Before-and-After Studies of New Starts Projects

Report to Congress

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FOREWORD

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

1. Northwest-Southeast Light Rail Project; Dallas, Texas (2010)
2. The Tide Light Rail Project; Norfolk, VA (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. For physical scope and capital costs, the "after" data collection occurs during project construction. For affecting transit service, operating and maintenance costs, and ridership the "after" data collection occurs two years after the project opens in order to permit conditions to stabilize.

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 two projects.

Northwest-Southeast Light Rail Project; Dallas, Texas (Final Update)

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 below provides a map of the Green Line, the federally-funded project, and the current Dallas-area light rail system.

The Green Line now extends 28.8 miles from southeast Dallas through downtown and then northwest 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 as part of 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 Dallas 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. These 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 update and final version of the report from the Before-and-After Study for the project. The 2014 summary was complete except for the ridership topic. Since then, DART has completed the survey of ridership patterns after opening of the project, and this update is limited to documenting the findings from that ridership survey.

Physical scope

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 southeast 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.

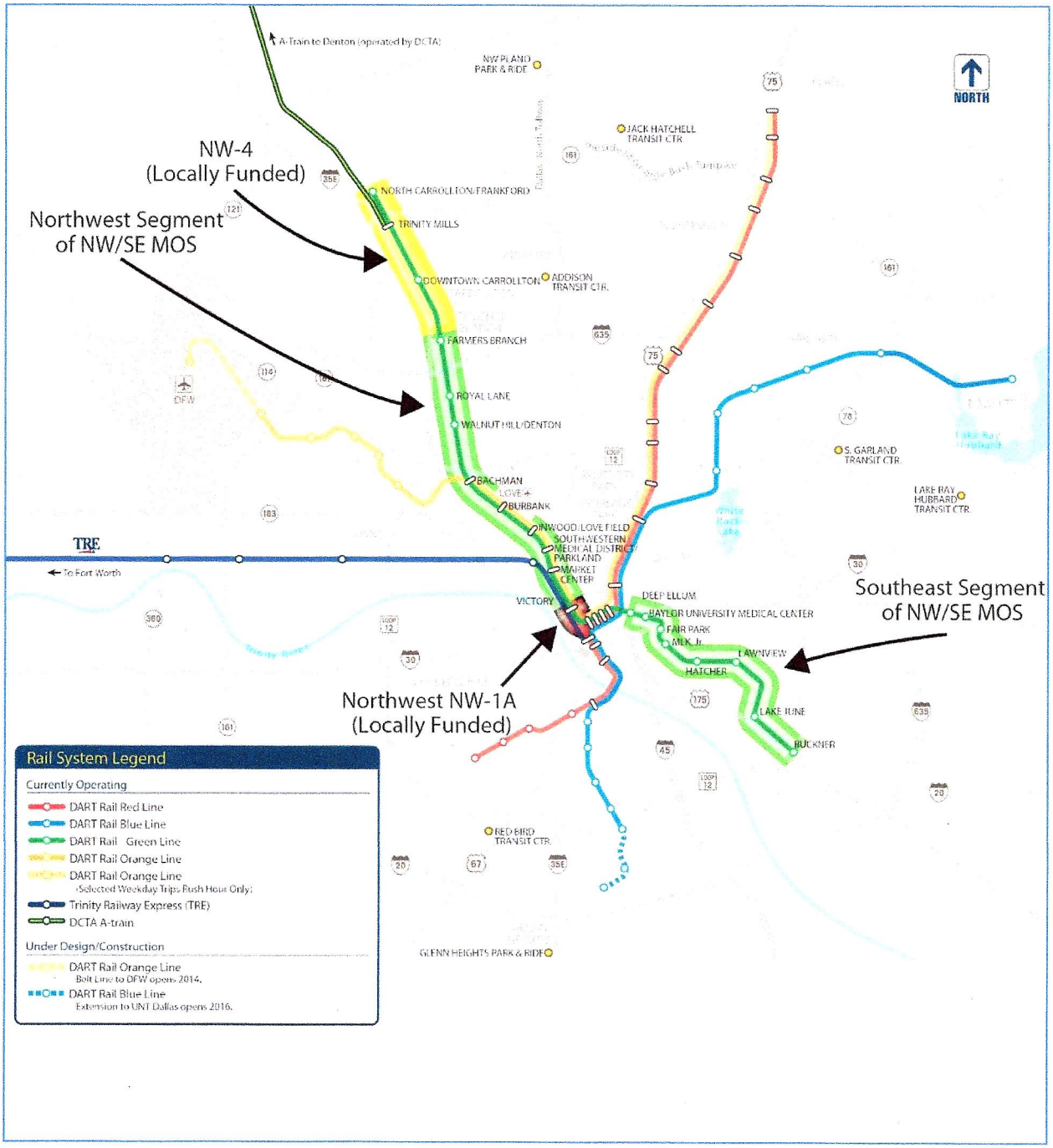


Figure 1. The DART Green Line and Its Components

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 each have three sections including a low- floor center section, two articulation joints, a seated capacity of approximately 100 passengers, for 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, the 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, or $59.7 million per mile excluding 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) the assumption of 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. Correcting the entry-into-PE cost estimate for these four differences yields a 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 southeast 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-hour 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

The average number of weekday trips on the project in 2014 was 32,949. This total includes trips to, from, and among new stations on the project northwest and southeast of downtown Dallas. It includes trips on both the Green Line and the Orange Line that used the project itself, but excludes trips made elsewhere on the two lines.

Some 49 percent of weekday trips on the project comprise commuters traveling between home and work, while 40 percent are riders traveling between home and non-work activities, and the remaining 11 percent are riders traveling between two non-home locations. Project riders travel between home and their first train or bus largely by walking (66 percent), by parking and riding (18 percent), and as drop-offs from cars (15 percent). Park-ride access represents a somewhat higher share (25 percent) of travel to/from work while the walk share drops to 61 percent and the drop-off share remains largely unchanged (14 percent).

Low-income riders (with household incomes of less than $35,000 in 2014) make 52 percent of all trips on the project. Riders with household incomes between $35,000 and $75,000 represent another 40 percent of riders, while higher-income riders make only 9 percent of project trips. Incomes are somewhat higher for riders traveling between home and work: 42 percent low, 46 percent medium, and 11 percent higher. Riders from car-less households make 26 percent of all trips on the project while another 49 percent of trips are made by riders from car-owning households that have more workers than cars.

Weekday ridership on the DART light rail system grew from 62,000 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, and to 101,000 boardings in 2014. Weekday ridership on the DART bus routes was 151,000 boardings in 2007, 116,000 boardings in 2011, and 130,000 boardings in 2014. Total DART rail and bus ridership was 213,000 boardings in 2007 and 231,000 boardings in 2014. (Boardings count transferring riders each time they board a train or bus.)

Therefore, DART ridership growth over the interval between 2007 and late 2012 was driven entirely by the openings of the Green and Orange Lines. This growth was partially offset by a 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.

Opening year 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 three projects that were still in project planning at the time: the extension of the Orange Line to the west to DFW Airport and to the northeast into the Red Line corridor; 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 forecast prepared in 2008 added the northern-most stations of the Green Line and the A-Train (but not the Orange Line extensions), new demographic forecasts, and an updated travel-forecasting model. That forecast predicted 41,200 Green Line trips – essentially the same as the predictions at FD-entry and the FFGA. Those milestone predictions overestimated current project ridership of 33,000 weekday trips by 25 percent. Because no archives are available from the now-abandoned mainframe computer used to prepare these predictions, a detailed analysis of the causes of the overestimate is not possible.

The likely principal contributors to the difference between predicted and actual ridership are (1) lower-than-expected growth in the metro area and the Green Line corridor, (2) the actual 15-minute headways for all current light rail lines compared to the anticipated 10-minute peak-period headway for all lines, and (3) the lower-than-anticipated levels of bus service system-wide caused by budget constraints introduced by the national economic downturn in the late 2000s.

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. Because adverse economic conditions since the 2008 economic downturn have slowed growth at many stations, 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.

The Tide Light Rail Project; Norfolk, VA

The Tide is a 7.3-mile light rail line extending eastward from the western edge of downtown Norfolk, through downtown, and terminating at the Norfolk/Virginia Beach city line. The project was developed and built, and is now operated, by Hampton Roads Transit (HRT), the principal transit provider for the Hampton Roads area.

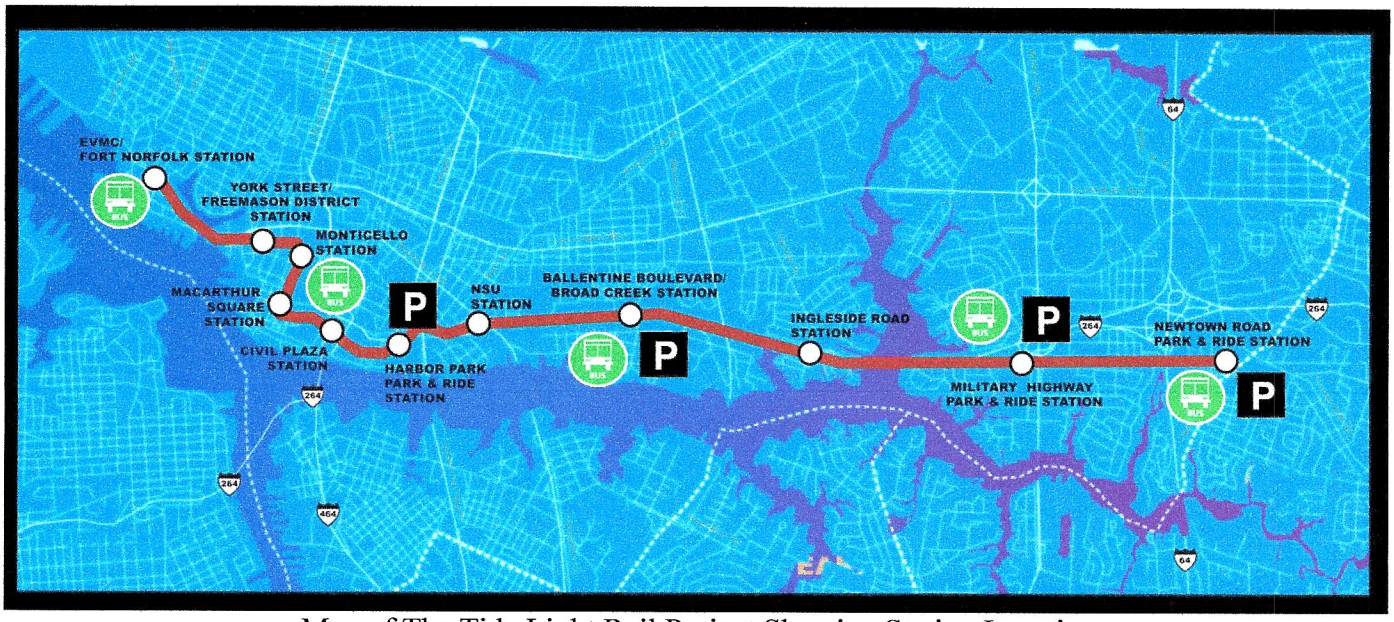
Planning for rail transit in the east-west corridor through Norfolk and Virginia Beach began in 1986. These efforts led to a Major Investment Study in 1997 that identified as the Locally Preferred Alternative a light rail line extending 18 miles from downtown Norfolk eastward to the Virginia Beach oceanfront.

In November 1999, a non-binding referendum in the City of Virginia Beach resulted in a majority vote against the rail proposal. In response, the Virginia Beach city council voted in February, 2000, to withdraw from the agreement with the City of Norfolk to build the project. The Norfolk city council subsequently voted to build the portion of the project located within the city.

The project entered into preliminary engineering in 2002, entered into final design in 2006, received a Full Funding Grant Agreement in 2007, and opened to service in 2011. The *before* milestone for this study was 2008 and the *after* milestone was 2013.

Physical scope

The figure is a map of the project, its 11 stations, and the east-west corridor it serves within the City of Norfolk. The line is double-tracked except for short distances of single track approaching both terminal stations and has over-head electrification throughout. The project is 7.34 miles long – at grade for 6.17 miles and on structures for 1.17 miles.



Map of The Tide Light Rail Project Showing Station Locations
and Identifying Stations with Park-Ride Lots and Bus Connection

- The 0.7-mile segment west of downtown Norfolk runs at grade alongside an arterial street, includes a new level-crossing of Elizabeth Creek, passes through three traffic-signal-controlled street intersections, and has two stations.
- The 1.5-mile alignment through downtown is generally located within public-street rights of way, primarily in reserved center lanes. One 0.2-mile segment operates in mixed traffic lanes and two short segments are located in exclusive off-street right of way. Intersections are traffic-signal controlled and left turns across the tracks are generally permitted. The downtown segment includes three stations.
- From the eastern edge of downtown, the line transitions from city streets via a 0.8-mile segment past the Harbor Park baseball stadium at grade and onto an elevated alignment comprising viaduct, retained fill, and bridges above several streets and an active railroad. This segment has two stations including the only elevated station at NSU.
- The aerial structure touches down at the site of the line's maintenance and control facility in an abandoned former railroad right of way in which the line continues 4.4 miles to its terminus at Newtown Rd. This segment has seven at-grade street crossings that are fully controlled by gates and signals. It also includes three structures – two rebuilt bridges over watercourses and a new overpass of an active railroad.

The project's 11 stations each have passenger shelters, ticket vending machines, bench seating, lighting, and an information kiosk. Ramps to low platforms provide full access and level boarding with low-floor vehicles. Nine stations have one-car platforms; two have 2-car platforms (MacArthur in downtown and NSU on the aerial section – both in locations where any future station lengthening would be particularly disruptive). Four stations have park-ride lots, as indicated on the project map above, with 100 to 270 spaces each, totaling 780 spaces. Parking is free.

The project scope includes nine transit vehicles. Each vehicle is double-articulated, low-floor, and 94 feet long; seats 68 passengers within a total capacity of 160-180 passengers; and has four doors on each side. Peak service requires six vehicles; so three vehicles are spares and provide extra capacity for special-event services.

In downtown Norfolk, train signals are coordinated with traffic signals and provide signal priority to trains. In the former railroad right-of-way east of the NSU station, an automatic block signaling (ABS) system is used for train control.

The Tide's facility for vehicle maintenance, vehicle storage, and train operations is located just east of NSU Station on a seven-acre site. The maintenance shop is approximately 28,000 square feet. HRT leases a second maintenance facility to house systems maintenance and provide warehouse storage for maintenance of way material and spare parts.

In terms of its principal characteristics, the predicted scope of the project matched the actual scope at all three milestones during development of the project. The predictions anticipated a 7.3-mile project with 11 stations, nine vehicles, a principally at-grade alignment, and a maintenance and storage facility. However, the predicted scope at all three milestones consistently understated the actual design requirements for many elements of the scope. This persistent problem appears to have had two sources:

- First, in an effort to meet FTA's cost-effectiveness criteria for advancing the project into preliminary engineering, HRT downsized many elements of the project to reduce its estimated costs. The downsized elements remained part of the scope definition through subsequent milestone reviews at PE-entry, FD-entry, and the FFGA. Many of these elements were restored or upgraded after the FFGA in response to operational requirements, safety reviews, building codes, and other realities. These post-FFGA adjustments included the block signaling system from Harbor Park Station to Newtown Road Station, an operations control center, improved coordination of rail/roadway traffic signal priority in downtown, a robust communications system, and expanded facilities and equipment for maintenance and storage.
- Second, the project experienced additional post-FFGA scope additions in response to requests by the City of Norfolk and NSU to add elements not anticipated at any project-development milestone. HRT was responsive to these requests to satisfy the interests of major stakeholders (and, in the case of the city, issuers of permits and inspections) but at the cost of unanticipated scope additions. Principal changes in this category include a complete revision of all station shelter and platform railing designs; the addition of the Newtown Road Operator's restroom; a change to brick facades for buildings in the operations and maintenance facility; a change to black-colored overhead catenary system poles in downtown Norfolk; a change to red-colored surface concrete in embedded track in downtown Norfolk; a non-revenue siding track; a significant increase in hazard mitigation signage, fencing, and barriers; the addition of visual screening along the tracks adjacent to I-264; additional fencing, crossing gates, sidewalk railings, signage, and barriers to prevent pedestrians from entering the ROW and to prevent incidents between trains and personal vehicles.

While these late additions to the scope did not change the general characteristics of the project, they significantly revised many of its physical features, added time for these changes to be incorporated late in project design (and, in some instances, during construction), and increased the professional engineering services needed to effect the changes.

Capital cost

The actual cost of the project was $314.6 million in year-of-expenditure (YOE) dollars for a construction period extending between 2008 and 2012, inclusive. The aggregate unit cost of the transit project in YOE dollars was $43.1 million per mile -- $38.2 million per mile without the vehicles. These average unit costs are generally consistent with the actual costs of other light rail lines built in the same time period.

Predictions of project costs in YOE dollars throughout project development consistently underestimated the actual cost outcome – by $120 million (37 percent) at PE-entry, $79 million (25 percent) at FD-entry, and $83 million (26 percent) at the FFGA.

- At PE entry, 54 percent of the underestimate was caused by underestimates of scope and unit prices; 34 percent was caused by an underestimate of the actual schedule for FTA reviews and ratings, project development and construction; and 12 percent was caused by underestimates of actual cost-inflation of heavy construction during the construction period.
- At FD entry and the FFGA when the project neared the beginning of construction, nearly all (94 percent) of the underestimate was caused by underestimates of scope and unit prices. Predicted costs of inflation were close to the actual outcome because predicted inflation rates were higher than actual rates and mostly offset the effects of a predicted schedule that did not anticipate the additional delays that would occur during project construction.

In addition to the incremental costs of the scope additions documented in the physical-scope section above, other effects contributed to the underestimates of costs, including:

- Project delays and change orders resulting from unexpected utility relocations, accompanied by right-of-way acquisition during construction;
- Schedule delays, utility conflicts, and environmental efforts;
- Added professional services resulting from schedule delays, contractor change orders and claims, project extensions, design additions and changes during construction; and
- Uncertainties among both HRT internal staff and the consultant team regarding FTA documentation requirements and strict adherence to the FFGA, resulting in some confusion in monitoring capital costs during project execution.

Discontinuities in FTA's assignment of project management oversight contractors meant that FTA was unable to provide timely and effective oversight of problems associated with realistic definitions of project scope, adherence to schedule, and containment of project costs.

Transit service

The Tide operates seven days per week, providing service between 6:00 a.m. and 11:00 p.m. Monday through Thursday, 6:00 a.m. and 12:00 midnight Friday and Saturday, and 11:00 a.m. and 9:00 p.m. on Sunday. Headways between trains are 15 minutes throughout the week except for 3.5-hour intervals of 10-minute headways during both mornings and evenings on weekdays. End-to-end running time on The Tide is approximately 26 minutes, including dwell times at stations, for an average speed of approximately 16.3 mph. With layovers at the terminal stations, the total round trip running time is 60 minutes. Six one-car trains provide service during peak periods; four one-car trains provide service at all other times. The one-trip fare is $1.75 and a day pass for unlimited travel is $4.00, both identical to fares for local bus routes.

Bus connections are available at eight of The Tide's 11 stations. HRT made 21 bus-service changes between the August 2011 initiation of light rail service and the August 2013 "after" milestone to integrate The Tide into the bus system. In general, the adjustments were minor – limited rerouting of existing routes so that they could stop at a nearby station and expanded hours of service early and late in the day to provide bus connections throughout The Tide's daily schedule. Only one existing route was truncated at a rail station and three new routes were implemented to provide feeder service to The Tide's terminal stations. HRT continued service on the three long-distance bus routes in the corridor running parallel to The Tide.

Overall, HRT's adjustments to the bus system were modest in scope and scale, largely for two reasons. First, The Tide provides new transit service in a new east-west transit corridor – the former railroad right of way. As a result, no existing bus routes became redundant, as they can where rail lines are introduced on or near arterial streets. Second, the initial segment of The Tide is relatively short. As a result, speed advantages on the largely exclusive rail right of way are limited in the amount of travel time that they can accumulate. Consequently, while it was useful to provide opportunities for bus-rail transfers, truncations of bus routes at rail stations made sense in few circumstances.

Predicted service levels for The Tide across all three project-development milestones matched actual service levels closely. Four differences are:

- The predictions anticipated 7.5-minute light rail headways in the peak periods while actual peak-period headways are 10 minutes. The longer headways are the consequence of recommendations by the state's rail safety oversight process.
- The predictions anticipated faster running speeds for The Tide and end-to-end runtimes of approximately 23 minutes compared to actual runtimes of 26 minutes. The slower actual running speeds are also the consequence of recommendations from the state's rail safety oversight process and the downtown traffic-signal system that actually provides only signal priority for trains rather than the predicted signal pre-emption.
- The predictions anticipated that off-peak trains would begin their return trips immediately from the terminal stations. Actual service includes the customary layover time at each terminal.
- The predictions anticipated an earlier end of light rail service on weeknights and a later start of service on Sundays.

The net effect of these differences is that the predictions overestimated by six percent the revenue-miles of service that The Tide provides, primarily because of the difference in weekday peak-period headways. Even so, the predictions underestimated by 12 percent the revenue-hours of service needed to provide the slightly reduced service, because they also anticipated faster average operating speeds.

Predicted changes to the bus system in conjunction with The Tide accurately anticipated the actual service outcomes. The anticipated strategic vision matched the actual outcome: that The Tide would be introduced with only minor adjustments to the existing bus routes in the corridor; few changes would be made to truncate existing routes and introduce new feeder routes; and those few changes would be focused at the two terminal stations.

Operating and maintenance costs

In 2013, annual operating and maintenance (O&M) cost of The Tide was $9.5 million. Average aggregate unit O&M cost was $318 per train-hour and, because trains comprise one light rail vehicle each, $318 per vehicle-hour. O&M costs for the HRT bus system were $46.2 million, excluding administrative costs. Bus-system costs increased by 6.0 percent compared to the $43.6 million annual cost in 2009, before implementation of The Tide. The average unit cost of bus service increased over this interval increased from $50.60 per revenue vehicle-hour in 2009 to $58.19 per revenue vehicle-hour in 2013, and increase of 14 percent that outpaced the 8.5 percent general inflation over that time. The net outcome in total bus O&M costs therefore reflects real increases in the unit cost of service, partially offset by modest reductions in bus service.

Predicted O&M costs underestimated the actual outcome by $1.9 million (20 percent, in inflation-adjusted 2013 dollars) at all three project-development milestones. Some $1.5 million of the underestimate is insurance premiums for coverage above HRT's self-insured level of $2 million per incident. The other contributor to the underestimates of O&M cost is the underestimate of train-hours needed to provide the specified Tide service at lower-than-anticipated train speeds. These underestimates were partly offset by an overestimate of rail maintenance costs. The predictions at all milestones assumed that all maintenance would be contracted. Actual maintenance is uses a mix of staff and contractor maintenance at a lower-than-predicted cost.

Ridership

At the "after" milestone in the fall of 2013, The Tide carried 4,600 trips per average weekday. Ridership on The Tide averaged over 5,000 weekday trips at the time of its opening in 2011 and subsequently rose to over 6,000 weekday trips during the summer of 2012 because of aggressive fare discounting that has since been discontinued. With the exception of the months of November, December, and January, which generally have lower ridership due to holidays and winter weather, ridership has stabilized at between 4,500 and 5,500 riders per day.

Some 61 percent of weekday trips on The Tide are attracted to the Norfolk core, an area that includes downtown Norfolk CBD, the Eastern Virginia Medical Center, and Norfolk State University.

Another 10 percent Tide trips are attracted to other destinations within the immediate project corridor—areas within approximately one mile of a Tide station. Only 29% of Tide LRT trips are attracted to locations more than a mile from The Tide.

The residential locations of Tide riders are dispersed over a larger area. Only 35% of trips on the project are made by residents located within one mile of the nearest Tide station. The remaining 65% of Tide riders begin their trips more than a mile from the nearest Tide station, meaning that a majority of users must drive or ride a bus to reach their home-end station.

Over half of all trips on The Tide are made by workers traveling to/from their place of work (43 percent) or students traveling to/from their college campus (19 percent). This orientation towards work and college trips is particularly pronounced for Tide riders who live outside the immediate Tide corridor. In contrast, residents of the corridor are more likely to also use The Tide for non-work trips.

Slightly more than half of all Tide trips are made by riders who are transit dependents – defined as travelers who are either members of zero-car households or do not possess a driver's license. Transit dependent riders constitute a lower share of Tide trips to downtown Norfolk and a higher share for Tide trips to other parts of the region.

Most Tide riders (73 percent) travel to their first transit stop using a non-motorized mode – either walk or bike. Motorized access – driving or being dropped off – claims a 53 percent share only for Tide trips that begin outside of the immediate corridor and travel to the Norfolk core.

The introduction of The Tide appears to have resulted in a modest increase in transit ridership in the region. Weekday linked trips (not counting transfers) on the HRT transit system increased from 35,700 in 2011 to 38,700 in 2013, a gain of 8 percent. Most of this growth in overall transit ridership occurred in travel to the Norfolk core, where ridership increased from 5,800 to 8,000 weekday trips – a 38 percent gain.

Predictions of opening-year ridership are available for the FD-entry milestone. (HRT prepared only horizon-year predictions at PE-entry and adopted the FD-entry predictions for the later FFGA milestone.) At FD-entry, HRT projected that The Tide would carry 2,900 weekday trips, 37 percent below the actual 2013 ridership of 4,600 weekday trips. The accuracy of the prediction varies significantly across trip purposes:

- The predicted 2,200 weekday trips on The Tide between home and work were higher than actual work-trip ridership by 12 percent. The work-trip prediction correctly anticipated that the key attraction location for these trips would be the Norfolk core but over-estimated this market by 700 weekday trips.
- The predicted 180 Tide trips between home and non-work activities grossly underestimated the actual ridership of 2,000 weekday trips in this category. The reasons for this underestimate are not known with certainty. The most likely explanation is that

the unique characteristics of attractions in the Norfolk core may not have been fully represented in the regional travel forecasting models used at the time. The Norfolk core includes governmental centers, universities, major medical institutions, sports venues, performing arts venues, and regional shopping centers that draw visitors from a broader area than most non-work attractions in other parts of the region. Without specific representation in the ridership-forecasting methods, travel to these regional activity centers in downtown Norfolk was largely missing as a travel market from which The Tide actually attracts many trips. Reviews of the ridership forecasts by FTA staff missed this underestimated component of Tide ridership.

- The predicted 500 weekday trips between non-home activities closely approximated actual ridership of 570 non-home-based trips. The prediction correctly anticipated that most non-home-based ridership would occur to, from, or within the Norfolk core.

The other special market of interest in The Tide ridership forecasts was park-ride access at downtown fringe lots. This market was reasonably well developed by the early 2000s using electric buses to shuttle workers from fringe parking lots to downtown jobs. In the ridership forecasts, the market contributed a modest number of trips to the project. Currently, however, the fringe park-ride market has declined, the electric shuttle service has been discontinued, and fringe-park ride trips are largely absent in actual Tide ridership.

HRT employed conventional methods for predictions of Tide ridership. Since that time, these methods have generally evolved nationally to recognize travel for "special markets" like those in downtown Norfolk. These more detailed methods are less likely to miss the significant ridership contributions that these markets can make to new fixed-guideway transit projects.

Station-area Development

In 2008 at the *before* milestone, HRT prepared an inventory of planned developments within Tide station areas and then examined the status of those plans in 2013 at the *after* milestone. The 2008 inventory found 25 planned developments; by 2013, 13 had been built while 12 had not been built. The planned developments that were not built were a mix of sizes, scales and uses with no apparent commonalities that caused them to remain unbuilt.

Between 2008 and 2014, downtown Norfolk experienced a significant upward trend in development and redevelopment. Similar development surges have happened during this timeframe in downtowns throughout the country. The 2013 assessment was able to identify anecdotal evidence for a role of The Tide in final commitments to build three projects within one-half mile of a Tide station: a medical building with retail space and structured parking near the Eastern Virginia Medical Center station; a luxury apartment building in downtown; and a mixed-use tower in downtown with office, retail, and residential space along with 1,800 structured parking spaces. Developers specifically noted the proximity of Tide light rail service and their expectations that this proximity would enhance the marketability of their developments.

Beyond these three developments, the 2013 assessment was unable to document evidence to indicate that the development that has happened in Norfolk since 2008 can be directly attributed to LRT. The development of MacArthur Center, a large-scale regional mall that opened in

Norfolk's central business district in March of 1999, was a critical first step in reversing the previous cycle of downtown disinvestment, and can be credited with beginning a cycle of reinvestment that has resulted in the renaissance of downtown Norfolk as a vibrant, mixed-use regional destination.

Market forces catalyzed by the success of the MacArthur Center are responsible for this broader downtown renaissance; introduction of The Tide contributed to development decisions for at least some development projects in and near downtown.

Parking

City-controlled garages provide 90 percent of all spaces in the Norfolk CBD. Between 2008 and 2014, the number of spaces in city-controlled garages and lots increased by eight percent as the city opened two new garages and closed five lots/garages to make way for new development.

The Norfolk city council in 2005 adopted a Transit Oriented Downtown Parking Policy to encourage higher development densities, particularly near transit stations, and cap privately-controlled parking spaces in downtown at 3.7 spaces per 1,000 square feet of leasable office space. In 2014, the city council amended the zoning ordinance to lower by 25 percent the parking requirements for non-residential land uses within 1,500 feet of a rail station.

Analysis of changes in parking data between 2008 and 2014 has not been able to demonstrate any direct correlation, so far, between Tide rail service and parking supply, demand, and pricing in Norfolk's CBD.