transit travel times, for instance, by dedicating lanes for exclusive use by transit vehicles. Selecting a multi-lane cross-section for a microsimulation analysis may reveal potential service improvements that are not possible on the rest of Philadelphia's trolley streets.

Physical Layout

There are two typical roadway cross-sections within the study area. The widest is the western cross-section, between Broad Street and 6th Street, including, in each direction, a parking lane, two travel lanes, and a lane striped for trolley traffic only (see *Figure 14* and *Figure 15*). These trolley-only lanes allow vehicular left turns where applicable (see *Figure 13*, left side of photo).

In the study area, Route 15 stops at Broad Street, Front Street, Frankford Avenue, and each numbered street except for 13th, 10th, 9th, and 6th Streets. There is a westbound stop at 4th Street, but not an eastbound stop, where space is kept clear for the Philadelphia Fire Department's Engine 29 station.

Figure 13: Typical station, western cross-section

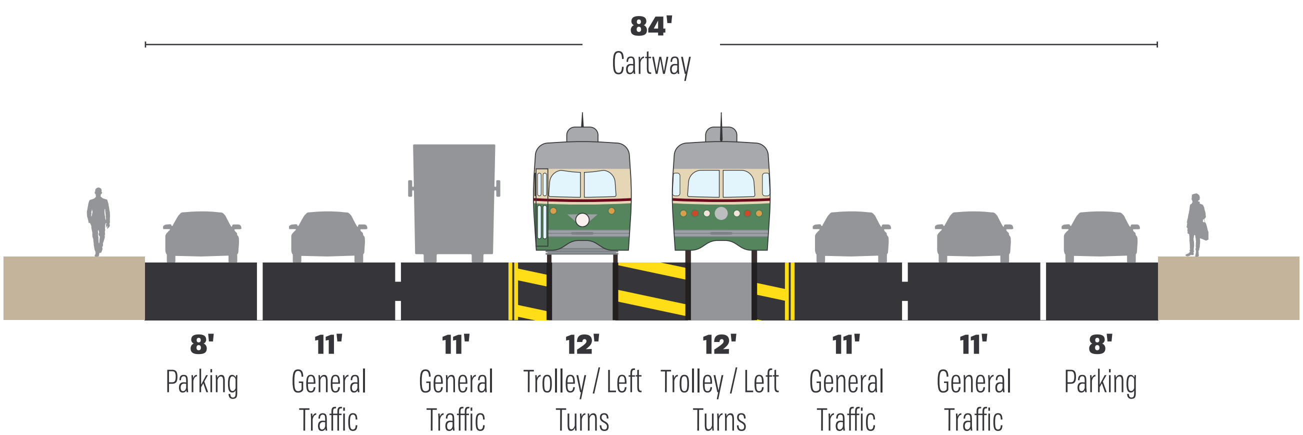


Figure 14: Typical lane configuration, western cross-section

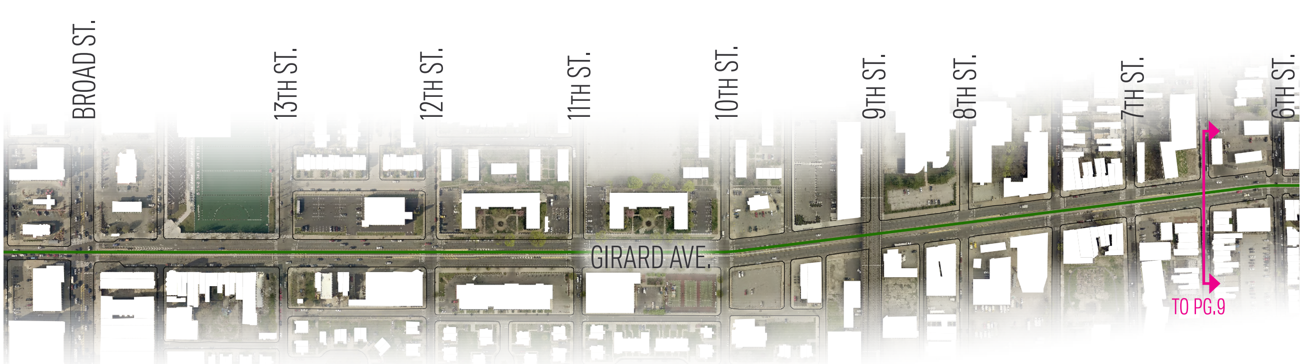


Figure 15: Corridor aerial view, west

Source: Aerial imagery, building footprints: City of Philadelphia 2017 | Curb lines: City of Philadelphia, 2016

Figure 16: Typical station, eastern cross-section

The eastern typical cross-section occurs between 6th Street and Frankford Avenue, and includes, in each direction, a parking lane, and two travel lanes (see *Figure 17* and *Figure 18*). Trolleys operate in the centermost travel lanes in each direction in mixed traffic.

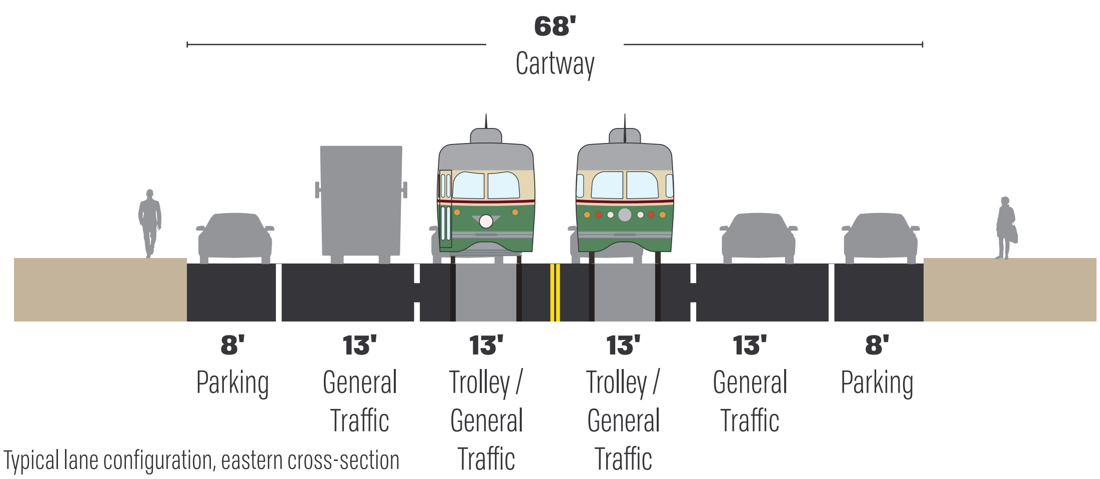


Figure 17: Typical lane configuration, eastern cross-section

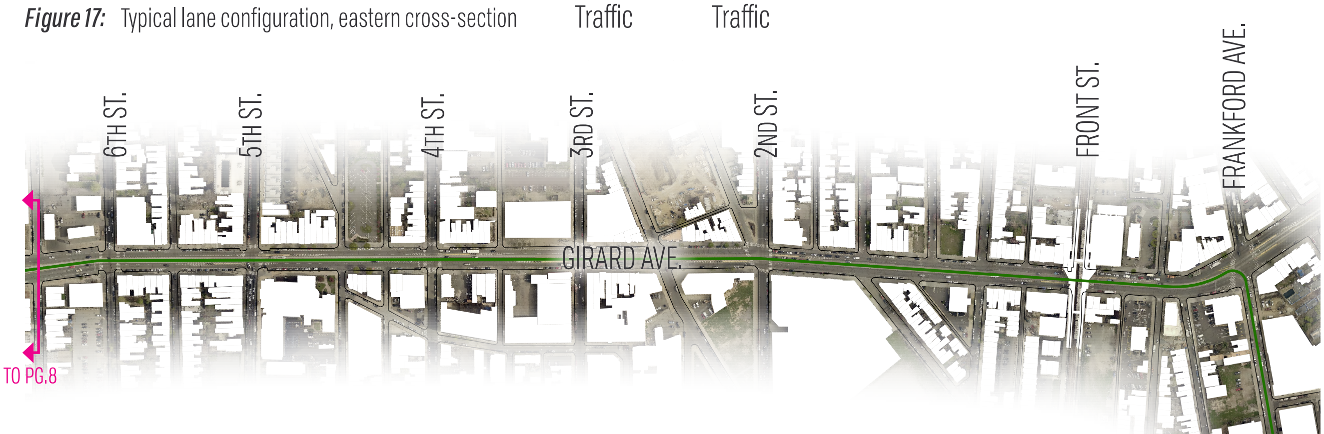


Figure 18: Corridor aerial view, east
Source: Aerial imagery, building footprints: City of Philadelphia 2017 | Curb lines: City of Philadelphia, 2016

What is Microsimulation?

Traffic microsimulation is used to assess the effect of changes to the transportation system at a fine level of detail. Microsimulation works by modeling the actions of every vehicle on the road at a sub-second basis. The microsimulation is based on 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. Traffic microsimulation is a powerful predictive tool because both vehicle physics and driver behavior are modeled at an elementary level.

The use of a simulation model further allows for an accounting of the interactions between different design interventions (i.e., the combined effects of multiple interventions together may be smaller or larger than the sum of those same interventions in isolation). A properly calibrated microsimulation model can better estimate overlapping impacts than a simpler cumulative spreadsheet exercise by responding both to traveler behavior, and to the specific physical characteristics of a given study area.

This microsimulation was built to model transit, auto, and pedestrian activity within the study area, as well as passenger boarding and alighting on transit vehicles. The model was mainly built and calibrated using traffic counts taken by video in spring 2017 at A.M. and P.M. peak hours, 7:30-8:30 A.M. and 4:30-5:30 P.M. The results are presented as end-to-end travel times within the study area for transit vehicles and for all other vehicles.

Two products from PTV Group's Vision software suite, VISUM and VISSIM, served as the primary modeling tools used for this project's technical analysis. DVRPC's regional VISUM forecasting model served as the macro-level demand package. VISSIM is a micro-level traffic analysis simulator that allows for realistic replication of multimodal transportation networks.

Scenario Development

The steering committee gathered in January 2018 for a kickoff meeting to develop concepts that would then be coded into a microsimulation model. Two build scenarios were drawn directly from the *Modern Trolley Station Design Guide*, while a third was added in response to the steering committee's concerns about potential trolley failure.

Build Scenarios

Three build scenarios were coded into a VISSIM microsimulation to identify travel times within the study area for transit vehicles and for all other vehicles.

+ **Curbside Bus Service**
  40'-long buses, 1-door boarding, 2-door alighting, in mixed traffic. To eliminate the safety hazard of in-street station platforms, bus service was moved to the outer lanes of Girard Avenue.

+ **Basic Trolley Modernization**
  Approximately 80'-long, 4-door boarding/alighting, accessible trolleys in mixed traffic. Except for larger station platforms, this scenario's roadway configuration is very similar to existing conditions.

+ **Premium Trolley Modernization**
  Approximately 80'-long, 4-door boarding/alighting, accessible trolleys in a dedicated right-of-way. This scenario requires reducing the number of vehicular travel lanes in each direction from two to one.

At the project kickoff, the steering committee expressed several concerns about the long-term prospects of trolley service on Girard Avenue. SEPTA staff noted that the 18 PCC-II trolleys serving Route 15 are experiencing mechanical decline, being taken out of service more frequently as time goes on. These particular vehicles were built in 1947, but overhauled in 2002, with the overhaul designed for a 15-year useful lifespan. SEPTA staff report that buses frequently substitute for trolleys on Route 15 due to mechanical failures, and expressed doubts that all of the PCC-II's will remain operational between today and Trolley Modernization. Both

SEPTA and City staff noted persistent non-mechanical reliability issues for Route 15, such as turning traffic or crashes that block trolley tracks.

To address these issues, and test a wider set of scenarios for Route 15, the steering committee asked the project team to model a scenario with buses instead of trolleys, resulting in the Curbside Bus Service scenario. This allowed the project team to explore potential differences in vehicle dynamics of buses compared to trolleys under normal conditions, and to compare travel times between the inner and outer lanes of Girard Avenue.

Stop Consolidation

Stop consolidation is a strategy to improve transit speed and reliability by strategically eliminating stops from a route. Reducing the total number of stops on a route speeds up service for all riders, but increases the time it takes to access a stop for some riders. Stop consolidation is especially relevant to Trolley Modernization because modern trolley stops are much more expensive and difficult to build than existing stops.

To test the travel time effects of stop consolidation, the project team developed a scenario in which one third of existing stops were consolidated in each build scenario for modeling purposes only. This modeling scenario is not meant to recommend a particular level of stop consolidation or any specific stops to be consolidated. In the real world, stop consolidation will include careful consideration and robust community outreach.

Stop Configuration

We modeled the travel time impacts of far-side stops for the Curbside Bus Service and Premium Trolley Modernization scenarios. In the Curbside Bus scenario, we modeled an iteration with buses stopping at the near side of intersections, and an iteration with buses stopping at the far side of intersections. In the Premium Trolley Modernization scenario, all iterations featured far-side stops, under the assumption that such a total right-of-way overhaul would allow for safe far-side stops.

Scenario Summary

Existing Conditions	
0.a	Existing Conditions Models the existing PCC-II trolleys in Girard Avenue's mix of semi-exclusive right-of-way and mixed traffic.
Curbside Bus Service	
1.a	Near-Side Stops Models 40-foot buses in the outer lanes, stopping at each current stop with near-side stops.
1.b	Far-Side Stops Models 40-foot buses in the outer lanes, stopping at each current stop with far-side stops.
1.c	Near-Side Stops with Stop Consolidation Models 40-foot buses in the outer lanes, with ⅓ of stops consolidated, and near-side stops.
1.d	Far-Side Stops with Stop Consolidation Models 40-foot buses in the outer lanes, with ⅓ of stops consolidated, and far-side stops.
Basic Trolley Modernization	
2.a	Near-Side Stops Models 80-foot trolleys in the inner lanes, with semi-exclusive right-of-way between Broad and 6th Streets, and stopping at each current stop with near-side stops.
2.b	Near-Side Stops with Stop Consolidation Models 80-foot trolleys in the inner lanes, with semi-exclusive right-of-way between Broad and 6th Streets, with ⅓ of stops consolidated, with near-side stops.
Premium Trolley Modernization	
3.a	Far-Side Stops Models 80-foot buses in an exclusive right-of-way, stopping at each current stop with far-side stops.
3.b	Far-Side Stops with Signal Optimizations Models 80-foot buses in an exclusive right-of-way, stopping at each current stop with far-side stops, and signals optimized for this new lane configuration.
3.c	Far-Side Stops with Stop Consolidation Models 80-foot trolleys in an exclusive right-of-way, with ⅓ of stops consolidated, and far-side stops.
3.d	Far-Side Stops with Stop Consolidation Models 80-foot trolleys in an exclusive right-of-way, with ⅓ of stops consolidated, far-side stops, and signals optimized for this new lane configuration.

Table 3: Scenario summary

Results

We used a robust dataset to build and calibrate the existing conditions model for the study area covering the A.M. peak hour and the P.M. peak hour. Once each build scenario was coded into VISSIM, the model was run several times to achieve an acceptable sample size of model runs, which were then averaged together. The results are presented as end-to-end travel time in each direction for each peak hour. Average travel times for

				A.M. Peak		P.M. Peak		Average Both Directions, Both Periods		
				Eastbound	Westbound	Eastbound	Westbound	Travel Time	Δ Time	Δ Percent
Existing Conditions	0.a	Near-side Stops	Trolleys Only	12:05.3	12:31.2	11:41.8	10:28.3	11:41.7		
			All Other Vehicles	6:07.3	7:36.1	6:21.9	5:56.0	5:56.0		
Curbside Bus	1.a	Near-Side Stops	Buses Only	12:51.4	13:17.8	13:00.2	12:17.4	12:51.7	+ 01:10.0	+ 10.0%
			All Other Vehicles	6:11.9	7:54.3	6:36.7	6:00.4	6:40.8	+ 00:10.5	+ 2.7%
	1.b	Far-Side Stops	Buses Only	12:11.7	13:35.3	12:12.8	12:14.8	12:33.7	+ 00:52.0	+ 7.4%
			All Other Vehicles	6:01.3	8:04.4	6:25.8	5:59.7	6:37.8	+ 00:07.5	+ 1.9%
	1.c	Near-Side Stops with Stop Consolidation	Buses Only	11:48.3	12:21.4	11:27.9	11:25.9	11:45.8	+00:04.2	+ 0.6%
			All Other Vehicles	6:01.9	7:52.9	6:28.3	5:47.3	6:32.6	+ 00:02.3	+ 0.6%
	1.d	Far-Side Stops with Stop Consolidation	Buses Only	11:00.8	12:33.9	10:43.5	11:19.5	11:24.4	- 00:17.2	-2.5%
			All Other Vehicles	5:59.9	8:09.7	6:21.0	5:57.0	6:36.9	+ 00:06.6	+ 1.7%
Basic Trolley Modernization	2.a	Near-Side Stops	Trolleys Only	11:12.7	11:44.8	10:56.7	9:32.8	10:51.8	- 00:49.9	-7.1%
			All Other Vehicles	5:51.9	7:36.0	6:21.6	5:59.2	6:27.1	- 00:03.2	-0.8%
	2.b	Near-Side Stops with Stop Consolidation	Trolleys Only	9:37.1	11:02.6	9:27.8	9:02.0	9:47.4	- 01:54.3	-16.3%
			All Other Vehicles	5:42.4	7:46.3	6:21.5	5:48.4	6:24.7	- 00:05.6	-1.4%
Premium Trolley Modernization	3.a	Far-Side Stops	Trolleys Only	10:04.4	12:13.2	9:14.7	10:05.7	10:24.5	- 01:17.1	-11.0%
			All Other Vehicles	6:31.3	8:37.4	8:42.8	7:08.1	7:44.9	+ 01:14.6	+ 19.1%
	3.b	Far-Side Stops with Signal Optimizations	Trolleys Only	9:42.9	11:32.8	8:53.5	9:41.0	9:57.6	- 01:44.1	-14.8%
			All Other Vehicles	6:33.2	7:41.5	7:06.1	5:49.6	6:47.6	+ 00:17.3	+ 4.4%
	3.c	Far-Side Stops with Stop Consolidation	Trolleys Only	9:57.8	10:54.4	9:01.9	9:33.8	9:52.0	- 01:49.7	-15.6%
			All Other Vehicles	6:33.9	8:31.3	8:36.6	7:20.3	7:45.5	+ 01:15.2	+ 19.3%
	3.d	Far-Side Stops with Stop Consolidation and Signal Optimizations	Trolleys Only	9:36.0	10:21.2	8:27.9	9:03.5	9:22.1	- 02:19.5	-19.9%
			All Other Vehicles	6:33.7	7:22.8	6:47.1	5:56.1	6:39.9	+ 00:09.6	+ 2.5%

Table 4: Microsimulation results

transit vehicles are presented separately from those for all other vehicles. We also present the average across both directions and both peak hours. This "average of averages" for each build scenario is compared to that of the existing conditions model, both as a change in travel time (the "Δ Time" column) and as a percentage change (the "Δ Percent" column).

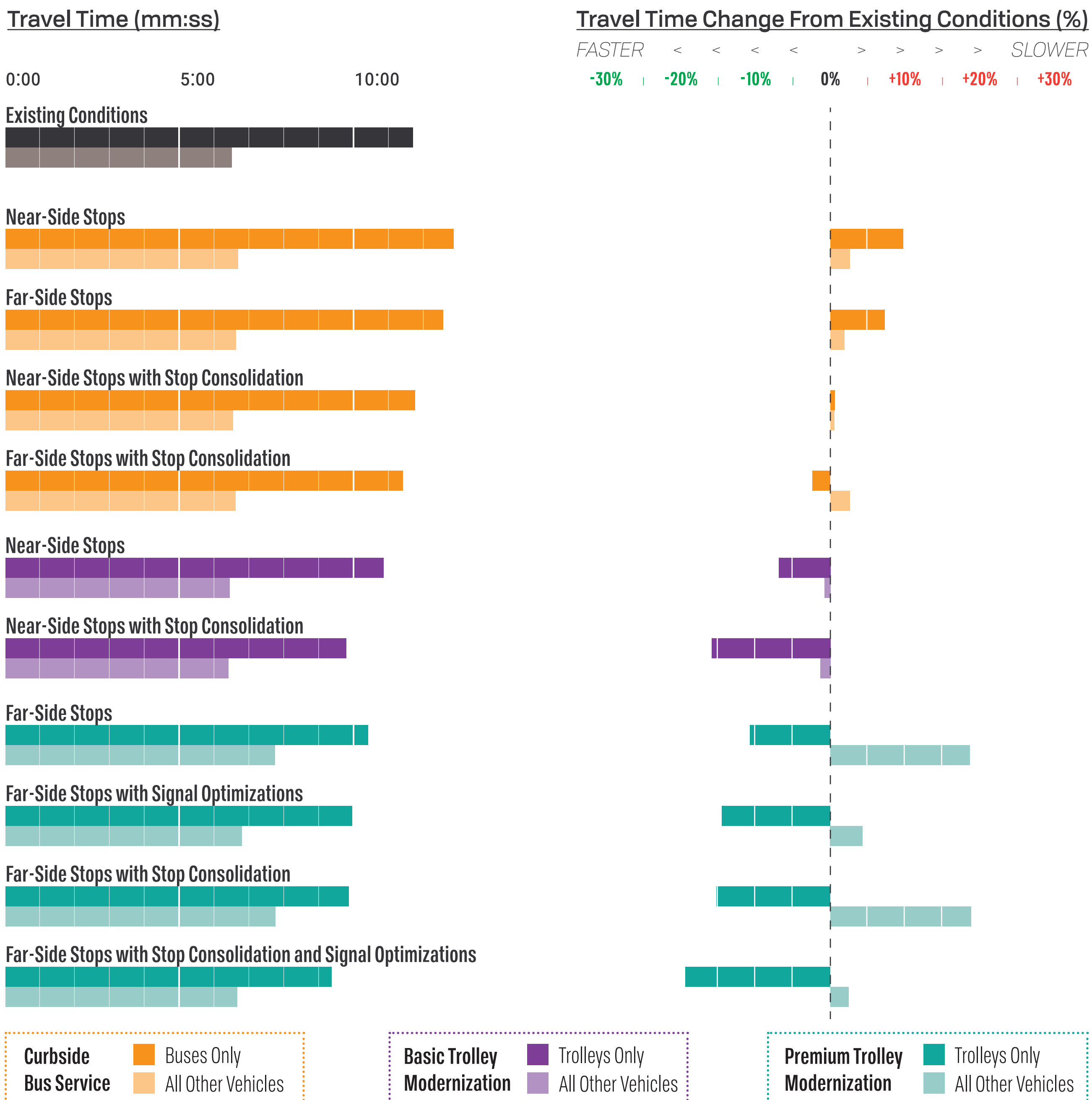


Figure 19: Microsimulation results

Findings

Modal Comparison: Trolleys vs. Buses

Under normal peak period conditions, we find travel time reductions for transit riders in each simulated Trolley Modernization build scenario. Conversely, we estimated that three of four Curbside Bus Service scenarios would increase travel times for transit riders.

Based on our observations of the microsimulation, we attribute the improvements in transit travel times primarily to dwell time reductions related to boarding policies assumed to go along with Trolley Modernization, such as multi-door boarding/alighting, low-friction fare payment, and near-level boarding/alighting. This finding is consistent with our 2016 *Analysis of Modernization Scenarios for SEPTA Route 34*.

We observed two conditions that contributed to slower bus travel times in the Curbside Bus Service scenarios. First, due to the boarding policy differences noted above, per-passenger dwell times for buses (2.57 seconds) were longer than for modern trolleys (1.5 seconds), which caused delay in the bus simulations.[2]

Second, buses traveling in the outer lanes experienced delay more frequently than trolleys in the inner lanes. This was the result of more "traffic friction" in the outer lanes, namely, vehicles turning to or from side streets. Buses were coded into the microsimulation with the ability to change lanes—an apparent advantage over trolleys—but this rarely occurred during the model runs.

There is a major caveat to this comparison: our model simulates *normal* traffic conditions—peak traffic congestion on an average weekday. Buses have some advantage over mixed-traffic trolleys under *abnormal* traffic conditions, such as crashes, or construction activity. **Our results demonstrate that modern trolley service is faster for passengers if it is prioritized.**

Right-of-Way Condition: Mixed Traffic vs. Exclusive

We found only modest improvements in travel times for trolleys in an exclusive right-of-way compared to trolleys in mixed traffic. Comparing scenarios 2.a and 3.a showed that modern trolleys in an exclusive right-of-way were estimated to save 27.2 seconds, on average, compared to modern trolleys in mixed traffic, or only 3.9 percent more compared to existing conditions.

With stop consolidation coded into the model (scenarios 2.b and 3.c), trolleys in mixed traffic were even faster, on average, than in a dedicated right-of-way.

We observed that the corridor's signal characteristics limited travel time improvements under the Premium Trolley Modernization scenario in several ways.

The dedicated right-of-way required introducing a short "protected left turn" signal phase to prevent traffic turning left from Girard Avenue from conflicting with through-moving trolleys. (Most left turns on Girard Avenue today are "permitted left turns.") Coding signals to allow for protected left turns caused significant delay for non-transit vehicles, and limited travel time reductions for trolleys (see scenarios 3.a and 3.c).

Scenarios 3.b and 3.d introduced signal optimizations designed to improve traffic flow along Girard Avenue for both trolleys and non-transit vehicles. These signal optimizations reduced travel times noticeably for all roadway users compared to build scenarios with existing signal phasing and offsets. These signal optimizations are highly calibrated to this build scenario, and would likely require further study before real-world implementation was possible.

Like the comparison between buses and trolleys, **our results depend on *normal* peak-hour traffic conditions**. A dedicated right-of-way ensures normal traffic conditions for trolleys at all times. **Thus, we would expect to see reliability benefits accrue to trolleys in a Premium Trolley Modernization scenario that are not reflected in these typical travel time comparisons**.

2 We found that per-passenger dwell times at existing Route 15 trolley stops (2.5 seconds) were nearly identical to those for existing SEPTA buses (2.57 seconds). We also found that our simulated bus runs rarely changed lanes within the model. Therefore, the travel time results of our Existing Conditions model serve as a useful proxy for estimating bus service speeds in the inner lanes of Girard Avenue.

Effects on Non-transit Vehicles

We estimated that travel times for non-Route 15 vehicles varied based on each build scenario's transit operating conditions.

In the Curbside Bus Service base scenario, we found a minor increase in travel time for all other vehicles (10.5 seconds, or 2.7 percent longer than existing conditions) along with a more significant increase in bus travel time (1 minute and 10 seconds, or 10 percent longer than existing conditions). Additional interventions to speed up buses, such as stop consolidation and far-side stops, mostly improved private vehicle travel times as well, though the change from existing conditions remained minor. Our observations of the microsimulation suggest that more bus-vehicle interactions in the outer lanes caused this travel time increase.

The Basic Trolley Modernization build scenario also showed minimal reduction in private vehicle travel times in our simulation. This was a predictable result, as the build scenario largely mimicked existing conditions, with the exception of shorter dwell times for trolleys at stations, which eliminated a source of delay for all other vehicles.

The initial iterations of the Premium Trolley Modernization scenario showed a significant travel time penalty for non-transit vehicles, approximately 19 percent slower than existing conditions (scenarios 3.a and 3.c).

When the signal timings and offsets were optimized to assist traffic flow on Girard Avenue, in scenarios 3.b and 3.d, delay for non-transit vehicles compared to existing conditions dropped dramatically. This result suggests that it is possible, with some effort and calibration, to move Girard Avenue's current volume of traffic with only one vehicular travel lane per direction.

Implementing this scenario in the real world, however, would be a complex undertaking, with several additional factors to be considered. For example, our analysis held traffic volume on Girard Avenue constant across all build scenarios. It is reasonable to expect traffic volumes would change if Girard Avenue's vehicular capacity were reduced, and that Route 15's ridership would increase. Our model is also limited to our study area, covering a mile of Girard Avenue, but only about a block's length of each cross street. As a result, our understanding of the impacts to the wider transportation network is not complete. These and other questions must be addressed in further research first if this build scenario is pursued.

Stop Consolidation: Time Savings Across All Scenarios

We found that simulating consolidation of 33 percent of stops within the study area significantly reduced transit travel times under all build scenarios.

Scenario Comparison	Percent Change from Existing Conditions: Existing Stop Program	Percent Change from Existing Conditions: With Stop Consolidation	Difference With Stop Consolidation
Near-Side Stops (1.A → 1.C)	+10.0%	+0.6%	- 9.4%
Far-Side Stops (1.B → 1.D)	+ 7.4%	-2.5%	-9.9%
Near-Side Stops (2.A → 2.B)	-7.1%	-16.3%	- 9.2%
Far-Side Stops (3.A → 3.C)	-11.0%	-15.6%	- 4.6%
Far-Side Stops with Signal Optimizations (3.B → 3.D)	-14.8%	-19.9%	- 5.1%

Table 5: Stop consolidation comparison

Stop consolidation was estimated to be most effective for transit in mixed traffic, with a reduction of about 9 percent to 10 percent of existing end-to-end travel time in the Curbside Bus Service and Basic Trolley Modernization scenarios. The model estimated diminishing returns in terms of travel time reductions when trolleys had a dedicated right-of-way, though we still estimated travel time savings of approximately 5 percent related to stop consolidation.

Future of Route 15

Our analysis is one piece in a larger discussion about the future of Route 15. **Our results show that, if modern trolleys are prioritized, they can offer significant travel time savings compared to mixed-traffic trolleys or buses. Absent this transit prioritization, few operational benefits are likely, despite the large investment of upgrading the route.**

Other factors besides potential travel time savings bear on the future of Route 15. SEPTA staff report that breakdowns of the PCC-II vehicles occur more frequently as time goes on, such that, on a typical day, one to two buses are needed to provide a full, peak-period fleet.

More fundamentally, Route 15 exemplifies some of the limitations of trolley service. As Jarrett Walker and Associates wrote in their 2018 *Philadelphia Bus Network Choices Report*: "operating Route 15 as a trolley limits SEPTA's ability to design the best possible network to maximize freedom and opportunity for the city's transit customers."[3] JWA specifically highlights the western end of Route 15, which terminates about a mile from 69th Street Transportation Center. If Route 15 terminated at 69th Street, it would "provide a much faster and easier connection for many people in West and North Philadelphia to jobs and opportunities in Delaware County. Likewise, it would provide a much easier connection for people in Delaware County to destinations along Girard Avenue."[4] JWA identifies the choice, simply, as between a costly extension of trolley infrastructure to 69th Street, or converting Route 15 to a bus with an easy extension to 69th Street.

Lastly, this analysis helps SEPTA understand the travel time impacts of Trolley Modernization on a multi-lane street, but not all of Route 15 operates on a multi-lane street. Any opportunity to improve travel time on this segment of Girard Avenue must be balanced against potential delays on other parts of Route 15, where trolleys run in narrower lanes in mixed traffic.

3 Jarrett Walker and Associates. Philadelphia Bus Network Choices Report (Philadelphia: SEPTA, 2018), 88.
4 Ibid., 88.

Recent SEPTA efforts help us understand sources of delay more specifically. Route 15 was bus substituted for three weeks in late July and early August, 2018, and buses were equipped with real-time automatic passenger counter devices, which measured both travel time and ridership. This dataset was collected in the summer, when ridership was approximately 15 percent lower than the spring, when our model was calibrated, meaning an apples-to-apples comparison to our model is not possible. The results, however, do make clear that the locations where buses most often experienced delays are between Broad Street and 40th Street—outside of our study area.

Part of this area, west of 31st Street, is a multi-lane roadway where trolleys contend with congestion around the Interstate 76 on-ramps. But the segment between 31st and Broad Streets is a one-lane-per-direction street, where it would be much more challenging to prevent street disruptions.

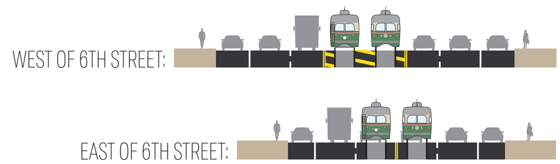
As we note several times in this analysis, street disruptions greatly influence whether Route 15 can perform effectively as a trolley route. Our model only estimates the travel time effects of normal traffic congestion, not street disruptions. Before determining the best vehicles to serve Route 15, further study is required to understand how frequently these street disruptions occur, and what their travel time effects are.

Recommendations for Further Analysis

Our results suggest areas for further study for Route 15 as SEPTA plans for Trolley Modernization in the face of the aging PCC-II vehicles. Our analysis provides one piece of the decision-making puzzle, but not enough for SEPTA to make a final decision. Specifically, we recommend:

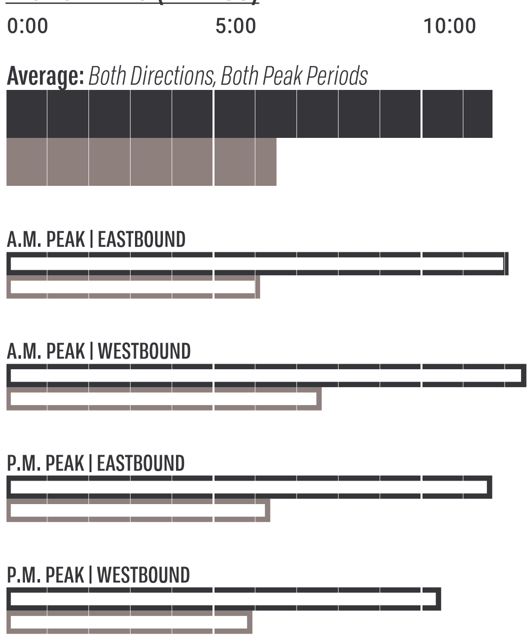
+ A travel time analysis similar to this report focused on Route 15 between 31st Street and Belmont Avenue, and
+ A full analysis of end-of-line options for Route 15.

Build Scenario 0: Existing Conditions



Scenario results (mm:ss)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Trolleys Only	**11:41.7**	12:05.3	12:31.2	11:41.8	10:28.3
All Other Vehicles	**6:30.3**	6:07.3	7:36.1	6:21.9	5:56.0

Travel Time (mm:ss)



Trolleys Only   All Other Vehicles

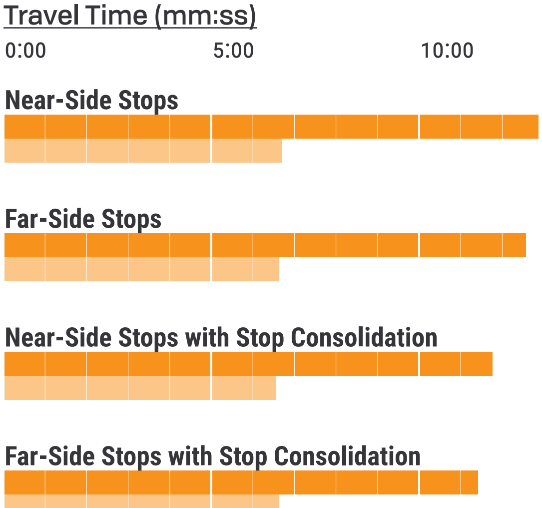
Build Scenario 1: Curbside Bus Service

WEST OF 6TH STREET:

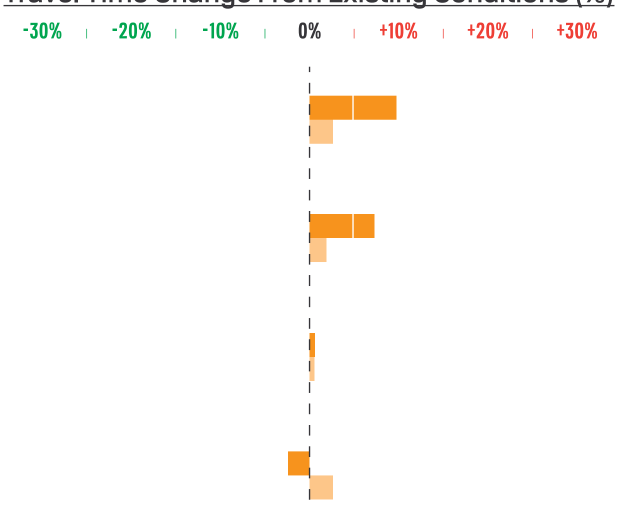
EAST OF 6TH STREET:

		Travel Time (mm:ss) Both directions, both peak periods	***Travel Time (mm:ss)*** Change from existing conditions	***Travel Time (%)*** Change from existing conditions
1.a Near-Side Stops	Buses Only	12:51.7	+ 01:10.0	+ 10.0%
	All Other Vehicles	6:40.8	+ 00:10.5	+ 2.7%
1.b Far-Side Stops	Buses Only	12:33.7	+ 00:52.0	+ 7.4%
	All Other Vehicles	6:37.8	+ 00:07.5	+ 1.9%
1.c Near-Side Stops with Stop Consolidation	Buses Only	11:45.8	+ 00:04.2	+ 0.6%
	All Other Vehicles	6:32.6	+ 00:02.3	+ 0.6%
1.d Far-Side Stops with Stop Consolidation	Buses Only	11:24.4	- 00:17.2	- 2.5%
	All Other Vehicles	6:36.9	+ 00:06.6	+ 1.7%

Travel Time (mm:ss)



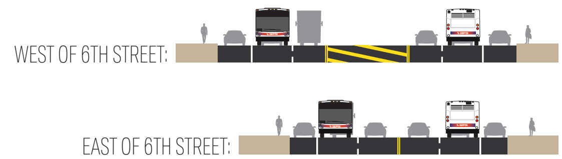
Travel Time Change From Existing Conditions (%)



Buses Only   All Other Vehicles

1.A Near-Side Stops

+ Near-side stops
+ Existing stop spacing

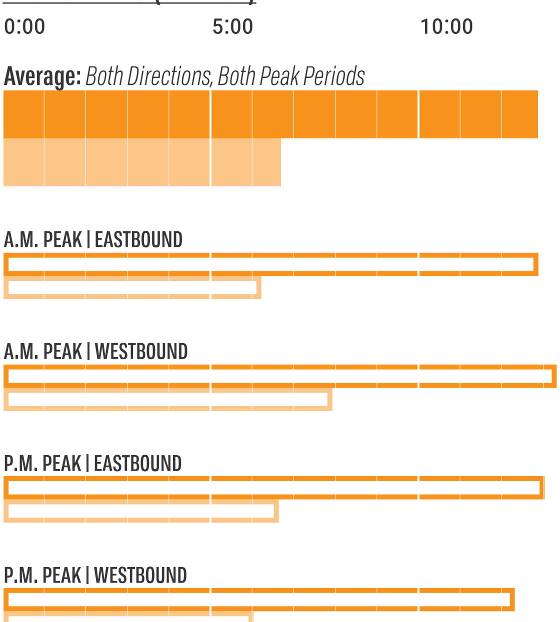


Scenario results (mm:ss)	Average	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Buses Only	**12:51.7**	12:51.4	13:17.8	13:00.2	12:17.4
All Other Vehicles	**6:40.8**	6:11.9	7:54.3	6:36.7	6:00.4

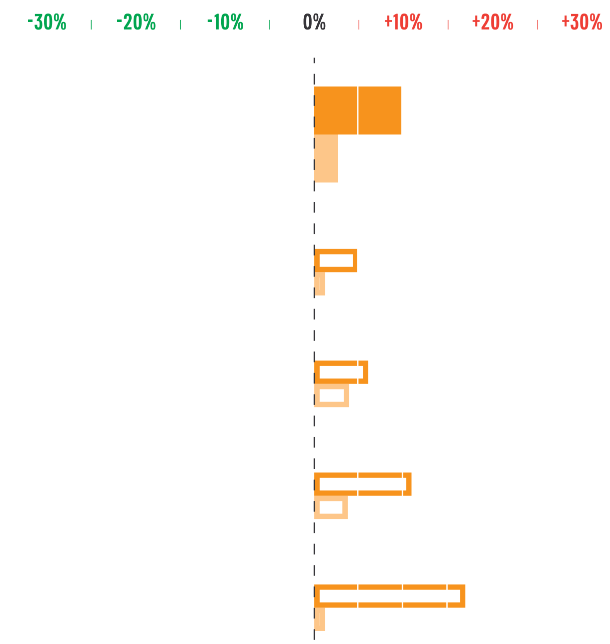
Change from existing conditions (mm:ss)	Average	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Buses Only	**+ 01:10.0**	+ 00:46.6	+ 00:46.1	+ 01:18.4	+ 01:49.1
All Other Vehicles	**+ 00:10.5**	+ 00:04.6	+ 00:18.2	+ 00:14.7	+ 00:04.4

Change from existing conditions (%)	Average	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Buses Only	**+ 10.0%**	+ 6.4%	+ 6.2%	+ 11.2%	+ 17.4%
All Other Vehicles	**+ 2.7%**	+ 1.3%	+ 4.0%	+ 3.9%	+ 1.2%

Travel Time (mm:ss)



Travel Time Change From Existing Conditions (%)



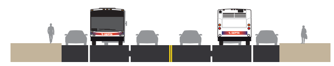
Buses Only   All Other Vehicles

1.B Far-Side Stops

+ Far-side stops
+ Existing stop spacing

WEST OF 6TH STREET:

EAST OF 6TH STREET:

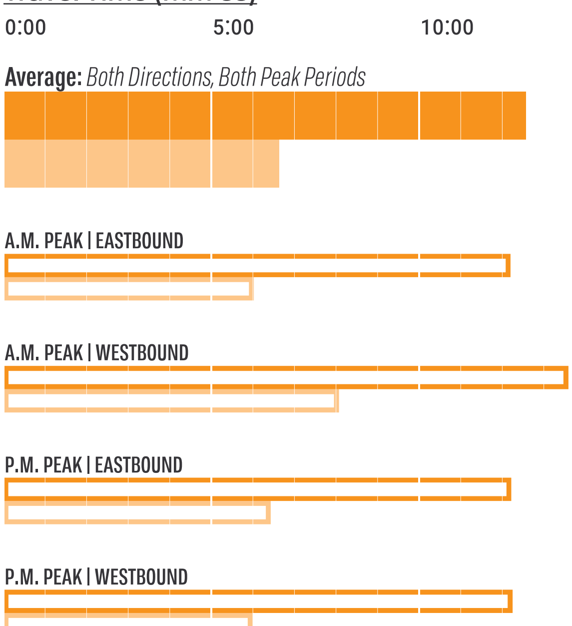


Scenario results (mm:ss)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Buses Only	**12:33.7**	12:11.7	13:35.3	12:12.8	12:14.8
All Other Vehicles	**6:37.8**	6:01.3	8:04.4	6:25.8	5:59.7

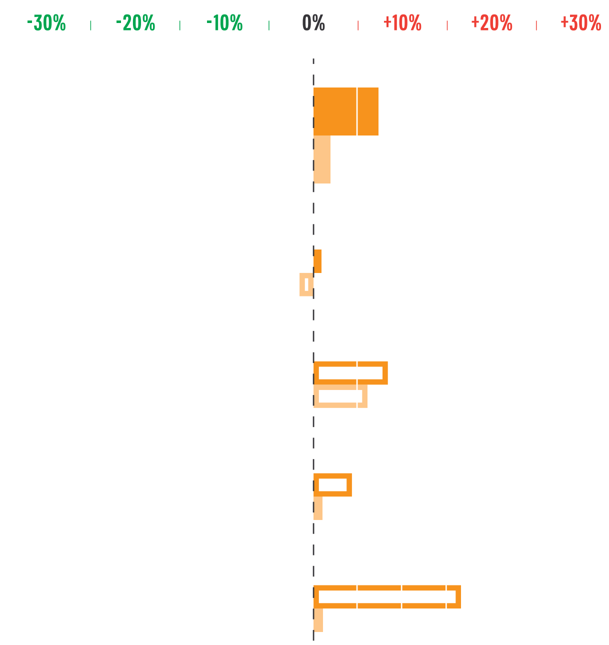
Change from existing conditions (mm:ss)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Buses Only	**+ 00:52.0**	+ 00:06.4	+ 01:04.2	+ 00:31.0	+ 01:46.6
All Other Vehicles	**+ 00:07.5**	- 00:05.9	+ 00:28.3	+ 00:03.8	+ 00:03.8

Change from existing conditions (%)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Buses Only	**+ 7.4%**	+ 0.9%	+ 8.5%	+ 4.4%	+ 17.0%
All Other Vehicles	**+ 1.9%**	- 1.6%	+ 6.2%	+ 1.0%	+ 1.1%

Travel Time (mm:ss)



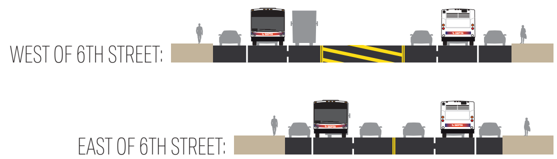
Travel Time Change From Existing Conditions (%)



Buses Only | All Other Vehicles

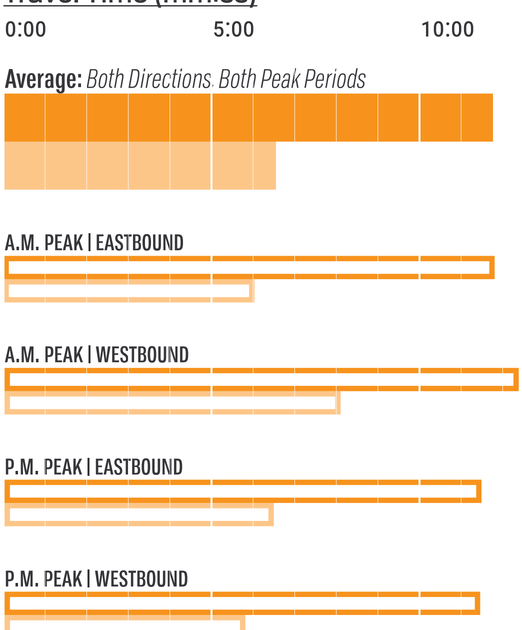
1.C Near-Side Stops with Stop Consolidation

+ Near-side stops
+ 33 percent stop consolidation

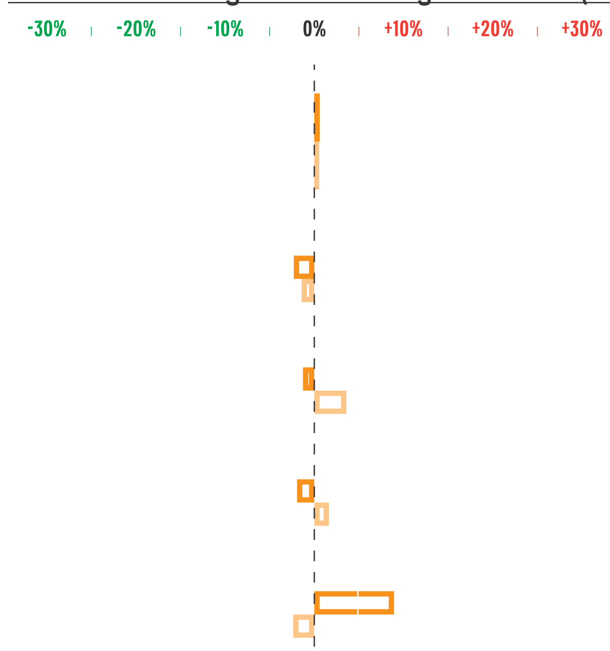


		A.M. Peak		P.M. Peak	
Scenario results (mm:ss)	***Average***	*Eastbound*	*Westbound*	*Eastbound*	*Westbound*
Buses Only	**11:45.8**	11:48.3	12:21.4	11:27.9	11:25.9
All Other Vehicles	**6:32.6**	6:01.9	7:52.9	6:28.3	5:47.3
Change from existing conditions (mm:ss)					
Buses Only	**+ 00:04.2**	- 00:17.1	- 00:09.8	- 00:14.0	+ 00:57.6
All Other Vehicles	**+ 00:02.3**	- 00:05.4	+ 00:16.8	+ 00:06.4	- 00:08.7
Change from existing conditions (%)					
Buses Only	**+ 0.6%**	- 2.4%	- 1.3%	- 2.0%	+ 9.2%
All Other Vehicles	**+ 0.6%**	- 1.5%	+ 3.7%	+ 1.7%	- 2.4%

Travel Time (mm:ss)



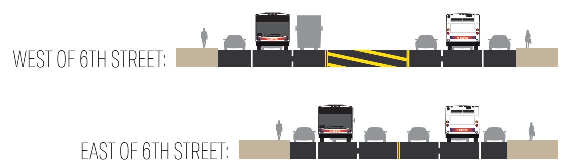
Travel Time Change From Existing Conditions (%)



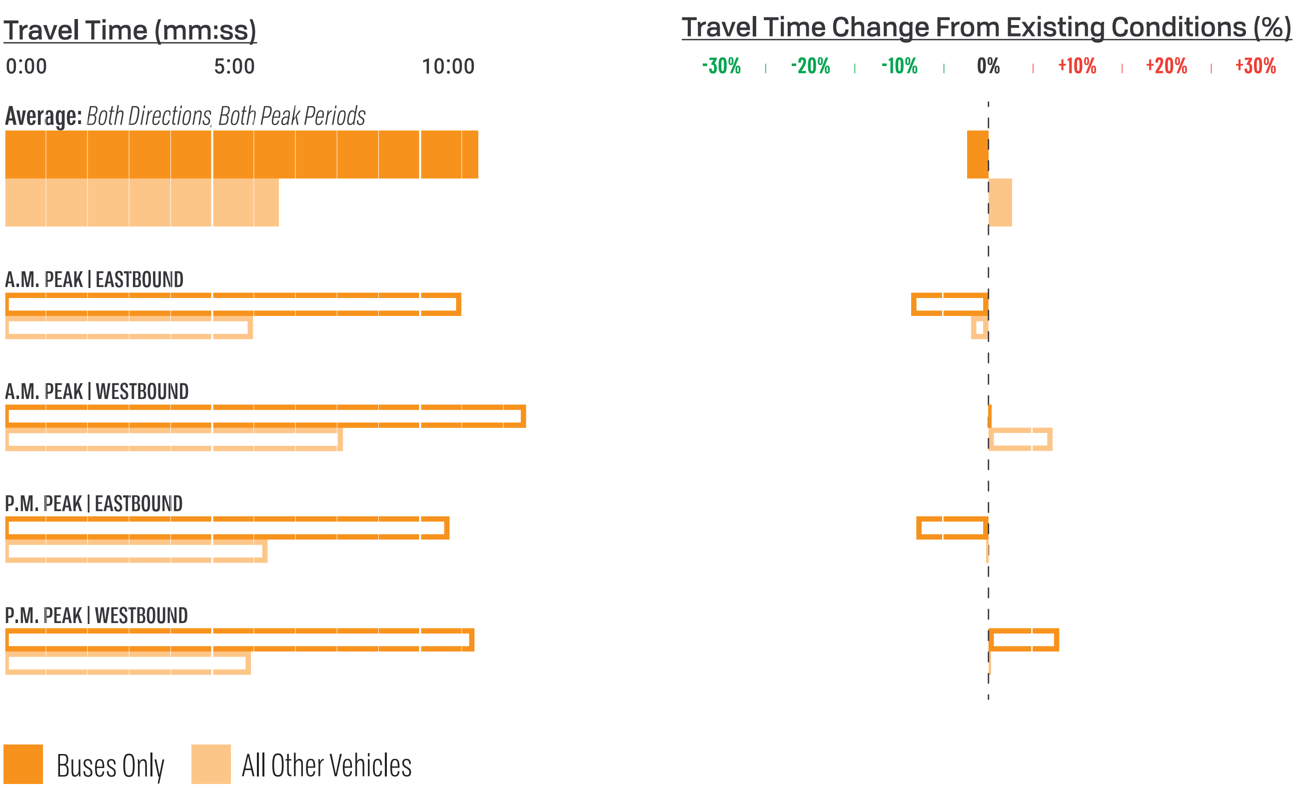
Buses Only All Other Vehicles

1.D Far-Side Stops with Stop Consolidation

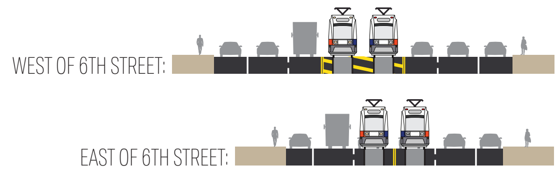
+ Far-side stops
+ 33 percent stop consolidation



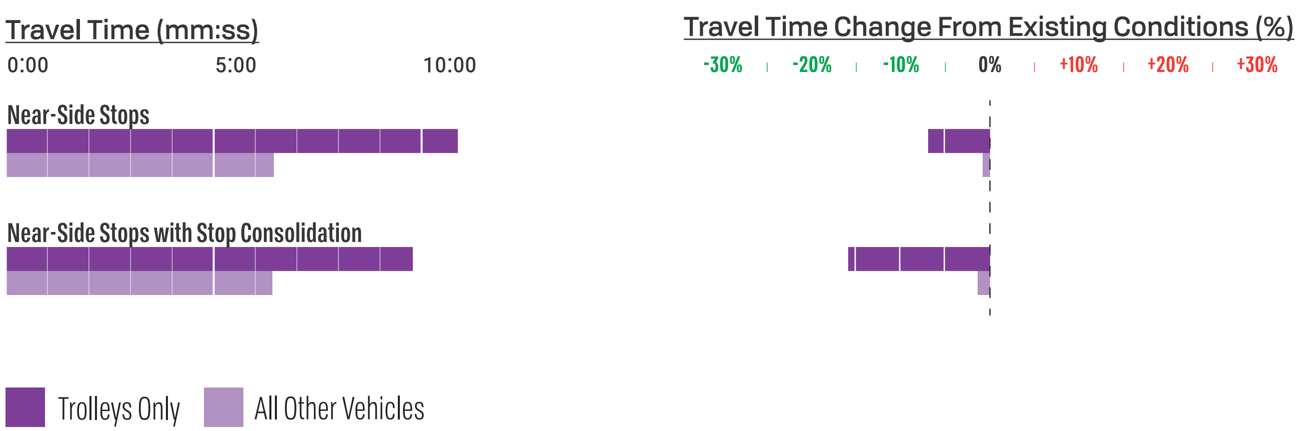
		A.M. Peak		*P.M. Peak*	
Scenario results (mm:ss)	***Average***	*Eastbound*	*Westbound*	*Eastbound*	*Westbound*
Buses Only	**11:24.4**	11:00.8	12:33.9	10:43.5	11:19.5
All Other Vehicles	**6:36.9**	5:59.9	8:09.7	6:21.0	5:57.0
Change from existing conditions (mm:ss)					
Buses Only	**- 00:17.2**	- 01:04.6	+ 00:02.7	- 00:58.3	+ 00:51.2
All Other Vehicles	**+ 00:06.6**	- 00:07.4	+ 00:33.7	- 00:00.9	+ 00:01.0
Change from existing conditions (%)					
Buses Only	**- 2.5%**	- 8.9%	+ 0.4%	- 8.3%	+ 8.1%
All Other Vehicles	**+ 1.7%**	- 2.0%	+ 7.4%	- 0.2%	+ 0.3%



Results: Basic Trolley Modernization, All Iterations

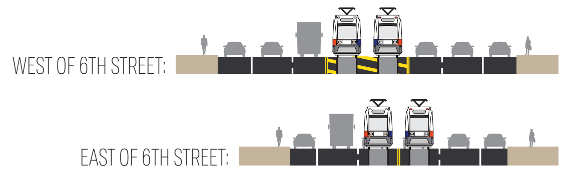


		Travel Time (mm:ss) Both directions, both peak periods	***Travel Time (mm:ss)*** Change from existing conditions	***Travel Time (%)*** Change from existing conditions
2.a Near-Side Stops	Trolleys Only	**10:51.8**	**- 00:49.9**	**-7.1%**
	All Other Vehicles	**6:27.1**	**- 00:03.2**	**-0.8%**
2.b Near-Side Stops with Stop Consolidation	Trolleys Only	**9:47.4**	**- 01:54.3**	**-16.3%**
	All Other Vehicles	**6:24.7**	**- 00:05.6**	**-1.4%**



2.A NEAR-SIDE STOPS

+ Near-side stops
+ Existing stop spacing

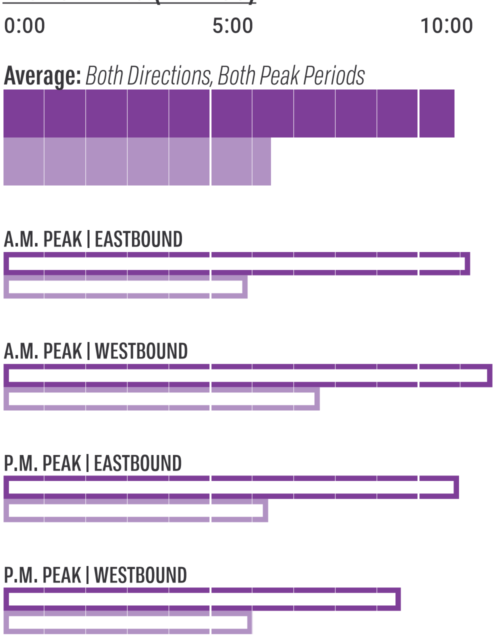


Scenario results (mm:ss)	*Average*	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Trolleys Only	**10:51.8**	11:12.7	11:44.8	10:56.7	9:32.8
All Other Vehicles	**6:27.1**	5:51.9	7:36.0	6:21.6	5:59.2

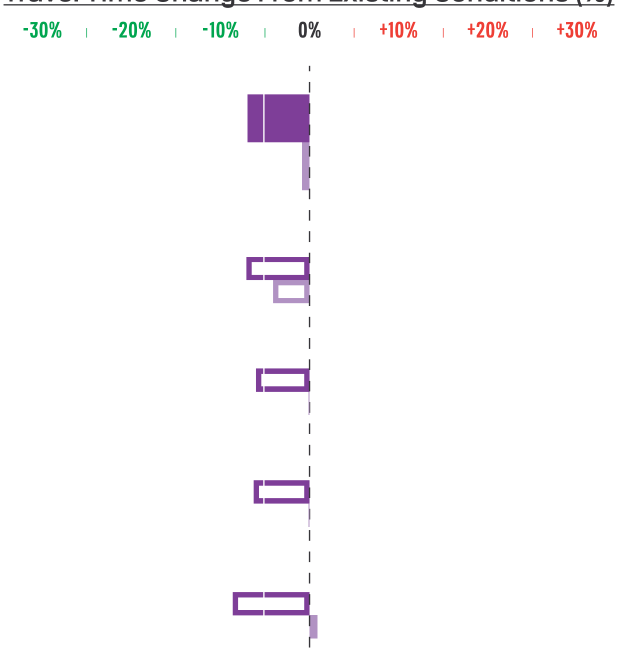
Change from existing conditions (mm:ss)	*Average*	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Trolleys Only	**-00:49.9**	-00:52.6	-00:46.4	-00:45.1	-00:55.5
All Other Vehicles	**-00:03.2**	-00:15.4	-00:00.1	-00:00.4	+00:03.2

Change from existing conditions (%)	*Average*	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Trolleys Only	**-7.1%**	-7.3%	-6.2%	-6.4%	-8.8%
All Other Vehicles	**-0.8%**	-4.2%	0.0%	-0.1%	+ 0.9%

Travel Time (mm:ss)



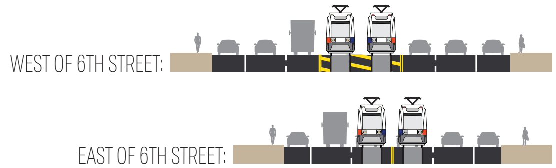
Travel Time Change From Existing Conditions (%)



Trolleys Only   All Other Vehicles

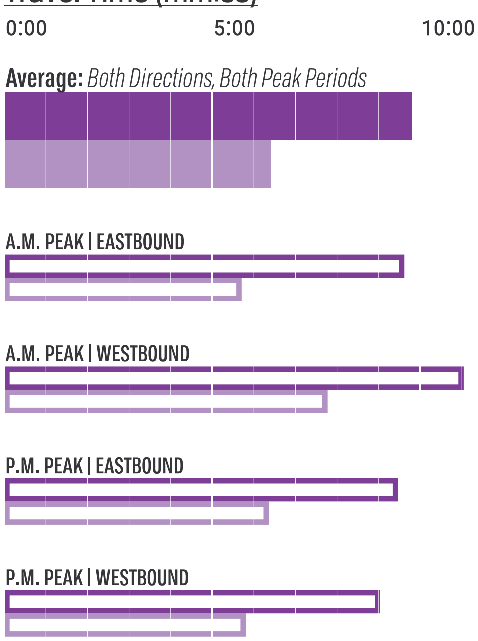
2.B NEAR-SIDE STOPS WITH STOP CONSOLIDATION

+ Near-side stops
+ 33 percent stop consolidation

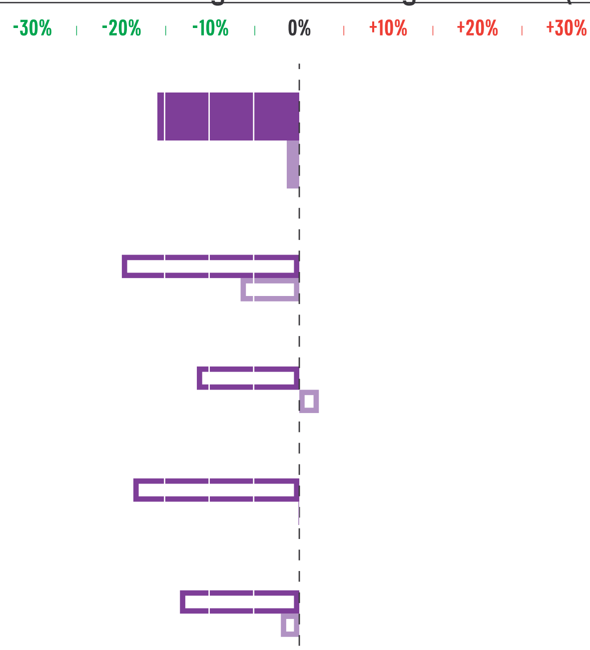


		A.M. Peak		P.M. Peak	
Scenario results (mm:ss)	***Average***	*Eastbound*	*Westbound*	*Eastbound*	*Westbound*
Trolleys Only	**9:47.4**	9:37.1	11:02.6	9:27.8	9:02.0
All Other Vehicles	**6:24.7**	5:42.4	7:46.3	6:21.5	5:48.4
Change from existing conditions (mm:ss)					
Trolleys Only	**-01:54.3**	-02:28.2	-01:28.6	-02:14.1	-01:26.3
All Other Vehicles	**-00:05.6**	-00:24.8	+ 00:10.3	-00:00.5	-00:07.5
Change from existing conditions (%)					
Trolleys Only	**-16.3%**	-20.4%	-11.8%	-19.1%	-13.7%
All Other Vehicles	**-1.4%**	-6.8%	+ 2.3%	-0.1%	-2.1%

Travel Time (mm:ss)

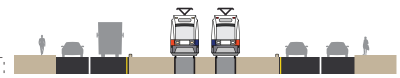


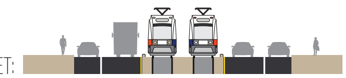
Travel Time Change From Existing Conditions (%)



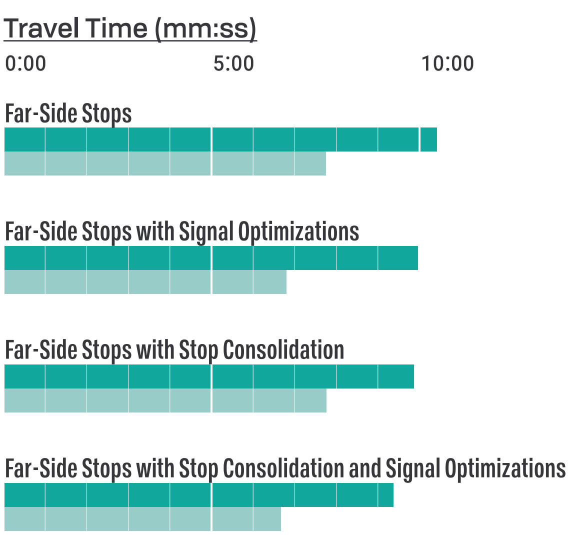
Trolleys Only   All Other Vehicles

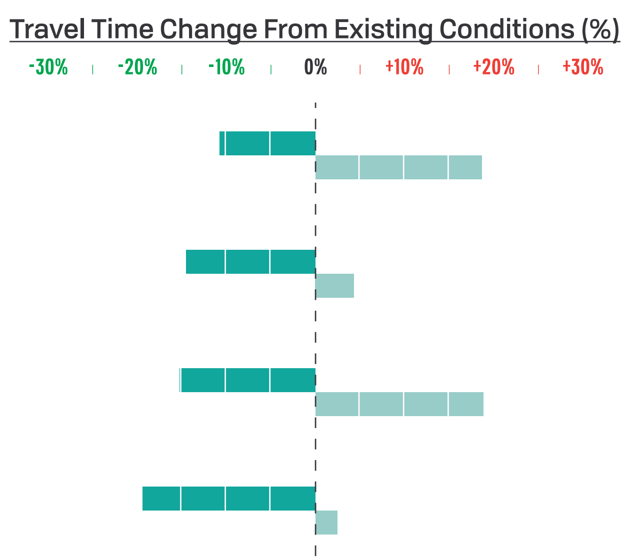
Build Scenario 3: Premium Trolley Modernization

WEST OF 6TH STREET:


EAST OF 6TH STREET:


		Travel Time (mm:ss) Both directions, both peak periods	*Travel Time (mm:ss)* Change from existing conditions	*Travel Time (%)* Change from existing conditions
3.a Far-Side Stops	Trolleys Only	10:24.5	-01:17.1	-11.0%
	All Other Vehicles	7:44.9	+01:14.6	19.1%
3.b Far-Side Stops with Signal Optimizations	Trolleys Only	9:57.6	-01:44.1	-14.8%
	All Other Vehicles	6:47.6	+00:17.3	4.4%
3.c Far-Side Stops with Stop Consolidation	Trolleys Only	9:52.0	-01:49.7	-15.6%
	All Other Vehicles	7:45.5	+01:15.2	19.3%
3.d Far-Side Stops with Signal Optimizations and Stop Consolidation	Trolleys Only	9:22.1	-02:19.5	-19.9%
	All Other Vehicles	6:39.9	+00:09.6	2.5%

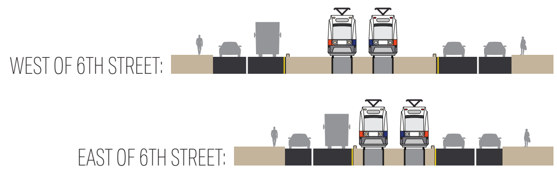




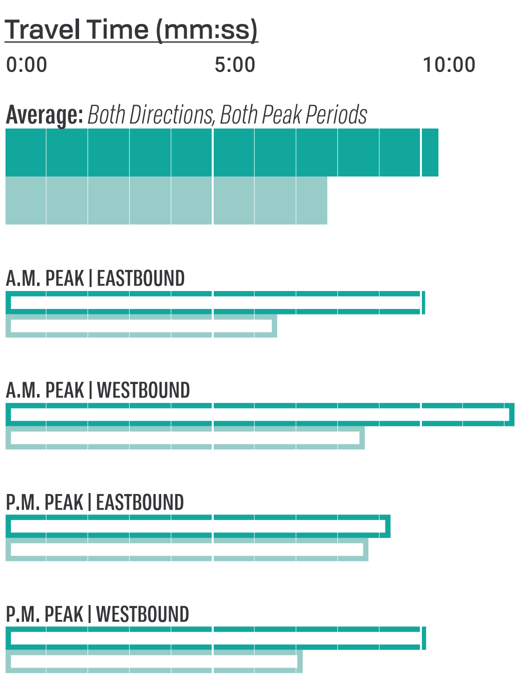
Trolleys Only All Other Vehicles

3.A Far-Side Stops

+ Dedicated trolley right-of-way
+ Far-side stops
+ Existing stop spacing



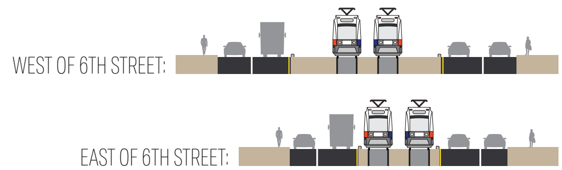
Scenario results (mm:ss)	Average	A.M. Peak Eastbound	A.M. Peak Westbound	P.M. Peak Eastbound	P.M. Peak Westbound
Trolleys Only	**10:24.5**	10:04.4	12:13.2	9:14.7	10:05.7
All Other Vehicles	**7:44.9**	6:31.3	8:37.4	8:42.8	7:08.1
Change from existing conditions (mm:ss)					
Trolleys Only	**- 01:17.1**	- 02:00.9	- 00:17.9	- 02:27.2	- 00:22.6
All Other Vehicles	**+ 01:14.6**	+ 00:24.1	+ 01:01.4	+ 02:20.9	+ 01:12.2
Change from existing conditions (%)					
Trolleys Only	**-11.0%**	-16.7%	-2.4%	-21.0%	-3.6%
All Other Vehicles	**+ 19.1%**	+ 6.6%	+ 13.5%	+ 36.9%	+ 20.3%



Trolleys Only   All Other Vehicles

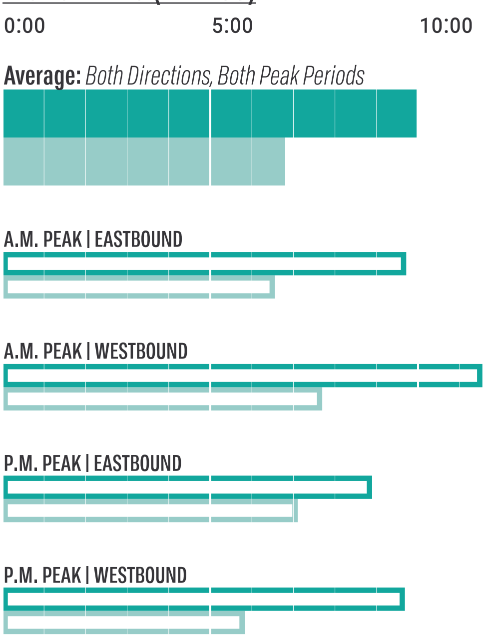
3.B Far-Side Stops with Signal Optimizations

+ Dedicated trolley right-of-way
+ Far-side stops
+ Existing stop spacing
+ Signal timings and offsets optimized

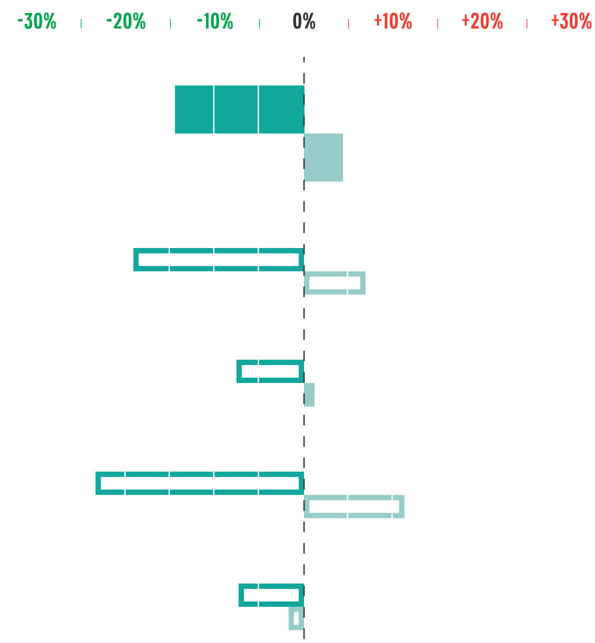


Scenario results (mm:ss)	*Average*	*A.M. Peak* Eastbound	*A.M. Peak* Westbound	*P.M. Peak* Eastbound	*P.M. Peak* Westbound
Trolleys Only	**9:57.6**	9:42.9	11:32.8	8:53.5	9:41.0
All Other Vehicles	**6:47.6**	6:33.2	7:41.5	7:06.1	5:49.6
Change from existing conditions (mm:ss)					
Trolleys Only	**- 01:44.1**	- 02:22.4	- 00:58.4	- 02:48.4	- 00:47.3
All Other Vehicles	**+ 00:17.3**	+ 00:26.0	+ 00:05.5	+ 00:44.1	-00:06.3
Change from existing conditions (%)					
Trolleys Only	**-14.8%**	-19.6%	-7.8%	-24.0%	-7.5%
All Other Vehicles	**4.4%**	+ 7.1%	+ 1.2%	+ 11.6%	-1.8%

Travel Time (mm:ss)



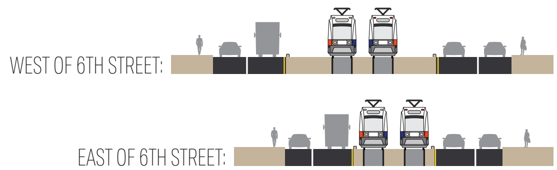
Travel Time Change From Existing Conditions (%)



Trolleys Only   All Other Vehicles

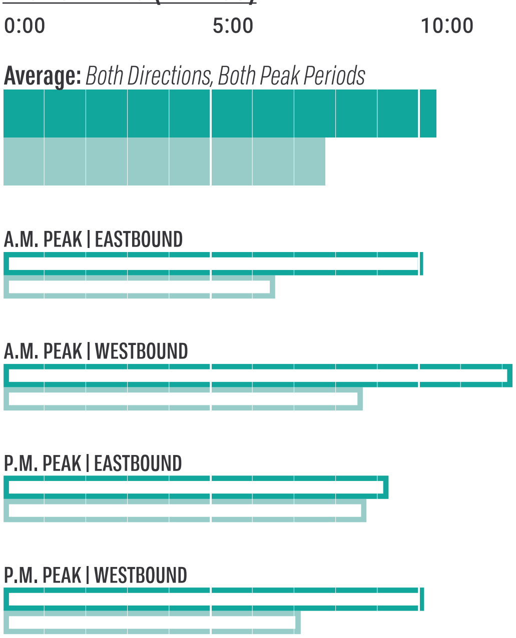
3.C Far-Side Stops with Stop Consolidation

+ Dedicated trolley right-of-way
+ Far-side stops
+ 33 percent stop consolidation

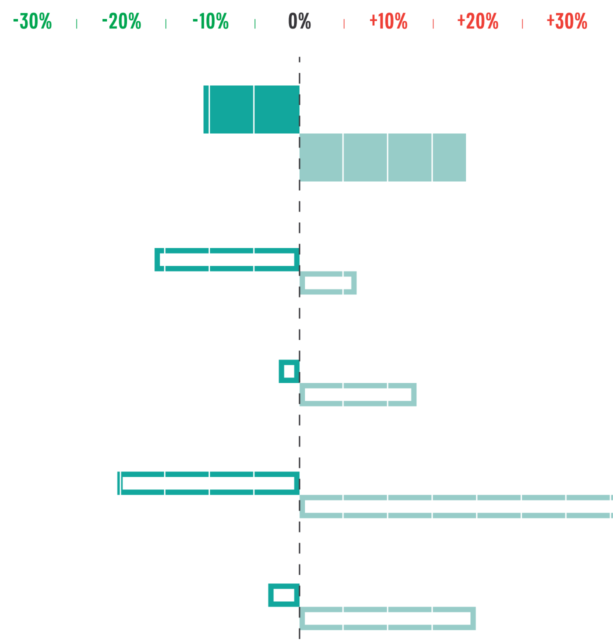


Scenario results (mm:ss)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Trolleys Only	**10:24.5**	10:04.4	12:13.2	9:14.7	10:05.7
All Other Vehicles	**7:44.9**	6:31.3	8:37.4	8:42.8	7:08.1
Change from existing conditions (mm:ss)					
Trolleys Only	**- 01:17.1**	- 02:00.9	- 00:17.9	- 02:27.2	- 00:22.6
All Other Vehicles	**+ 01:14.6**	+ 00:24.1	+ 01:01.4	+ 02:20.9	+ 01:12.2
Change from existing conditions (%)					
Trolleys Only	**-11.0%**	-16.7%	-2.4%	-21.0%	-3.6%
All Other Vehicles	**+ 19.1%**	+ 6.6%	+ 13.5%	+ 36.9%	+ 20.3%

Travel Time (mm:ss)

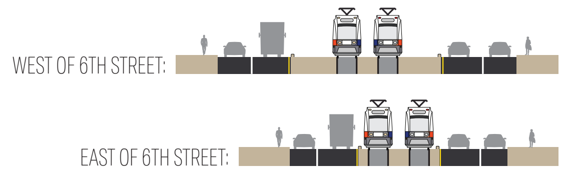


Travel Time Change From Existing Conditions (%)



Trolleys Only   All Other Vehicles

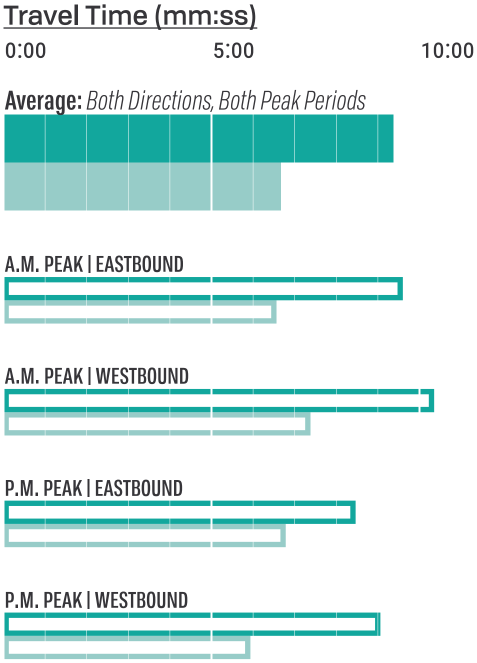
3.D Far-Side Stops with Signal Optimizations



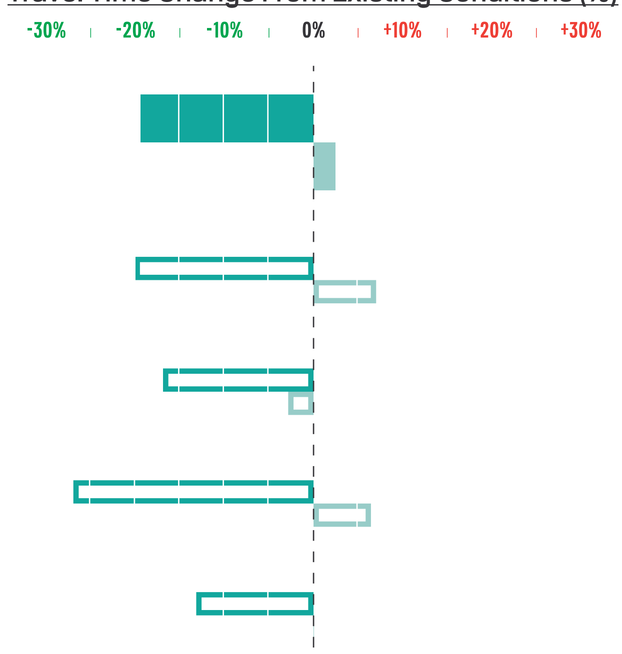
+ Dedicated trolley right-of-way
+ Far-side stops
+ 33 percent stop consolidation
+ Signal timings and offsets optimized

Scenario results (mm:ss)	*Average*	*A.M. Peak* *Eastbound*	*A.M. Peak* *Westbound*	*P.M. Peak* *Eastbound*	*P.M. Peak* *Westbound*
Trolleys Only	**9:22.1**	9:36.0	10:21.2	8:27.9	9:03.5
All Other Vehicles	**6:39.9**	6:33.7	7:22.8	6:47.1	5:56.1
Change from existing conditions (mm:ss)					
Trolleys Only	**- 02:19.5**	- 02:29.3	- 02:10.0	- 03:13.9	- 01:24.7
All Other Vehicles	**+ 00:09.6**	+ 00:26.5	- 00:13.3	+ 00:25.2	+ 00:00.2
Change from existing conditions (%)					
Trolleys Only	**-19.9%**	- 20.6%	- 17.3%	- 27.6%	- 13.5%
All Other Vehicles	**+ 2.5%**	+ 7.2%	- 2.9%	+ 6.6%	+ 0.1%

Travel Time (mm:ss)



Travel Time Change From Existing Conditions (%)



Trolleys Only   All Other Vehicles

Model Development

Two of PTV Vision's software packages, VISUM and VISSIM, served as the primary modeling tools used for the technical analysis for this project. DVRPC's regional VISUM forecasting model and served as the macro-level demand package. VISSIM is a micro-level traffic analysis simulator that allows for realistic replication of multi-modal transportation networks.

The greater Route 15 study area encompassing the blocks surrounding Girard Avenue, from Broad Street to Frankford Avenue, was isolated and exported from VISUM, then imported into VISSIM via an automated process. The buffer of several blocks surrounding Girard Avenue ensured all relevant travel demand data would be included in the export. This step also served as a significant time savings compared to building the network from scratch in VISSIM. This VISUM export included all of the transit data, such as routes and timetables for the study area.

Once opened in VISSIM, the network was trimmed to replicate only the immediate study area and cross streets. The roadway system was adjusted to better match the underlying aerial images. Additionally, the network was quality checked for prohibited turning movements, directionality, lane configuration, roadway width, and other geometric parameters. Vehicular travel speeds were assigned for all vehicles entering the network at speeds in a distribution that centered slightly above the posted speed limit of 25 mph. Reduced speed areas were also inserted to ensure vehicles made turns at the appropriate speeds.

Turning movement counts for this study were collected by video at all signalized intersections during the spring of 2017. An examination of these counts during the peak periods was performed. The hour during the AM and PM peak periods where volumes were highest would serve as the peak hour. This hour would also serve as the hour used for performance reporting. These hours were determined to be 7:30-8:30 AM and 4:30-5:30 PM.

Turning movements for the respective peak hours were plotted and balanced. Once this was completed, it was noted that large discrepancies existed between the signalized intersections. A re-examination of the videos revealed significant side street activity throughout the corridor. The videos were then reviewed to collect the side street and mid-block turning movements. Turning movements to/from the side streets were then added to the plotted network. Once this was completed, only minor adjustments were needed to complete end-to-end volume balancing for the respective AM and PM peak hours.

The balanced vehicular volumes served as input to the model. Other data inputs and field-collected measurements included traffic signal timing and offsets, peak period heavy vehicle percentages, stop-control, yield parameters, and vehicle routes.

Pedestrian crossing counts were taken as part of the data collection efforts for this project. Directional pedestrian volumes were entered into the model for the respective peak hours at all locations where pedestrians were recorded. Additionally, conflict areas were set in VISSIM to ensure that vehicles yield to pedestrians.

Model Calibration

Vehicular Calibration

The model was set up for peak hour simulations and to collect performance measurements. In order to avoid collecting data on an empty network when the simulation begins, a 15-minute 'seeding time' was run prior to the peak hour. A 75-minute simulation is run, but data is collected for the last 60 minutes. Volumes during the seeding periods are set slightly lower than during the actual peak our, typically 80 percent volume.

Data collection points were input into the model at all intersections throughout the network. These points collect vehicle information each time a vehicle passes over, given a defined time period. The simulation was run, and the turning movements in the simulation (via data collection points) were compared to the target counts. This was done in a spreadsheet and set up for simple comparison.

In order for simulated volumes to better match counted volume targets, small adjustments were made to the volume input, vehicle routing distribution, or a combination of both. This continued until a reasonable level of calibration was achieved for through, turning, and mid-block volumes.

Transit Calibration

Trolley timetables embedded in VISSIM were checked against published SEPTA schedules. The headway times for the Route 15 trolleys eastbound at Broad and westbound on Frankford were verified. Travel time segments were set up in VISSIM to capture end-to-end trolley times and checked against the SEPTA schedule.

A robust dataset of Route 15 trolley ridership was provided by SEPTA. Boarding, alighting, and occupancy data, by direction, for the AM and PM peak hours were mined and averaged across many weekdays.

The intersection turning movement videos were also used to collect more detailed trolley ridership data. Many of the trolley stops could be viewed from the traffic count videos, and boarding/alighting counts were taken where visible to supplement SEPTA's dataset.

The traffic count videos also offered a visual method for collecting detailed stop-level ridership of existing trolley service. The following dwell time information was tabulated:

+ *Complete stop to the start of boarding*
+ *Per-passenger boarding/alighting time*
+ *Last boarding/alighting to doors close*
+ *Doors close to vehicle starts moving*

Approximately 50 samples were acquired and averaged. Data was gathered primarily at stops in the middle of the corridor at lower-volume stop locations. The *Complete stop to the start of boarding* was found to be 1.8 seconds. For *passenger boarding/alighting time*, the greater of the two was divided by the total boarding/alighting time. For all sample records, whether boarding or alighting, the average per-passenger time was 2.5 seconds. The *last boarding/alighting to doors close* was 2.86 seconds. The *doors close to vehicle starts moving* was 2.67 seconds.

This information was entered into VISSIM as a per-stop dwell time. In calculating a time distribution, a standard deviation of .56 was used. This was calculated by dividing the average per-passenger boarding/alighting time (2.5 seconds) by the standard deviation of the per-passenger boarding/alighting time (1.41 seconds) to get a factor of .56. This follows the methodology outlined in the *Transit Capacity and Quality of Service Manual, 3rd Edition*.

Several build scenarios involved substituting trolley service with bus service. Dwell time data for bus service was collected via existing video counts from bus stops on Spring Garden Street and Erie Avenue, which feature SEPTA routes similar to Route 15. Approximately 40 samples were collected. Mimicking data collection for trolley dwell time, the same information was collected for SEPTA buses. The *Complete stop to the start of boarding* was found to be 1.89 seconds. For boarding/alighting time, the greater of the two was divided by the total boarding/alighting time. For all sample records, whether boarding or alighting, the average per person time was 2.57 seconds. The *Last boarding/alighting to doors close* was 3.91 seconds. The *Doors close to vehicle starts moving* was 1.11 seconds. Incidentally, we observed several instances of buses moving before closing the doors, which were averaged in as zero-second samples. In aggregate, dwell time operations for buses were very similar to that of the Route 15 trolley.

Before the VISSIM network was ready for performance collection, a visual inspection of the simulation was conducted. This included examining the interaction between modes (transit, vehicular, pedestrian), gap acceptance, and following distances. Other driver-behavior parameters were adjusted as needed to ensure the network was coded appropriately.

Dwell Time: Existing Conditions	
Complete stop to the start of boarding	1.8 sec.
Per-passenger boarding/alighting time	2.5 sec.
Last boarding/alighting to doors close	2.86 sec.
Doors close to vehicle starts moving	2.67 sec.
Per-stop dwell time:	7.33 sec. + 2.5 sec. per passenger

Dwell Time: Curbside Bus Service	
Complete stop to the start of boarding	1.89 sec.
Per-passenger boarding/alighting time	2.57 sec.
Last boarding/alighting to doors close	3.91 sec.
Doors close to vehicle starts moving	1.11 sec.
Per-stop dwell time:	6.91 sec. + 2.57 sec. per passenger

Dwell Time: Basic Trolley Modernization	
Complete stop to the start of boarding	1.8 sec.
Per-passenger boarding/alighting time	1.2 sec.
Last boarding/alighting to doors close	2.86 sec.
Doors close to vehicle starts moving	2.67 sec.
Per-stop dwell time:	7.33 sec. + 1.2 sec. per passenger

Dwell Time: Premium Trolley Modernization	
Complete stop to the start of boarding	1.8 sec.
Per-passenger boarding/alighting time	1.2 sec.
Last boarding/alighting to doors close	2.86 sec.
Doors close to vehicle starts moving	2.67 sec.
Per stop dwell time:	7.33 sec. + 1.2 sec. per passenger

Build Scenarios and Iterations

Over 20 scenarios were developed for both the AM and PM peak hour models. Most involved some combination of the following interventions: existing conditions, bus service, modern trolley vehicles, a dedicated trolley right-of-way, stop consolidation, and new signal timings.

Existing Conditions

The Existing Conditions scenario reflects the traffic conditions on a typical travel day during 2017. Data input from real-world conditions are modeled and calibrated. This serves as a baseline from which subsequent scenarios can be compared.

Curbside Bus Service

For the Curbside Bus Service scenario, dwell times were updated to reflect bus operations. The modeled vehicle was changed from a 53' trolley to a 40' bus. Also, the bus was not limited to the right lane. Buses were allowed to change lanes based on traffic conditions, though this rarely occurred in the simulations. Buses were modeled with the same boardings/alighting volumes as the existing trolley, and adhere to same schedules and headways.

Basic Trolley Modernization

To reflect improvements yielded from a modern trolley vehicle, per-passenger boarding times were taken from *Analysis of Modernization Scenarios for SEPTA Route 34*, page 5. This document suggested a per-passenger time of 1.2 seconds. The significant decrease in per-passenger boarding/alighting time vs. the existing trolley can be attributed to near-level platforms, expedited fare payment, and wider, multi-door operations.

Because no specific vehicle has been selected by SEPTA, operational characteristics of new trolleys are still unknown. As a result, the other parameters of dwell time (complete stop to the start of boarding, last boarding/alighting to doors close, and doors close to vehicle starts moving) were kept the same as the existing trolley.

The trolley is assumed to be 80' long and modeled to that length. The stop areas were lengthened to 90' to accommodate the new trolley. Lastly, in the VISSIM model, it is important to understand that it is not required for a transit vehicle to be completely over a designated stop to board/alight passengers. Passenger activity can occur when a transit vehicle is partially aligned with a modeled stop location.

Premium Trolley Modernization

The Premium Trolley Modernization scenario eliminates one travel lane in each direction on Girard between Frankford Avenue and Broad Street. The reassigned capacity from the lane reduction is used for creating an exclusive, transit-only lane in the middle of Girard. Due to the dedicated transit lanes, mid-block crossings by vehicles have been eliminated. All unsignalized side streets function as right-in/right-out under Premium Trolley Modernization conditions. This includes the intersection at Girard Avenue and 9th Street. This intersection is currently stop controlled, but the median is closed in this build scenario.

The mid-block closure of the median along Girard displaces a significant number of vehicles turning to and from the side streets. In the model, displaced volumes were shifted to the next logical intersection from which turns are permitted. This required shifting volumes and routes within VISSIM. It is important to note that the total number of vehicles turning to/from/across Girard Avenue was held constant.

To allow for left turns to be made at the signalized intersections, a short, protected-only turn phase is introduced. With center-running transit, permitted left turns can no longer be allowed. Furthermore, to reduce redundancy and unnecessary delay, left turns were eliminated at 7th Street and Franklin Street. Left turning vehicles were shifted to 8th Street, which allows both eastbound and westbound left turns.

With the introduction of a left-turn phase at many of the signalized intersections, new signal timings needed to be developed. Using signal optimization software, signal timing data was entered into the network that was previously used to balance the volumes. Optimization was run for the peak traffic flows: AM westbound and PM eastbound. Several iterations of optimized timings were tested. The end result yielded new offsets for improved traffic flow.

In order to accommodate a left-turn phase, the green time for the through movement in the opposite direction needed to be reduced. In the new timing scheme, all signals on Girard Avenue operate on a 90 second cycle length, with typically a 60/30 split for Girard Avenue/side street. At intersections with a protected left turn, the opposite green time is reduced from 55 seconds to 45 seconds.

Several alternatives to reducing green time were investigated. One option was to increase the cycle length, but this would have to be done at all intersections to maintain the offsets. The other option was to reduce green time from the side streets at signalized intersections. However, in the eastern part of the study area, the addition of a left turn lane widens the cross width on Girard from 60' to roughly 75', requiring more time for safe pedestrian crossings. In the western half, the cross-section is approximately 90' wide, requiring a 26-second pedestrian crossing time (with an assumed 3.5 foot/second walking speed.) As a result, reducing green time at side streets was not a viable solution.

Stop Consolidation

As mentioned in the report, transit stops were eliminated at 2nd, 7th, and 12th Streets eastbound and 2nd, 4th, 7th, and 12th Streets westbound. These stops were selected with the goal of retaining the highest-ridership stops, while balancing the resulting distance between stops. Various iterations of stop consolidation were tested. For each, the ridership at the removed stop was shifted, depending on the proximity to the nearest adjacent stop or stops.

Performance Reporting

The primary performance reporting measure collected from the VISSIM simulations was travel time. Travel time segments were set up at several beginning and end points, both eastbound and westbound, to capture the travel times and speeds of both transit and passenger vehicles. Only vehicles that completed the entire travel segment are recorded. In order to get an effective sample size, 15 random seeds of all iterations were run. Typically by direction, 5 or 6 transit vehicles complete their run during the peak hour. This allows for data to be collected on a large sample (5.5 x 15 = 82.5). Data from multiple simulations is automatically averaged in VISSIM. With a known distance, travel times can be converted to operating speeds for quick comparison.

Nodes were also set up in VISSIM at all signalized intersections. Nodes collect delay data on individual approach and movement. This data can be post-processed and aggregated to intersection delay, and the appropriate level-of-service can be assigned. Because the amount of this data is overwhelming, this information was not included in this report.

For scenario comparison, network-wide statistics were used. Average delay, average speed, and average stopped delay were collected and calculated as an aggregation of all vehicles in the network, for the entire time they are on the network.

Transit Signal Priority

Transit Signal Priority (TSP) is an adjustment to a traffic signal whereby the signal timing is modified in response to a transit vehicle. Typically, the green phase is extended to provide more time for the transit vehicle to pass through the intersection. TSP was considered by the project team as a possible study task. After careful consideration, the work required to build and test TSP within the VISSIM model was not regarded as cost-effective exercise. Travel time improvement for transit vehicles aided by TSP applications are well documented, and expected improvements from TSP could be applied on Girard Avenue simply as a factor or a percent reduction in travel time.

ROUTE 15 TROLLEY MODERNIZATION: OPERATIONS ANALYSIS FOR EASTERN GIRARD AVENUE

Publication Number: 18028

Publication Date: June 2019

Geographic Area Covered: Philadelphia, Pennsylvania

Key Words: Trolley Modernization, SEPTA, Route 15, accessibility, microsimulation

Abstract: SEPTA is preparing to replace its trolley fleet with accessible light rail vehicles. This project tests the travel time effects of new trolleys on Route 15 using a microsimulation model. We estimate that replacing trolleys with curbside-lane-running buses would yield either a travel time penalty, or a very slight benefit for transit riders, depending on the interventions made. We find that modern trolleys can offer significant travel time savings within the study area, and even greater travel time savings when prioritized in a dedicated right-of-way.

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