Before-and-After Studies of New Starts Projects

Report to Congress

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Prepared by:

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FOREWORD

This eighth annual report to Congress on Before-and-After Studies summarizes the findings for three projects that opened to service in 2011 and 2012, presented in order of their opening date:

1. Mid-Jordan Light Rail Project; Salt Lake City, UT (August 2011)
2. Northshore Connector Light Rail Project; Pittsburgh, PA (March 2012)
3. Streetcar Loop Project; Portland, OR (September 2012)

Before-and-After Studies help sponsoring agencies and the Federal Transit Administration (FTA) to accumulate insights into the actual costs and impacts of major capital transit investments and to evaluate the accuracy of the predictions of the costs and impacts made for these projects.

Each Before-and-After Study documents the actual outcomes of a New Starts or Small Starts project in five dimensions: physical scope, capital costs, transit service levels, operating and maintenance costs, and ridership. To support this part of the study, project sponsors collect data on actual conditions before and after implementation of the project. The "before" data collection occurs before any impacts of the project are realized – soon before the project opens to service or, in some cases, before project construction disrupts transit service and ridership in the corridor. The "after" data collection for physical scope and capital costs occurs immediately after project opening. The "after" data collection for changes in transit service, operating and maintenance costs, and ridership occurs two years after the project opens in order to permit conditions to stabilize.

The study also examines the accuracy of, and causes of any inaccuracies in, the predictions that were provided by project sponsors to the FTA to support FTA's ratings of the project and decisions on advancing and recommending projects for funding. The number of these points depends on the nature of each project (New Starts or Small Starts) and the FTA procedures under which it was developed. The project summaries in this report identify the decision points for each project.

This report reflects the full extent of information that FTA has obtained from the sponsors of these three projects.

Mid-Jordan Light Rail Project; Salt Lake City, Utah

The Mid-Jordan Light Rail Project is a 10.6 mile, at-grade, double tracked addition to the Utah Transit Authority's (UTA) TRAX light rail system. The project is located in the southwest quadrant of the Salt Lake Valley in Salt Lake County and traverses parts of the cities of Murray, Midvale, West Jordan, and South Jordan as well as the new major community of Daybreak. The project connects to the TRAX North-South line, built in the late 1990s, at the Fashion Place West Station. Figure 1 provides a map of the project.

UTA planned and built the Mid-Jordan line and now operates service on the line as part of the TRAX system.

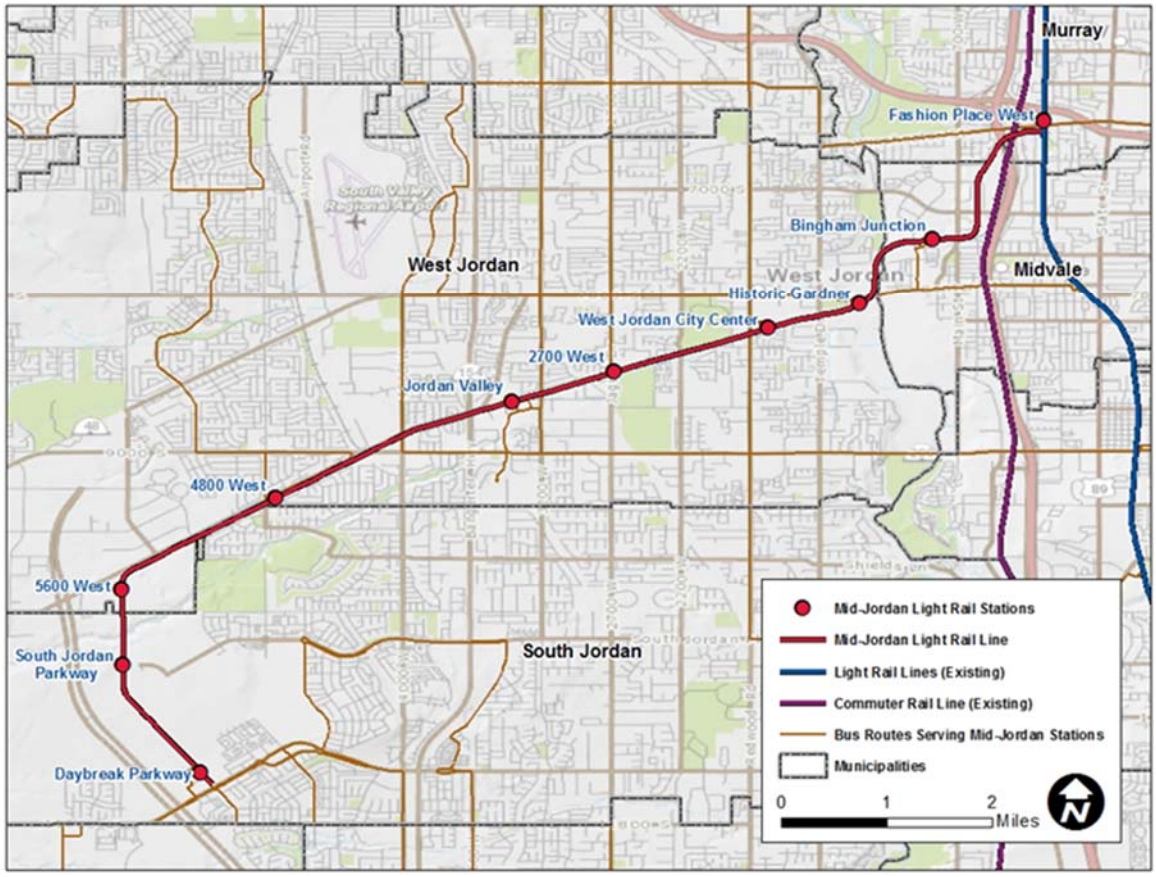

Figure 1. The Mid-Jordan Light Rail Extension

In December 2000, the South Salt Lake County Transit Corridors Analysis identified the Mid-Jordan corridor as a priority for transit improvements. In July 2005, UTA completed a Draft Environmental Impact Statement (EIS) that considered alternative transit investments in the corridor. Based on this analysis, UTA selected a light rail project as the locally preferred alternative for the corridor. These studies emphasized the importance of high capacity transit as part of a "shared solution" to meet regional transportation and land use goals and to prepare for the projected 60 percent growth in population and employment by 2030 in Salt Lake County generally and even higher growth anticipated specifically in the southwest quadrant of the county.

The project entered into Preliminary Engineering (PE) in May 2007, entered into Final Design (FD) in April 2008, received a Full Funding Grant Agreement (FFGA) in January 2009, and opened to service in August 2011.

Development of the Mid-Jordan project occurred as part of an ongoing program of rail construction by UTA that began in the mid-1990s. Under that program, UTA completed multiple rail projects: the TRAX North/South line in 1999, the TRAX University Line in 2001, FrontRunner Commuter Rail North in 2008, the Mid Jordan and West Valley TRAX branches in 2011, FrontRunner South in 2012, and the Airport TRAX extension in 2013.

Physical scope of the project

The Mid-Jordan Light Rail project is 10.6 miles long and double-tracked throughout. The project is entirely at-grade but is located in two different environments. For 8.3 miles southwest from its junction with UTA's North/South line, the project is located in the right-of-way (ROW) of the former Union Pacific Railroad (UPRR) Bingham Branch. The ROW ranges from 50 to 200 feet wide, more than sufficient to accommodate two tracks. The UPRR Bingham Branch was single-tracked, however; so all bridges and underpasses were built to accommodate only one track. UTA purchased this ROW from UPRR in 2002 under an agreement that permits continued freight service in this 8.3-mile section, operating only during night-time hours when TRAX provides no service.

The scope of the Mid-Jordan project in this segment included the replacement of the existing single track, the addition of a second track, and the provision of revised connections to freight sidings. For the eight existing structures, all of which accommodated only the single freight track, the scope included either (1) continued use of the existing structure plus the addition of a second structure for the second track or (2) replacement of the existing structure with a new 2-track structure.

At approximately 5600 West, the Mid-Jordan line leaves the railroad ROW and follows the alignment of a future roadway for 2.3 miles to a terminus in the Daybreak development in South Jordan. Both tracks are located on ballast in the median of the future roadway, separated from the roadway by curbs. The roadway will be one lane in each direction with signalized intersections approximately every tenth of a mile through the major downtown area envisioned for the future.

The Mid-Jordan extension added nine new stations, each with feeder-bus facilities and a park-and-ride lot or structure that together provide a total of 3,100 parking spaces. The low-level rail platforms are 400 feet long and are equipped with ticket vending machines (TVM). All stations comply with requirements of the Americans with Disabilities Act for access to transit service. The project also expanded the Fashion Place West Station (originally built as part of UTA's North/South project) to add a new platform, a new parking lot, and a new third track to allow greater operating flexibility at the junction with the TRAX North/South line. An overhead catenary power distribution system and eight substations electrify the line. As part of the project, UTA acquired 28 new low-floor light rail vehicles and expanded the capacity of the Lovendahl Rail Service Maintenance Facility in Midvale from 69 to 100 rail vehicles. The project crosses 16 active roadways at grade. At another 12 at-grade crossings that will eventually be built as the

roadway system in the Daybreak area is completed, the project scope included only the construction of the underground elements of the crossings so as to avoid future disruptions to service. Other elements of the future crossings were outside of the project scope.

UTA's predictions of project scope during the development of the Mid-Jordan project accurately anticipated the length of line, the ROW requirements, the number of stations and rail vehicles, and the nature and extent of systems elements. At PE-entry, differences from the as-built scope of the project were generally minor. The largest differences related to the way that UTA planned to adapt the UPRR line to joint use by transit and freight operations. At PE-entry, UTA planned a three-track configuration that retained the single UPRR track and its structures and built new double tracks and structures for the light rail line. During PE, however, UTA entered into successful negotiations with UPRR to instead demolish the existing UPRR single track, build an entirely new double-track facility for both freight and light rail, and separate transit and freight operations by time-of-day restrictions. Other minor elements missing from the anticipated scope at PE-entry included items typically identified during PE as the physical scope of the project is refined including additional trackwork, fencing, and relocation of unanticipated utilities in the right-of-way.

One element of the scope was over-estimated at PE-entry. The scope anticipated 4,377 parking spaces in total at the Mid-Jordan stations, based on ridership forecasts and projected parking needs for the 2030 horizon year. Subsequently, FTA agreed to participate in funding only those spaces that would be required in the opening year of the project; so UTA reduced the number of parking spaces during PE, eventually building 3,103 spaces.

UTA engaged a design-build contractor six months prior to entry of the project into FD. This arrangement allowed UTA and the design-build contractor to make significant progress towards final design and address many potential risk issues before FD-entry. As a result, UTA did not have to make scope changes during the nine months between entry into FD and the FFGA.

At the FFGA, the anticipated scope of the project matched the actual as-build scope with one isolated exception. UTA did not anticipate the opportunity that arose after the FFGA to create a Transit Oriented Development (TOD) at the Jordan Valley station. To conserve land for the development, two parking structures were built at that station rather than the surface parking lot anticipated at the FFGA.

UTA's success in the accurate prediction of the project scope, even at early milestones, reflects four characteristics of the context for the Mid-Jordan project. First, the right-of-way for the project was friendly to light-rail construction in both the UPRR and future-roadway segments. Second, UTA's experience with implementing light rail projects in similar settings helped the agency to predict accurately the Mid-Jordan scope, beginning in early project planning. Third, UTA's experience with the UPRR as part of both the initial North/South light-rail project and the Frontrunner commuter rail projects prepared the agency for early negotiations with UPRR. Finally, the engagement of a design-build contractor at the conclusion of PE and entry to FD stabilized the scope of the project, reduced overall risk, and helped UTA to complete the project on schedule.

Capital cost

The actual cost of the Mid-Jordan project was $509.8 million in year-of-expenditure (YOE) dollars, equivalent to $48.1 million per mile ($38.0 million per mile excluding the vehicles). The subtotal cost of construction of physical facilities was $269 million (53 percent of the total project cost). The 28 new light rail vehicles cost $107.1 million, a relatively high share (21 percent) of the total cost because trains serving the 10.6-mile Mid-Jordan extension also run through downtown Salt Lake City to the University – a total of 23 miles. The required number of vehicles therefore reflects new rail service that extends well beyond the limits of the project itself. Notably, the construction of guideway and track elements cost only $47.4 million (9.3 percent) of total project costs because 98.7 percent of the project is at grade, the alignment includes few bridges over roadways or watercourses, and UTA was able to use some of the existing UPRR bridges and infrastructure.

At PE-entry in 2007, UTA predicted that the project would cost $521.8 million, an overestimate of $12.9 million (2.5 percent). This small overestimate resulted from UTA's projection that the annual rate of inflation in construction costs would continue at the high levels that occurred over the previous several years. Inflation cooled significantly, however, with the subsequent onset of the severe national recession in 2008 and actual inflation effects were lower than UTA anticipated. This overestimate of inflation costs was partially offset by an $8.6 million underestimate of the constant-dollar (uninflated) cost prediction – largely caused by the minor elements missing at PE-entry from the project scope. It was also partially offset by an underestimate of the costs of subsequent delays in the construction schedule.

At FD-entry in 2008, UTA predicted that the project would cost $535.4 million, an overestimate of 5.2 percent. As at PE-entry, this overestimate was driven primarily by the assumption of persistently high inflation in construction costs. In contrast to the prediction at PE-entry, the underestimates of constant-dollar costs and the construction schedule had been corrected and no longer offset the overestimate of inflation effects.

At the FFGA in 2009, UTA continued to use the $535.4 million cost estimate as the best available prediction of project costs. Overall, the predicted capital costs at all three project-development milestones were quite accurate.

Transit service

The TRAX Red Line provides service on the Mid-Jordan extension. Figure 2 shows the Red Line in the context of entire UTA light rail system. The Red Line extends from the Daybreak station along the full length of the project, merges with the Blue Line as it heads north into downtown, and then turns east to its terminus at the University Medical Center.

Red Line service operates every day of the week: at 15-minute headways from 5:00 a.m. until midnight Mondays through Saturdays; and on 20-minute headways from 9:30 a.m. until and 8:45 p.m. on Sundays. Travel time on the project itself, from the Daybreak station to the junction with the Blue Line is 21 minutes, including stops at stations – an average speed of 30 mph. Travel time on the full length of the Red Line – from Daybreak station to its terminus at the University of Utah – is 59 minutes – an average speed of 23 mph.

Bus connections are available at six of the nine new stations on the Mid-Jordan project. Most connecting buses operate on weekdays only, with 30-minute headways in peak periods and 60-minute headways off-peak.

Prior to the Mid-Jordan extension, the TRAX system comprised two lines: the North-South line from downtown Sandy to the Intermodal Hub (the connection to the FrontRunner commuter rail line now renamed Salt Lake Central station) just west of downtown Salt Lake City; and the University line running east-west from Salt Lake Central station to the University of Utah Medical Center. Both TRAX lines operated on 15-minute headways on weekdays and 20-minute headways on weekends. TRAX riders from the south reached the University of Utah by transferring at the Courthouse station in downtown Salt Lake City from the North-South line to the University line, or by waiting for a less-frequent service variation that routed North-South trains directly to the University. This additional university-direct service, added to the 15-minute headway of the basic North-South service, yielded a combined 12-minute headway during weekday peak periods as far as the Courthouse station in downtown.

Figure 2. The Red Line and the 2013 TRAX System

The opening of the Mid-Jordan extension in September 2011 was part of a large expansion of the TRAX light rail system between 2011 and 2013. The 2011-2013 TRAX extensions were Mid-Jordan (September 2011), West Valley (September 2011), Salt Lake City International Airport (May 2013), and Draper Town Center (August 2013). . (The FrontRunner South project also opened during this interval in December 2012.)

With these openings, UTA reconfigured TRAX service into three lines – Red, Blue, and Green – and dropped the east-west line between the Intermodal Hub and the University Medical Center. Figure 2 shows the revised services on the TRAX system. All three TRAX lines operate on 15-minute headways on weekdays and 20-minute headways on weekends. These changes had three significant consequences for existing TRAX riders.

First, the changes improved transit access to and from the corridors served by the extensions. Second, they made TRAX service more frequent at most stations on the north-south segment. Where the Red Line and Blue Line share tracks into downtown, the combined headway became 7.5 minutes on weekdays and 10 minutes on weekend days compared with the previous 15- and 20-minute headways, respectively. Over the short distance where the Green Line also shares these tracks, the combined headways became 5.0 minutes peak and 6.7 minutes off-peak. Third,

for riders from existing stations south of the junction of the Red and Blue lines, the changes made TRAX service marginally less convenient. With the elimination of the university-direct service, the combined headway to the Courthouse station lengthened from 12 to 15 minutes and all riders destined for the University now had to transfer to a Red Line train.

The 2011-2013 expansion of the TRAX system occurred simultaneously with UTA's reduction of its operating budget in response to declining sales tax revenues caused by the national recession. Since the opening of the extensions, UTA has slightly reduced weekend rail service and moderately reduced bus service by (1) the elimination of some express routes, (2) cut-backs of some fixed- and flex-routes to feeders at Red or Green Line stations, and (3) conversion of other fixed routes to flex-routes. Flex routes help to maintain geographic coverage by departing from their fixed routings at riders' requests for an additional fare. Overall in the Mid-Jordan corridor, these changes reduced bus-miles of service by six percent.

UTA accurately anticipated the broad outlines of the light-rail system expansion during the planning and development of the Mid-Jordan project. Predicted hours of service, headways, and operating speeds for TRAX matched the actual outcomes closely for Monday through Thursday service. Predictions for weekend LRT service were similar to the actual outcomes but anticipated somewhat more frequent service and slightly longer service hours. The predictions at each milestone for TRAX did not foresee systems-level decisions made after the Mid-Jordan FFGA that revised the pairing of southern and northern termini of two lines. UTA revised the Red Line to run from the Mid-Jordan extension to the University rather than its earlier planned terminus at the Intermodal Hub. UTA also revised the Green Line to run from West Valley to the Airport rather than to the University. UTA continued with the plan to operate Sandy/Draper trains to the Intermodal Hub.

Predicted bus service levels did not anticipate the sales tax revenue declines during the recession or the resulting moderate reductions in bus service. Bus services predicted for the Mid-Jordan corridor after project opening included the retention of some express services and the addition of bus rapid transit (BRT) routes but did not include the introduction of cost-saving flex routes. The actual bus network includes flex routes (also introduced in other corridors) and the elimination of all express bus services. UTA anticipates the implementation of the BRT routes when operating revenues permit their introduction in the future.

Operating and maintenance (O&M) costs

In 2013, the actual system-wide O&M cost of UTA's bus and light rail service was $61.0 million -- $51.1 million for bus and $9.9 million for TRAX light rail. Based on an allocation of TRAX costs based on the vehicle-hours and vehicle-miles of service on each operating line, the actual O&M cost for the entire Red Line was $4.1 million, of which $1.7 million was attributable to service on the Mid-Jordan extension itself.

To predict the additional O&M costs of the Mid-Jordan and West Valley project openings in 2011, UTA extrapolated from the costs predicted by the agency's O&M cost model for the TRAX system in place at the time. The predictions matched the actual outcome fairly well, underestimating Mid-Jordan O&M costs by seven percent at PE-entry and 12 percent at FD-entry.

Ridership

Actual ridership on the project was 7,400 trips per average weekday in 2013, two years after project opening. Of this total, 81 percent were made by residents of the corridor traveling to locations outside of the corridor. Some 70 percent of these trips (equivalent to 57 percent of all trips on the project) were to jobs, school, and other activities in the urban core comprising downtown Salt Lake City, the University, and other areas east of downtown. Only 15 percent of all trips on the project were made by residents of other areas traveling to jobs and other activities in the Mid-Jordan corridor. The remaining 4 percent were made entirely within the corridor itself.

At FD-entry and the FFGA, UTA predicted that 6,300 weekday trips would be made on the project in its opening year, an under-prediction of 15.0 percent. Within this overall outcome, the prediction of trips by corridor residents to other areas was low by 28 percent – almost entirely for travel to the urban core. Offsetting this under-estimated component were over-estimates of trips by residents of other areas traveling to the Mid-Jordan corridor and trips made entirely within the corridor; both were approximately double the actual ridership in these two markets.

These variations aside, the overall accuracy of the ridership predictions continues a pattern of realistic forecasts produced by UTA and the Wasatch Front Regional Council, the metropolitan planning organization that develops and maintains the travel forecasting methods for the Salt Lake City metropolitan area.

North Shore Connector; Pittsburgh, PA

The North Shore Connector project is a 1.2-mile extension of the Pittsburgh light rail system from the existing Gateway station in downtown, under the Allegheny River, to the North Shore district. Figure 3 is a map of the project and its connection to the existing light rail system in downtown Pittsburgh.

The Port Authority of Allegheny County (Port Authority) developed and built the project. Port Authority now operates light rail service on the extension along with bus and light rail services throughout metropolitan Pittsburgh

Planning for an extension of the downtown subway to the North Shore neighborhood of Pittsburgh began in the late 1980s with the Spine Line Study of transit options in a corridor reaching from the North Shore through downtown Pittsburgh and to Oakland and other areas east of downtown. The study examined light rail extensions to the North Shore via an existing highway bridge, an existing railroad bridge, and a new bridge, all with at-grade alignments north of the Allegheny River. That study concluded in 1993 and Port Authority deferred further attention to the corridor while the agency focused on the planning, development, and construction of the Airport Busway. That facility, since renamed as the West Busway, broke ground in 1994 and opened to service in 2001.

Focus on North Shore connections resumed in 1997 with the initiation of a Major Investment Study (MIS) sponsored by the City of Pittsburgh and the Southwestern Pennsylvania Commission. The motivation for the study was to connect the North Shore to downtown as part of the City of Pittsburgh's plan to redevelop and expand its Central Business District beyond the traditional boundaries of the Golden Triangle into both the North Shore and South Shore. The MIS recommended a new rapid transit link between the Golden Triangle and the North Shore. The MIS evaluated many different alignments and three different rapid transit technologies (light rail transit, people mover and low-speed MAGLEV). Two potential alignments and all three technologies were recommended for further analyses.

Port Authority assumed responsibility for the corridor in January 1999 with the initiation of the North Shore Connector Draft Environmental Impact Statement (DEIS) to consider the remaining alternatives. The DEIS effort identified as the Locally Preferred Alternative (LPA) a 1.2-mile light rail extension from a reconstructed Gateway Center Station via a new tunnel under the Allegheny River to an at-grade alignment with three new stations on the North Shore. The LPA also included a 0.3-mile Convention Center extension of the rail spur already in place from Steel Plaza Station to Penn Station.

The proposed project entered into Preliminary Engineering (PE) in January 2001, entered into Final Design (FD) in April 2003, received a Full Funding Grant Agreement (FFGA) in 2006. After the FFGA was awarded, costs escalated and FTA required the development of a Recovery Plan to identify a path to project completion. FTA approved the Recovery Plan in 2009 and the project opened to service in 2012.

Figure 3. The North Shore Connector from Gateway Station to Allegheny Station

During Final Design, escalating costs led to the downsizing of the proposed project and the elimination of the Convention Center extension and other elements of the LPA. Consistent with other Before-and-After Studies of projects with similar histories, this study focuses on the project that was built and the accuracy of the predicted costs and impacts of that project. Consequently, while the study provides context regarding the difficulties that led to downsizing and identifies the elements that were dropped from the project, it considers only the as-built project in the comparisons predicted and actual outcomes.

Physical scope

The North Shore Connector is a 1.2-mile double-tracked LRT extension of the light-rail line in downtown Pittsburgh. The extension is physically and operationally compatible with the existing light rail system -- electrically powered by the same overhead catenary system, outfitted with the same signal and communication systems, and served by the same light rail vehicles. The line is completely grade separated from street traffic and adjacent land uses. The first 0.52 miles of the alignment from Gateway Station are below grade, while the remaining 0.68-miles are on elevated structure. The line transitions from subway to elevated structure approximately midway between the two stadiums on the North Shore.

The project includes the reconstruction of Gateway Station, formerly the terminus of the light-rail subway alignment through downtown, and two new stations on the North Shore. Reconstruction of the underground Gateway Station converted it from a loop turn-around station with east-west oriented side platforms to a through station with a north-south-oriented center platform.

North of the river, the North Side Station is located within the underground segment of the extension and has a center platform. At street level above the station is a high-capacity parking garage that was funded separately from the project, developed by the Pittsburgh Parking Authority, and owned by the Stadium Authority of the City of Pittsburgh. It provides 1,321 spaces in ten floors of parking and includes 25,000 square feet of currently vacant retail space, a transit center lobby, and accommodations for bicycles.

Allegheny Station, the terminus, is on the elevated segment, has a center platform, includes a bus-transfer platform at street level, and has tail tracks for the staging of light-rail vehicles.

The project did not include new light rail vehicles because Port Authority had a sufficient number of spares in the existing 83-vehicle fleet to add trains necessary to provide service on the extension. Consequently, the project did not include any expansion of existing maintenance and storage facilities for light rail vehicles. The project scope also did not include park-ride lots or structures because existing nearby parking facilities – particularly those providing parking for the baseball and football stadiums – have sufficient parking for transit riders.

(As noted above, the scope at PE-entry also included the 0.3-mile extension of the Steel Plaza spur from its current terminus at Penn Station to a new station at the Convention Center. This major element is not part of the project that was built and is therefore not included in this study's comparisons of predicted and actual costs and impacts of the project.)

At entry into PE, the anticipated scope of the project was different from the actual outcome in several ways. First, the anticipated alignment on the North Shore was at-grade with three stations. During PE, however, community concerns about at-grade operations amidst heavy traffic and pedestrian movements during stadium events led to the as-built design with an underground segment transitioning to an elevated segment. Because the grades of the transition do not allow the placement of a station near the transition, Port Authority eliminated one of the three anticipated North Shore stations. Second, the anticipated scope included the purchase of 10 new light rail vehicles. Further analysis during PE determined that only four new vehicles would be needed to provide service with the short extension of the rail system. Finally, the anticipated scope included a new mid-day storage facility for light rail vehicles. With the later elimination of new vehicles from the project scope, Port Authority reduced the storage facility to two tail tracks at the Allegheny Station.

At entry into FD, the anticipated scope was different from the actual as-built project only in the anticipated purchase of four light rail vehicles. (The scope at FD-entry also continued to include the extension of the Steel Plaza spur to Penn Station that was later dropped from the project.) During FD, Port Authority began to solicit construction bids and, given the complexity and risks associated with the tunnel segment underneath the river, included the tunnels among the first solicitations. When the bid prices for the tunnels came in well above the budgeted amounts, Port Authority undertook a comprehensive analysis to determine which elements of the project could be deferred. The analysis led to a decision to drop the four vehicles (and the Convention Center extension) from the project scope.

At the FFGA, the anticipated scope of the project matched the actual as-built project. Costs continued to escalate after the FFGA and FTA required the development of a Recovery Plan to identify a path to project completion. The Recovery Plan detailed the specific risk mitigation measures that were taken by Port Authority to mitigate cost and schedule issues. It focused on changes to the project schedule, budget performance, financial management, and capacity to complete the project. The Recovery Plan produced an updated cost for the project but made no changes to the project scope as defined in the FFGA.

Capital cost

The actual capital cost of the project was $510.4 million in year-of-expenditure (YOE) dollars. Construction costs represented 76 percent of the total. Construction of the guideway, including both the tunnels and the elevated segment, was the most costly component (31 percent of the total cost), followed by construction of the stations (24 percent), site-work (13 percent), and systems (8 percent). The costs of all non-construction items were limited to 24 percent of total project costs including real estate (2 percent) and professional services (22 percent). The relatively large share of project costs associated with stations reflects the scale of the reconstruction of the underground Gateway Station and the construction of relatively costly North Shore stations – one underground and one elevated. The small shares for site-work and real estate reflect the underground alignment of approximately one half of the project length, the use of public rights-of-way where possible, and the limited at-grade footprint of the elevated segment.

Under-estimates of project costs were a persistent problem throughout the development of the North Shore Connector. (The following comparisons exclude the predicted cost of the Convention Center extension because it was dropped from the as-built project.) At PE-entry, the predicted cost in YOE-dollars (that includes both the baseline cost estimate in constant dollars and the effects of anticipated annual rates of inflation in construction costs over the anticipated construction schedule) was $326.7 million, an underestimate of $183.7 million (36 percent) compared to the actual cost of $510.4 million. Two-thirds of this under-estimate was the result of underestimated baseline unit costs and an understated scope: the anticipated scope had the North Shore alignment and stations at-grade rather than the actual outcome in tunnel and on elevated structure. This difference was offset somewhat by the 10 new light rail vehicles and their new maintenance facility in the anticipated scope that were not part of the actual outcome. The remainder is attributable to schedule delays (21 percent) and higher-than-anticipated rates of inflation in construction costs (13 percent).

At entry into Final Design, the predicted YOE cost was $326.8 million, an underestimate of $183.6 million (36 percent). Because the anticipated project scope at this milestone was much closer to the actual outcome, most (80 percent) of the under-estimate was because of underestimated unit costs. The remaining 20 percent occurred because of schedule delays. None of the difference was the result of anticipated rates of construction inflation as projected inflation rates aligned closely with actual inflation rates.

At the FFGA, the predicted YOE cost was $435.0 million, an underestimate of $75.3 million. All of this under-estimate occurred because of underestimated unit costs in baseline-year dollars. Predicted costs of inflation matched the actual outcomes closely. The Recovery Plan produced a revised estimate for total project costs of $538.7 million, an overestimate of $28.4 million (5.6 percent).

Transit service

Service on the North Shore Connector is provided by the Red and Blue Lines that originate from various points in southern Allegheny County, pass through downtown Pittsburgh, and cross the Allegheny River to the North Shore. All trains entering downtown proceed to the Allegheny Station terminus on the North Shore. The combined frequency of the Red and Blue Lines in the morning and afternoon peak periods is 15 trains per hour – averaging 4-minute headways between trains. Headways lengthen to 7.5 minutes mid-day, 10 minutes in the evenings, and 7.5-minute headways on Saturdays and Sundays. All trains have 2-car consists in the peak periods and for special events and one-car consists mid-day, evenings, and weekends. The runtime from the Wood Street Station in downtown Pittsburgh to Allegheny Station in the North Shore averages nine minutes (an average operating speed of 8.6 mph).

Two bus routes connect to light rail at Allegheny Station. The #14 extends northwest, serving communities along the Ohio River. The #18 serves the nearby Manchester section of the North Shore. Both routes terminate at Allegheny Station.

The principal changes to the existing transit system that were made with the opening of the project were the conversion of the #18 and #14 bus routes into feeder routes to Allegheny Station. Before project opening, both routes crossed the Allegheny River into downtown. Now,

all riders destined for downtown on these two routes must transfer at Allegheny Station in order to continue their trips. The additional transfer and waiting times increased travel time by three minutes for riders traveling from Manchester and Ohio Valley destinations to downtown Pittsburgh. None of the 10 other bus routes serving the North Shore was similarly affected.

The service plans prepared during project development anticipated accurately the actual service levels for both light rail and bus routes in the North Shore area. Those plans did not foresee the system-wide service reductions made by Port Authority in 2007 and 2011 in response to budget constraints. While these reductions did not affect service on the project or North Shore bus routes, they eliminated 27 percent of all Port Authority transit service. The consequence was a four percent reduction in ridership and a more efficient transit system.

Operating and maintenance (O&M) costs

Port Authority estimates that the share of system-wide light rail O&M costs attributable to service on the North Shore Connector was $4.0 million in 2013 – an increase of 17 percent in system-wide light rail costs compared to 2011, before the extension opened to service. The savings in bus O&M costs attributable to the rerouting of the #14 and #18 bus routes from downtown to Allegheny Station is estimated to be $2.5 million.

At PE-entry, predictions of the O&M costs of the extension of the light rail system anticipated an increase of $4.7 million, an overestimate of actual costs by 17 percent.

Ridership

Actual ridership on the North Shore Connector in March 2016 was 11,100 trips per average weekday. Of this total, 7,400 trips were made to jobs, shopping, and other activities in downtown Pittsburgh. Sixty percent of these trips to downtown came from the immediate North Shore area and other areas of Allegheny County further north and northwest. However, trips on the project originated in other neighborhoods throughout the greater Pittsburgh area – including southern areas of the City of Pittsburgh and Allegheny County. This pattern occurs because travelers to downtown find it convenient to use a less costly parking facility near one of the North Shore stations and then use light rail to complete their trips into downtown.

Another 1,500 trips were made to jobs, education, entertainment, and other activities on the North Shore. These trips originated throughout areas to the south of the Allegheny River.

Trips between home and work represented 64 percent of all trips on the project; trips between home and non-work activities were another 22 percent; and trips between two non-home locations were 14 percent of all project trips. Some 56 percent of all trips on the project relied on park-ride to access the transit system and then, later in the day, to return home. For project trips destined for downtown Pittsburgh, the park-ride share was 67 percent. A direct walk from and back to home provided access to the project for 20 percent of all project trips while 5 percent of all trips on the project used a bus from and back to home. Travelers from 0-car households comprised 15 percent of all trips on the project but just 6 percent of project trips destined for downtown Pittsburgh.

Port Authority predicted that 14,300 trips would use the North Shore Connector in 2025. Because no opening-year forecast was prepared, a direct comparison with actual ridership in 2016 is not possible. However, reaching the 2025 forecasts from current levels would require average annual ridership growth of 2.85 percent. The likelihood of that outcome depends on a host of influences including the continuation of the fare-free zone for trips between the North Shore and downtown, the health of the downtown economy, continued development of the North Shore, the availability of operating funding sufficient to maintain current service levels, gasoline prices, and other factors.

Streetcar Loop Project; Portland, Oregon

The project is a 3.3-mile streetcar line extending from the existing Portland streetcar system east across the Willamette River and south through the Portland Eastside Industrial District to the Oregon Museum of Science and Industry. Figure 4 is a map of both the existing 4.1-mile streetcar line west of the river and the eastside Streetcar Loop project.

The project was a significant increment toward, but not the completion of, the planned streetcar loop in the Portland core. The loop has since been completed with the September 2015 opening of the Portland-Milwaukie light rail project. That project added a new bridge, the Tillicum Crossing, over the Willamette River that carries both the Milwaukie light rail line and the now-completed streetcar loop. The Portland-Milwaukie light rail project and its impacts on the streetcar loop are not part of this study. A separate Before-and-After Study will document the outcomes and accuracy of predictions for that project.

The City of Portland owns the streetcar system. The City contracted with Portland Streetcar, Inc. (PSI) for design and construction management of the Streetcar Loop project. The City operates and maintains the entire system with its own employees as well as staff contracted from PSI and the Tri-County Metropolitan Transit District (TriMet).

A Central City transit loop was one element of the Portland Central City Plan adopted in 1988 and the Central City Transportation Management Plan developed in 1995. Between 2001 and 2007, the City opened four streetcar segments, proceeding south from the Pearl District to Portland State University initially, and then with incremental extensions to and through the South Waterfront District for a total of 4.1 miles.

The Streetcar Loop project entered into Project Development (PD) in April 2007 and received a grant from the Small Starts program of the Federal Transit Administration (FTA) in October, 2009. The project opened to service in September 2012. The “before” time-point for this Before-and-After Study was 2011 and the “after” time-point was 2015.

Physical scope

The streetcar project is double-tracked over its entire 3.3 miles and therefore comprises 6.6 track-miles. Except for 0.45 track-miles that are located in exclusive trackway, tracks are embedded in existing streets. East of the Willamette River, the tracks are located on separate, parallel streets one block apart so that each street has one track embedded primarily in a curb lane. Except for 440 feet of elevated structure at its southern terminus and the segment that uses the pre-existing Broadway Bridge, the entire extension is at-grade.

Other elements of the project include: the retrofit of the Broadway Bridge to carry the streetcar extension to the east side of the river; retrofits of four arterial street overpasses on the east side of the river; 28 new streetcar stops with shelters, fare-collection equipment, and dynamic displays of next-train arrival times; six new double-articulated low-floor streetcars; overhead trolley-wire electrification and five new electrical substations; the addition or modification of traffic signals at 49 intersections with signal priority at eight locations; and a new maintenance-and-storage facility for the streetcars.

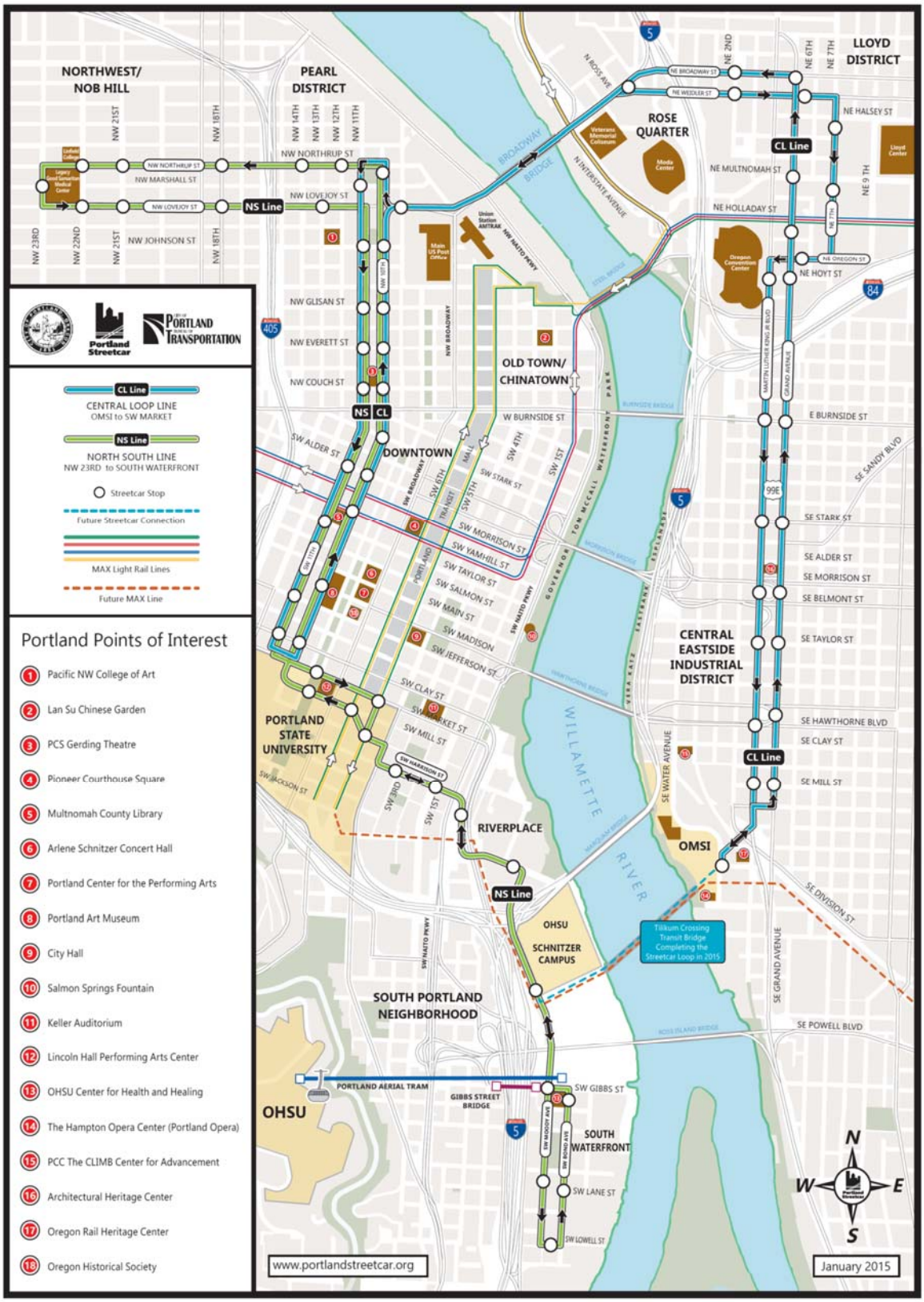

Figure 4. Map of the Portland Streetcar Loop Project and the Streetcar System

The predictions of the scope of the project at entry into PD and at the FTA grant award accurately anticipated the as-built project. The dual role of the City of Portland contributed to the accuracy of the predictions. The City was both a co-sponsor of the project and a principal permitting and regulatory agency. Consequently, inclinations to add elements to the project scope during the permitting process were tempered by the direct understanding of implications for project costs.

Capital cost

The actual cost of the project was $148.8 million in year-of-expenditure (YOE) dollars including $128.8 for all project elements except the six additional streetcars that were purchased separately by the City of Portland at a total cost of $20.0 million. Aggregate unit cost of the project was $44.9 million per mile – $38.9 million per mile without the vehicles. The costs of guideway construction and vehicle procurement represented 82 percent of all project costs.

Predictions of project costs prepared during the planning and development of the project were quite accurate. The prediction at PD-entry was $151.9 million in YOE dollars (2 percent higher than the actual cost). The prediction at the FTA grant award was $148.8, matching the actual cost.

Transit service

In the three-year interval between the opening of the Eastside project in 2012 and the completion of the entire streetcar loop in 2015, service on the project was provided by the "Central Loop" streetcar line. Figure 1 shows the alignment of this 4.5-mile line – extending from the project's southern terminus on the Eastside north to the Broadway bridge crossing and then south on the pre-existing streetcar line as far as Portland State University. This service operated on a 15-minute headway from 5:30 a.m. to 11:30 p.m. seven days a week.

End-to-end run times on the entire Central Loop line varied between 33 and 40 minutes (6.7 mph to 8.2 mph) depending on the time of day. Run times on the 3.3-mile project itself varied between 22 and 28 minutes (7.0 mph to 9.0 mph).

With the opening of the Central Loop line, service on the pre-existing streetcar line went from 12-minute to 15-minute headways. Where the two lines share tracks on the west side, the resulting headway is 7.5 minutes. TriMet made no changes to any bus routes with the extension of streetcar service to the Eastside.

At the "after" milestone, individual trips on the streetcar system required either a $1.00 ticket that was valid for two hours or a $23 monthly pass. TriMet tickets and passes are also valid for trips on the streetcar system.

Anticipated service plans for the project varied somewhat from the actual outcome. At PD-entry, the service plan anticipated more frequent service (12-minute headways compared to the actual 15-minute headways) and a longer Central Loop service – extending 0.9 miles further south on the west side past Portland State University (PSU) to a terminus in the South Waterfront District. The service plan called for 38,300 annual vehicle-hours of service compared to 27,100 vehicle-hours in the actual outcome. At the FTA grant award, in response to uncertainties in TriMet

operating funds, the service plan anticipated streetcar service on the project that would be confined to the project itself, requiring riders to transfer between the project and the west side streetcar line. Subsequent resolution of funding uncertainties permitted the actual service on the project to be through-routed to the west side as far as PSU.

Operating and maintenance (O&M) costs

Actual system-wide streetcar O&M costs were $12.3 million in TriMet fiscal year 2014, an increase of $3.4 million compared to fiscal year 2012 before opening of the project. This increase reflects the introduction of the Central Loop service both on the project itself and extending onto the pre-existing line on the west side. It also reflects the reduction in service frequency on the west-side line and a 15 percent decrease in the average per-vehicle-hour O&M cost caused by modest economies of scale in the expanded streetcar system.

Allocating system-wide costs based on vehicle-hours of service, actual O&M costs for the entire Central Loop line were $5.0 million and for the part of that service that operated on the project itself were $3.9 million.

Variations in predicted O&M costs primarily reflected differences in the amount of service anticipated in the service plan for the project at each milestone. The prediction at PD-entry, when the service plan more closely resembled the actual outcome, was $7.0 million – an overestimate of $2.0 million (40 percent). The overestimate is the direct result of the 0.9-mile longer Central Loop line and more frequent service planned at PD-entry compared to the actual outcome. The overestimate was offset somewhat by the incorrect per-hour labor costs employed in the predictions. The predictions implied an average cost of $181 per vehicle hour – reflecting the direct costs of streetcar service but omitting $35 per-vehicle-hour of indirect costs (a 16 percent understatement of the full unit cost).

Ridership

In 2015, before the opening of the Tillicum Crossing bridge and consequent completion of the entire streetcar loop, the project carried an average of 2,500 trips per weekday (where trips on the project include any trip that boarded and/or exited the Central Loop streetcar line at a new streetcar station on the east side). The average length of these trips was 1.7 miles, including the distance some of those trips traveled on the pre-existing west-side line.

Ridership on the project comprises two primary markets: first, the 1,700 circulation trips that begin and end within the Central City (67 percent of all project trips); and, second, the distribution of transit trips made to and from the Central City by residents of other areas (23 percent). Other small markets comprise the remaining 10 percent of all trips on the project, including the collection of trips made by residents of the Central City who transfer to regional transit service to travel to and from outlying areas.

Circulation trips on the project are, by the definition used in this analysis, made exclusively via streetcar and exclusively within the Central City. Streetcar riders making these trips may be residents of the Central City or workers and other visitors to the Central City. (Data limitations prevent differentiation between these two groups of riders on the project.) Some 63 percent of circulation trips have one end at the rider's residence. The other end of the trip is work (46

percent), college (9 percent), or other non-work activities (44 percent). Half of these residence-based circulation trips are made by residents of 0-car households.

The remaining 37 percent of circulation trips have neither end at home; 36 percent of these trips have one end at the rider's workplace but most (64 percent) are made between two non-work and non-home activities. Some 29 percent of non-home-based circulation trips are made by residents of 0-car households. This fraction is lower than for home-based circulation trips because many of the riders making non-home-based trips have traveled to the Central City from residences in outlying areas (where auto-ownership is higher) and are using the streetcar to circulate within the area over the course of their day.

The largest attractors of all circulation trips on the project are the Central Eastside District and, just to its north, the Lloyd District. These two districts are also the largest producers of circulation trips, along with the Pearl District and Old Town on the west side of the river.

The 500 distribution trips on the project comprise 23 percent of all project trips and require, by definition, a transfer between the streetcar and a regional bus or rail line for residents of outlying areas traveling to and from the Central City. Of these trips, 55 percent are to/from work, 10 percent are to/from college, and 32 percent are to various other purposes (shopping, personal business, etc.).

Ridership forecasts prepared for PD-entry used the regional travel model maintained by Metro, the metropolitan planning organization for the Portland area. The forecasts predicted that 8,100 average weekday trips would be made on the project in its opening year. A comparison of that prediction to a survey of riders on the initial streetcar segment on the west side led Metro, TriMet, and FTA to pursue a second ridership forecasting method to prepare forecasts that would be available at the FTA grant-award milestone. The second method used a "direct-generation" approach that predicted the average number of streetcar trips generated per household and per job located in proximity to the project. The rates were computed from the number of trips on the west side streetcar line at the time and the numbers of households and jobs proximate to that line. Application of the alternative method yielded a prediction of 3,900 weekday trips on the project in its opening year.

Analysis of the difference between the regional model's prediction of 8,100 trips on the project and the actual 2,500 trips leads to several observations:

- Part of the difference was caused by the more frequent service on the project anticipated during project planning and development – 12-minute headways versus the actual 15 minutes.
- The predicted number of circulation trips on the project was largely accurate: 1,950 predicted trips versus 1,700 actual trips.
- Almost all of the difference was accounted for by collection/distribution trips – those made by transit riders either coming into the Central City from residences elsewhere and transferring to the streetcar to reach their destinations (and later making the reverse trip to return home) or traveling from Central City residences via streetcar and a transfer to a

regional line to travel to destinations elsewhere. The model predicted 5,900 of these trips compared to the actual 700 collection/distribution trips made on the project.

- The source of the difference in the collection/distribution trips estimate was apparently the component of the regional travel model that simulates the way that transit travelers choose specific travel paths through the transit system. Transit trips that arrive in the Central City on a regional bus or light rail line have the choice of walking from that line to their destination or, for Eastside destinations, transferring to the Central Loop streetcar. The model appears to have overstated the attractiveness of the streetcar-transfer option for these trips compared to direct walks to Eastside destinations.

Metro has since adjusted the regional travel model to deal more accurately with these trips. This experience with the regional model highlights the challenges inherent in applying regional models to ridership prediction for relatively small-scale transit projects in the urban core.

Economic development

At this point in time it is difficult to discern the specific development impacts of the Portland Loop Project portion of the streetcar line, as it only opened in 2012. However, in 2015, the City of Portland and Portland Streetcar, Inc. commissioned a study of development in the urban core, focusing specifically on the influence of proximity to the full streetcar system. The analysis examined the combined effects of both regional land development policies and the streetcar, and did not attempt to separate their individual contributions to development outcomes. Factors that likely contributed to development impacts during the time period covered by the study include:

- Coordinated policies at the state, metropolitan, and local levels in regards to land use and urban growth controls. Since 1973, the State of Oregon has maintained a strong statewide program for top-down land use planning based goals that emphasize infill growth, transit development, and transit usage.
- Aggressive implementation of policies for areas targeted for growth, including re-zoning, financial incentives, publicly-funded packages of amenities, and transit-supportive development. In the Portland metropolitan region, the Central City was designated as the main focus of growth, followed by lesser regional and town centers, all within an adopted urban growth boundary.
- Robust demand for new housing and commercial space supported by the nearby presence of a thriving central business district.
- Development of the streetcar system in close coordination with other regional investments such as the expansion of the light-rail system.

Some key findings of the 2015 study include:

- Since the 1997 decision to build the streetcar system, $4.5 billion of market value has been developed in the targeted areas of the urban core, including 7.7 million square feet of commercial space and over 18,000 residential units. Existing properties have increased by $7.1 billion in market value. Overall, market value in the targeted areas has increased from 11 percent to 17 percent of the total market value in the City of Portland.

- A detailed analysis of the 7,000 residential condominium sales within two miles of the streetcar found a price premium associated with proximity to the package of infrastructure improvements, the streetcar line, and the transit-supportive policies. Controlling for building features, neighborhood amenities, and macro-economic trends, the long-term price premium appears to be 10 to 20 percent for condominium units adjacent to the line and nine percent for units one-quarter mile from the line. The price premium dissipates completely beyond one-half mile.
- The analysis estimated that, without the increased property values associated with the development policies and streetcar implementation, 35 percent (2.7 million square feet) of the commercial development and 41 percent (7,400 units) of the residential development would not have occurred.

Efforts to extrapolate the Portland experience to other metropolitan areas should be mindful of the full set of characteristics of the Portland setting and actions taken by state and local governments in the area, in addition to investments in the Central City streetcar network.