Before-and-After Studies of New Starts Projects

Report to Congress

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FOREWORD

This seventh annual report to Congress on Before-and-After Studies summarizes the findings for three projects that opened to service in 2009, 2010 and 2011, reported here in the order of their opening date:

1. Green Line Light Rail Project; Portland, Oregon (2009)
2. Northwest-Southeast Light Rail Project; Dallas, Texas (2010)
3. Mountain Link Bus Rapid Transit Project; Flagstaff, Arizona (2011)

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 investments in transit and to improve the reliability of the predictions of the costs and impacts of proposed 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 occurs during project construction for physical scope and capital costs and then two years after the project opens to permit conditions to stabilize regarding transit service, operating and maintenance costs, and ridership.

The study also examines the accuracy of the predictions of those outcomes prepared to support local and federal decisions at key points in project development: entry into preliminary engineering (or project development for Small Starts), entry into final design, and execution of the Full Funding Grant Agreement (or Project Construction Grant Agreement for Small Starts). Finally, the study also identifies the sources of differences between predicted and actual outcomes.

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

Green Line Light Rail Project; Portland, Oregon

The Green Line project added a new line to the light rail system in Portland, Oregon. The Green Line connects Clackamas Town Center in the southeastern suburbs to downtown Portland via new light rail construction along I-205 South, shared tracks with the existing Banfield light rail line, and a new light rail alignment through downtown to Portland State University (PSU).

The figure provides a map of the project and the corridor that it serves. The total length of the project is 14.5 miles comprising 6.5 miles along I-205 South, 6.2 miles on the Banfield segment, and 1.8 miles on the downtown Transit Mall.

The project was developed, built, and is now operated by TriMet, as part of the Metropolitan Area Express (MAX) light rail system that is 52 miles in length, serves 87 stations, and attracts 120,000 passenger boardings per day. TriMet also provides the bus, commuter rail, and paratransit services in metro Portland. Total ridership on all services averages 320,000 passenger boardings per weekday.

The project was initially identified in 1994 as part of planning for north-south expansion of the light rail system in the I-5 and I-205 corridors. Subsequent decisions prioritized three extensions: Interstate MAX, which opened in 2004 as the Yellow Line; I-205 South, which opened in 2009 as part of the Green Line; and Milwaukie, which is under construction and scheduled to open in 2015.

These planning efforts also identified the need for an additional light-rail route through downtown to add capacity and expand geographic coverage. Subsequent decisions identified the reconstruction of the downtown Bus Mall for bus and rail operations as part of the Green Line project.

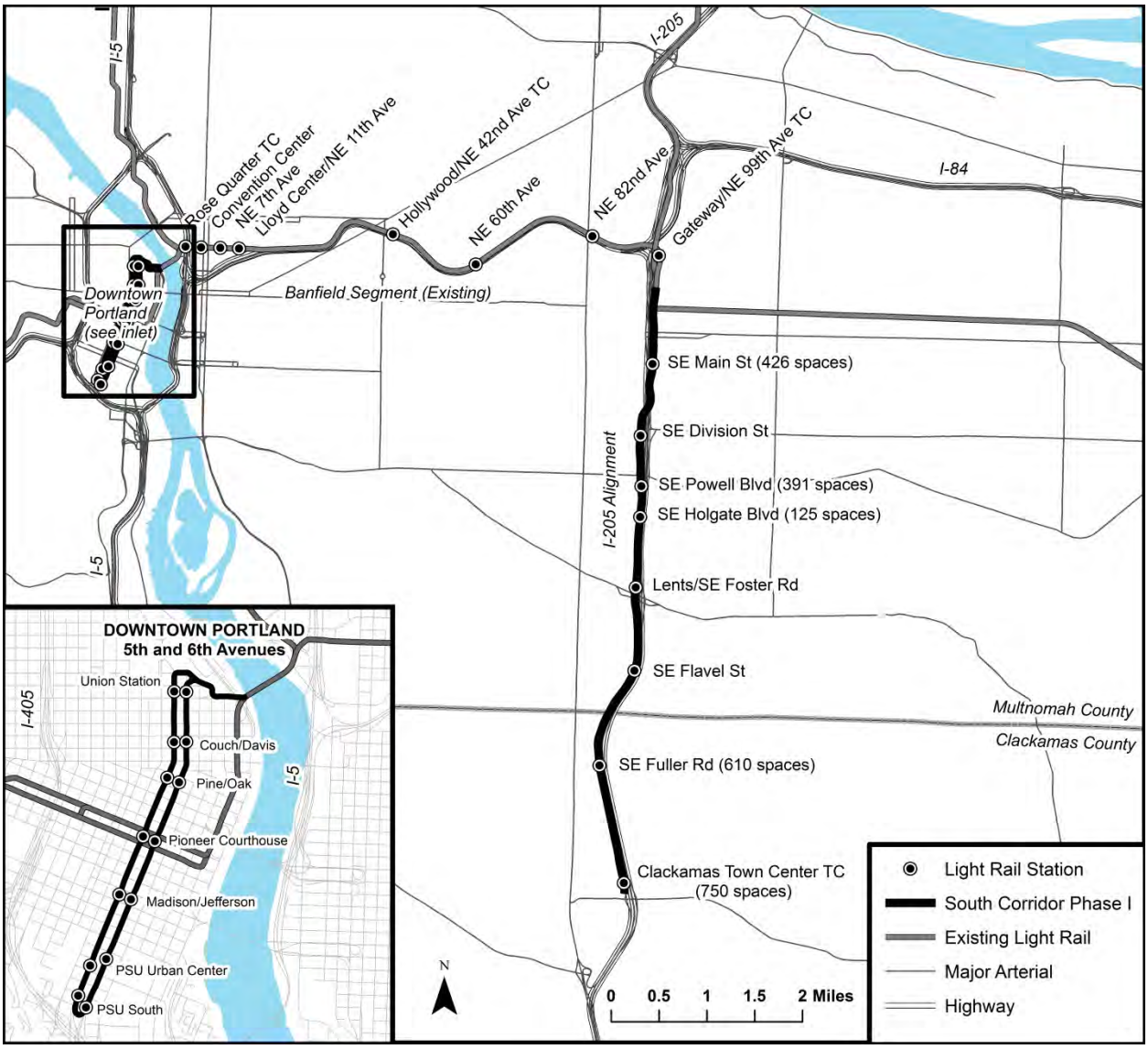
The project entered into preliminary engineering (PE) in 2004, entered into final design (FD) in 2005, received a Full Funding Grant Agreement (FFGA) in 2007, and opened to service in 2009.

Physical scope of the project

The Green Line employs conventional light-rail components with overhead electrification, cab signaling, articulated vehicles, and level-boarding at stations. The project has three segments:

1. New construction along I-205 South;
2. Minor upgrades of the existing light rail facility along the Banfield freeway; and
3. New construction in downtown Portland to convert the existing bus mall into a transit mall for both buses and light rail.

The 6.5-mile segment along I-205 South is entirely new double-tracked construction. In this segment, the alignment is largely at grade, immediately adjacent to the I-205 highway, and within an alignment prepared for light rail as part of the construction of I-205 in the 1970s. Design features built as part of highway construction included a wider right of way and longer overpasses to accommodate both the highway and a transit-way, and an underpass where the transit-way alignment transitions from the west side to the east side of the highway. The light rail project added two new street underpasses totaling 180 linear feet and seven aerial structures totaling 2,700 feet that carry the alignment over highway ramps and arterial streets. The result is an alignment that is exclusive to light rail with only one at-grade crossing – on an arterial street. The I-205 South segment has eight stations that are 200 feet long to accommodate two-car trains.



The Green Line
In Downtown Portland, on the Existing Banfield Light Rail Segment,
and along the New I-205 Alignment

Five of these stations have park-ride facilities, four with surface lots totaling 1,550 spaces and the terminal station at Clackamas Town Center with 750 spaces in a parking garage.

The 6.2-mile Banfield segment was built in the 1980s as part of the initial light rail project in Portland. Most of this segment is located immediately adjacent to I-84, the Banfield Expressway, in an alignment exclusive to light rail. As it proceeds west, the rail alignment transitions from the highway onto arterial streets through the dense activity concentrations in Lloyd Center and the Rose Quarter, and across the Willamette River into downtown Portland. The Green Line now shares this segment with the MAX Blue and Red Lines. All three lines serve the eight stations on the segment. For this segment, the scope of the Green Line project included only the addition of one power substation and an upgrade to the signaling system – both needed to expand the capacity of the segment from 20 to 30 trains per hour.

The downtown Portland segment consists chiefly of the reconstructed Transit Mall that traverses 1.4 miles of downtown on both 5th and 6th Avenues from Union Station at the north end to Portland State University at the southern edge of downtown. The project reconstructed 5th and 6th Avenues from property line to property line, transforming the former bus mall into a shared facility that accommodates both trains and buses and includes 14 rail stations, 31 bus stations, pedestrian amenities, benches, public art, covered bicycle parking, and landscaping. The Green Line operates as a single-track one-way couplet, southbound on 5th Avenue and northbound on 6th Avenue, sharing the track with the Yellow line that was rerouted to the Transit Mall as part of the Green line project. With turn-around tracks and the two-track connection between the Transit Mall and the Banfield line, the downtown segment of the Green line comprises 3.6 one-way track miles.

The project included 22 low-floor light rail vehicles that provide accessible seating and level boarding at all doors. The vehicles carry automated on-board bridge plates at every door to overcome the two-inch vertical difference between the platform and the vehicle-floor heights. The project also included minor modifications to two existing vehicle-maintenance facilities to expand their maintenance and storage capacity.

Overall, the physical scope of the project anticipated at the project development milestones was consistent with the as-built project. Minor differences included:

- At entry into PE, a new ramp structure providing access from the Steel Bridge to the Transit Mall that was dropped in favor of modifications to the existing ramp in the as-built project; and two at-grade crossings in the I-205 South segment that were actually grade-separated in the as-built project;
- Variations at entry into PE and entry into FD in the locations and individual capacities of parking facilities at stations in the I-205 South – but with no difference in the total number of park-ride spaces in this segment;
- At entry into FD, an underestimate of the scope of streetscape improvements for the downtown Transit Mall, subsequently upgraded in response to the downtown business community; and
- A change from 24 vehicles in the FFGA scope to 22 in the as-built project – to accommodate anticipated ridership in 2018 rather than in the 2025 horizon year and to help control project costs.

Overall, the actual as-built scope of the project was well anticipated at the milestones – reflecting the long-planned nature of the project, the transit right-of-way prepared as part of the I-205

South highway construction, and TriMet's long experience in the development and construction of light rail projects.

Capital cost

The actual capital cost was $576 million in year-of-expenditure (YOE) dollars. Excluding the 6.2 miles of the existing Banfield segment and counting separately the 5th and 6th Avenue components of the Transit Mall, the aggregate unit cost of the transit project was $69.4 million/mile, $59.7 million/mile excluding vehicles. Some 77 percent of project costs were for physical elements of the project: guideway construction, vehicles, and systems.

The predicted capital cost at entry into PE was low by 14 percent, almost entirely because of unanticipated inflation effects. The predicted inflation effect assumed a historic annual rate of 3.0 percent over a 3.5 year period of design and construction – an 11 percent increase caused by inflation. However, the actual annual rate of inflation over the period averaged 6.5 percent – driven by national and international conditions that increased labor and commodity prices. These conditions, together with an additional year needed in the project schedule, produced a 33 percent increase in project costs because of inflation. Expressed in constant dollars – with inflation effects removed – the capital cost predicted at entry into PE was only two percent lower than the actual cost.

The predicted costs at entry into FD and at the FFGA were within three percent of the actual cost in both YOE dollars and constant dollars. The accuracy of these predictions resulted from recognition at these milestones of both continuing period of higher inflation and the longer schedule needed for construction.

Transit service

The Green Line operates on weekdays with 15 minutes between trains all day except evenings, when trains are 35 minutes apart. Service on weekend days operates with trains 17 minutes apart all day and 35 minutes apart in the evenings.

End-to-end running time averages 48 minutes, including stops at stations and traffic intersections, equivalent to an average speed 18.1 mph. This relative high average speed for a light rail line reflects the line's almost complete separation from traffic in the I-205 South segment and much of the Banfield segment.

Almost no changes were made to the bus system because of the introduction of the Green Line. This outcome reflects three characteristics:

- The Green Line replaces no pre-existing bus service because no bus routes followed a routing similar to that of the Green Line.
- East-west bus routes in the I-205 South segment provide connections to Green Line stations, obviating the need to establish feeder-bus services.
- Bus services in the Banfield segment were already configured with respect to the existing Blue and Red Lines.
- The downtown Transit Mall accommodates the same regional bus services that used the Bus Mall prior to its reconstruction to include light rail service.

The principal impacts of the Green Line on transit service are (1) the extension of light rail service to PSU, a substantial attractor of transit trips; (2) the expanded light rail coverage within

downtown Portland, also a substantial transit attractor; (3) the introduction of light rail service and new park-ride opportunities in the I-205 South corridor, and (4) the somewhat more frequent light rail service at stations in the Banfield segment. The new connection to PSU occurred both for the Green Line and the Yellow Line after its rerouting in downtown Portland onto the reconstructed Transit Mall.

Predicted Green Line service frequencies through all project-development milestones anticipated 10 minutes between trains during weekday peak periods and 15 minutes during other times. The project opened with 15-minute intervals throughout the day and 35-minute intervals in the evenings because of a drop in tax revenues associated with the national recession in 2008. The same financial challenges also led to reductions in service on existing light rail lines and bus routes that were not anticipated during the development of the project. Between 2009 and 2011, rail and bus service was reduced by 11 percent system-wide. As revenues expand with the economic recovery, TriMet is now restoring service.

Operating and maintenance (O&M) costs

Per vehicle-hour of service, Green Line O&M costs are consistent with the cost experience of the TriMet light rail system. Consequently, total O&M costs have increased in direct proportion to the increase in light rail service associated with the Green Line. Because bus service levels were effectively unchanged by the Green Line opening, bus O&M costs did not change because of the project.

Predictions of O&M costs for the project itself and its direct impact on the bus system accurately anticipated these outcomes. Those predictions anticipated higher system-wide costs compared to current actual costs because they did not foresee a severe national recession and subsequent service reductions.

Ridership

Actual ridership on the Green Line averages 24,000 trips on weekdays. The largest ridership market is the 63 percent of Green Line trips that travel to and from work or other activities in the core of the region: downtown Portland, PSU, and the Lloyd Center. The other ends of these trips to/from the core are located along the I-205 South segment (35 percent), within the core itself (24 percent), along the Banfield segment (19 percent), and in outlying areas (the remaining 22 percent). The purposes of these trips include travel between home and work (41 percent), school (27 percent, overwhelmingly to PSU), and other activities (17 percent). The remaining 15 percent of Green Line trips involving the regional core occur between non-home locations, particularly within the core where workers use transit services to travel to lunch, meetings, and other activities in the mid-day and evening.

The second largest ridership market is the 16 percent of Green Line trips that travel to/from jobs and other activities along the I-205 South segment. These trips are produced in roughly equal proportions elsewhere along the Green Line and throughout the Portland metro area. They are marginally less oriented towards work and school, and are more oriented towards shopping and other non-work activities.

Some 72 percent of trips on the Green Line access the transit system by either walking or transferring from buses or other light rail lines. The remaining 28 percent of all trips rely on an automobile to access a Green Line station (primarily park-ride but also drop-offs). Auto access

is particularly prominent for residents of the I-205 South segment where 33 percent of trips to all other locations arrive at Green Line stations by automobile. For Green Line trips from the I-205 South corridor that travel to the core of the region, auto access has its largest share at 48 percent. Nearly all auto-access trips on the Green Line – 95 percent – travel to activities in the regional core in downtown Portland, PSU, and Lloyd Center – effectively the areas where parking charges or parking restrictions (residential parking permits) are found.

Households with incomes under $40,000 produce 58 percent of trips on the Green Line. Households without cars produce 20 percent of trips on the Green Line.

The predicted number of opening-year weekday trips on the Green Line was 30,400 at entry into PE and was revised to 25,250 during PE. The revision apparently resulted from work to update the regional travel model as year-2000 Census data became available, including the preparation of new estimates of land use, population, and employment distributions – plus the recalibration of the travel model against then-current ridership patterns. The revised prediction remained in place at entry into FD and at the FFGA. Thus, the predicted opening-year ridership at those two milestones was within four percent of the actual 24,000 average weekday trips.

Two differences between predicted and actual ridership exist within this close match on total Green Line ridership.

First, predicted ridership significantly understated the importance of the regional core in both generating and attracting Green Line trips. At the "after" milestone in 2011, 63 percent of trips on the Green Line had one or both ends within the core compared to 33 percent in the ridership prediction. Just over half (57 percent) of this under-prediction occurred for trips to/from locations outside the core and the remainder occurred for trips within the core.

Some of the difference for trips to the core occurred because operating speeds were over-estimated for bus routes between the I-205 South corridor and the regional core. Consequently, some trips that actually use the Green Line were shifted in the ridership predictions to the artificially fast bus services. Some of the difference for intra-core trips is likely to be caused by a change in fare policy. The ridership predictions assumed the continuation of "Fareless Square" that let trips within the core use bus and rail services without paying any fare. In 2011, however, TriMet had changed the policy to "Free Rail Zone" in which bus travel required a fare payment. That change in fare policy is likely to have shifted some former bus trips onto the rail system, including the Green Line within the core.

Second, while the predictions of the total number of Green Line trips using auto access were within 12 percent of the actual total, the predicted pattern of these trips was substantially different from the actual outcome. Nearly all Green Line trips – 93 percent – that use park-ride access actually go to work or other attractions in the core – downtown Portland, PSU, and Lloyd Center. In contrast, the forecasts anticipated that park-ride trips would go to locations throughout the metro area and only 51 percent to the core. The pattern of actual park-ride trips suggests that travelers with ready availability of a car are likely to drive to transit only when they are traveling to locations with charges for, or restrictions on, daily parking.

Recent updates of the regional travel model for the Portland area have corrected the difficulties in prediction of overall transit travel to the regional core and the orientation of park-ride trips to the core.

Northwest-Southeast Light Rail Project; Dallas, Texas

The Northwest-Southeast Minimum Operable Segment is the federally-funded part of the Green Line addition to the Dallas area's light rail system. The figure provides a map of the Green Line, the federally-funded project, and the current Dallas-area light rail system.

The full Green Line extends 28.8 miles from southeast Dallas through downtown and then northeast to Carrollton. The federally-funded project comprises 20.9 miles of the Green Line: 10.8 miles of the northwest segment and the entire 10.1 miles of the southeast segment. The three other segments of the Green Line are a 5.5-mile locally funded northward extension of the northwest segment, a 1.2-mile locally funded segment just west of downtown, and the 1.2-mile downtown segment built in the 1990s with the initial Dallas area light rail lines.

The project was developed, built, and is now operated by Dallas Area Rapid Transit (DART), the regional transit agency.

Light rail lines to the northwest and southeast have been elements of the regional rail plan since its earliest version in 1983. Light rail extensions for both corridors emerged as the preferred alternatives from separate planning studies in 2000. The extensions then advanced through separate federal environmental reviews but were evaluated and funded as a single project in the Federal Transit Administration's New Starts program.

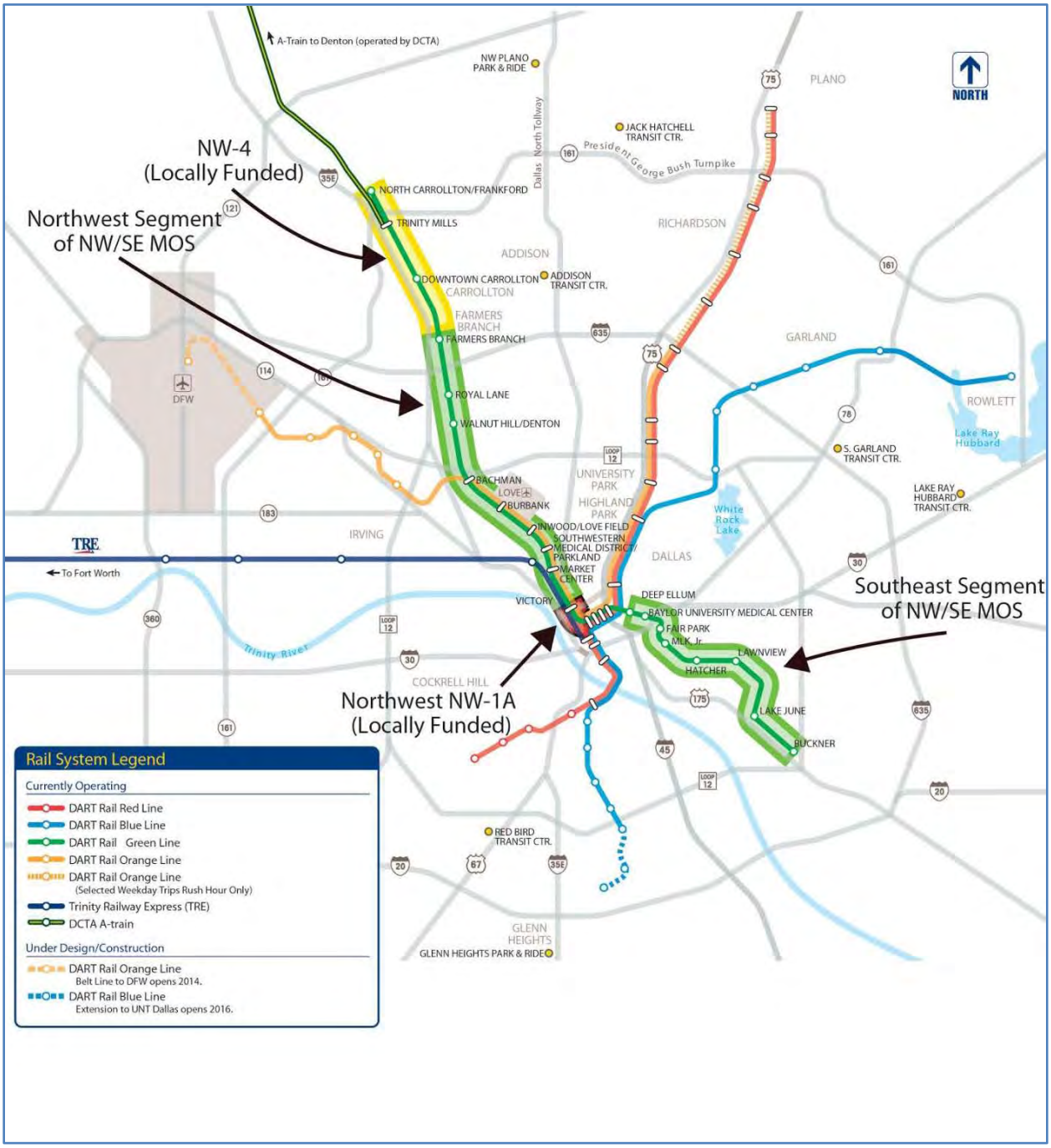
The project entered preliminary engineering (PE) in July 2001, entered final design (FD) in June 2005, received a Full Funding Grant Agreement (FFGA) in July 2006, and opened to service over the full length of the Green Line in December 2010. The "before" milestone for this Before-and-After study is 2007/2008. The "after" milestone is 2012 except as noted below.

This summary is an interim report on the outcomes of the project and the accuracy of predictions made during the development of the project. In 2012, DART proposed, and FTA agreed, to postpone the collection of detailed ridership data on the project until a system-wide survey of riders planned for spring 2014. DART completed a snapshot survey of Green Line riders in June 2013 and the planned system-wide survey of all DART bus and rail routes in June 2014. Surveys of other transit systems in the Dallas/Ft. Worth area, including two with direct connections to the Green Line, will occur in fall 2014. In spring 2015, DART will use the final survey data to examine Green Line ridership impacts and update the final report from the Before-and-After Study. FTA will update this summary of findings in the 2015 Report to Congress.

Physical scope of the project

The Green Line project is a double-tracked guideway with overhead electrification and full separation from street traffic except at at-grade crossings. Most of the project is located within railroad right-of-way purchased by DART in 1990. Active freight operations continue in some sections including from Merrell Road to just south of Mockingbird Lane in the northwest segment and from near Hatcher Station to Buckner Station in the southeast segment. Freight and light rail operate in a shared right-of-way but on their own physically separated tracks.

Of the 20.9 miles of the project, 12.19 miles are built at grade, 2.49 miles are on fill, 5.95 miles are on elevated structure, and 0.29 miles are below grade within a runway protection zone near Dallas Love Field Airport. The northwest segment is elevated for 5.2 miles of its 10.8 mile length and has 48 grade-separated street crossings and 11 at-grade crossings. The southwest



The DART Green Line and Its Components

segment is at grade for 8.1 miles of its 10.1-mile length and has 4 grade-separated crossings and 33 at-grade crossings.

The project has 16 new rail stations, eight each on the northwest and southeast segments. All stations accommodate three-vehicle trains and have platforms that provide level-boarding at selected locations along the length of the platform. Six of the eight northwest stations, and four of the eight southeast stations, have park-ride lots that together provide a total of 3,276 parking spaces.

The project includes 18 new "super" light rail vehicles that have three sections including a low-floor center section, two articulation joints, a seated capacity of approximately 100 passengers, and a total capacity with standees of 200 passengers per vehicle. The project also includes 38 low-floor vehicle inserts that enabled DART to continue its program to convert its entire fleet of 115 two-section articulated light rail vehicles to super vehicles.

The predicted scope of the project matched the actual outcome, with these exceptions at individual milestones.

- At PE entry, Victory Station was included in the anticipated project scope, but was built early with local funds and not included in the actual project. That change occurred during PE; so the Victory Station was not included in the anticipated scope at FD entry or the FFGA.
- At PE entry, the NW alignment through the medical district was anticipated to be on Harry Hines Boulevard while the actual outcome is on railroad right-of-way to the east. The routing was changed during PE to avoid negative impacts and provide better connections to areas slated for transit-oriented development.
- At PE entry, NW alignment was planned to be largely at grade between Northwest Highway and LBJ Freeway while 2.5 miles of track in this segment are actually on aerial structure. This change was made during PE to avoid 13 at-grade crossings as well as adverse impacts on traffic, freight movements, and floodplains.
- At PE entry, the NW alignment near Love Field did not include the Burbank Station that is part of the as-built project scope. This station was added during PE entry to serve Southwest Airlines headquarters and the Love Field West neighborhood.
- At PE entry, the anticipated project scope included the purchase of additional standard light rail vehicles rather than super light rail vehicles and inserts that were part of the as-built project. DART made this change during PE as part of the decision to convert the entire light rail fleet to the "super" configuration.

Because scope changes made during preliminary engineering eliminated these differences from the as-built scope, the scope of the project anticipated at entry into FD and the FFGA matched closely the as-built physical scope of the project.

Capital cost

The actual cost of the project is $1,406.2 million in year of expenditure (YOE) dollars. Construction of the guideway and track elements, stations, maintenance facility, sitework, and systems elements accounted for $816.3 million (58.1 percent) of the project cost. Right-of-way accounted for $108.5 million (7.7 percent) and vehicles were $158.4 million (11.3 percent). Professional services and other soft costs were $205.2 million (14.6 percent), and finance

charges accounted for $117.8 million (8.4 percent). The aggregate unit cost of the transit project was $67.3 million per mile – $59.7 million per mile without the new vehicles and vehicle-inserts.

At entry into PE, the cost estimate in YOE dollars was $1,151.4 million, an underestimate of 18 percent. The underestimate was caused by (1) the omission of an allowance for professional services, (2) the absence of finance charges which at that time were not required by FTA to be documented as part of project costs, (3) a shorter-than-actual construction schedule, and (4) assumed annual inflation rates that were consistent with recent history and did not foresee spike in global commodity prices that occurred at the start of Green Line construction. Recalculation of the entry-into-PE cost estimate correcting for these four differences yields at revised estimate of $1,363 million, an underestimate of only three percent.

At entry to FD, the cost estimate in YOE dollars was $1,490.1 million, an overestimate of six percent. The overestimate was caused by overestimates of costs for professional services ($260 million versus $205 million actual) and finance charges ($239 million versus $118 million actual). The overestimates for these cost categories offset the continuing underestimates of costs for construction and vehicles. Again, the YOE cost estimates for those items did not foresee the substantial increase in global commodity prices that would drive up unit costs significantly as Green Line construction got underway.

At the FFGA, the estimate matched the actual outcome in terms of total project cost. Within the totals, the pattern of differences that occurred at entry into FD remained: overestimates of the costs of professional services and finance charges offset underestimates of the costs of construction and vehicles. DART was able to reduce the cost of professional services through Construction Management-General Contractor contracts and an Owner-Controlled Insurance Program. Finance charges decreased because interest rates dropped with the national economic downturn and because DART was able to reduce borrowing with a $78 million grant from the American Recovery and Reinvestment Act and additional funds from FTA. Underestimates for construction and vehicles were again caused by the unforeseen increases in unit costs driven by global commodity prices.

Transit service

On weekdays, service on the project operates at 15-minute headways in the peak periods, 20 minutes at most other times of day, and 30 minutes in late evening. On weekends, service generally operates at 20-minute headways, with 30-minute headways early and late in the day. Service extends from 5am to 1am on both weekdays and weekends. Trains generally have two super light-rail vehicles but some trains include three vehicles to increase capacity during the weekday peak periods. Run time on the project (between the Farmers Branch and Buckner stations including the Victory Station and downtown segments) is 64 minutes including dwell times at stations – an average speed of 22 mph. Average speed is somewhat faster on the partially grade-separated northwest segment – 24 mph between the Farmers Branch station and the Akard station in downtown – than on the largely at-grade southwest segment – 20 mph between the Buckner and Akard stations.

While not part of the FFGA for the Green Line, service on much of the DART Orange Line operates on facilities built under the Green Line FFGA. Consequently, service and ridership on the Orange Line are part of the direct consequences of the Green Line project. Simultaneously with the Green Line opening in December 2010, DART initiated partial Orange Line service

only in the peak hour of the peak periods between Bachman station on the Green Line and Parker Road station on the Red Line. This interim service improved train headways and expanded capacity on the highest ridership segments of the DART system that were formerly served only by the Red Line.

Since the full Orange Line opened in fall 2012, the combined Green/Orange headway between downtown and the Bachman station on the northwest segment has been 7.5 minutes in the peak periods and 10 minutes at most other times of day. Headway on the downtown transit mall where all four light rail lines operate is now 3.75 minutes in the peak periods.

DART made significant adjustments to the rail and bus systems in 2010 with the opening of the entire Green Line and the partial Orange Line service. These changes both integrated the Green/Orange Line into the regional transit system and helped to address budget pressures caused by the national economic downturn. DART eliminated downtown-oriented bus routes that would become duplicative of the new Green Line service, adjusted local and crosstown bus routes in the Green Line corridor to connect with the new rail stations, and changed peak headways on all light rail lines from 10 minutes to 15 minutes.

For the rail system, the net effect from 2007 to 2012 was a 65 percent increase in train hours of service. For the bus system, the net effect over the same interval was a one percent increase in bus hours and a 12 percent decrease in bus miles. The bus changes indicate that the elimination of duplicative bus service was largely offset by additional services to feed rail stations. The concurrent drop in bus service miles and the slight increase in bus service hours indicates that system-wide average bus speed slowed down – the result of the elimination of relatively faster express and limited-stop routes and the expansion of service on relatively slower local routes connecting to stations.

The kinds of adjustments to the bus system made at the full opening of the Green Line were consistent with types of changes anticipated in the transit service plans at each milestone during the development of the project. However, service levels on the Green Line itself are lower than anticipated. During planning and development of the Green Line, service plans anticipated 10-minute peak and 20-minute off-peak headways rather than the 15- and 20-minute headways in current service. Because bus connections to light rail stations are designed, in part, to reflect train headways, transit service plans during project development anticipated feeder-bus headways consistent with the planned 10-minute – rather than the actual 15-minute – rail headways during the peak periods. These differences are the consequences of unforeseen DART budget constraints resulting from lower operating revenues caused by the national economic downturn.

Operating and maintenance (O&M) costs

System-wide, light rail O&M costs increased by 52 percent between 2007 and 2012. This increase was driven by the openings of the Green and Orange Lines, partially offset by the longer peak-period headways on the Red and Blue Lines. Because train-hours increased by a net 65 percent, average O&M cost per train dropped by 7.7 percent over the interval. Bus O&M costs increased by 2.4 percent while bus vehicle-hours increased by 1.0 percent – an increase in O&M costs per bus-hour of 1.4 percent.

Ridership

Average weekday ridership on the Green Line in 2012 was 31,000 boardings, with the federally funded segment accounting for 29,000 of these boardings. Details of ridership patterns on the Green Line will come from analysis of the 2014-2015 system-wide survey of DART ridership.

Weekday ridership on the DART light rail system grew from 58,000 boardings in 2007 to 69,000 in 2011 after the full Green Line opened to 93,000 in late 2012 after the full Orange Line opened. Weekday ridership on the DART bus routes was 143,000 boardings in 2007, 116,000 boardings in 2011, and 124,000 boardings in 2013. Total DART rail and bus ridership was 201,000 boardings in 2007 and 216,000 boardings in 2012. (Boardings count transferring riders each time they board a train or bus.)

Therefore, DART ridership growth over the interval between 2007 and late 2012 were driven entirely by the openings of the Green and Orange Lines. This growth was partially offset by a modest decrease in bus boardings likely caused by the reorientation of bus routes in the affected corridors to connect with new light rail stations. Growth was also moderated by the nationwide economic downturn that began in late 2008 and led to lower-than-anticipated service levels on light rail and rail-oriented bus routes and to higher unemployment levels.

Predictions of Green Line ridership at both the FD-entry and FFGA milestones anticipated 40,300 weekday trips on the project. The transit system represented in this forecast did not include two projects that were still in project planning at the time: the three northern-most stations on the northwest segment of the Green Line and the Denton County A-Train commuter rail line that now terminates at the Trinity Mills station on the northwest segment of the Green Line. A revised prediction prepared in 2008 with updates of the system-wide transit plan, demographic forecasts, and travel-forecasting model produced a forecast of 41,200 Green Line trips.

One cause of the difference between predicted and actual ridership is the 10-minute peak-period headway anticipated in the predictions for all light rail services compared to the actual 15-minute peak-period headway in current service. A complete analysis of the specific sources of differences between actual and predicted ridership will come from detailed comparison of the forecasts to the 2014-2015 system-wide survey of DART ridership.

Land-use impacts

Because the economic-development consequences of light rail investments are important to local agencies and decision-makers, DART has elected to add land-use impacts to the Before-and-After Study.

The Green Line project is located almost entirely within a former freight-railroad right-of-way. Consequently, significant opportunities exist in adjacent land uses for in-fill development, redevelopment of industrial areas, added land-use density, and increases in population and employment. Three years after project opening, corridor-level changes in land use across all stations combined have been minimal. Multi-family land use has experienced the largest increase in acreage and has produced a somewhat more significant increase in housing units and population in the station areas.

Development of the Green Line project was accompanied by supporting changes in plans and policies by the cities of Dallas and Farmers Branch. Both cities have replaced traditional zoning

with form-based planning and regulatory requirements, and have established Tax Increment Financing districts and Planned Developments to support transit-oriented development. The City of Dallas developed its first comprehensive plan in 2005 that identified a mixed use/transit oriented focus around several DART stations. The City has also created action plans for high priority areas at many stations and is making progress at several of these stations. Farmers Branch purchased land surrounding its station area during project planning and developed a strategic vision for its development. Two mixed-use and multi-family developments are now underway.

Expectations during the development of the project were that growth in the corridor would be substantial given the ample opportunities for development and redevelopment. Adverse economic conditions since the 2008 economic downturn have slowed growth at many stations and additional time will be needed to adequately assess the impact of the investment on growth.

DART will continue to monitor land use development and growth in the corridor in order to track the economic-development impacts of the rail line.

Mountain Link Bus-Rapid-Transit Project; Flagstaff, Arizona

Mountain Link is an arterial bus rapid transit (BRT) project serving a four-mile corridor from downtown Flagstaff southwest through the campus of Northern Arizona University to the Woodland Village residential area. The figure provides a map of the project and the corridor that it serves.

The project was developed by the Northern Arizona Intergovernmental Public Transportation Authority (NAIPTA), the City of Flagstaff, and Northern Arizona University (NAU). It is the first BRT service in Flagstaff. Mountain Link is now operated by NAIPTA as part of its transit system of seven fixed routes and a fleet of 20 buses.

Mountain Link was developed as a Very Small Starts project, entering into project development (PD) in January, 2009, and receiving a Small Starts grant in May 2011. After a brief construction period, the project opened to service in August 2011.

Mountain Link was one element of the 2005 Transit Master Plan that called for a substantial expansion of NAIPTA services funded by a proposed increase in the City of Flagstaff sales tax. Voters approved a 0.29-cent increase in the sales tax in 2008. NAIPTA has increased its fixed-route system from service provided by four buses in the peak periods in 2001, to 10 buses in 2009, 11 buses in 2011, and 15 peak-period buses in 2013.

Over the interval between 2001 and 2010 – just before the opening of the Mountain Link project – NAIPTA ridership increased from 115,000 annual boardings to 1.1 million annual boardings. With the project and continued growth, ridership is expected to surpass 2.0 million boardings for all of 2014.

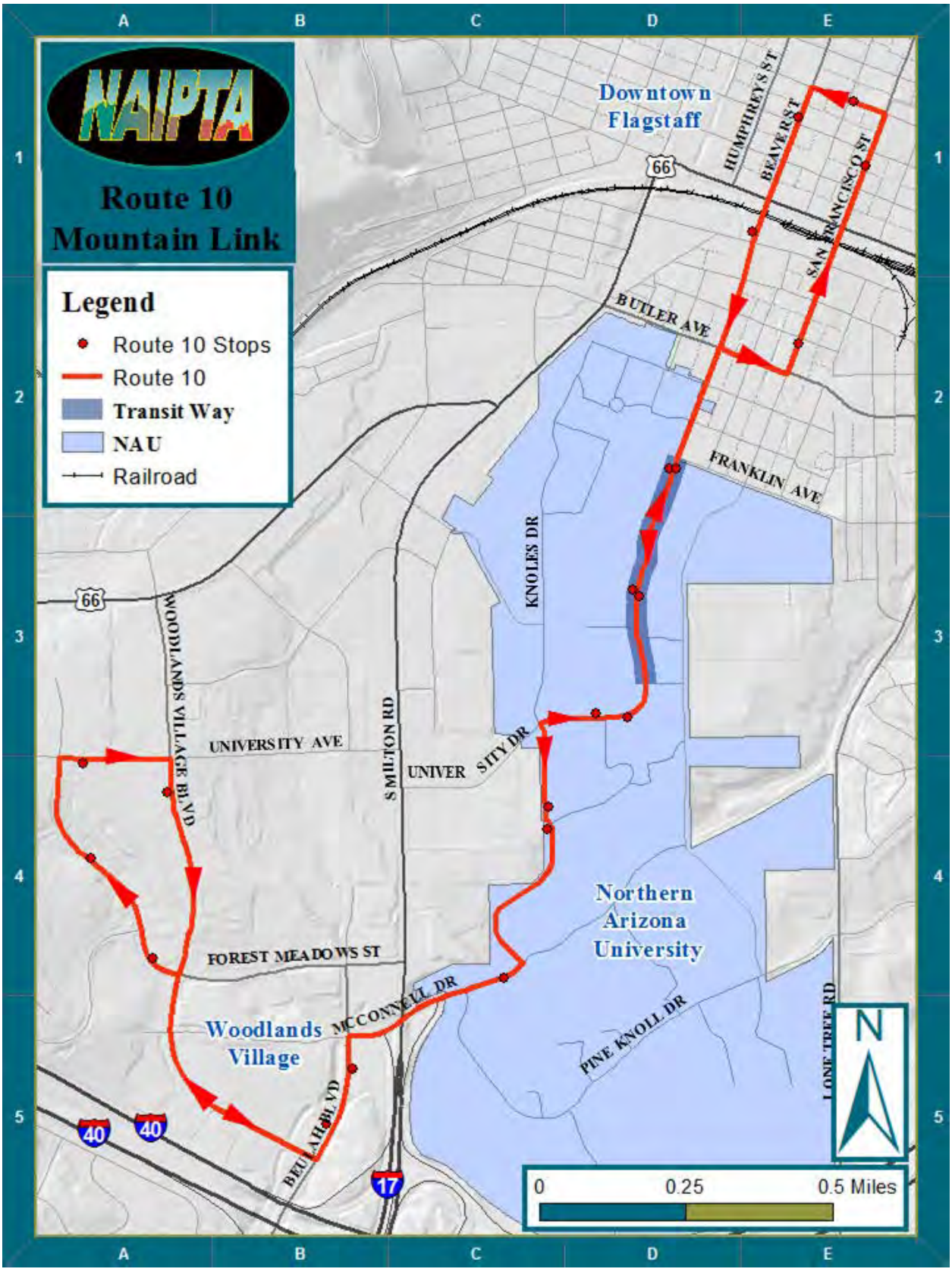
For the Before-and-After Study, the "before" milestone was October 2010. The "after" milestone was October 2013, 26 months after the beginning of service.

Physical scope of the project

Mountain Link is an arterial BRT project that includes 2.3 miles of two-way operation on campus roadways and city streets, a 1.2-mile one-way loop through downtown, and a 1.0-mile one-way loop through residential areas at the southwest end. The on-campus segment includes a 0.4-mile transit-way, a new facility built as part of the project and reserved for BRT buses, campus buses, bicycles, and pedestrians. Overall, including the central two-way segment and both terminal loops, the project comprises 6.8 one-way lane-miles. Except for the 0.8 lane-miles on the transit-way, all BRT service operates in mixed traffic on pre-existing roadways and streets.

Development of the transit-way was coordinated with an ongoing effort by NAU to remove surface parking lots from the center of campus and relocate spaces to new parking structures around the campus periphery. For the transit-way, NAU removed a string of narrow parking lots and made the resulting right-of-way available to the project.

The project also includes 21 passenger stops with passenger shelters and other amenities, and six hybrid-electric 35-foot buses. Shelters at BRT stops are branded with architectural treatments unique to the BRT service. BRT buses are branded with a Mountain Link design unique to the BRT service. The buses are effectively based on the same hybrid-electric vehicle specifications



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used by most of the NAIPTA fleet – a strategy that avoids extra costs associated with the maintenance of different vehicle types.

Mountain Link has no traffic-signal priorities or reserved lanes outside of the transit way.

Predictions of the project's scope at the planning and development milestones were close to the actual outcome. At entry to project development, the anticipated scope was different from the as-built scope in four ways.

- The predicted scope anticipated a longer transit-way across the NAU campus – 0.7 miles rather than the as-built 0.4 miles – that would have provided a more direct reserved routing for BRT buses. Problems with right-of-way availability led to the shorter as-built transit-way and added 0.5 miles in each direction to the mixed-traffic routing of BRT buses on existing campus roadways.
- The predicted scope anticipated 24 BRT stops but engineering and property-acquisition problems led to the elimination of three of those stops in the as-built project.
- The predicted scope included eight new BRT vehicles but refinements to the operating plan and efforts to contain costs led to the acquisition of six BRT vehicles as part of the as-built project.
- The predicted scope included a pro-rated contribution to the construction of a new facility for vehicle maintenance and administration. Subsequently, other funding was found to cover the full costs of that facility and the contribution was dropped from the project budget.

NAIPTA made these refinements to the project scope during project development. Consequently, the project scope defined in the grant accurately anticipated the as-built scope of the project.

Capital cost

The actual cost of the Mountain Link project was $8.25 million in year-of-expenditure dollars. Principal cost items were construction for the transit-way and at stop locations, the BRT vehicles, engineering and design services, and passenger facilities at the stops.

Without vehicle costs, the average project cost was $1.8 million per guideway-mile (counting every 2.0 lane-miles in the terminal loops as equivalent to 1.0 guideway-mile), well below the $3.0 million per mile limit for Very Small Starts projects.

Predicted costs at entry to project development were $10.41 million in year-of-expenditure dollars. The principal sources of over-estimates of the actual costs were two extra scope items: eight anticipated vehicles versus six in the as-built project ($1.5 million), and the planned contribution to the vehicle-maintenance facility ($1.5 million) that was actually funded from other sources. The principal under-estimates were for unanticipated right-of-way purchases ($0.6 million) and engineering services ($0.8 million).

Predicted costs in the Small Starts grant accurately anticipated the actual costs of the as-built project.

Transit service

Mountain Link provides service every day, including weekends, with 10 minutes between buses during weekday peak times, 15 minutes between buses early and late on weekdays, and 40

minutes between buses on weekend days. The 6.8-mile round trip is scheduled at 32 minutes on weekdays, an average operating speed of 12.8 miles-per-hour. Travel time lengthens during peak hours when crush loads on the NAU campus add to dwell times at bus stops. Travel time may also increase when Mountain Link buses encounter trains at the two at-grade railroad crossings on their loop through downtown Flagstaff.

Mountain Link initially provided service only on weekdays but feedback from riders and from NAU led to the addition of weekend service within two months after project opening.

In general NAIPTA bus services require a $1.25 cash fare for each trip or a $2.50 day-pass for unlimited travel. Monthly, semester, and annual passes are available at discounted prices. Fares and passes are available to youths and seniors at 50-percent of regular prices. Mountain Link and the campus shuttle system are free-fare to NAU students, all of whom pay a transportation fee among other academic fees. Further, NAU faculty and staff who choose to obtain a free ecoPASS from the university can ride all NAIPTA routes, including Mountain Link, at no fare.

Prior to the introduction of Mountain Link, no NAIPTA services operated on the NAU campus. The campus shuttle system provided internal transportation, connecting south campus to north campus via Pine Knoll Drive, McConnell Drive, and Knoles Drive. Shuttle buses operated at 3-5 minute spacing during the school day but not in evening hours or on weekends.

NAIPTA made no changes to its existing routes because of the introduction of Mountain Link. NAU rerouted the northern segment of the campus shuttle from Knoles Drive to the transit-way and eventually added a second shuttle route to restore some service along Knoles Drive.

The introduction of Mountain Link BRT continued the ongoing expansion of the NAIPTA fixed-route bus system. By itself, Mountain Link added 12,100 annual service hours to the system, a 32 percent increase. Adjustments to existing routes, where service had been significantly expanded in recent years, added another one percent to service hours over the same interval.

During project development, NAIPTA accurately anticipated weekday service levels on Mountain Link but did not anticipate the immediate demand for service on weekend days.

Operating and maintenance costs

The per-hour operating and maintenance (O&M) costs of Mountain Link BRT service are essentially the same as other NAIPTA routes because, while the BRT vehicles are uniquely branded with a distinct color scheme, they are effectively the same hybrid-electric vehicles that NAIPTA uses for other fixed routes.

The overall NAIPTA O&M budget has increased by 35 percent between 2010 and 2013 – a direct consequence of service expansion driven primarily by the addition of Mountain Link to the fixed-route system.

At the planning and development milestones, NAIPTA underestimated Mountain Link O&M costs by 20 percent, primarily (1) because of the unanticipated demand for BRT service on weekend days and (2) because administrative costs were not fully allocated to the new service in the predictions.

Ridership

Mountain Link has averaged 3,300 trips per weekday when the university is in session and reached its highest average of 4,200 trips in October, 2013. Continued growth is attributable to continued efforts by NAU to foster transit use and relocate parking to the campus periphery, and to changes in student residential choices to locations in the Mountain Link corridor where they can take advantage of BRT connections to campus.

The principal ridership market on Mountain Link comprises students traveling between the NAU campus and their off-campus residences in the Woodlands Village area. This market is large enough to cause crush-loading conditions during peak times of the day. The second largest ridership market is travel between on-campus locations where BRT buses complement the similarly crush-loaded campus shuttle system. Travel to and from downtown Flagstaff represents a small share of Mountain Link ridership, largely because downtown is within walking distance of many on-campus locations.

The Transit Master Plan in 2005 predicted that the BRT project would attract 3,500 weekday transit trips. Although no ridership prediction was required for the project under FTA's Very Small Starts procedures, a forecast of 4,150 weekday trips was documented in FTA's 2007 profile of the project. With current ridership in the range of 3,500 to 4,200, ridership predictions for Mountain Link have proven to be quite accurate.

Development impacts

The substantial use of Mountain Link by students living in off-campus residences has begun to affect the development pattern for additional off-campus housing. Four new student-oriented housing developments have been proposed in the BRT corridor compared to only two in all other near-campus locations. Developer feedback indicates that the BRT route is now a major factor in decisions about new off-campus student housing developments.

The NAU student body is projected to grow from 19,000 to 25,000 by 2020. With on-campus housing already capped by NAU at 9,500 beds, all of this growth will have to be accommodated by the addition of off-campus student housing. Mountain Link is expected to continue to help shape the pattern of these new developments.