Final Report from the Before-and-After Study of the Tide Light Rail Project

HAMPTON ROADS TRANSIT

Hampton Roads Transit

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Table of Contents

List of Appendices

1.0 Introduction

The Tide Light Rail project is a 7.3-mile Light Rail Transit (LRT) line connecting the Eastern Virginia Medical Center (EVMC) complex east through downtown Norfolk to Newtown Road at the Norfolk-Virginia Beach border. The project was developed and built, and is now operated, by Hampton Roads Transit (HRT). It is the first light rail line in the Hampton Roads area.

Early History of Norfolk Tide

Tidewater Regional Transit (TRT), one of the two predecessor agencies of Hampton Roads Transit (HRT), completed several system planning studies, a Major Investment Study and a Draft, Supplemental Draft and Final Environmental Impact Statements of a major transit improvement for the Hampton Roads area. Previous studies included:

<u>Systems Planning Studies</u>

- Study of the Cost Effectiveness of Restoring Passenger Rail Service, May 1986
- Rail Systems Analysis and Fixed Guideway Service Plan, Sept 1991

<u>Major Investment Study</u>

- Norfolk-Virginia Beach Corridor Major Investment Study, 1997

<u>Environmental Impact Statements</u>

- Norfolk-Virginia Beach Light Rail Transit System East/West Corridor Project, Draft Environmental impact Study, 1999
- Norfolk-Virginia Beach Light Rail Transit System East/West Corridor Project Final Environmental Impact Statement, March, 2000
- Norfolk Light Rail Transit Project, Supplemental Draft Environmental Impact Statement, January 2003
- Norfolk Light Rail Transit Project Final environmental Impact Statement, October 2005

The Major Investment Study utilized and built upon results from past planning efforts in evaluating the feasibility of implementing various transit alternatives and documented the selection of a Locally Preferred Alternative of an 18-mile light rail transit system running between downtown Norfolk and the Virginia Beach oceanfront. The Final Environmental Impact Statement for the 18 mile project was issued in March, 2000.

The modification of the Norfolk-Virginia Beach alignment was necessitated by a decision of the Virginia Beach City Council to withdraw from the bi-city agreement concerning the proposed LRT project. This decision was made as a result of a November 2, 1999 city-wide non-binding referendum in which the outcome of the election indicated an unwillingness of the citizens of Virginia Beach to permit the development of light rail in their city. In February, 2000 the City Council of Norfolk adopts a resolution to move forward with the development of light rail transit entirely within the boundaries of the city. The preparation of the Supplemental Draft Environmental Impact Statement is initiated.

Key milestone dates in project development were:

Milestone Dates in Project Development	
Milestone	**Date**
Entry into Preliminary Engineering	November 4, 2002
Entry into Final Design	September 2006
Full Funding Grant Agreement (FFGA)	October 2007
Revenue service	August 29, 2011

Before-and-After Studies

HRT received partial funding for the project through a Full Funding Grant Agreement (FFGA) with the Federal Transit Administration (FTA). Federal transit law requires any transit agency that receives project funding through an FFGA to complete a Before-and-After Study for the project. These studies have two purposes: first to document the actual outcomes of each project and second to evaluate the accuracy of the predicted outcomes prepared by the transit agency during the planning and development of the project. The studies must consider five outcomes of the project: physical scope, capital cost, impacts on transit services, consequences for transit-system operating and maintenance (O&M) costs, and the resulting ridership response. HRT has chosen to add four other topics to the actual outcomes considered in this study: farebox revenues, land use and development, parking, and traffic.

To understand the actual outcomes on the physical scope and capital costs of the project, the study examines the as-built scope of the project and near-final capital costs soon after the opening of the project. To understand the impacts on transit service, O&M costs, and ridership, the analysis compares the actual outcomes after project opening to actual conditions before the project was built. The "after" milestone for this analysis is typically two years after project opening – a timeframe that permits the transit agency to complete service adjustments and ridership to settle into new patterns in response to the project. For the Tide light rail project, the "before" milestones are typically the first three Project Development milestones shown in the table above, and the "after" milestone varies across the outcomes that have been evaluated, but is typically 2013 data.

To evaluate the accuracy of the predictions, the study compares the predictions made at key milestones in project development to the actual outcomes, identifies the sources of any significant differences, and suggests any lessons learned.

This final report has nine additional sections, one for each of the nine project characteristics. Each chapter first documents the actual outcome of the project as of 2013 (with some variations). The first six chapters then evaluate the accuracy of outcomes predicted at entry into preliminary engineering (PE), entry into final design (FD), and the FFGA. The remaining three chapters (land use, parking, and traffic) do not undertake this evaluation because no forecasts were made for these characteristics during project development.

The report has nine appendices that provide additional detail on the analysis for each of the nine project characteristics.

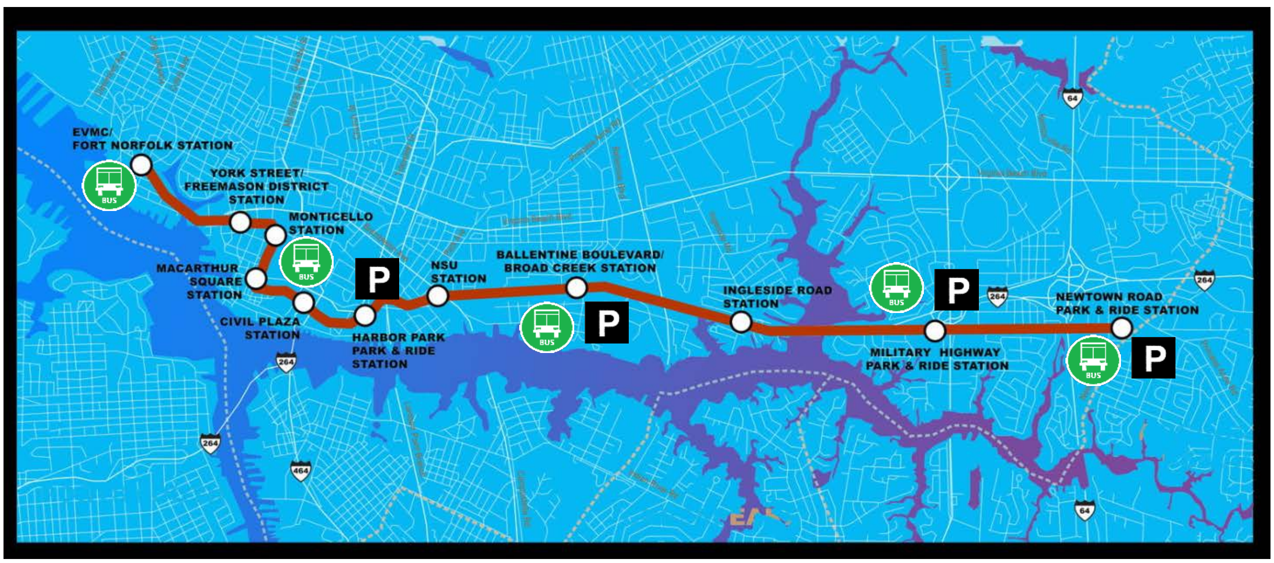
2.0 Physical Scope of the Project

Actual Outcome

The Tide LRT project began revenue operations on August 29, 2011. The Tide typically operates for 17 hours Monday through Thursday, 18 hours on Friday and Saturday, and 10 hours on Sunday, utilizing six light rail vehicles (LRV) during peak periods. Table 4 in **Appendix A:** *Physical Scope* summarizes the as-built physical scope and the predicted physical scope at Entry into PE, Entry into Final Design, and the FFGA. The following sections describe the elements of the project organized by FTA's standard cost categories (SCC). The categories relevant to physical scope are as follows:

- SCC 10: Guideway and Track Elements
- SCC 20: Stations, Stops, Terminals, Intermodal
- SCC 30: Support Facilities: Yards, Shops, Administrative Buildings
- SCC 40: Sitework & Special Conditions
- SCC 50: Systems
- SCC 60: ROW, Land, Existing Improvements
- SCC 70: Vehicles

Figure 2.1 2013 Tide Alignment and Stations



Source: HRT

Guideway and Track Elements (SCC 10)

The as-built project consists of a 7.34-mile, double-tracked light rail system with a reserved transit corridor by operating agreement in the downtown portion of the alignment and a dedicated right-of-way (ROW) on abandoned Norfolk Southern Railroad ROW from Norfolk State University (NSU) Station to Newtown Road Station. The project is single-tracked for short distances heading into the western and eastern terminal stations. A short portion of the alignment (0.2 miles) on Charlotte and Bute Streets are on shared lanes with vehicular traffic and not on dedicated ROW.

Guideway Subcategories - The project as built includes portions of semi-exclusive at-grade guideway, mixed-use at-grade guideway, exclusive aerial guideway, and retained fill guideway. There are approximately 4.4 route miles of at-grade, semi-exclusive guideway along the former Norfolk Southern Railroad ROW portion of the alignment from the crossing of the Lamberts Point Branch to the Newtown Station at the eastern terminus of the project. Within the Norfolk Central Business District (CBD), approximately 1.3 route miles of guideway is semi-exclusive, and 0.21 route miles is mixed-use. Aerial structure was constructed for a total of approximately 1.17 route miles in length at three creek crossings (Smith Creek, Broad Creek, Moseley Creek), two active Norfolk Southern freight crossings, and three roadway crossings (Park Avenue, Claiborne Avenue, and Brambleton Avenue). Retained fill sections total approximately 0.22 route miles and primarily occur in the areas adjacent to I-264 between Lambert's Point railroad crossing and the Brambleton Avenue Bridge adjacent to Norfolk University. Other minor segments of retained fill are located primarily at bridge approaches.

Track Subcategories - Six categories of track were utilized for the as-built project: direct fixation, embedded, ballasted, open deck, full-depth crossing, and special trackwork. Full-depth crossing is similar to ballasted track and open deck is similar to direct fixation; as these categories are not listed in the FTA SCC, they have been included in the lengths for ballasted and open deck track, respectively. Direct fixation track was used for approximately 0.36 track miles on the aerial structures of the project. Open deck track was also used on aerial structures, in the amount of approximately 1.98 track miles. Embedded track was utilized in the Norfolk Central Business District (CBD) in the amount of approximately 3.03 track miles. Ballasted track, in the amount of approximately 8.75 track miles, was used along the abandoned Norfolk Southern corridor, between York Street/Freemason Station, along Brambleton Avenue heading toward EVMC/Fort Norfolk Station, and in the Norfolk Tide Facility (NTF).

Stations (SCC 20)

The as-built light rail facility has 11 stations, each having a covered platform shelter with bench seating, space for two ticket vending machines, and ADA ramp access. All stations incorporate a metal clad wood-frame shelter with sectioned glazing, a gable roof, special tubular steel railings, globe lighting, and an information kiosk. Nine stations have one-car platforms, the MacArthur Station was built with two-car platforms, and the lone aerial station was built as a two-car platform, but designed to accommodate three. Table 2.1 summarizes the station characteristics of the constructed project. Specific station elements are described in more detail in **Appendix A:** *Physical Scope*.

Table 2.1 As-Built Station Characteristics				
Station	**Platform Type**	**Station Profile**	**Bus Bays**	**Parking**
EVMC/Fort Norfolk Station	Side	At grade	2*	250*
York Street/Freemason Station	Side	At grade	None	None
Monticello Station	Center	At grade	None	None
MacArthur Square Station	Side	At grade	None	None
Civic Plaza Station	Side	At grade	1***	None
Harbor Park Station	Center	At grade	None	176
NSU Station	Center	Aerial	None**	None
Ballentine/Broad Creek Station	Side	At grade	2 (and 1 passenger drop-off area)	105
Ingleside Road Station	Side	At grade	None	On-street^
Military Highway Station	Side	At grade	2	232
Newtown Road Station	Center	At grade	3	266

Source: URS, HRT, 2014.
**EVMC/Fort Norfolk Station: Two bus bays were installed after project completion by the city, not at project cost; Parking only available M-TH 6:00 p.m.-11:59 p.m. and 6:00 p.m. Friday until 11:59 p.m. Sunday*
***NSU Station as funded by the project did not include any bus bays, however, two bus bays were installed in 2013 by the City of Norfolk.*
****An existing HRT bus stop already was located at St. Paul's Blvd. and Plume St. to provide transfer service to the LRT.*
^On-street parking reserved for area residents only

Support Facilities (SCC 30)

The Norfolk Tide Facility (NTF) is located just east of NSU Station on a parcel that encompasses approximately seven acres of land. The facility houses light rail vehicle maintenance, rail operations/dispatch, and the Operations Control Center (OCC).The NTF also serves as an operator relief point along the mainline. The NTF has the following yard tracks: Y-1E, Y-1W, Y-2, Y-3, Y-3 Future, Y-4, and L-1. The maintenance shop is approximately 28,000 square feet and includes a two-bay vehicle wash. The site includes 60 parking spaces. A second maintenance facility, Mangrove Maintenance Facility, is being leased to house systems maintenance and provide warehouse storage for maintenance of way material and spare parts. This additional facility was required when it was determined that routine systems and other right-of-way maintenance would not be contracted, but handled by internal forces.

The shop building structure is a steel frame structure with full brick facing and a number of architectural features (e.g., decorative roof cupolas) intended to visually integrate the building with the adjacent Norfolk State University campus. The vehicle maintenance functions of the shop were designed to be minimal, consistent with an original operating plan for contract vehicle maintenance. This was not the case, however, and the as-built shop includes equipment consistent with typical light vehicle maintenance, such as wheel presses, floor level traction power ("stingers"), and portable vehicle lifts. These items were procured during the construction phase of the project.

The as-built project also includes a temporary building at Sewell's Point, originally erected to test and commission vehicles. The temporary building is a 120-foot by 25-foot pre-fabricated fabric tent with a concrete platform that was needed due to delays in the construction of the vehicle maintenance facility and yard. The LRT vehicles were scheduled to be delivered to the yard, but the yard construction was 18 months behind schedule. A temporary spur track was constructed to connect the mainline NSRR freight tracks with a temporary LRT maintenance building, and HRT was able to arrange the LRT vehicles to be delivered by train. The building and spur track were initially intended to be temporary, but HRT decided to keep them both. Minor upgrades to the spur track were completed to make the track permanent, and the building remains in use post project implementation as a covered storage facility.

Sitework and Special Conditions (SCC 40)

Hazardous Materials and Contaminated Soil Removal/Mitigation- The former Kirn Library building was demolished for the construction of MacArthur Square Station. The demolition required asbestos abatement techniques to be utilized. Two other asbestos-contaminated buildings adjacent to the library site were also demolished for the station. The demolition work included the removal of contaminated soil and two underground storage tanks (UST), one at Kirn Library and one at the Baylor building. Two USTs on the site of Newtown Road Station and three tanks at Bollard's Chicken at NSU Station were also removed as part of the project.

Wetlands Mitigation- Wetlands mitigation for the project consisted of constructing a 2.8-acre wetland on a site formerly used by the City of Norfolk for construction waste disposal along the eastern branch of the Elizabeth River, adjacent to a Norfolk neighborhood called Grandy Village. The mitigation was required due to project impacts to wetlands along the corridor, and the constructed wetlands resulted in a net gain of wetland area.

Pedestrian Bridge- A path from the existing pedestrian bridge over I-264 near the shop and yard was constructed around the yard and shop and a pathway provided to Brambleton Avenue so that it could maintain its functionality while not interfering with rail operations.

Utility Relocations/Protection- Utility relocations for the project consisted of three different relocation categories: utilities on public property but not public ROW, utilities within Norfolk Southern ROW, and utilities within the Central Business District (CBD). CBD utilities were relocated at no cost to the project, as these utilities fell under the City of Norfolk's franchise agreement. CBD utilities required a new duct bank system rather than just typical relocation activities, because the utilities downtown were old and had been modified to the point that relocation was not an option. All utility relocations on public property east of Harbor Park did not fall under the franchise agreement and thus were paid for by the project. Relocations of Dominion Virginia electrical distribution line poles within the Norfolk Southern ROW were also required and paid for by the project. The complexities and effort associated with the types of relocations needed in the Norfolk Southern ROW were not adequately understood and thus the necessary time was not incorporated into the project schedule. This resulted in construction delays.

Existing Freight Bridge over Broad Creek- The existing freight bridge over Broad Creek was removed for the LRT project. The as-built construction includes a new double track structure with all former wood piles removed.

New Norfolk Southern Connection at Sewell's Point Branch- The project required adding a new Norfolk Southern freight siding track from the north-south Sewell's Point Branch to the east-west line in order to deliver the LRT vehicles.

Systems (SCC 50)

Traction Power Substations- Seven 1.0 megawatt (MW) capacity TPSS (Traction Power Substation) facilities were constructed for the project. Table 2.2 provides descriptions of the locations of the TPSS facilities as constructed. Three TPSSs were constructed with building facades to mitigate adverse visual impacts: 2nd Street (TPSS #1), York Street (TPSS #2), and Newtown Road (TPSS #7). The need to mitigate these impacts was identified early in the planning process and included in the Final Environmental Impact Statement (FEIS).

Table 2.2
As-Built TPSS Locations

TPSS	Location	Engineering Station	Location Description
TPSS #1	Second Street	119+00	South side of tracks, east of Second Street
TPSS #2	York Street Station	141+90	North side of tracks, across from station
TPSS #3	Holt Street	235+25	Holt Street under the I-264 structure
TPSS #4	VMSF	262+85	West of shop building
TPSS #5	Sewell's Point Bridge	327+25	East of I-264 at western base of bridge
TPSS #6	Military Highway Station	430+00	East of Corporate Blvd., north side of tracks across from station on Curlew Drive
TPSS #7	Newtown Road Station	492+00	Eastern terminus, eastern end of station

Source: Norfolk Light Rail Transit Project As-Built Drawings, January 2008.

Signaling and Communications- The project includes a train signaling system between NSU Station and Newtown Road Station. The system in operation is an automatic block signaling (ABS) system which prevents trains from colliding with one another when operating on the same track. There are also three sets of localized track signals along the alignment: lockouts at EVMC and Newtown Road Station approaches and an island circuit in the yard at the shop entrance.

The project also includes a communication system and an operations control center (OCC). The OCC is located in the shop building and it houses a supervisory control and data acquisition (SCADA) system on a fiber optic network that allows the controllers to see the locations of the trains in the signalized territory between NSU Station and Newtown Road Station and allows communication and administrative control between the TPSS facilities and the OCC.

Crossing Protection- The as-built project includes a number of safety features that were added shortly before or shortly after revenue operations began as a result of an operational hazards analysis (OHA) that was conducted by HRT. Additional fencing, crossing gates, sidewalk railings, signage, and barriers were added along the project to prevent pedestrians from entering the ROW and to prevent incidents between trains and personal vehicles.

Right-of-Way and Land (SCC 60)

The project required 157 acquisitions and easements in total, of which 21 were full acquisitions, 29 were partial acquisitions, 35 were permanent easements, 18 were permanent subsurface easements, and 54 were temporary construction easements. Nine residential and eight business relocations were required, for a total of 17 relocations. All necessary right-of-way documents were platted and recorded as part of the project work.

Vehicles (SCC 70)

Nine Siemens S70 low-floor light rail vehicles were procured for the Norfolk Light Rail Transit Project. Six one-car trains operate along the mainline during peak periods, leaving three vehicles as spares. The spare vehicles are required for operations during special events such as Norfolk's HarborFest and Grand Illumination.

Accuracy of Predictions

The *Physical Scope Technical Memorandum*, included as **Appendix A:** *Physical Scope* to this report, summarizes the as-built scope of The Tide LRT Project and the anticipated scope of the project at three predictive milestones: Entry into PE, Entry into Final Design, and the FFGA. The memo also identifies how well the as-built project was predicted at the three milestones.

Analysis of the project's physical scope across the milestones revealed that the overall project was generally well-predicted. No significant alignment or profile changes occurred over the course of project planning. General station locations remained constant across milestones, although three station sites and one park-and-ride lot location changed after the FFGA was executed due to the availability of the planned parcels for the original sites. Table 2.3 presents a comparison of an abbreviated selection of as-built scope specifications of The Tide LRT Project with the predicted outcomes for each scope item at Entry into Preliminary Engineering (PE), Entry into Final Design, and the Full Funding Grant Agreement (FFGA) milestones. The comparison is organized by FTA SCC. A table which includes all SCC line items is included in **Appendix A:** *Physical Scope*.

No significant alignment or profile changes occurred over the course of project planning.

The most significant changes in the physical scope of the project were related to the Systems category (SCC 50). Adding a signaling system from east of Harbor Park Station to Newtown Road Station, an Operations Control Center (OCC), improved LRT/roadway downtown traffic signal priority coordination, and a robust communications system after the FFGA was executed are the key changes to the physical scope of the project.

The majority of other changes also occurred post-FFGA, and many occurred during construction. Primary 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 and brick building facades for the Norfolk Tide Facility (NTF); a change to black-colored overhead catenary system (OCS) 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; and the deletion of proposed missile screens on roadways over the LRT with no pedestrian access.

Table 2.3 The Tide Physical Scope Milestone Comparison					
FTA Standard Cost Category (SCC)	**Unit**	**Actual (After)**	**Entry into PE**	**Entry into FD**	**FFGA**
10 GUIDEWAY and TRACK ELEMENTS					
10.02 Guideway: At grade, semi-exclusive	TF	59,668	-	60,639	60,639
10.10 Track: Embedded	TF	16,088	-	15,828	15,828
10.11 Track: Ballasted	TF	47,985	-	49,136	49,136
10.12 Track: Special (switches, turnouts)	EA	15	0	14	14
10.13 Track: Vibration and noise dampening					
Noise dampening – wayside rail lubricators	EA	10	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL					
20.01 At-grade station, stop, shelter, mall, terminal, platform					
Shelters	EA	18	16	16	16
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS					
30.04 Storage or Maintenance of Way Bldg.	EA	1	0	0	0
30.05 Yard and Yard Track					
Yard track	TF	6,414	0	5,734	5,734
Turnouts (No. 8 Turnouts)	EA	9	0	0	9
Parking area	SP	69	0	0	60
40 SITEWORK & SPECIAL CONDITIONS					
40.01 Demolition, Clearing, Earthwork	AC	61.22	0	63.47	63.47
40.05 Site Structures, including Retaining Walls, Sound Walls	EA	2	0	1	2
40.06 Pedestrian/Bike Access and Accommodation, Landscaping					
Station Pedestrian Access (Ramps, 2 per platform)	EA	30	-	32	32
Station Bike Access (Bike racks on concrete pads)	EA	12	0	0	0
40.07 Automobile, Bus, Van Access Ways, including Roads, Parking Lots, Park-and-Ride Spaces	SP	603	824	598	598
40.08 Temporary Facilities and Other Indirect Costs During Construction	EA	1	0	0	0
50 SYSTEMS					
50.01 Train Control and Signals	LF	15,840	0	0	0
50.02 Traffic Signals and Crossing Protection					
Total crossings (pedestrian and/or vehicle)	EA	87	-	-	-
Traffic signals	EA	45	-	-	-
Crossing protection (Flashers and Gates)	EA	15	-	-	-
50.05 Communications	System	1	0	0	0
50.06 Fare Collection System and Equipment	EA	25	-	-	25
60 ROW, LAND, EXISTING IMPROVEMENTS					
60.01 Purchase or Lease of Real Estate					
Full acquisitions	EA	21	-	-	$\geq$10
Partial acquisitions	EA	29	-	-	-

Table 2.3 The Tide Physical Scope Milestone Comparison					
FTA Standard Cost Category (SCC)	**Unit**	**Actual (After)**	**Entry into PE**	**Entry into FD**	**FFGA**
Permanent easements	EA	35	-	-	-
Permanent subsurface easements	EA	18	-	-	-
Temporary construction easements	EA	54	-	-	-
60.02 Relocation of Existing Households and Businesses					
Residential relocations	EA	9	-	7	7
Business relocations	EA	8	-	3	3
70 VEHICLES					
70.06 Non-revenue vehicles	EA	2	0	0	0
70.07 Spare Parts					
Maintenance-of-way spare parts		1	0	0	0

Source: URS, HRT, 2014.

The following paragraphs describe the major physical scope changes in The Tide LRT Project. Additional detail on the physical scope of the project is provided in **Appendix A:** *Physical Scope*.

Stations (SCC 20)

The general station locations predicted in the FFGA accurately anticipated the as-built locations, however specific siting of the stations differed in the case of EVMC Station and Military Highway Station. EVMC Station as constructed is approximately 300 feet shorter than it was planned to be at the FFGA stage. HRT was not able to acquire all the land necessary for construction of the station as planned, therefore it had to be shortened and moved. The as-built platform is 450 feet east of the FFGA location. Due to this change, the single track at the western terminus was extended beyond the planned length and a switch was moved east of Colley Avenue. The as-built switch location is 600 feet east of the location in the FFGA. Additionally, no bus bays or shelters at the EVMC Station were accounted for in the FFGA, but the City decided to build two bus bays with funds from the City's capital budget. Two bus shelters were built at project cost to accompany the bus bays.

The Military Highway Park-and-Ride was constructed in a different location than was identified in the FFGA. A categorical exclusion (CE) was prepared for this change. The parking lot was identified in the FFGA on the south side of the alignment and south of Curlew Drive. Due to development on the identified parcel before HRT was able to acquire it, the planned park-and-ride had to be moved to a new location. The location chosen was on the north side of Curlew Drive and north of the station platform, and that is where the parking lot was ultimately constructed.

Station shelters and railing were simple, minimal structures in the FFGA. The shelter was a barreled roof structure, and there was minimal railing planned. In 2008, the more elaborate structures and enhanced railing that were ultimately constructed were designed to meet City requests and requirements.

Support Facilities (SCC 30)

The Vehicle Storage and Maintenance Facility (VSMF) was planned in the FFGA to be constructed south of NSU and east of Brambleton Avenue, in an area of land between I-264 and the NSU campus. The facility was planned to accommodate nine vehicles but would be able to be expanded to accommodate up to 16. The facility would also include a vehicle wash. The building would have a footprint of approximately 23,000 square feet and an upper mezzanine storage area of 4,800 square feet. The yard, yard track, stormwater management and drainage facilities, and all other necessary items for the yard were also included in this category.

The VSMF predicted in the FFGA did not accurately anticipate the as-built maintenance facility, called the Norfolk Transit Facility (NTF), due to the following changes occurring after the FFGA was executed: the addition of the OCC, upgrades to the planned façade of the building, and an increase in parking capacity. Addition of the OCC did not change the footprint of the building, however the addition did require some interior spaces to be reconfigured. The shop building plan was changed from a pre-fabricated metal building to a building with a brick façade. The foundation plans had to be changed to accommodate the new building façade plans. The footprint and the interior design of the building were not altered by the change to a brick façade.

The as-built project also includes two additional support facilities that were added to the project after the FFGA: a temporary building at Sewell's Point to test and commission vehicles and the lease of a spare parts storage facility and rail operations support on Mangrove Avenue. The Sewell's Point and Mangrove facilities are described in the *As-Built Physical Scope* section under the SCC 30 sub-heading.

Systems (SCC 50)

Line-of-sight operation was planned for the project in the FFGA, so the FFGA scope does not include a signaling system, except for three sets of localized track signals: lockouts at EVMC and Newtown Road approaches and an island circuit in the yard at the shop entrance. Light rail signal priority was planned along the downtown portion of the alignment, except at the intersections of Charlotte and Boush Streets and St. Paul's Boulevard at Government Center Plaza. Crossing protection for six gated crossings and signal prioritization equipment for the remaining crossings were planned and included in this category.

The signaling and communications plan in the FFGA did not accurately anticipate the as-built systems for the project due to changes that occurred after the FFGA was executed. One of the largest scope changes of the project occurred under SCC 50. It was determined after the FFGA was executed that line-of-sight operation would not be adequate from a safety perspective and that a signaling system would be required for safety reasons. After the FFGA was issued and before construction began, the Virginia Department of Rail and Public Transportation reviewed the project plans and determined that line-of-sight operation east of Downtown would be unsafe. The Commonwealth of Virginia mandated installation of a train signaling system, communication system, and an operations control center. A system was designed as a design-build project so as to minimize the delay to the rest of the project. Additionally, the SCADA planned in the FFGA was simpler than what was ultimately installed, due to the change from line-of-sight operations to signalized operations and the addition of the OCC.

3.0 Capital Costs of the Project

Actual Outcomes

The final recognized capital costs of The Tide were $315,755,511. This figure, finalized in 2014, accounts for all SCC's for the project, including Professional Services and Finance Charges. This final capital cost recognized in the After constructed condition is significantly different than the otherwise relatively consistent predictions made during the Entry into PE, Entry into FD, and FFGA milestones, which varied between $198 and $235 million.

Table 3.1 Actual Cost by FTA Standard Cost Category			
		Actual (millions)	**Percent**
Opening Date Actual Cost in Year of Expenditure $		**August 2011** **$315,755,511**	
10	GUIDEWAY & TRACK ELEMENTS	$83.3	26.6%
20	STATIONS, STOPS, TERMINALS, INTERMODAL	$1.0	0.3%
30	SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	$12.3	3.9%
40	SITEWORK & SPECIAL CONDITIONS	$55.9	17.9%
50	SYSTEMS	$34.4	11.0%
60	ROW, LAND, EXISTING IMPROVEMENTS	$15.9	5.1%
70	VEHICLES	$36.0	11.5%
80	PROFESSIONAL SERVICES	$76.8	23.7%
90	UNALLOCATED CONTINGENCY	$ -	-
100	FINANCE CHARGES	$ 0.05	0%
	TOTAL PROJECT COST	**$315.8**	**100%**

Accuracy of Predictions

The predicted capital costs at the project-development milestones reflected variations in the physical scope of the project, estimated unit prices for project components, base-year dollar valuations, anticipated schedules for project construction, and anticipated future inflation rates. Table 3.2 transforms both the predicted and the actual total costs of the project in several ways in order to permit direct comparisons of the predictions. The analysis relies on the Engineering News Record historical index of construction costs for construction-dollar valuations over time.

Cost Measure	Actual	Predictions		
		Entry into PE (2003)	Entry into FD (2006)	FFGA (2006)
Constant Dollars (millions)				
Total capital cost in 2003 constant dollars	$242.6	$182.0	---	---
Total capital cost in 2006 constant dollars	$281.0	---	$213.6	---
Total capital cost in 2006 constant dollars	$281.0	---	---	$210.8
Inflation				
Dollar-weighted mid-point of project expenditures	Jun09	Nov05	Jun08	Jun08
Opening year	Aug11	Dec07	Jan10	Jan10
Inflation effects compared to 2003 constant dollars	29.6%	9.0%	---	---
Inflation effects compared to 2006 constant dollars	12.0%	---	10.2%	---
Inflation effects compared to 2006 constant dollars	12.0%	---	---	10.1%
Year-of-Expenditure (YOE) Dollars (millions)				
Total capital cost in YOE dollars	$314.6	$198.3	$235.3	$232.1
Predicted minus actual total capital cost in YOE dollars	---	-$119.6	-$79.3	-$82.5
-- component attributable to scope/unit-cost differences	---	-$65.0	-$74.2	-$77.2
-- component attributable to inflation-rate differences	---	-$14.2	$3.8	$3.7
-- component attributable to schedule differences	---	-$40.5	-$8.8	-$9.0

Table 3.2
Predicted and Actual Total Capital Costs – Constant Year Dollars

The “constant dollar” section of the table focuses on the base-year cost predictions prepared by HRT at each milestone. Constant-dollar predictions are the first step in cost estimation – a step that temporarily ignores inflation effects and states the predicted cost in dollars valued in the year the prediction was made. The table shows that the predicted costs ranged from $182.0 million in 2003 dollars at PE-entry to $213.6 million in 2006 dollars at FD-entry to $210.8 million in 2006 dollars at the FFGA (FFGA is dated 2007 but calculated in 2006 dollars). Constant-dollar entries in the “Actual” column transform the actual $314.6 million total cost of the project from its year-of-expenditure (YOE) dollars to its equivalent cost in constant dollars. These equivalent actual costs are lower because dollars valued in 2003 and 2006 had not been subject to as much inflation as dollars spent to build the project in 2007 through 2011; so, it would have required fewer of those dollars to build the project. Comparison of predicted and actual costs in these constant-dollar terms shows that the predictions consistently underestimated the actual costs: by 25 percent at PE-entry ($182.0 million versus $242.6 million), 24 percent at FD-entry, and 25 percent at the FFGA.

The “inflation” section of the table then examines the costs that inflation added to the predicted and actual costs of the project. Inflation results from the combined effects of two influences: (1) the time that elapses between a cost estimate and actual expenditures on the project, and (2) the annual rates of inflation that erode construction-dollar values over that time. The table shows that the predictions at each milestone underestimated the time that would be needed for development, construction, and opening of the project to service. The underestimated length of the construction period, plus underestimated inflation rates, led to predicted inflation effects that were lower than actual inflation, particularly at PE-entry – a prediction of 9.0 percent added by inflation effects to the constant-dollar cost estimate compared to 29.6 percent added in the actual outcome.

Finally, the "year-of-expenditure dollars" section of the table combines the constant-dollar estimates and the inflation estimates and compares them to the actual $314.6 million cost of the project in YOE dollars. The predictions underestimated actual YOE costs by $119.6 million (38 percent) at PE-entry, $79.3 million (25 percent) at FD-entry, and $82.5 million (26 percent) at the FFGA. At PE-entry, most of the underestimate was caused by underestimates of project scope and/or unit costs of its components ($65.0 million of the $119.6 million total underestimate, or 54 percent). Inflation effects – underestimates of actual inflation rates and the construction schedule – combined to cause the remaining 46 percent of the underestimate. At the later milestones, the contributions of inflation effects largely disappeared: anticipated annual rates of inflation turned out to be higher than actual rates and the anticipated construction schedule was much closer to the actual schedule. Consequently, underestimates of scope and unit costs were the causes of essentially the entire underestimates at FD-entry and the FFGA.

To identify the sources of these underestimates, Table 3.3 compares predicted costs to actual costs for the individual SCC categories. The table translates all costs into 2006 dollars in order to exclude inflation effects and focus on the underlying scope and unit-cost elements of the base-year-dollar predictions.

Table 3.3
Actual and Predicted Expenditures Converted to FFGA Base-year Dollars (2006)(millions)

STANDARD COST CATEGORY	Actual	Predictions at Project-Development Milestones					
		Entry into PE		Entry into FD		FFGA	
	Cost	Cost	Diff.	Cost	Diff.	Cost	Diff.
10 GUIDEWAY & TRACK ELEMENTS	$75.8	**$56.7**	**-$19.1**	**$52.0**	**-$23.9**	**$52.0**	**-$23.9**
20 STATIONS, STOPS, TERMINALS	* $0.9	$9.1	$8.2	$5.2	$4.3	$5.2	$4.3
30 SUPPORT: YARDS, SHOPS, ADMIN.	$11.3	$12.7	$1.3	$15.4	$4.1	$15.4	$4.1
40 SITEWORK & SPECIAL CONDITIONS	$50.9	**$23.2**	**-$27.2**	**$12.5**	**-$38.4**	**$12.5**	**-$38.4**
50 SYSTEMS	$30.7	$27.6	-$3.1	$25.6	-$5.1	$25.6	-$5.1
60 ROW, LAND, EXISTING IMPROVEMENTS	$14.5	$11.3	-$3.1	$10.5	-$4.0	$10.5	-$4.0
70 VEHICLES	$32.7	$31.7	-$1.0	$36.8	$4.0	$33.4	$0.7
80 PROFESSIONAL SERVICES	$71.8	**$38.6**	**-$33.1**	**$40.8**	**-$31.0**	**$40.8**	**-$31.0**
90 UNALLOCATED CONTINGENCY	$0.0	$0.0	$0.0	$10.0	$10.0	$10.0	$10.0
100 FINANCE CHARGES	$0.0	$0.0	$0.0	$4.9	$4.8	$4.9	$4.8
Total	$288.7	$210.9	$-77.8	$213.6	$-75.2	$210.2	-$78.5

* This total for actual station costs clearly has some errors. Many actual costs of stations are thought to be misclassified into the actual costs for SCC 40.

The last line in the table confirms that the difference between predicted and actual costs in constant dollar terms remained largely constant across the project-development milestones: -$71.8 million, $-75.2 million, and -$78.5 million. The large majority of these differences occur in SCCs 10, 20, 40, and 80. SCC20 (stations) is included only because some actual costs for stations were misclassified during project construction into SCC 10. Consequently, the causes of the predicted-versus-actual cost differences apparently occurred in these cost categories. The scope section above examined the differences in project scope across the milestones. Consequently, the discussion here simply highlights the key scope differences that drove the constant-dollar cost differences in these key categories.

When accounting for inflation and schedule impacts by reviewing data in 2006 constant year dollars, the pre-construction predictions of total project costs are 21% to 23% below the final recognized project costs. The predicted total construction costs of the Tide were relatively consistent through the PE, Entry into FD, and FFGA conditions, maintaining many of the base assumptions made prior to Entry into PE for the entire design process. However, once construction began, construction costs significantly exceeded predictions, primarily due to increased scope, change orders, and impacts to the construction schedule. Additionally, both HRT and consultant construction management team members appear to have been inconsistent with coding charges to SCC codes. Due to unfamiliarity or misunderstanding, these inaccuracies have resulted in some confusion when assessing inaccuracies of predictions made at preconstruction milestones. Many of these inaccuracies are noted below.

Constructions costs exceeded expectations due to increased scope, change orders, and impacts to the construction schedule.

Discussions below are generalized to compare the preconstruction milestone estimates to the After condition. This is due to the consistency of cost predictions in the engineering phase milestones, and the lack of change in system assumptions. Some poor assumptions, such as the need for a communications system for train operations, were ultimately proven to be incorrect. Many of these assumptions persisted throughout design and were only rectified during the construction phase, resulting in the consistency of preconstruction estimates. Therefore, the information below describes the differences in preconstruction and Actual costs.

Table 3.4 provides the actual project costs in year of expenditure (YOE) and 2006 constant year dollars, organized by SCC, as compared to the other milestones. These values are investigated further below, with commentary on variances and circumstances encountered during project development and construction. Additional information concerning the summary discussions below is described in greater detail in **Appendix B**: *Capital Costs*.

<u>SCC 10:</u> Cost predictions remained consistent through design milestone estimates at between $52 and $56.7 million. The physical scope of the track elements remained mostly consistent between predicted and actual conditions in general; however, several items were coded to this category, including approximately $10 million for traction power substation (TPSS) units and some smaller value for civil work associated with SCC 20. The remaining difference between the predictions and the realized costs (base year value of $75.8 million) appears to be approximately $14 million. While project delays and change orders with respect to utilities and right-of-way affected the SCC 10 total, the primary reasons for the discrepancy appear to be attributable to construction costs associated with SCC 10.01 – At-Grade Exclusive Right-of-Way and SCC 10.04 – Aerial Structures. Contract prices for SCC 10.01 exceeded the predictions by nearly $20 million, and for bridge structures exceeded estimated values on larger lump sum structure items by nearly $9 million in 2006 base-year dollars. Several other subcategories of this SCC were lower than predicted accounting for the different in summary values presented here. Consequently, project delays and change orders resulting from unexpected utility relocations, accompanied by right-of-way acquisition, were the primary drivers of the SCC 10 variances.

<u>SCC 20:</u> As noted above, predictions for SCC 20 were consistently predicted through preconstruction milestones, and then dramatically under-ran those predictions during construction. This difference in predicted versus actual values, estimated around $4 million, is likely due to miscoding of the costs during implementation of a few of the construction contracts. It is suspected that the majority of the site work costs for station areas, including grading, concrete curbs, platforms, and similar items, were captured under

SCC 40, with some minor amount potentially being assigned to SCC 10 subcategories. Some station locations and configurations were adjusted during construction, and station furnishings (shelter, handrails, etc.) were changed at the request of the City of Norfolk, which resulted in higher-than-predicted costs. However, these overruns appear to have been minimal. It is suspected that the After value of SCC 20 was close to the predicted value of between $ 4 and $5 million, rather than the surprisingly low value of under $1 million documented here.

SCC 40: Actual capital costs for SCC 40 greatly exceed the predicted values from the pre-construction milestones. The primary reason for these inaccurate predictions appears to be attributed to bid and change order costs resulting from schedule delays, utility conflicts, and environmental efforts. SCC 40 costs for utility relocations in the downtown area were significantly underestimated, and did not sufficiently include costs for new services required for the Tide. Asbestos mitigation costs incurred for the demolition of the Kirn Library were not sufficiently included in preconstruction predictions. Combined, utility conflicts and asbestos mitigation resulted in over one year in project construction schedule delays. Also as noted above, SCC 40 inherited approximately $4 million in costs from SCC 20 and potentially minor costs from other SCC's as well. Other minor costs to install various civil elements modified or added for local stakeholders also are attributed to this SCC. At the conclusion of the project, these additional costs for environmental and utility complications, combined with the various additional costs also noted here, overran predicted values by $38.4 million – nearly four times the predicted preconstruction cost for this SCC.

SCC 50: Preconstruction estimates for SCC 50 ranged from $25.6 to $27.6 million, which appear to predict the After value of $30.7 million relatively well. However, this similarity in prediction versus outcome is likely circumstantial as $10 million in TPSS costs were mis-assigned to SCC 10. The design assumed that the LRT system could function with line-of-sight operations. This base assumption, made during value engineering efforts prior to Entry into PE, proved to be inaccurate during construction, and a simple communications system, fiber optic duct bank, and supervisory control and data acquisition (SCADA) systems were added to the project at the direction of the Virginia Department of Rail and Public Transportation (DRPT). Additionally, fare collection costs were assigned to SCC 70 – Vehicles, rather than this SCC. When accounting for these discrepancies, it is estimated that SCC 50 exceeded the predicted cost by approximately $10 million rather than the $3 to $5 million noted in Table 3.3 above.

SCC 80: Predictions for Professional Services costs were very consistent through the pre-construction milestones, varying between $31 and $33.1 million. The After cost for this SCC in 2006 dollars was $71.8 million. The majority of these costs were attributed to Final Design, Project Management for Design and Construction, and Construction Administration and Management. HRT was heavily dependent on consultant expertise and support during nearly all phases of the project, meaning this SCC was particularly susceptible to increases resulting from schedule delays, contractor change orders, and project extensions. Design additions and changes during construction also contributed to the under-estimations seen in the pre-construction milestone values.

SCC's 90 and 100: Of little impact to the overall project cost, but of important note, is the role of Unallocated Contingency and Financing Costs. The pre-construction milestone estimates assumed only a small amount of Unallocated Contingency, typically 5% of the project cost. This low amount of contingency proved to be insufficient for the added items and modified designs implemented during the construction of the Tide. Conversely, the Tide incurred only negligible Financing Costs during the project.

General Discussion

Several items and details described above as being added or addressed during construction, such as the train communications system in SCC 50, resulted in unpredicted costs to the project. However, several of these items were originally envisioned as parts of the project prior to the Entry into PE milestone but were removed from the scope as part of a value engineering exercise. Responding to recommendations from and working with FTA regional representatives in 2001 and 2003, HRT reduced the scope of the project to improve the Cost Effectiveness Index (CEI) value, in turn eliminating some of the items ultimate required by review and oversight agencies such as DRPT.

It should be noted that the Tide project was still ultimately competitive with respect to project cost. As the Tide is the first segment of light rail transit for HRT in the area, capital costs for the project cannot be compared to other system segments. Calculating the project costs on a per mile basis, the Tide is cost-competitive with other systems:

	Cost Per Mile of System
The Tide – Norfolk, 2011 (with maintenance facility and vehicles)	$43.3 million / mile
The Tide – Norfolk, 2011 (without maintenance facility or vehicles)	$37.5 million / mile
Blue Line Light Rail – Charlotte, 2007	$42 million / mile
DART – Dallas, 2010	$46 million / mile

As noted in the SCC descriptions above, several items appear to have been unresolved during the design process but ultimately included in the constructed project. Adjustments and enhancements to project designs, such as station requirements, city ordinances, and building codes, all affected the project costs, specifically SCC's 20 and 40. Right-of-way acquisition and utility relocation efforts occurred in large part during the construction phase, slowing project progress. Greater stakeholder coordination, and thorough incorporation of stakeholder concerns, may have increased the predicted project costs, but could also have resulted in a more accurate prediction with respect to these items.

In an effort to identify potential challenges ahead of construction, HRT did develop and maintain a Risk Management Plan throughout the design process and into construction. In 2006, the plan did identify some of the primary issues previously noted, such as asbestos mitigation in the Kirn Library building, the need to review station finishes with the City of Norfolk and SHPO, and concerns about the elevator at the Norfolk State University Station. In the first year of construction (2008), the Risk Register identified $10 million in potential additional costs.

Conclusions

Assumptions incorporated in the cost forecasts through each phase of project development were based on the best information available at the time and served as justifiable estimates in the Tide Light Rail financial plan; however, some key factors dramatically affected the construction cost and schedule. The predicted physical scope of the project did not significantly change through the course of the pre-construction milestones. Despite this consistency, portions of the project scope did change during the construction phase to the cost of the project. Many of the cost variations during construction can be attributed to three factors: schedule delays and claims, the addition of physical scope items during construction, and project documentation and controls. These and other lessons learned are described below, in detail in a letter from HRT to FTA dated December 17, 2012, and also included in the Project Management Plan, Revised December 19, 2012.

Lessons Learned

Schedule: The project construction schedule greatly exceeded the duration predicted in design. Possible mitigation of schedule challenges could include development and maintenance of a master project schedule that monitors the progress of all contracts and contractors from receipt of FFGA to completion of construction. Additionally, addressing project unknowns ahead of construction through advanced Utility Relocation contracts and by purchasing of right-of-way and easements could have addressed or mitigated project delay issues. HRT is committed to actively monitoring program schedules in a holistic manner on all future work.

Maintenance of a master project schedule may have mitigated schedule overruns.

Design Scope versus Constructed Infrastructure: Several project items appear to have been unresolved during the design process but included in the constructed project after FFGA, resulting in changes during the construction phase and contributing to the inaccuracies of cost predictions. Major assumptions made before Entry into PE for the purpose of reducing project capital costs, such as removal of a train signaling system and operational control center, were later proven to be overreaching, requiring items to be reinserted into the project during construction. These reintroduced items, accompanied by other items added during construction, account for the largest amount of discrepancy between actual and predicted capital costs. Continued oversight from FTA, open communication with stakeholders and oversight agencies, and a thorough response to identified potential risks could have provided a more accurate prediction of the actual costs incurred on the Tide. HRT is committed to sharing project details, including base assumptions, designs, and budgets, with stakeholders throughout the design and construction phases of future projects, in an effort to identify and address scope and capital costs issues before they become an issue.

Inaccurate cost-cutting assumptions made before Entry into PE accounted for the largest discrepancy between actual and predicted capital costs.

Project Documentation and FTA Requirements: Both the HRT internal staff and consultant team struggled with FTA documentation requirements and strict adherence to the FFGA. The resulting construction documentation resulted in some confusion in monitoring capital costs during project execution and in post-construction accounting. As a lesson learned, and in an effort to mitigate this issue on future projects, HRT intends to pursue improved oversight and specific direction from FTA, specifically with respect to base assumptions made at the beginning of the project. HRT has already expanded staff resources to include experience in the construction of major transit corridors in order to better vet base project assumptions while bringing familiarity with FTA processes and FFGA requirements. With expanded in-house resources and FTA involvement, HRT will be able to efficiently direct their consultant team and effectively manage future projects.

Unfamiliarity with FTA documentation requirements led to some confusion monitoring capital costs.

4.0 Transit Service Levels

Actual Outcomes

The Tide operates seven days per week with spans of service and headways between trains that are designed to meet ridership demand. Table 4.1 summarizes these service characteristics.

Table 4.1 The Tide Service Spans and Headways, 2013					
Service Day	**Span of Service**	**Peak**	**Off-Peak**	**Early Morning (Before 6:30 am M-F or 9:00 am Sat.)**	**Late Night (after 10:00 pm)**
Mon-Thurs	6:00 am - 11:00 pm	10 min.	15 min.	15 min.	30 min.
Friday	6:00 am - 12:00 am	10 min.	15 min.	15 min.	30 min.
Saturday	6:00 am - 12:00 am	N/A	15 min.	30 min.	30 min.
Sunday	11:00 am - 9:00 pm	N/A	15 min.	N/A	N/A

Notes: - Weekday peak periods are 6:30 AM to 9:00 AM and 3:30 PM to 7:00 PM.
- Early morning is before 6:30 AM on weekdays and before 9:00 AM on Saturdays.
- Late night is after 10:00 PM.

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. On an average weekday, the Tide operates a total of 90 revenue hours covering 1,158 revenue miles. Annually, HRT provides a total of 29,249 revenue hours and 377,097 revenue miles of LRT service (assuming 253 regular/weekday schedules, 57 Saturday schedules and 55 Sunday schedules operated in 2013).

Table 4.2 summarizes the bus connections that are available at eight of the Tide's 11 stations. HRT made 21 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 and involved two kinds of changes to these connecting routes:

- Minor adjustments to the existing route so that it 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.

The table notes two exceptions to these minor adjustments: an existing route that was truncated at the Newtown Road rail station and several new routes that were implemented to provide feeder service to the Tide's terminal stations. Other changes to bus routes made during this timeframe related to the relocation of the Cedar Grove transfer center to the DNTC. **Appendix C**: *Service Levels* discusses these changes. From west to east, adjustments for buses connecting at each station are:

- At the EVMC/Ft. Norfolk station, the western terminus of the new rail line, route 2 from Naval Station Norfolk now serves the EVMC/Ft. Norfolk Station. Route 16 is a new feeder service from the north serving Old Dominion University. Route 23 is an east-west service that roughly parallels the Tide on Princess Anne Avenue, approximately one mile north of the rail alignment; the route now has its western terminus at the rail station. Route 44 crosses the Elizabeth River from Portsmouth and stops at the station on its way to the Downtown Norfolk Transit Center (DNTC).

Table 4.2 Bus Connections at Rail Stations, 2013	
Station	**Connecting Bus Routes**
EVMC/Ft. Norfolk	2, 16[2], 23, 44
York Street/ Freemason	none
Monticello	1, 3
MacArthur Square	none
Civic Plaza/ Government Center	6, 8, 17, 45, 960, 961
Harbor Park	none
NSU	9, 13, 18
Ballentine	18
Ingleside Road	none
Military Highway	15, 23, 967
Newtown Road	20, 22[2], 25, 27[1], 28[2]

Notes: 1 – Existing route truncated at the rail station
2 – New feeder route

- In downtown Norfolk, 16 bus routes from throughout the region converge at the Downtown Norfolk Transit Center (DNTC). Eight of these routes also circulate throughout downtown and make easy connections to the Tide at either the Civic Plaza/Government Center or the Monticello station. Connections at those two stations make bus-rail connections at MacArthur Square – the third downtown station – unnecessary.
- No bus routes connect to the Tide at its Harbor Park station.
- Mid-corridor at the NSU and Ballentine stations, HRT made minor adjustments to establish connections to three routes – the 9, 13, and 18 – already serving the area. Routes 9 and 18 originate north of the rail alignment and run south to connections with the Tide before proceeding west into downtown Norfolk. Route 13 originates to the south in Portsmouth, crosses the Elizabeth River to a connection at the NSU station, and then also proceeds into downtown Norfolk.
- There are no bus routes that connect at the Ingleside Road station due to the inability to turn buses around within the small footprint of that station area.
- At the Military Highway station, HRT made minor adjustments to three very different existing bus routes to connect them to the rail line. Route 15 is a "crosstown" route on Military Highway serving areas both north and south of the Elizabeth River. Route 23 is an east-west route that parallels the Tide roughly one mile to the north on Princess Anne Avenue between the bus route's eastern terminus at the Military Highway station and its western terminus at the EVMC/Ft. Norfolk station. Route 967 now has its eastern terminus at the rail station, crosses the Elizabeth River to reach its former eastern terminus at the Indian River park-and-ride lot, and then proceeds west and north through Chesapeake and Portsmouth to the Chesapeake Bay Bridge-Tunnel to a terminus in Newport News.
- The Newtown Road station has the largest number of bus connections because it is the eastern terminus of the rail line and is without the geographic limits on its service area that water bodies impose on the western terminus at the EVMC/Ft. Norfolk station. Routes 20 and 28 provide service from the oceanfront in Virginia Beach to the Tide, largely along Virginia Beach Boulevard. The Route 20 connection is a modest detour from the route's long itinerary from Virginia Beach to

downtown Norfolk. In contrast, Route 28 is a new skip-stop feeder service that terminates at the Newtown Road station. Existing routes 25 and 27 serve areas southeast and northeast of the station, respectively. HRT adjusted the routing of existing route 25 to stop at the station on its way to its terminus at the Military Circle Mall transit center and made a minor adjustment to terminate route 27 at the station rather than its previous terminus at the Military Circle Mall transit center. Finally, HRT added route 22 as a new feeder service from the northeast, terminating at the station.

HRT continued service on the three long-distance bus routes in The Tide corridor – route 20 on Virginia Beach Boulevard, route 23 on Princess Anne Avenue, and MAX route 960 express on Interstate 264 between Virginia Beach and downtown Norfolk.

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 could with rail lines introduced on or near arterials 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, truncations of bus routes at rail stations make sense only when transferring passengers will travel most of the length of the rail line. Shorter trips on the Tide will not save enough time to offset the inconvenience of the transfer. This reality is reflected in HRT's adjustments to the bus system: bus routes terminate only at the eastern and western terminal station – and only for some routes at those stations. At other stations, the bus service adjustments provide an opportunity for passengers to transfer to rail but do not force a transfer.

In January 2012, five months after the start of LRT service and the accompanying adjustments to bus routes, HRT made another set of service changes recommended by a Service and Schedule Efficiency Study (January 2012). The focus of these service changes was to reallocate financial resources from low performing routes (or trips within a route's service day) to higher performing routes and trips. In addition, the study provided guidance to improve cost efficiency without having to increase fares. A total of 40 bus routes in the HRT service area (17 routes in Hampton and Newport News on the north side of the Chesapeake Bay and 23 routes in Norfolk, Virginia Beach, Portsmouth, and Chesapeake on the south side) were changed by either eliminating trips or reducing the frequency of the service. Recommendations were based on minimum passenger boarding thresholds for bus routes. Routes averaging fewer than 10 boardings per trip were defined as underperforming routes that would be either discontinued or modified to eliminate low performing trips during the fringes of the service day.

HRT made these two sets of significant changes to the system: first to improve the bus and rail interface and then to make overall improvements to service productivity and cost efficiencies. **Appendix C**: *Service Levels* provides a detailed catalog of all service changes between 2009 and 2013. Table 4.3 summarizes the changes to bus service two years before and after the implementation of The Tide for routes within the corridor, as well as for all routes operating in the Southside (Tidewater) area of the HRT System. . As shown, the majority of Southside routes provide some service within the Tide corridor, connecting this key area with the larger system. Although the overall number of Southside routes remains fairly steady across the period, a noticeable increase in the number of corridor routes is evident, particularly on Saturdays.

Table 4.3 Summary of Bus Service Characteristics, 2009 and 2013						
	Before System (2009)			After System (2013)		
	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday
Corridor Local Routes	18	13	12	21	20	14
Corridor System Max Routes	6	2	2	6	2	2
Corridor Revenue Miles	16,390	11,354	5,201	14,991	11,720	5,395
Corridor Revenue Hours	1,256	926	404	1,276	990	445
Southside Local Routes	39	33	20	38	37	22
Southside Max Routes	7	2	2	7	2	2
Southside Revenue Miles	22,686	16,847	7,094	20,946	17,312	7,065
Southside Revenue Hours	1,840	1,427	637	1,815	1,448	659

The weekday, Saturday and Sunday revenue miles and hours were annualized for 2009 and 2013 to produce annual revenue hour and revenue mile totals shown in Table 4.4. Total annual revenue hours and miles for the Southside System decreased, largely due to the elimination of service to and around the City of Suffolk when the City withdrew from the HRT service district. Within The tide LRT corridor however, revenue hours increased by approximately 10,000 hours, driven by an increase in span of service early morning, late night, and on weekends for routes with direct connections to the LRT line.

Table 4.4 System-Level Service Overview			
System-Level Characteristics	**Before (2009)**	**After (2013)**	**Percent Change**
Corridor Bus Routes			
Annual Revenue Hours	393,821	403,747	2.5%
Annual Revenue Miles	5,091,517	4,757,608	-6.6%
Southside Bus Total			
Revenue Vehicle-Hours	583,363	580,291	-0.5%
Revenue Vehicle-Miles	7.11 mil	6.67 mil	-6.1%

Based on 253 weekdays, 58 Saturdays, and 55 Sundays in 2009; and 253 weekdays, 57 Saturdays, and 55 Sundays in 2013. Source: HRT

Comparison of Predicted and Actual Service Levels

Table 4.5 compares the predicted LRT service characteristics at each milestone to the actual service levels. Service level predictions for the Tide were fairly consistent across all three milestones and match actual service levels closely. Three 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 generated 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.

- The predictions anticipated an earlier end of light rail service on weeknights and a later start of service on Sundays. Just before revenue service began on the Tide, rail service hours were extended by an additional hour on weeknights, and the start of Sunday service was changed to 10:55 a.m. instead of 7:00 a.m.

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 anticipated faster operating speeds.

Table 4.5
Actual and Predicted Tide Service Levels

Day / Period	2013 Actual	Predictions during Project Development		
		Entry into PE	Entry into FD	FFGA
Span of Service				
Weekday (Mon-Th)	6:00 am-11:00 pm	6:00 am-10:00 pm	6:00 am-10:00 pm	6:00 am-10:00 pm
Weekend (Fri-Sat)	6:00 am-12:00 am	6:00 am-12:00 am	6:00 am-12:00 am	6:00 am-12:00 am
Sunday (Sun)	10:55 am-9:00 pm	7:00 am-9:00 pm	7:00 am-9:00 pm	7:00 am-9:00 pm
Headways (mins)				
Weekday Peak	10	7.5	7.5	7.5
Weekday Off-peak	15	15	15	15
Weekday Evening	30	30	30	30
Saturday base	15	15	15	15
Saturday (M/E)	30	30	30	30
Sunday base	15	15	15	15
Sunday (M)	N/A	30	30	30
Annual Revenue Mi.	**377,097**	**400,500**	**400,200**	**400,200**
Weekday	292,974	309,600	310,100	310,100
Weekend	84,123	90,900	90,100	90,100
Annual Revenue Hrs.	**29,249**	**25,950**	**25,990**	**25,990**
Weekday	22,770	19,770	19,850	19,850
Weekend	6,479	6,180	6,140	6,140
End-to-end runtime				
Weekday	26 minutes	22.5 minutes	23.0 minutes	23.3 minutes

Notes: M = morning, E = evening

Table 4.6 compares the bus connections planned for each station at the prediction milestones against the actual bus-connections to the Tide. The table illustrates the continued refinements that HRT made to the service plan for the Tide during project development. A total of 47 bus-rail connections were either planned or actually implemented. Some 24 of these connections exist in current service – meaning that 23 other connections were considered at some point but ultimately not made. The service plans at both Entry into PE and Entry into FD anticipated that 33 of these bus-rail connections would be made. That dropped to 25 connections at the FFGA. Most of the difference is attributable to the relocation of the transit center in downtown Norfolk and the associated rerouting of buses within downtown. For the Monticello station, as an illustration, the table shows that the service plans at those milestones anticipated connections to 10 bus routes. By the FFGA, however, the revised service plan anticipated that bus routes would focus on the new transit center and that no connections would be made at the Monticello station. In the actual outcome, two routes – the 1 and the 3 – stop at both the transit center and the Monticello station. Plans for connections at the Civic Plaza/Government Center station evolved in much the same way. Other differences between the actual and planned bus connections include:

- At the EVMC/Ft. Norfolk Station, routes 4 and 11 were modified after the opening of rail service, to serve the new transit center and no longer make a connection with LRT. Route 2 was originally planned to continue into downtown Norfolk and connect to the Monticello Avenue and Government Center Stations, but now terminates at the EVMC/Ft. Norfolk Station instead. Route 16 to Old Dominion University was added to the service plan proposed just before the FFGA milestone.
- The Harbor Park Station was planned for park-and-ride access, and was to be served by the Route 64, but this route was subsequently eliminated.
- In the mid-corridor, routes 9 and 13 serve the NSU station as planned. Route 18 serves the Ballentine station as planned and has been rerouted to provide a connection at the NSU station as well.
- At the eastern end of the Tide, the Military Highway and Newtown Road stations serve suburban locations with large park-and-ride facilities. Throughout project development, route 20 was planned to connect to the Tide at Military Highway but actually makes the connection at Newtown Road. Conversely, the eastern terminus of Route 23 is actually at the Military Highway Station instead of the Newtown Road Station as planned. Routes 24 and 63 that were planned for connections to Newton Road have been eliminated while new routes 22 and 28 have added service from Newtown Road to the northeast and east.

Table 4.6
Actual and Planned Bus Connections at Rail Stations

Station	Bus Route	Actual 2013 Connection	Connections Anticipated at:		
			Entry into PE	Entry into FD	FFGA
EVMC/Ft. Norfolk	2	yes	no	no	yes
	4	no	yes	yes	no
	11	no	yes	yes	yes
	16	yes	no	no	yes
	23	yes	yes	yes	yes
	44	yes	yes	yes	yes
York Street/ Freemason	3	no	no	no	yes
	4	no	no	no	yes
	44	yes	no	no	no
Monticello	1	yes	yes	yes	no
	2	no	yes	yes	no
	3	yes	yes	yes	no
	4	no	yes	yes	no
	6	no	yes*	yes	no
	8	no	yes	yes	no
	9	no	yes	yes	no
	13	no	yes	yes	no
	23	no	yes	yes	no
	45	no	yes*	yes	no
Civic Plaza/ Government Center	1	no	yes	yes	yes
	2	no	yes	yes	no
	3	no	yes	yes	no
	6	yes	yes*	yes	yes
	8	yes	yes	yes	yes
	9	no	yes	yes	no
	13	no	yes	yes	no
	45	yes	yes*	yes	yes
	960	yes	no	no	yes
	961	yes	no	no	yes

Table 4.6 (continued)
Actual and Planned Bus Connections at Rail Stations

Station	Bus Route	Actual 2013 Connection	Connections Anticipated at:		
			Entry into PE	Entry into FD	FFGA
Harbor Park	64	no	yes	yes	no
NSU	9	yes	yes	yes	yes
	13	yes	yes	yes	yes
	18	yes	no	no	yes
Ballentine	13	no	no	no	yes
	18	yes	yes	yes	yes
Military Highway	15	yes	yes	yes	yes
	20	no	yes	yes	yes
	23	yes	no	no	yes
	967	yes	no	no	yes
Newtown Road	20	yes	no	no	no
	22	yes	no	no	no
	23	no	yes	yes	no
	24	no	yes	yes	no
	25	yes	yes	yes	yes
	27	yes	yes	yes	yes
	28	yes	no	no	yes
	63	no	yes	yes	no
Connections Made	---	24	33	33	25
Connections Not Made	---	23	14	14	22

Conclusions

In general, the service plans at the project development milestones accurately anticipated the actual service outcomes. Most differences in bus-rail connections were a result of minor route tweaks occurring after the relocation of the downtown transfer center. The strategic vision remained the same: 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 changes would be focused at the two terminal stations.

The service plan at Entry to FD was a fairly accurate predictor of the overall character of the network.

A detailed table of changes to proposed schedule, headway, and station connections for each route is available in **Appendix C**: *Service Levels*.

5.0 Operations and Maintenance Costs

Actual Outcomes

In 2013, the Tide LRT operated for a total of over 29,000 train-hours and 373,000 car-miles, resulting in an annual cost of approximately $9.5 million. Table 5.1 shows the operating characteristics for the Tide two years after implementation of service

Table 5.1
2013 LRT Operating Characteristics

Variable	
Annual O&M Cost	$9,501,238
Annual Train-Hours	29,849
Annual Car-Miles	373,045
Cost per Train-Hour	$318.31
Cost per Car-Mile	$25.47

Source: HRT, costs include an administrative component allocated to light rail

In 2013, the HRT bus system operated approximately 794,000 revenue hours and almost 10 million revenue miles for an annual cost of approximately $46.2 million, excluding administrative costs. Comparable figures for 2009 were 860,000 revenue hours and 11.8 million revenue miles for an annual cost of approximately $43.6 million. On a per revenue hour basis, 2013 costs were $58.19/hour versus the 2009 rate of $50.69/hour or about a 14% increase in unit cost. BLS statistics indicate about 8.5% inflation between 2009 and 2013. However, costs for personnel services and materials/supplies (i.e. maintenance) at HRT outpaced inflation, significantly.

Overall, system operating costs were approximately $88.4 million in 2013. Over half of this was incurred by the bus program, while approximately 25% was spent on administration, 10% on LRT, 10% on para-transit, and less than 2% on other services such as ferry boat and van pool. Approximately $670,000 of administrative costs has been allocated to LRT. Additional details are available in **Appendix D:** *Operations & Maintenance.*

Accuracy of Predictions

Tables 5.2 and 5.3 compare the predicted and actual LRT service characteristics and O&M costs. Predicted service levels remained relatively steady across the milestones. The predictions anticipated fewer train-hours but more car-miles than the actual service in 2013. At all milestones, the predictions underestimated the cost of LRT service by approximately $1.9 million. These underestimates had three primary causes.

Variations between predicted and actual O&M costs were driven by:
- **Underestimated insurance costs**
- **The addition of layover time**
- **A shift towards on-site maintenance**

1. The casualties & liabilities cost category was underestimated by approximately $1.5 million. While HRT is self-insured, the final details of when additional insurance is invoked resulted in higher costs than the milestone models predicted by almost a factor of 10. A risk assessment independent for the project development process was conducted in November 2009 to inform decision makers on the coverage and level of insurance to be purchased by HRT. The decision to self-insure up to $2 million per incident was reached and premiums were estimated to be $2.3 million per year. Actual premiums in 2013 were still higher than the predicted values during project development but considerably lower at $1.6 million, than the risk assessment in 2009.

2. The number of service hours and resulting platform hours were underestimated. Significant layover time was added in the off-peak hours to the schedule to enhance schedule adherence and facilitate driver breaks and change-overs. The operations plans anticipated during project development included this additional layover time only during peak service. The plans also underestimated running time because they assumed signal priority (rather than pre-emption). Together, the longer layover time and longer running time increased the off-peak vehicle requirement from four to five vehicles and added 3,600 revenue hours into the system, annually. The required number of platform hours needed to supply the additional 3000 revenue hours is the primary reason for the increase in actual personnel services shown in Table 5.3.

3. Throughout LRT O&M cost development for Entry into PE and FD, HRT staff initially assumed 100% contracted maintenance. In actuality, the Tide used a mix of internal and contracted maintenance in 2013. This shift towards on-site employment for maintenance contributed to the lower-than-expected costs for services.

Table 5.2
Comparison of Predicted O&M Characteristics (Costs in Millions, $2013)

	2013 Actual	PE - 2021 Build	Final Design - 2010 Build	FFGA - 2010 Build
Bus System Operational Estimates*				
Annual Bus Revenue Hours	794,369	634,000	664,230	527,740
Annual Bus Revenue Miles	9,975,730	8,023,400	7,664,200	6,594,000
Fully Allocated O&M Costs	$66.74M	$68.79 M	$50.49 M	$50.49 M
Cost per Revenue Hour	$84.01	$108.50	$76.01	$95.67
The Tide LRT Operational Estimates				
Annual Train-Hours	29,849	25,950	25,980	26,750
Annual Car-Miles	373,045	400,500	400,100	392,700

Table 5.2 Comparison of Predicted O&M Characteristics (Costs in Millions, $2013)				
	2013 Actual	PE - 2021 Build	Final Design - 2010 Build	FFGA - 2010 Build
Fully Allocated LRT O&M Costs	$9.50 M	$7.59 M	$7.68 M	$7.65
Cost per Train-Hour	$318.31	$292.49	$295.61	$285.98

Source: HRT, BLS

** Bus statistics reflect total system figures rather than Southside only as shown in Section 4.*

Table 5.3 Comparison of Predicted LRT Personnel and Services Costs					
LRT Cost Category	**2013 Actual**	**Entry into PE**		**Final Design**	
	2013$	**2002$**	**2013$ Adj.**	**2006$**	**2013$ Adj.**
Personnel Services	$5,964,849	$3,161,221	$4,093,544	$3,548,300	$4,100,206
Services	$777,845	$1,247,529	$1,615,456	$1,342,900	$1,551,776
Casualties & Liabilities	$1,643,977	$188,160	$243,653	$138,800	$160,389

Source: HRT, Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations and Maintenance Plan, HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report BLS

Lessons Learned

As shown, all three milestone reports predicted a lower service level for bus than the actual system levels in 2013. Some of these service differences may reflect the efficiencies incorporated into the bus routing and timing that resulted from the Service Efficiency Plan of 2012 which allowed for more bus service to be provided with minimal change to costs. However, a comparison of the hourly rates suggests that the milestone estimates were relatively consistent with the actual costs in 2013. There were several bus routes added to the system at the time of LRT implementation and resulted in indirect costs being spread across more revenue hours.

6.0 Ridership

As of the Fall of 2013, the Tide carried 4,600 trips per average weekday. As shown in Figure 6.1, the Tide attracted over 5,000 average weekday trips at the time of its opening. Ridership rose to over 6,000 trips per average weekday during the Summer of 2012 due to aggressive fare discounting that has since been discontinued. With the exception of the months of November, December, and January, which have lower ridership due to the winter weather, ridership has stabilized to between 4,500 and 5,500 riders per day.

Table 6.1 presents a summary of Fall 2013 trips by place of residence and attraction location. Some 61% of these trips are attracted to the Norfolk core area including the Norfolk CBD, EVMC and Norfolk State University. Another 10% of Tide LRT 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. This result is consistent with experience in other cities where LRT is most likely to serve attractions near the LRT system, particularly the regional Central Business District.

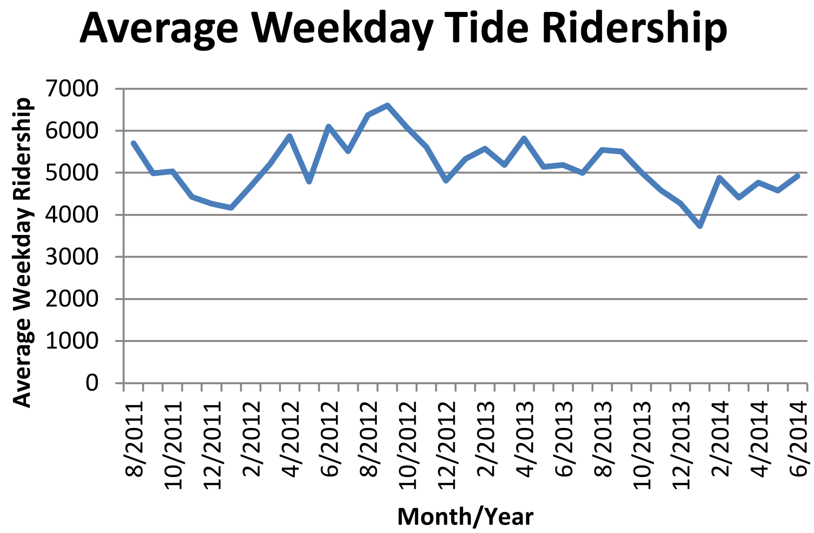


Figure 6.1 Average Weekday Ridership by Month

By contrast, and like other LRT systems in the United States, 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.

Table 6.1
Year 2013 Weekday Tide LRT Unlinked Trips by Production and Attraction Location

		Attracted to Workplaces and Other Activities in				
	Daily Trips on the Project	Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations	Share
Produced by Residents of	Locations in the Tide Corridor including the CBD	991	195	403	1,589	35%
	Locations Outside the Tide Corridor	1,812	274	916	3,002	65%
	All Locations	2,803	469	1,320	4,592	100%
	Share	61%	10%	29%	100%	

Over half of all trips on the Tide are made by riders traveling to their place of work or education. Tables 6.2 and 6.3 show that 43% of all Tide LRT riders are making home-based work (HBW) trips and 19% of Tide LRT riders are traveling between home and university (HBU). The HBW trip share is lowest for travelers with a residence in the corridor and traveling to attractions in the Norfolk Core or other corridor locations. The share of HBW trips is highest for travelers residing outside of the corridor. This result suggests that regional travelers are more likely to consider the Tide for work-related travel while corridor travelers, who are closer to the Tide, are more likely to consider the LRT for all types of travel.

Table 6.2
HBW Share of 2013 Weekday Tide LRT Unlinked Trips by Production and Attraction Location

	Daily Trips on the Project	Attracted to Workplaces and Other Activities in: Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	26%	27%	32%	28%
	Locations Outside the Tide Corridor	45%	67%	59%	51%
	All Locations	39%	50%	50%	43%

Table 6.3
HBU Share of 2013 Weekday Tide LRT Unlinked Trips by Production and Attraction Location

	Daily Trips on the Project	Attracted to Workplaces and Other Activities in: Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	19%	0%	9%	14%
	Locations Outside the Tide Corridor	27%	3%	15%	21%
	All Locations	24%	2%	13%	19%

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. Table 6.4 shows that the proportion of transit dependent riders is lowest among trips to the CBD and higher for Tide trips to other parts of the region. This pattern reflects the impediments to automobile travel to the CBD including traffic congestion and the costs and limited supply of parking that can induce a larger share of choice riders to choose transit.

Table 6.4
Transit Dependent Share of 2013 Weekday Tide LRT Unlinked Trips by Production and Attraction Location

	Daily Trips on the Project	Attracted to Workplaces and Other Activities in: Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	51%	70%	63%	56%
	Locations Outside the Tide Corridor	37%	74%	72%	51%
	All Locations	42%	72%	69%	53%

Table 6.5 shows the share of Tide riders who travel from home to their first transit stop by a non-motorized access mode. These trips include both passengers that walk or bike directly to the LRT and customers who walk or bike to a feeder bus that takes them to the Tide. Most Tide riders (73%) travel to their first transit stop using a non-motorized mode – either walk or bike. Only trips that begin outside of the immediate corridor and travel to the Norfolk core are more likely to drive or be driven to their first transit stop.

Table 6.5
Non-Motorized Access-to-Transit Share of 2013 Weekday Tide LRT Unlinked Trips by Production and Attraction Location

		Attracted to Workplaces and Other Activities in			
	Daily Trips on the Project	Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	94%	100%	99%	96%
	Locations Outside the Tide Corridor	47%	84%	84%	62%
	All Locations	64%	90%	88%	73%

The introduction of Tide LRT service appears to have resulted in a modest increase in transit ridership in the region. As shown in Tables 6.6 and 6.7, overall HRT daily system-wide linked trips increased from 35,700 in 2011 to 38,700 in 2013, an increase of 8%. Differences between the 2011 and 2013 rider-survey techniques have led to variations in the geographic distribution of transit ridership that complicate attempts to identify specific changes to Hampton Roads ridership patterns. Nevertheless, the growth in transit ridership attracted to the Norfolk Core (from 5,800 to 8,000 daily trips, 38% growth) is sufficiently large to suggest that the Tide has contributed to increasing transit use in the areas that it serves.

The 38% growth in ridership attracted to the Norfolk Core suggests that the Tide has contributed to increased transit use.

Table 6.6
Year 2011 System-Wide Weekday Linked Transit Trips Flows (Before)

		Attracted to Workplaces and Other Activities in			
	Daily Trips on the Project	Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	1,952	772	2,720	5,444
	Locations Outside the Tide Corridor	3,870	1,398	25,002	30,270
	All Locations	5,822	2,170	27,722	35,714

Table 6.7 Year 2013 System-Wide Weekday Linked Transit Trips Flows (After)					
		Attracted to Workplaces and Other Activities in			
	Daily Trips on the Project	Norfolk Core	Other Corridor Locations	Locations Outside the Tide Corridor	All Locations
Produced by Residents of	Locations in the Tide Corridor including the CBD	1,567	213	3,084	4,864
	Locations Outside the Tide Corridor	6,462	1,695	25,645	33,802
	All Locations	8,029	1,908	28,729	38,666

Table 6.8 compares actual ridership using the Tide in 2013 to predictions of opening year ridership prepared for each project development milestone. At Entry into PE, HRT prepared horizon year forecasts but did not prepare opening year predictions of Tide ridership. HRT used identical methods and assumptions to prepare opening year ridership forecasts for both the Entry into FD and FFGA milestones. Consequently, the forecasts of opening year ridership are identical for the two milestones.

Actual ridership has beaten projected ridership by 37%.

At the Entry into FD and FFGA milestones, HRT projected that that the Tide would attract 2,891 weekday riders. This projection is 37% below actual 2013 ridership of 4,592 boardings per day.

Table 6.8 Actual Year 2013 Weekday Tide LRT Ridership Compared to Opening Year Forecasts at Milestones				
Purpose	Actual	Entry into PE	Entry into FD	FFGA
HBW	1,983	Not estimated	2,221	2,221
HBO	2,034	Not estimated	178	178
NHB	574	Not estimated	492	492
Total	4,592	Not estimated	2,891	2,891

The difference is not uniform across all trip purposes; nearly all of the discrepancy occurs for home-based other (HBO) trips. Projections of both HBW and non-home based (NHB) trips accurately anticipated overall travel for these purposes. Key comparisons of predicted versus actual ridership are as follows:

- Predictions of 2,200 daily Tide HBW trips exceeded actual ridership by 12%. The forecasts correctly anticipated that the key attraction location for HBW trips is the Norfolk Core but over-estimated ridership to this area by 700 daily trips.
- HRT projected that the Tide would attract only 180 home-based other (HBO) trips as compared to actual ridership of 2,000 daily HBO trips. The reasons for this difference are not known with certainty. It appears 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, sporting 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. Many of these trips elect to use the Tide.

- Predictions of 490 daily non-home-based (NHB) trips closely approximate actual ridership of 570 NHB trips. The majority of predicted NHB ridership occurs to, from, or within the core and matches observed ridership patterns. One reason for the success of the NHB forecasts is that the project sponsors used the FTA supplemental NHB forecasting model to estimate the effect that the Tide LRT would have on increasing ridership for midday travel between work and other non-home locations. The FTA supplemental model contributed 350 out of 490 total predicted NHB trips.

Lessons Learned

These results demonstrate that carefully validated forecasting models can accurately forecast HBW trip purposes and that the FTA supplemental NHB forecasting techniques can help to understand the impact that new fixed guideway services can have on induced travel between workplaces and other non-home destinations. The substantial under-prediction of HBO trips suggests that additional effort may be needed to properly represent the unique HBO attractions in downtown areas to properly estimate ridership drawn from throughout the region to these unique facilities.

Carefully validated forecasting models can improve the accuracy of ridership predictions.

Appendix E: *Ridership* provides more detailed information on the impacts of the Tide LRT project on transit ridership and on the accuracy of the ridership predictions.

7.0 Farebox Revenues

Fare Structure Comparison 2009 (Before) and 2013 (After)

The 2013 fare structure for the HRT system, shown in Table 7.1, is identical to the system's fare structure in 2009 except for the added fare media for the GoPass365 and 3-day Full/Half GoPasses. While the GoPass 365 had a significant impact on LRT fare revenue and ridership, the 3-day GoPasses were specifically for shuttle services in Virginia Beach and had minimal bearing on the ridership and use of fare media on the light rail system. The GoPass 365 pass, an annual unlimited ride pass, is available to area universities and community colleges, as well as through select area employers who purchase the pass directly from HRT and then provide to their employees only. For a significant period in FY 2013, the GoPass365 was available for as low as $6.50 annually and it had a profound impact on system revenue.

Table 7.1 2013 Fares by Mode and Fare Category					
Fare Category	**Bus**	**LRT**	**Ferry**	**MAX**	**VB Wave**
Cash Fares					
Adult	$1.50	$1.50	$1.50	$3.00	$1.00
Half-fare*	$0.75	$0.75	$0.75	$1.50	$0.50
Youth (under 17)	$1.00	$1.00	$1.50	$3.00	$1.00
Children (less than 38”)	Free	Free	Free	Free	Free
HRT GoPass					
1 Day	$3.50	$3.50	$3.50	$5.50	$2.00
1 Day Half-fare**	$1.75	$1.75	$1.75	n/a	$1.00
1 Day Bundle of 5	$16.50	$16.50	$16.50	$24.75	$10.00
1 Day Half-fare** Bundle of 5	$8.75	$8.75	$8.75	N/A	N/A
3 Day	N/A	N/A	N/A	N/A	$5.00
3 Day Half-fare**	N/A	N/A	N/A	N/A	$2.50
7 Day	$17.00	$17.00	$17.00	N/A	N/A
30 Day	$50.00	$50.00	$50.00	$95.00	N/A
30 Day Half-fare**	$35.00	$35.00	$35.00	N/A	N/A
HRT Go365					
Go365***					

** Seniors, disabled and Medicaid-eligible riders are eligible for half-priced cash fares*
*** Seniors, disabled and Medicaid-eligible riders, and students are eligible for reduced-priced GoPasses*
**** Go365, Annual pass sold to employers directly and not available to individuals*
Source: HRT

Comparison of Before and After Fare Revenues

For fiscal year 2013, spanning from July of 2012 to June of 2013, total HRT system revenue was approximately $15.1 million. This was a decrease of approximately $1.8 million from FY09 when total system revenue was approximately $16.9 million. The decrease occurred in spite of 19.2% increase in overall system ridership, attributable mostly to the implementation of the Tide and new riders attracted by the big drop in fares per boarding cited below.. The GoPass365, which was offered for only half of the FY 13 (re-priced in January 2013), significantly reduced the revenue per boarding generated on the light rail. There were other deep discounts (3-day passes) added to the fare structure that had a smaller negative impact of fare per boarding as well.

Deep fare discounts – which positively impacted ridership – negatively impacted revenue generated by the Tide.

Since the Tide has no fare-collection equipment that would count rider fares, estimating the amount of fare revenue credited to LRT service can only be based on the system average fare per boarding. Average fare per boarding in 2009 was about $1.10. In 2013, the average fare person dropped to $0.82. Since 2013, the average fare per boarding has rebounded to levels at or above $0.94 now that the GoPass 365 pass is more reasonably priced.

Comparison to Milestone Predictions

Actual system fare revenue is considerably lower than milestone predictions primarily because the predictions were based on the assumption that HRT would implement an initial fare increase corresponding with the introduction of rail and a second fare increase during the FY 2013 operating year. Even though actual ridership was considerably higher than forecasts, the system did not generate the predicted level of revenue because the fare increases never materialized. In addition, HRT added deeper discounts (GoPass 365) into the fare structure. As discussed in the ridership section, the lower fares had a positive impact on ridership.

Despite higher-than-predicted ridership, Tide revenue did not meet projections because planned fare increases did not occur.

At Entry into PE, the FY 2013 system fare revenue was projected to be $22.5 million This prediction was based on an average fare per boarding of $1.29, added two inflation-based fare increases, and only used overall system ridership in the calculation. At Entry to FD, the FY 2013 system fare revenue was projected to be $19.0 million. This later revenue forecast was more conservative, using a fare per boarding of $1.01. The fare per boarding assumed in both predictions was higher than the actual $0.82 per boarding average in FY 2013.

8.0 LRT's Role in Station Area Development

Purpose of the Analysis

In the 2008 *Documentation of Conditions Before Project Implementation Report,* a list of 33 planned developments was compiled to create a baseline of expected developments against which "realized" station area developments (what was actually constructed) could later be measured. The purpose of this analysis is to identify the impacts of Tide operations on station area development activity. This was analysis was structured to determine which of the projects listed in the 2008 report have been constructed to date, identify station area developments that were not yet planned in 2008 but have subsequently been constructed, which of the station area developments can be attributed to LRT operations, and to identify developments that were planned in 2008 but have not been constructed.

Actual Station Area Development

31 real estate projects have been built (or have begun construction) within a half-mile of Tide LRT stations (defined as the station area) since 2008. These represent a combination of completed projects noted in the 2008 report, as well as projects that were not yet in planning or development in 2008. These developments are a mixture of sizes, scales and uses. The majority of this development has occurred in the station areas nearest the downtown.

Station Area Development Attributable to LRT

According to staff from the City of Norfolk Department of Development and HRT, three station area developments were directly attributable to Tide LRT operations. According to the City and HRT staff, the closure of these three development deals was dependent on a number of factors and concessions, including LRT service. Developers valued LRT's role in increasing transportation access options to their developments, and believed that this increased level of access would increase the marketability of their property.

Table 8.1 Developments since 2008 within a Half-Mile of Tide LRT Stations that are Directly Attributable to LRT Service				
Name	**LRT Station Area(s)**	**In 2008 Report?**	**Description**	**Investment Value**
Fort Norfolk Plaza	EVMC / Fort Norfolk	✔	195,890 square feet of medical office, retail, parking	$80 million (2006)
Belmont at Freemason	York Street / Freemason Monticello MacArthur Square	✔	240+ luxury apartments	$45 million (2007)
Wells Fargo (Wachovia) Tower	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔	Mixed use tower, including 255,000 square feet of office; 50,000 square feet of retail; 1,800+ parking spaces and 121 residential units	$180 million (2010)

Source: Norfolk Department of Development, HRT Planning Staff

These three projects represent more than $305 million and 500,000 square feet of investment attributed by the City to the Tide System. While other developments built since 2008 may be attributable to or influenced by the Tide, there is no information available to make a direct connection.

Planned Developments That Have Not Been Constructed

Of the 33 planned developments listed in the 2008 report, 13 have been constructed, 12 have not been constructed, and eight fall outside of an LRT station area. The planned developments that were not constructed were a mixture of sizes, scales and uses. There does not appear to be a pattern or common reason that these developments did not move forward into construction.

33 station-area developments were planned in 2008; 13 have been constructed to-date, of which three can be attributed to LRT service.

Conclusion

With the exception of the three developments specifically noted above, there is very little 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 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, although there are limited examples (discussed above) where LRT operations can be credited for specific developments. Additional discussion is contained in **Appendix F:** *Land Use & Development.*

9.0 Parking

Purpose of the Analysis

Appendix G: *Parking* was prepared to review and compare City of Norfolk parking policies, parking supply, and parking utilization reports before and after the implementation of the Tide LRT service in an attempt to determine the impact of LRT service on parking in the Central Business District (CBD) and fringe CBD. City-controlled garages provide 90 percent of all spaces in the Norfolk CBD.

The number of spaces, utilization rates, and costs of City-controlled parking garages and parking lots in Norfolk's CBD and fringe CBD were inventoried in the 2008 *Before Project Implementation* Report. This inventory, which relied on 2006/2008 data, has been updated with 2014 data as part of this *Report* and is discussed below. Details of the City's parking policy and regulatory changes, and a comparison of between 2006/2008 and 2014 parking supply, demand, and cost for City-controlled lots and garages in Norfolk's CBD and fringe CBD can be found in the sections below.

There is no direct correlation between Tide operations and parking supply, demand, and pricing in the Norfolk CBD.

A comparison of 2006/2008 and 2014 parking data does not demonstrate a direct correlation between Tide LRT service and parking supply, demand, and pricing in Norfolk's CBD. The data does show that the supply of parking (number of spaces) in City-controlled parking garages and lots has increased by 8% between 2006 and 2014 (two new garages have opened and five lots/garages have closed) while the utilization rate has declined by 4%. This means that the number of utilized City-controlled parking spaces has remained stable between 2006 and 2014. The price of parking has increased to some degree between 2008 and 2014 for all City-controlled parking garages and lots within the CBD, but the degree of increase is determined by the City's 2010 pricing restructure from tiered to flat pricing in City-controlled lots and garages.

<u>City of Norfolk Parking Policy and Regulations</u>

In addition to understanding the parking data discussed in the following two sections, it is helpful to understand the City parking policy and regulations because those policies and regulations guide the supply of, demand for (through pricing decisions), and cost of parking.

In October 2005, Norfolk City Council passed a Resolution to "adopt a parking policy to support a greater use of public transit," with an attached policy titled "Transit Oriented Downtown Parking Policy" (Resolution 1, 289). One of the policy goals within the Resolution encouraged "promotion of greater development density particularly near transit stations." As documented in the Norfolk LRT Documentation of Conditions Before Project Implementation Report (2008), this policy set the Maximum Downtown Parking Capacity at 3.7 privately-controlled parking spaces per 1,000 square feet of leasable office space within the CBD.

Beginning in 2010, City of Norfolk staff began researching and proposing parking policy changes to satisfy market demand for reduced parking requirements and reduce a perceived oversupply of downtown parking. In February 2014, Norfolk City Council members (based on research and recommendations by City staff) recommended a series of changes to the Zoning Ordinance, including a 25 percent reduction in required parking minimums for non-residential (including commercial) uses within 1,500 feet of a LRT station. The parking minimums vary by land use and location; details can be found in the revised ordinance, which can be found in **Appendix G:** *Parking*.

This policy change was partially catalyzed by the realization that "application of suburban parking standards in the Arts District and in Fort Norfolk has created a barrier to revitalization" and to improve compliance with Character Districts defined in plaNorfolk2030, the city's General Plan. The City Council approved the amendments to the Zoning Ordinance on March 25, 2014.

It is too soon to quantitatively measure the impacts of this 2014 zoning change on the supply of downtown parking, but the adoption of the Transit Oriented Downtown Parking Policy and the 25 percent reduction in the required parking minimum for non-residential uses within 1,500 feet of an LRT station indicate the City's belief that Tide LRT can play a role in reducing demand for parking and the City's desire for transit-supportive land uses in LRT station areas.

Parking Supply

The City controls 90% of the parking in downtown Norfolk; the remaining 10% is privately-controlled. Privately-controlled parking facilities are not included in this inventory. Two garages, the Bank and Charlotte Street Garages, were built in 2010 after the 2008 *Before Project Implementation Report* was completed. Their primary purpose was to accommodate demand that was generated by the construction of the Wells Fargo Tower. These garages were opened just before the City started considering changes to its parking policy in 2010 (described in Appendix G).

While the utilization rate of the City-controlled parking garages and lots has decreased 4%, the total number of parking spaces has increased over 8% (from 16,418 to 17,925) between 2006 and 2014. This increase in the number of spaces reflects the construction of the Bank and Charlotte Street Garages, which added 1,858 additional parking spaces to the CBD. The majority of spaces in these two new garages (80%) are designated for monthly parking. Five lots/garages closed between 2006 and 2014, resulting in the loss of 1,390 spaces; these lots/garages were closed to so that the underlying land could be redeveloped.

A comparison of 2006 and 2014 parking supply data does not demonstrate a direct correlation between Tide LRT operations and parking supply in Norfolk's CBD. Further, the data does not immediately indicate that parking policies have made a difference to parking utilization or construction. Additional time is needed to see if the policies will make long term changes to parking supplies in the CBD.

Parking Pricing

In response to concerns that parking demand generated by CBD development would exceed the existing parking supply, the City of Norfolk established a three-tiered pricing structure in 2002 for City-controlled parking garages and lots. The intent was to use pricing as a policy mechanism to distribute parking demand more evenly throughout City-owned garages and lots. The tiering of the garages was based on proximity to prime demand generators: garages and lots closest to those generators were classified as Tier 1, which was the most expensive tier. Garages and lots that were located successively further away from those demand generators were classified in the less expensive Tiers 2 and 3. In 2010, the City eliminated the tiered parking garage pricing structure because development was more evenly distributed throughout the city than anticipated, which resulted in a more even distribution of parking demand than anticipated. The City decided that the tiered structure was not necessary to balance demand among the City-controlled parking lots and garages.

A comparison of 2008 and 2014 parking pricing data does not demonstrate a direct correlation between Tide LRT operations and parking costs in Norfolk's CBD.

Additional Transit Network Factors

The Norfolk Electric Transit (NET) Circulator (HRT Route 17) was a downtown circulator bus route that was established in 1999 to connect residents and visitors with employment, dining, entertainment, shopping, and other destinations within downtown. Operation of the route was intended to reduce parking demand, as riders could choose to circulate car-free throughout the downtown. The service, which originally was fare-free, was converted to the HRT bus fare structure in 2011 to reduce a perceived competition (due to redundant service along some routes) with the new LRT service. The service routing was modified in 2011 and 2013, and was discontinued in July 2014.

Free LRT park-and-ride lots (Harbor Park, Ballentine/Broad Creek, Military Highway, and Newtown Road) have increased transit system access by suburban users. Despite these free parking facilities, however, HRT Planning Department staff report that some commuters have continued to park at CBD fringe lots and garages and walk into the CBD as a means to more directly access to their final destination.

Lessons Learned

A comparison of 2006/2008 and 2014 parking data does not demonstrate a direct correlation between Tide LRT operations and parking supply, demand, and pricing in Norfolk's CBD. There are, however, additional opportunities for the City of Norfolk to better align transit and parking policy to manage supply of and demand for parking (through zoning changes, pricing, number of available spaces) to support transit ridership.

The City of Norfolk is making regulatory changes that reflect the belief that the Tide will play a role in reducing demand for parking in the future.

10.0 Traffic

Purpose of the Analysis

In the 2008 *Documentation of Conditions Before Project Implementation* report, Average Daily Traffic (ADT) and intersection turn movement counts of major roadway segments and intersections were conducted in 2007 at the same locations as in the project *Final Environmental Impact Statement*. A subset of these segment and intersection locations was updated with 2014 count data. The methodology and results of this update, as well as reasons for changes in the count volumes, are included in the sections below and described in more detail in **Appendix H:** *Traffic*.

Actual Outcomes

Average Daily Traffic (ADT)

In the 2008 *Documentation of Conditions Before Project Implementation* Report, ADT counts of 52 major roadway segments were conducted in 2007 at the same locations as in the project Final Environmental Impact Statement. A subset of these locations – seven locations, listed below – was updated with 2014 count data. ADT counts were taken over the course of week (including the weekend) at seven locations. A comparison of the 2007 and 2014 ADT data is shown in Table 10.1.

Table 10.1
Comparison of Average Daily Traffic Counts, 2007 and 2014

Roadway Name	Segment From	Segment To	2007	2014	Change	% Change
City Hall Avenue	Monticello Avenue	St. Paul's Boulevard	13,990	6,449	-7,541	-54%
St. Paul's Boulevard	Waterside	City Hall Avenue	14,885	8,546	-6,339	-43%
Eastbound City Hall Avenue	St. Paul's Boulevard	Berkeley Bridge	42,410	13,522	-23,072	-154%

Table 10.1
Comparison of Average Daily Traffic Counts, 2007 and 2014

Roadway Name	Segment From	Segment To	2007	2014	Change	% Change
Westbound City Hall Avenue	St. Paul's Boulevard	Berkeley Bridge		5,816		
Brambleton Avenue	Tidewater Drive	Park Avenue	28,650	32,035	3,385	12%
Brambleton Avenue	Park Avenue	I-264	39,630	34,216	-5,414	-14%
Ballentine Boulevard	I-264	Virginia Beach Boulevard	29,935	14,859	-15,076	-50%

ADT counts have declined at six of the seven count locations between 2007 and 2014. Two main issues influenced the variation in ADT counts between 2007 and 2014:

- Construction of the new City Hall complex on the east side of St. Paul's Boulevard in the vicinity of City Hall Avenue has resulted in lane closures and various traffic impacts.
- Tolls have been added to the Downtown and Midtown Tunnels, with major shifts in traffic orientation and mixed impacts: drivers either avoid the tolls using alternate routes, or shift travel times to avoid peak-hour prices.

ADT count declines were driven by:
- ***Lane closures/traffic impacts of the new City Hall complex***
- ***New tunnel tolls***

There is not sufficient data to link this decline to Tide operations.

The decreased ADT counts along Ballentine Boulevard may reflect some Norfolk State students shifting transportation mode from cars to LRT. Decreases may also reflect drivers choosing alternate routes to avoid intersection congestion from LRT signal preemption. However, there is no survey data to substantiate these potential explanations.

Intersection Turning Movements and Level of Service (LOS)

In the 2008 *Documentation of Conditions Before Project Implementation Report*, peak period turn movement counts were conducted in 2007 at 38 intersections. A subset of these locations – nine locations, listed below – was updated with 2014 count data. Intersection turn movement counts were taken during the AM peak period (6:00 am to 9:00 am) and PM peak period (3:00 pm to 6:00 pm) during a weekday at nine locations. A summary comparison of the 2007 and 2014 turn movement count data and explanations for changes overtime are shown in Table 10.2, with more detailed information available in **Appendix H:** *Traffic***.** With a few exceptions, intersection turn counts declined between 2007 and 2014; we do not have sufficient data to link these changes to LRT operations.

While intersection turn counts declined between 2007 and 2014, there is not sufficient data to link this decline to LRT operations.

Table 10.2 Comparison of Intersection Turn Movement Counts, 2007 and 2014				
Intersection	Change, 2007 to 2014			
	AM Peak Intersection Total Change	AM Peak Intersection Percent Change	PM Peak Intersection Total Change	PM Peak Intersection Percent Change
St. Paul's Boulevard and City Hall Avenue	-643	-21%	221	5%
Monticello Avenue and City Hall Avenue*	-682	-57%	-471	-32%
Monticello Avenue and Freemason Street	-276	-42%	-407	-40%
Monticello Avenue and Charlotte Street	-245	-36%	-258	-27%
Boush Street and Charlotte Street / Bute Street*	206	10%	-186	-8%
Duke Street and Bute Street	38	10%	-91	-15%
Duke Street and Brambleton Avenue	-654	-14%	-870	-17%
Ballentine Boulevard and Westbound Off/Westbound On Ramp*	-577	-22%	-397	-14%
Ballentine Boulevard and Eastbound Off/Eastbound On Ramp / Westminster Avenue	-313	-17%	-82	-4%

11.0 Summary

More than three years after the start of revenue service, the Tide LRT has exceeded ridership projections and become a critical element of Norfolk's transit – and transportation – network. Of the nine categories of characteristics that have been analyzed as part of this Before-and-After Study, two met projections (Physical Scope and Service Levels), and four deviated from projections (Capital Costs, Operations & Maintenance, Ridership and Farebox Revenue). Predictions related to three categories (Land Use & Development, Parking and Traffic) cannot fully be assessed because of difficulty isolating data for analysis.

As described in this report and appendices, some of the differences between predicted and actual outcomes resulted from inaccurate assumptions (capital and O&M costs) and failure to enact a planned fare increase (and instead offering deep fare discounts). Others resulted from short-term cost-cutting measures and regulatory delays. The analysis has shown that deviations in one category sometimes impacted related categories: the lower-than-anticipated farebox revenue reflects policy decisions that supported the higher-than-anticipated ridership.

While inaccurate predictions can be expected over the planning, construction, and operations life cycle of a major transit investment, the Before-and-After Study has resulted in the identification of "lessons learned" that may have minimized these deviations, including:

- **Manage the construction schedule to control costs:** HRT believes that the creation of a master project schedule that monitors the progress of all contracts and contractors from receipt of the FFGA to completion of construction could have minimized cost overruns.
- **Manage cost-cutting efforts over the project life-cycle:** Major assumptions made before Entry into PE for the purpose of reducing project capital costs were later proven to be overreaching, requiring items to be reinserted into the project during construction. These reintroduced items, accompanied by other items added during construction, account for the largest amount of discrepancy between actual and predicted capital costs. Continued oversight from FTA, open communication with stakeholders and oversight agencies, and a thorough response to identified potential risks could have provided a more accurate prediction of the actual costs incurred on the Tide.
- **Train staff on project critical path activities and FTA processes:** Mistakes in cost estimates and lost time may have been avoided if HRT project staff were fully trained on the critical path activities to project completion (revenue operations) and the FTA conventions/processes for achieving project completion.

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix A: Physical Scope

HAMPTON ROADS TRANSIT

Introduction

The purpose of this technical memorandum (tech memo) is to document the physical scope of The Tide, Hampton Roads Transit's (HRT) first light rail transit (LRT) line. HRT's governing body, the Transportation District Commission of Hampton Roads (TDCHR), was awarded a Full Funding Grant Agreement (FFGA) on October 1, 2007 by the Federal Transit Administration (FTA) under its New Starts program in the amount of $127,980,000. This tech memo provides documentation of the project's physical scope as constructed and as predicted at three key milestones in the planning process: Entry into PE, Entry into Final Design, and the FFGA. The documentation provided in this tech memo will be summarized in the project's Before-and-After Study, an FTA-required study for projects receiving New Starts funding.

The tech memo begins with a description of the as-built physical scope of the project. The physical scope descriptions at each of the three milestones will then follow. For each milestone, differences in the predicted scope compared to the as-built scope will be identified and described. For the purposes of this document, an element is described as "not accurately predicted" if any changes to the project element occurred during the planning process, even when changes are relatively minor.

As-Built Physical Scope

The Tide LRT project began revenue operations on August 29, 2011. The corridor as constructed and operated extends approximately 7.3 route-miles from the Eastern Virginia Medical Center (EVMC) complex east through downtown Norfolk to Newtown Road at the Norfolk-Virginia Beach border. It is served by 11 stations and four park-and-ride lots. The Tide typically operates for 17 hours Monday through Thursday, 18 hours on Friday and Saturday, and 10 hours on Sunday, utilizing six light rail vehicles (LRV) during peak periods. A table is provided at the end of this section that summarizes the as-built physical scope and the predicted physical scope at Entry into PE, Entry into Final Design, and the FFGA. The following sections describe the elements of the project organized by FTA's standard cost categories (SCC). The categories relevant to physical scope are as follows:

- SCC 10: Guideway and Track Elements
- SCC 20: Stations, Stops, Terminals, Intermodal
- SCC 30: Support Facilities: Yards, Shops, Administrative Buildings
- SCC 40: Sitework & Special Conditions
- SCC 50: Systems
- SCC 60: ROW, Land, Existing Improvements
- SCC 70: Vehicles

Guideway and Track Elements (SCC 10)

The as built project consists of a 7.34-mile, double-tracked light rail system with a reserved transit corridor by operating agreement in the downtown portion of the alignment and a dedicated right-of-way (ROW) on abandoned Norfolk Southern Railroad ROW from Norfolk State University (NSU) Station to Newtown Road Station. The project is single-tracked for short distances heading into the western and eastern terminal stations. A short portion of the alignment (0.2 miles) on Charlotte and Bute Streets are on shared lanes with vehicular traffic and not on dedicated ROW.

Guideway Subcategories- The project as built includes portions of semi-exclusive at-grade guideway, mixed-use at-grade guideway, exclusive aerial guideway, and retained fill guideway. There is approximately 4.4 route miles of at-grade, semi-exclusive guideway along the former Norfolk Southern Railroad ROW portion of the alignment from the crossing of the Lamberts Point Branch to the Newtown Station at the eastern terminus of the project. Within the Norfolk Central Business District (CBD), approximately 1.3 route miles of guideway is semi-exclusive, and 0.21 route miles is mixed-use. Aerial structure was constructed for a total of approximately 1.17 route miles in length at three creek crossings (Smith Creek, Broad Creek, Moseley Creek), two active Norfolk Southern freight crossings, and three roadway crossings (Park Avenue, Claiborne Avenue, and Brambleton Avenue). Retained fill sections total approximately 0.22 route miles and primarily occur in the areas adjacent to I-264 between Lambert's Point railroad crossing and the Brambleton Avenue Bridge adjacent to Norfolk University. Other minor segments of retained fill are located primarily at bridge approaches.. **Table 1** summarizes the as-built guideway and track elements.

Table 1
As-Built Guideway and Track Elements

Guideway Element	Length (Track miles)
At Grade	11.77 mi
Below Grade	0.00 mi
Aerial	2.35 mi
Retained Fill	0.35 mi
Total	**14.47 mi**
Exclusive ROW	2.75 mi
Semi-exclusive ROW	11.30 mi
Mixed-use ROW	0.41 mi
Track Element	
Direct Fixation	0.36 mi
Embedded	3.03 mi
Ballasted	8.75 mi
Open Deck	1.98 mi
Full-Depth Crossing	0.33 mi
Total	**14.45 mi**

Source: URS, HRT, 2014.

Track Subcategories- Six categories of track were utilized for the as-built project: direct fixation, embedded, ballasted, open deck, full-depth crossing, and special trackwork. Full-depth crossing is similar to ballasted track and open deck is similar to direct fixation; as these categories are not listed in the FTA SCC, they have been included in the lengths for ballasted and open deck track, respectively. Direct fixation track was used for approximately 0.36 track miles on the aerial structures of the project. Open deck track was also used on aerial structures, in the amount of approximately 1.98 track miles. Embedded track was utilized in the Norfolk Central Business District (CBD) in the amount of approximately 3.03 track miles. The embedded track includes the construction of a red concrete surface pour, installed for aesthetic reasons at the request of the City. Ballasted track was used along the abandoned Norfolk Southern corridor and between York Street/Freemason Station and along

Brambleton Avenue heading toward EVMC/Fort Norfolk Station. Ballasted track is also in the Norfolk Tide Facility (NTF), the vehicle maintenance facility and yard. Ballasted track totaled approximately 8.75 track miles. The special trackwork included turnouts, crossovers, guard rail, restraining rail, two spring switches for the terminal stations, and track drains.

Stations (SCC 20)

The as-built light rail facility has eleven stations, each of which having a covered platform shelter with bench seating, space for two ticket vending machines, and ADA ramp access. Nine stations have one-car platforms, the MacArthur Station was built with two-car platforms, and the lone aerial station was builtas a two-car platform, but designed to accommodate three. From west to east, the following paragraphs highlight elements specific to each station, and **Table 2** summarizes the station characteristics of the constructed project. All as built stations incorporate a vinyl-clad wood frame shelter with sectioned glazing, a gable roof, special tubular steel railings, globe lighting, and special information kiosk.

EVMC/Fort Norfolk Station- This station is located at the western terminus of the project on the south side of Brambleton Avenue, just west of Colley Avenue, and serves the Eastern Virginia Medical Center complex, Norfolk Public Health Department, Sentara Norfolk General Hospital, Children's Hospital of The King's Daughters, and the American Red Cross. This at-grade station includes a side platform, two bus bays, and 250 parking spaces. The bus bays were installed by the City of Norfolk after project completion. Parking at this station is only available at designated times: 6:00 to 11:59 p.m. Monday through Thursday and 6:00 p.m. Friday through 11:59 p.m. Sunday. Bus Routes 2, 16, 23, and 44 serve the LRT station.

York Street/Freemason Station- This station is an at-grade station located on York Street between Dunmore Street and Yarmouth Street, adjacent to the existing YMCA. The walk-up, side-platform station serves the northern end of the Norfolk Central Business District and the Chrysler Museum of Art. No bus connections or parking were provided as part of the federally-funded project and no bus transfers were offered at the start of revenue service; however, Route 44 now goes along Brambleton Avenue.

Monticello Station- This station is an at-grade station located in the center of Monticello Avenue near Charlotte Street and Freemason Street in front of the Wells Fargo Center. The walk-up, center platform station serves The Norfolk Scope, Chrysler Hall, MacArthur Center, Granby Street entertainment/commercial district, Walter E. Hoffman United States Courthouse, the Roper Center for the Performing Arts, The Wells Theater, and the downtown campus of Tidewater Community College (TCC). No bus connections or parking were provided as part of the federally-funded project, and no bus transfers were offered at the start of revenue service; however, Routes 1 and 3 now serve Monticello Station with stops on Monticello Avenue near Charlotte Street.

MacArthur Square Station- This station is located between Bank and Atlantic Streets on the east and west and between City Hall Avenue and Plume Street on the north and south. The walk-up station serves the central portion of the Norfolk Central Business District, MacArthur Center, the MacArthur Memorial, and Norfolk Central Library. The two-car, side station platforms sit on the former Kirn Library site and contain two station shelters side-by-side in each direction with the tracks in the center. No bus connections or parking are provided.

Table 2 As-Built Station Characteristics				
Station	**Platform Type**	**Station Profile**	**Bus Bays**	**Parking**
EVMC/Fort Norfolk Station	Side	At grade	2*	250*
York Street/Freemason Station	Side	At grade	None	None
Monticello Station	Center	At grade	None	None
MacArthur Square Station	Side	At grade	None	None
Civic Plaza Station	Side	At grade	1***	None
Harbor Park Station	Center	At grade	None	176
NSU Station	Center	Aerial	None**	None
Ballentine/Broad Creek Station	Side	At grade	2 (and 1 passenger drop-off area)	105
Ingleside Road Station	Side	At grade	None	On-street^
Military Highway Station	Side	At grade	2	232
Newtown Road Station	Center	At grade	3	266

Source:
**EVMC/Fort Norfolk Station: Two bus bays were installed after project completion by the city, not at project cost; Parking only available M-TH 6:00 p.m.-11:59 p.m. and 6:00 p.m. Friday until 11:59 p.m. Sunday*
***NSU Station as funded by the project did not include any bus bays, however, two bus bays were installed in 2013 by the City of Norfolk.*
****An existing HRT bus stop already was located at St. Paul's Blvd. and Plume St. to provide transfer service to the LRT.*
^On-street parking reserved for area residents only

Civic Plaza Station- This station is located on the plaza at Norfolk City Hall and serves the eastern end of the Norfolk Central Business District, Circuit court, General District court, and Juvenile Domestic Relations court. Bus Routes 6, 8, 45, 960, and 961 serve the station.

Harbor Park Station- This station is located at the east end of Harbor Park and serves the baseball stadium. The at-grade, center-platform station provides 176 parking spaces for use by transit patrons.

NSU Station- This station is an aerial station located at Brambleton Avenue that serves the main campus of Norfolk State University (NSU). An elevator and stairs provide access to the station. Bus Routes 9, 13, and 18 serve the station.

Ballentine/Broad Creek Station- This station is located on Ballentine Road at the entrance and exit ramps of I-264 near Norfolk State University. The at-grade, side-platform station serves the eastern end of the NSU campus and several residential neighborhoods: Middletown Arch, Stonebridge Crossing, Chesterfield Heights, and the Broad Creek Renaissance. The station provides 105 parking spaces and a bus connection with Route 18.

Ingleside Road Station- This station is located on the western side of Ingleside Road between Mississippi Avenue and I-264 and serves the adjacent residential neighborhood. No bus connections are provided at the at-grade, side-platform station, and on-street parking is available to neighborhood residents by permit only.

Military Highway Station- This station consists of station side platforms and at-grade alignment on the south side of Curlew Drive and the park-and-ride facility on the north side. Both the platforms and the parking are located to the west of Military Highway. There are two bus bays and 232 parking spaces. The station is served by Routes 15, 23, and 967.

Newtown Road Station- This station is located at the eastern terminus of the project on Newtown Road and includes an at-grade, single platform; four bus bays; and 266 parking spaces. Overflow parking in the amount of 708 spaces is leased by HRT from the First Baptist Church of Norfolk. This parking lot located north of the station on Kempsville Road is primarily utilized during special events, but it is available to riders at any time. The station serves residential neighborhoods, the Interstate Corporate Center, and Sentara Lehigh Memorial Hospital. Bus Routes 20, 22, 25, 27, and 28 serve the station. The station also includes a sound wall to mitigate noise impacts from idling buses in the eastern terminal station.

Support Facilities (SCC 30)

The Norfolk Tide Facility (NTF) is located just east of NSU Station on a parcel that encompasses approximately seven acres of land. The facility houses light rail vehicle maintenance, rail operations/dispatch, and the Operations Control Center (OCC).The NTF also serves as an operator relief point along the mainline. The NTF has the following yard tracks: Y-1E, Y-1W, Y-2, Y-3, Y-3 Future, Y-4, and L-1. The maintenance shop is approximately 28,000 square feet and includes a two-bay vehicle wash. The site includes 60 parking spaces. A second maintenance facility, Mangrove Maintenance Facility, is being leased to house systems maintenance and provide warehouse storage for maintenance of way material and spare parts. This additional facility was required when it was determined that routine systems and other right-of-way maintenance would not be contracted, but handled by internal forces.

The shop building structure is a steel frame structure with full brick facing and a number of architectural features (e.g., decorative roof cupolas) intended to visually integrate the building with the adjacent Norfolk State University campus. The vehicle maintenance functions of the shop were designed to be minimal, consistent with an original operating plan for contract vehicle maintenance. This was not the case, however, and the as-built shop includes equipment consistent with typical light vehicle maintenance, such as wheel presses, floor level traction power (“stingers”), and portable vehicle lifts. These items were procured during the construction phase of the project.

The as-built project also includes a temporary building at Sewell’s Point, originally erected to test and commission vehicles. The temporary building is a 120-foot by 25-foot pre-fabricated fabric tent with a concrete platform that was needed due to delays in the construction of the vehicle maintenance facility and yard. The LRT vehicles were scheduled to be delivered to the yard, but the yard construction was 18 months behind schedule. A temporary spur track was constructed to connect the mainline NSRR freight tracks with a temporary LRT maintenance building, and HRT was able to arrange the LRT vehicles to be delivered by train. The building and spur track were initially intended to be temporary, but HRT decided to keep them both. Minor upgrades to the spur track were completed to make the track permanent, and the building remains in use post project implementation as a covered storage facility.

Sitework and Special Conditions (SCC 40)

Hazardous Materials and Contaminated Soil Removal/Mitigation- The former Kirn Library building was demolished for the construction of MacArthur Square Station. The demolition required asbestos abatement techniques to be utilized. Two other asbestos-contaminated buildings adjacent to the library site were also demolished for the station. The demolition work included the removal of contaminated soil and two underground storage tanks (UST), one at Kirn Library and one at the Baylor building.

Two USTs on the site of Newtown Road Station and three tanks at Bollard's Chicken at NSU Station were also removed as part of the project.

Wetlands Mitigation- Wetlands mitigation for the project consisted of constructing a 2.8-acre wetland on a site formerly used by the City of Norfolk for construction waste disposal along the eastern branch of the Elizabeth River, adjacent to a Norfolk neighborhood called Grandy Village. The mitigation was required due to project impacts to wetlands along the corridor, and the constructed wetlands resulted in a net gain of wetland area.

Pedestrian Bridge- A path from the existing pedestrian bridge over I-264 near the shop and yard was constructed around the yard and shop and a pathway provided to Brambleton Avenue so that it could maintain its functionality while not interfering with rail operations.

Utility Relocations/Protection- Utility relocations for the project consisted of three different relocation categories: utilities on public property but not public ROW, utilities within Norfolk Southern ROW, and utilities within the Central Business District (CBD). CBD utilities were relocated at no cost to the project, as these utilities fell under the City of Norfolk's franchise agreement. CBD utilities required a new duct bank system rather than just typical relocation activities, because the utilities downtown were old and had been modified to the point that relocation was not an option. All utility relocations on public property east of Harbor Park did not fall under the franchise agreement and thus were paid for by the project. Relocations of Dominion Virginia electrical distribution line poles within the Norfolk Southern ROW were also required and paid for by the project. The complexities and effort associated with the types of relocations needed in the Norfolk Southern ROW were not adequately understood and thus the necessary time was not incorporated into the project schedule. This resulted in construction delays.

Existing Freight Bridge over Broad Creek- The existing freight bridge over Broad Creek was removed for the LRT project. The as-built construction includes a new double track structure with all former wood piles removed.

New Norfolk Southern Connection at Sewell's Point Branch- The project required adding a new Norfolk Southern freight siding track from the north-south Sewell's Point Branch to the east-west line in order to deliver the LRT vehicles.

Systems (SCC 50)

Traction Power Substations- Seven 1.0 megawatt (MW) capacity TPSS facilities were constructed for the project. **Table 3** provides descriptions of the locations of the TPSS facilities as constructed. Three TPSSs were constructed with building facades to mitigate adverse visual impacts: 2nd Street (TPSS #1), York Street (TPSS #2), and Newtown Road (TPSS #7). The need to mitigate these impacts was identified early in the planning process and included in the Final Environmental Impact Statement (FEIS).

Table 3
As-Built TPSS Locations

TPSS	Location	Engineering Station	Location Description
TPSS #1	Second Street	119+00	South side of tracks, east of Second St.
TPSS #2	York Street Station	141+90	North side of tracks, across from station
TPSS #3	Holt Street	235+25	Holt Street under the I-264 structure
TPSS #4	VMSF	262+85	West of shop building
TPSS #5	Sewell's Point Bridge	327+25	East of I-264 at western base of bridge
TPSS #6	Military Highway Station	430+00	East of Corporate Blvd., north side of tracks across from station on Curlew Drive
TPSS #7	Newtown Road Station	492+00	Eastern terminus, eastern end of station

Source: Norfolk Light Rail Transit Project As-Built Drawings, January 2008.

Signaling and Communications- The project includes a train signaling system between NSU Station and Newtown Road Station. The system in operation is an automatic block signaling (ABS) system which prevents trains from colliding with one another when operating on the same track. There are also three sets of localized track signals along the alignment: lockouts at EVMC and Newtown Road Station approaches and an island circuit in the yard at the shop entrance.
The project also includes a communication system and an operations control center (OCC). The OCC is located in the shop building and it houses a supervisory control and data acquisition (SCADA) system on a fiber optic network that allows the controllers to see the locations of the trains in the signalized territory between NSU Station and Newtown Road Station and allows communication and administrative control between the TPSS facilities and the OCC.

Crossing Protection- The as-built project includes a number of safety features that were added shortly before or shortly after revenue operations began as a result of an operational hazards analysis (OHA) that was conducted by HRT. Additional fencing, crossing gates, sidewalk railings, signage, and barriers were added along the project to prevent pedestrians from entering the ROW and to prevent incidents between trains and personal vehicles.

Right-of-Way and Land (SCC 60)

The project required 157 acquisitions and easements in total, of which 21 were full acquisitions, 29 were partial acquisitions, 35 were permanent easements, 18 were permanent subsurface easements, and 54 were temporary construction easements. Nine residential and eight business relocations were required, for a total of 17 relocations. All necessary right of way documents were platted and recorded as part of the project work.

Vehicles (SCC 70)

Nine Siemens S70 low-floor light rail vehicles were procured for the Norfolk Light Rail Transit Project. Six one-car trains operate along the mainline during peak periods, leaving three vehicles as spares. The spare vehicles are required for operations during special events such as Norfolk's HarborFest and Grand Illumination.

Physical Scope Milestone Comparison

Table 4 provides a comparison of The Tide LRT Project as built with the project as predicted at Entry into PE, Entry into Final Design, and the FFGA. The comparison is organized by FTA Standard Cost Category.

Table 4
The Tide Physical Scope Milestone Comparison

FTA Standard Cost Category (SCC)	Unit	As-Built	Entry into PE	Entry into Final Design	FFGA
10 GUIDEWAY and TRACK ELEMENTS					
10.01 Guideway: At-grade, exclusive ROW	TF	265	-	265	265
10.02 Guideway: At grade, semi-exclusive	TF	59,668	-	60,639	60,639
10.03 Guideway: At-grade in mixed traffic	TF	2,190	-	2,190	2,190
10.04 Guideway: Aerial	TF	12,396	-	12,396	12,396
10.08 Guideway: Retained cut or fill	TF	1,870	-	1,870	1,870
10.09 Track: Direct Fixation	TF	12,396	-	12,396	12,396
10.10 Track: Embedded	TF	16,088	-	15,828	15,828
10.11 Track: Ballasted	TF	47,985	-	49,136	49,136
10.12 Track: Special (switches, turnouts)					
No. 8 turnouts	EA	14	-	14	14
No. 10 turnouts	EA	1	-	0	0
10.13 Track: Vibration and noise dampening					
Vibration dampening	EA	0	0	0	0
Noise dampening – vehicle stick lubricators	Set	9	9	9	9
Noise dampening – wayside rail lubricators	EA	10	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL					
20.01 At-grade station, stop, shelter, mall, terminal, platform					
EVMC/Fort Norfolk Station platform	EA	1	1	1	1
York Street/Freemason Station platform	EA	2	2	2	2
Monticello Station platform	EA	1	1	1	1
MacArthur Square Station platform	EA	2	2	2	2
Civic Plaza Station platform	EA	2	2	2	2
Harbor Park Station platform	EA	1	1	1	1
Ballentine/Broad Creek Station platform	EA	2	2	2	2
Ingleside Road Station platform	EA	2	2	2	2

Table 4 The Tide Physical Scope Milestone Comparison					
FTA Standard Cost Category (SCC)	**Unit**	**As-Built**	**Entry into PE**	**Entry into Final Design**	**FFGA**
Military Highway Station platform	EA	2	2	2	2
Newtown Road Station platform	EA	1	1	1	1
Station Shelter (1 per platform, except at MacArthur Square Station)	EA	18	16	16	16
	EA				
20.02 Aerial station, stop, shelter, mall, terminal, platform	EA				
NSU Station platform	EA	1	1	1	1
Station Shelter (1 per platform)	EA	1	1	1	1
20.03 Underground station, stop, shelter, mall, terminal, platform	EA				
	EA	0	0	0	0
20.07 Elevators, escalators					
Elevators	EA	1	1	1	1
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS					
30.01 Admin. bldg., office, sales, storage, revenue counting					
(included in 30.02 Light Maintenance Facility)	EA	0	0	0	0
30.02 Light Maintenance Facility					
NTF (vehicle maintenance facility)	EA	1	1	1	1
30.03 Heavy Maintenance Facility					
None	EA	0	0	0	0
30.04 Storage or Maintenance of Way Bldg.					
Facility on Mangrove	EA	1	0	0	0
30.05 Yard and Yard Track					
Yard track	TF	6,414	-	5,734	5,734
Turnouts (No. 8 Turnouts)	EA	9	-	-	9
Parking area	SP	69	-	-	60
40 SITEWORK & SPECIAL CONDITIONS					
40.01 Demolition, Clearing, Earthwork					
Non-revenue demolition/clearing	Ac	7.73	-	6.70	6.70
Mainline demolition/clearing	Ac	45.45	-	45.99	45.99
Park-and-Ride demolition/clearing	Ac	8.04	-	10.78	10.78
40.02 Site Utilities, Utility Relocation					
Drainage and Irrigation	LS	LS	LS	LS	LS
Wet Utilities	LS	LS	LS	LS	LS
Dry Utilities	LS	LS	LS	LS	LS
Private Utilities	LS	LS	LS	LS	LS
40.03 Hazardous Materials, Contaminated Soil Removal/Mitigation, Groundwater Treatment					
Asbestos abatement for building demolition	EA	1	1	1	1
40.04 Environmental Mitigation, e.g, Wetlands,					

Table 4 The Tide Physical Scope Milestone Comparison					
FTA Standard Cost Category (SCC)	Unit	As-Built	Entry into PE	Entry into Final Design	FFGA
Historic/Archeological					
Wetland Mitigation	EA	1	1	1	1
40.05 Site Structures, including Retaining Walls, Sound Walls					
Retaining walls (1 location: Military Hwy PNR)	EA	1	-	-	1
Noise walls (1 location: Newtown Road Station)	EA	1	-	1	1
Sound insulation	EA	0	0	0	0
40.06 Pedestrian/Bike Access and Accommodation, Landscaping					
Station Landscaping and Irrigation		1	1	1	1
Station Pedestrian Access (Ramps, 2 per platform)	EA	30	-	32	32
Station Bike Access (Bike racks on concrete pads)	EA	12	0	0	0
40.07 Automobile, Bus, Van Access Ways, including Roads, Parking Lots					
York Street/Freemason Station Park-and-Ride	SP	0	128	0	0
Ballentine/Broad Creek Station Park-and-Ride	SP	105	100	100	100
Military Highway Station Park-and-Ride	SP	232	330	232	232
Newtown Road Station Park-and-Ride	SP	266	266	266	266
40.08 Temporary Facilities and Other Indirect Costs During Construction					
Siding track and commissioning building	EA	1	0	0	0
50 SYSTEMS					
50.01 Train Control and Signals					
ABS Wayside Aspect	LF	15,840	0	0	0
50.02 Traffic Signals and Crossing Protection					
Total crossings (pedestrian and/or vehicle)	EA	87	-	-	-
Traffic signals	EA	45	-	-	-
Crossing protection (Flashers and Gates)	EA	15	-	-	-
50.03 Traction Power Supply: Substations					
	EA	7	7	7	7
50.04 Traction Power Distribution: Catenary and Third Rail					
Catenary		1	1	1	1
50.05 Communications					
Fiber optic system, SCADA		1	0	0	0
50.06 Fare Collection System and Equipment					
Station TVMs (2 per station, plus three spares)	EA	25	-	-	25
50.07 Central Control					
Control Center at NTF		1	1	1	1
60 ROW, LAND, EXISTING IMPROVEMENTS					
60.01 Purchase or Lease of Real Estate					

Table 4 The Tide Physical Scope Milestone Comparison					
FTA Standard Cost Category (SCC)	Unit	As-Built	Entry into PE	Entry into Final Design	FFGA
Full acquisitions	EA	21	-	-	≥10
Partial acquisitions	EA	29	-	-	-
Permanent easements	EA	35	-	-	-
Permanent subsurface easements	EA	18	-	-	-
Temporary construction easements	EA	54	-	-	-
60.02 Relocation of Existing Households and Businesses					
Residential relocations	EA	9	-	7	7
Business relocations	EA	8	-	3	3
70 VEHICLES					
70.01 Light Rail					
	EA	9	9	9	9
70.04 Bus					
	EA	0	0	0	0
70.05 Other					
	EA	0	0	0	0
70.06 Non-revenue vehicles					
	EA	2	0	0	0
70.07 Spare Parts					
LRV spare parts kit	EA	9	9	9	9
Maintenance-of-way spare parts		1	0	0	0

Source: HRT, URS, 2014.

Physical Scope at Entry into PE

The project as described at Entry into PE was a 7.4-mile light rail system comprised of exclusive, double-tracked guideway with sections of shared street ROW. Eleven stations were included in the project. Revenue operations were predicted to begin in the Summer of 2008.

Guideway and Track Elements (SCC 10)

Guideway Subcategories- Entry into PE identified 1.21 miles of above-grade guideway, zero miles of below grade, and 6.20 miles of at-grade guideway. The entire 7.41-mile length was planned to be in exclusive or semi-exclusive guideway (no areas of mixed traffic).

Track Subcategories- The project was planned to include embedded track for all downtown streets in a semi-exclusive ROW except for use by emergency vehicles.

Accuracy of Predictions and Causes of Differences- The 7.41 mile corridor predicted at Entry into PE did not accurately anticipate the as-built project due to slight changes at the western terminus of the project. The project corridor was shortened by 450 feet (0.08 mile) at EVMC Station during construction, which reduced corridor length to approximately 7.33 miles. Additionally, the single track portion of the alignment was extended to a location from just west of Colley Avenue to its current location 420 feet east of Colley Avenue at the same time, which reduced the track feet of the as-built project as compared to the predictive milestones.

The Entry into PE milestone also did not accurately anticipate the track elements of the as-built project. Red surface embedded concrete was added to a section of the project in the CBD. This change occurred after the FFGA was executed due to a request by the City of Norfolk. The York Street Crossover was changed from a left-hand crossover to a right-hand crossover after the FFGA was executed. Additionally, a permanent siding switch/track was constructed at the location of the site initially constructed as a temporary vehicle inspection site before revenue operations that then became a permanent facility for storage. The planned grade crossing at the Military Highway Park-and-Ride was eliminated after the FFGA was executed, due to a necessary change in the location of the park-and-ride.

Stations (SCC 20)

Eleven stations were planned at this stage of project development, and they were planned to be constructed as one-car platforms but would be designed to accommodate expansion to three-car platforms.

Woodis Station was a potential future station between EVMC/Fort Norfolk Station and York Station. The future station has been included in plans at each milestone discussed in this document and was included in the Contract 40 "conformed plans." It was proposed to be located just east of Second Street, however, was not constructed as part of the final project. **Table 5** summarizes the station characteristics proposed at Entry into PE.

Accuracy of Predictions and Causes of Differences- The predicted station and platform designs at Entry into PE did not accurately anticipate these elements in the as-built project. The constructed project consists of one-car platforms at nine stations, a two-car platform at MacArthur Station, and an elevated, two-car platform at NSU Station, rather than one-car platforms for all stations. All stations are designed to accommodate future expansion to a two-car platform, not a three-car platform as planned at Entry into PE. The station platform concept at Entry into PE included prefabricated barrel vault shelters, functional railings, and minimal information signage. The shelter concepts and decorative railings were proposed in 2007, but were not implemented on the plans, nor were the associated costs incurred until 2008, after the FFGA signing. The information kiosk design was not finalized until 2010.

The general station locations predicted at Entry into PE accurately anticipated the as-built locations, however specific siting of the stations differed in the case of EVMC Station and Military Highway Station. EVMC Station as constructed is approximately 300 feet to the east of where it was planned to be at the FFGA stage. HRT was not able to acquire all the land necessary for construction of the station as planned, therefore it had to be shortened and moved. The as-built platform is 450 feet east of the FFGA location. Due to this change, the single track at the western terminus was extended beyond the planned length and a switch was moved east of Colley Avenue. The as-built switch location is 600 feet east of the location in the FFGA. Additionally, no bus bays or shelters at the EVMC Station were accounted for in the FFGA, but the City decided to build two bus bays with funds from the City's capital budget. Two bus shelters were built at project cost to accompany the bus bays.

The Military Highway Park-and-Ride was constructed in a different location than was identified in the FFGA. A categorical exclusion was prepared for this change. The parking lot was identified in the FFGA on the south side of the alignment and south of Curlew Drive. Due to development on the identified parcel before HRT was able to acquire it, the planned park-and-ride had to be moved to a new location. The location chosen was on the north side of Curlew Drive and north of the station platform, and that is where the parking lot was ultimately constructed.

Several station names evolved over the course of the planning process. Medical Center became EVMC/Fort Norfolk, York Street became York Street/Freemason, Freemason District became Monticello, Plume Street became MacArthur Square, Government Center became Civic Plaza, Norfolk State University became NSU, Ballentine Boulevard became Ballentine/Broad Creek, and Ingleside became Ingleside Road. **Table 6** highlights the station name changes from Entry to PE to the as-built condition.

Table 5
Station Characteristics at Entry into PE

Station	Platform Type	Bus Bays	Parking	Comparison to As-Built
Medical Center	Center	Yes	0	Side platform change; No Change in bus bays/parking*
York Street	Side	None	128	Parking changed to 0 spaces; no change in platform/bus bays
Freemason District	Center	None	0	No Change
Plume Street	Side	None	0	No Change
Government Center	Center	On-street	0	Side platform change; Bus bays changed to 1; No change in parking
Harbor Park	Side	On-street	1,100	Center platform change; bus bays changed to 0; parking changed to 176
Norfolk State University	Center	None	0	No Change
Ballentine Boulevard	Center	On-street	100	Side platform change; parking changed to 105; no change to bus bays
Ingleside	Center	None	0	Side platform change; no change to bus bays/parking^
Military Highway	Center	Yes	330	Side platform change; parking changed to 232; no change to bus bays

Table 5 Station Characteristics at Entry into PE				
Station	**Platform Type**	**Bus Bays**	**Parking**	**Comparison to As-Built**
Newtown Road	Center	Yes	266	Parking changed to 266; no change in platform/bus bays

Source: Norfolk Light Rail Transit Project Section 5309 New Starts Submission for Fiscal Years 2004 and 2005, August 2002 and August 2003.
**While there is parking available at EVMC/Fort Norfolk Station at certain times of day, this parking was not part of the New Starts project.*
^Permit parking for neighborhood residents exists on-street adjacent to the station, however this parking was not part of the New Starts project.

Table 6 Station Names at Entry into PE and As Built	
Entry into PE	**As Built**
Medical Center	EVMC/Fort Norfolk
York Street	York Street/Freemason
Freemason District	Monticello
Plume Street	MacArthur Square
Government Center	Civic Plaza
Harbor Park	Harbor Park
Norfolk State University	NSU
Ballentine Boulevard	Ballentine/Broad Creek
Ingleside	Ingleside Road
Military Highway	Military Highway
Newtown Road	Newtown Road

Source: URS, 2014.

Support Facilities (SCC 30)

The Vehicle Storage and Maintenance Facility (VSMF) was planned to be constructed in a linear piece of Virginia Department of Transportation (VDOT)-owned land bounded by the tracks to the north, I-264 to the south, and Brambleton Avenue to the west. It would include a vehicle wash, maintenance building, maintenance of way building, and a yard. The approximately seven-acre site would be used for light repairs; heavy maintenance would occur off-site at a location to be determined. On the east side, the facility would extend into the LRT track approximately 450 feet west of the proposed Ballentine Boulevard Station. Storage for 15 vehicles, not including storage within the shop, would be available.

Accuracy of Predictions and Causes of Differences- The VSMF predicted at Entry into PE did not accurately anticipate the as-built NTF due to the following changes that occurred after the FFGA was executed: the addition of the OCC, upgrades to the planned façade of the building, and an increase in the parking capacity. Addition of the OCC did not change the footprint of the building, however the addition did require some interior spaces to be reconfigured.

After the FFGA was executed, the shop building plan was changed from a pre-fabricated metal building to a building with a brick façade. The foundation plans had to be changed to accommodate the new building façade plans. The as-built project also includes two additional support facilities that were added to the project after the FFGA: a temporary building at Sewell's Point to test and commission vehicles and the lease of a spare parts storage facility and rail operations support on Mangrove Avenue. The temporary building is a 120-foot by 25-foot pre-fabricated fabric tent with a concrete platform that was needed due to delays in the construction of the yard. The LRT vehicles were scheduled to deliver to the yard, but the yard construction was 18 months behind schedule. A temporary spur track was constructed to connect the mainline with the temporary building, and HRT was able to arrange the vehicles to be delivered by train. The building and spur track were initially intended to be temporary, but HRT decided to keep them both. Minor upgrades to the spur track were completed to make the track permanent, and the building remains in use post project implementation as a storage facility.

Sitework and Special Conditions (SCC 40)

Work planned under SCC 40 at Entry into PE included yard sitework, site utilities, utility relocation, environmental mitigation, and extension of pedestrian bridge near the yard.

Hazardous Materials and Contaminated Soil Removal/Mitigation- The Kirn Library site was the planned site for Plume Street Station, so demolition of the library would be required. Based on preliminary environmental studies, it was anticipated that minimal asbestos abatement would be required in the demolition process for the building.

Wetlands Mitigation- Predicted wetlands mitigation for the project consisted of constructing a 2.8-acre wetland at a site on the Elizabeth River. The mitigation was anticipated at this phase of the project due to potential project impacts to wetlands along the corridor.

Pedestrian Bridge- At Entry into PE, it was known that an existing pedestrian bridge over I-264 near the future shop and yard would need to be either modified or removed before rail operations began. Ultimately, an extended path was constructed so that it could maintain its functionality while not interfering with rail operations.

Utility Relocations/Protection- It was assumed that most public and private utilities would not need to be relocated but protected or adjusted in some manner during construction. The project management team during Final Design found that most of the private utilities in the Central Business District (CBD) were very old or had been reconstructed numerous times as the CBD changed. From January 2007 through August 2007, the project design team worked with the City of Norfolk to address all the public utility relocations that need to be performed during construction. Most of the relocations identified by the City were addressed, but the final design did not reflect all these relocations needed to construct the project in the CBD.

All private utilities were asked to attend individual meetings with the project management in August 2007. These meetings were done to officially notify each private utility that the Norfolk "Franchise Agreements" would be enforced to relocate their utilities within the Public Right-of Way. From August 2007 to the issuance of the major civil construction contracts meetings with the private utilities discussed the options for relocations but no relocations were incorporated into the conformed plans.

Accuracy of Predictions and Causes of Differences- The sitework and special conditions predicted at Entry into PE did not accurately anticipate the as-built condition due to several changes that occurred after the FFGA was executed. The demolition of the former Kirn Library and other asbestos-contaminated buildings required more elaborate asbestos abatement techniques to be utilized during the demolition process than was anticipated, due to the reliance on an inadequate level of asbestos site assessment during the project.

Systems (SCC 50)

A signaling system was not planned at this stage of project planning. Line-of-sight operations were deemed appropriate for the project.

Accuracy of Predictions and Causes of Differences- The signaling and communications plan at Entry into PE did not accurately anticipate the as-built systems for the project due to changes that occurred after the FFGA was executed. A review of the project by the Virginia Department of Rail and Public Transportation as part of their safety oversight responsibilities resulted in the addition of a signal and communications systems, as described in the as-built project description and the FFGA Systems section.

Right-of-Way and Land (SCC 60)

The proposed ROW was a mix of city streets, privately-owned parcels, and a NSRR-owned freight rail line. NSRR intended to abandon this portion of the alignment, as no active service had operated on this segment since December, 2002. At Entry into PE, HRT, NSU, the City of Norfolk, and the City of Virginia Beach were in the process of executing an MOU to jointly purchase the NSRR alignment.

Accuracy of Predictions and Causes of Differences- The right-of-way needs predicted at Entry into PE accurately anticipated the right-of-way required for the as-built project, to the extent that the needs were assessed at the Entry into PE milestone. Temporary and permanent easements were not fully and precisely determined and documented until after the FFGA was executed.

Vehicles (SCC 70)

Nine LRVs were to be procured for the project at the Entry into PE phase.

Accuracy of Predictions and Causes of Differences- The number of LRVs predicted at Entry into PE accurately anticipated the as-built condition of the project.

Physical Scope at Entry into Final Design

Revenue operations were scheduled to commence in January of 2010 at Entry into Final Design.

Guideway and Track Elements (SCC 10)

Guideway Subcategories- Exclusive double-track guideway with some sections of shared street ROW was planned at this stage of the project. **Table 7** summarizes guideway and track elements at Entry into Final Design. At Entry into Final Design, it was anticipated that the existing freight bridge over Broad Creek would be rehabilitated and used as the eastbound track of the Norfolk Light Rail Transit Project. A new parallel structure would be built for the westbound track. This decision was estimated to save $2.5M, but it was not ultimately carried out in the completed project.

Track Subcategories- Track elements included direct fixation, open deck, embedded, ballasted, and full depth crossing. **Table 7** provides a summary of track elements at Entry into Final Design.

Table 7 **Final Design Guideway and Track Elements**	
Guideway Element	**Length (Track miles)**
At Grade	11.95 mi
Below Grade	0.00 mi
Aerial	2.35 mi
Retained Fill	0.35 mi
Total	**14.65 mi**
Exclusive ROW	2.75 mi
Semi-exclusive ROW	11.48 mi
Mixed-use ROW	0.41 mi
Track Element	
Direct Fixation	0.36 mi
Embedded	3.00 mi
Ballasted	8.97 mi
Open Deck	1.98 mi
Full-Depth Crossing	0.33 mi
Total	**14.65 mi**

Accuracy of Predictions and Causes of Differences- The 7.41 mile corridor predicted at Entry into Final Design did not accurately anticipate the as-built project due to slight changes at the western terminus of the project. The project corridor was shortened by 450 feet (0.08 mile) at EVMC Station during construction, which reduced corridor length to approximately 7.33 miles. Additionally, the single track portion of the alignment was extended to a location from just west of Colley Avenue to its current location 420 feet east of Colley Avenue at the same time, which reduced the track feet of the as-built project as compared to the predictive milestones.

The Entry into Final Design milestone also did not accurately anticipate the track elements of the as-built project. Red surface embedded concrete was added to a section of the project in the CBD. This change occurred after the FFGA was executed due to a request from an HRT Commissioner. The York Street Crossover was changed from a left-hand crossover to a right-hand crossover after the FFGA was executed. Additionally, a permanent siding switch/track was constructed at the location of the site initially constructed as a temporary vehicle inspection site before revenue operations that then became a permanent facility for storage. The planned grade crossing at the Military Highway Park-and-Ride was eliminated after the FFGA was executed, due to a necessary change in the location of the park-and-ride.

Stations (SCC 20)

Table 8 provides a summary of station characteristics at Entry into Final Design. At this stage of the project, Government Center Station (now Civic Plaza Station) was planned to be a center platform but was ultimately constructed with two side platforms. Station platforms were planned to be constructed as one-car, 90-foot platforms but would be designed to accommodate three-car platforms in the future. Center station platforms would be approximately 20 feet wide with one platform between the two LRT tracks and side platforms would be approximately 12 feet wide with one platform on each side of the LRT tracks.

Accuracy of Predictions and Causes of Differences- The general station locations predicted at Entry into Final Design accurately anticipated the as-built locations, however specific siting of the stations differed in the case of EVMC Station and Military Highway Station. Medical Center Station was moved slightly to the east after the FFGA was executed, so the as-built station location is slightly different than predicted at the milestones discussed in this technical memorandum. The Military Highway Station platform and park-and-ride sites predicted at Entry into Final Design did not accurately anticipate as-built sites, as sites shifted post-FFGA due to land availability.

EVMC Station as constructed is approximately 300 to the east of where it was planned to be at the FFGA stage. HRT was not able to acquire all the land necessary for construction of the station as planned, therefore it had to be shortened and moved. The as-built platform is 450 feet east of the Final Design location. Due to this change, the single track at the western terminus was extended beyond the planned length and a switch was moved east of Colley Avenue. The as-built switch location is 600 feet east of the location in the Final Design. Additionally, no bus bays or shelters at the EVMC Station were accounted for in the Final Design, but the City decided to build two bus bays with funds from the City's capital budget. Two bus shelters were built at project cost to accompany the bus bays.

The Military Highway Park-and-Ride was constructed in a different location than was identified in the Entry into Final Design and the FFGA. A categorical exclusion was prepared for this change. The parking lot was identified in the FFGA on the south side of the alignment and south of Curlew Drive. Due to development on the identified parcel before HRT was able to acquire it, the planned park-and-ride had to be moved to a new location. The location chosen was on the north side of Curlew Drive and north of the station platform, and that is where the parking lot was ultimately constructed.

The predicted station and platform designs at Entry into Final Design did not accurately anticipate these elements in the as-built project. The constructed project consists of one-car platforms at nine stations, a two-car platform at MacArthur Station, and an elevated, two-car platform at NSU Station, rather than one-car platforms for all stations. All stations are designed to accommodate future expansion to a two-car platform, not a three-car platform as planned at Entry into Final Design. The station platform concept at Entry into Final Design included prefabricated barrel vault shelters, functional railings, and minimal information signage. The shelter concepts and decorative railings were proposed in 2007, but were not implemented on the plans, nor were the associated costs incurred until 2008, after the FFGA signing. The information kiosk design was not finalized until 2010.

Station	Platform Type	Station Profile	Bus Bays	Parking Spaces	Comparison to As-Built
Table 8 Station Characteristics at Entry into Final Design					
Medical Center	Side	At grade	Yes (4)^	0	Bus bays changed to 2
York Street	Side	At grade	None	0	No change
Monticello	Center	At grade	None	0	No change
Plume Street	Side	At grade	None	0	No change
Government Center	Center	At grade	On-street	0	Side platform change; bus bays changed to 1
Harbor Park	Center	At grade	On-street	1,100	Bus bays changed to 0; parking changed to 176
Norfolk State University	Center	Aerial	On-street	0	Bus bays changed to 0
Ballentine Boulevard	Side	At grade	On-street	100*	Parking changed to 105
Ingleside	Side	At grade	None	0	No change
Military Highway	Side	At grade	Yes (3)	232 (4 Kiss-and-Ride spaces)	Bus bays changed to 2; parking changed to 232
Newtown Road	Side	At grade	Yes (4)	266 (7 Kiss-and-Ride spaces)	Center platform change; bus bays changed to 3; parking changed to 266

Source: Norfolk Light Rail Transit Project FEIS, 2006. FY08 New Starts submittal, June 2006.
^Bus pull-out spaces are not located on the station site, but rather a block away along Southampton Avenue
**Shared arrangement with NSU*

Support Facilities (SCC 30)

The VSMF was planned to be constructed in a linear piece of VDOT-owned land bounded by the tracks to the north, I-264 to the south, and Brambleton Avenue to the west. It would include a vehicle wash, maintenance building, maintenance of way building, and a yard. The approximately seven-acre site would be used for light repairs; heavy maintenance would occur off-site at a location to be determined. On the east side, the facility extends into the LRT track approximately 450 feet west of the proposed Ballentine Boulevard Station. Storage for 15 vehicles, not including storage within the shop, would be available. Approximately 1.4 miles of track would be constructed for the VSMF.

Accuracy of Predictions and Causes of Differences- The VSMF predicted at Entry into Final Design did not accurately anticipate the as-built NTF due to the following changes: the addition of the OCC, upgrades to the planned façade of the building, and changes to parking capacity. Addition of the OCC did not change the footprint of the building. After the FFGA was executed, the shop building plan was changed from a pre-fabricated metal building to a building with a brick façade. The foundation plans had to be changed to accommodate the new building façade plans. The footprint and the interior design of the building were not altered by this change.

The as-built project also includes two additional support facilities that were added to the project after the FFGA: a temporary building at Sewell's Point to test and commission vehicles and the lease of a spare parts storage facility and rail operations support on Mangrove Avenue. The temporary building is a 120-foot by 25-foot pre-fabricated fabric tent with a concrete platform that was needed due to delays in the construction of the yard. The LRT vehicles were scheduled to deliver to the yard, but the yard construction was 18 months behind schedule. A temporary spur track was constructed to connect the mainline with temporary building, and HRT was able to arrange the vehicles to be delivered by train. The building and spur track were initially intended to be temporary, but HRT decided to keep them both. Minor upgrades to the spur track were completed to make the track permanent, and the building remains in use post project implementation as a storage facility.

Sitework and Special Conditions (SCC 40)

Hazardous Materials and Contaminated Soil Removal/Mitigation- The Kirn Memorial Library site was the planned site for Plume Street Station, so demolition of the library would be required. Due to preliminary environmental studies, it was anticipated that minimal asbestos abatement would be required in the demolition process for the building.

Wetlands Mitigation- Predicted wetlands mitigation for the project consisted of constructing a 2.8-acre wetland on a site on the eastern branch of the Elizabeth River. The mitigation was anticipated due to potential project impacts to wetlands along the corridor.

Pedestrian Bridge- At Entry into Final Design, concerns were documented regarding the existing pedestrian bridge over I-264 connecting the NSU campus north of the highway to the south side of the highway. An unprotected grade crossing is utilized by pedestrians, and the bridge connects at the proposed site of the maintenance facility. Pedestrian traffic from the bridge would need to be re-directed or the bridge would need to be removed before implementation of the LRT project. The FEIS indicated plans to extend an existing pedestrian bridge over I-264 near the future shop and yard over the LRT tracks.

Utility Relocations- At this stage it was assumed that existing franchise agreements between the City of Norfolk and various private utilities would cover the majority of the identified utility relocations. It was also anticipated that a number of unidentified utilities would be encountered, due to the age of the city facilities.

Existing Freight Bridge over Broad Creek- It was recommended that the existing freight bridge over Broad Creek would be rehabilitated for the LRT project as a cost-saving measure. The rehabilitated bridge would carry the eastbound track and a new bridge structure would be built parallel to the existing structure to carry the westbound track.

Accuracy of Predictions and Causes of Differences- The sitework and special conditions predicted at Entry into Final Design did not accurately anticipate the as-built conditions due to several changes that occurred after the FFGA was executed. The demolition of the former Kirn Library and other asbestos-contaminated buildings required more elaborate asbestos abatement techniques to be utilized during the demolition process than was anticipated, due to the reliance on an inadequate level of asbestos site assessment during the project.

Another prediction at this milestone that did not prove accurate was the plan to rehabilitate the freight bridge over Broad Creek. This idea was initiated as a cost-saving measure, but ultimately, it was not feasible and did not take place; instead, a new, two-track bridge was constructed, and all wooden piles were removed.

Systems (SCC 50)

TPSS- In response to stakeholder and community input, three of the seven proposed TPSS facilities were identified to receive aesthetic treatments to shield the facilities from view, as described in the as-built TPSS discussion. The types of treatments proposed for TPSS #1, TPSS #2, and TPSS #7 include masonry construction, walls, and vegetation. The three locations and the general mitigation techniques did not change from this stage in the planning process to the as-built condition. Seven TPSSs were planned, each being one to two miles apart. The TPSSs would provide 750 volts direct current (d.c.) to the overhead catenary system (OCS). **Table 9** summarizes the predicted TPSS locations at Entry into Final Design.

Table 9
TPSS Locations at Entry into Final Design

TPSS	Location	Engineering Station	Description	Comparison with As-Built
TPSS #1	Medical Center Station	103+40	North side of Brambleton Ave. just east of existing pedestrian overpass	Change- moved to Second Street
TPSS #2	York Street Station	141+75	Between York St. and Brambleton Ave. on west side of Yarmouth St.	No change
TPSS #3	Harbor Park Station	235+25	North side of I-264 between Holt St. and concrete basin just east of the station	No change
TPSS #4	VSMF Site	263+35	In the yard	No change
TPSS #5	Holt Street	332+00	Between Sewell's Point tracks and South Beach Branch connection to Sewell's Point, approximately 30 feet south of track centerline (between Ballentine Boulevard and Ingleside Stations)	No change

Table 9 TPSS Locations at Entry into Final Design				
TPSS	**Location**	**Engineering Station**	**Description**	**Comparison with As-Built**
TPSS #6	Military Highway Station	426+00	South of Curlew Dr. just west of the station	Change- moved north of tracks and east
TPSS #7	Newtown Road Station	492+00	Northwest corner of Bangor Ave. and Newtown Rd. south of proposed station bus waiting area	No change

Source: FEIS, 2006.

Signaling and Communications- A very limited communication system was planned at Entry into Final Design. The system would have the capability to communicate to HRT via wireless antenna when there is a problem at a substation, such as a shutdown. The system would work like an alarm, with no ability for the OCC to communicate or interact remotely with the substations. Trouble-shooting of the problem could only occur at the site of the substation with the issue.

Crossing Protection- The grade separation analysis conducted for the FEIS resulted in the recommendation of one grade separation at Brambleton Avenue between Park Avenue and I-264. Grade separation was also recommended at Park Avenue and Clairborne Avenue due to their proximity to two other elevated sections. Holt Street was planned for grade separation due to its proximity to the NSRR Lamberts Point Branch grade separation. Four streets were identified as "at-grade crossing possible with delay to LRT trains:" Colley Avenue, Brambleton Avenue, Boush Street, and Ballentine Boulevard; these crossings were recommended for improvements to minimize delays due to the at-grade crossing. **Table 10** provides a summary of the anticipated traffic control measures at Entry into Final Design.

Table 10 Grade Crossing Analysis at Entry into Final Design	
Traffic Control Measure	**Number of Grade Crossings**
Traffic Signal without Transit Priority	2
Traffic Signal with Transit Priority	17
Traffic Signal Interconnect	3
Automatic Crossing Gates	6
Supplemental Active Warning Devices	5
Grade Separations	4
Grade Crossing Closure Recommended	14
Grade Crossing Closure Suggested	2

Source: Norfolk LRT Project FEIS, 2005.

Accuracy of Predictions and Causes of Differences- The signaling and communications plan at Entry into Final Design did not accurately anticipate the as-built systems for the project due to changes that occurred after the FFGA was executed. A review of the project by the Virginia Department of Rail and Public Transportation as part of their safety oversight responsibilities resulted in the addition of signal and communications systems, as described in the as-built project description and the FFGA Systems section.

Right-of-Way and Land (SCC 60)

The City of Norfolk and Norfolk Southern executed an MOU for the purchase of NSRR ROW on November 8, 2005, and a draft purchase and sale agreement was under review in June of 2006. It was anticipated that the purchase and sale agreement would be finalized by the Fall of 2006. An easement from VDOT would also be needed for the VSMF, and those discussions were underway.

In addition to these acquisitions, ten displacements were anticipated in the FEIS including three businesses and seven residences.

Accuracy of Predictions and Causes of Differences- The right-of-way needs predicted at Entry into Final Design accurately anticipated the right-of-way required for the as-built project, to the extent that the needs were assessed at the Entry into Final Design milestone. Temporary and permanent easements were not fully and precisely determined and documented until after the FFGA was executed.

Vehicles (SCC 70)

At Entry into Final Design, nine vehicles were planned for the system. Six LRVs would be used during peak periods, so at least three LRVs would not be in service at any given time. The low-floor, articulated vehicles would have a seated capacity of 70, total capacity of 150 people, and a maximum speed of 55 mph.

Accuracy of Predictions and Causes of Differences- The number and type of LRVs predicted at Entry into Final Design accurately anticipated the as-built condition of the project.

Physical Scope at the FFGA Milestone

The FFGA was issued on October 1, 2007. In the FFGA, HRT agreed to achieve revenue operations of the project on or before January 1, 2010. The information in this section documents what was included in the FFGA.

Guideway and Track Elements (SCC 10)

The project as described in the FFGA was a 7.4-mile, double-tracked light rail system with dedicated ROW in the downtown portion of the alignment and utilizing abandoned Norfolk Southern Railroad ROW from NSU to Newtown Road. The FFGA included small portions of single track heading into each terminal station.

Guideway Subcategories- The project as presented in the FFGA included portions of exclusive at-grade guideway, semi-exclusive at-grade guideway, aerial guideway, and retained fill guideway. Approximately 4.6 miles of at-grade, semi-exclusive guideway was planned along the former Norfolk Southern Railroad

ROW portion of the alignment from the crossing of the Lamberts Point Branch to the Newtown Station at the eastern terminus of the project. Within the Norfolk Central Business District (CBD), approximately 1.5 miles of guideway were planned to be mixed-use, meaning that it would allow for cross-traffic. Aerial structure was planned for a total of approximately 0.83 miles in length at three creek crossings (Smith Creek, Broad Creek, Moseley Creek), two active Norfolk Southern freight crossings, and three roadway crossings (Park Avenue, Claiborne Avenue, Brambleton Avenue). Retained fill sections totaled approximately 0.48 miles in length and were primarily planned in the areas adjacent to I-264 between Lamberts Point railroad crossing and the Brambleton Avenue Bridge adjacent to Norfolk University. Other minor segments of retained fill were planned along York Street at the approach to the Smith Creek Bridge and at the Military Highway park-and-ride lot at Curlew Drive. **Table 11** summarizes the guideway elements as described in the FFGA and compares the guideway at each milestone.

Table 11
Guideway Characteristics at Each Milestone (In Route Miles)

Milestone	At Grade	Below Grade	Aerial	Retained Fill	Total	Exclusive ROW	Semi-exclusive ROW	Mixed-use ROW
Entry into PE	6.20	0.00	1.21	N/A	7.41	7.41	0.00	0.00
Entry into Final Design	6.02	0.00	1.17	0.22	7.41	1.41	0.00	0.21
FFGA	6.02	0.00	1.17	0.22	7.41	1.41	5.79	0.21
As Built	5.95	0.00	1.17	0.22	7.34	1.41	5.72	0.21

Source: HRT, 2014.

Track Subcategories- The FFGA planned for four categories of track: direct fixation, embedded, ballasted, and special trackwork. Direct fixation track was planned for approximately 8,655 feet on the aerial structures of the project. Of that amount, 1,785 feet was true direct fixation and 6,870 feet was open deck track. Embedded track was planned to be utilized in the Norfolk Central Business District (CBD) in the amount of approximately 15,080 feet of track. Ballasted track was planned along the abandoned Norfolk Southern corridor and adjacent to some of the streets on the edge of the CBD. Ballasted track totaled 52,240 feet of track. The special trackwork included turnouts, crossovers, guard rail, restraining rail, two spring switches for the terminal stations, and track drains.

Accuracy of Predictions and Causes of Differences-
The 7.41 mile corridor predicted at the time of the FFGA did not accurately anticipate the as-built project due to slight changes at the western terminus of the project. The project corridor was shortened by 450 feet (0.08 mile) at EVMC Station during construction, which reduced corridor length to approximately 7.34 miles. Additionally, the single track portion of the alignment was extended to a location from just west of Colley Avenue to its current location 420 feet east of Colley Avenue at the same time, which reduced the track feet of the as-built project as compared to the predictive milestones.

The FFGA milestone also did not accurately anticipate the track elements of the as-built project. Red surface embedded concrete was added to a section of the project in the CBD. This change occurred after the FFGA was executed due to a request by the City of Norfolk. The York Street Crossover was changed from a left-hand crossover to a right-hand crossover after the FFGA was executed. Additionally, a permanent siding switch/track was constructed at the location of the site initially constructed as a temporary vehicle inspection site before revenue operations that then became a permanent facility for storage. The planned grade crossing at the Military Highway Park-and-Ride was eliminated after the FFGA was executed, due to a necessary change in the location of the park-and-ride.

Stations (SCC 20)

Eleven stations were included in the project as described in the FFGA. Park-and-ride facilities were planned at four of the stations and six would have bus transfer areas.

- Park-and-Rides:
  - Harbor Park
  - Ballentine Boulevard
  - Military Highway
  - Newtown Road

- Bus Transfer Areas:
  - Medical Center
  - Government Center
  - NSU
  - Ballentine Boulevard
  - Military Highway
  - Newtown Road

Ingleside Station was planned to be a “walk-on” only station with no parking, bus transfer, or kiss-and-ride capabilities. Ten stations were planned to be at grade and one station (NSU Station) was planned to be aerial. NSU Station was planned in the FFGA to be located on the east side of Brambleton Avenue.
Accuracy of Predictions and Causes of Differences- The general station locations predicted in the FFGA accurately anticipated the as-built locations, however specific siting of the stations differed in the case of EVMC Station, NSU Station, and Military Highway Station. EVMC Station as constructed is approximately 300 feet to the east of where it was planned to be at the FFGA stage. HRT was not able to acquire all the land necessary for construction of the station as planned, therefore it had to be shortened and moved. The as-built platform is 450 feet east of the FFGA location. Due to this change, the single track at the western terminus was extended beyond the planned length and a switch was moved east of Colley Avenue. The as-built switch location is 600 feet east of the location in the FFGA. Additionally, no bus bays or shelters at the EVMC Station were accounted for in the FFGA, but the City decided to build two bus bays with funds from the City’s capital budget. Two bus shelters were built at project cost to accompany the bus bays.

NSU Station as constructed is on the west side of Brambleton Avenue rather than the east side as planned in the FFGA. This change occurred post-FFGA at the request of Norfolk State University. As part of the change, the station platform length increased from 90 feet to 174 feet.

The Military Highway Park-and-Ride was constructed in a different location than was identified in the FFGA. A categorical exclusion was prepared for this change. The parking lot was identified in the FFGA on the south side of the alignment and south of Curlew Drive. Due to development on the identified parcel before HRT was able to acquire it, the planned park-and-ride had to be moved to a new location. The location chosen was on the north side of Curlew Drive and north of the station platform, and that is where the parking lot was ultimately constructed.

Station shelters and railing were simple, minimal structures in the FFGA. The shelter was a barreled roof structure, and there was minimal railing planned. In 2008, the more elaborate structures and enhanced railing that were ultimately constructed were designed post-FFGA to meet City requests and requirements. Additionally, an operator restroom was added during construction at Newtown Road Station that had not been previously planned.

Support Facilities (SCC 30)

The VSMF was planned to be constructed south of NSU and east of Brambleton Avenue, in an area of land between I-264 and the NSU campus. The facility was planned to accommodate nine vehicles but would be able to be expanded to accommodate up to 16. The facility would also include a vehicle wash. The building would have a footprint of approximately 23,000 square feet and an upper mezzanine storage area of 4,800 square feet. The yard, yard track, stormwater management and drainage facilities, and all other necessary items for the yard were also included in this category. The FFGA also included non-revenue vehicles and equipment consistent with full contract maintenance.

Accuracy of Predictions and Causes of Differences- The VSMF predicted in the FFGA did not accurately anticipate the as-built NTF due to the following changes occurring after the FFGA was executed: the addition of the OCC, upgrades to the planned façade of the building, and an increase in parking capacity. Addition of the OCC did not change the footprint of the building, however the addition did require some interior spaces to be reconfigured. The shop building plan was changed from a pre-fabricated metal building to a building with a brick façade. The foundation plans had to be changed to accommodate the new building façade plans. The footprint and the interior design of the building were not altered by the change to a brick façade.

The as-built project also includes two additional support facilities that were added to the project after the FFGA: a temporary building at Sewell's Point to test and commission vehicles and the lease of a spare parts storage facility and rail operations support on Mangrove Avenue. The temporary building is a 120-foot by 25-foot pre-fabricated fabric tent with a concrete platform that was needed due to delays in the construction of the yard. The LRT vehicles were scheduled to deliver to the yard, but the yard construction was 18 months behind schedule. A temporary spur track was constructed to connect the mainline with temporary building, and HRT was able to arrange the vehicles to be delivered by train. The building and spur track were initially intended to be temporary, but HRT decided to keep them both. Minor upgrades to the spur track were completed to make the track permanent, and the building remains in use post project implementation as a storage facility.
Additionally, the maintenance plan predicted in the FFGA did not accurately anticipate the as-built condition. The FFGA planned for all maintenance to be contracted out to a third party. The plan changed post-FFGA to include primary maintenance performed in-house by HRT Operations and heavy maintenance to be out-sourced to a third party. As a result, the equipment and non-revenue vehicles acquired for the as-built project are different than what was planned in the FFGA.

Sitework and Special Conditions (SCC 40)

Several types of work were included in this category. Demolition, clearing, and grading along the alignment were included. Examples of this work included:

- Demolition of private residences for the construction of Newtown Road Station
- Clearing and grading of the abandoned Norfolk Southern portion of the alignment

Site utilities and relocation costs for public utilities were also included in this category. Private utility relocation costs were excluded, because such relocations are the responsibility of the utility owner under Virginia common law.

Environmental remediation and mitigation was included in this category. A small tidal wetland was planned for in the FFGA as mitigation for project impacts to regulated waters.
Pedestrian/bike access and landscaping was also included in the category. Examples include:

- Bike racks at every station except the aerial station
- ADA compliant pedestrian ramps to station platforms
- Bus transfer areas
- Park-and-ride facilities
- Vegetative buffers at park-and-rides, the yard and maintenance facility, and traction power substations

In addition, automobile, bus, and van accessways were included in this category. Examples include:

- Roads
- Parking lots
- Park-and-rides at Newtown Road, Military Highway, Ballentine Boulevard, and Harbor Park Stations

Two track removals were identified in the June 28, 2007 Plan and Profile Sheets. One was the removal of the existing track at Sewell's Point Bridge, and the other was removal of an existing grade crossing at engineering station 447+00.

Accuracy of Predictions and Causes of Differences- The former Kirn Library building was demolished for the construction of MacArthur Square Station. The demolition required asbestos abatement techniques to be utilized. Two other asbestos-contaminated buildings adjacent to the library site were also demolished for the station.

Another prediction at this milestone that did not prove accurate was the plan to rehabilitate the freight bridge over Broad Creek. This idea was initiated as a cost-saving measure, but ultimately, it was not feasible and did not take place; instead, a new, two-track bridge was constructed, and all wooden piles were removed.

Predicted visual screening was generally accurate, with the exception of adding visual screening along the tracks adjacent to I-264 and providing brick facades for three TPSS facilities rather than only vegetative buffers.

Utility relocation predictions also did not align with what occurred in the as-built project. All civil contracts (Contracts 20, 30 and 40) assumed in the project specifications that the contractor would coordinate the relocations within its contract. The process for relocations differed depending on where along the alignment the relocation was required. This can be broken down into three categories, Public Property, Norfolk Southern Right of Way and the Central Business District.

Dominion Virginia Power had underground electrical services within the Harbor Park and Government Center area that were not covered by the franchise agreement. Each location had to be designed and cost estimated by DVP and the project had to approve the cost estimate and pay for the relocation. Most of these relocations did not have an effect on time but were not in the project budget.

Norfolk Southern Right of Way (NS RR) relocations occurred within Contract 30. The NS RR agreement required the project to reimburse DVP for the relocation of overhead electrical distribution system since their utility was within the NS RR right of way. Each pole found to be in conflict with the light rail overhead contact wires had to be relocated. The project management team did not fully understand the complexities of this type of relocation and the effort it took to complete these relocations. This type of relocation had an overall effect on time and schedule since all the design work and relocations took place during the construction of this section of the light rail alignment. The cost of these relocations was not included with the project budget.

All of the private utilities companies would not commence relocation plans until DVP had settled on its approach to this section of the project. DVP started a fiscal survey of all its structures in December 2007 after the award of the FFGA. This survey was completed approximately in May 2008. It was found that the entire underground electrical network with the limits of the project needed to be replaced. Most of the structures and conduits had been modified to a point that relocation was not an option. DVP entered into a Design – Build Contract during the Summer of 2008 for the construction of a new duct bank system within the CBD. As DVP developed there planned relocations the other private utilities used these plans to establish if they need to be relocated and could stay in place. All of this had an effect on schedule and cost to Contract 40 and the other constructions contracts issued for work to be performed within the CBD. Some of these could have been addressed earlier in Final Design, when DVP requested a guarantee that their engineering design cost would be reimbursed if the project did not received an FFGA from the FTA.

Systems (SCC 50)

This category included hand-held train radio communication equipment and an automatic vehicle location (AVL) system for tracking the light rail vehicles. Also included were 22 ticket vending machines (TVM), an emergency telephone system at the aerial station, traction power substations (TPSS), signal prioritization, and crossing protection.

TPSS- Seven traction power substations (TPSS) were planned at the FFGA stage of project development. Six were to be placed along the alignment and one at the yard. **Table 12** summarizes TPSS locations at the time of the FFGA and compares these locations to the as-built locations. A wireless supervisory control and data acquisition (SCADA) system for monitoring and controlling the traction power substations was also planned in the FFGA, however it was to be a rudimentary system that would only identify outages or other problems at the TPSS facilities but not be able to interact with the TPSS to power it off or manipulate it in any way.

Table 12 TPSS Locations at FFGA				
TPSS	**Location**	**Engineering Station**	**Location Description**	**Comparison to As-Built**
TPSS #1	East of Second Street	118+75	Near future Woodis Station location	No Change
TPSS #2	York Street Station	141+80	North side of station	No Change
TPSS #3	Harbor Park Station	235+25	Near junction of LRT, Holt Street, NSRR Lambert's Point Branch, and I-264 (south side of alignment)	No Change
TPSS #4	VMSF Site	263+35	South side of alignment	No Change
TPSS #5	Holt Street	327+25	Sewell's Point Bridge, on SE side of I-264 (south side of alignment)	No Change
TPSS #6	Military Highway Station	428+00	South of tracks	Changed
TPSS #7	Newtown Road Station	492+00	Eastern Terminus, eastern end of station	No Change

Source: Plan and Profile Sheets, June 28, 2007.

Signal Prioritization and Crossing Protection- Line-of-sight operation was planned for the project in the FFGA, so the FFGA scope does not include a signaling system, except for three sets of localized track signals: lockouts at EVMC and Newtown Road approaches and an island circuit in the yard at the shop entrance. Light rail signal priority was planned along the downtown portion of the alignment, except at the intersections of Charlotte and Boush Streets and St. Paul's Boulevard at Government Center Plaza. Crossing protection for six gated crossings and signal prioritization equipment for the remaining crossings were planned and included in this category. An additional safety feature that was planned was the installation of missile screens, a type of barrier to prevent objects being thrown over bridges down onto the LRT tracks.

Accuracy of Predictions and Causes of Differences- The signaling and communications plan in the FFGA did not accurately anticipate the as-built systems for the project due to changes that occurred after the FFGA was executed. One of the largest scope changes of the project occurred under SCC 50. It was determined after the FFGA was executed that line-of-sight operation would not be adequate from a safety perspective and that a signaling system would be required for safety reasons. After the FFGA was issued and before construction began, the Virginia Department of Rail and Public Transportation reviewed the project plans and determined that line-of-sight operation east of Downtown would be unsafe. The Commonwealth of Virginia mandated installation of a train signaling system, communication system, and an operations control center. A system was designed as a design-build project so as to minimize the delay to the rest of the project. Additionally, the SCADA planned in the FFGA was simpler than what was ultimately installed, due to the change from line-of-sight operations to signalized operations and the addition of the OCC.

The TPSS visual screening plan in the FFGA did not accurately anticipate the as-built condition. Brick facades for three TPSS facilities were planned at earlier stages in the project as mitigation for adverse visual and aesthetic impacts. These items were removed from the FFGA for cost reasons and later reinstated during construction. The FFGA included only vegetative buffers for TPSS facilities.

Additionally, the planned missile screening was removed during construction, because it was determined that it was an overly conservative item not typically installed for light rail projects.

Right-of-Way and Land (SCC 60)

The FFGA included costs for full and partial parcel acquisitions, several franchise agreements, easements, and leases. This included legal services required for the process. Also included under this category were relocation costs for seven households and three businesses, and related legal services and court expenses. All of the households and two of the businesses were located in the Newtown Station area and needed to be removed in order to construct the bus turn-around and park-and-ride facilities. The third business was located downtown in the vicinity of York Street Station at Duke Street.

Accuracy of Predictions and Causes of Differences- The right-of-way needs predicted in the FFGA accurately anticipated the right-of-way required for the as-built project, to the extent that the needs were assessed at the FFGA milestone. Temporary and permanent easements were generally known at this stage but were not precisely determined or documented. As such, the apparent scope change contributed to a portion of the capital cost differences for SCC 60.

Vehicles (SCC 70)

Nine light rail vehicles were included in the project that was awarded the FFGA. The vehicles were planned to be equipped with a low floor to provide level boarding at the platforms of all eleven stations.

Accuracy of Predictions and Causes of Differences- The number and type of LRVs predicted in the FFGA accurately anticipated the as-built condition of the project.

Conclusions and Lessons Learned

The *Physical Scope Technical Memorandum* summarized the as-built scope of The Tide LRT Project and the anticipated scope of the project at three predictive milestones: Entry into PE, Entry into Final Design, and the FFGA. The memo also identified how well the as-built project was predicted at the three milestones. The analysis of the project across the milestones revealed that the overall project was generally well predicted. No significant alignment or profile changes occurred over the course of project planning. General station locations remained constant across milestones, although three station sites and one park and ride lot location changed after the FFGA was executed due to the availability of the planned parcels for the original sites.

The most significant changes in the physical scope of the project were related to the Systems category (SCC 50). Adding a signaling system from east of Harbor Park Station to Newtown Road Station, an OCC, improved LRT/roadway downtown traffic signal priority coordination, and a robust communications system after the FFGA was executed are the key changes to the physical scope of the project.

The majority of other, more minor, changes also occurred post-FFGA, and many occurred during construction. Primary 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 and brick building facades for the NTF; a change to black-colored OCS 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; and the deletion of proposed missile screens on roadways over the light rail with no pedestrian access.

Lessons Learned

The main overarching lesson of The Tide LRT Project is the crucial importance of having personnel on staff who understand the critical path of rail development and construction as well as the interface with local jurisdictions. HRT has learned from The Tide experience and is now well-positioned and highly prepared from a staffing perspective to manage or coordinate future light rail expansion projects in a successful and efficient manner.

Another lesson of The Tide LRT Project is that cost-cutting measures in the early stages of the project could ultimately result in time delays and additional costs later if the cuts were not based on sound logic and analysis. System safety or project feasibility should not be compromised for the appearance of cost savings in the short term. HRT has also learned these lessons and have since completely transformed the culture of the organization to one of transparency and accountability.

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix B: Capital Costs

HAMPTON ROADS TRANSIT

Introduction

This memorandum documents the capital costs of the Tide, Hampton Roads Transit's (HRT) Norfolk Light Rail Transit (LRT) system. HRT's governing body, Transportation District Commission of Hampton Roads, was awarded a Full Funding Grant Agreement (FFGA) on October 1, 2007 by the Federal Transit Administration (FTA) through the Section 5309 New Starts program. The amount of the Federal New Starts Financial Contribution was $127,980,000, for a total estimated net project cost of $232.1 million.

This memorandum documents both the actual cost of the project and the forecasted costs for the project at project milestones during planning and design, evaluating the accuracy of those costs. The three prediction milestones evaluated herein as compared to the constructed project are:

- Entry into Preliminary Engineering (PE) - November 4, 2002
- Entry into Final Design (FD) - September 2006
- Full Funding Grant Agreement (FFGA) - October 2007

As-Built Capital Costs

This section documents the actual, or as-built, capital costs of the project. Table 1 provides the actual project costs organized by FTA's standard cost categories (SCCs). The actual as-built cost of the Tide Light Rail project was $315.7 million, as constructed between January 2008 and August 29, 2011, when revenue service began. Within the total cost, $187.8 million or 59% of the project expenditure was used for the physical elements (SCC 10 through SCC 50), and 41% or $128.8 million was used for purchasing right-of-way, vehicles, certain utility costs, and various elements of professional services (SCC 60 through 100).

Table 1
Actual Cost by FTA Standard Cost Category

		Actual (After)	Percent
Opening Date Actual Cost in Year of Expenditure $		**August 2011** **$315,755,511**	
10	**GUIDEWAY & TRACK ELEMENTS**	**$83.3**	**26.6%**
20	**STATIONS, STOPS, TERMINALS, INTERMODAL**	**$1.0**	**0.3%**
30	**SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS**	**$12.3**	**3.9%**
40	**SITEWORK & SPECIAL CONDITIONS**	**$55.9**	**17.9%**
50	**SYSTEMS**	**$34.4**	**11.0%**
60	**ROW, LAND, EXISTING IMPROVEMENTS**	**$15.9**	**5.1%**

Table 1 Actual Cost by FTA Standard Cost Category			
		Actual (After)	Percent
70	VEHICLES	$36.0	11.5%
80	PROFESSIONAL SERVICES	$76.8	23.7%
90	UNALLOCATED CONTINGENCY	$ -	-
100	FINANCE CHARGES	$ 0.05	0%
	Total Project Cost	$315.8	100%

Values for SCC categories in millions.

Sources: HRT Accounting Documentation "Categorization of Project Costs FFGA & Concurrent Non-FFGA", and separation of SCC code values indicated on the final contract payment applications.

Table 2 Project Contracts List			
HRT No.	Contract	Contract Description	Final Contract Values
Contract 10	LR 46401	Wetlands Mitigation Grandy Village	$ 536,129.78
Contract 20	LR 46402	Viaduct at Brambleton	$ 15,715,333.19
Contract 30	LR 46403	Track and Civil Elements - Norfolk Southern ROW (later Contract 40A, included in Contract 40)	$ -
Contract 40	LR 46404	Track and Civil Elements - Downtown	$ 98,166,099.63
Contract 07-46527A T1		Noise and Vibration Monitoring	$ 286,246.40
Contract 50653		DNC Business Signage	$ 38,230.30
Contract 60	LR 46406	Traction Power	$ 40,403,178.26
Contract 80	LR 46408	Vehicle Storage Maintenance Facility	$ 13,558,377.46
Contract 100	LR 46410	Park & Rides	$ 4,353,300.00
Contract 110	LR 46411	Station Finishes	$ 4,684,283.33
Contract 120	LR 46412	Light Rail Vehicles	$ 36,016,517.76
Contract 08-48116		Fare Vending Equip.	$ 1,467,250.00
Contract 150	LR 46415	Demolition	$ 1,512,315.00
Contract 07-46527A T4		Asbestos Project Monitoring	$ 80,590.36
Contract 160	LR-46416	Construction of Temp Siding Track	$ 53,729.90
Contract 180	LR46418	Temporary Shelter Purchase	$ 49,697.00
Contract 230	230	Temporary Shelter for LRVS	$ 18,650.00
Contract 250	LR 46425	VSMF Direct Current Power Distribution	$ 105,035.76
Contract 260	LR-46426	Temporary Spur Track Sewells Point	$ 114,883.00
Contract 280	LR 46428	IDIQ Overhead Structures	$ 822,682.29
Contract 340	LR 46434	IDIQ Systems Services – Inspection, Maintenance, and Construction	$ 36,060.00

Table 2 Project Contracts List			
HRT No.	**Contract**	**Contract Description**	**Final Contract Values**
Contract 360	LR 46436	IDIQ Railway Services Maintenance – Light Rail Track Work	$ 129,233.00
Contract 1000	1000	Landscaping	$ 479,149.00
Contract 2000	2000	Drainage under I-264	$ 835,894.00

Table 3
Project Construction Schedule

HRT Contract No.	Contract Title (Per Payment Applications)
10	LR 46401 - HRT 10, Grandy Village Wetlands Mitigation
20	LR 46402 - HRT 20, Harbor Park to NSU Viaduct
40	LR 46404 - HRT 40, Overall Track/Civil Construction
60	LR 46406 - HRT 60, Systems
80	LR 46408 - HRT 80, VSMF (Yard & Shop)
100A	LR 46410A - HRT 100A
100A-C1	LR 46410C1 - HRT 100C1
100B	LR 46410B - HRT 100B, Ballentine Boulevard Park & Ride Lot
100C2	LR 46410C-II - HRT 100C-II
100D	LR 46410D- Operators Restroom
110	LR 46411 - Station Finishes
150	LR 46415 - HRT 150: Kirn Library Demo
160	LR-46416 - Construction of a Temporary Siding Track
180	LR46418, HRT 180: Shelter Structures, Inc.
250	LR 46425 - HRT 250: Direct Current Power Distribution
260	LR-46426 - HRT 260: Turnout Welding and Insulated Joint Installation
280 - Task Order #22	LR 46428 - HRT 280: IDIQ Job Order Contracting Serv.
340	LR 46434, HRT 340, Inspection, Maintenance and Construction Services
360	LR 46436, HRT 360: Light Rail Track Work

Construction of the Tide lasted over three years and six months. Project construction began with the initial Notice to Proceed (NTP) of Contract 20 on January 14, 2008, and was substantially complete with beginning of revenue service in August 2011, however, some elements of construction continued to May 2012. In early 2008, the need to perform multiple utility relocations and to purchase necessary rights-of-way resulted in many months of delay and the eventual combining of Contracts 30 and 40 into a single Contract 40 (later separated into Contracts 40 and 40A for invoicing purposes). With that combination, over $14.6 million in change orders and over one year in contract delays were recognized in the two contracts. Other delays and change orders compounded in subsequent contracts. The project schedule, with respect to SCC's, was as follows. Durations shown below extend beyond the beginning of revenue service date to account for final invoice payments.

Table 4
Project Construction Schedule by Standard Cost Code

SCHEDULE	(Rev.16, June, 2014)	
Norfolk Light Rail Transit Project	Today's Date	**1/14/08**
City of Norfolk, VA	Yr of Base Year $	2008
Phase: Construction	Yr of Revenue Ops	2011

Insert comments, notes, etc.	Start Date	End Date	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Construction														
10 GUIDEWAY & TRACK ELEMENTS	03/03/08	06/20/12												
20 STATIONS, STOPS, TERMINALS, INTERMODAL	01/14/08	01/12/12												
30 SUPPOERT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	12/15/08	06/30/11												
40 SITEWORK & SPECIAL CONDITIONS	01/12/09	10/11/11												
50 SYSTEMS	06/14/08	04/12/13												
60 ROW, LAND, EXISTING IMPROVEMENTS	01/14/08	05/12/12												
70 VEHICLES	01/14/08	05/12/12												
80 PROFESSINAL SERVICES	01/14/08	05/12/12												
90 UNALLOCATED CONTINGENCY	01/14/08	05/12/12												
100 FINANCE CHARGES														

In general, the construction of the Tide was a challenging process requiring multiple change orders and design revisions. Many of these challenges are discussed in detail in other reports performed by the Commonwealth of Virginia, "Special Review – Hampton Roads Transit – Norfolk Light Rail – Report Number 2010-211" dated December 14, 2010, and the "Final Monitoring Report", dated October 31, 2012, performed and provided by the Project Management Oversight Contractor (PMOC).

Concerning the comparison of construction costs to the various other milestone values
Pay item costs were tracked per bid item as well as per SCC code to the extent possible during construction. During the course of this review, some notable items have been found to be assigned to an incorrect SCC or subcategory. However, the values represented in this report reflect documentation provided by HRT, and therefore any costs that may have been miscoded during construction have not been revised. Items of note or of a sufficient cost to affect the comparison between SCC values at the various milestones have been identified and described in the sections below. Additionally, the values represented below reflect project costs per SCC and potentially include work performed outside of the Tide project value – tracked by HRT as Concurrent Non-FFGA effort. It is assumed that these variations account for the approximate $1 million variation between the values provided in Table 1 above and the values shown in Tables 5 through 14 below.

Guideway and Track Elements (SCC 10)

The Tide consists of approximately 7.3 route-miles of both ballasted and embedded double track. At-Grade Exclusive Right-of-Way costs were primarily performed under project Contracts 40, 60, and 110. Several items, including five traction power substations (TPSS) totaling $9.8 million, were coded as SCC 10.01 in Contract 60. These and other items likely attributable to SCCs 40 and 50 would likely reduce the overall SCC 10 value to approximately $70 million, and increase systems to nearly $40 million. Contract 110 – Station Finishes had over $1.5 million in costs coded to SCC 10.01, consisting mostly of retaining walls, concrete platforms and ramps, signage, and electrical work. These items should likely have been coded to SCC 40.

Several large bridge structures were constructed with the Tide. Aerial structure costs were included in both Contracts 20 and 40.

Table 5
Actual Costs– SCC 10 –Detailed Description

10	Guideway and Track Elements	Actual
10.01	At-Grade exclusive ROW	$ 28,674,685
10.02	At-Grade semi-exclusive	$ 10,643
10.03	At-Grade in mixed traffic	$ (12,600) *
10.04	Aerial structure	$ 25,570,861
10.05	Built-up Fill	$ 123,201
10.06	Underground cut & cover	$ -
10.07	Underground tunnel	$ -
10.08	Retained cut or fill	$ 5,219,571
10.09	Track: direct fixation	$ 7,430,559
10.10	Track: embedded	$ 9,221,255
10.11	Track: ballasted	$ 3,942,933
10.12	Track: Special (switches)	$ 2,976,829
10.13	Track: vibration and noise damp.	$ 585,212
		$ 83,743,148

** Negative value shown for Contract 40A.*

The amounts of guideway and track elements were moderately affected during construction. The project limits of the Tide system were shortened by approximately 450 LF near the Eastern Virginia Medical Center (EVMC) Station. The as-built switch location is approximately 600 feet east of the location defined in the FFGA.

The construction schedule for SCC 10 elements extended from Q2 2008 to mid-2012, to beyond the beginning of revenue service date.

Stations, Stops, Terminals, Intermodal (SCC 20)

The Tide project includes eleven stations along the alignment, each with a covered platform area and bench seating, ticket vending machines, and ADA facilities. Values represented in Table 6 for the After condition represent primarily the elevator system installed at the Norfolk State University (NSU) Station at Brambleton (Contract 20), as well as station site furnishings (Contracts 110). The costs for the sitework, such as curbs, ramps, and other civil elements, were not captured under this SCC; many of these costs are included in SCC 10 (see above).

Table 6
Actual Costs– SCC 20 –Detailed Description

20	Stations, Stops, Terminals, Intermodal	Actual
20.01	At-grade station, stop, shelter, mall, terminal, platform	$ 179,749
20.02	Aerial station, stop, shelter, mall, terminal, platform	$ 65,620
20.03	Underground station, stop, shelter, mall, terminal, platform	$ -
20.04	Other stations, landings, terminals: Intermodal, ferry, trolley, etc.	$ 70,708
20.05	Joint Development	$ -
20.06	Automobile parking multi-story structure	$ -
20.07	Elevators, escalators	$ 689,738
		$ 1,005,816

Support Facilities: Yards, Shops, Administrative Buildings (SCC 30)

The Norfolk Tide Facility (NTF), which includes the yard, maintenance building, and small rail operations center, is located near the NSU Station. The NTF contract was bid in July 2008 and constructed in the summer of 2010. The building was ultimately constructed with a brick façade and "Stinger" system facilitating power for vehicle movement within the building.

Performed mostly under Contract 80, nearly all of the costs attributed to SCC 30 went towards the NTF building itself, in SCC 30.02. It should be noted that SCC 30.02, as a result of the change orders issued, includes approximately $1.26 million in building redesign efforts in addition to the capital costs of the building. These design fees should have been more appropriately applied to SCC 80.

Also included in this value is a facility at Sewell's Point, which served to temporarily house vehicles during testing and commissioning.

Table 7
Actual Costs – SCC 30 –Detailed Description

30	Support Facilities: Yards, Shops, Terminals	Actual
30.01	Admin bldg: Office, sales, storage, revenue counting	$42,000
30.02	Light Maintenance Facility ("Shops and Equipment" in FY05 New Starts)	$9,826,072
30.03	Heavy Maintenance Facility	$ -
30.04	Storage or Maintenance of Way Building	$49,697
30.05	Yard Trackwork	$2,435,809
		$12,353,579

Sitework & Special Conditions (SCC 40)

SCC 40 items were included in nearly all of the Tide construction contracts. This category includes a wide variety of work, ranging from general civil construction, demolition, public and private utility relocations and adjustments, to asbestos abatement. Additionally, some item not included in the original FFGA and bid documents were added to the contract after the Operations Hazards Analysis (OHA) review, many of which were included in this category (and performed under Contract 280). Contracts 40 and 40A included $18.5 million, or 33%, of SCC 40 costs.

The largest percentage of work was performed in SCC 40.02 and SCC 40.08, each at approximately 28% of the total SCC 40 cost of $56.2 million. The largest portion of SCC 40.02 was included in Contract 40A, attributable to public utilities such as water, waste water, storm water, and power / street lighting installations. Relocation of a segment of Dominion Virginia Power (DVP) electrical distribution poles are also included in Contract 40A and accounted for here. SCC 40.08 was primarily performed as part of Contract 40 as well, spent on traffic control and temporary construction items, as well as a number of change orders to address delays.

SCC 40.02 and 40.08 also include additional costs incurred for electrical services installed for the TPSS units, signal houses, platforms, traffic and train signals, and other elements requiring a power feed, as these feeds were not covered by the utility franchise agreement. A large DVP duct bank was installed during the project under the franchise agreement and therefore was not paid for by the project, however, the project delays incurred as a result of the late addition of this duct bank adversely impacted the project schedule and cost.

Table 8
Actual Costs – SCC 40 –Detailed Description

40	Sitework and Special Conditions	Actual
40.01	Demolition, Clearing, Earthwork	$7,760,031
40.02	Site Utilities, Utility Relocation	$15,515,744
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	$876,771
40.04	Environmental Mitigation, e.g. wetlands, historic/archeological, parks	$2,122,803
40.05	Site structures including retaining walls, sound walls	$3,601,689
40.06	Pedestrian/bike access and accommodation, landscaping	$5,047,049
40.07	Road/street mods	$5,507,043
40.08	Temporary Facilities and other indirect costs during construction	$15,770,916
		$56,202,050

Systems (SCC 50)

The Tide project was constructed with a communications and signaling system, including a conduit network, fiber optic communications system, and simple SCADA (supervisory control and data acquisition) system connecting the vehicles and traction power substations (TPSS) units to the operations control center at the NTF. The signaling system employed on the Tide is an automatic block signaling (ABS) system. This system, and other SCC elements, was installed as part of Contracts 40 and 60. It should be noted that SCC 50.03 – Traction Power, performed under Contracts 40, 60, and 80, does not include the substations themselves; this cost is captured in SCC 10 as previously noted.

Crossing protection and other safety items are also included in this SCC. Responding to the findings of an operational hazards analysis (OHA) performed during construction, fencing, gates, railings, signage, and other barriers were implemented on the project. These elements are captured in SCC's 40 and 50.

Table 9
Actual Costs – SCC 50 –Detailed Description

50	Systems	Actual
50.01	Train Control and signals	$9,690,145
50.02	Traffic signals and crossing protection	$9,712,932
50.03	TPSS	$554,389
50.04	OCS	$13,923,516
50.05	Communication	$642,502
50.06	Fare Collection	$ -
50.07	Central Control	$ -
		$34,523,487

ROW, Land, Existing Improvements (SCC 60)

The final constructed project includes 157 affected parcels resulting in approximately $16 million in right-of-way (ROW) costs. Purchases of ROW include full and partial acquisitions, various easements, and relocations. Easements and ROW on NSU campus were not acquired prior to the bidding of the Tide project in early 2008, increasing costs during construction and delaying construction through the entire project.

Table 10
Actual Costs – SCC 60 –Detailed Description

60	ROW, Land, Existing Improvements	Actual
60.01	Purchase or lease of real estate (FY05 New Starts cost estimate combined these two line items into "Property Acquisition including Escl & Relocation")	$15,157,193
60.02	Relocation of existing households and businesses	$788,307
		$15,945,500

Vehicles (SCC 70)

HRT acquired nine Siemens S70 low-floor light rail vehicles for the project. Costs associated with vehicle spare parts and system maintenance equipment are included as a subsection of "Start-Up and Pre-Revenue Operations" in final project accounting, under SCC 80.08 – System Start-Up. The value of the "parts and materials" is approximately $1.4 million.

Table 11 Actual Costs – SCC 70 –Detailed Description		
70	**Vehicles**	**Actual**
70.01	Light Rail	$36,066,517
70.02	Heavy Rail	$ -
70.03	Commuter Rail	$ -
70.04	Bus	$ -
70.05	Other	$ -
70.06	Non-revenue vehicles	$ -
70.07	Spare parts	$ -
70.01	**Light Rail**	**$36,066,517**

Professional Services (SCC 80)
SCC 80 costs were utilized throughout the duration of the Tide project. The largest percentage of work was performed in SCC 80.02, 80.03, and 80.04, which combined account for 68% of the SCC 80 total value.

Table 12 Actual Costs – SCC 80 –Detailed Description		
80	**Professional Services**	**Actual**
80.01	Preliminary Engineering	$8,754,000
80.02	Final Design	$17,323,163
80.03	Project Management for Design and Construction	$21,680,086
80.04	Construction Administration & Management	$13,279,442
80.05	Insurance	$7,975,637
80.06	Legal, Permits, Review Fees by other agencies/cities	$421,318
80.07	Surveys, Testing, Investigation, Inspection	$ -
80.08	System Start-up	$7,374,425
		$76,808,071

Unallocated Contingency (SCC 90)
There is no Unallocated Contingency accounted for in the constructed After condition. However, it should be noted that most or all of the project construction contracts were bid and awarded with no contingency.

Table 13 Actual Costs – SCC 90 –Detailed Description		
90	**Unallocated Contingency**	**Actual**
		N/A

Finance Charges (SCC 100)
According to the HRT's final project documentation, $51,987 in finance charges was recognized on the project.

Table 14 Actual Costs – SCC 100 –Detailed Description		
100	**Finance Charges**	**Actual**
		$ 51,987

Accuracy of Predictions at Project Milestones
This section documents the predicted costs at the three pre-construction milestones, and compares the predictions made to the actual outcome of the Tide project.

HRT developed predictions of capital costs at three milestones – Entry into PE, Entry into FD, and the FFGA (see Table 15 below for submitted milestone values). These predictions all occurred at different time periods with varying predictions of project duration and inflation rates. To review the accuracy of these milestone predictions, the raw data of each milestone estimate has been analyzed to independently account for inflation and construction duration as overall construction cost factors. Per information developed and included in the FTA-provided New Starts Application spreadsheet submitted at each milestone, raw cost prediction data for each milestone was taken from the "Main Worksheet – Build Alternative" and "Inflation Worksheet" forms. Additionally, the recognized Actual construction data, including recognized schedule and inflation rates with respect to bid prices, was converted into the same FTA-application format. This data was then used to generate the following tables.

Table 15, below, summarizes the actual capital cost of the project and the predictions at the three milestones. The table presents the costs in two different dollar valuations. First, values in "constant" dollars rely on the value of a dollar in a specific year, effectively assuming that the project is built entirely within that year and ignoring the effects of inflation. Second, values in "year-of-expenditure" (YOE) dollars specifically recognize the schedule for project construction, the annual cost-inflation that erodes the value of the dollar over time, and the real-world cash flow for the project. HRT followed standard practice in the prediction of capital costs for the Tide LRT project, first developing a cost prediction in constant dollars and then inflating that prediction to YOE dollars based on the anticipated project construction schedule and annual rates of construction cost inflation.

Table 15 examines the accuracy of HRT's predictions of total project cost in both constant and YOE dollars. Table Alpha in the appendix presents the underlying calculations of actual and predicted costs for each year of the project-development schedule.

Line No.	Cost Measure	Actual	Predictions: Entry into PE (2003)	Predictions: Entry into FD (2006)	Predictions: FFGA (2006)
Table 15 Predicted and Actual Total Capital Costs – Constant Year Dollars					
Constant Dollars (millions)					
1	Total capital cost in 2003 constant dollars	$242.6	$182.0	---	---
2	Total capital cost in 2006 constant dollars	$281.0	---	$213.6	---
3	Total capital cost in 2006 constant dollars	$288.7	---	---	$221.3
Inflation					
4	Dollar-weighted mid-point of project expenditures	Jun09	Nov05	Jun08	Jun08
5	Opening year	Aug11	Dec07	Jan10	Jan10
6	Inflation effects compared to 2003 constant dollars	29.6%	9.0%	---	---
7	Inflation effects compared to 2006 constant dollars	12.0%	---	10.2%	---
8	Inflation effects compared to 2006 constant dollars	12.0%	---	---	10.1%
Year-of-Expenditure (YOE) Dollars (millions)					
9	Total capital cost in YOE dollars	$314.6	$198.3	$235.3	$232.1
10	Predicted minus actual total capital cost in YOE dollars	---	-$119.6	-$79.3	-$82.5
11	-- component attributable to scope/unit-cost differences	---	-$65.0	-$74.2	-$77.2
12	-- component attributable to inflation-rate differences	---	-$14.2	$3.8	$3.7
13	-- component attributable to schedule differences	---	-$40.5	-$8.8	-$9.0

Line 1 of Table 15 shows that HRT predicted a constant-2003-dollar project cost $182.0 million at Entry into PE in 2003. Line 1 also presents the actual cost of the project, translated from YOE dollars into constant 2003 dollars. Comparison of the predicted and actual cost indicates that the HRT prediction was not accurate – an underestimate of $65 million. Similarly, Line 2 compares the predicted constant-2006-dollar project cost at the 2006 Final Design milestone to the actual project cost translated into constant 2006 dollars, followed by the 2006 constant-dollar comparison for the FFGA provided in Line 3 (note that the FFGA, while dated 2007, was calculated with 2006 dollar values). Again, the HRT prediction was not accurate by similar margins – underestimating the constant-year project cost by $74.2 and $77.2 million, respectively. Overall, HRT was consistent in the underestimation of project capital costs by nearly one-quarter the total value at all three pre-construction milestones in terms of total project cost in constant-dollars.

Lines 4 and 5 describe actual and predicted conditions related to inflation effects on the Tide LRT project costs. Line 4 presents the mid-points of expenditures on the project computed from the actual and predicted schedules of annual expenditures. Line 5 documents the actual and predicted date of project opening. At Entry into PE in 2003, HRT anticipated a project schedule with a mid-point in November 2005 and project opening in 2007. At Entry into FD in 2006, these schedule predictions were revised to a construction mid-point in June of 2008 and project opening on January 1, 2010. These predictions were also used in the FFGA in 2007. As described later in this memorandum, the actual project construction duration was extended well beyond the original project schedules envisioned in the pre-construction milestones.

Lines 6, 7, and 8 summarize the actual and predicted impacts of construction-cost inflation on project costs. At Entry into PE on Line 6, HRT predicted that inflation would add 9.0% to the 2006 constant-dollar cost estimate based on the anticipated project schedule. The Entry into PE milestone was not developed in the now-standard FTA format utilizing SCC categories. As such, inflation was assumed to be at an annual rate of 3%, applied to the midpoint of construction of various project items. The actual impact of inflation on the constant-dollar cost estimate was 29.6%, well above the 9.0% prediction.

At Entry into FD (Line 7) and FFGA (Line 8), HRT utilized the FTA SCC format in development of the cost estimate. The Entry into FD prediction assumed inflation would hold steady at a rate of 3.875% per year, resulting in an overall percentage increase of 10.2% for the duration of the construction contract. This prediction proved mostly true, as the actual recognized inflation increased the project costs by 12.0% to the 2006 constant-dollar cost estimate. The FFGA milestone, also in 2006 dollars, also predicted inflation at 12%, based on revised construction schedule and the assumption of nationwide values for Engineering News Record construction costs. This prediction proved inaccurate as the actual recognized inflation encountered for this milestone was 10.1%.

The actual effect of inflation on the constant-dollar cost estimates appears to have been noticeable for the Tide LRT project. The actual 29.6% increase from the Entry into PE estimate was particularly significant. None of the predicted amounts were greater than those experienced in the Actual column. There could be several causes of the underestimates of inflation effects, including the three different calculations of rates in the three milestones. Table B summarizes the annual increase in construction costs as measured by the Engineering News Records national-average index of construction costs. For 2003 through 2006, the index rose by a total 15.8% (6694 in 2003 to 7751 in 2006), an average increase of 4.4% per year. This pace far outstripped the 3% per year assumption made at Entry into PE. Similarly, the “great recession” that began in 2007 cooled national and international demand for construction materials and labor, reducing inflation rates in 2007, 2009, and 2010. This provided for much more accurate predictions to prevail in the Entry into FD estimate and the FFGA with respect to inflation.

Lines 9 through 13 show the causes of differences between the predicted and actual costs in YOE dollars. Line 9 reflects the predicted total costs at the various years of expenditure. Line 10 provides the total amount difference between actual expenditures and the predicted, inflated amounts.
Lines 11, 12, and 13 distribute the overall difference in costs according to unit cost / scope, inflation, and schedule. This is accomplished by a series of calculations: Line 11 compares the construction unit cost distribution against the three milestones in their constant year dollar value per SCC, Line 12 compares inflation by quantifying the difference in values when the different inflation predictions are applied, and Line 13 accounts for the effects of inflation on the project when comparing the predicted years of construction to the actual years of construction.

At Entry into PE, even with the poor prediction of inflation, the most significant impact resulted from the scope / unit cost differences and the schedule impacts. Predictions of underlying scope and unit-cost differences contributed a significant overrun to the project. The anticipated construction schedule contributed an impact as well, demonstrating the impacts of a prolonged construction schedule on the capital costs. At Entry into FD and FFGA milestones, by far the largest impact resulted from scope and unit-cost differences, further reflecting inaccurate predictions of the scope and need of the project.

Table 16
Actual Changes in Construction Costs

Year	Index*	Effective Rate	Year	Index*	Effective Rate
2000	6221	---	2008	8310	4.3%
2001	6343	2.0%	2009	8570	3.1%
2002	6538	3.1%	2010	8802	2.7%
2003	6694	2.4%	2011	9080	3.2%
2004	7115	6.3%	2012	9308	2.5%
2005	7446	4.7%	2013	9547	2.6%
2006	7751	4.1%	2014	9821	2.9%
2007	7966	2.8%	2015	10086	2.7%

Source: Engineering News Record – National Construction Cost Index History, Annual Averages.

Table 17 examines the accuracy of predicted costs for individual components of the project grouped into FTA's Standard Cost Categories (SCCs). All predicted costs in the table are in constant 2006 dollars to remove inflation effects from any differences between the predicted and actual costs. Consequently, the causes of any cost differences are limited to differences in project scope and/or differences in the base-year unit costs at each milestone. The table flags a significant difference between the predicted and actual cost of an SCC when the absolute difference exceeds ±$10 million and the relative difference exceeds ±20%).

Table 17 Actual and Predicted Expenditures Converted to FFGA-Year (2006) Dollars										
	Actual cost	Predictions and Differences from Actual Costs								
		Entry into PE			Entry into FD			FFGA		
Original dollar year of the actual or predicted costs	2006	2003			2006			2007 (2006 dollars)		
Standard Cost Category	Actual Costs (millions of $2006)	Predicted Costs (millions of $2006)	Absolute Difference (millions of $2006)	Relative Difference (percent)	Predicted Costs (millions of $2006)	Absolute Difference (millions of $2006)	Relative Difference (percent)	Predicted Costs (millions of $2006)	Absolute Difference (millions of $2006)	Relative Difference (percent)
10 GUIDEWAY & TRACK ELEMENTS	$75.8	**$56.7**	**-$19.1**	-25%	**$52.0**	**-$23.9**	-31%	**$52.0**	**-$23.9**	-31%
20 STATIONS, STOPS, TERMINALS, INTERMODAL	$0.9	$9.1	$8.2	886%	$5.2	$4.3	466%	$5.2	$4.3	466%
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN.	$11.3	$12.7	$1.3	12%	$15.4	$4.1	36%	$15.4	$4.1	36%
40 SITEWORK & SPECIAL CONDITIONS	$50.9	**$23.2**	**-$27.7**	-54%	**$12.5**	**-$38.4**	-75%	**$12.5**	**-$38.4**	-75%
50 SYSTEMS	$30.7	$27.6	-$3.1	-10%	$25.6	-$5.1	-17%	$25.6	-$5.1	-17%
60 ROW, LAND, EXISTING IMPROVEMENTS	$14.5	$11.3	-$3.1	-22%	$10.5	-$4.0	-28%	$10.5	-$4.0	-28%
70 VEHICLES	$32.7	$31.7	-$1.0	-3%	$36.8	$4.0	12%	$33.4	$0.7	2%
80 PROFESSIONAL SERVICES	$71.8	**$38.6**	**-$33.1**	-46%	**$40.8**	**-$31.0**	-43%	**$40.8**	**-$31.0**	-43%
90 UNALLOCATED CONTINGENCY	$0.0	$0.0	$0.0	0%	$10.0	$10.0	0%	$10.0	$10.0	0%
100 FINANCE CHARGES	$0.0	$0.0	$0.0	-100%	$4.9	$4.8	9698%	$4.9	$4.8	9698%
Total	$288.7	$210.9	-$77.8	-27%	$213.6	-$75.2	-26%	$210.2	-$78.5	-27%

This table highlights many differences, including several massively large percentage differences for lines with little or no actual cost identified (SCC's 20 and 100). However, the most significant differences are shown in the three largest SCC's – SCC 10, SCC 40, and SCC 80. These three SCC values most clearly represent the large variations in project scope as well as significantly missed financial predictions. All three of these categories appear to have been underestimated due to unit cost or scope challenges rather than inflation or schedule. While project schedule was a significant issue during construction, as discussed elsewhere in this memorandum, it does not appear to have been the primary reason for the recognized costs.

Two notable overestimates in predicted costs are reflected in SCC's 20 and 30. Due to unintentional documentation and categorization errors during construction (such as concrete site work for station platforms being attributed to SCC 40 instead of SCC 20), the costs coded to these SCC's are lower than expended on the items themselves, therefore the actual difference may not be as significant as shown here for these two SCC's. This situation is discussed in further detail in the FFGA section in this document.

Table A demonstrates that the three milestones were all consistently between 23% and 25% lower than the recognized actual costs in constant year dollars (accounting for inflation). Table C confirms those findings in showing that, when reviewed in 2006 constant year dollars, the Relative Differences of the total costs are 21%, 24%, and 25% under actual value, respectively. These values are used as a point of reference throughout the remainder of the memorandum when discussing and comparing SCC subcategory values.

Capital Cost Estimates at Project Milestones

The predicted total construction costs for the Tide were relatively consistent through the Preliminary Engineering (PE), Final Design (FD), and FFGA conditions. For these milestones, the scope of the project remained steady, consisting of approximately 7.3 miles of ballasted and embedded double track, with an estimated need of 9 vehicles and 11 stations. The constructed project closely resembled those designs; however, costs significantly exceeded expectations. Table 18 provides the actual and predicted project costs organized by SCC according to the original source documents. Values shown below represent YOE costs, including allocated contingency.

Table 18
Actual Cost Comparison to Milestone Cost Estimates by FTA Standard Cost Category

		Actual	Entry into Preliminary Engineering (PE)	Entry into Final Design (FD)	FFGA (Before)
Date of Cost Estimate		**2011**	**8/1/2003**	**6/29/2006**	**10/1/2007**
Opening Date (planned or actual)		**August 2011**	**2008**	**2010**	**2010**
Estimate in Estimate Year Dollars			**$182,681,000***	**$213,583,000**	**$221,325,000**
Estimate in Year of Expenditure $		**$315,755,511**	**$198,491,000**	**$235,318,000**	**$232,100,000**
Difference from Actual Costs (%)		**-**	**-37%**	**-25%**	**-26%**
10	**GUIDEWAY & TRACK ELEMENTS**	**$83.3**	**$53.5**	**$57.2**	**$56.1**

Table 18 Actual Cost Comparison to Milestone Cost Estimates by FTA Standard Cost Category					
		Actual	Entry into Preliminary Engineering (PE)	Entry into Final Design (FD)	FFGA (Before)
20	STATIONS, STOPS, TERMINALS, INTERMODAL	$1.0	$8.7	$5.7	$5.7
30	SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	$12.3	$12.1	$17.0	$17.6
40	SITEWORK & SPECIAL CONDITIONS	$55.9	$21.9	$14.4	$16.7
50	SYSTEMS	$34.4	$26.6	$29.3	$32.5
60	ROW, LAND, EXISTING IMPROVEMENTS	$15.9	$10.5	$10.5	$10.7
70	VEHICLES	$36.1	$29.7	$41.9	$36.0
80	PROFESSIONAL SERVICES	$76.8	$35.5	$42.4	$42.1
90	UNALLOCATED CONTINGENCY	$ -	$ -	$11.3	$10.8
100	FINANCE CHARGES	$ 0.05	$ -	$5.6	$3.9
	Total Project Cost	$315.8	$198.5	$235.3	$232.1

** Estimated value. Original Entry into PE estimate predated standard SCC codes. Values for SCC Categories in millions.*
Sources:
Actual: HRT Accounting Documentation "Categorization of Project Costs FFGA & Concurrent Non-FFGA", and separation of SCC code values indicated on the final contract payment applications.
Entry - PE: Supplemental to October 2002 Capital Cost Results Report, dated August 1, 2003, used to support the FY 2005 New Starts Submittal Dated August 2003.
Entry - FD: Updated Request to Enter Final Design, FY 2008 New Starts Submittal, dated June 29, 2006.
FFGA: Full Funding Grant Agreement – Transportation District Commission of Hampton Roads – Norfolk Light Rail Project – VA-03-0107, dated October 1, 2007.

Capital Costs at Entry into Preliminary Engineering

The initial project cost estimate provided in the "Capital Cost Results Report" dated November 2001, was established during the Supplemental Draft Environmental Impact Statement (SDEIS) process. As discussed in the "Chronology of Capital Costs Estimates for Norfolk LRT Project", dated February 2005, and through two value engineering processes performed between 2001 and 2003, HRT refined the project to a state similar in scope to the As-Built condition. In November 2001, the original project estimate was $360 million. Though later reduced in length, this initial project design was 7.9-miles and envisioned to follow the same corridor as was ultimately constructed.

Through an FTA meeting in Norfolk with representatives from HRT, the City of Norfolk, and FTA, the project team explored potential capital cost reductions to lower the project Cost Effectiveness Index (CEI) to an acceptable level. HRT and the City proposed many adjustments that resulted in a project cost of $278.5 million, a revised financial plan, supplemental information on land use development and downtown parking supply constraints, and a revised ridership forecasting methodology. Changes notably included:

- use of single-car platforms (with capacity for future expansion) in place of two-car platforms,
- eliminating the purchase of two significant properties (the City-owned library parcel and Barry Robinson properties, removed from the project with the reduction in project length), and
- a reduction of soft costs (contingency, escalation, and engineering efforts).

A second capital cost reduction workshop was held in Norfolk in August 2002. The project team was directed by FTA to identify further reductions through value engineering efforts. A panel of HRT staff, the Program Management Consultant, FTA engineering representatives, and other engineering experts was convened to address a re-definition of the Baseline Alternative, accounting for new ridership predictions and an increase in project CEI. This workshop generated recommendations to reduce the project cost. These recommendations, later implemented into the design, included some key project elements:

- alternative bridge configurations and structure types,
- prefabricated station shelter structures,
- deferring of the automated train control (ATC) systems and operating under line-of-sight rules,
- deferring communications, SCADA, public address, and other systems, and operating the system with radios, supplemented with a GPS-based automatic vehicle location (AVL) system,
- smaller traction power units, and
- a simplified vehicle maintenance facility, including deferral of the control center.

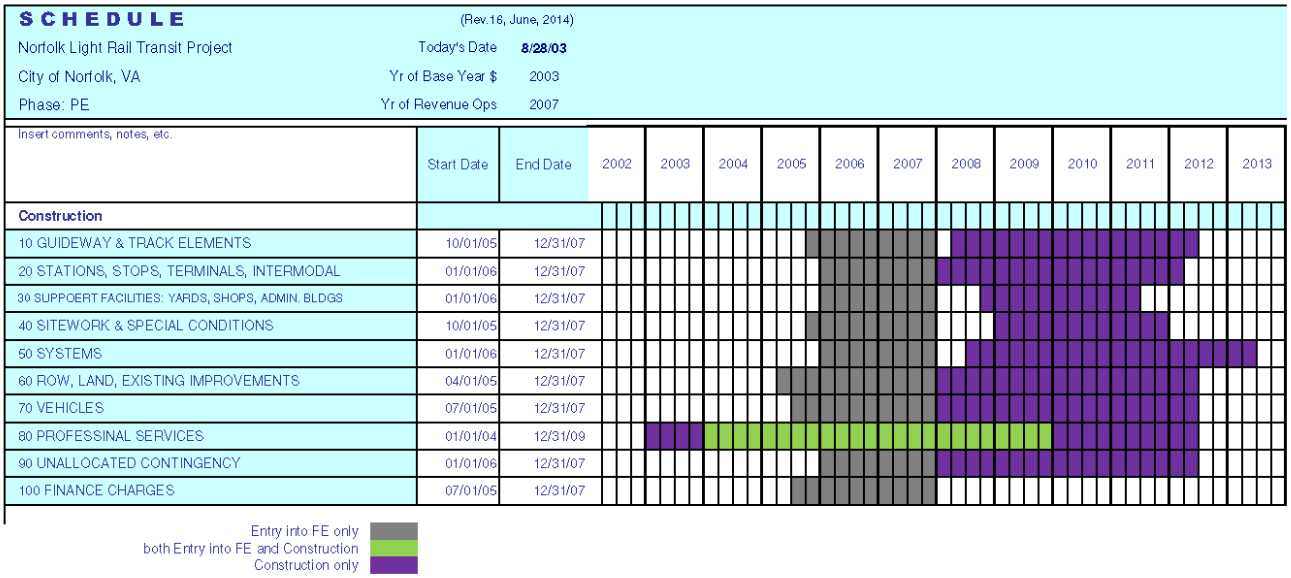
The result of this second effort was a 7.4-mile system with a capital cost estimate of $221.9 million, completed in October 2002. By August 2003, and through further reductions to traction power systems and utility relocation efforts, revisions to structural designs, and the elimination of a light rail vehicle, this estimate was reduced to the $198.5 million estimate examined in this memorandum. This original estimate, used as the Entry into PE, predated and therefore did not utilize FTA's SCC's in breaking down the project costs. This initial milestone assumed revenue service to begin in 2008.

For the purposes of this study, the values provided in the original Entry into PE documentation have been converted into the SCC format to the extent possible. Table 15 provides the estimates at each milestone (Entry into PE, Entry into Final Design, and the FFGA) in YOE dollars, and the actual or as-built construction costs.

The tables in this section reflect YOE dollars as documented on the New Starts application spreadsheets submitted to FTA for the various milestones, compared to actual costs. When necessary, findings of note are also discussed with respect to 2006 constant year dollars, as shown in Tables A and C. Since inflation and other values have not be developed specifically for sub-categories of the SCC's, the overall 2006 constant dollar value for the SCC's was applied to all of the individual sub-categories. This data is referenced as needed for items of note, in an effort to not over- or understate the importance of the difference in predicted versus actual values for individual SCC sub-categories.

The initial schedule developed for the project predicted construction to occur primarily in 2006 and 2007, with revenue operations beginning in 2007. This time frame was later adjusted with subsequent New Starts submittals. The notable variation between this prediction and the constructed project was primarily the duration of construction, and how predicted construction duration of between two and three years ultimately was extended to nearly four years.

Table 19
Project Entry into PE Schedule compared to Actual Construction Schedule:



Guideway and Track Elements (SCC 10)

Table 20 Actual and Predicted Costs – SCC 10 Details					
10	**Guideway and Track Elements**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
10.01	At-Grade exclusive ROW	$ 28,674,685	$ 10,929,459	$ 4,664,000	$ 5,276,000
10.02	At-Grade semi-exclusive	$ 10,643	$ -	$ 5,846,000	$ 6,893,000
10.03	At-Grade in mixed traffic	$ (12,600)	$ -	$ -	$ -
10.04	Aerial structure	$ 25,570,861	$ 27,851,545	$ 18,235,000	$ 16,339,000
10.05	Built-up Fill	$ 123,201	$ -	$ -	$ -
10.06	Underground cut & cover	$ -	$ -	$ -	$ -
10.07	Underground tunnel	$ -	$ -	$ -	$ -
10.08	Retained cut or fill	$ 5,219,571	$ -	$ 8,101,000	$ 7,678,000
10.09	Track: direct fixation	$ 7,430,559	$ 1,179,227	$ 2,521,000	$ 3,052,000
10.10	Track: embedded	$ 9,221,255	$ 2,499,330	$ 5,644,000	$ 5,270,000
10.11	Track: ballasted	$ 3,942,933	$ 8,932,044	$ 10,803,000	$ 10,087,000
10.12	Track: Special (switches)	$ 2,976,829	$ 2,095,400	$ 1,398,000	$ 1,501,000
10.13	Track: vibration and noise damp.	$ 585,212	$ -	$ -	$ -
		$ 83,743,148	$ 53,487,005	$ 57,211,000	$ 56,096,000
SCC 10 – 2006 constant Year Dollars		*$75.8 M*	*$56.7 M*	*$52.0 M*	*$52.0 M*

The project limits of the Tide system remained relatively consistent throughout the project milestones, having approximately 7.3 miles of ballasted and embedded double track corridor. The Entry into PE milestone had the earliest year of revenue service identified (2008) and consequently the largest variation with respect to project schedule as shown in Table 15. Predictions for inflation and unit costs were also significant.

Per the Capital Cost Report for this milestone, the SCC 10 value includes approximately 7,000 route feet of Embedded Track, 23,450 route feet of Ballasted Track (either with open track bed or adjacent to a roadway), and 15 at-grade roadway crossings totaling over 1400 feet – values similar to those in the After condition. Despite the relative consistency in the scope, SCC 10 contains several subcategories that were significantly underestimated at the Entry into PE milestone, apparently due to unit cost predictions. In attempting to quantify these differences, some inference can be made based on unit prices of some key items.

Originally developed in metric measurements, Entry into PE unit prices have been converted into English units, and escalated to account for inflation at the construction year of the PE design (typically 10.910%) and to include 15% contingency per the same methodology used to originally generate the FY 2005 New Starts Submission. Direct Fixation track, Open Deck Aerial Structure, and several other potential key indicator items were not compared since they were typically paid for as large lump sum items as part of Contract 40A. Also, the 2002 Capital Cost Results Report includes several different values for ballasted and embedded track for various locations and scenarios. The highest value of these numbers was used, the results of which are shown in Table 21.

Table 21
Actual Cost Comparison to Entry into PE – SCC 10 – Key Indicators

	Actual	Entry Into PE			
Bid Item	**Unit Price**	**Unit Price**	**Converted Unit Price**	**Escalated**	**% Change**
Mainline Ballasted Track	$450 / Track Foot	$907 / Rt. Meter	$138.26 / TF	$176.35 / TF	255%
Mainline Embedded Track	$470 / TF	$917 / RM	$139.75 / TF	$178.25 / TF	264%
Special Trackwork – Ballasted Turnout	$200,000 / Each	$250,000 / Each		$318,866 / EA	-63%

Sources:
Actual: HRT Accounting Documentation – Contract 40 – Final Payment Application – March 29, 2012.
Entry - PE: Supplemental to October 2002 Capital Cost Results Report, dated August 1, 2003, used to support the FY 2005 New Starts Submittal Dated August 2003.

An attempt at comparing SCC 10.04 – Aerial Structure estimates was made (due to the large costs in the subcategory) using the Entry Into PE price of $9,193 per route meter of track, or $2,802 per linear foot of bridge. The 3000-foot long Lamberts/Brambleton Viaduct structure was constructed as part of Contract 20 and paid for as a $7.395 million lump sum cost. This value equates to approximately $2,459 per linear foot of structure. The After cost should be inflated relative to the Entry into PE cost to account for several smaller items broken out separately and potentially applied to other SCC codes. This approach would likely result in similar values and a relatively accurate unit price prediction for aerial guideway costs.

Accuracy of Predictions and Causes of Differences
The above section demonstrates that unit price assumptions for certain SCC 10 items were a factor in the inaccuracy of this predictions at the Entry into PE milestone. Only the "Aerial structure" and "Track: Ballasted" sections were overestimated, while the "Track: direct fixation" and "At-Grade exclusive ROW" were significantly underestimated. All other sub-categories were underestimated, with the exception of Track: Special. When reviewed in 2006 constant year dollars, that sub-category was well predicted.

While the predictions from Entry into PE were not accurate, some items were also misclassified in the After condition. Some costs likely attributable to other SCC's are thought to be included in the After SCC 10.01 (see SCC 20 of the After Condition).

Stations, Stops, Terminals, Intermodal (SCC 20)
The Tide project includes eleven stations along the alignment in both the After and Entry into PE milestones. Originally envisioned with single car platforms, a two-car platform was ultimately constructed at the NSU station. The costs for the site work were not captured under this SCC in the After condition; many of these costs are included in SCC 10, contributing to the large discrepancies shown in Table 22. It is believed that more of these miscoded costs were assigned to SCC 40.

Accuracy of Predictions and Causes of Differences:
The Entry Into PE milestone assigns all station construction values to SCC 20.01 and 20.02, while the After condition distributes its costs over four subcategories. The total SCC 20 value of the constructed project was just over $1 million. When translated into 2006 constant year dollars, the constructed SCC 20 is less than 10% of the $9.1 million predicted at Entry into PE. Values represented in Table 22 for the After condition represent primarily the elevator system installed at the Norfolk State University (NSU) station at Brambleton Station (Contract 20), as well as station site furnishings (Contracts 110). With many site / civil items wrapped into Lump Sum items, actual costs for specific station elements are not easily discerned in the After estimate and likely are miscoded to SCC 40 subcategories, with some charges potentially attributed to SCC 10 as well. Costs predicted during the Entry into PE milestones included nearly all of the elements of construction to be recognized during station installation, including concrete site work and nearby park-and-ride facilities.

An initial assumption made in the Entry into PE prediction that proved inaccurate was the nature of the stop shelters. Originally envisioned as a prefabricated shelter, the designs were revised to a unique shelter structure during construction at the request and direction of the City of Norfolk. This change does not result in significant cost variations due to the miscoding issues discussed above; however, it is a source of discrepancy.

Table 22
Actual and Predicted Costs – SCC 20 Details

20	Stations, Stops, Terminals, Intermodal	Actual	Entry Into PE	Entry into FD	FFGA
20.01	At-grade station, stop, shelter, mall, terminal, platform (FY05 New Starts cost estimate combined stations and park-and-rides)	$ 179,749	$ 7,668,404	$ 4,219,000	$ 4,285,000

Table 22 Actual and Predicted Costs – SCC 20 Details					
20	Stations, Stops, Terminals, Intermodal	Actual	Entry Into PE	Entry into FD	FFGA
20.02	Aerial station, stop, shelter, mall, terminal, platform	$ 65,620	$ 1,019,228	$ 1,250,000	$ 1,188,000
20.03	Underground station, stop, shelter, mall, terminal, platform	$ -	$ -	$ -	$ -
20.04	Other stations, landings, terminals: Intermodal, ferry, trolley, etc.	$ 70,708	$ -	$ -	$ -
20.05	Joint Development	$ -	$ -	$ -	$ -
20.06	Automobile parking multi-story structure	$ -	$ -	$ -	$ -
20.07	Elevators, escalators	$ 689,738	$ -	$ 187,000	$ 198,000
		$ 1,005,816	$8,687,632	$ 5,657,000	$ 5,671,000
SCC 20 – 2006 constant Year Dollars		*$0.9 M*	*$9.1 M*	*$5.2 M*	*$5.2 M*

Support Facilities: Yards, Shops, Administrative Buildings (SCC 30)

The Tide project included over $12 million in SCC 30 project costs, of which the vast majority was spent on the maintenance facility itself. Included primarily in Contract 80, the structure included a brick façade, full building redesign, and associated soft costs during construction.

The predicted condition shown in the Entry into PE figures appears to represent a relatively accurate prediction of SCC 30 costs, even with addition of the brick façade. However, it should be noted that two other items confuse this prediction. When compared in 2006 constant year dollars, the Actual cost becomes $11.3 million, while the Entry into PE value increases to $12.7 million. Secondly, the shop traction power substation was included in the original Entry into PE estimate but not coded to the Actual SCC 30 during construction. These factors, combined with the building redesign and associated schedule delays, confuse how accurate a prediction was presented at the Entry into PE milestone.

Table 23 Actual and Predicted Costs – SCC 30 Details					
30	Support Facilities: Yards, Shops, Terminals	Actual	Entry Into PE	Entry into FD	FFGA
30.01	Admin bldg: Office, sales, storage, revenue counting	$42,000	$ -	$ -	$ -
30.02	Light Maintenance Facility ("Shops and Equipment" in FY05 New Starts)	$9,826,072	$9,641,256	$8,270,000	$9,240,000
30.03	Heavy Maintenance Facility	$ -	$ -	$ -	$ -
30.04	Storage or Maintenance of Way Building	$49,697	$ -	$ -	$ -

Table 23 Actual and Predicted Costs – SCC 30 Details					
30	Support Facilities: Yards, Shops, Terminals	Actual	Entry Into PE	Entry into FD	FFGA
30.05	Yard Trackwork	$2,435,809	$2,499,080	$8,721,000	$8,380,000
		$12,353,579	$12,140,336	$16,991,000	$17,620,000
SCC 30 – 2006 constant Year Dollars		*$11.3 M*	*$12.7 M*	*$15.4 M*	*$15.4 M*

Sitework & Special Conditions (SCC 40)

In 2006 constant year dollars, the actual cost of SCC 40 was more than twice the prediction made at the Entry into PE milestone. The predictions made at the Entry into PE did have relatively accurate predictions for subcategories SCC 40.02 and 40.04, and when accounting for 2006 constant year dollars, SCC 40.07 was also closely predicted, but all of the other Entry into PE values vastly underestimated the Actual costs incurred with project demolition, site structures, and temporary facilities. Demolition costs with respect to the Kirn Library and other buildings exceeded the predictions of the Entry into PE milestone. For the constructed condition, SCC 40.05 costs were recognized primarily in Contract 40 (over $12 million), but also were seen in nearly all of the other construction contracts. These costs were predicted at just over $2 million in the Entry into PE milestone.

The Entry into PE milestone included approximately $1.3 million for the relocation of the Dominion Virginia Power overhead lines. The overhead power relocation is estimated to have ultimately cost over $4 million in the After condition.

Table 24 Actual and Predicted Costs – SCC 40 Details					
40	Sitework and Special Conditions	Actual	Entry Into PE	Entry into FD	FFGA
40.01	Demolition, Clearing, Earthwork (includes "Yard Sitework" from FY05 New Starts)	$7,760,031	$2,027,802	$703,000	$662,000
40.02	Site Utilities, Utility Relocation	$15,515,744	$14,329,839	$7,340,000	$7,579,000
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	$876,771	$ -	$1,540,000	$1,523,000
40.04	Environmental Mitigation, e.g. wetlands, historic/archeological, parks	$2,122,803	$1,477,554	$514,000	$547,000
40.05	Site structures including retaining walls, sound walls (Extension of pedestrian bridge near yard??)	$3,601,689	$315,079	$ -	$ -
40.06	Pedestrian/bike access and accommodation, landscaping	$5,047,049	$ -	$382,000	$248,000
40.07	Road/street mods	$5,507,043	$3,757,296	$3,987,000	$6,111,000
40.08	Temporary Facilities and other	$15,770,916	$ -	$ -	$ -

Table 24 Actual and Predicted Costs – SCC 40 Details					
40	Sitework and Special Conditions	Actual	Entry Into PE	Entry into FD	FFGA
	indirect costs during construction				
		$56,202,050	$21,907,569	$14,466,000	$16,670,000
SCC 40 – 2006 constant Year Dollars		*$50.9 M*	*$23.2 M*	*$12.5 M*	*$12.5 M*

Systems (SCC 50)

The signaling and communications design envisioned at the Entry into PE milestone is vastly different than what was constructed, due in large part to a project audit performed by the State of Virginia. That audit, discussed in more detail in the FFGA – SCC 50 section of this document, resulted in the addition and construction of more robust signal and communications systems. At Entry into PE, the communications and train signaling systems were predicted to be rudimentary, using line-of-sight operations. Public address and closed circuit television (CCTV) systems at stations, fiber optic lines, and a SCADA system for TPSS units were also absent in the Entry into PE design. TPSS units were designed at a reduced in capacity; 750 kilowatt units were utilized in place of the constructed 1 megawatt TPSS's. One TPSS unit, eliminated from the design during the PE phase, was added back to the project during construction. The majority of these value engineering decisions made prior to Entry into PE and largely upheld in the other pre-construction milestones, were revised during construction and recognized in the Actual construction costs.

It should be noted that SCC 50.04 – OCS was predicted with relative accuracy. SCC 50.06 – Fare Collection for the After condition is reflected in the vehicle costs in SCC 70, and therefore is not compared in the SCC 50 discussion.

Accuracy of Predictions and Causes of Differences

This SCC was not accurately predicted by the Entry into PE assumptions. The largest variations are reflected in values for SCC's 50.01 and 50.02.

In SCC 50.03, the Entry into PE milestone estimated approximately $5 million, while the Actual cost for this SCC subcategory is about $500,000. During construction, several TPSS units costing approximately $9 million were coded to SCC 10.01 in Contract 60 (described in the After condition discussion). What is represented in Table 25 reflects a large underestimation of SC 50.03 made at the Entry into PE milestone, as well as a significant miscoding and underrepresentation of SCC 50 Actual construction costs.

Table 25 Actual and Predicted Costs – SCC 50 Details					
50	Systems	Actual	Entry Into PE	Entry into FD	FFGA
50.01	Train Control and signals	$9,690,145	$3,448,620	$2,560,000	$2,484,000
50.02	Traffic signals and crossing protection	$9,712,932	$4,076,269	$4,125,000	$4,870,000

Table 25 Actual and Predicted Costs – SCC 50 Details					
50	Systems	Actual	Entry Into PE	Entry into FD	FFGA
50.03	TPSS	$554,389	$4,717,712	$7,470,000	$ 10,027,000
50.04	OCS	$13,923,516	$11,584,604	$12,751,000	$13,044,000
50.05	Communication	$642,502	$536,606	$550,000	$524,000
50.06	Fare Collection	$ -	$2,216,713	$1,825,000	$1,553,000
50.07	Central Control	$ -	$ -	$ -	$ -
		$34,523,487	$26,580,523	$29,281,000	$32,502,000
SCC 50 – 2006 constant Year Dollars		*$30.7 M*	*$27.6 M*	*$25.6 M*	*$25.6 M*

ROW, Land, Existing Improvements (SCC 60)

The estimate for SCC 60 costs developed at Entry into PE was based mostly on predicted impacts at station locations and lump sum average percentage estimates. These predictions appear to be inaccurate but relatively close to the Actual costs incurred by the project for the parcels encountered. The Entry into PE prediction appears to have failed to account for the dozens of easements, acquisitions, and relocations required for track and utilities. These issues were addressed during construction.

Table 26 Actual and Predicted Costs – SCC 60 Details					
60	ROW, Land, Existing Improvements	Actual	Entry Into PE	Entry into FD	FFGA
60.01	Purchase or lease of real estate (FY05 New Starts cost estimate combined these two line items into "Property Acquisition including Escl & Relocation")	$15,157,193	$10,461,000	$10,305,000	$10,406,000
60.02	Relocation of existing households and businesses	$788,307	$ -	$221,000	$308,000
		$15,945,500	$10,461,000	$10,526,000	$10,714,000
SCC 60 – 2006 constant Year Dollars		*$14.5 M*	*$11.3 M*	*$10.5 M*	*$10.5 M*

Vehicles (SCC 70)

Nine vehicles were assumed through all phases of the Tide project. HRT acquired nine Siemens S70 low-floor light rail vehicles for the project. The Entry into PE estimate predicted that these vehicles could be procured through piggybacking on another order, thus reducing the overall vehicle costs. Purchased under the Charlotte Light Rail Vehicle order, the vehicles were ultimately procured at a competitive price. The original Entry into PE prediction for SCC 70.01 was low; however, when converted into 2006 constant year dollars, the estimate appears to be fairly accurate.

It should be noted that the original Entry into PE prediction included the acquisition of over $3 million in busses. This cost was not recognized in the constructed project.

Table 27 Actual and Predicted Costs – SCC 70 Details					
70	**Vehicles**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
70.01	Light Rail	$36,066,517	$26,557,373	$38,039,000	$36,015,000
70.02	Heavy Rail	$ -	$ -	$ -	$ -
70.03	Commuter Rail	$ -	$ -	$ -	$ -
70.04	Bus	$ -	$3,141,600	$3,825,000	$ -
70.05	Other	$ -	$ -	$ -	$ -
70.06	Non-revenue vehicles	$ -	$ -	$ -	$ -
70.07	Spare parts	$ -	$ -	$ -	$ -
		$36,066,517	$29,698,973	$41,864,000	$36,015,000
SCC 70 – 2006 constant Year Dollars		*$32.7 M*	*$31.7 M*	*$36.8 M*	*$33.4 M*

Professional Services (SCC 80)

SCC 80 costs were utilized throughout the duration of the Tide project. As is shown in Table 28, the Entry into PE predictions was significantly lower than the costs actually incurred during project design and construction in nearly every subcategory. SCC's 80.01 and 80.02 combined proved to be twice the predicted design amount; SCC 80.04 was nearly double the original prediction. When accounting for 2006 constant year dollars, these under-predictions change to 60% of the Actual costs for these SCC's.

The value of SCC 80.04 is likely due in part to the extended duration of construction and continued cost of professional services. Design changes continued throughout the protracted construction schedule, incurring costs for engineering, construction administration, and project management and oversight. Regardless, the Entry into PE underestimated Actual efforts by 40%.

Table 28 Actual and Predicted Costs – SCC 80 Details					
80	**Professional Services**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
80.01	Preliminary Engineering	$8,754,000	$ -	$8,045,000	$9,032,000
80.02	Final Design	$17,323,163	$9,282,435	$8,819,000	$7,738,000
80.03	Project Management for Design and Construction	$21,680,086	$ -	$5,951,000	$5,881,000
80.04	Construction Administration & Management	$13,279,442	$17,626,598	$11,014,000	$10,524,000
80.05	Insurance	$7,975,637	$5,222,827	$5,309,000	$5,745,000
80.06	Legal, Permits, Review Fees by other agencies/cities	$421,318	$1,393,403	$1,155,000	$1,135,000
80.07	Surveys, Testing, Investigation, Inspection	$ -	$ -	$2,075,000	$ -

Table 28 Actual and Predicted Costs – SCC 80 Details					
80	**Professional Services**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
80.08	System Start-up	$7,374,425	$2,000,000	$ -	$2,064,000
		$76,808,071	$35,525,263	$42,368,000	$42,119,000
SCC 80 – 2006 constant Year Dollars		*$71.8 M*	*$38.6 M*	*$40.8 M*	*$40.8 M*

Unallocated Contingency (SCC 90)

SCC 90 – Unallocated Contingency was not utilized in either the Entry into PE or the After milestone.

Table 29 Actual and Predicted Costs – SCC 90 Details					
90	**Unallocated Contingency**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ -	$ -	$11,341,000	$10,757,000
SCC 90 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$10.0 M*	*$10.0 M*

Finance Charges (SCC 100)

SCC 100 – Finance Charges was not utilized in either the Entry into PE or the After milestone.

Table 30 Actual and Predicted Costs – SCC 100 Details					
100	**Finance Charges**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ 51,987	$ -	$5,612,000	$3,938,000
SCC 100 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$4.9 M*	*$4.9 M*

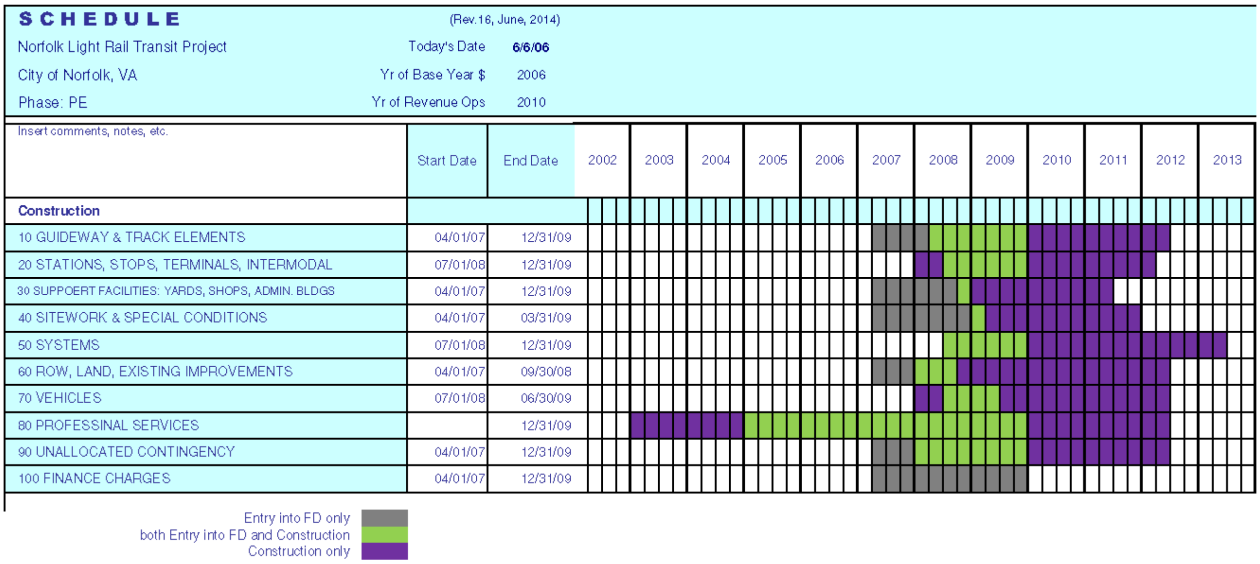
Capital Costs at Entry into Final Design

In 2006, an estimate at $235,317,000 was approved by FTA, allowing the project to enter Final Design (FD). The New Starts Submission for Fiscal Year 2008, shown here as the Entry into FD milestone, still predicted the Tide project to be 7.4 miles long with 11 stations, with start of revenue service (year of operations) assumed to be 2010. Developed in the current FTA format, the Entry into Final Design estimate was established in SCC codes.

The tables in this section reflect YOE dollars as documented on the New Starts application spreadsheets submitted to FTA for the various milestones, compared to actual costs. When necessary, findings of note are also discussed with respect to 2006 constant year dollars, as shown in Tables A and C. Since inflation and other values have not be developed specifically for sub-categories of the SCC's, the overall 2006 constant dollar value for the SCC's was applied to all of the individual sub-categories. This data is referenced as needed for items of note, in an effort to not over- or understate the importance of the difference in predicted versus actual values for individual SCC sub-categories.

The schedule developed for the Entry into FD milestone shifted the predicted construction duration to occur between beginning of 2007 and end of 2009. Compared to the prediction made at Entry into PE, this estimation more closely represented the actual construction duration of four years. The prediction of opening service in 2009 proved inaccurate compared to actual revenue service beginning in 2011.

Table 31
Project Entry into FD Schedule compared to Actual Construction Schedule



Guideway and Track Elements (SCC 10)

The project limits of the Tide system remained relatively consistent with the previous milestone, having approximately 7.4 miles of ballasted and embedded double track corridor. Predicted costs from Entry into FD remained consistent with those shown in the Entry into PE milestone, but distributed to more subcategories. When accounting for 2006 constant year dollars, Entry into FD values totaled nearly $5 million less than the previous milestone.

Table 32
Actual and Predicted Costs – SCC 10 Details

10	Guideway and Track Elements	Actual	Entry Into PE	Entry into FD	FFGA
10.01	At-Grade exclusive ROW	$ 28,674,685	$ 10,929,459	$ 4,664,000	$ 5,276,000
10.02	At-Grade semi-exclusive	$ 10,643	$ -	$ 5,846,000	$ 6,893,000
10.03	At-Grade in mixed traffic	$ (12,600)	$ -	$ -	$ -
10.04	Aerial structure	$ 25,570,861	$ 27,851,545	$ 18,235,000	$ 16,339,000
10.05	Built-up Fill	$ 123,201	$ -	$ -	$ -
10.06	Underground cut & cover	$ -	$ -	$ -	$ -

Table 32 Actual and Predicted Costs – SCC 10 Details					
10	Guideway and Track Elements	Actual	Entry Into PE	Entry into FD	FFGA
10.07	Underground tunnel	$ -	$ -	$ -	$ -
10.08	Retained cut or fill	$ 5,219,571	$ -	$ 8,101,000	$ 7,678,000
10.09	Track: direct fixation	$ 7,430,559	$ 1,179,227	$ 2,521,000	$ 3,052,000
10.10	Track: embedded	$ 9,221,255	$ 2,499,330	$ 5,644,000	$ 5,270,000
10.11	Track: ballasted	$ 3,942,933	$ 8,932,044	$ 10,803,000	$ 10,087,000
10.12	Track: Special (switches)	$ 2,976,829	$ 2,095,400	$ 1,398,000	$ 1,501,000
10.13	Track: vibration and noise damp.	$ 585,212	$ -	$ -	$ -
		$ 83,743,148	$ 53,487,005	$ 57,211,000	$ 56,096,000
SCC 10 – 2006 constant Year Dollars		*$75.8 M*	*$56.7 M*	*$52.0 M*	*$52.0 M*

Entry into FD SCC 10.04 – Aerial Structure costs was greatly reduced from the previous Entry into PE milestone, which appears to have been an originally conservative prediction. Shortly after the Entry into FD time point, the project design in the Harbor Park area was altered as part of a value engineering exercise, where retaining walls and fill material were replaced with an aerial structure to reduce costs. These savings are reflected in the FFGA estimate. The Entry into FD milestone was the closest prediction for SCC 10.04 costs.

Accuracy of Predictions and Causes of Differences

While the Entry into FD total value for SCC 10 was consistent with the predictions made at Entry into PE, it remained short of the costs recognized in the After condition. Incongruities were seen in subcategories 10.01, 10.09, and 10.10, suggesting that predictions for embedded and ballasted track costs were underestimated. It should be noted that Entry into FD cost predictions were inaccurate in a manner consistent with those shown in the Entry into PE milestone, and when accounting for 2006 constant year dollars, the underestimation of Entry into FD costs was greater than that seen in the Entry into PE predictions. Pricing inaccuracies may have been a factor; however, it is likely that schedule delays encountered throughout the duration of construction were the primary impact on this prediction. Construction difficulties are discussed in more detail in the "Capital Costs at FFGA" section of this report.

Stations, Stops, Terminals, Intermodal (SCC 20)

At Entry into FD, the Tide project continues to include eleven stations along the alignment. The FD condition includes the single car platforms shown in the Entry into PE plan, and not the two-car platform ultimately constructed at the NSU station. The costs for sitework were not captured under this SCC during construction (represented in the Actual values); many of these costs are included in SCC 10, contributing to the large discrepancies shown in Table 33.

Shown in SCC 20.01, the predicted costs have decreased by approximately $3.4 million as compared to the Entry into PE. With stop platform civil elements attributed to SCC 10 (mentioned above), comparisons to SCC 20.01 are difficult.

Additional anticipated costs for elevators were identified at this milestone for the NSU station.

Accuracy of Predictions and Causes of Differences
The construction costs documented in the After milestone assigned most station construction values to SCC 10 subcategories, and therefore recognized only minor costs in SCC 20. In contrast, the Entry into FD condition assigned these values to three SCC 20 subcategories. The Entry into FD predicted SCC 20 value was nearly $5.7 million – notably less than the Entry into PE prediction and very similar to that made during FFGA. However, an accurate comparison to the After condition cannot be made due to the reasons previously discussed. One prediction that can be compared is that of SCC 20.07 – Elevators, Escalators. The constructed cost recognized in the After condition is significantly higher than the predicted values.

Table 33
Actual and Predicted Costs – SCC 20 Details

20	Stations, Stops, Terminals, Intermodal	Actual	Entry Into PE	Entry into FD	FFGA
20.01	At-grade station, stop, shelter, mall, terminal, platform (FY05 New Starts cost estimate combined stations and park-and-rides)	$ 179,749	$ 7,668,404	$ 4,219,000	$ 4,285,000
20.02	Aerial station, stop, shelter, mall, terminal, platform	$ 65,620	$ 1,019,228	$ 1,250,000	$ 1,188,000
20.03	Underground station, stop, shelter, mall, terminal, platform	$ -	$ -	$ -	$ -
20.04	Other stations, landings, terminals: Intermodal, ferry, trolley, etc.	$ 70,708	$ -	$ -	$ -
20.05	Joint Development	$ -	$ -	$ -	$ -
20.06	Automobile parking multi-story structure	$ -	$ -	$ -	$ -
20.07	Elevators, escalators	$ 689,738	$ -	$ 187,000	$ 198,000
		$ 1,005,816	$8,687,632	$ 5,657,000	$ 5,671,000
SCC 20 – 2006 constant Year Dollars		*$0.9 M*	*$9.1 M*	*$5.2 M*	*$5.2 M*

Support Facilities: Yards, Shops, Administrative Buildings (SCC 30)
The predicted costs at Entry into FD were based on similar assumptions made in the Entry into PE estimate, however, the overall cost of SCC 30 increased by approximately $4.8 million. This increase, included under SCC 30.05 – Yard Trackwork, likely represents an increased level of detail for the design as many of the quantities and proposed construction elements did not change. This value was still an overestimation of the Actual costs recognized.

Table 34 Actual and Predicted Costs – SCC 30 Details					
30	**Support Facilities: Yards, Shops, Terminals**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
30.01	Admin bldg: Office, sales, storage, revenue counting	$42,000	$ -	$ -	$ -
30.02	Light Maintenance Facility ("Shops and Equipment" in FY05 New Starts)	$9,826,072	$9,641,256	$8,270,000	$9,240,000
30.03	Heavy Maintenance Facility	$ -	$ -	$ -	$ -
30.04	Storage or Maintenance of Way Building	$49,697	$ -	$ -	$ -
30.05	Yard Trackwork	$2,435,809	$2,499,080	$8,721,000	$8,380,000
		$12,353,579	$12,140,336	$16,991,000	$17,620,000
SCC 30 – 2006 constant Year Dollars		*$11.3 M*	*$12.7 M*	*$15.4 M*	*$15.4 M*

Sitework & Special Conditions (SCC 40)

Entry into FD is the lowest milestone for SCC 40 values in either the submitted or 2006 constant year dollar prediction, representing only two thirds of the Entry into PE value and predicting only one quarter of the After condition costs. There are many areas of significant cost deviations, most notably SCC 40.01, 40.02, and 40.08. As discussed in the As-Built section of this report, SCC 40 inherited many project costs incurred during construction. It seems apparent that these items, likely including earthwork, demolition, environmental mitigation, real estate, and utility relocation costs, were not included, or were significantly underestimated, in the Entry into FD estimate.

Table 35 Actual and Predicted Costs – SCC 40 Details					
40	**Sitework and Special Conditions**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
40.01	Demolition, Clearing, Earthwork (includes "Yard Sitework" from FY05 New Starts)	$7,760,031	$2,027,802	$703,000	$662,000
40.02	Site Utilities, Utility Relocation	$15,515,744	$14,329,839	$7,340,000	$7,579,000
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	$876,771	$ -	$1,540,000	$1,523,000
40.04	Environmental Mitigation, e.g. wetlands, historic/archeological, parks	$2,122,803	$1,477,554	$514,000	$547,000
40.05	Site structures including retaining walls, sound walls (Extension of pedestrian bridge near yard??)	$3,601,689	$315,079	$ -	$ -
40.06	Pedestrian/bike access and accommodation, landscaping	$5,047,049	$ -	$382,000	$248,000

Table 35 Actual and Predicted Costs – SCC 40 Details					
40	**Sitework and Special Conditions**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
40.07	Road/street mods	$5,507,043	$3,757,296	$3,987,000	$6,111,000
40.08	Temporary Facilities and other indirect costs during construction	$15,770,916	$ -	$ -	$ -
		$56,202,050	$21,907,569	$14,466,000	$16,670,000
SCC 40 – 2006 constant Year Dollars		*$50.9 M*	*$23.2 M*	*$12.5 M*	*$12.5 M*

Systems (SCC 50)

The Entry into FD Physical Scope for the signaling and communications system at this milestone is consistent with the Entry into PE assumptions but vastly different than what was constructed in the After condition. Variations were anticipated in both the Traction Power and OCS subcategories between Entry into PE and Entry into FD, however, neither milestone anticipated the signaling system and crossing protection ultimate constructed.

Note that the difference of approximately $5.3 million between the Entry into FD and After condition is not accurate, as approximately $9 million in traction power substation costs were included under different SCC codes during project construction.

Table 36 Actual and Predicted Costs – SCC 50 Details					
50	**Systems**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
50.01	Train Control and signals	$9,690,145	$3,448,620	$2,560,000	$2,484,000
50.02	Traffic signals and crossing protection	$9,712,932	$4,076,269	$4,125,000	$4,870,000
50.03	TPSS	$554,389	$4,717,712	$7,470,000	$ 10,027,000
50.04	OCS	$13,923,516	$11,584,604	$12,751,000	$13,044,000
50.05	Communication	$642,502	$536,606	$550,000	$524,000
50.06	Fare Collection	$ -	$2,216,713	$1,825,000	$1,553,000
50.07	Central Control	$ -	$ -	$ -	$ -
		$34,523,487	$26,580,523	$29,281,000	$32,502,000
SCC 50 – 2006 constant Year Dollars		*$30.7 M*	*$27.6 M*	*$25.6 M*	*$25.6 M*

ROW, Land, Existing Improvements (SCC 60)

Entry into FD predictions for real estate needs on the project were nearly identical to those made at Entry into PE. The predicted amount remained stable however, when accounting for 2006 constant year dollars; it appears that the moderate increase in submitted prediction value was insufficient to address inflation costs encountered over this period. This initial Entry into FD estimation of project costs in SCC 60.02 ultimately was insufficient for the needs of the project.

Table 37 Actual and Predicted Costs – SCC 60 Details					
60	ROW, Land, Existing Improvements	Actual	Entry Into PE	Entry into FD	FFGA
60.01	Purchase or lease of real estate (FY05 New Starts cost estimate combined these two line items into "Property Acquisition including Escl & Relocation")	$15,157,193	$10,461,000	$10,305,000	$10,406,000
60.02	Relocation of existing households and businesses	$788,307		$221,000	$308,000
		$15,945,500	$10,461,000	$10,526,000	$10,714,000
SCC 60 – 2006 constant Year Dollars		*$14.5 M*	*$11.3 M*	*$10.5 M*	*$10.5 M*

Vehicles (SCC 70)

HRT assumed nine vehicles at all phases of the project, including Entry into FD. The overestimated costs represented at this milestone are inflated from the original Entry into PE value, presumably with the assumption that HRT may need to purchase vehicles independently. It is understood that HRT was later able to obtain the vehicles at a reduced rate by piggybacking on Charlotte's Siemen's S-70 order. This real reduction in project costs is most visible when comparing the Entry into FD and After milestones.

Table 38 Actual and Predicted Costs – SCC 70 Details					
70	Vehicles	Actual	Entry Into PE	Entry into FD	FFGA
70.01	Light Rail	$36,066,517	$26,557,373	$38,039,000	$36,015,000.00
70.02	Heavy Rail	$ -	$ -	$ -	$ -
70.03	Commuter Rail	$ -	$ -	$ -	$ -
70.04	Bus	$ -	$3,141,600	$3,825,000	$ -
70.05	Other	$ -	$ -	$ -	$ -
70.06	Non-revenue vehicles	$ -	$ -	$ -	$ -
70.07	Spare parts	$ -	$ -	$ -	$ -
		$36,066,517	$29,698,973	$41,864,000	$36,015,000
SCC 70 – 2006 constant Year Dollars		*$32.7 M*	*$31.7 M*	*$36.8 M*	*$33.4 M*

Professional Services (SCC 80)

The Entry into FD milestone predicted an overall increase in SCC 80 costs when compared to the Entry into PE milestone. Subcategory 80.08 – Start-up and Testing was noticeably absent from this prediction. This milestone did not predict the intense Professional Services costs recognized during construction and at the After milestone.

Table 39 Actual and Predicted Costs – SCC 80 Details					
80	Professional Services	Actual	Entry Into PE	Entry into FD	FFGA
80.01	Preliminary Engineering	$8,754,000	$ -	$8,045,000	$9,032,000

Table 39 Actual and Predicted Costs – SCC 80 Details					
80	**Professional Services**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
80.02	Final Design	$17,323,163	$9,282,435	$8,819,000	$7,738,000
80.03	Project Management for Design and Construction	$21,680,086	$ -	$5,951,000	$5,881,000
80.04	Construction Administration & Management	$13,279,442	$17,626,598	$11,014,000	$10,524,000
80.05	Insurance	$7,975,637	$5,222,827	$5,309,000	$5,745,000
80.06	Legal, Permits, Review Fees by other agencies/cities	$421,318	$1,393,403	$1,155,000	$1,135,000
80.07	Surveys, Testing, Investigation, Inspection	$ -	$ -	$2,075,000	$ -
80.08	System Start-up	$7,374,425	$2,000,000	$ -	$2,064,000
		$76,808,071	$35,525,263	$42,368,000	$42,119,000
SCC 80 – 2006 constant Year Dollars		*$71.8 M*	*$38.6 M*	*$40.8 M*	*$40.8 M*

Unallocated Contingency (SCC 90)
Unallocated Contingency was identified and included in the Entry into FD milestone as 5% of overall project cost, an insufficient amount to cover the unanticipated costs encountered during construction.

Table 40 Actual and Predicted Costs – SCC 90 Details					
90	**Unallocated Contingency**	**Actual (After)**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ -	$ -	$11,341,000	$10,757,000
SCC 90 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$10.0 M*	*$10.0 M*

Finance Charges (SCC 100)
Entry into FD estimated finance charges to be approximately 2% of project costs. Only a nominal amount of funds was ultimately used in this SCC.

Table 41 Actual and Predicted Costs – SCC 100 Details					
100	**Finance Charges**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ 51,987	$ -	$5,612,000	$3,938,000
SCC 100 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$4.9 M*	*$4.9 M*

Capital Costs at Full Funding Grant Agreement

In general, the capital costs identified at receipt of FFGA are very similar to those defined in the Entry into FD, with a total project cost estimate set at $232,102,000. The physical scope and corresponding capital cost estimate of the project remained relatively unchanged from the previous milestone, with the very similar predictions of final project costs as were utilized in the Entry into FD estimate.

The FFGA Capital Cost time point represents the final estimate of capital costs prior to beginning of construction. The Full Funding Grant Agreement was approved by FTA on October 1, 2007. After this date, plans were immediately finalized, bid, and conformed. Construction on the first project contract – Contract 20 – began only a few months later, on January 14th, 2008.

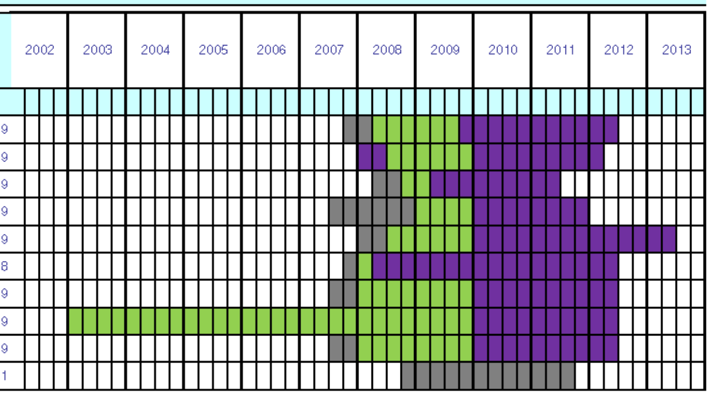
The schedule developed for the FFGA shifted and shortened the predicted construction duration slightly from that proposed at the Entry into FD milestone, while maintaining the previously stated opening date in 2009. Construction durations were reduced to 2.5 years, to occur between mid-2007 and end of 2009. This prediction at FFGA proved inaccurate compared to the actual construction duration. Utility coordination, construction delays, rights-of-way acquisition, and change orders extended the construction duration from the predicted opening in early 2010 to late 2011.

Table 42
FFGA Schedule compared to Actual Construction Schedule

SCHEDULE (Rev.16, June, 2014)

Norfolk Light Rail Transit Project	Today's Date	**10/1/07**
City of Norfolk, VA	Yr of Base Year $	2006
Phase: PE	Yr of Revenue Ops	2010

Insert comments, notes, etc.	Start Date	End Date
Construction		
10 GUIDEWAY & TRACK ELEMENTS	10/01/07	09/30/09
20 STATIONS, STOPS, TERMINALS, INTERMODAL	07/01/08	12/31/09
30 SUPPOERT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	04/01/08	03/31/09
40 SITEWORK & SPECIAL CONDITIONS	07/01/07	12/31/09
50 SYSTEMS	01/01/08	12/31/09
60 ROW, LAND, EXISTING IMPROVEMENTS	10/01/07	03/31/08
70 VEHICLES	07/01/07	12/31/09
80 PROFESSINAL SERVICES	01/01/03	12/31/09
90 UNALLOCATED CONTINGENCY	07/01/07	12/31/09
100 FINANCE CHARGES	10/01/08	09/30/11



FFGA only
both FFGA and Construction
Construction only

Contracts 10 and 20 were released for construction in early 2008. Contract 30 was issued shortly thereafter; however, construction progress was halted due to utility relocation and right-of-way issues. The impact this early delay in the construction phase had on the overall project schedule was not fully realized due to the fact that there was no fully integrated construction schedule developed for the project at that time. The interaction between the various contracts and contractors was not fully understood until much later in the construction phase.

The tables in this section reflect YOE dollars as documented on the New Starts application spreadsheets submitted to FTA for the various milestones, compared to actual costs. When necessary, findings of note are also discussed with respect to 2006 constant year dollars, as shown in Tables A and C. Since inflation and other values have not be developed specifically for sub-categories of the SCC's, the overall 2006 constant dollar value for the SCC's was applied to all of the individual sub-categories. This data is referenced as needed for items of note, in an effort to not over- or understate the importance of the difference in predicted versus actual values for individual SCC sub-categories.

Guideway and Track Elements (SCC 10)

The project limits of the Tide system remained relatively consistent throughout the project milestones, having approximately 7.4 miles of ballasted and embedded double track corridor. Cost variations between the milestones during project design reflect an increase in detail and definition, and continue to be incongruous with the After costs recognized on the project.

FFGA 10.04 – Aerial Structure costs were reduced from the previous milestones due to a change in the design. An elevated section of track designed to be retaining walls and structural fill between Brambleton and Holt Street was revised to be an open deck structure with almost no fill. This new design reduced the estimated cost, accounting for the reduction shown between Entry into FD and FFGA. These savings were not recognized in the After condition, likely primarily due to project delays.

Table 43
Actual and Predicted Costs – SCC 10 Details

10	Guideway and Track Elements	Actual	Entry Into PE	Entry into FD	FFGA
10.01	At-Grade exclusive ROW	$ 28,674,685	$ 10,929,459	$ 4,664,000	$ 5,276,000
10.02	At-Grade semi-exclusive	$ 10,643	$ -	$ 5,846,000	$ 6,893,000
10.03	At-Grade in mixed traffic	$ (12,600)	$ -	$ -	$ -
10.04	Aerial structure	$ 25,570,861	$ 27,851,545	$ 18,235,000	$ 16,339,000
10.05	Built-up Fill	$ 123,201	$ -	$ -	$ -
10.06	Underground cut & cover	$ -	$ -	$ -	$ -
10.07	Underground tunnel	$ -	$ -	$ -	$ -
10.08	Retained cut or fill	$ 5,219,571	$ -	$ 8,101,000	$ 7,678,000
10.09	Track: direct fixation	$ 7,430,559	$ 1,179,227	$ 2,521,000	$ 3,052,000
10.10	Track: embedded	$ 9,221,255	$ 2,499,330	$ 5,644,000	$ 5,270,000
10.11	Track: ballasted	$ 3,942,933	$ 8,932,044	$ 10,803,000	$ 10,087,000
10.12	Track: Special (switches)	$ 2,976,829	$ 2,095,400	$ 1,398,000	$ 1,501,000
10.13	Track: vibration and noise damp.	$ 585,212	$ -	$ -	$ -
		$ 83,743,148	$ 53,487,005	$ 57,211,000	$ 56,096,000
SCC 10 – 2006 Constant Year Dollars		*$75.8 M*	*$56.7 M*	*$52.0 M*	*$52.0 M*

Accuracy of Predictions and Causes of Differences:

While the FFGA total value for SCC 10 was consistent with the predictions made at Entry into FD, it remained short of the costs recognized in the After condition. As with the Entry into FD, variances were apparent in subcategories 10.01, 10.09, and 10.10. However, even when accounting for extra items (such as the TPSS units in 10.01), both embedded and ballasted track installation costs were underestimated. This is likely due to project design changes during construction, as discussed in the "After" section of this report.

Concerning project bids, contractor bid prices were relatively in line with engineering estimates for the first two contracts addressing structural construction and wetland remediation / installation. The first unit bid prices noticeably inconsistent with engineer expectations were those of bridge track and ballast track in Contracts 30 and 40. These costs are shown in subcategories 10.01 and 10.04.

Stations, Stops, Terminals, Intermodal (SCC 20)

The Tide project includes eleven stations along the alignment at both the After and FFGA milestones. Originally envisioned with single car platforms, a two-car platform was ultimately constructed at the NSU station. The costs for the sitework were not captured under this SCC in the After condition; many of these costs are included in SCC 40 (see As-Built section above), contributing to the large discrepancies shown in Table 44.

Table 44
Actual and Predicted Costs – SCC 20 Details

20	Stations, Stops, Terminals, Intermodal	Actual	Entry Into PE	Entry into FD	FFGA
20.01	At-grade station, stop, shelter, mall, terminal, platform (FY05 New Starts cost estimate combined stations and park-and-rides)	$ 179,749	$ 7,668,404	$ 4,219,000	$ 4,285,000
20.02	Aerial station, stop, shelter, mall, terminal, platform	$ 65,620	$ 1,019,228	$ 1,250,000	$ 1,188,000
20.03	Underground station, stop, shelter, mall, terminal, platform	$ -	$ -	$ -	$ -
20.04	Other stations, landings, terminals: Intermodal, ferry, trolley, etc.	$ 70,708	$ -	$ -	$ -
20.05	Joint Development	$ -	$ -	$ -	$ -
20.06	Automobile parking multi-story structure	$ -	$ -	$ -	$ -
20.07	Elevators, escalators	$ 689,738	$ -	$ 187,000	$ 198,000
		$ 1,005,816	$8,687,632	$ 5,657,000	$ 5,671,000
SCC 20 – 2006 constant Year Dollars		*$0.9 M*	*$9.1 M*	*$5.2 M*	*$5.2 M*

Improved site furnishings, including a substitution of unique shelters in place of prefabricated structures, and upgrades to proposed railings, were required by the City of Norfolk and included in the project for approval through the design review process and Planning Commission. Accommodations were also made for NSU at their station. The university requested the elevator location be moved to the west side of Brambleton Avenue, from the east side shown in the project plans. The request was made during construction, and was implemented by HRT. The resulting redesign and revised construction costs ultimately added an additional $4 million to the project. These items were not included in the FFGA.

Accuracy of Predictions and Causes of Differences

Construction costs for the After condition were not accurately predicted in the FFGA. As stated previously, values represented in SCC 20 for the After condition do not appear to include concrete sitework for platforms, curb, ramps, and other various civil construction elements. Costs predicted in the FFGA estimate mimic those presented in the Entry into FD milestone.

Support Facilities: Yards, Shops, Administrative Buildings (SCC 30)

The predictions made for the Norfolk Tide project during Entry into PE and Entry into FD were largely carried into the FFGA milestone. These pre-construction predictions did not include some of the ultimately-required costly elements of the site. A brick façade and associated enhanced foundations for the building, as well as a "stinger" traction power system ultimately installed and utilized to move vehicles in the shop building, were not identified in the FFGA but were added to the project scope and cost during construction. Several retaining walls were also removed from the design as part of a value engineering proposal, slightly reducing the SCC 30 costs.

Originally envisioned as a simple structure, a brick façade was added to the NTF design during construction at the request of the City of Norfolk and NSU during negotiations for obtaining project right-of-way. The weight of the added brick façade necessitated additional design efforts, increasing construction costs and delaying work until the summer of 2011. It was this delay and the delivery of light rail vehicles prior to completion of the facility that required work to be removed from Contract 80 and later issued as Contracts 180 and 230. This enabled the light rail vehicles to be stored and tested in a separate temporary facility during NTF completion. These three contracts total $173,382, of which $49,697 is coded to SCC 30.04. The separate facility at Sewell's Point, located on a former rail spur near Moseley Creek, includes a tail track and temporary shelter building which is still retained and maintained by HRT.

Table 45
Actual and Predicted Costs – SCC 30 Details

30	Support Facilities: Yards, Shops, Terminals	Actual	Entry Into PE	Entry into FD	FFGA
30.01	Admin bldg: Office, sales, storage, revenue counting	$42,000	$ -	$ -	$ -
30.02	Light Maintenance Facility ("Shops and Equipment" in FY05 New Starts)	$9,826,072	$9,641,256	$8,270,000	$9,240,000
30.03	Heavy Maintenance Facility	$ -	$ -	$ -	$ -
30.04	Storage or Maintenance of Way Building	$49,697	$ -	$ -	$ -
30.05	Yard Trackwork	$2,435,809	$2,499,080	$8,721,000	$8,380,000
		$12,353,579	$12,140,336	$16,991,000	$17,620,000
SCC 30 – 2006 constant Year Dollars		*$11.3 M*	*$12.7 M*	*$15.4 M*	*$15.4 M*

Sitework & Special Conditions (SCC 40)

The FFGA milestone, while not having the lowest predicted estimate for SCC 40, did not accurately predict the ultimate costs associated with the Sitework and Special Conditions. This milestone represented only about one quarter of the costs ultimately recognized in SCC 40 in the After milestone (a similar value when accounting for 2006 constant year dollars), which includes significantly higher costs for Demolition and Earthwork (SCC 40.01) among other SCC's.

Change orders recognized in SCC 40 totaled over $12.6 million and more than 380 days in contract delays. These costs and delays are attributable to a number of factors, most notably the mitigation of asbestos encountered with the demolition of the Kirn Library and Baylor buildings for project construction, unsuitable subsurface (soil) condition issues and overrunning of fill material quantities encountered on both Contracts 40 and 40A on track and roadway construction, and the large delays incumbent upon the issuance of Contract 40. When this contract was ultimately awarded, HRT could only release the contractor to perform construction at the end-of-line near EVMC, in and around Harbor Park, and the bridge over Smith Creek near Brambleton Avenue. Due to continued real estate acquisition and ongoing utility relocation prior to contract award, nearly all other locations on the project were unavailable to the contractor.

In addition to the challenges noted above, several SCC 40 items were added to or expanded upon during the construction phase. The demolition of several buildings and the resulting mitigation of asbestos delayed the project schedule and added to project costs. Noise abatement, in the form of sound walls, was constructed for at least one park-and-ride facility. Other items, such as the delayed design and real estate acquisition for two parking facilities, exacerbated the impacts to SCC 40 subcategories.

Utility cost assumptions were based on a city franchise agreement, meaning the project had virtually no estimated cost for the relocation of private utilities. This assumption proved inaccurate as it did not account for the power feed needs of the new traction power substations, power meters for train and traffic signal cabinets, and other power feed needs resulting from the project. Additionally, a large transmission duct bank was ultimately needed by Dominion Virginia Power to maintain service to the city and the new light rail line. Months of delays and several million dollars in utility costs not anticipated by or included in the FFGA were recognized in the After project.

Table 46
Actual and Predicted Costs – SCC 40 Details

40	Sitework and Special Conditions	Actual	Entry Into PE	Entry into FD	FFGA
40.01	Demolition, Clearing, Earthwork (includes "Yard Sitework" from FY05 New Starts)	$7,760,031	$2,027,802	$703,000	$662,000
40.02	Site Utilities, Utility Relocation	$15,515,744	$14,329,839	$7,340,000	$7,579,000
40.03	Hazmat, contaminated soil removal/mitigation, ground water treatments	$876,771	$ -	$1,540,000	$1,523,000
40.04	Environmental Mitigation, e.g. wetlands, historic/archeological, parks	$2,122,803	$1,477,554	$514,000	$547,000
40.05	Site structures including retaining walls, sound walls (Extension of pedestrian bridge near yard??)	$3,601,689	$315,079	$ -	$ -
40.06	Pedestrian/bike access and accommodation, landscaping	$5,047,049	$ -	$382,000	$248,000

Table 46 Actual and Predicted Costs – SCC 40 Details					
40	**Sitework and Special Conditions**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
40.07	Road/street mods	$5,507,043	$3,757,296	$3,987,000	$6,111,000
40.08	Temporary Facilities and other indirect costs during construction	$15,770,916	$ -	$ -	$ -
		$56,202,050	$21,907,569	$14,466,000	$16,670,000
SCC 40 – 2006 Constant Year Dollars		*$50.9 M*	*$23.2 M*	*$12.5 M*	*$12.5 M*

As mentioned in the After section of this memo, the predicted scope and schedule of SCC 40 work proved to be inaccurate during construction, and in turn contributed to some of the project financial overruns encountered. Predicted to be constructed between mid-2007 and the end of 2009, the actual construction schedule for SCC 40 items was not finished until beginning of revenue service in August of 2011.

Systems (SCC 50)

The project cost developed at FFGA reflected a system that functioned on line-of-sight operations. This type of operation is much less expensive than other train control systems typically used on light rail systems. The need for a more sophisticated communications system became apparent early in the construction process. Acting upon direction provided in the Draft *Norfolk Light Rail Project Assessment*, dated October 23, 2008 (Commonwealth of Virginia Department of Rail and Public Transportation), HRT issued an official change order for the inclusion of train control and communication items in 2010. Completion of the conduit network and installation of the communication system occurred in 2011 immediately prior to opening of the system. These items were not included in the FFGA document or cost estimate.

The Tide project was constructed with a communications and signaling system at the direction of the Virginia Department of Rail and Public Transportation (DRPT). Elements implemented with this change order include a SCADA system connecting the operations center to the TPSS units, a communications duct bank, and basic train control systems. As a result, SCC 50 items recognized a significant cost increase. The signaling and communications predicted costs at this milestone are vastly different than what was constructed, as is shown in SCC 50.01 and 50.02.

The total SCC 50 capital costs for the FFGA and After milestones do not reflect the large difference in overall SCC costs. The apparent FFGA milestone overestimations in SCC 50.03 – TPSS and SCC 50.06 – Fare Collection balance out the large underestimations shown in SCC 50.01 and 50.02. However, as discussed earlier, nearly $10 million in Actual costs were coded to SCC’s 10 and 70 rather than to SCC 50.03 and 50.06. When $9 million in TPSS costs from SCC 10 in the After condition are factored into the table below, the costs identified in the FFGA SCC 50.03 appear to provide a more accurate prediction of the Actual costs recognized in the SCC subcategory. Additionally, once that additional $10 million is included in this SCC, the overall value was significantly underestimated at the FFGA milestone.

Table 47 Actual and Predicted Costs – SCC 50 Details					
50	**Systems**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
50.01	Train Control and signals	$9,690,145	$3,448,620	$2,560,000	$2,484,000
50.02	Traffic signals and crossing protection	$9,712,932	$4,076,269	$4,125,000	$4,870,000
50.03	TPSS	$554,389	$4,717,712	$7,470,000	$ 10,027,000
50.04	OCS	$13,923,516	$11,584,604	$12,751,000	$13,044,000
50.05	Communication	$642,502	$536,606	$550,000	$524,000
50.06	Fare Collection	$ -	$2,216,713	$1,825,000	$1,553,000
50.07	Central Control	$ -	$ -	$ -	$ -
		$34,523,487	$26,580,523	$29,281,000	$32,502,000
SCC 50 – 2006 Constant Year Dollars		*$30.7 M*	*$27.6 M*	*$25.6 M*	*$25.6 M*

ROW, Land, Existing Improvements (SCC 60)

FFGA predictions for real estate needs on the project were nearly identical to those made at Entry into PE and Entry into FD. Real estate needs for utility relocations, the NSU station, and other corridor sites, were acquired during construction and not during the design process, resulting in project delays and additional costs. Envisioned to be performed between October 2007 and March 2008 in the FFGA application, this work occurred throughout the duration of construction. The purchase of right-of-way, and corresponding challenges to do so during construction, led to the redesign and relocation of project features such as two park-and-ride sites. Consequently, the FFGA estimate under-predicted the Actual cost for SCC 60 by a wide margin (over 30% when comparing in 2006 constant year dollars).

Table 48 Actual and Predicted Costs – SCC 60 Details					
60	**ROW, Land, Existing Improvements**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
60.01	Purchase or lease of real estate (FY05 New Starts cost estimate combined these two line items into "Property Acquisition including Escl & Relocation")	$15,157,193	$10,461,000	$10,305,000	$10,406,000
60.02	Relocation of existing households and businesses	$788,307		$221,000	$308,000
		$15,945,500	$10,461,000	$10,526,000	$10,714,000
SCC 60 – 2006 Constant Year Dollars		*$14.5 M*	*$11.3 M*	*$10.5 M*	*$10.5 M*

Vehicles (SCC 70)

As predicted in all of the project milestones, HRT acquired nine Siemens S70 low-floor light rail vehicles for the project. Purchased under the Charlotte Light Rail Vehicle order, the vehicles were delivered to HRT prior to completion of the NTF, requiring installation of a temporary shelter and utilization of a temporary test track so that HRT could "burn in" the vehicles. Note that no spare parts were included in the project construction contracts, but rather, were acquired through a separate contract directly between HRT and the vehicle supplier, allowing HRT staff to select the desired spare parts and maintenance equipment for the entire system. This value, included as a subsection of "Start-Up and Pre-Revenue Operations" in final project accounting, is included under SCC 80.08 – System Start-Up. The value of the "parts and materials" is approximately $1.4 million. SCC 70 was accurately predicted, with a minor variation becoming apparent in the 2006 constant year dollar comparison.

Table 49
Actual and Predicted Costs – SCC 70 Details

70	Vehicles	Actual	Entry Into PE	Entry into FD	FFGA
70.01	Light Rail	$36,066,517	$26,557,373	$38,039,000	$36,015,000.00
70.02	Heavy Rail	$ -	$ -	$ -	$ -
70.03	Commuter Rail	$ -	$ -	$ -	$ -
70.04	Bus	$ -	$3,141,600	$3,825,000	$ -
70.05	Other	$ -	$ -	$ -	$ -
70.06	Non-revenue vehicles	$ -	$ -	$ -	$ -
70.07	Spare parts	$ -	$ -	$ -	$ -
		$36,066,517	$29,698,973	$41,864,000	$36,015,000
SCC 70 – 2006 constant Year Dollars		*$32.7 M*	*$31.7 M*	*$36.8 M*	*$33.4 M*

Professional Services (SCC 80)

SCC 80 items were utilized throughout the duration of the Tide project. HRT anticipated substantial Construction Administration and Management support from consultants, as is shown in SCC 80.03 and 80.04. The predicted needs at FFGA proved to be inaccurate. The extent of support needed by HRT during construction with respect to project design, management, and inspection, greatly exceeded the budgets anticipated in the FFGA milestone. HRT, as an agency, experienced difficulty in overall project controls both in design and construction phases. Agency oversight of budget and schedules was delegated to team members performing the work. Challenges arising from this approach were not fully addressed until February 2010, when HRT removed the consultant project management team and assumed full control of project oversight, management, and administration. A fully integrated HRT-endorsed staffing plan for all project contracts needs was only developed when HRT assumed full project control. Combined with inherent additional Professional Services costs from the extended schedule, HRT recognized additional SCC 80 costs due to the management challenges described above.

Table 50
Actual and Predicted Costs – SCC 80 Details

80	Professional Services	Actual	Entry Into PE	Entry into FD	FFGA
80.01	Preliminary Engineering	$8,754,000	$ -	$8,045,000	$9,032,000
80.02	Final Design	$17,323,163	$9,282,435	$8,819,000	$7,738,000
80.03	Project Management for Design and Construction	$21,680,086	$ -	$5,951,000	$5,881,000
80.04	Construction Administration & Management	$13,279,442	$17,626,598	$11,014,000	$10,524,000

Table 50 Actual and Predicted Costs – SCC 80 Details					
80	**Professional Services**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
80.05	Insurance	$7,975,637	$5,222,827	$5,309,000	$5,745,000
80.06	Legal, Permits, Review Fees by other agencies/cities	$421,318	$1,393,403	$1,155,000	$1,135,000
80.07	Surveys, Testing, Investigation, Inspection	$ -	$ -	$2,075,000	$ -
80.08	System Start-up	$7,374,425	$2,000,000	$ -	$2,064,000
		$76,808,071	$35,525,263	$42,368,000	$42,119,000
SCC 80 – 2006 constant Year Dollars		*$71.8 M*	*$38.6 M*	*$40.8 M*	*$40.8 M*

Unallocated Contingency (SCC 90)

The Unallocated Contingency for the project was set at 5% at the FFGA milestone, equating to $10,757,000 (approximately $10 million in 2006 constant year dollars). Nearly all of the project contracts were bid and awarded with no contingency held by HRT. The third contract issued by HRT was Contract 40. Awarded in mid-2008, the contract value exceeded the HRT budget by approximately $17 million, accounting for the entire total available project contingency less than six months into the construction phase. The predictions made in all of the pre-construction milestones did not account for the costs recognized by the project in the After condition.

Table 51 Actual and Predicted Costs – SCC 90 Details					
90	**Unallocated Contingency**	**Actual (After)**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ -	$ -	$11,341,000	$10,757,000
SCC 90 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$10.0 M*	*$10.0 M*

Finance Charges (SCC 100)

The FFGA milestone (as well as the Entry into FD milestone) anticipated Finance Charges for the project totaling around 2% of the project value. Only a nominal amount was recognized in the final construction project.

Table 52 Actual and Predicted Costs – SCC 100 Details					
100	**Finance Charges**	**Actual**	**Entry Into PE**	**Entry into FD**	**FFGA**
		$ 51,987	$ -	$5,612,000	$3,938,000
SCC 100 – 2006 constant Year Dollars		*$0.0 M*	*$0.0 M*	*$4.9 M*	*$4.9 M*

Conclusions and Lessons Learned

The Capital Costs Technical Memorandum has summarized the as-built condition and corresponding costs for the Hampton Roads Transit Light Rail Transit Project, also known as The Tide, as well as the capital cost predictions made at three pre-construction milestones: Entry into PE, Entry into FD, and at the FFGA. This memo has also described the accuracy of predictions made at those milestones as compared to the final recognized project capital costs.

The final recognized Capital Costs of the Hampton Roads Transit Light Rail Transit Project, also known as The Tide, was $315,755, 511. This figure, finalized in 2014, accounts for all Standard Cost Categories as defined by FTA for the project, including Professional Services and Finance Charges. This final capital cost recognized in the After condition is significantly different than the predictions made during the Entry into Preliminary Engineering, Entry into Final Design, and Full Funding Grant Agreement milestones, which varied between $198 and $235 million. When accounting for inflation and adjusting costs into 2006 constant year dollars, these pre-construction predictions appear to be consistently 21% to 25% below the final recognized project cost. Inaccuracies in predictions are seen in several standard cost categories, most notably SCC 10 – Guideway and Track Elements, SCC 40 – Sitework and Special Conditions, and SCC 80 – Professional Services. Inflation and overall project duration did impact the capital cost predictions, but when accounting for a constant year of expenditure, unit prices and scope changes had the largest impact.

Assumptions incorporated in the cost forecasts through each phase of project development were based on the best information available at the time and served as justifiable estimates in the Tide Light Rail financial plan; however, some key factors dramatically affected the construction cost and schedule. The predicted physical scope of the project did not significantly change through the course of the pre-construction milestones; however, the project scope did evolve during the construction phase. Many of the cost variations during construction can be attributed to three factors: schedule delays and claims, the addition of physical scope items during construction, and project documentation and controls. These and other lessons learned are described in detail in a letter from HRT to FTA dated December 17, 2012, and also included in the Project Management Plan, Revised Nineteen December 2012.

With respect to Capital Costs, some important findings and lessons learned include:

Schedule

The project construction schedule greatly exceeded the duration predicted in design. Possible mitigation of schedule challenges could include development and maintenance of a master project schedule that monitors the progress of all contracts and contractors from receipt of FFGA to completion of construction. Additionally, addressing project unknowns ahead of construction through advanced Utility Relocation contracts and by purchasing of right-of-way and easements could have addressed or mitigated project delay issues. HRT is committed to actively monitoring program schedules in a holistic manner on all future work.

Design Scope versus Constructed Infrastructure

Several project items appear to have been unresolved during the design process but included in the constructed project after FFGA, resulting in changes during the construction phase and contributing to the inaccuracies of cost predictions. Major assumptions made before Entry into PE for the purpose of reducing project capital costs, such as removal of a train signaling system and operational control center. Many of these assumptions were proved to inaccurate during construction and were added back into the project. These reintroduced items, accompanied by other items added during construction, account for the largest amount of discrepancy between actual and predicted capital costs. HRT is committed to sharing project details, including base assumptions, designs, and budgets, with stakeholders throughout the design and construction phases of future projects, in an effort to identify and address scope and capital costs issues before they become an issue.

Project Documentation and FTA Requirements

Both the HRT internal staff and consultant team struggled with FTA documentation requirements and strict adherence to the FFGA. The resulting construction documentation resulted in some confusion in monitoring capital costs during project execution and in post-construction accounting. As a lesson learned, and in an effort to mitigate this issue on future projects, HRT intends to pursue improved oversight and specific direction FTA, specifically with respect to base assumptions made at the beginning of the project. HRT has already expanded staff resources to include experience in the construction of major transit corridors in order to better vet base project assumptions while bringing familiarity with FTA processes and FFGA requirements. With expanded in-house resources and FTA involvement, HRT will be able to efficiently direct their consultant team and effectively manage future projects.

Appendix 1

Hampton Roads Transit - After Study - Capital Costs Technical Memorandum

Analysis of capital costs predicted at the milestones: Entry into PE, Entry into FD, and FFGA

SOURCE	Components: Dollar Year	Components: Total Cost	Components: Inflation Rates	Components: Expend Sched	Calc	Annual Costs ($ millions): Total	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Notes
ACTUAL	YOE	actual	actual	actual	A	314.6	0.0	3.7	3.7	3.7	3.7	7.5	40.6	75.3	73.1	70.6	30.0	2.1	0.4	0.0	0.0	Actual $YOE costs from the "actual" tab
DERIVED	2003	actual	actual	actual	B	242.6	0.0	3.7	3.5	3.4	3.2	6.3	32.7	58.8	55.6	52.1	21.6	1.5	0.3	0.0	0.0	Actual $YOE costs from A translated to constant $2003
DERIVED	2006	actual	actual	actual	C	281.0	0.0	4.3	4.1	3.9	3.7	7.3	37.9	68.1	64.4	60.3	25.0	1.7	0.3	0.0	0.0	Actual $YOE costs from A translated to constant $2006
DERIVED	2007	actual	actual	actual	D	288.7	0.0	4.4	4.2	4.0	3.8	7.5	38.9	70.0	66.2	62.0	25.7	1.8	0.3	0.0	0.0	Actual $YOE costs from A translated to constant $2007
PE ENTRY	2003	pred	pred	pred	E	182.0	0.0	3.3	10.3	48.6	63.4	54.5	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Predicted $2003 costs from the 'e2pe' tab
PE ENTRY	YOE	pred	pred	pred	F	198.3	0.0	3.3	10.7	51.5	69.3	61.4	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Predicted $YOE costs from the 'e2pe' tab
DERIVED	YOE	actual	pred	pred	G	264.4	0.0	4.5	14.2	68.7	92.4	81.8	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2003 in D inflated with pred rates & pred sched
DERIVED	YOE	actual	actual	pred	H	278.6	0.0	4.5	14.7	72.0	97.9	86.5	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2003 in D inflated with act rates & pred sched
DERIVED	YOE	actual	actual	actual	I	314.6	0.0	3.7	3.7	3.7	3.7	7.5	40.6	75.3	73.1	70.6	30.0	2.1	0.4	0.0	0.0	$YOE costs from $2003 in C inflated with act rates & act sched
Pred - Actual	Total cost ($2003)				E - B	-60.7	0.0	-0.4	6.8	45.2	60.2	48.2	-31.8	-57.9	-55.6	-52.1	-21.6	-1.5	-0.3	0.0	0.0	PvA difference in $2003 costs
Pred - Actual	Total cost ($YOE)				F - A	-116.3	0.0	-0.4	6.9	47.8	65.5	53.9	-39.6	-74.2	-73.1	-70.6	-30.0	-2.1	-0.4	0.0	0.0	PvA difference in $YOE costs
Pred - Actual	-caused by scope/unit-cost differences				F - G	-66.1	0.0	-1.1	-3.6	-17.2	-23.1	-20.5	-0.4	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Component of difference caused by $2003 differences
Pred - Actual	-caused by inflation-rate differences				G - H	-14.2	0.0	0.0	-0.5	-3.3	-5.5	-4.7	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Component of difference caused by inflation-rate differences
Pred - Actual	-caused by schedule differences				H - I	-36.0	0.0	0.7	10.9	68.3	94.1	79.0	-39.1	-73.8	-73.1	-70.6	-30.0	-2.1	-0.4	0.0	0.0	Component of difference caused by schedule differences
FD ENTRY	2006	pred	pred	pred	E	213.6	0.0	0.0	0.0	7.8	0.2	14.7	59.7	110.4	20.7	0.0	0.0	0.0	0.0	0.0	0.0	Predicted $2006 costs from the 'e2fd' tab
FD ENTRY	YOE	pred	pred	pred	F	235.3	0.0	0.0	0.0	7.6	0.2	15.2	64.4	123.8	24.1	0.0	0.0	0.0	0.0	0.0	0.0	Predicted $YOE costs from the 'e2fd' tab
DERIVED	YOE	actual	pred	pred	G	309.5	0.0	0.0	0.0	9.9	0.3	20.0	84.8	162.8	31.7	0.0	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2006 in D inflated with pred rates & pred sched
DERIVED	YOE	actual	actual	pred	H	330.5	0.0	0.0	0.0	11.2	0.3	21.4	90.9	173.3	33.4	0.0	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2006 in D inflated with act rates & pred sched
DERIVED	YOE	actual	actual	actual	I	314.6	0.0	3.7	3.7	3.7	3.7	7.5	40.6	75.3	73.1	70.6	30.0	2.1	0.4	0.0	0.0	$YOE costs from $2006 in C inflated with act rates & act sched
Pred - Actual	Total cost ($2006)				E - B	-29.1	0.0	-3.7	-3.5	4.5	-3.0	8.4	27.0	51.6	-34.9	-52.1	-21.6	-1.5	-0.3	0.0	0.0	PvA difference in $2006 costs
Pred - Actual	Total cost ($YOE)				F - A	-79.3	0.0	-3.7	-3.7	3.8	-3.5	7.8	23.8	48.5	-49.0	-70.6	-30.0	-2.1	-0.4	0.0	0.0	PvA difference in $YOE costs
Pred - Actual	-caused by scope/unit-cost differences				F - G	-74.2	0.0	0.0	0.0	-2.4	-0.1	-4.8	-20.3	-39.0	-7.6	0.0	0.0	0.0	0.0	0.0	0.0	Component of difference caused by $2006 differences
Pred - Actual	-caused by inflation-rate differences				G - H	-20.9	0.0	0.0	0.0	-1.3	0.0	-1.4	-6.1	-10.5	-1.7	0.0	0.0	0.0	0.0	0.0	0.0	Component of difference caused by inflation-rate differences
Pred - Actual	-caused by schedule differences				H - I	15.9	0.0	-3.7	-3.7	7.5	-3.4	13.9	50.3	98.0	-39.8	-70.6	-30.0	-2.1	-0.4	0.0	0.0	Component of difference caused by schedule differences
FFGA	2007	pred	pred	pred	E	221.3	0.0	0.0	0.0	7.8	0.0	5.9	67.3	106.6	32.9	0.9	0.0	0.0	0.0	0.0	0.0	Predicted $2007 costs from the 'ffga' tab
FFGA	YOE	pred	pred	pred	F	232.1	0.0	0.0	0.0	7.8	0.0	5.9	68.9	113.0	35.5	1.0	0.0	0.0	0.0	0.0	0.0	Predicted $YOE costs from the 'ffga' tab
DERIVED	YOE	actual	pred	pred	G	302.8	0.0	0.0	0.0	10.1	0.0	7.7	89.9	147.4	46.4	1.3	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2007 in D inflated with pred rates & pred sched
DERIVED	YOE	actual	actual	pred	H	307.1	0.0	0.0	0.0	9.5	0.0	7.7	91.6	149.6	47.5	1.3	0.0	0.0	0.0	0.0	0.0	$YOE costs from $2007 in D inflated with act rates & pred sched
DERIVED	YOE	actual	actual	actual	I	314.6	0.0	3.7	3.7	3.7	3.7	7.5	40.6	75.3	73.1	70.6	30.0	2.1	0.4	0.0	0.0	$YOE costs from $2007 in C inflated with act rates & act sched
Pred - Actual	Total cost ($2007)				E - B	-67.4	0.0	-4.4	-4.2	3.8	-3.8	-1.6	28.3	36.6	-33.2	-61.1	-25.7	-1.8	-0.3	0.0	0.0	PvA difference in $2007 costs
Pred - Actual	Total cost ($YOE)				F - A	-82.5	0.0	-3.7	-3.7	4.0	-3.7	-1.6	28.3	37.7	-37.6	-69.6	-30.0	-2.1	-0.4	0.0	0.0	PvA difference in $YOE costs
Pred - Actual	-caused by scope/unit-cost differences				F - G	-70.7	0.0	0.0	0.0	-2.4	0.0	-1.8	-21.0	-34.4	-10.8	-0.3	0.0	0.0	0.0	0.0	0.0	Component of difference caused by $2007 differences
Pred - Actual	-caused by inflation-rate differences				G - H	-4.3	0.0	0.0	0.0	0.7	0.0	0.0	-1.7	-2.1	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	Component of difference caused by inflation-rate differences
Pred - Actual	-caused by schedule differences				H - I	-7.5	0.0	-3.7	-3.7	5.7	-3.7	0.2	50.9	74.3	-25.6	-69.3	-30.0	-2.1	-0.4	0.0	0.0	Component of difference caused by schedule differences

Milestone	From year to year with specified annual rates of inflation		Dollar conversion factors: 2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Notes	
Dollar conversions for PE entry	This year to 2003 using predicted rates	---	1.000	1.000	0.971	0.943	0.915	0.888	0.863	0.837	0.806	0.781	0.756	0.732	0.709	0.687	0.665	To translate normalized $YOE predicted costs to $2003	
	This year to 2003 using actual rates	---	1.024	1.000	0.941	0.899	0.864	0.840	0.806	0.781	0.761	0.737	0.719	0.701	0.682	0.664	0.646	To translate $YOE actual costs to $2003	
	2003 to this year using predicted rates	---	1.000	1.000	1.030	1.061	1.093	1.126	1.159	1.194	1.240	1.281	1.322	1.365	1.410	1.455	1.503	To replicate inflation effects predicted at e2pe	predicted
	2003 to this year using actual rates	---	0.977	1.000	1.063	1.112	1.158	1.190	1.241	1.280	1.315	1.356	1.390	1.426	1.467	1.507	1.547	To translate $2003 actual and predicted costs to $YOE	actual
Dollar conversions for E2FD	This year to 2006 using predicted rates	---	1.173	1.173	1.173	1.173	1.104	1.039	1.000	0.963	0.927	0.892	0.859	0.832	0.806	0.780	0.756	To translate normalized $YOE predicted costs to $2006	
	This year to 2006 using actual rates	---	1.186	1.158	1.089	1.041	1.000	0.973	0.933	0.904	0.881	0.854	0.833	0.812	0.789	0.769	0.748	To translate $YOE actual costs to $2006	
	2006 to this year using predicted rates	---	0.852	0.852	0.852	0.852	0.906	0.963	1.000	1.039	1.079	1.121	1.164	1.202	1.241	1.281	1.323	To replicate inflation effects predicted at e2fd	
	2006 to this year using actual rates	---	0.844	0.864	0.918	0.961	1.000	1.028	1.072	1.106	1.136	1.171	1.201	1.232	1.267	1.301	1.336	To translate $2006 actual and predicted costs to $YOE	
Dollar conversions for FFGA	This year to 2007 using predicted rates	---	0.971	1.000	1.000	1.000	1.000	1.000	0.976	0.943	0.927	0.892	0.859	0.832	0.806	0.780	0.756	To translate normalized $YOE predicted costs to $2007	
	This year to 2007 using actual rates	---	1.218	1.190	1.120	1.070	1.028	1.000	0.959	0.930	0.905	0.877	0.856	0.834	0.811	0.790	0.769	To translate $YOE actual costs to $2007	
	2007 to this year using predicted rates	---	1.030	1.000	1.000	1.000	1.000	1.000	1.024	1.060	1.079	1.121	1.164	1.202	1.241	1.281	1.323	To replicate inflation effects predicted at ffga	
	2007 to this year using actual rates	---	0.821	0.840	0.893	0.935	0.973	1.000	1.043	1.076	1.105	1.140	1.168	1.198	1.233	1.266	1.300	To translate $2007 actual and predicted costs to $YOE	

		dollar weights: $const	dollar weights: $YOE		dollar weights: $const	dollar weights: $YOE
Dollar-weighted mid-point of expenditure	actual	2009.5	2009.6		Jun09	Feb09
	e2pe	2005.9	2005.9	=	Nov05	Jan06
	e2fd	2008.5	2008.6		Jun08	Sep08
	ffga	2008.7	2008.7		Jun08	Jun08

M A I N W O R K S H E E T - B U I L D A L T E R N A T I V E

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project		Today's Date	8/28/03
City of Norfolk, VA		Yr of Base Year $	2003
Phase: PE		Yr of Revenue Ops	2007

	Quantity	Base Year Dollars w/o Contingency (X000)	Base Year Dollars Allocated Contingency (X000)	Base Year Dollars TOTAL (X000)	Base Year Dollars Unit Cost (X000)	Base Year Dollars Percentage of Construction Cost	Base Year Dollars Percentage of Total Project Cost	YOE Dollars Total (X000)
10 GUIDEWAY & TRACK ELEMENTS (route miles)	**5.50**	48,955	-	**48,955**	**8,901**	**44%**	**27%**	**53,485**
10.01 Guideway: At-grade exclusive right-of-way	4.90	10,003		10,003	2,041			10,929
10.02 Guideway: At-grade semi-exclusive (allows cross-traffic)				-				-
10.03 Guideway: At-grade in mixed traffic				-				-
10.04 Guideway: Aerial structure	0.60	25,492		25,492	42,487			27,851
10.05 Guideway: Built-up fill				-				-
10.06 Guideway: Underground cut & cover				-				-
10.07 Guideway: Underground tunnel				-				-
10.08 Guideway: Retained cut or fill				-				-
10.09 Track: Direct fixation		1,079		1,079				1,179
10.10 Track: Embedded		2,287		2,287				2,499
10.11 Track: Ballasted		8,175		8,175				8,932
10.12 Track: Special (switches, turnouts)		1,918		1,918				2,095
10.13 Track: Vibration and noise dampening				-				-
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	**11**	7,833	-	**7,833**	**712**	**7%**	**4%**	**8,687**
20.01 At-grade station, stop, shelter, mall, terminal, platform	10	6,915		6,915	691			7,668
20.02 Aerial station, stop, shelter, mall, terminal, platform	1	919		919	919			1,019
20.03 Underground station, stop, shelter, mall, terminal, platform				-				-
20.04 Other stations, landings, terminals: Intermodal, ferry, trolley, etc.				-				-
20.05 Joint development				-				-
20.06 Automobile parking multi-story structure				-				-
20.07 Elevators, escalators				-				-
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	5.50	10,948	-	**10,948**	**1,990**	**10%**	**6%**	**12,140**
30.01 Administration Building: Office, sales, storage, revenue counting				-				-
30.02 Light Maintenance Facility		8,694		8,694				9,641
30.03 Heavy Maintenance Facility				-				-
30.04 Storage or Maintenance of Way Building				-				-
30.05 Yard and Yard Track		2,254		2,254				2,499
40 SITEWORK & SPECIAL CONDITIONS	5.50	20,054	-	**20,054**	**3,646**	**18%**	**11%**	**21,908**
40.01 Demolition, Clearing, Earthwork		1,856		1,856				2,028
40.02 Site Utilities, Utility Relocation		13,118		13,118				14,330
40.03 Haz. mat'l, contam'd soil removal/mitigation, ground water treatments				-				-
40.04 Environmental mitigation, e.g. wetlands, historic/archeologic, parks		1,353		1,353				1,478
40.05 Site structures including retaining walls, sound walls		288		288				315
40.06 Pedestrian / bike access and accommodation, landscaping				-				-
40.07 Automobile, bus, van accessways including roads, parking lots		3,439		3,439				3,757
40.08 Temporary Facilities and other indirect costs during construction				-				-
50 SYSTEMS	5.50	23,831	-	**23,831**	**4,333**	**21%**	**13%**	**26,582**
50.01 Train control and signals		3,092		3,092				3,449
50.02 Traffic signals and crossing protection		3,654		3,654				4,076
50.03 Traction power supply: substations		4,230		4,230				4,718
50.04 Traction power distribution: catenary and third rail		10,386		10,386				11,585
50.05 Communications		481		481				537
50.06 Fare collection system and equipment		1,988		1,988				2,217
50.07 Central Control		-		-				-
Construction Subtotal (10 - 50)	5.50	111,621	-	**111,621**	**20,295**	**100%**	**61%**	**122,802**
60 ROW, LAND, EXISTING IMPROVEMENTS	5.50	9,789	-	**9,789**	**1,780**		**5%**	**10,461**
60.01 Purchase or lease of real estate		9,789	-	9,789				10,461
60.02 Relocation of existing households and businesses				-				-
70 VEHICLES (number)	**20**	27,387	-	**27,387**	**1,369**		**15%**	**29,698**
70.01 Light Rail	9	24,491	-	24,491	2,721			26,557
70.02 Heavy Rail				-				-
70.03 Commuter Rail				-				-
70.04 Bus	11	2,897		2,897	263			3,141
70.05 Other				-				-
70.06 Non-revenue vehicles				-				-
70.07 Spare parts				-				-
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	5.50	33,378	-	**33,378**	**6,069**	**30%**	**18%**	**35,313**
80.01 Project Development				-				-
80.02 Engineering		8,721		8,721				9,226
80.03 Project Management for Design and Construction				-				-
80.04 Construction Administration & Management		16,562		16,562				17,522
80.05 Professional Liability and other Non-Construction Insurance		4,907		4,907				5,192
80.06 Legal; Permits; Review Fees by other agencies, cities, etc.		1,309		1,309				1,385
80.07 Surveys, Testing, Investigation, Inspection		-		-				-
80.08 Start up		1,879		1,879				1,988
Subtotal (10 - 80)	5.50	182,175	-	**182,175**	**33,123**		**100%**	**198,274**
90 UNALLOCATED CONTINGENCY				**-**			**0%**	**-**
Subtotal (10 - 90)	5.50			**182,175**	**33,123**		**100%**	**198,274**
100 FINANCE CHARGES				**-**			**0%**	**-**
Total Project Cost (10 - 100)	5.50			**182,175**	**33,123**		**100%**	**198,274**
Allocated Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Unallocated Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Total Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Unallocated Contingency as % of Subtotal (10 - 80)				0.00%				
YOE Construction Cost per Mile (X000)								22,328
YOE Total Project Cost per Mile Not Including Vehicles (X000)								30,650
YOE Total Project Cost per Mile (X000)								36,050

INFLATION WORKSHEET

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project

City of Norfolk, VA

Phase: PE

Today's Date **8/28/03**

Yr of Base Year $ 2003

Yr of Revenue Ops 2007

Insert comments, notes, etc.

BASE YEAR DOLLARS (X$000)	Base Yr Dollars	Double-Check Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	48,955	48,957	0	0	0	0	-	12,604	24,473	11,880	-	-		0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	7,833	7,834	0	0	0	0	-	-	3,975	3,859	-	-		0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	10,948	10,948	0	0	0	0	-	-	5,555	5,393	-	-		0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	20,054	20,054	0	0	0	0	-	6,195	8,020	5,839	-	-		0	0	0	0	0	0
50 SYSTEMS	23,831	23,830	0	0	0	0	-	-	7,298	16,532	-	-		0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	9,789	9,789	0	0	0	0	-	7,395	2,393	-	-	-		0	0	0	0	0	0
70 VEHICLES (number)	27,387	27,388	0	0	0	0	-	13,997	6,794	6,597	-	-		0	0	0	0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	33,378	33,166	0	0	0	3,340	10,347	8,371	4,877	4,419	919	893		0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	-	-	0	0	0	0	-	-	-	-	-	-		0	0	0	0	0	0
100 FINANCE CHARGES	-	-	0	0	0	0	-	-	-	-	-	-		0	0	0	0	0	0
Total Project Cost (10 - 100)	182,175	181,966	**0**	**0**	**0**	**3,340**	**10,347**	**48,562**	**63,385**	**54,520**	**919**	**893**	**-**	**0**	**0**	**0**	**0**	**0**	**0**
Inflation Rate			0.00000	0.00000	0.00000	0.00000	0.03000	0.03000	0.03000	0.03000	0.03000	0.03000	0.03874	0.03250	0.03250	0.03250	0.03250	0.03250	0.03250
Compounded Inflation Factor			1.0000	1.0000	1.0000	1.0000	1.0300	1.0609	1.0927	1.1255	1.1593	1.1941	1.2403	1.2806	1.3222	1.3652	1.4096	1.4554	1.5027
YEAR OF EXPENDITURE DOLLARS (X$000)	YOE Dollars		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	53,485		0	0	0	0	-	13,371	26,743	13,371	-	-	-	0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	8,687		0	0	0	0			4,344	4,344			-	0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	12,140		0	0	0	0			6,070	6,070			-	0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	21,908		0	0	0	0		6,572	8,763	6,572			-	0		0	0	0	0
50 SYSTEMS	26,582		0	0	0	0			7,975	18,607			-	0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	10,461		0	0	0	0		7,846	2,615				-	0	0	0	0	0	0
70 VEHICLES (number)	29,698		0	0	0	0		14,849	7,425	7,425			-	0	0	0	0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	35,313		0	0	0	3,340	10,658	8,881	5,329	4,974	1,066	1,066	-	0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	-		0	0	0	0							-	0	0	0	0	0	0
100 FINANCE CHARGES	-		0	0	0	0							-	0	0	0	0	0	0
Total Project Cost (10 - 100)	198,274		**0**	**0**	**0**	**3,340**	**10,658**	**51,520**	**69,262**	**61,363**	**1,066**	**1,066**	**-**	**0**	**0**	**0**	**0**	**0**	**0**

M A I N W O R K S H E E T - B U I L D A L T E R N A T I V E

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project	Today's Date	**6/6/06**
City of Norfolk, VA	Yr of Base Year $	2006
Phase: PE	Yr of Revenue Ops	2010

	Quantity	Base Year Dollars w/o Contingency (X000)	Base Year Dollars Allocated Contingency (X000)	Base Year Dollars TOTAL (X000)	Base Year Dollars Unit Cost (X000)	Base Year Dollars Percentage of Construction Cost	Base Year Dollars Percentage of Total Project Cost	YOE Dollars Total (X000)
10 GUIDEWAY & TRACK ELEMENTS (route miles)	**7.40**	46,203	5,755	**51,958**	**7,021**	**47%**	**24%**	**57,212**
10.01 Guideway: At-grade exclusive right-of-way	4.90	3,683	552	4,235	864			4,664
10.02 Guideway: At-grade semi-exclusive (allows cross-traffic)	1.50	4,617	693	5,310	3,540			5,847
10.03 Guideway: At-grade in mixed traffic				-				-
10.04 Guideway: Aerial structure	0.60	14,401	2,160	16,561	27,602			18,236
10.05 Guideway: Built-up fill				-				-
10.06 Guideway: Underground cut & cover				-				-
10.07 Guideway: Underground tunnel				-				-
10.08 Guideway: Retained cut or fill	0.40	6,688	669	7,357	18,394			8,101
10.09 Track: Direct fixation		2,081	206	2,287				2,518
10.10 Track: Embedded		4,660	466	5,126				5,644
10.11 Track: Ballasted		8,919	892	9,811				10,803
10.12 Track: Special (switches, turnouts)		1,154	115	1,269				1,397
10.13 Track: Vibration and noise dampening				-				-
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	**11**	4,476	729	**5,205**	**473**	**5%**	**2%**	**5,656**
20.01 At-grade station, stop, shelter, mall, terminal, platform	10	3,326	556	3,882	388			4,218
20.02 Aerial station, stop, shelter, mall, terminal, platform	1	1,000	150	1,150	1,150			1,250
20.03 Underground station, stop, shelter, mall, terminal, platform				-				-
20.04 Other stations, landings, terminals: Intermodal, ferry, trolley, etc.				-				-
20.05 Joint development				-				-
20.06 Automobile parking multi-story structure				-				-
20.07 Elevators, escalators		150	23	173				188
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	7.40	13,991	1,399	**15,390**	**2,080**	**14%**	**7%**	**16,992**
30.01 Administration Building: Office, sales, storage, revenue counting				-				-
30.02 Light Maintenance Facility		6,810	681	7,491				8,271
30.03 Heavy Maintenance Facility				-				-
30.04 Storage or Maintenance of Way Building				-				-
30.05 Yard and Yard Track		7,181	718	7,899				8,721
40 SITEWORK & SPECIAL CONDITIONS	7.40	10,953	1,546	**12,499**	**1,689**	**11%**	**6%**	**14,466**
40.01 Demolition, Clearing, Earthwork		528	79	607				703
40.02 Site Utilities, Utility Relocation		5,515	827	6,342				7,340
40.03 Haz. mat'l, contam'd soil removal/mitigation, ground water treatments		1,210	121	1,331				1,540
40.04 Environmental mitigation, e.g. wetlands, historic/archeologic, parks		404	40	444				514
40.05 Site structures including retaining walls, sound walls				-				-
40.06 Pedestrian / bike access and accommodation, landscaping		300	30	330				382
40.07 Automobile, bus, van accessways including roads, parking lots		2,996	449	3,445				3,987
40.08 Temporary Facilities and other indirect costs during construction				-				-
50 SYSTEMS	7.40	22,380	3,205	**25,585**	**3,457**	**23%**	**12%**	**29,280**
50.01 Train control and signals		1,945	292	2,237				2,560
50.02 Traffic signals and crossing protection		3,134	470	3,604				4,125
50.03 Traction power supply: substations		5,676	851	6,527				7,470
50.04 Traction power distribution: catenary and third rail		9,688	1,453	11,141				12,750
50.05 Communications		418	63	481				550
50.06 Fare collection system and equipment		1,519	76	1,595				1,825
50.07 Central Control				-				-
Construction Subtotal (10 - 50)	7.40	98,003	12,634	**110,638**	**14,951**	**100%**	**52%**	**123,606**
60 ROW, LAND, EXISTING IMPROVEMENTS	7.40	10,461	-	**10,461**	**1,414**		**5%**	**10,526**
60.01 Purchase or lease of real estate		10,241	-	10,241				10,305
60.02 Relocation of existing households and businesses		220		220				221
70 VEHICLES (number)	**10**	36,618	160	**36,778**	**3,678**		**17%**	**41,864**
70.01 Light Rail	9	33,418	-	33,418	3,713			38,039
70.02 Heavy Rail				-				-
70.03 Commuter Rail				-				-
70.04 Bus	1	3,200	160	3,360	3,360			3,825
70.05 Other				-				-
70.06 Non-revenue vehicles				-				-
70.07 Spare parts				-				-
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	7.40	38,601	2,234	**40,835**	**5,518**	**37%**	**19%**	**42,368**
80.01 Project Development		7,754	-	7,754				8,045
80.02 Engineering		8,500	-	8,500				8,819
80.03 Project Management for Design and Construction		5,214	521	5,735				5,950
80.04 Construction Administration & Management		9,651	965	10,616				11,015
80.05 Professional Liability and other Non-Construction Insurance		4,652	465	5,117				5,309
80.06 Legal; Permits; Review Fees by other agencies, cities, etc.		1,012	101	1,113				1,155
80.07 Surveys, Testing, Investigation, Inspection		1,818	182	2,000				2,075
80.08 Start up		-	-	-				-
Subtotal (10 - 80)	7.40	183,683	15,029	**198,712**	**26,853**		**93%**	**218,364**
90 UNALLOCATED CONTINGENCY				**9,986**			**5%**	**11,341**
Subtotal (10 - 90)	7.40			**208,698**	**28,202**		**98%**	**229,705**
100 FINANCE CHARGES				**4,884**			**2%**	**5,612**
Total Project Cost (10 - 100)	7.40			**213,582**	**28,862**		**100%**	**235,317**
Allocated Contingency as % of Base Yr Dollars w/o Contingency				8.18%				
Unallocated Contingency as % of Base Yr Dollars w/o Contingency				5.44%				
Total Contingency as % of Base Yr Dollars w/o Contingency				13.62%				
Unallocated Contingency as % of Subtotal (10 - 80)				5.03%				
YOE Construction Cost per Mile (X000)								16,704
YOE Total Project Cost per Mile Not Including Vehicles (X000)								26,142
YOE Total Project Cost per Mile (X000)								31,800

I N F L A T I O N   W O R K S H E E T

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project

City of Norfolk, VA

Phase: PE

Today's Date **6/6/06**

Yr of Base Year $ 2006

Yr of Revenue Ops 2010

Insert comments, notes, etc.

BASE YEAR DOLLARS (X$000)	Base Yr Dollars	Double-Check Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	51,958	52,001	0	0	0	0	0	-	-	-	25,610	26,391	-	0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	5,205	5,176	0	0	0	0	0	-	-	-	3,463	1,712	-	0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	15,390	15,408	0	0	0	0	0	-	-	-	6,645	8,763	-	0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	12,499	13,062	0	0	0	0	0	-	-	-	4,341	8,554	167	0	0	0	0	0	0
50 SYSTEMS	25,585	25,998	0	0	0	0	0	-	-	-	1,642	19,527	4,829	0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	10,461	10,034	0	0	0	0	0	-	-	7,473	2,561	-	-	0	0	0	0	0	0
70 VEHICLES (number)	36,778	37,055	0	0	0	0	0	-	-	-	-	29,394	7,661	0	0	0	0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	40,835	39,776	0	0	0	0	0	7,847	206	7,061	11,778	10,014	2,870	0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	9,986	10,188	0	0	0	0	0	-	-	-	3,405	5,297	1,486	0	0	0	0	0	0
100 FINANCE CHARGES	4,884	4,884	0	0	0	0	0	-	-	125	282	796	3,681	0	0	0	0	0	0
Total Project Cost (10 - 100)	213,582	213,582	**0**	**0**	**0**	**0**	**0**	**7,847**	**206**	**14,660**	**59,727**	**110,449**	**20,695**	**0**	**0**	**0**	**0**	**0**	**0**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Inflation Rate	0.00000	0.00000	0.00000	0.00000	0.06250	0.06250	0.03875	0.03875	0.03875	0.03874	0.03874	0.03250	0.03250	0.03250	0.03250	0.03250	0.03250
Compounded Inflation Factor	0.8523	0.8523	0.8523	0.8523	0.9061	0.9627	1.0000	1.0388	1.0790	1.1208	1.1642	1.2021	1.2411	1.2815	1.3231	1.3661	1.4105

YEAR OF EXPENDITURE DOLLARS (X$000)	YOE Dollars		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	57,212		0	0	0	0	0	-	-	-	27,633	29,579	-	0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	5,656		0	0	0	0	0	-	-	-	3,737	1,919	-	0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	16,992		0	0	0	0	0	-		-	7,170	9,822	-	0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	14,466		0	0	0	0	0	-	-	-	4,684	9,587	195	0		0	0	0	0
50 SYSTEMS	29,280		0	0	0	0	0	-	-	-	1,772	21,886	5,622	0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	10,526		0	0	0	0	0	-	-	7,763	2,763	-	-	0	0	0	0	0	0
70 VEHICLES (number)	41,864		0	0	0	0	0	-	-	-	-	32,945	8,919	0	0	0	0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	42,368		0	0	0	0	0	7,554	206	7,335	12,708	11,224	3,341	0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	11,341		0	0	0	0	0	-	-	-	3,674	5,937	1,730	0	0	0	0	0	0
100 FINANCE CHARGES	5,612		0	0	0	0	0	-	-	130	304	892	4,286	0	0	0	0	0	0
Total Project Cost (10 - 100)	235,317		**0**	**0**	**0**	**0**	**0**	**7,554**	**206**	**15,228**	**64,445**	**123,791**	**24,093**	**0**	**0**	**0**	**0**	**0**	**0**

M A I N W O R K S H E E T - B U I L D A L T E R N A T I V E

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project		Today's Date	10/1/07
City of Norfolk, VA		Yr of Base Year $	2006
Phase: PE		Yr of Revenue Ops	2010

	Quantity	Base Year Dollars w/o Contingency (X000)	Base Year Dollars Allocated Contingency (X000)	Base Year Dollars TOTAL (X000)	Base Year Dollars Unit Cost (X000)	Base Year Dollars Percentage of Construction Cost	Base Year Dollars Percentage of Total Project Cost	YOE Dollars Total (X000)
10 GUIDEWAY & TRACK ELEMENTS (route miles)	**7.42**	47,341	6,237	**53,578**	**7,221**	**44%**	**24%**	**56,097**
10.01 Guideway: At-grade exclusive right-of-way	4.61	4,382	657	5,039	1,093			5,276
10.02 Guideway: At-grade semi-exclusive (allows cross-traffic)	1.50	5,725	859	6,584	4,389			6,893
10.03 Guideway: At-grade in mixed traffic				-				-
10.04 Guideway: Aerial structure	0.83	13,570	2,036	15,606	18,802			16,339
10.05 Guideway: Built-up fill				-				-
10.06 Guideway: Underground cut & cover				-				-
10.07 Guideway: Underground tunnel				-				-
10.08 Guideway: Retained cut or fill	0.48	6,377	957	7,334	15,279			7,678
10.09 Track: Direct fixation		2,650	265	2,915				3,052
10.10 Track: Embedded		4,576	458	5,034				5,270
10.11 Track: Ballasted		8,758	876	9,634				10,087
10.12 Track: Special (switches, turnouts)		1,303	130	1,433				1,501
10.13 Track: Vibration and noise dampening				-				-
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	**11**	4,627	694	**5,322**	**484**	**4%**	**2%**	**5,669**
20.01 At-grade station, stop, shelter, mall, terminal, platform	10	3,498	525	4,023	402			4,285
20.02 Aerial station, stop, shelter, mall, terminal, platform	1	970	145	1,115	1,115			1,188
20.03 Underground station, stop, shelter, mall, terminal, platform		-		-				-
20.04 Other stations, landings, terminals: Intermodal, ferry, trolley, etc.		-		-				-
20.05 Joint development		-		-				-
20.06 Automobile parking multi-story structure		-		-				-
20.07 Elevators, escalators		160	24	184				196
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	7.42	14,662	2,129	**16,791**	**2,263**	**14%**	**8%**	**17,620**
30.01 Administration Building: Office, sales, storage, revenue counting				-				-
30.02 Light Maintenance Facility		7,657	1,149	8,806				9,240
30.03 Heavy Maintenance Facility				-				-
30.04 Storage or Maintenance of Way Building				-				-
30.05 Yard and Yard Track		7,005	981	7,986				8,380
40 SITEWORK & SPECIAL CONDITIONS	7.42	13,897	1,995	**15,892**	**2,142**	**13%**	**7%**	**16,670**
40.01 Demolition, Clearing, Earthwork		549	82	631				662
40.02 Site Utilities, Utility Relocation		6,283	942	7,225				7,579
40.03 Haz. mat'l, contam'd soil removal/mitigation, ground water treatments		1,320	132	1,452				1,523
40.04 Environmental mitigation, e.g. wetlands, historic/archeologic, parks		474	47	521				547
40.05 Site structures including retaining walls, sound walls				-				-
40.06 Pedestrian / bike access and accommodation, landscaping		205	31	236				248
40.07 Automobile, bus, van accessways including roads, parking lots		5,066	760	5,826				6,111
40.08 Temporary Facilities and other indirect costs during construction				-				-
50 SYSTEMS	7.42	26,870	3,891	**30,761**	**4,146**	**25%**	**14%**	**32,503**
50.01 Train control and signals		2,044	307	2,351				2,484
50.02 Traffic signals and crossing protection		4,008	601	4,609				4,870
50.03 Traction power supply: substations		8,252	1,238	9,490				10,027
50.04 Traction power distribution: catenary and third rail		10,735	1,610	12,345				13,044
50.05 Communications		431	65	496				524
50.06 Fare collection system and equipment		1,400	70	1,470				1,553
50.07 Central Control		0	0	-				-
Construction Subtotal (10 - 50)	7.42	107,398	14,946	**122,343**	**16,488**	**100%**	**55%**	**128,558**
60 ROW, LAND, EXISTING IMPROVEMENTS	7.42	10,461	-	**10,461**	**1,410**		**5%**	**10,714**
60.01 Purchase or lease of real estate		10,160		10,160				10,406
60.02 Relocation of existing households and businesses		301		301				308
70 VEHICLES (number)	**9**	33,818	-	**33,818**	**3,758**		**15%**	**36,015**
70.01 Light Rail	9	33,818		33,818	3,758			36,015
70.02 Heavy Rail		-		-				-
70.03 Commuter Rail		-		-				-
70.04 Bus	0	-		-				-
70.05 Other		-		-				-
70.06 Non-revenue vehicles		-		-				-
70.07 Spare parts		-		-				-
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	7.42	37,763	3,059	**40,822**	**5,502**	**33%**	**18%**	**42,119**
80.01 Project Development		8,754		8,754				9,032
80.02 Engineering		6,674	826	7,500				7,738
80.03 Project Management for Design and Construction		5,182	518	5,700				5,881
80.04 Construction Administration & Management		9,273	927	10,200				10,524
80.05 Professional Liability and other Non-Construction Insurance		5,062	506	5,568				5,745
80.06 Legal; Permits; Review Fees by other agencies, cities, etc.		1,000	100	1,100				1,135
80.07 Surveys, Testing, Investigation, Inspection				-				-
80.08 Start up		1,818	182	2,000				2,064
Subtotal (10 - 80)	7.42	189,440	18,005	**207,445**	**27,958**		**94%**	**217,405**
90 UNALLOCATED CONTINGENCY				**10,244**			**5%**	**10,757**
Subtotal (10 - 90)	7.42			**217,689**	**29,338**		**98%**	**228,162**
100 FINANCE CHARGES				**3,637**			**2%**	**3,938**
Total Project Cost (10 - 100)	7.42			**221,325**	**29,828**		**100%**	**232,100**
Allocated Contingency as % of Base Yr Dollars w/o Contingency				9.50%				
Unallocated Contingency as % of Base Yr Dollars w/o Contingency				5.41%				
Total Contingency as % of Base Yr Dollars w/o Contingency				14.91%				
Unallocated Contingency as % of Subtotal (10 - 80)				4.94%				
YOE Construction Cost per Mile (X000)								17,326
YOE Total Project Cost per Mile Not Including Vehicles (X000)								26,427
YOE Total Project Cost per Mile (X000)								31,280

I N F L A T I O N   W O R K S H E E T

(Rev.9, Feb. 6, 2007)

Project Sponsor Name: Norfolk Light Rail Transit Project	Today's Date	5/21/07
Project Name and Location: City of Norfolk, VA	Yr of Base Year $	2007
Current Phase: Applic. For FFGA	Yr of Revenue Ops	2010

Below, show all project costs in the year in which they occurred or are planned to occur through the completion of the project or the fulfillment of the New Starts funding commitment, whichever is expected to occur later in time.

BASE YEAR DOLLARS (X$000)	Base Yr Dollars	Double-Check Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	53,578	53,578	0	0	0	0	0	0	0	0	21,364	29,194	3,020	0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	5,322	5,322	0	0	0	0	0	0	0	0	0	3,948	1,374	0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	16,791	16,791	0	0	0	0	0	0	0	0	5,105	11,686	0	0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	15,892	15,892	0	0	0	0	0	0	0	0	6,444	6,701	2,747	0	0	0	0	0	0
50 SYSTEMS	30,761	30,761	0	0	0	0	0	0	0	0	7,122	16,026	7,613	0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	10,461	10,461	0	0	0	0	0	0	0	0	10,461	0	0	0	0	0	0	0	0
70 VEHICLES (number)	33,818	33,818	0	0	0	0	0	0	0	0	0	25,517	8,301	0	0	0	0	0	0
80 PROFESSIONAL SERVICES	40,822	40,822	0	0	0	0	0	7,754	0	5,890	12,668	8,386	6,124	0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	10,244	10,244	0	0	0	0	0	0	0	0	3,993	4,151	2,100	0	0	0	0	0	0
100 FINANCE CHARGES	3,637	3,637	0	0	0	0	0	0	0	0	112	957	1,667	900	0	0	0	0	0
Total Project Cost (10 - 100)	221,325	221,325	**0**	**0**	**0**	**0**	**0**	**7,754**	**0**	**5,890**	**67,269**	**106,566**	**32,946**	**900**	**0**	**0**	**0**	**0**	**0**

Below insert estimated inflation rates for each year. For 2007 and beyond, the YOE dollars are calculated automatically. For 2006 and previous years, the Base Year dollars are automatically inflated to reflect the value of past expenditures in 2007 dollars.

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Inflation Rate			0.03000	0.03000	0.03000	0.00000	0.00000	0.00000	0.00000	0.02419	0.03535	0.01754	0.03874	0.03874	0.03250	0.03250	0.03250	0.03250	0.03250
Compounded Inflation Factor			1.09273	1.06090	1.03000	1.00000	1.00000	1.00000	1.00000	1.00000	1.02419	1.06039	1.07899	1.12079	1.16421	1.20205	1.24111	1.28145	1.32310

YEAR OF EXPENDITURE DOLLARS (X$000)	YOE Dollars		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	56,097		0	0	0	0	0	0	0	0	21,881	30,957	3,259	0	0	0	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	5,669		0	0	0	0	0	0	0	0	0	4,186	1,483	0	0	0	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	17,620		0	0	0	0	0	0	0	0	5,229	12,392	0	0	0	0	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	16,670		0	0	0	0	0	0	0	0	6,600	7,106	2,964	0	0	0	0	0	0
50 SYSTEMS	32,503		0	0	0	0	0	0	0	0	7,294	16,994	8,214	0	0	0	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	10,714		0	0	0	0	0	0	0	0	10,714	0	0	0	0	0	0	0	0
70 VEHICLES (number)	36,015		0	0	0	0	0	0	0	0	0	27,058	8,957	0	0	0	0	0	0
80 PROFESSIONAL SERVICES	42,119		0	0	0	0	0	7,754	0	5,890	12,974	8,892	6,608	0	0	0	0	0	0
90 UNALLOCATED CONTINGENCY	10,757		0	0	0	0	0	0	0	0	4,090	4,402	2,266	0	0	0	0	0	0
100 FINANCE CHARGES	3,938		0	0	0	0	0	0	0	0	115	1,015	1,799	1,009	0	0	0	0	0
Total Project Cost (10 - 100)	232,100		**0**	**0**	**0**	**0**	**0**	**7,754**	**0**	**5,890**	**68,897**	**113,002**	**35,548**	**1,009**	**0**	**0**	**0**	**0**	**0**

Norfolk Light Rail Transit Project
Categorization of Project Costs FFGA & Concurrent Non-FFGA

Contract	Bid Items Original FFGA	CTC FFGA	CNFA	TOTAL	Estimated Current CTC November 2012
Contract 10 - Wetlands Mitigation Grandy Village	$ 539,989.00	$ 536,129.78	$ -	$ 536,129.78	$ 536,129.78
Contract 20 - Viaduct Brambleton	$ 11,673,099.45	$ 15,053,844.12	$ 661,489.07	$ 15,715,333.19	$ 15,715,333.19
Contract 30 - NS ROW	$ 31,501,026.47	$ -	$ -	$ -	$ -
Contract 40 - Downtown	$ 36,134,927.88	$ 94,721,148.95	$ 3,444,950.68	$ 98,166,099.63	$ 98,166,099.63
Contract 07-46527A T1 - Noise and Vibration Monitoring	$ -	$ 286,246.40	$ -	$ 286,246.40	$ 286,246.40
Contract 50653 - DNC Business Signage	$ -	$ 38,230.30	$ -	$ 38,230.30	$ 38,230.30
Contract 60 - Traction Power	$ 25,150,094.00	$ 24,873,167.26	$ 15,531,638.95	$ 40,404,806.21	$ 40,403,178.26
Contract 80 - Vehicle Storage Maintenance Facility	$ 10,565,628.00	$ 11,596,993.14	$ 1,961,384.32	$ 13,558,377.46	$ 13,558,377.46
Contract 100 - Park & Rides	$ 2,768,741.22	$ 4,161,962.25	$ 191,337.75	$ 4,353,300.00	$ 4,353,300.00
Contract 110 - Station Finishes	$ 2,455,000.00	$ 2,670,295.10	$ 2,013,988.23	$ 4,684,283.33	$ 4,684,283.33
Contract 120 - Light Rail Vehicles	$ 30,857,014.00	$ 36,016,517.76	$ -	$ 36,016,517.76	$ 36,016,517.76
Contract 08-48116 - Fare Vending Equip.	$ 1,553,000.00	$ 1,467,250.00	$ -	$ 1,467,250.00	$ 1,467,250.00
Contract 08-48116 - Fare Vending Equip. (CNFA) Deleted 10/2012	$ -	$ -	$ -	$ -	$ -
Contract 150 - Demolition	$ 926,194.00	$ 1,512,315.00	$ -	$ 1,512,315.00	$ 1,512,315.00
Contract 07-46527A T4 - Asbestos Project Montioring	$ -	$ 80,590.36	$ -	$ 80,590.36	$ 80,590.36
Contract 160 - Construction of Temp Siding Track	$ 48,750.00	$ 53,729.90	$ -	$ 53,729.90	$ 53,729.90
Contract 180 - Temporary Shelter Purchase	$ 49,697.00	$ 49,697.00	$ -	$ 49,697.00	$ 49,697.00
Contract 230 - Temporary Shelter for LRVS	$ 16,800.00	$ 18,650.00	$ -	$ 18,650.00	$ 18,650.00
Contract 250 - VSMF Direct Current Power Distribution	$ 99,403.77	$ 105,035.76	$ -	$ 105,035.76	$ 105,035.76
Contract 260 - Temporary Spur Track Sewells Point	$ 20,009.00	$ 20,009.00	$ 94,874.00	$ 114,883.00	$ 114,883.00
Contract 280 - IDIQ Overhead Structures	$ -	$ 364,457.94	$ 458,224.35	$ 822,682.29	$ 822,682.29
Contract 340 - IDIQ Systems Services	$ -	$ 36,060.00	$ -	$ 36,060.00	$ 36,060.00
Contract 360 - IDIQ Railway Services Maintanence	$ -	$ 129,233.00	$ -	$ 129,233.00	$ 129,233.00
Contract 1000 - Landscaping	$ -	$ 479,149.21	$ -	$ 479,149.21	$ 479,149.00
Contract 2000 - Drainage under I-264	$ -	$ 645,111.43	$ 190,782.20	$ 835,893.63	$ 835,894.00
Purchase or Lease of Real Estate	$ 10,406,000.00	$ 15,157,193.00	$ -	$ 15,157,193.00	$ 15,157,193.00
Relocate Households & Businesses	$ 308,000.00	$ 788,307.00	$ -	$ 788,307.00	$ 788,307.00
Utilities	$ -	$ 3,539,074.96	$ -	$ 3,539,074.96	$ 3,539,075.00
Insurance (OCIP)	$ 5,745,000.00	$ 7,703,809.00	$ -	$ 7,703,809.00	$ 7,975,637.00
Preliminary Engineering	$ 9,032,000.00	$ 8,754,000.00	$ -	$ 8,754,000.00	$ 8,754,000.00
Final Design	$ 7,738,000.00	$ 13,489,097.88	$ 3,834,065.26	$ 17,323,163.14	$ 17,323,163.14
Project Management	$ 5,881,000.00	$ 11,418,601.00	$ 3,691,734.00	$ 15,110,335.00	$ 15,110,335.00
Project Support	$ -	$ 189,807.72	$ 126,538.48	$ 316,346.20	$ 316,346.20
Project Office Costs	$ -	$ 583,798.52	$ 389,199.02	$ 972,997.54	$ 972,997.54
HRT Project Management and Administration	$ -	$ 2,083,068.47	$ 1,388,712.31	$ 3,471,780.78	$ 3,471,780.79
HRT Public Involvement	$ -	$ 581,340.56	$ 387,560.38	$ 968,900.94	$ 968,900.94
Construction Management (includes Construction Project Support)	$ 10,524,000.00	$ 11,686,323.00	$ 774,882.00	$ 12,461,205.00	$ 12,461,205.00
Professional Services AECOM	$ -	$ 818,237.00	$ -	$ 818,237.00	$ 818,237.00
Professional Services - "After" Study	$ -	$ 706,560.00	$ -	$ 706,560.00	$ 839,725.31
Legal Fees and Permits	$ 1,135,000.00	$ 421,318.00	$ -	$ 421,318.00	$ 421,318.00
Start-Up and Pre-Revenue Operations					$ -
Parts and Materials	$ 313,600.00	$ 1,394,113.53	$ -	$ 1,394,113.53	$ 1,394,113.53
Rail Lubricators	$ -	$ 446,926.20	$ -	$ 446,926.20	$ 446,926.20
Rail Personnel Training	$ 257,440.00	$ 276,907.10	$ -	$ 276,907.10	$ 276,907.10
Project Support	$ -	$ 521,483.59	$ -	$ 521,483.59	$ 521,483.59
General Liability Insurance	$ 200,000.00	$ -	$ -	$ -	$ -
PR/Grand Opening	$ 100,000.00	$ -	$ -	$ -	$ -
LRV Security	$ 129,000.00	$ 363,874.28	$ -	$ 363,874.28	$ 363,874.28
Energy and Utilities	$ -	$ 204,381.88	$ -	$ 204,381.88	$ 204,381.88
Rail Operarions Staff	$ 1,192,960.00	$ 4,164,375.16	$ -	$ 4,164,375.16	$ 4,164,375.16
Bus Training and Pre Revenue Testing	$ -	$ 2,363.00	$ -	$ 2,363.00	$ 2,363.00
Finance Charges	$ 3,937,000.00	$ 51,987.00	$ -	$ 51,987.00	$ -
Contingency	$ 10,757,000.00	$ 3,494,418.00	$ -	$ 3,494,418.00	$ -
Total	**$ 222,015,373.79**	**$ 283,757,189.52**	**$ 35,141,360.99**	**$ 318,898,550.51**	**$ 315,755,511.08**

MAIN WORKSHEET-BUILD ALTERNATIVE

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project	Today's Date **1/14/08**
City of Norfolk, VA	Yr of Base Year $ 2008
Phase: Construction	Yr of Revenue Ops 2011

	Quantity	Base Year Dollars w/o Contingency (X000)	Base Year Dollars Allocated Contingency (X000)	Base Year Dollars TOTAL (X000)	Base Year Dollars Unit Cost (X000)	Base Year Dollars Percentage of Construction Cost	Base Year Dollars Percentage of Total Project Cost	YOE Dollars Total (X000)
10 GUIDEWAY & TRACK ELEMENTS (route miles)	**7.40**	83,744	-	**83,744**	**11,317**	**45%**	**27%**	**83,744**
10.01 Guideway: At-grade exclusive right-of-way	4.90	28,675		28,675	5,852			28,675
10.02 Guideway: At-grade semi-exclusive (allows cross-traffic)	1.50	11		11	7			11
10.03 Guideway: At-grade in mixed traffic		(13)		(13)				(13)
10.04 Guideway: Aerial structure	0.60	25,571		25,571	42,618			25,571
10.05 Guideway: Built-up fill		123		123				123
10.06 Guideway: Underground cut & cover		-		-				-
10.07 Guideway: Underground tunnel		-		-				-
10.08 Guideway: Retained cut or fill	0.40	5,220		5,220	13,050			5,220
10.09 Track: Direct fixation		7,431		7,431				7,431
10.10 Track: Embedded		9,221		9,221				9,221
10.11 Track: Ballasted		3,943		3,943				3,943
10.12 Track: Special (switches, turnouts)		2,977		2,977				2,977
10.13 Track: Vibration and noise dampening		585		585				585
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	**11**	1,005	-	**1,005**	**91**	**1%**	**0%**	**1,005**
20.01 At-grade station, stop, shelter, mall, terminal, platform	10	179		179	18			179
20.02 Aerial station, stop, shelter, mall, terminal, platform	1	66		66	66			66
20.03 Underground station, stop, shelter, mall, terminal, platform		-		-				-
20.04 Other stations, landings, terminals: Intermodal, ferry, trolley, etc.		71		71				71
20.05 Joint development		-		-				-
20.06 Automobile parking multi-story structure		-		-				-
20.07 Elevators, escalators		689		689				689
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	7.40	12,354	-	**12,354**	**1,669**	**7%**	**4%**	**12,354**
30.01 Administration Building: Office, sales, storage, revenue counting		42		42				42
30.02 Light Maintenance Facility		9,826		9,826				9,826
30.03 Heavy Maintenance Facility		-		-				-
30.04 Storage or Maintenance of Way Building		50		50				50
30.05 Yard and Yard Track		2,436		2,436				2,436
40 SITEWORK & SPECIAL CONDITIONS	7.40	56,203	-	**56,203**	**7,595**	**30%**	**18%**	**56,203**
40.01 Demolition, Clearing, Earthwork		7,760		7,760				7,760
40.02 Site Utilities, Utility Relocation		15,516		15,516				15,516
40.03 Haz. mat'l, contam'd soil removal/mitigation, ground water treatments		877		877				877
40.04 Environmental mitigation, e.g. wetlands, historic/archeologic, parks		2,123		2,123				2,123
40.05 Site structures including retaining walls, sound walls		3,602		3,602				3,602
40.06 Pedestrian / bike access and accommodation, landscaping		5,047		5,047				5,047
40.07 Automobile, bus, van accessways including roads, parking lots		5,507		5,507				5,507
40.08 Temporary Facilities and other indirect costs during construction		15,771		15,771				15,771
50 SYSTEMS	7.40	34,523	-	**34,523**	**4,665**	**18%**	**11%**	**34,523**
50.01 Train control and signals		9,690		9,690				9,690
50.02 Traffic signals and crossing protection		9,713		9,713				9,713
50.03 Traction power supply: substations		554		554				554
50.04 Traction power distribution: catenary and third rail		13,924		13,924				13,924
50.05 Communications		642		642				642
50.06 Fare collection system and equipment		-		-				-
50.07 Central Control		-		-				-
Construction Subtotal (10 - 50)	7.40	187,829	-	**187,829**	**25,382**	**100%**	**60%**	**187,829**
60 ROW, LAND, EXISTING IMPROVEMENTS	7.40	15,945	-	**15,945**	**2,155**		**5%**	**15,945**
60.01 Purchase or lease of real estate		15,157		15,157				15,157
60.02 Relocation of existing households and businesses		788		788				788
70 VEHICLES (number)	**10**	36,067	-	**36,067**	**3,607**		**11%**	**36,067**
70.01 Light Rail	9	36,067		36,067	4,007			36,067
70.02 Heavy Rail		-		-				-
70.03 Commuter Rail		-		-				-
70.04 Bus	1	-		-	-			-
70.05 Other		-		-				-
70.06 Non-revenue vehicles		-		-				-
70.07 Spare parts		-		-				-
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	7.40	74,681	-	**74,681**	**10,092**	**40%**	**24%**	**74,681**
80.01 Project Development		8,754		8,754				8,754
80.02 Engineering		17,323		17,323				17,323
80.03 Project Management for Design and Construction		-		-				-
80.04 Construction Administration & Management		34,960		34,960				34,960
80.05 Professional Liability and other Non-Construction Insurance		5,753		5,753				5,753
80.06 Legal; Permits; Review Fees by other agencies, cities, etc.		421		421				421
80.07 Surveys, Testing, Investigation, Inspection		-		-				-
80.08 Start up		7,470		7,470				7,470
Subtotal (10 - 80)	7.40	314,522	-	**314,522**	**42,503**		**100%**	**314,522**
90 UNALLOCATED CONTINGENCY				**-**			**0%**	**-**
Subtotal (10 - 90)	7.40			**314,522**	**42,503**		**100%**	**314,522**
100 FINANCE CHARGES				**52**			**0%**	**52**
Total Project Cost (10 - 100)	7.40			**314,574**	**42,510**		**100%**	**314,574**
Allocated Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Unallocated Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Total Contingency as % of Base Yr Dollars w/o Contingency				0.00%				
Unallocated Contingency as % of Subtotal (10 - 80)				0.00%				
YOE Construction Cost per Mile (X000)								25,382
YOE Total Project Cost per Mile Not Including Vehicles (X000)								37,636
YOE Total Project Cost per Mile (X000)								42,510

I N F L A T I O N   W O R K S H E E T

(Rev.16, June, 2014)

Norfolk Light Rail Transit Project

City of Norfolk, VA

Phase: Construction

Today's Date **1/14/08**

Yr of Base Year $ 2008

Yr of Revenue Ops 2011

Insert comments, notes, etc.

BASE YEAR DOLLARS (X$000)	Base Yr Dollars	Double-Check Total	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	83,744	83,744	0	0	0	0	0	0	0	0	10,887	20,936	20,936	20,936	10,049		0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	1,005	1,005	0	0	0	0	0	0	0	0	241	241	241	241	40		0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	12,354	12,354	0	0	0	0	0	0	0	0	1,853	4,324	4,324	1,853			0	0	0
40 SITEWORK & SPECIAL CONDITIONS	56,203	56,203	0	0	0	0	0	0	0	0		22,481	16,861	16,861			0	0	0
50 SYSTEMS	34,523	34,523	0	0	0	0	0	0	0	0	1,726	5,178	8,631	8,631	8,631	1,726	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	15,945	15,945	0	0	0	0	0	0	0	0	3,348	3,348	3,348	3,348	2,551		0	0	0
70 VEHICLES (number)	36,067	36,067	0	0	0	0	0	0	0	0	7,574	7,574	7,574	7,574	5,771		0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	74,681	74,681	0	0	0	3,734	3,734	3,734	3,734	7,468	14,936	11,202	11,202	11,202	2,987	373	373	0	0
90 UNALLOCATED CONTINGENCY	-	-	0	0	0	0	0	0	0	0		-					0	0	0
100 FINANCE CHARGES	52	52	0	0	0	0	0	0	0	0	52						0	0	0
Total Project Cost (10 - 100)	314,574	314,574	**0**	**0**	**0**	**3,734**	**3,734**	**3,734**	**3,734**	**7,468**	**40,618**	**75,285**	**73,117**	**70,647**	**30,029**	**2,100**	**373**	**0**	**0**

			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Inflation Rate			0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Compounded Inflation Factor			1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

YEAR OF EXPENDITURE DOLLARS (X$000)	YOE Dollars		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
10 GUIDEWAY & TRACK ELEMENTS (route miles)	83,744		0	0	0	0	0	0	0	0	10,887	20,936	20,936	20,936	10,049	-	0	0	0
20 STATIONS, STOPS, TERMINALS, INTERMODAL (number)	1,005		0	0	0	0	0	0	0	0	241	241	241	241	40	-	0	0	0
30 SUPPORT FACILITIES: YARDS, SHOPS, ADMIN. BLDGS	12,354		0	0	0	0	0	0	0	0	1,853	4,324	4,324	1,853	-	-	0	0	0
40 SITEWORK & SPECIAL CONDITIONS	56,203		0	0	0	0	0	0	0	0	-	22,481	16,861	16,861	-	-	0	0	0
50 SYSTEMS	34,523		0	0	0	0	0	0	0	0	1,726	5,178	8,631	8,631	8,631	1,726	0	0	0
60 ROW, LAND, EXISTING IMPROVEMENTS	15,945		0	0	0	0	0	0	0	0	3,348	3,348	3,348	3,348	2,551	-	0	0	0
70 VEHICLES (number)	36,067		0	0	0	0	0	0	0	0	7,574	7,574	7,574	7,574	5,771	-	0	0	0
80 PROFESSIONAL SERVICES (applies to Cats. 10-50)	74,681		0	0	0	3,734	3,734	3,734	3,734	7,468	14,936	11,202	11,202	11,202	2,987	373	373	0	0
90 UNALLOCATED CONTINGENCY	-		0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0
100 FINANCE CHARGES	52		0	0	0	0	0	0	0	0	52	-	-	-	-	-	0	0	0
Total Project Cost (10 - 100)	314,574		**0**	**0**	**0**	**3,734**	**3,734**	**3,734**	**3,734**	**7,468**	**40,618**	**75,285**	**73,117**	**70,647**	**30,029**	**2,100**	**373**	**0**	**0**

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix C: Service Levels

HAMPTON ROADS TRANSIT

Introduction

Hampton Roads Transit (HRT) is the regional provider of public transportation for the Southside and Peninsula areas of the Hampton Roads metropolitan area, which consists of the cities of Norfolk, Hampton, Newport News, Portsmouth, Chesapeake, and Virginia Beach. HRT was formed with the merger of the South Hampton Roads transit provider (Tidewater Regional Transit, TRT) and the north side operator (Peninsula Transit, Pentran). The HRT service area covers more than 515 square miles with a population of nearly 1.439 million.

The purpose of this technical memorandum (tech memo) is (1) to document actual service levels provided by the Tide, HRT's first light rail transit (LRT) line, as well as bus routes in the Tide corridor and (2) to examine the consistency of service plans prepared for each project-development milestone with those outcomes. HRT's governing body, the Transportation District Commission of Hampton Roads, was awarded a Full Funding Grant Agreement (FFGA) on October 1, 2007 by the Federal Transit Administration (FTA) under its New Starts program in the amount of $127,980,000. This tech memo provides documentation of the project's service characteristics as operated two years after implementation of the light rail and as predicted at three key milestones in the planning process. The report will also examine the consistency of the planned service levels at the milestones with the actual outcomes. The documentation provided in this tech memo will be summarized in the project's Before and After Study, an FTA-required study for projects receiving New Starts funding.

The Tide revenue service began on August 29, 2011. The route starts just west of Downtown Norfolk, at the Eastern Virginia Medical Center (EVMC)/Fort Norfolk Station. It extends east, through Downtown Norfolk and along the north side of the eastern branch of the Elizabeth River, ending at the Newtown Road Station at Newtown Road and Kempsville Road.

HRT also operates bus, ferry, and paratransit service. The HRT bus network includes over 40 locations for timed transfer connections to other routes. Bus service within The Tide project corridor includes routes 1, 2, 3, 4, 6, 8, 9, 11, 13, 15, 16, 17, 18, 20, 22, 23, 25, 27, 28, 44 45, 918, 919, 922, 960, 961, 962, and 967.

This report will focus on how the Tide and the bus system operated approximately two years after implementation of the light rail line. Service conditions approximately two years before implementation of the light rail will also be documented, and the changes in service levels from the Before period to the After period will be discussed. The following dates are used to assess the before and after conditions:

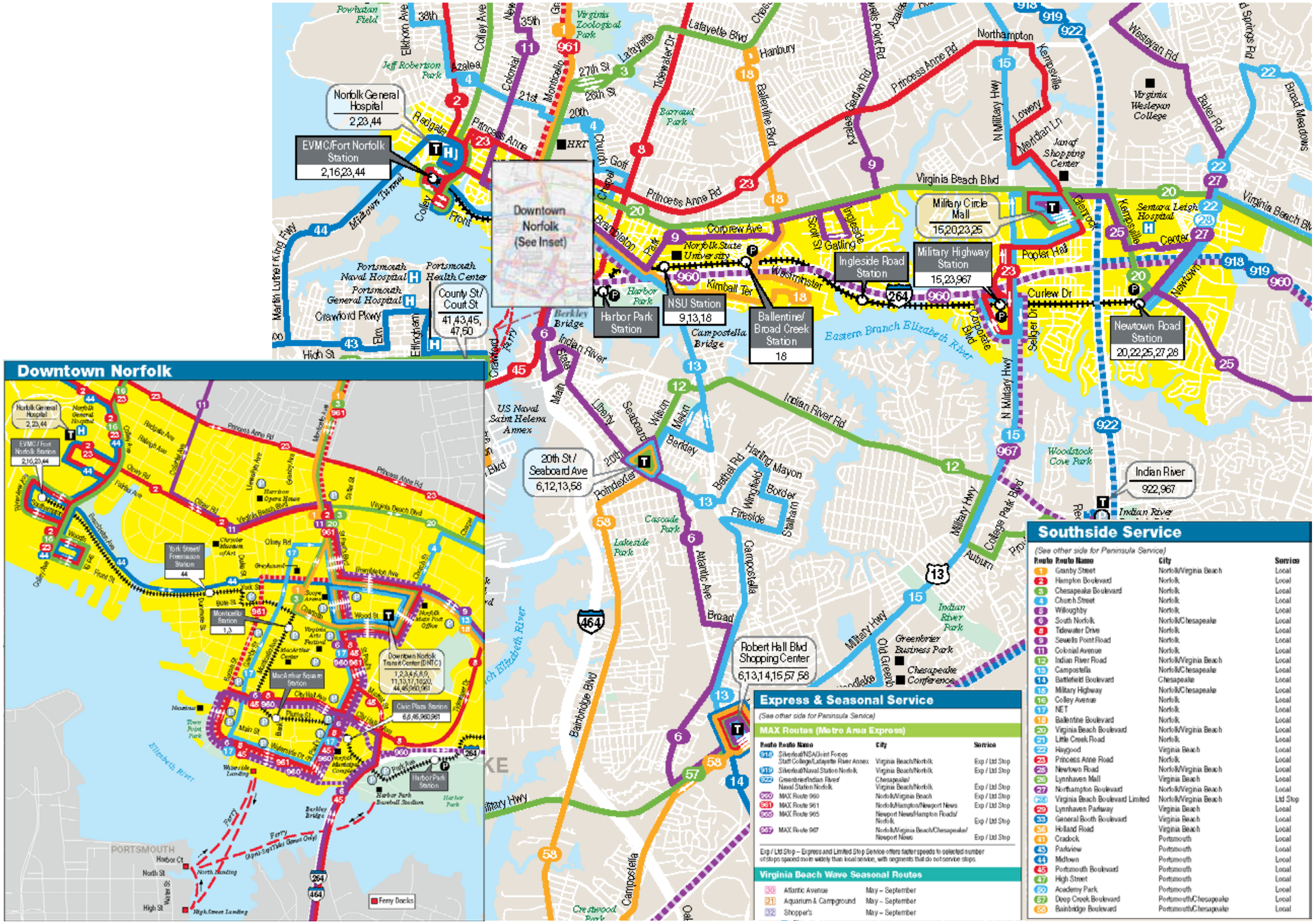
- Before conditions are represented by August 2009 service levels.
- After conditions are represented by August 2013 service levels. These are the same levels of service in effect at the time of this report and are also referred to as "actual" service levels in comparison with predicted levels.

In addition, this report will examine the accuracy of service level predictions at three key milestones:

- Entry into PE (November 2002),
- Entry into Final Design (September 2006), and
- FFGA (October 2007).

The comparison of transit services across milestone dates will be focused geographically on routes which occur inside The Tide service corridor, defined as south of Princess Anne Road and Virginia Beach Boulevard, north and east of the Elizabeth River, extending just beyond the Norfolk city limits to the east. This area is depicted in yellow in **Figure 1**. In addition, summary-level tables will describe the broader changes for the Southside bus system, and the HRT system as a whole.

Figure 1: 2013 HRT System Map, the Tide LRT Service Area



After Service Conditions (August 2013)

The Tide LRT Service

The Tide extends 7.4 miles from the EVMC complex east through downtown Norfolk to Newtown Road at the border of Virginia Beach, as shown in Figures 1 and Figure 2. The Tide makes stops at 11 stations. Four of these, the Harbor Park, Ballentine/Broad Creek, Military Highway, and Newton Road stations, feature park-and-ride lots. The EVMC/Fort Norfolk, York Street/Freemason, Monticello, Civic Plaza, NSU (Norfolk State University), Ballentine/Broad Creek, Military Highway, and Newton Road Stations also serve as points of transfer to corridor bus routes. The MacArthur Square and Ingleside Road Stations serve walk-up traffic only.

Figure 2: 2013 The Tide LRT Stations

The Tide operates with 10-minute headways during weekday peak periods (approximately 6:30 a.m. to 9:00 a.m. and 3:30 p.m. to 7:00 p.m.) and 15-minute to 30-minute headways during the off peak and on weekends, as described in **Table 1**.

Table 1
The Tide Service Spans and Headways, 2013

Service	Span of Service	Peak	Off-Peak	Early Morning (Before 6:30 am, or 9:00 am Sat.)	Late Night (after 10:00 pm)
Monday-Thursday	6:00 AM-11:00 PM	10 min.	15 min.	15 min.	30 min.
Friday	6:00 AM-12:00 AM	10 min	15 min.	15 min.	30 min.
Saturday	6:00 AM-12:00 AM	N/A	15 min.	30 min.	30 min.
Sunday	11:00 AM-9:00 PM	N/A	15 min.	N/A	N/A

The one-way travel time from the EVMC Station to the Newtown Road Station is approximately 26 minutes. The total round trip running time is one hour with layovers and requires six one-car train consists during peak periods. The 2013 system utilizes a total fleet of nine one-car electric light rail vehicles which includes three spares.

On an average weekday, The Tide operates a total of 90 revenue hours covering 1,158 revenue miles. As shown in **Table 2**, approximately 79% of those hours are spent in-service with 21% as layover. The Tide travels with an average speed of approximately 16.3 mph, not including layovers. Annually[1], HRT provides a total of 29,249 revenue hours and 377,097 revenue miles of LRT service.

Table 2 The Tide Service Characteristics, 2013				
Weekday Vehicle Statistics				
	Weekday Train Hours	**Percent**	**Weekday Train Miles**	**Average Speed (mph)**
In-service	71	78.52%	1,158	16.32
Layover	19	21.22 %	---	---
Deadhead	0	---	---	---
Pull-in/out	0.25	0.26%	0.0	0.0
Total	90	100%	1,158	16.27
Revenue Service				
	Revenue Hours	*Revenue Miles*		
Weekday	*90*	*1,158*		
Saturday	*77*	*894*		
Sunday	*38*	*603*		
Annual	*29,249*	*377,097*		

Bus Service

Table 3 summarizes 2013 bus service within The Tide corridor, as well as for the overall network of routes operating in the Southside (Tidewater) area of the HRT system. As shown, the majority of Southside System routes provide some service within the Tide corridor, connecting this key area with the larger system.

Table 3 Summary of Bus Service Characteristics, 2013			
	Weekday	**Saturday**	**Sunday**
Corridor Local Routes	21	20	14
Corridor System Max Routes	6	2	2
Corridor Revenue Miles	14,991	11,720	5,395
Corridor Revenue Hours	1,276	990	445
Southside Local Routes	38	37	22
Southside Max Routes	7	2	2
Southside Revenue Miles	20,946	17,312	7,065
Southside Revenue Hours	1,815	1,448	659

Local routes 1, 2, 3, 6, 8, 9, 13, 15, 16, 17, 18, 20, 22, 23, 25, 27, 28, 44, and 45 and MAX routes 960, 961, and 967 directly serve the Tide LRT stations. The majority of these operate in a primarily north/south

[1] Revenue hours and miles were annualized based on an assumption of 253 regular/weekday schedules, 57 Saturday schedules and 55 Sunday schedules operated in 2013.

direction, feeding into the nearest rail stations for east/west connections. Routes 20 and 23 provide service that more closely parallels the Tide alignment along Virginia Beach Boulevard and Princess Anne Road, respectively, and tie back into the LRT line near the termini. Two local routes, 4 and 11, serve the Downtown Norfolk Transit Center which is approximately three blocks east of the Monticello Station and four blocks north of the Civic Plaza Station. Although located inside the Tide service area these routes do not directly serve LRT stations without a short walk or transfer. MAX Express Routes 918, 919, and 922 operate through the corridor along I-64 and I-264, but do not make stops or provide additional service within the corridor.

Before Service Characteristics (August 2009)

Table 4 summarizes the HRT Southside bus routes, as well as bus routes specific to the Tide Corridor, two years after the implementation of the Tide. Nearly half of Southside local routes and the majority of MAX routes operate within the Tide LRT corridor. These routes account for approximately 68% of the Southside's overall annual revenue hours, and 72% of the Southside total revenue miles.

Table 4
Summary of Bus Service Characteristics, 2009

	Weekday	Saturday	Sunday
Corridor Local Routes	18	13	12
Corridor System Max Routes	6	2	2
Corridor Revenue Miles	16,390	11,354	5,201
Corridor Revenue Hours	1,256	926	404
Southside System Local Routes	39	33	20
Southside System Max Routes	7	2	2
Southside Revenue Miles	22,686	16,847	7,094
Southside Revenue Hours	1,840	1,427	637

Comparison of Before and After System Operating Characteristics

Change in Bus Service from 2009 to 2013

Between 2009 and 2013 eight local routes and two express routes were eliminated from the Southside bus system. Only one of these, MAX Route 962, was located within the Tide corridor. Six local routes and one express route were added to the Southside bus system. Three of these, Routes 16, 22, and 28 provide additional service within the Tide LRT corridor, serving the Newtown Road and/or EVMC/Fort Norfolk Stations.

Most changes within the corridor were schedule or alignment adjustments to existing routes, as described in **Table 5**. Although regular service updates occur one to two times per year at HRT, major service changes were implemented at two key periods of time between 2009 and 2013.

- *August 2011 Service Changes – Introduction of LRT*: A total of 21 service changes were implemented in August 2011 and were focused on incorporating the LRT line into the system. Bus routes in the LRT corridor were adjusted to provide direct connections to LRT stations. In addition, the spans of service for some connecting routes were extended to provide equal service hours for bus and rail to improve connections between the modes.

- *January 2012 Service Changes – Service and Schedule Efficiency Study Recommendations*: The focus of the service change recommendations from the Service and Schedule Efficiency Study was to reallocate financial resources from low performing routes (or trips within a routes' service day) to higher performing routes and trips. In addition, the study provided guidance to improve cost efficiency without having to increase fares. A total of 40 bus routes (17 routes in the north and 23 routes in the south) were changed by either eliminating trips or reducing the frequency of the service. Recommendations were based on minimum passenger boarding thresholds for bus routes. Routes averaging less than 10 boardings per trip were defined as underperforming routes and would either be discontinued or modified to eliminate low performing trips during the fringes of the service day. Nearly 660 daily bus trips were eliminated systemwide as a result of the study analysis.

HRT made these significant changes to the system to improve the bus and rail interface and connections and to make overall improvements to service productivity and cost efficiencies. Although the focus of this report is to detail the changes to the bus service as a result of the introduction of the Tide, other service changes during the time period from 2009 to 2013 will also be catalogued to provide a comprehensive understanding of service levels. Both service changes seemed effective overall and improved system performance. **Table 5** provides a detailed comparison of the change in service characteristics between 2009 and 2013.

Bus Service Changes Occurring at the Introduction of LRT

Route 16 was added in 2011 with the introduction of the Tide LRT. It provides service between the EVMC/Fort Norfolk Station and Powhatan Avenue (Old Dominion University). The service ran every 30 minutes, Monday through Saturday.

In addition, a total of 17 existing routes within the Tide LRT corridor were modified in 2011 in conjunction with the opening of the LRT line. Local routes 2, 6, 8, 9, 13, 15, 17, 18, 20, 23, 25, 27, 44, and 45 and MAX routes 960, 961, and 967 were adapted to connect to LRT stations. Many of these routes also experienced adjustments to frequencies and extended service hours to match The Tide's revenue hours of operation, as shown in **Table 5**. Routes 25 and 27 increased their span of service by six hours or more.

Bus Service Changes Resulting from the Service Efficiency Study

The 2012 service efficiency study prompted the realignment of Route 17 to serve the Civic Plaza Station as well as several minor schedule and frequency adjustments. Routes 4, 6, 11, 17, and 31 and MAX Route 960 were less frequent in 2013 than they had been in 2009. Routes 3 and 27 operated more frequently than before implementation of The Tide service. Routes 1, 4, 15, 45, and MAX Route 960 underwent a reduction in span of service of approximately one to two hours. Many of the other changes associated with the service efficiency study occurred on routes outside of the LRT corridor.

Table 5
Comparison of Corridor Bus Service Characteristics (2009 and 2013)

	2009 (Before)				2013 (After)				
	Headways			Span of Service	Headways			Span of Service	
Route	Peak	Base	Sat, Sun	(Weekday)	Peak	Base	Sat, Sun	(Weekday)	Year, Alignment Changes
Local Routes									
1	15	30	30/60, 60	4:45 AM-2:15 AM	15	30	30/60, 60	4:45 AM-12:45 AM	2013, slight route adjustment to Granby St. corridor to service Monticello Station and new Downtown Norfolk Transit Center (DNTC)
2	30	30	30/45, 60	5:00 AM-1:00 AM	30	30	60	5:00 AM-1:45 AM	2011, slight route adjustment to Hampton Blvd. corridor to service Ft. Norfolk Station. 2013, slight modification to serve DNTC
3	30	30	30/60, 60	5:00 AM-1:30 AM	15	30	30/60, 60	5:00 AM-1:45 AM	2013, slight route adjustment to Chesapeake Blvd. corridor to service Monticello Station and DNTC
4	60	60	60	4:45 AM-7:45 PM	70	70	70	6:00 AM-6:45 PM	2013, Church St./21st St. corridor was slightly modified to serve new DNTC
6	30	30	30/60, NS	5:15 AM-12:45 AM	30	60	60	5:30 AM-12:45 AM	2011, slight route adjustment to service Civic Plaza station.2013, slight modification to serve DNTC
8	30	30	60, 90	5:15 AM-12:45 AM	30	30	30/60, 60	5:15 AM-1:15 AM	2011, slight route alignment to Tidewater Dr. corridor to service Civic Plaza Station. 2013, slight modification to serve DNTC
9	30	30	30/60, NS	5:15 AM-10:15 PM	30	30	60, NS	5:45 AM-12:15 AM	2011, adjustment made to Sewells Pt. Rd. corridor to service the NSU station. 2013, slight modification to serve DNTC
11	30	30	30/60, 60	5:45 AM-6:45 PM	60	60	60	6:00 AM-6:30 PM	2013, Colonial Rd. corridor was slightly modified to serve DNTC
13	30	30	30/60, 60	4:45 AM-12:45 AM	30	30/60	60	4:45 AM-12:45 AM	2011, adjustment made to Campostella Rd. corridor to service the NSU Station. 2013, slight modification to serve DNTC
15	15	30	30/60, 60	4:45 AM-2:00 AM	15	30	30/60, 60	4:45 AM-1:15 AM	2011, the Military Hwy. corridor was slightly modified to service the Military Hwy. Station.
16	N/A	N/A	N/A	N/A	30	30	30/60, 60	6:00 AM-12:30 AM	2011, new Colley Ave. corridor was implemented to service the Ft. Norfolk Station
17	6/9	15	15	6:00 AM-11:15 PM	15	15/30	30	6:00 AM-12:45 AM	2011, the Granby St. corridor was modified to serve the Ft. Norfolk Station. 2012, realigned to provide service to Civic Plaza station. 2013, slight modification to serve DNTC
18	60	60	60, NS	4:45 AM-7:15 PM	60	60	60, NS	5:45 AM-10:45 PM	2011, the Ballentine Blvd. corridor began serving the Ballentine/Broad Creek Station (no alignment modification needed). 2013, slight modification to serve DNTC
20	15	30	30/60, 60	4:45 AM-1:15 AM	15	30	30/60, 60	5:00 AM-1:15 AM	2011, the Virginia Beach Blvd. corridor was realigned to service the Newtown Rd. Station. 2013, slight modification to serve DNTC
22	N/A	N/A	N/A	N/A	60	60	60, NS	6:00 AM-7:00 PM	2012, New Newtown Rd./S. Independence corridor was implemented to provide service from Newton Road Station to previously unserved community
23	30	30	30/60, 60	5:00 AM-12:30 AM	30	30	30/60, 60	5:00 AM-1:30 AM	2011, Princess Anne Rd. Corridor was modified to service Ft. Norfolk and Military Hwy. stations.
25	30	30	NS	6:00 AM-6:45 PM	60	60	60, NS	6:00 AM-12:45 AM	2011, the Princess Anne Corridor was modified to serve Newtown Rd. Station. 2013, Saturday service was added.
27	60	60	60, NS	6:15 AM-7:00 PM	30	60	60, NS	5:45 AM-1:00 AM	2011, the Newtown Rd. corridor was modified to service the Newtown Rd. Station
28	N/A	N/A	N/A	N/A	30	NS	NS	6:00 AM-6:45 PM	2012, New Virginia Beach corridor implemented to provide limited stop service from Newtown Rd. Station to 19th St./Pacific Ave.
44	60	60	60, NS	6:00 AM-7:00 PM	60	60	60, NS	6:00 AM-7:45 PM	2011, Midtown corridor was modified to provide service to the EVMC/Ft. Norfolk Station. 2013, slight modification to serve DNTC
45	30	30	30/75, 60/90	4:30 AM-12:45 AM	30	30	30/60, 60	4:45 AM-12:00 AM	2011, the Portsmouth Blvd. corridor was modified to provide service to the Civic Plaza Station. 2013, slight modification to serve DNTC
Express Routes									
918	Varies	NS	NS	N/A	Varies	NS	NS	5:45 AM-5:00 PM*	No alignment changes within LRT corridor (some alignment adjustments made at Norfolk Naval Air Station)
919	Varies	NS	NS	5:15 AM-5:15 PM*	Varies	NS	NS	5:00 AM-5:00 PM*	No alignment changes within LRT corridor (some alignment adjustments made at Norfolk Naval Air Station)
922	Varies	NS	NS	5:15 AM-5:30 PM*	Varies	NS	NS	5:00 AM-5:15 PM*	No alignment changes within LRT corridor (some alignment adjustments made at Norfolk Naval Air Station)
960	30	30	60	5:00 AM-8:45 PM	60	60	60	5:30 AM-8:15 PM	2011, the route was modified to provide service to Civic Plaza Station. 2013, slight modification to serve DNTC
961	30	30/60	30/60, 60	5:00 AM-10:15 PM	30	30/60	30/60	5:00 AM-10:15 PM	2011, the route was modified to provide service to Civic Plaza Station. 2013, slight modification to serve DNTC
962	30	30	NS	5:00 AM-8:15 PM	N/A	N/A	N/A	N/A	2011, service reduction with Suffolk's withdrawal from HRT. 2012, service eliminated.
967	N/A	N/A	N/A	5:00 AM-7:45 PM*	Varies	NS	NS	4:45 AM-6:45 PM*	2011, modified to provide service to Military Hwy Station.

*Route does not provide midday service.

Other Bus Service Changes

Route 22 was created in 2012 at the request of the city of Virginia Beach in order to serve a community that had no local bus service, as well as serving a new major city recreational center in that community. This route extends northeast from the Newton Road Terminal Station.

Route 28 was created at the request of the city of Virginia Beach in order to implement a skip stop, express service along Virginia Beach Boulevard in order to save commuters approximately 45 minutes between Oceanfront to downtown Norfolk. This route added an extension of transit services due east from the Newton Road Terminal Station.

MAX Route 962, which in 2009 provided service from the Magnolia Park & Ride Station to the Cedar Grove transfer station in downtown Norfolk, was modified in 2010 to serve from downtown Suffolk to the County/Court Transfer center in Portsmouth. This route was eliminated in 2012 when the city of Suffolk dropped out of the HRT system.

On July 7, 2013, local routes 1, 2, 3, 4, 6, 8, 9, 11, 13, 17, 18, 20, 44, and 45 and MAX routes 960 and 961 were modified to move from the old transfer center at Cedar Grove to the Downtown Norfolk Transit Center (DNTC) on Wood Street, between Church Street and Saint Paul's Boulevard. In addition, Route 3 was modified to serve the Monticello Station as a result of 2013 service adjustments.

Operating Statistics Comparison of Corridor Routes

Table 6 and **Table 7** (on the following pages) show a route-by-route comparison between 2009 and 2013 for annual revenue hours and miles (respectively). Total revenue hours for the Southside System decreased, largely due to the elimination of several routes including service to and around the City of Suffolk. Within the Tide LRT corridor however, revenue hours increased by approximately 10,000 hours or 2.5 percent. This trend is predominantly driven by an increase in span of service for routes with direct connections to the LRT line. Revenue miles have decreased both within and beyond the LRT corridor. Outside the corridor, this is driven by the same reduction in service to Suffolk. Inside the corridor, this results from the splitting of routes with previous schedule adherence issues.

System-level Comparison

Table 8 provides a system-wide comparison of service levels in 2009 and 2013. Bus revenue hours and peak-hour vehicles in operation have remained relatively constant between 2009 and 2013. As the Tide is HRT's first LRT line, the increase in train hours and train vehicles accounts for the entirety of the 2013 LRT system. Ferry Service has remained fairly consistent between 2009 and 2013.

Table 6 Comparison of 2009 and 2013 Corridor Revenue Hours									
Route Number	2009 Daily Revenue Hours			2009 Total*	2013 Daily Revenue Hours			2013 Total*	Percent Change
	Weekday	Saturday	Sunday		Weekday	Saturday	Sunday		
1	93.1	78.7	39.2	30,277	118.9	77.6	37.8	36,579	20.8%
2	53.5	50.7	26.9	17,963	61.5	39.4	36.1	19,793	10.2%
3	82.5	80.2	39.4	27,691	90.5	70.4	35.4	28,843	4.2%
4	28.5	28.5	22.3	10,091	13.7	11.8	10.3	4,707	-53.4%
6	46.2	41.9	NS	14,114	41.0	32.2	12.8	12,903	-8.6%
8	60.3	32.5	15.0	17,962	52.5	50.7	26.6	17,629	-1.9%
9	57.9	58.1	NS	18,008	60.6	36.9	NS	17,433	-3.2%
11	25.8	25.7	10.4	8,586	12.4	12.5	9.0	4,337	-49.5%
13	61.0	61.0	18.9	20,009	40.0	32.5	16.7	12,897	-35.5%
15	132.8	101.7	51.8	42,356	105.7	77.7	30.9	32,878	-22.4%
16	NS	NS	NS	NS	32.7	33.7	16.9	11,115	New Service
17	64.3	24.0	16.0	18,527	31.5	18.3	16.3	9,904	-46.5%
18	16.3	16.1	NS	5,048	19.4	16.0	NS	5,814	15.2%
20	149.0	94.0	69.1	46,957	177.4	132.4	68.8	56,221	19.7%
22	NS	NS	NS	NS	25.6	24.5	NS	7,868	New Service
23	64.8	64.9	24.7	21,523	87.6	87.1	42.2	29,448	36.8%
25	25.6	NS	NS	6,469	36.7	36.6	NS	11,367	75.7%
27	12.6	12.4	NS	3,911	24.0	19.1	NS	7,158	83.0%
28	NS	NS	NS	NS	18.2	NS	NS	4,612	New Service
44	36.4	36.2	NS	11,307	38.3	38.1	NS	11,859	4.9%
45	62.3	48.9	16.7	19,522	65.1	65.1	31.4	21,910	12.2%
918	NS	NS	NS	NS	2.4	NS	NS	607	New Service
919	12.2	NS	NS	3,074	10.1	NS	NS	2,560	-17.3%
922	10.6	NS	NS	2,678	10.6	NS	NS	2,673	-0.1%
960	44.5	27.5	25.5	14,222	29.3	27.4	26.1	10,412	-27.9%
961	53.2	43.6	27.8	17,506	58.1	49.8	27.8	19,069	8.9%
962	42.5	NS	NS	10,744	NS	NS	NS	NS	Eliminated Service
967	20.9	NS	NS	5,275	12.5	NS	NS	3,150	-34.7%
Corridor Total*	**317,878**	**53,742**	**22,201**	**393,821**	**322,863**	**56,411**	**24,473**	**403,747**	**2.5%**
Southside System TOTAL*	**465,533**	**82,781**	**35,049**	**583,363**	**459,280**	**84,788**	**36,223**	**580,291**	**-0.5%**

**Based on 253 weekdays, 58 Saturdays, and 55 Sundays in 2009; and 253 weekdays, 57 Saturdays, and 55 Sundays in 2013.*
Source: HRT

Table 7 Comparison of 2009 and 2013 Corridor Revenue Miles									
Route Number	2009 Daily Revenue Miles			2009 Total*	2013 Daily Revenue Miles			2013 Total*	Percent Change
	Weekday	Saturday	Sunday		Weekday	Saturday	Sunday		
1	1182.8	970.4	480.0	381,942	1266.3	997.5	483.6	403,828	5.7%
2	601.7	676.4	363.1	211,431	664.1	466.7	429.2	218,219	3.2%
3	820.8	800.4	447.0	278,670	1008.9	833.9	422.5	326,019	17.0%
4	264.5	264.5	205.4	93,560	132.4	110.4	99.3	45,261	-51.6%
6	412.2	400.9	NS	127,531	383.9	323.1	131.6	122,785	-3.7%
8	649.3	338.4	188.9	194,283	557.5	540.0	232.8	184,622	-5.0%
9	682.7	682.7	NS	212,307	693.9	404.8	NS	198,625	-6.4%
11	165.3	165.3	66.9	55,081	89.2	89.2	64.2	31,182	-43.4%
13	720.3	720.3	163.0	232,986	379.3	307.7	150.7	121,783	-47.7%
15	1620.6	1246.2	636.3	517,294	1217.0	935.4	371.3	381,630	-26.2%
16	NS	NS	NS	NS	299.6	299.6	159.3	101,628	New Route
17	497.7	163.5	113.9	141,661	160.4	92.7	82.7	50,419	-64.4%
18	171.0	171.0	NS	53,191	187.8	176.7	NS	57,583	8.3%
20	1649.8	1166.8	879.0	533,416	1869.3	1497.9	828.9	603,897	13.2%
22	NS	NS	NS	NS	308.7	296.3	NS	94,998	New Route
23	749.5	749.5	284.0	248,710	779.6	764.5	328.9	258,917	4.1%
25	360.3	NS	NS	91,146	514.0	514.0	NS	159,338	74.8%
27	204.2	204.2	NS	63,505	362.6	293.1	NS	108,433	70.7%
28	NS	NS	NS	NS	279.4	NS	NS	70,679	New Route
44	408.6	408.6	NS	127,083	405.3	405.3	NS	125,655	-1.1%
45	675.4	661.2	209.0	220,710	647.9	649.3	313.3	218,154	-1.2%
918	NS	NS	NS	NS	60.0	NS	NS	15,186	New Route
919	315.2	NS	NS	79,756	263.5	NS	NS	66,669	-16.4%
922	263.4	NS	NS	66,644	264.8	NS	NS	66,989	0.5%
960	956.1	582.4	541.1	305,432	659.0	614.7	591.4	234,283	-23.3%
961	1135.2	981.1	624.3	378,444	1145.5	1107.5	704.7	391,691	3.5%
962	1095.2	NS	NS	277,084	NS	NS	NS	NS	Removed Route
967	789.1	NS	NS	199,651	391.8	NS	NS	99,135	-50.3%
Corridor Total*	**4,146,897**	**658,521**	**286,099**	**5,091,517**	**3,792,840**	**668,068**	**296,700**	**4,757,608**	**-6.6%**
TOTAL*	**5,739,517**	**977,123**	**390,160**	**7,106,800**	**5,299,290**	**986,801**	**388,582**	**6,674,672**	**-6.1%**

**Based on 253 weekdays, 58 Saturdays, and 55 Sundays in 2009; and 253 weekdays, 57 Saturdays, and 55 Sundays in 2013.*
Source: HRT

Table 8 System-Level Service Overview			
System-Level Characteristics	**Before (2009)**	**After (2013)**	**Percent Change**
Southside Bus			
Revenue Vehicle-Hours	583,363	580,291	-0.5%
Revenue Vehicle-Miles	7.11 mil	6.67 mil	-6.1%
Peak Bus Pull-out	46	45	-2.2%
LRT			
Revenue Vehicle-Hours	-	51,228	N/A
	-	377,097	N/A
Peak Vehicle Pull-out	-	6	N/A
Ferry			
Revenue Vehicle-Hours	19,749	19,718	-0.2%

Comparison of Predicted Service Levels to Actual Service Levels

In this section, predicted LRT and bus service levels at three project-development milestones will be documented: Entry into PE, Entry into FD, and the FFGA. The predicted service plan at each milestone will then be compared to the actual service plan for bus and light rail in operation approximately two years after implementation of the light rail project. A comparison of the predicted LRT service characteristics at each milestone is shown in **Table 9**. **Table 10** compares bus routes within the Tide LRT corridor for each milestone year. The following sections will describe the proposed service level characteristics for bus corridor routes and The Tide at each milestone date.

Table 9 The Tide Service Levels - Milestones & 2013 Actual				
Span of Service	**2013 Actual**	**Entry to PE**	**Final Design**	**FFGA**
Weekday (Mon-Th)	6:00AM-11:00PM	6:00AM-10:00PM	6:00AM-10:00PM	6:00AM-10:00PM
Weekend (Fri-Sat)	6:00AM-12:00AM	6:00AM-12:00AM	6:00AM-12:00AM	6:00AM-12:00AM
Sunday (Sun)	10:55AM-9:00PM	7:00AM-9:00PM	7:00AM-9:00PM	7:00AM-9:00PM
Headways (minutes)				
Weekday Peak	10	7.5	7.5	7.5
Weekday Off-peak	15	15	15	15
Weekday Evening	30	30	30	30
Saturday base	15	15	15	15
Saturday (M/E)	30	30	30	30
Sunday base	15	15	15	15
Sunday (M)	N/A	30	30	30
Annual Passenger Mi.	**377,097**	**400,500**	**400,200**	**400,200**
Weekday	292,974	309,600	310,100	310,100
Weekend	84,123	90,900	90,100	90,100
Annual Revenue Hrs.	**29,249**	**25,950**	**25,990**	**25,990**
Weekday	22,770	19,770	19,850	19,850
Weekend	6,479	6,180	6,140	6,140

Table 10 Corridor Bus Service Levels - Milestones & 2013 Actual															
	Predicted Headways				Weekday Service Spans		Service Days				Connecting LRT Stations*				
Route	Actual	PE	Final Design	FFGA	Actual	Final Design	Actual	PE	Final Design	FFGA	Actual	PE	Final Design	FFGA
1	15-60	30-60	15-60	15-30	4:45 AM-12:45 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	Monticello	Monticello, Govt. Center	Monticello, Govt. Center	Govt. Center
2	30-60	30-60	30-60	30	5:00 AM-1:45 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	EVMC/Ft. Norfolk	Monticello, Govt. Center	Monticello, Govt. Center	Medical Ctr.
3	15-60	60	60	15-30	5:00 AM-1:45 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	Monticello	Monticello, Govt. Center	Monticello, Govt. Center	Freemason
4	70	15-60	30-60	60	6:00 AM-6:45 PM	5:00AM-12:30AM	M-Sun	M-Sun	M-Sun	M-Sun	No Connections	Medical Ctr, Monticello	Medical Ctr, (Monticello)	Freemason
6	30-60	60	60	30	5:30 AM-12:45 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	Civic Plaza/Govt. Center	Not Stated	Monticello, Govt. Center	Govt. Center
8	30-60	30-60	30-60	30	5:15 AM-1:15 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	Civic Plaza/Govt. Center	Monticello, Govt. Center	Monticello, Govt. Center	Govt. Center
9	30-60	30-60	30-60	30	5:45 AM-12:15 AM	5:30AM-10:30PM	M-Sat	M-Sat	M-Sat	M-Sun	NSU	Monticello, Govt. Center, NSU	Monticello, Govt. Center, NSU	Ballentine, NSU
11	60	30-60	30-60	60	6:00 AM-6:30 PM	6:00AM-7:00PM	M-Sun	M-Sun	M-Sun	M-Sun	No Connections	Medical Ctr, Monticello	Medical Ctr, (Monticello)	Medical Ctr.
13	30-60	30-60	15-60	30-60	4:45 AM-12:45 AM	4:45AM-12:45AM	M-Sun	M-Sun	M-Sun	M-Sun	NSU	Monticello, Govt. Center, NSU	Monticello, Govt. Center, NSU	NSU
15	15-60	15-60	15-60	15-30	4:45 AM-1:15 AM	4:45AM-2:00AM	M-Sun	M-Sun	M-Sun	M-Sun	Military Hwy	Military Hwy	Military Hwy	Military Hwy
16	30-60			30	6:00 AM-12:30 AM		M-Sun			M-Sun	EVMC/Ft. Norfolk			Medical Ctr.
17	15-30				6:00 AM-12:45 AM		M-Sun				No Connections			
18	60	30-60	30-60	60	5:45 AM-10:45 PM	5:00AM-10:30PM	M-Sat	M-Sun	M-Sun	M-Sun	Ballentine, NSU	Ballentine	Ballentine	Ballentine, NSU
20	15-60	30-60	15-60	15-30	5:00 AM-1:15 AM	4:45AM-1:30AM	M-Sun	M-Sun	M-Sun	M-Sun	Newton Rd.	Military Hwy	Military Hwy	Military Hwy
22	60				6:00 AM-7:00 PM		M-Sat				Newton Rd.			
23	30-60	30-60	30-60	30	5:00 AM-1:30 AM	5:00AM-12:30AM	M-Sun	M-Sun	M-Sun	M-Sun	EVMC/Ft. Norfolk, Military Hwy	Medical Ctr, Newton Rd, Monticello	Medical Ctr, Newton Rd, Monticello	Military Hwy, Medical Ctr.
24		30-60	60			6:00AM-7:00PM		M-Sat	M-Sat			Newton Rd.	Newton Rd.	
25	60	60	30-60	60	6:00 AM-12:45 AM	6:00AM-10:30PM	M-Sat	M-Sat	M-Sat	M-Sun	Newton Rd.	Newton Rd.	Newton Rd.	Newton Rd.
27	30-60	60	60	60	5:45 AM-1:00 AM	6:00AM-10:30PM	M-Sat	M-Sat	M-Sat	M-Sun	Newton Rd.	Newton Rd.	Newton Rd.	Newton Rd.
28	30			30	6:00 AM-6:45 PM		M-F			M-Sun	Newton Rd.			Newton Rd.
44	60	30-60	30-60	60	6:00 AM-7:45 PM	5:00AM-10:30PM	M-Sat	M-Sat	M-Sat	M-Sun	EVMC/Ft. Norfolk, York St./Freemason	Medical Ctr.	Medical Ctr.	Medical Ctr.
45	30-60	60	30-60	30	4:45 AM-12:00 AM	Not Stated	M-Sun	M-Sun	M-Sun	M-Sun	Civic Plaza/Govt. Center	Not Stated	Monticello, Govt. Center	Govt. Center
63		15-60	30-60			5:00AM-12:30PM		M-Sun	M-Sun			Newton Rd.	Newton Rd.	
64		30-60	30-60			6:00AM-7:00PM		M-Sun	M-Sun			Ballentine, Harbor Park, NSU	Ballentine, Harbor Park, NSU	
310				60						M-Sun				Govt. Center
918	Varies				5:45 AM-5:00 PM*		M-F				No Connections			
919	Varies				5:00 AM-5:00 PM*		M-F				No Connections			
922	Varies				5:00 AM-5:15 PM*		M-F				No Connections			
960	60			ND	5:30 AM-8:15 PM		M-Sun			ND	Civic Plaza/Govt. Center			Govt. Center
961	30-60			ND	5:00 AM-10:15 PM		M-Sun			ND	Civic Plaza/Govt. Center			Govt. Center
962				ND						ND				Govt. Center
967	Varies			ND	4:45 AM-6:45 PM*		M-F			ND	Military Hwy			Military Hwy

*Government Center Station, as referred to in the PE, Final Design, and FFGA documentation, was later renamed to Civic Plaza Station. The change in name was not associated with any changes to the location or design of this station.

Service Plan Anticipated at Entry into PE

The Tide Service Levels at Entry into PE

At entry into PE, weekday service was predicted to begin at 6:00 a.m. and end at 10:00 p.m. Monday through Thursday. On Fridays and Saturdays, service would operate from 6:00 a.m. to midnight. Sunday service would operate from 7:00 a.m. to 9:00 p.m.

The Tide would operate at 7.5-minute headways during weekday peak periods, 15-minute headways in off-peak periods, and 30-minute headways in the evening. On weekends, the Tide would operate at 15-minute headways during the day and 30-minute headways in the early morning, evening, and late evening hours.

The service would operate seven trains during peak pull-out, four trains during base hours on weekdays and weekends, and two trains during evening and late evening hours on weekdays and weekends. In total, the Tide was predicted to reach 400,500 annual revenue car miles and 25,950 annual revenue train hours.

The Tide Service Levels – Differences between Entry into PE and Actual

Just before revenue service began on The Tide, and not until after the FFGA had been signed, service hours for LRT were extended an additional hour on weeknights, and Sunday service hours were modified to start at 10:55 instead of 7:00 a.m. Proposed peak headways went from 7.5 minutes to 10 minutes between trains.

Bus Service Levels at Entry into PE

The following section provides detail into the proposed changes at the Entry into PE phase. A description of the proposed weekday service characteristics for bus routes within the LRT corridor follows. There were no changes proposed to non-corridor routes.

Bus Service Levels – Differences between Entry into PE and Actual

In the Preliminary Engineering phase there were 21 proposed bus routes which would provide service to at least one LRT station. These routes were called “corridor routes.” All but two corridor routes (Route 63 and Route 64) were existing routes which would have been modified to support the LRT network. The changes to bus service occurring between entry into PE and 2013 can be categorized according to geography as relating to 1)the western terminus, 2) downtown Norfolk 3) the I-264 corridor, 4) the eastern terminus.

At the western terminus, the station designated at entry into PE as Medical Center has been renamed to EVMC/Ft. Norfolk. At entry into PE, Routes 4, 11, 23, and 44 were designated to serve this station. Routes 23 and 44 serve this station as proposed, with Route 44 adding an additional connection at the nearby York Street/Freemason Station. Routes 4 and 11 were modified after the start of revenue service, to serve the new Downtown Norfolk Transit Center (DNTC) and no longer make a connection with LRT. Route 2 was originally proposed with service to the Monticello Avenue and Government Center Stations, but has been modified and now serves the EVMC/Ft. Norfolk Station instead. Route 16 to Old Dominion University now serves the western terminus as well, but this route had not yet been proposed at the Entry to PE milestone.

The downtown Norfolk core is served primarily by three stations: Monticello, MacArthur Square, and Civic Plaza (formerly Government Center) Stations. MacArthur Square Station serves a dense, walkable area, and was not planned to include bus service at any of the milestone dates. At Entry into PE, the Monticello and Government Center Stations were situated along a common path that many routes would take to the old cedar Grove transfer location. Routes 1, 2, 3, 8, 9 and 13 all had proposed connections at both the Monticello and Government Center Stations.

Upon relocating the transfer center to Wood Street, it was no longer necessary to serve both stations with a single route. Routes 1 and 3 have been modified to serve the Monticello Station only. Route 8 now only serves Civic Plaza/Government Center. Route 2 was rerouted to the western terminus, while Routes 9 and 13, which were originally proposed with connections at Monticello, Government Center, and NSU, now only serve NSU. In addition, Routes 4 and 23 had proposed connections at Monticello Station at Entry to PE but do not serve any downtown LRT station currently. Route 4 is a short route terminating at the DNTC and route 23 bypasses the downtown area, serving the EVMC/Fort Norfolk and Military Highway Stations instead. Other routes currently serving the Government Center/Civic Plaza Station either were not planned at Entry into PE (Routes 960 and 961), or had no planned interactions with rail (Route 45).

Along the I-264 corridor, the Ingleside Road Station was accurately proposed as a neighborhood walk-up station. The Harbor Park Station was proposed as a predominantly park and ride oriented station, only served by Route 64, which has been significantly modified and is no longer a corridor Route. Neither of these stations are served by existing bus routes. Routes 9 and 13 serve NSU station as proposed. Route 18 serves Ballentine Station as proposed and has added a connection at NSU station.

At the eastern terminus, routes 25 and 27 serve the Newton Road Station as proposed. Route 20 also terminates at the Newton Road Station instead of the Military Highway Station as proposed. Meanwhile, Route 23 now terminates at Military Highway Station instead of the Newton Road Station as proposed. Two routes with proposed service to Newton Road (Routes 24 and 63) have been eliminated while two new routes (Routes 22 and 28) have added service from Newtown Road to the northeast and east.

Overall, the service plan at Entry into PE was a fairly accurate predictor of the overall character of the network and service to stations. Most changes to proposed LRT connections were a result of minor route tweaks occurring after the relocation of the downtown transfer center, with only a few proposed routes added, eliminated, or significantly rerouted over this 10+ year period.

Entry into Final Design Service Plan

The New Starts application for Fiscal Year 2007 provides detail into the proposed changes at the Entry into FD phase. There were no major changes from the Entry into PE phase. The subtle change in The Tide's annual passenger miles and annual revenue hours is due to small changes in trip time and route length. Four bus routes (Routes 13, 15, 20, and 25) had headways decrease and three routes (Routes 24, 63, and 64) had some headways increase. Route 64 added evening service to weekdays and Saturdays, but removed Sunday service.

The Tide Service Levels at Entry into Final Design

At Entry into FD, the span of service and headways for both weekdays and weekends were not changed from the Entry into PE phase.

Bus Service Levels at Entry into Final Design
A description of the proposed weekday service characteristics for bus routes within the LRT corridor follows. There were no proposed changes to non-corridor routes.

Bus Service Levels – Differences between Entry into Final Design and Actual
No changes to proposed bus connections to LRT stations occurred between Entry into PE and Entry into FD. Therefore, the accuracy of the predictions at entry into FD are identical to those described above at Entry into PE. Only a few minor schedule assumptions differentiated PE from FD, and those changes neither increased nor decreased the overall accuracy of predicted bus service.

FFGA Service Plan

The HRT 2008 System Plan provides detail for the proposed changes at the Full Funding Grant Agreement (FFGA) phase. There were no major changes to The Tide service plan from the Entry into Final Design phase to the FFGA. Minor differences between the two milestones are summarized as follows.

- There was one bus route added to connect to LRT stations (Routes 16).
- Three routes were removed (Routes 24, 63, and 64).

The Tide Service Levels in the FFGA
The span of service and headways for both weekdays and weekends were not changed from the Entry into PE phase. The hours of operation for light rail were adjusted just prior to the start of revenue service, well after the signing of the FFGA. The LRT system as predicted at the time of the FFGA is the same as that predicted at entry into Final Design.

Bus Service Levels in the FFGA
Service level characteristics for the bus routes proposed as corridor routes are described in this section Routes were designated into three tiers based on headways. A description of the proposed weekday service characteristics for bus routes within the LRT corridor follows.

Bus Service Levels – Differences between FFGA and Actual
At the western terminus, Routes 2, 16, 23 and 44 were accurately predicted to serve the EVMC/Ft. Norfolk Station. Route 44 now has an additional connection at the nearby York Street/Freemason Station. Route 11 was modified after the start of revenue service, to serve the DNTC and no longer makes a connection at the Medical Center as Planned.

In downtown Norfolk, Routes 6, 8, 45, 960 and 961 had been sufficiently refined at FFGA to accurately predict service to the Civic Plaza/Government Center Station. Route 310 was proposed at the FFGA milestone only with service to Civic Plaza/Government Center Station as well, but this route never materialized. The primary change from the FFGA milestone surrounds Refinement of the interaction between Monticello Station and the DNTC. Routes 1 and 3 currently connect to LRT at the Monticello Station instead of as proposed at Civic Plaza/Government Center Station and Freemason Station (respectively).

Along the I-264 corridor, Route 13 serves NSU station, Route 18 serves NSU and Ballentine Station, and Route 967 serves the Military Highway station as proposed. Route 9 serves NSU as proposed but does not serve the Ballentine Station as predicted at FFGA.

At the eastern terminus, Routes 25, 27, and 28 serve the Newton Road Station as proposed. Routes 23 and 967 connect at the Military Highway Station as proposed. Route 20 now terminates at the Newton Road Station instead of the Military Highway Station as proposed. Route 22 from Newton Road to Shore Drive was added after the FFGA milestone.

Overall, the refinement of routes into FFGA allowed predictions at that milestone to be more accurate than at previous milestone, with the exception of Route 310, recommended only at this milestone.

Conclusion

The introduction of the Tide light rail service in August 2011 presented a major milestone for HRT. The light rail line provided a new premium transit alternative to the automobile on a corridor parallel to I-264. HRT was able to take advantage of utilizing an existing freight corridor that connected the suburban areas in the east to downtown Norfolk. Although no previous bus route operated on the exact line before the Tide service began, the routing had the benefit of directly serving major regional transit generators such as the Tidewater Community College and Norfolk State University campuses, downtown Norfolk, and the Eastern Virginia Medical Center campus.

As a result of implementation of the Tide service, there were no major changes to the bus network or services provided. Only one new bus route was created to increase service for Old Dominion University students and no routes needed to be eliminated. The August 2011 service changes were focused primarily on adjusting spans of service and headways of buses to match the light rail service and to adjust existing routes to serve stations in the vicinity of the route. In other words the Tide was incorporated into the system as a new east-west corridor, not as replacement of service

Service level predictions for the Tide were fairly consistent across all three milestones, calling for earlier service on Sunday and more frequent headways during peak periods than actually occurred.

Bus service level predictions at Entry into PE were moderately accurate, with some refinement needed to the interactions of bus routes with the downtown Norfolk LRT stations and the future (as yet to be planned) DNTC. Not much changed between entry into PE and entry into Final design, and predictions at that point were equally accurate. Refinements into FFGA increased the accuracy of almost all routes as planned and led to a highly accurate picture of the bus system as it exists today.

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix D: Operations & Maintenance

HAMPTON ROADS TRANSIT

Introduction

Hampton Roads Transit (HRT) is the regional provider of public transportation for the Southside and Peninsula areas of the Hampton Roads metropolitan area, which consists of the cities of Norfolk, Hampton, Newport News, Portsmouth, Chesapeake, and Virginia Beach. HRT was formed with the merger of the South Hampton Roads transit provider (Tidewater Regional Transit, TRT) and the north side operator (Peninsula Transit, PenTran). The HRT service area covers more than 369 square miles with a population of nearly 1.6 million.

The Tide light rail transit (LRT) service began in August of 2011. The route starts just west of Downtown Norfolk, at the Eastern Virginia Medical Center (EVMC)/Fort Norfolk Station. It extends east, through Downtown Norfolk and along the north side of the Elizabeth River Eastern Branch, ending at the Newtown Road Station at Newtown Road and Kempsville Road. HRT also operates bus, ferry, and paratransit service.

The purpose of this technical memorandum (tech memo) is to document the Operation and Maintenance (O&M) characteristics and costs of the HRT transit system, before and after implementation of The Tide, HRT's first LRT line. HRT's governing body, the Transportation District Commission of Hampton Roads, was awarded a Full Funding Grant Agreement (FFGA) on October 1, 2007 by the Federal Transit Administration (FTA) under its New Starts program in the amount of $127,980,000. This tech memo provides documentation of the project's O&M characteristics as operated two years after implementation of the light rail and as predicted at three key milestones in the planning process: Entry into Preliminary Engineering (PE), Entry into Final Design, and the FFGA. The documentation provided in this tech memo will be summarized in the project's Before-and-After Study, an FTA-required study for projects receiving New Starts funding.

The following dates are used to assess the before and after conditions:

- "Before" conditions are represented by August 2009 service levels.
- "After" conditions are represented by August 2013 service levels. These are the same levels of service in effect at the time of this report and are also referred to as "actual" service levels in comparison with predicted levels.

In addition, this report will describe the service levels predicted at three key milestones:

- Entry into PE (November 2002),
- Entry into Final Design (September 2006), and
- FFGA (October 2007).

"After" Operating and Maintenance Characteristics (August 2013)

The Tide LRT Operating Characteristics

In 2013, The Tide LRT operated for a total of over 29,000 train-hours and 373,000 car hours, for an annual cost of approximately $9.5 million. **Table 1** shows the operating characteristics for The Tide LRT two years after implementation of service. Performance measures such as cost per revenue hour and cost per revenue mile are moderately higher than the 2012 NTD reported national average ($255.5 per revenue hour and $16.3 per revenue mile).

Table 1
2013 LRT Operating Characteristics

Variable	
Annual O&M Cost	$9,501,238
Annual Train-Hours	29,849
Annual Car-Miles	373,045
Cost per Train-Hour	$318.31
Cost per Car-Mile	$25.47

Source: HRT, costs include an administrative component allocated to light rail

Bus Operating Characteristics

In 2013, the bus system operated approximately 794,000 revenue hours and almost 10 million revenue miles for an annual cost of approximately $46.2 million, excluding administrative costs.

HRT System O&M Costs

Overall, system operating costs were approximately $88.4 million in 2013. Over half of this was allocated to the bus program, with approximately 25% spent on administration, 10% spent on LRT, 10% on para-transit, and less than 2% on other services such as ferry boat and van pool. Approximately $670,000 of admin costs have been allocated to LRT in Table 1 above for a more relevant comparison of LRT cost predictions across milestone years.

"Before" Operating and Maintenance Characteristics (August 2009)

Bus Operating Characteristics

In 2009, the bus system operated approximately 860,000 revenue hours and 11.8 million revenue miles for an annual cost of approximately $43.6 million, excluding administrative costs

HRT System O&M Costs

System operating costs two years before implementation of The Tide were approximately $72.5 million. Approximately 60% was allocated to the bus program, 27% spent on administration, 10% on para-transit, and less than 1% on other services such as ferry boat and van pool. A small portion of funds, approximately 0.3% of the annual operating budget, was allocated for LRT project and start-up personnel.

Comparison of "Before" and "After" O&M Costs

From 2009 to 2013, overall bus service decreased. Because several routes were streamlined for efficiency and better timing and interaction with the LRT (described in more detail in the Service Planning Memo), revenue hours decreased by 7.6% and revenue miles decreased by 15.3%. At the same time, operating costs went up, leading to higher cost performance measures. **Table 2** shows the change in bus operating characteristics before and after the implementation of The Tide LRT.

Table 2
Comparison of 2009 & 2013 Bus Operating Characteristics

Operating Characteristic	Before (2009)	After (2013)	Percent Change
Annual Revenue Hours	860,170	794,369	-7.6%
Annual Revenue Miles	11,774,683	9,975,730	-15.3%
Annual O&M Cost*	$62,321,144	$66,738,261	7.1%
Cost* per Revenue-Hour	$72.45	$84.01	16.0%
Cost* per Revenue-Mile	$5.29	$6.69	26.4%

**Based on fully allocated costs*

The increase in bus costs and associated cost performance measures is primarily driven by inflation. When adjusted for inflation using the Bureau of Labor Statistics (BLS) national consumer price index (CPI) data, bus costs actually go down by 1.4%, as shown in **Table 3.** While raw costs went up across every service mode, only LRT, ferry, para-transit, support vehicle, and administrative spending increased beyond normal inflationary levels.

Table 3
Comparison of 2009 & 2013 System Operating Costs

Mode	Before (2009)	Before ($2013 Adj.)	After (2013)	Raw % Change	Adj. % Change
Bus	$62,321,144	$67,671,994	$66,738,261	7.1%	-1.4%
LRT	$223,205	$242,369	$9,501,237	NR	NR
Ferry	$1,202,473	$1,305,717	$1,477,547	22.9%	13.2%
Van Pool	$176,300	$191,437	$184,645	4.7%	-3.5%
Para-transit	$7,842,202	$8,515,528	$9,679,939	23.4%	13.7%
Support Vehicles	$717,419	$779,016	$849,283	18.4%	9.0%
TOTAL	$72,482,743	$78,706,061	$88,430,912	22.0%	12.4%

NR- Not relevant percentages because of LRT start-up
Source: HRT, BLS

Comparison to Milestone Predictions

The predicted system wide operating characteristics and yearly O&M costs for the build alternative are discussed in greater detail for each milestone in the following sections. Costs presented at the milestone level are given in 2002 dollar values (for PE) and 2006 dollar values (for Final Design and FFGA.) In order to compare changing assumptions across time periods, all costs in **Table 4** below have been converted to 2013 dollar values using the BLS CPI inflation calculator.

As shown, all three milestone reports predicted a lower service level for bus than the actual system levels in 2013. Some of these service differences may reflect the efficiencies incorporated into the bus routing and timing that resulted from the Service Efficiency Plan of 2012 which allowed for more bus service to be provided with minimal change to costs. However, a comparison of the hourly rates suggests that the milestone estimates were relatively consistent with the actual costs in 2013. There were several bus routes added to the system at the time of LRT implementation that indirect costs could be spread across more revenue hours.

Table 4
Comparison of predicted O&M Characteristics (Costs in Millions, $2013)

	2013 Actual	PE - 2021 Build	Final Design - 2010 Build	FFGA - 2010 Build
Bus System Operational Estimates				
Annual Bus Revenue Hours	794,369	634,000	664,230	527,740
Annual Bus Revenue Miles	9,975,730	8,023,400	7,664,200	6,594,000
Fully Allocated O&M Costs	$66.74 M	$68.79 M	$50.49 M	$50.49 M
Cost per Revenue Hour	$84.01	$108.50	$76.01	$95.67
The Tide LRT Operational Estimates				
Annual Train-Hours	29,849	25,950	25,980	26,750
Annual Car-Miles	373,045	400,500	400,100	392,700
Fully Allocated LRT O&M Costs	$9.50 M	$7.59 M	$7.68 M	$7.65 M
Cost per Train-Hour	$318.31	$292.49	$295.61	$285.98

Source: HRT, BLS

LRT service levels remain relatively steady across milestone years, with more train-hours but fewer car miles in 2013 than were predicted. All milestone reports underestimated the cost of LRT service by approximately $2 million or more. **Table 5** offers a more detailed look at and highlights the primary discrepancies of LRT estimates by cost category for PE and Final design predictions as well as 2013 actual costs. FFGA costs are not available at this level of detail. There were two primary sources of discrepancies between the predicted and actual LRT costs. The casualties & liabilities cost category was underestimated by approximately $1.5 million. While HRT is self-insured, the final details of when additional insurance is invoked resulted in higher costs than the milestone model predicted. A risk assessment was conducted in November 2009 to inform decision makers on the coverage and level of insurance to be purchased by HRT. The decision to self-insure up $2 million was reached and premiums were estimated to be $2.3 M per year. Actual premiums in 2013 were considerably lower at $1.6M.

The number of service hours and resulting platform hours were underestimated in pre-opening day projections. Significant layover time was added in the off-peak hours to the schedule to enhance schedule adherence and facilitate driver breaks and change-overs. The milestone operations plan only included this additional layover time during peak service. The layover time, in addition to slower operating speeds due to signal priority (rather than pre-emption); resulted in increased running time for the system and an additional vehicle during off-peak service times. Increasing from 4 to 5 vehicles to achieve base service added 3600 revenue hours into the system, annually.

Throughout LRT O&M cost development for Entry into PE and Final Design, HRT staff initially assumed 100% contracted maintenance. In actuality, The Tide used a mix of internal and contracted maintenance in 2013. This shift towards on-site employment for maintenance contributed to the lower-than-expected costs for services.

Table 5
Comparison of Fully Allocated LRT O&M Costs by Milestone

LRT Cost Category	2013 Actual	PE - Build Alternative		Final Design - Build Alternative	
Dollar Value Year	*2013*	*2002*	*2013 Adj.*	*2006*	*2013 Adj.*
Personnel Services	$5,964,849	$3,161,221	$4,093,544	$3,548,300	$4,100,206
Services	$777,845	$1,247,529	$1,615,456	$1,342,900	$1,551,776
Materials & Supplies	$274,135	$585,935	$758,742	$499,200	$576,846
Utilities	$646,660	$561,322	$726,870	$706,500	$816,390
Fuel	$0*	$11,824	$15,311	$7,200	$8,320
Casualties & Liabilities	$1,643,977	$188,160	$243,653	$138,800	$160,389
Purchased Transportation	$0	$0	$0	$0	$0
Other Miscellaneous Expenses	$193,772	$117,518	$152,177	$98,100	$113,359
TOTAL EXPENSES	**$9,501,238**	**$5,861,683**	**$7,590,440**	**$6,650,500**	**$7,684,925**

**No fuel costs were allocated to LRT in 2013.*
Source: HRT, Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations and Maintenance Plan, HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report BLS

Predicted O&M Costs at Entry into PE

The project as described in the FY05 New Starts submittal was a 7.4-mile light rail system comprised of exclusive, double-tracked guideway with sections of shared street ROW. Eleven stations were included in the project. FY05 New Starts identified a start date of summer 2008 for revenue operations.

The following sections overview the O&M data contained in the *Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations and Maintenance Plan*. The plan describes No-Build, Baseline and Build scenarios for a 2021 project horizon year. The No-Build Alternative assumes only a proportional increase in existing 2002 transit services. The Baseline Alternative assumes a more robust NET Service, a downtown Norfolk circulator, as well as a new Express Bus corridor. The Build Alternative slightly reduces NET service, while adding new LRT service. All estimates are modeled off of 2002 service statistics and are reported in 2002 dollar values.

The Tide LRT Operating Characteristics

At entry into PE, the Tide LRT system was not yet named and was referred to in documentation as 'Norfolk LRT.' Light rail O&M costs for the Build Alternative are based on the following system operating characteristics:

- 3.3 million annual rail passenger trips
- 7 peak cars/9 cars in fleet
- 400,500 annual revenue car-miles
- 25,950 annual revenue train-hours
- 11 LRT stations
- 1 rail yard

The LRT O&M cost model included a staffing plan which assumed a new division comprised of four departments would be required to implement ongoing rail service. This rail division included 64.5 Full time employment positions with salaries ranging from $27-95k. **Table 6** highlights O&M cost estimates for The Tide LRT. This cost does not include the additional $700,000 per year identified for LRT service-related changes to the HRT bus system identified in the FEIS bus service plans. The calculated cost per train-hour was lower than most other peer systems at the time. This was due to HRT's use of one-car trains. However, cost per car-mile was similar to Dallas, San Jose and Los Angeles.

Table 6
Norfolk LRT O&M Cost Estimates (2002$)

Variable	2021 Rail Plan
Annual O&M Cost	$5,861,683
Revenue Car-Miles	400,500
Revenue Train-Hours	25,950
Cost per Car-Mile	$14.64
Cost per Train-Hour	$226

Source: Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations and Maintenance Plan

Bus and Trolley Operating Characteristics

Table 7 provides a summary of service level predictions at entry into PE. The number of vehicles required (peak and fleet), revenue hours, and revenue miles are reported by service type for 2002 and 2021 horizon year alternatives. As expected, Express Route and Net Service statistics increase for the Baseline Alternative, while the Build Alternative shows a reduction in NET Service paired with an increase in Southside system local routes. Peninsula system service is constant across all alternatives.

Table 7 PE Estimated Operating Statistics					
Alternative	Southside Local Routes	New Corridor Express Routes	Southside NET Service	Other Bus Services	Total
Peak/Fleet Vehicles					
2002 Actual	146/175	N/A	6/8	128/154	280/337
2021 No-Build	176/210	N/A	6/8	160/193	342/411
2021 Baseline	182/218	6/7	20/25	160/193	368/443
2021 Build	185/221	N/A	4/5	160/193	349/419
Annual Revenue Bus-Hours					
2002 Actual	458,600	N/A	18,470	294,000	770,470
2021 No-Build	589,100	N/A	18,470	367,000	974,570
2021 Baseline	621,300	18,610	53,620	367,000	1,060,530
2021 Build	634,000	N/A	11,200	367,000	1,012,200
Annual Revenue Bus-Miles					
2002 Actual	6,031,800	N/A	118,400	3,903,400	10,043,600
2021 No-Build	7,550,800	N/A	118,400	4,879,000	12,548,200
2021 Baseline	7,928,500	306,200	181,100	4,879,000	13,294,800
2021 Build	8,023,400	N/A	55,500	4,879,000	12,957,900

Source: Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations Plans and O&M Cost Results Report

HRT System O&M Costs

In fiscal year 2002, the actual O&M costs were approximately $31.7 Million for the Southside system and $17.3 Million for the Peninsula transit system. HRT's total O&M costs were over $49 million across all public transportation modes.

The estimated 2021 O&M costs for the No-build, Baseline and Build alternatives are shown below in **Table 8**. Total system costs for each scenario include 'Other Transit Services' such as paratransit, vanpool, Maxi-Ride, and ferryboat services, in addition to the bus, trolley and rail improvements described above. These costs assumed a 25 percent increase in paratransit and vanpool services over 2002 levels, with no increase in Maxi-Ride or Ferryboat Service.

Table 8 PE Estimated O&M Costs (in Millions, $2002)				
Cost by Mode	2002 Actual	2021 No-Build	2021 Baseline	2021 Build
Bus/Trolley	$42.81	$51.36	$54.24	$53.12
Other Transit Services	$6.22	$7.29	$7.44	$7.29
NET	N/A	$0.80	$2.19	$0.48
The Tide LRT	N/A	N/A	N/A	$5.86
Total Estimated O&M Costs	$49.03	$59.45	$63.87	$66.74

Source: Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations Plans and O&M Cost Results Report

Predicted O&M Costs at Entry into Final Design

The following sections overview the O&M characteristics at entry into Final Design as described in the *Norfolk Light Rail Transit Project Final Design, O&M Cost Results Report*. Light rail revenue operations were scheduled to commence in January of 2010, two years later than originally intended at entry into PE. The plan describes similar No-Build, Baseline and Build alternatives but with a delayed project horizon year of 2030. The No-Build Alternative assumes only a proportional increase in existing 2002 transit services. The Baseline Alternative assumes a more robust NET Service. The Build Alternative slightly reduces NET service, but also adds The Tide LRT. The report also predicts operating statistics and costs for 2009 and 2010 opening year pre- and post-LRT service. The O&M model for Final Design was updated to incorperate 2006 service statistics and FY2004/2005 peer city LRT cost data. All estimates are reported in 2006 dollar values.

The Tide LRT Operating Characteristics

The estimated LRT service statistics for the 2030 horizon year are as follows:

- 7 peak vehicles/9 fleet vehicles
- 25,980 annual revenue train-hours
- 400,100 annual revenue car-miles
- 7.34 one-way/14.68 directional route-miles
- 11 LRT stations
- 1 rail yard

These assumptions are similar to the 2021 statistics assumed at entry into PE with the exceptions of an additional 30 annual revenue miles and 400 fewer annual revenue car miles. The primary differences in this iteration of the rail service plan are the delayed implementation year, updates the LRT O&M model to incorporate newer (2004-2006) cost data and revisions to the LRT staffing plan. At entry into Final Design, the rail staffing plan included only 58 full time employees with salaries ranging from $22-66k. **Table 9** highlights O&M cost estimates for The Tide LRT at entry into Final Design. The estimated cost per train-hour was lower than most other peer systems while the cost per car-mile was higher than peers due to the use of one-car train consists.

Table 9
The Tide LRT O&M Cost Estimates (2006$)

Variable	Build Alternative
Annual O&M Cost	$6,650,500
Revenue Car-Miles	400,200
Revenue Train-Hours	25,990
Cost per Car-Mile	$16.62
Cost per Train-Hour	$256

Source: HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report

Bus and Trolley Operating Characteristics

Table 10 provides a summary of service level predictions at entry into Final Design. The number of vehicles required (peak and fleet), revenue hours, and revenue miles are reported by service type for all 2030 horizon year alternatives as well as 2009 (pre-LRT service) and 2010 (post-LRT service) opening year predictions.

Table 10 Final Design Estimated Operating Statistics					
Alternative	Southside Local Routes+*MAX*Se rvice	New Corridor Express Routes	Southside NET Service	Other Bus Services	Total
Peak Vehicles					
2009 Pre-LRT	119	N/A	6	185	310
2010 Post-LRT	125	N/A	6	186	317
2030 No-Build	145	N/A	6	221	151
2030 Baseline	155	8	14	221	177
2030 Build	152	N/A	4	221	156
Annual Revenue Bus-Hours					
2009 Pre-LRT	502,080	N/A	18,570	389,818	910,468
2010 Post-LRT	527,740	N/A	18,170	397,581	943,491
2030 No-Build	638,200	N/A	18,570	476,048	1,132,818
2030 Baseline	678,040	23,560	33,560	476,048	1,211,208
2030 Build	664,230	N/A	11,230	476,048	1,151,058
Annual Revenue Bus-Miles					
2009 Pre-LRT	6,520,100	N/A	118,400	5,864,615	12,403,115
2010 Post-LRT	6,594,000	N/A	118,400	5,971,796	12,684,196
2030 No-Build	7,610,800	N/A	118,400	6,778,228	14,507,428
2030 Baseline	7,964,100	343,200	185,000	6,778,228	15,270,528
2030 Build	7,664,200	N/A	55,700	6,778,228	14,498,128

Source: HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report

HRT System O&M Costs

The estimated 2030 O&M costs for the No-build, Baseline and Build alternatives are shown below in **Table 11**. Total system costs for each scenario include 'Other Transit Services' such as paratransit, vanpool, Maxi-Ride, and ferryboat services, in addition to the bus, trolley and rail improvements described above. Ferry and vanpool 2030 service levels were determined by using the estimates from the *Vision for the Future* short-range plan. This included a significant increase in ferry service to 20,000 revenue-hours (predicted at intro into PE as 7,092 revenue-hours) and a vanpool fleet of 48 vans (predicted at intro into PE as 51 vans in 2021). A 25 percent increase was assumed for demand-response (paratransit) services. While the LRT system itself costs $6.6 Million, the baseline alternative spends approximately $3.6 Million more on bus, trolley, net and administration, resulting in a cost difference of only $3 Million between the Baseline and Build Alternatives.

Table 11 Final Design Estimated O&M Costs (in Millions, $2006)					
Cost by Mode	2009 Pre-LRT	2010 Post-LRT	2030 No-Build	2030 Baseline	2030 Build
Bus/Trolley	$42.52	$43.69	$50.93	$53.79	$51.76
NET	$0.82	$0.82	$0.82	$1.44	$0.47
Other Transit Services	$7.22	$7.42	$9.82	$9.82	$9.82
Administration	$16.72	$17.00	$18.61	$19.39	$18.78
The Tide LRT	N/A	$6.65	N/A	N/A	$6.65
Total Estimated O&M Costs	$67.28	$75.58	$80.18	$84.44	$87.48

Source: HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report

Predicted O&M Costs at the FFGA Milestone

The FFGA was issued on October 1, 2007. In the FFGA, HRT agreed to achieve revenue operations of the project on or before January 1, 2010. The information in this section documents what was included in the FFGA.

The Tide LRT Operating Characteristics

The FFGA presents three scenarios, all of which consist of some level of LRT service. Here, the baseline scenario refers to The Tide LRT service assumptions as carried forward from the Final Design Build Alternative. Slight adjustments to total annual revenue miles and O&M costs reflect the increasing level of detail available. Scenario 1 and Scenario 2 assume minor schedule modifications which result in fewer revenue miles and greater revenue hours compared to the Baseline. The Baseline assumes 7.5 minute peak headways and a 16 hour service day beginning at 6:00 a.m. Scenario 1 expands the span of service, beginning at 5:30 a.m. but keeps costs neutral by reducing the number of hours in peak service. Peak headways for Scenario 1 are eight minutes. Scenario 2 further expands the span of service, beginning at 5:00 a.m. on weekdays and Saturdays, and assumes a 10-minute headway (allowing more time built in for schedule recovery). **Table 12** provides the service characteristics for all three LRT options. All scenarios assume the previously described 7.34-mile line, with 11 stations and one rail yard.

LRT Staffing assumptions were identical for FFGA as they were at entry into Final Design, consisting of 58 full time employment positions with salaries between $22-66K per year.

Table 12 The Tide LRT O&M Cost Estimates (2006$) from FFGA			
Variable	**Baseline**	**Scenario 1**	**Scenario 2**
Peak/Fleet Rail Cars	7/9	7/9	6/9
Annual Revenue Train-hours	25,980	26,700	26,750
Annual Revenue Car-miles	400,000	399,500	392,700
Annual O&M Cost (Millions)	$6.65	$6.68	$6.62
Cost per Train-Hour	$255.99	$250.18	$247.55
Cost per Car-Mile	$16.63	$16.72	$16.86

Source: HRT

Bus and Trolley Operating Characteristics

Table 13 provides a summary of service level predictions at FFGA. The number of peak vehicles required, revenue hours, and revenue miles are reported by service type for 2009 (pre-LRT service) and 2010 (post-LRT service) alternatives. As expected, the post-LRT service alternative shows an overall increase in Southside local and MAX routes.

Table 13
FFGA Estimated Operating Statistics

Alternative	Southside Local Routes+*MAX* Service	New Corridor Express Routes	Southside NET Service	Other Bus Services	Total
Peak Vehicles					
2009 Pre-LRT	119	N/A	6	185	310
2010 Post-LRT	125	N/A	6	186	317
Annual Revenue Bus-Hours					
2009 Pre-LRT	502,080	N/A	18,570	389,818	910,468
2010 Post-LRT	527,740	N/A	18,570	397,581	943,491
Annual Revenue Bus-Miles					
2009 Pre-LRT	6,520,100	N/A	118,400	5,864,615	12,403,115
2010 Post-LRT	6,594,000	N/A	118,400	5,971,796	12,684,196

Source: HRT

HRT System O&M Costs

The estimated O&M costs for the 2009 Pre-LRT and 2010 Post-LRT alternatives are shown below in **Table 14**. Total system costs for each scenario include 'Other Transit Services' such as paratransit, vanpool, Maxi-Ride, and ferryboat services, in addition to the bus, trolley and rail improvements described above.

Table 14
FFGA Estimated O&M Costs (in Millions, $2006)

Cost by Mode	2009 Pre-LRT	2010 Post-LRT
Bus/Trolley	$42.52	$43.69
NET	$0.82	$0.82
Other Transit Services	$7.22	$7.42
Administration	$16.72	$17.00
The Tide LRT	N/A	$6.65
Total Estimated O&M Costs	$67.28	$75.58

Source: HRT

Summary

LRT service levels remain relatively steady across milestone years, with more train-hours but fewer car miles in 2013 than were predicted. All milestone reports underestimated the cost of LRT service by approximately $2 million or more. There were three primary sources of discrepancies between the predicted and actual LRT costs.

1. The casualties & liabilities cost category was underestimated by approximately $1.5 million. While HRT is self-insured, the final details of when additional insurance is invoked resulted in higher costs than the milestone models predicted. A risk assessment was conducted in November 2009 to inform decision makers on the coverage and level of insurance to be purchased by HRT. The decision to self-insure up to $2 million was reached and premiums were estimated to be $2.3 M per year. Actual premiums in 2013 were considerably lower at $1.6M.

2. The number of service hours and resulting platform hours were underestimated in pre-opening day projections. Significant layover time was added in the off-peak hours to the schedule to enhance schedule adherence and facilitate driver breaks and change-overs. The milestone operations plan only included this additional layover time during peak service. The layover time, in addition to slower operating speeds due to signal priority (rather than pre-emption); resulted in increased running time for the system and an additional vehicle during off-peak service times. Increasing from 4 to 5 vehicles to achieve base service added 3600 revenue hours into the system, annually.

3. Throughout LRT O&M cost development for Entry into PE and Final Design, HRT staff initially assumed 100% contracted maintenance. In actuality, The Tide used a mix of internal and contracted maintenance in 2013. This shift towards on-site employment for maintenance contributed to the lower-than-expected costs for services.

Table 15
Summary of Cost Drivers Underestimated during Milestone Projections

LRT Cost Driver	2013 Actual	PE - Build Alternative		Final Design - Build Alternative	
Annual LRT Revenue Hours	29,849	25,950		25,980	
LRT Cost Category	**2013$**	**2002$**	**2013$ Adj.**	**2006$**	**2013$ Adj.**
Personnel Services	$5,964,849	$3,161,221	$4,093,544	$3,548,300	$4,100,206
Services	$777,845	$1,247,529	$1,615,456	$1,342,900	$1,551,776
Casualties & Liabilities	$1,643,977	$188,160	$243,653	$138,800	$160,389

Source: HRT, Norfolk Light Rail Transit Project Preliminary Engineering FEIS, Transit Operations and Maintenance Plan, HRT Light Rail Transit Project Final Design, Draft O&M Cost Results Report BLS

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix E: Ridership

HAMPTON ROADS
TRANSIT

Introduction

The purpose of this technical memorandum (tech memo) is to document the ridership impacts of the Tide, Hampton Roads Transit's (HRT) first light rail transit (LRT) line. HRT's governing body, the Transportation District Commission of Hampton Roads, was awarded a Full Funding Grant Agreement (FFGA) on October 1, 2007 by the Federal Transit Administration (FTA) under its New Starts program in the amount of $127,980,000. This tech memo provides documentation of the project's ridership impacts as actually occurred approximately two years after opening and as predicted at three key milestones in the planning process: Entry into PE, Entry into Final Design, and the FFGA. The documentation provided in this tech memo will be summarized in the project's Before-and-After Study, an FTA-required study for projects receiving New Starts funding.

The tech memo is organized into two principal sections:

- Impacts of the project on transit ridership; and
- Accuracy of predicted ridership

Impacts of the Project on Transit Ridership

This section describes the impact that the Tide LRT project has had on transit ridership in the Hampton Roads area. These impacts are described in two sub-sections: (1) trips on the project itself and (2) changes to trip-making on the regional transit system.

Information on actual Tide LRT ridership and regional transit system ridership after the introduction of the Tide are based on a transit passenger survey conducted in 2013 and 2014. This survey was based on the most recent recommendations of good transit survey practices prepared by the Federal Transit Administration. Key aspects of this survey program included:

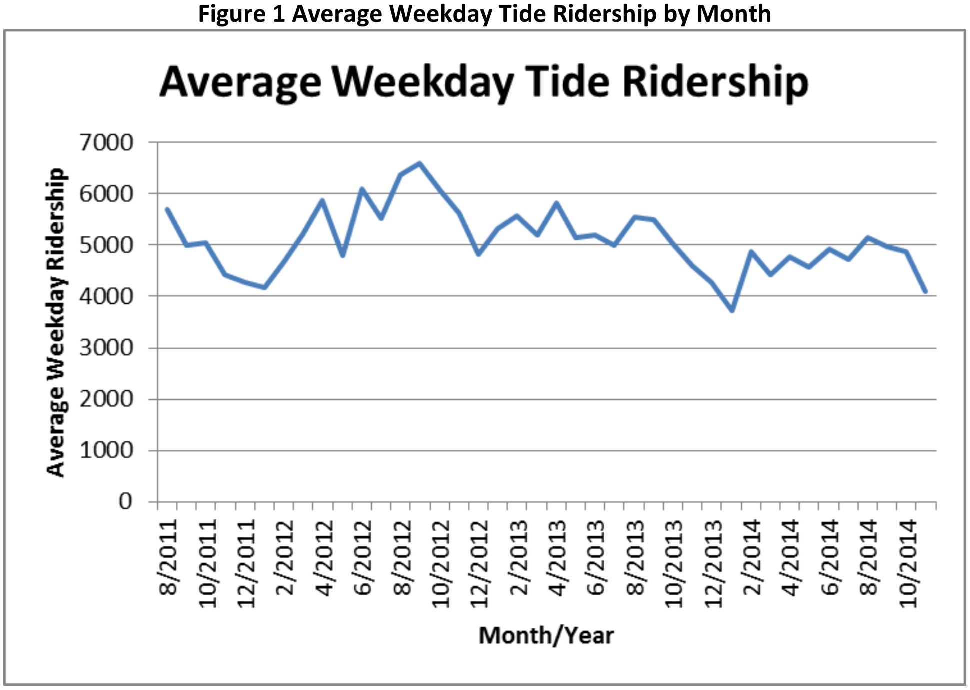
- An on-and-off-survey conducted in the Fall of 2013 that collected detailed information on passenger boarding and alighting locations. This survey collected information for 27,118 trips representing 47% of all weekday trips made on HRT.
- A comprehensive boarding and alighting count program that collected information on the number of passengers boarding and alighting at each stop.
- An intercept survey of nearly 9,000 trip-makers that collected information on passenger and trip characteristics. This survey was conducted in the Spring of 2014 using a personal interview approach with tablet PCs for real-time data entry, survey control, and quality control.
- Detailed survey expansion to weight passenger trip information to represent the total population of transit riders. Expansion was controlled by route, time-of-day period, boarding location, and alighting location.

The representation of HRT system ridership before the introduction of the Tide LRT service is based on a survey conducted in 2011 using then-current practices. This survey used traditional questionnaires and survey expansion was controlled by route. As part of this Before-and-After study, trips were re-weighted based on route and direction of travel and adjusted to account for missing information on origin and destination location. Because the older survey methodology did not control for time-of-day of travel or for boarding and alighting location, the results are not completely comparable with the 2013/2014 survey. Differences between the survey approaches are more likely to affect detailed information on trip purpose or traveler characteristics. Overall transit usage patterns are more likely to be comparable between the two surveys.

Project Ridership

As of the Fall of 2013, the Tide carried 4,600 trips per average weekday. As shown in Figure 1, the Tide attracted over 5,000 daily trips at the time of its opening. Ridership rose to over 6,000 trips per day during the summer of 2012 due to aggressive fare discounting. At the time, the HRT GoPass program offered a deeply discounted ticket that was phased out between June and December 2012. As this program was phased out, Tide ridership dropped to approximately 5,000 riders per day. More recently, ridership has ranged between 4,500 and 5,500 riders per weekday except in the months of November, December, and January, which have lower ridership due to the winter holidays. Ridership in January 2014 was also affected by a major snow storm which caused HRT to cancel service on one weekday.

Figure 1 Average Weekday Tide Ridership by Month



To understand the characteristics of these trips, Fall 2013 LRT passenger trip beginning and ending points from the intercept survey were geographically located according to whether the whether the trip-end was a production (home-end of the trip) or an attraction (non-home trip end)[1].

To provide a context for this analysis, Figure 2 presents a corridor map showing the location of Tide stations and nearby major roadways. Using the same map scale, Figure 3 shows the locations of trip

[1] In the case of non-home-based trips, the production trip end is assumed to be the same as the origin and the attraction trip-end is the same as the destination.

productions. Productions are most dense in areas immediately adjacent to the LRT line and in extended corridor areas (e.g., the Old Dominion University area of Norfolk and the Witchduck Road area of Virginia Beach). Trip productions also occur in a broader area but with less density.

Figure 4 presents Tide LRT trip attraction locations and shows that these trip ends are concentrated in the Central Business District (CBD), Eastern Virginia Medical Center (EVMC) and Norfolk State University areas of Norfolk. Travel to these areas constitute the core market for the Tide LRT. Other attractions are scattered along the corridor and throughout the region but at much less density. The pattern of concentrated attractions and more dispersed productions is similar to other fixed guideway transit systems around the country.

Trip flows from trip production locations to trip attraction locations provide information on the nature of travel occurring on the Tide LRT. These flows are aggregated by geographic areas (districts) that are defined so that they identify key concentrations of LRT travel. Figure 5 provides a map of the districts used in the analysis which are based on the LRT travel patterns described above.

Table 1 shows the number of total weekday LRT trips traveling from each production district to each attraction district. Each production district appears as a row in this table while each attraction district appears as a column.

Figure 2 Location of LRT Stations and Nearby Major Roadways

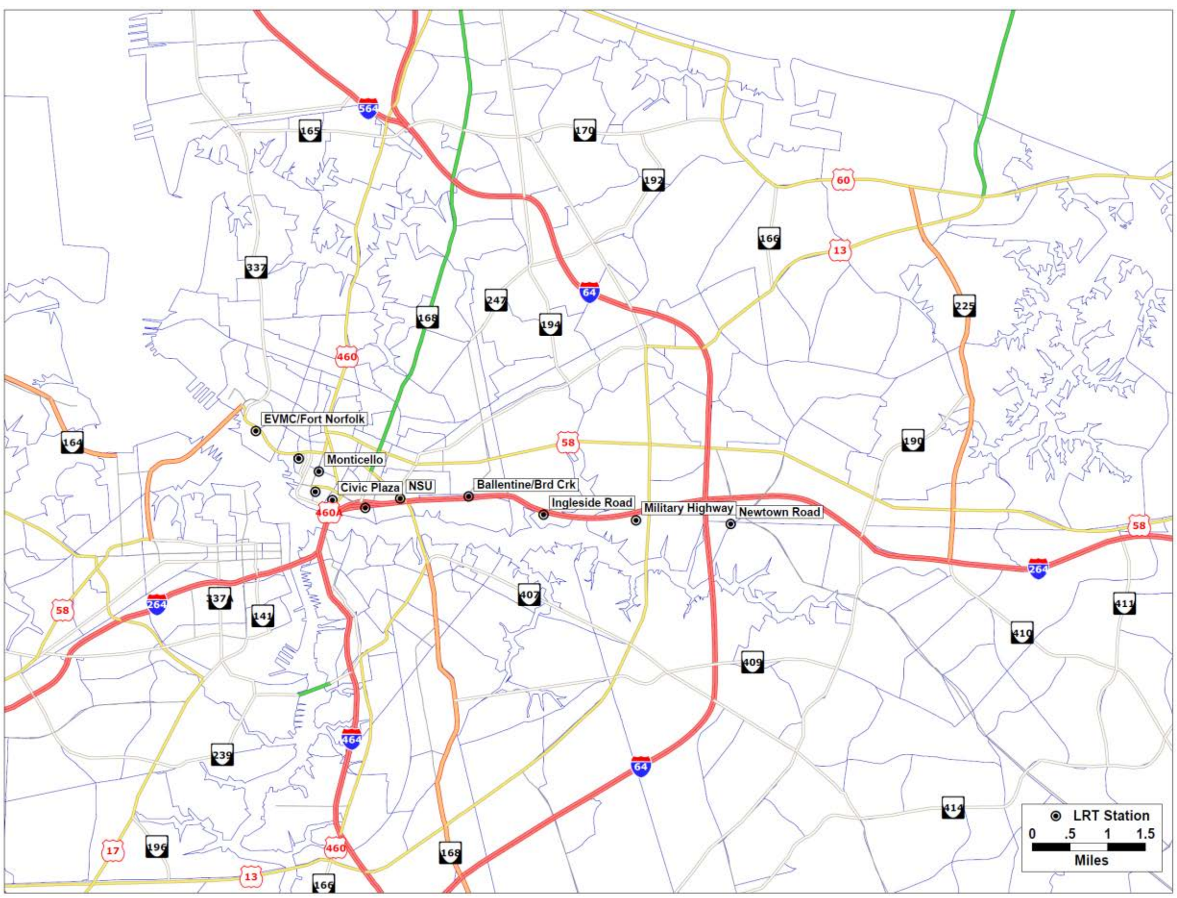


Figure 3 Location of Year 2013 Weekday Tide LRT Trip Productions

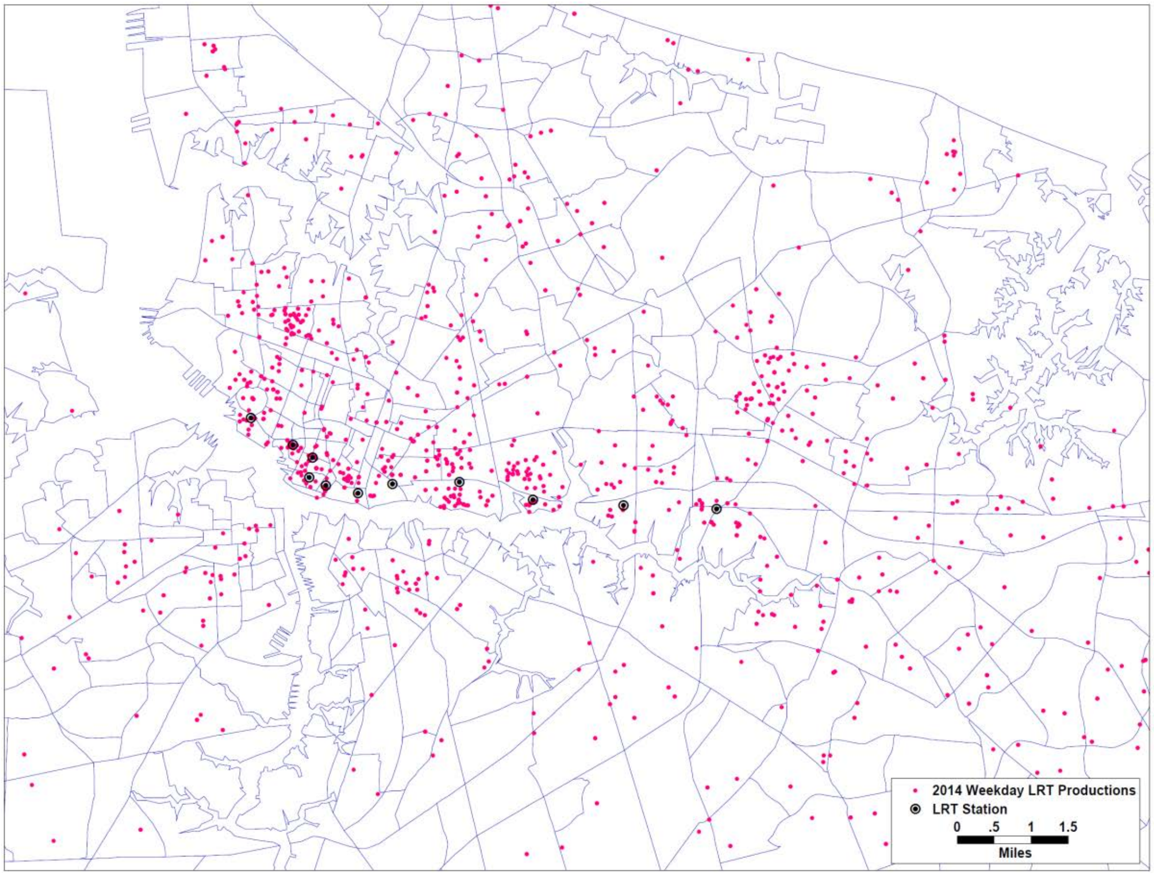


Figure 4 Location of Year 2013 Weekday Tide LRT Trip Attractions

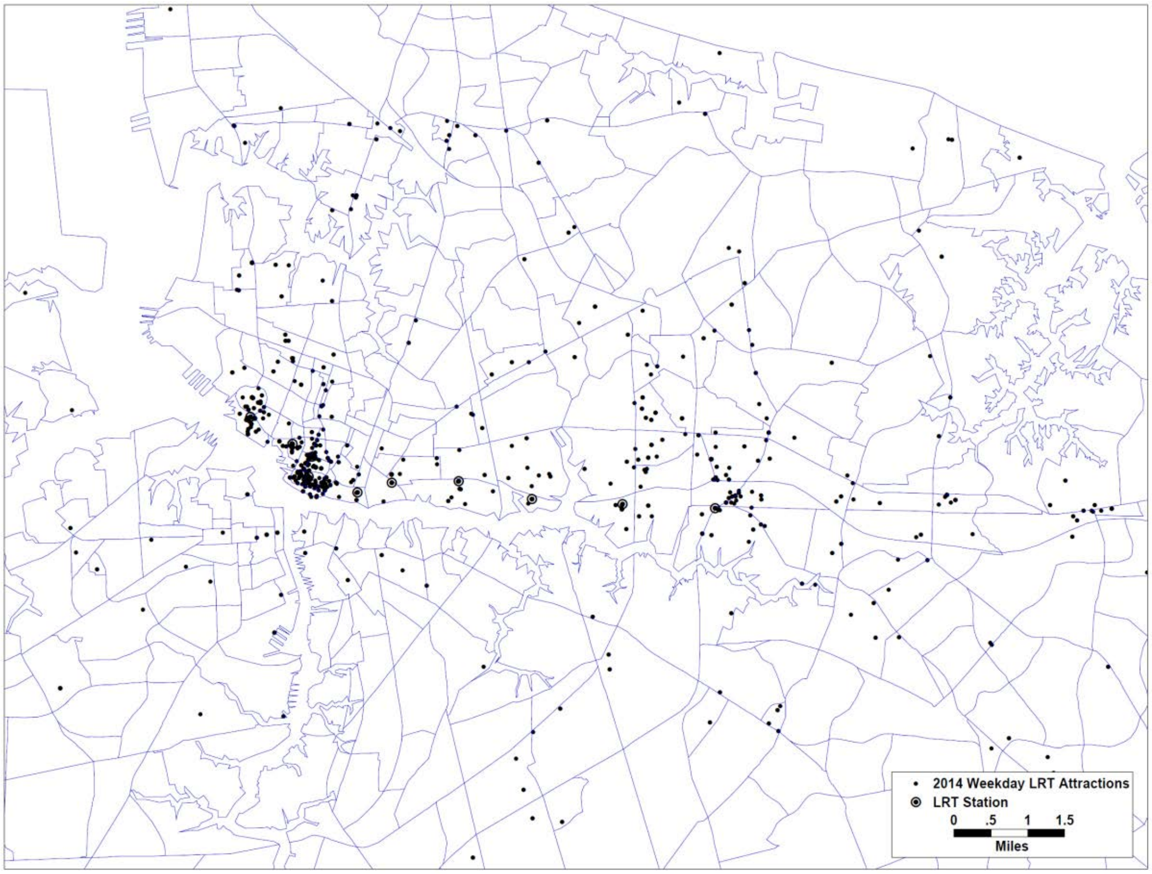


Figure 5 Districts Used for Summarizing Trip Productions and Attractions

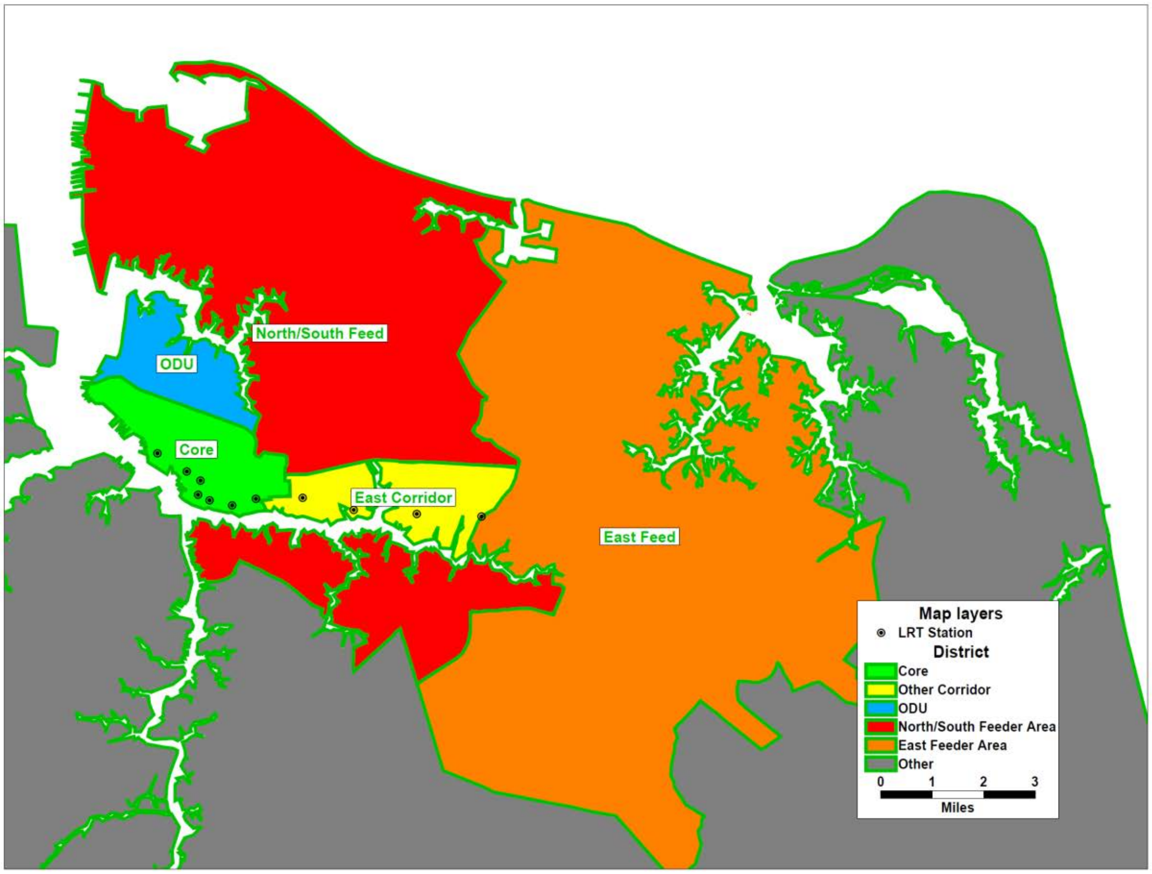


Table 1 Year 2013 Weekday Tide LRT Unlinked Trip Flows by District									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	618	126	4	87	114	56	1,005	22%
Other Corridor	2	373	69	17	37	35	52	584	13%
ODU	3	136	30	-	26	49	35	277	6%
N/S Feed Area	4	557	135	15	86	118	78	987	22%
East Feed Area	5	591	29	77	96	-	58	851	19%
Other	6	528	79	9	40	135	96	887	19%
Total		2,803	469	122	373	450	375	4,592	100%
Share		61%	10%	3%	8%	10%	8%	100%	

Consistent with the mapping described earlier, the Core area (Norfolk CBD, EVMC, NSU) attracts over 60% of all riders (2,803 out of 4,592). Remaining trip attractions are scattered over a large area with only 10% (469 out of 4,592) being attracted to corridor areas within walking distance of the line. The remaining trip attractions are distributed throughout much of the Southside[2] portion of the Tidewater area.

Productions are less concentrated than attractions. Only 35 percent (1,589 out of 4,592) trips are produced in the corridor (Core and Other Corridor). Another 28 percent of trips are produced in other parts of Norfolk (ODU and North/South Feed Area) with the area near ODU being responsible for 6 percent of all Tide trip productions. The remaining 38 percent of trip productions are scattered across a broad area of the Hampton Roads region.

Table 2 illustrates the contribution that LRT makes to serving the regional transit market. This flow table shows the percentage of all linked transit trips made on LRT for some or part of the journey. For travel to the Core from the corridor or adjoining areas of Norfolk and Virginia Beach, LRT serves as a key element of the transit system with over 60 percent of transit riders using LRT. Between 20 and 40 percent of travel between the corridor and other regional destinations are made by LRT. As expected, more broadly dispersed regional transit trips are less likely to be made by LRT.

Tables 3 and 4 show home-based work (HBW) unlinked LRT trip flows between all production and attraction districts as trips and as a percentage of the total LRT market. This trip purpose is the most common for LRT riders with 43 percent of all LRT riders making HBW trips. This percentage is lower in the core and project corridor and higher in areas further from the project corridor. This outcome suggests that travelers near the line are more likely to use the Tide for all types of trips while persons further from the line are more likely to consider the service for just regular work trips.

Tables 5 and 6 show home-based university (HBU) trip flows by production and attraction district as trips and as a percentage of the total LRT market. Nineteen percent of all LRT riders are making HBU trips. Generally, these trips are traveling to the core where Norfolk State University and Tidewater Community College have campuses near LRT stations. A smaller number of trips are also attracted to Old Dominion University. This campus is located on a bus corridor that connects to the Tide LRT line.

Tables 7 and 8 show transit-dependent[3] LRT unlinked flows by production and attraction district. Both the number of trips and the percentage of the total LRT market are shown. Slightly over half of all LRT riders are transit-dependents. The share of transit dependents is lower for trips attracted to the Core (42%) and higher in other areas served by the LRT.

[2] Southside is the portion of Tidewater south of the James River and Hampton Roads.

[3] Transit dependent trips are defined as those being made by members of 0-car households or travelers without a driver's license.

Table 2 Year 2013 Weekday Tide LRT Unlinked Trips as a Percentage of All Linked Transit Trips								
		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	61%	23%	3%	11%	35%	10%	29%
Other Corridor	2	68%	44%	31%	15%	23%	20%	41%
ODU	3	26%	25%	0%	6%	37%	18%	19%
N/S Feed Area	4	17%	22%	3%	2%	13%	6%	9%
East Feed Area	5	67%	17%	68%	16%	0%	7%	23%
Other	6	29%	28%	6%	4%	14%	1%	5%
Total		35%	25%	11%	5%	12%	2%	12%

Table 3 Year 2013 Weekday Tide LRT HBW Unlinked Trip Flows									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	173	37	-	13	32	12	267	13%
Other Corridor	2	86	15	15	9	32	17	173	9%
ODU	3	19	6	-	9	31	27	92	5%
N/S Feed Area	4	178	108	6	54	84	42	471	24%
East Feed Area	5	312	19	22	47	-	42	442	22%
Other	6	314	51	1	14	108	50	538	27%
Total		1,082	236	44	146	286	189	1,983	100%
Share		55%	12%	2%	7%	14%	10%	100%	

Table 4 Year 2013 Weekday Tide LRT HBW Trips as a Percentage of LRT Transit Trips								
		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	28%	29%	0%	15%	28%	22%	27%
Other Corridor	2	23%	21%	90%	25%	90%	33%	30%
ODU	3	14%	21%		33%	62%	77%	33%
N/S Feed Area	4	32%	80%	38%	63%	71%	54%	48%
East Feed Area	5	53%	64%	28%	49%		73%	52%
Other	6	59%	65%	15%	34%	80%	51%	61%
Total		39%	50%	36%	39%	64%	51%	43%

Table 5 Year 2013 Weekday Tide LRT HBU Unlinked Trip Flows									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	87	-	-	1	8	17	114	13%
Other Corridor	2	101	-	2	-	-	7	109	13%
ODU	3	65	3	-	4	6	4	83	10%
N/S Feed Area	4	202	-	5	4	3	17	230	27%
East Feed Area	5	148	-	52	14	-	11	225	26%
Other	6	75	6	7	-	6	6	100	12%
Total		679	9	66	24	24	61	861	100%
Share		79%	1%	8%	3%	3%	7%	100%	

Table 6
Year 2013 Weekday Tide LRT HBU Trips as a Percentage of LRT Transit Trips

Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
		Attraction District						
Core	1	14%	0%	0%	2%	7%	31%	11%
Other Corridor	2	27%	0%	10%	0%	0%	13%	19%
ODU	3	48%	10%		17%	12%	11%	30%
N/S Feed Area	4	36%	0%	33%	4%	3%	21%	23%
East Feed Area	5	25%	0%	67%	15%		19%	26%
Other	6	14%	7%	82%	0%	4%	6%	11%
Total		24%	2%	54%	6%	5%	16%	19%

Table 7
Year 2013 Weekday Tide LRT Transit-Dependent Trip Flows

Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
		Attraction District							
Core	1	281	78	-	73	65	21	518	21%
Other Corridor	2	228	58	10	34	9	40	379	16%
ODU	3	89	28	-	20	36	21	195	8%
N/S Feed Area	4	247	90	13	61	100	62	572	24%
East Feed Area	5	198	29	42	92	-	47	409	17%
Other	6	131	54	3	37	81	47	355	15%
Total		1,174	338	68	317	290	239	2,427	100%
Share		48%	14%	3%	13%	12%	10%	100%	

Table 8 Year 2013 Weekday Tide LRT Transit Dependent Trips as a Percentage of LRT Transit Trips								
		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	46%	62%	0%	84%	57%	37%	51%
Other Corridor	2	61%	84%	58%	91%	25%	77%	65%
ODU	3	65%	94%		77%	74%	60%	70%
N/S Feed Area	4	44%	66%	86%	71%	85%	80%	58%
East Feed Area	5	34%	100%	55%	95%		82%	48%
Other	6	25%	69%	36%	93%	60%	49%	40%
Total		42%	72%	56%	85%	65%	64%	53%

Tables 9 and 10 show LRT trip flows for passengers that use a non-motorized mode to access the first transit service they use. These trips include those that walk or bike directly to an LRT station and those that walk or bike to a bus and then transfer to the LRT. It excludes travelers who use an automobile to travel to or from transit, either as a driver or passenger. Over 70 percent of all LRT riders walk or bike to reach their first transit mode. Only trips traveling to the Core from origins outside the LRT corridor are more likely to drive or be driven than to use a non-motorized mode of access.

Table 9 Year 2013 Weekday Tide LRT Trip Flows for Riders that Walk/Bike to the Transit System									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	591	126	4	87	109	55	973	29%
Other Corridor	2	341	69	16	37	35	52	551	16%
ODU	3	119	28	-	26	45	35	252	7%
N/S Feed Area	4	293	100	13	86	101	66	658	19%
East Feed Area	5	249	29	38	85	-	26	427	13%
Other	6	190	71	6	37	132	74	511	15%
Total		1,783	424	77	359	421	308	3,373	100%
Share		53%	13%	2%	11%	12%	9%	100%	

Table 10 Year 2013 Weekday Tide LRT Walk/Bike Access Trips as a Percentage of Total LRT Trips								
		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	96%	100%	100%	100%	96%	98%	97%
Other Corridor	2	91%	100%	96%	100%	100%	100%	94%
ODU	3	87%	93%		100%	91%	100%	91%
N/S Feed Area	4	53%	74%	86%	100%	85%	85%	67%
East Feed Area	5	42%	100%	49%	88%		45%	50%
Other	6	36%	90%	67%	93%	98%	77%	58%
Total		64%	90%	63%	96%	94%	82%	73%

Change in Overall Transit Ridership

Tables 11-14 present a comparison of total system-wide weekday linked transit trips before and after the introduction of the Tide LRT service. Between 2011 and 2013, system-wide HRT linked trips grew from 35,700 to 38,700, an increase of 3,000 trips (8%). Much of this growth consists of transit trips attracted to the Core (2,200) and trips attracted to the North/South Feeder Area (1,100). Growth in trip productions is highest in the North/South Feeder Area and East Feeder Area. For travel to the Core it appears that the LRT has created new markets for travel via feeder bus and LRT to reach downtown Norfolk. Enhanced feeder bus service has also attracted additional ridership to HRT as demonstrated by the significant increase in N/S Feed Area-to-N/S Feed Area travel. Travel within the Core appears to have declined slightly which is potentially an outcome of the termination of shuttle route 310 (the Downtown circulator) when the Tide went into revenue service.

Table 11 Year 2011 System-wide Weekday Total Linked Transit Trip Flows (BEFORE)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	1,626	604	85	904	157	736	4,111	12%
Other Corridor	2	326	168	100	337	192	210	1,333	4%
ODU	3	508	89	121	317	70	206	1,312	4%
N/S Feed Area	4	1,850	722	298	3,110	623	1,125	7,729	22%
East Feed Area	5	168	244	37	336	1,005	801	2,591	7%

Table 11
Year 2011 System-wide Weekday Total Linked Transit Trip Flows (BEFORE)

Production District		Attraction District: Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Other	6	1,343	342	103	989	883	14,977	18,638	52%
Total		5,822	2,170	744	5,993	2,929	18,056	35,714	100%
Share		16%	6%	2%	17%	8%	51%	100%	

Table 12
Year 2013 System-wide Weekday Total Linked Transit Trip Flows (AFTER)

Production District		Attraction District: Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	1,016	546	170	818	325	570	3,446	9%
Other Corridor	2	551	159	54	241	151	262	1,418	4%
ODU	3	523	121	38	429	133	191	1,435	4%
N/S Feed Area	4	3,237	618	532	3,891	911	1,389	10,577	27%
East Feed Area	5	883	176	112	587	1,178	809	3,745	10%
Other	6	1,818	287	152	1,098	965	13,723	18,044	47%
Total		8,029	1,908	1,059	7,065	3,663	16,943	38,666	100%
Share		21%	5%	3%	18%	9%	44%	100%	

Table 13
Year 2011 to Year 2013 Growth in System-wide Weekday Total Linked Transit Trips

Production District		Attraction District: Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	(610)	(58)	85	(85)	167	(165)	(666)
Other Corridor	2	225	(9)	(46)	(96)	(41)	52	85
ODU	3	15	31	(83)	112	63	(16)	123
N/S Feed Area	4	1,386	(104)	234	780	288	263	2,849
East Feed Area	5	715	(68)	75	251	173	8	1,155
Other	6	475	(55)	49	110	82	(1,255)	(594)
Total		2,207	(262)	314	1,072	733	(1,113)	2,952

Table 14 Year 2011 to Year 2013 Percentage Growth in System-wide Weekday Total Linked Transit Trips								
		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	-37%	-10%	101%	-9%	106%	-22%	-16%
Other Corridor	2	69%	-5%	-46%	-29%	-21%	25%	6%
ODU	3	3%	35%	-69%	35%	91%	-8%	9%
N/S Feed Area	4	75%	-14%	78%	25%	46%	23%	37%
East Feed Area	5	426%	-28%	202%	75%	17%	1%	45%
Other	6	35%	-16%	48%	11%	9%	-8%	-3%
Total		38%	-12%	42%	18%	25%	-6%	8%

Tables 15 to 18 present a comparison of Year 2011 and 2013 system-wide HBW linked transit trips. These tables show a slight drop in HBW trip making (-8 percent) distributed across many parts of the region. The North/South and East Feeder Areas are exceptions and show growth in HBW linked transit trips during the same period. These differences could be the result of different survey techniques applied for the 2011 and 2013 surveys or may represent a shift in transit demand patterns during that period.

Table 15 Year 2011 System-wide Weekday HBW Linked Transit Trip Flows (BEFORE)									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	800	266	18	420	136	406	2,046	11%
Other Corridor	2	169	35	69	189	72	169	702	4%
ODU	3	287	29	44	213	62	141	776	4%
N/S Feed Area	4	917	454	194	1,917	425	689	4,596	25%
East Feed Area	5	109	120	29	229	504	562	1,552	8%
Other	6	914	166	45	653	407	6,827	9,013	48%
Total		3,196	1,070	399	3,621	1,606	8,795	18,686	100%
Share		17%	6%	2%	19%	9%	47%	100%	

Table 16 Year 2013 System-wide Weekday HBW Linked Transit Trip Flows (AFTER)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	321	195	46	411	144	236	1,353	8%
Other Corridor	2	141	57	29	90	68	162	547	3%
ODU	3	197	33	12	258	93	98	691	4%
N/S Feed Area	4	995	314	195	1,801	521	706	4,533	26%
East Feed Area	5	427	78	18	407	551	462	1,943	11%
Other	6	753	141	48	712	459	5,997	8,109	47%
Total		2,834	818	347	3,679	1,836	7,662	17,176	100%
Share		17%	5%	2%	21%	11%	45%	100%	

Table 17 Year 2011 to Year 2013 Growth in Weekday HBW System-wide Linked Transit Trips								
		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	(478)	(71)	28	(10)	8	(170)	(693)
Other Corridor	2	(27)	22	(40)	(99)	(4)	(7)	(155)
ODU	3	(90)	5	(32)	44	31	(43)	(86)
N/S Feed Area	4	78	(140)	1	(115)	96	17	(64)
East Feed Area	5	318	(42)	(11)	179	47	(100)	391
Other	6	(162)	(25)	3	59	52	(830)	(903)
Total		(362)	(252)	(52)	58	230	(1,133)	(1,510)

Table 18
Year 2011 to Year 2013 Percentage Growth in HBW System-wide Linked Transit Trips

		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	**Total**
Core	1	-60%	-27%	157%	-2%	6%	-42%	-34%
Other Corridor	2	-16%	62%	-58%	-53%	-5%	-4%	-22%
ODU	3	-32%	16%	-72%	21%	50%	-31%	-11%
N/S Feed Area	4	9%	-31%	0%	-6%	23%	2%	-1%
East Feed Area	5	292%	-35%	-39%	78%	9%	-18%	25%
Other	6	-18%	-15%	6%	9%	13%	-12%	-10%
Total		-11%	-24%	-13%	2%	14%	-13%	-8%

ACCURACY OF PREDICTED RIDERSHIP

Table 19 presents a comparison of actual (counted) 2013 weekday Tide LRT ridership to forecasts of ridership at each project development milestone. Actual ridership in the Fall of 2013 was equal to 4,600 weekday boardings. Ridership forecasts prepared at the time of entry into Preliminary Engineering did not include an estimate of opening year ridership. New Starts reports prepared one year later estimated opening year ridership equal to 10,400 trips per day but the source of this number is not known. In its November 2003 project summary, the Federal Transit Administration reported this number but indicated that it had concerns about the ridership forecasts and did not rate the project. By entry into Final Design, these concerns were resolved and opening year ridership was estimated to be equal to 2,891 weekday trips, 37 percent less than what was actually attracted to the Tide LRT in 2013. These forecasts were unchanged at the time of the Full Funding Grant Agreement, one year later.

The opening year forecasts prepared for Entry into Final Design and the Full Funding Grant Agreement were based on Year 2011 demographic inputs and used without adjustment to represent 2009 or 2010 opening years. In the analysis that follows, these forecasts are labeled as “Predicted 2011 Opening Year Ridership” since they are most representative of expected conditions in that year.

The degree to which ridership was under-predicted at the time of Entry into Final Design and FFGA (2011 projection) is not evenly distributed across the region. In fact, the forecasting model correctly anticipated that the core would be the single most important attraction location for the Tide LRT and that attractions to other areas would be much more thinly distributed.

Tables 20 through 23 present a comparison of predicted versus actual total LRT ridership by district of production and district of attraction using the same district system from earlier sections. Total predicted LRT ridership for the year 2011 is less than actual year 2013 ridership by 1,700 riders per day (37%). Most significant markets (over 100 trips per day) are underestimated by 10 to 90 percent. The most notable exception is travel between the East Feeder District and the Core which is overestimated by 20 percent.

Table 19 Actual Year 2013 Weekday Tide LRT Ridership Compared to Opening Year Forecasts at Milestones				
	Actual	Predictions at Milestones		
		Entry into Preliminary Engineering (11/4/2002)	Entry into Final Design (9/13/2006)	Full Funding Grant Agreement (10/2007)
Weekday Ridership	4,592	Not estimated	2,891	2,891
Notes:				
Year	2013	Not estimated	2009	2010
Demographic data		Not estimated	2011	2011
Source		Template prepared by forecasting consultant, 8/1/2002	FY 2008 New Start Report, June 29, 2006	FY 2008 New Start Report, June 29, 2006
Comments		FY2005 New Starts Report, August 28, 2003 has 10,400 opening year riders in 2008	Final report prior to final design milestone	Opening year forecasts unchanged between entry into final design and Full Funding Grant Agreement

Table 20 Opening Year (2011) Weekday Tide LRT Total Unlinked Trip Flows (PREDICTED)									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	533	64	3	16	37	6	661	23%
Other Corridor	2	271	64	14	40	37	13	440	15%
ODU	3	30	28	-	5	14	1	78	3%
N/S Feed Area	4	330	65	2	9	46	5	457	16%
East Feed Area	5	710	24	10	22	5	12	783	27%
Other	6	415	28	2	9	16	4	473	16%
Total		2,289	273	32	101	154	41	2,891	100%
Share		79%	9%	1%	4%	5%	1%	100%	

Table 21
Year 2013 Weekday Tide LRT Total Unlinked Trip Flows (ACTUAL)

Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
		Attraction District							
Core	1	618	126	4	87	114	56	1,005	22%
Other Corridor	2	373	69	17	37	35	52	584	13%
ODU	3	136	30	-	26	49	35	277	6%
N/S Feed Area	4	557	135	15	86	118	78	987	22%
East Feed Area	5	591	29	77	96	-	58	851	19%
Other	6	528	79	9	40	135	96	887	19%
Total		2,803	469	122	373	450	375	4,592	100%
Share		61%	10%	3%	8%	10%	8%	100%	

Table 22
Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT Total Unlinked Trips

Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
		Attraction District						
Core	1	(84)	(62)	(1)	(71)	(76)	(50)	(345)
Other Corridor	2	(102)	(6)	(2)	3	1	(39)	(144)
ODU	3	(106)	(2)	-	(21)	(35)	(34)	(199)
N/S Feed Area	4	(227)	(70)	(13)	(77)	(72)	(72)	(531)
East Feed Area	5	119	(5)	(66)	(74)	5	(46)	(68)
Other	6	(113)	(51)	(7)	(31)	(119)	(92)	(414)
Total		(514)	(196)	(90)	(272)	(296)	(334)	(1,701)

Table 23 Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT Total Unlinked Trips								
		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	-14%	-49%	-27%	-81%	-67%	-89%	-34%
Other Corridor	2	-27%	-8%	-14%	9%	4%	-75%	-25%
ODU	3	-78%	-6%		-81%	-72%	-98%	-72%
N/S Feed Area	4	-41%	-52%	-85%	-90%	-61%	-93%	-54%
East Feed Area	5	20%	-19%	-87%	-77%		-79%	-8%
Other	6	-21%	-65%	-81%	-78%	-88%	-96%	-47%
Total		-18%	-42%	-74%	-73%	-66%	-89%	-37%

Predictions of overall commute travel to and from work are reasonably close to actual results and properly anticipate the fact that the Core would be the key attraction district for commuter trips. Nevertheless, predictions of home-based work (HBW) LRT travel overstate this concentration and underestimate travel to other districts. Tables 24 through 27 show that predicted weekday HBW LRT trips are higher than actual 2013 trips by 200 trips per day (12 percent). Almost all of the over-prediction of HBW trips occurs for travel to the Core which was over-predicted by 700 trips per day (65 percent). Trips to other locations in the region were under-predicted by approximately 500 trips per day. The largest percentage differences occur in areas that are away from the corridor and may represent the effect that reorganizing the feeder bus system had on ridership patterns.

Table 24 Opening Year (2011) Weekday Tide LRT HBW Unlinked Trip Flows (PREDICTED)									
		Attraction District							
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	131	33	2	11	23	5	206	9%
Other Corridor	2	214	38	10	27	25	11	325	15%
ODU	3	29	20	-	4	11	1	64	3%
N/S Feed Area	4	320	47	2	7	39	5	420	19%
East Feed Area	5	683	16	9	20	5	12	744	34%
Other	6	411	23	2	8	14	4	462	21%
Total		1,787	177	25	78	117	36	2,221	100%
Share		80%	8%	1%	3%	5%	2%	100%	

Table 25
Year 2013 Weekday Tide LRT HBW Unlinked Trip Flows (ACTUAL)

Production District		Attraction District Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	173	37	-	13	32	12	267	13%
Other Corridor	2	86	15	15	9	32	17	173	9%
ODU	3	19	6	-	9	31	27	92	5%
N/S Feed Area	4	178	108	6	54	84	42	471	24%
East Feed Area	5	312	19	22	47	-	42	442	22%
Other	6	314	51	1	14	108	50	538	27%
Total		1,082	236	44	146	286	189	1,983	100%
Share		55%	12%	2%	7%	14%	10%	100%	

Table 26
Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBW Unlinked Trips

Production District		Attraction District Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	(43)	(4)	2	(2)	(8)	(8)	(61)
Other Corridor	2	128	23	(5)	18	(6)	(6)	151
ODU	3	9	13	-	(5)	(20)	(26)	(28)
N/S Feed Area	4	142	(61)	(4)	(47)	(45)	(37)	(50)
East Feed Area	5	371	(3)	(12)	(27)	5	(31)	302
Other	6	97	(28)	0	(5)	(94)	(46)	(76)
Total		705	(59)	(18)	(68)	(169)	(153)	238

Table 27 Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBW Unlinked Trips								
		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	-25%	-10%		-12%	-26%	-62%	-23%
Other Corridor	2	149%	159%	-36%	196%	-20%	-37%	87%
ODU	3	49%	209%		-53%	-65%	-97%	-30%
N/S Feed Area	4	80%	-56%	-64%	-87%	-53%	-88%	-11%
East Feed Area	5	119%	-13%	-57%	-58%		-73%	68%
Other	6	31%	-55%	30%	-39%	-87%	-93%	-14%
Total		65%	-25%	-42%	-47%	-59%	-81%	12%

The market for LRT travel between home and a non-work location (home-based other [HBO] trips) was largely missed by the forecasting procedures. Tables 28 through 31 show the differences between predicted and actual weekday HBO LRT travel. The predicted ridership includes very few LRT riders (178 trips per day) while the survey shows that actual ridership for this market exceeds 2,000 trips per day, more than the number of actual HBW trips carried by the Tide. The differences between predicted and actual HBO ridership are generally uniform across the entire analysis region.

Table 28 Opening Year (2011) Weekday Tide LRT HBO Unlinked Trip Flows (PREDICTED)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	21	13	0	2	5	0	41	23%
Other Corridor	2	35	18	3	10	8	2	76	43%
ODU	3	1	6	-	1	2	0	10	6%
N/S Feed Area	4	5	13	0	1	5	0	25	14%
East Feed Area	5	12	4	0	1	(0)	0	19	10%
Other	6	2	3	0	0	1	0	7	4%
Total		76	58	4	15	21	2	178	100%
Share		43%	33%	2%	9%	12%	1%	100%	

Table 29 Year 2013 Weekday Tide LRT HBO Unlinked Trip Flows (ACTUAL)									
		Attraction District							
Production District		**Core 1**	**Other Corridor 2**	**ODU 3**	**N/S Feed Area 4**	**East Feed Area 5**	**Other 6**	**Total**	**Share**
Core	1	232	40	-	35	38	27	372	18%
Other Corridor	2	232	55	2	28	4	33	354	17%
ODU	3	114	20	-	15	15	8	172	8%
N/S Feed Area	4	350	27	8	25	27	28	464	23%
East Feed Area	5	246	11	55	41	-	11	364	18%
Other	6	200	20	8	25	20	37	309	15%
Total		1,374	172	72	169	103	144	2,034	100%
Share		68%	8%	4%	8%	5%	7%	100%	

Table 30 Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBO Unlinked Trips								
		Attraction District						
Production District		**Core 1**	**Other Corridor 2**	**ODU 3**	**N/S Feed Area 4**	**East Feed Area 5**	**Other 6**	**Total**
Core	1	(211)	(27)	0	(33)	(34)	(27)	(331)
Other Corridor	2	(197)	(37)	2	(18)	4	(32)	(277)
ODU	3	(113)	(13)	-	(15)	(12)	(8)	(162)
N/S Feed Area	4	(344)	(14)	(8)	(24)	(21)	(28)	(439)
East Feed Area	5	(234)	(6)	(54)	(40)	(0)	(11)	(345)
Other	6	(198)	(17)	(8)	(24)	(19)	(37)	(302)
Total		(1,298)	(114)	(68)	(153)	(81)	(142)	(1,856)

Table 31 Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide HBO LRT Unlinked Trips							
	Attraction District						
	Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District	1	2	3	4	5	6	Total
Core 1	-91%	-67%		-94%	-88%	-99%	-89%
Other Corridor 2	-85%	-67%	92%	-66%	121%	-95%	-78%
ODU 3	-99%	-68%		-95%	-84%	-100%	-94%
N/S Feed Area 4	-98%	-52%	-98%	-94%	-80%	-99%	-95%
East Feed Area 5	-95%	-60%	-99%	-97%		-99%	-95%
Other 6	-99%	-83%	-100%	-98%	-94%	-100%	-98%
Total	-94%	-66%	-94%	-91%	-79%	-98%	-91%

The substantial under-prediction of HBO trips may be a result of the forecasting techniques used at the time in this model and many others throughout the country. HBO models typically include a wide range of potential trip purposes such as shopping, medical visits, university trips, and personal business with only limited stratifications to account for different geographic distributions associated with each category. Even the most advanced forecasting tools seldom account for differences such as:

- Regional shopping centers that draw customers from throughout a metropolitan area as compared to strip malls which serve a local market
- Major medical institutional campuses that serve the region as compared to medical office buildings housing primary care physicians
- Major government centers where much personal business is conducted (City Hall, the City Court complex, Federal Court House, etc.) as compared to banks and post offices where routine chores are handled.
- Universities, which may serve a dispersed population of students living throughout a region.
- Sporting venues, such as the Scope, and the home for the Virginia Symphony-Chrysler Hall

The Tide LRT serves the Norfolk CBD, EVMC, and NSU—areas which have many examples of specialized attraction locations which would draw travelers from a much broader area than typical HBO trips.

The models used to forecast ridership were calibrated to match regional transit ridership by trip purpose. At the time of calibration, the model generated 16,100 regional daily HBW trips and 9,300 HBO trips—a ratio of 0.57 HBO trips for each HBW trip. The actual LRT trip ratio is 1.03 HBO trips per HBW trip. The model predicted .08 HBO LRT trips per HBW trip. Barring a simple application error, this outcome is most likely to be the result of an HBO trip generation and distribution process that did not fully recognize the unique nature of HBO attractions in the LRT corridor, their region-wide significance, and their ability to draw travelers from a broad area.

This possibility is reinforced by the nature of HBO trips actually using the LRT and the presence of nearby major regional institutions and facilities. Table 32 presents the numbers of trips for different HBO-sub purposes and lists major attraction opportunities that could draw visitors from throughout the Tidewater area.

These findings suggest that future forecasting efforts for projects like the Tide LRT should carefully review HBO models to confirm that they properly understand HBO travel to regional attractions.

Table 32
Actual Weekday HBO LRT Trips with Known Detailed Trip Purposes

Sub-purpose	2013 Surveyed Trips	Nearby institutions/facilities
Recreation	26	Nauticus/Scope/Chrysler Hall
Eat/dine	44	Granby Street
Medical	120	EVMC/Sentara Hospital (s)
Social visit	69	
University	681	NSU, TCC, ODU (bus transfer)
Other business	51	
Personal business	191	Norfolk City Hall, Norfolk Courts Complex, Federal Courthouse
Shopping	196	MacArthur Center
Total	1,378	

In contrast to the HBO predictions, the non-home based (NHB) markets were predicted well.

Tables 33 through 36 present a comparison of predicted versus actual weekday NHB LRT travel. The predicted ridership matches actual ridership closely, under-predicting region-wide NHB trips by only 14 percent region-wide. The geographic distribution of travel is generally good, with the predicted values anticipating that the majority of NHB LRT trips would travel to or from the Core. The predicted values also anticipated that many of these trips would occur entirely within the Core (i.e., both the production and attraction trip ends located in the Core). This concentration is over-estimated in the predicted values but still properly represents the orientation of these trips.

One key reason for this success is the fact that the Norfolk LRT predictions made use of a special model that used experience with past transit fixed guideway projects to supplement estimates of NHB transit trips. This supplemental model represents additional NHB ridership generated by travelers attracted to LRT station areas for home-based purposes and then using the LRT to make additional non-home based trips. The supplemental model was responsible for 350 out of prediction of 490 NHB LRT trips. Nearly all of these trips are internal to the core.

Table 33 Opening Year (2011) Weekday Tide LRT NHB Unlinked Trip Flows (PREDICTED)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	382	18	0	3	10	1	414	84%
Other Corridor	2	22	8	1	4	3	1	39	8%
ODU	3	1	2	-	0	1	-	4	1%
N/S Feed Area	4	5	5	0	0	1	0	12	2%
East Feed Area	5	14	3	0	1	0	0	20	4%
Other	6	2	1	0	0	0	0	4	1%
Total		426	38	2	8	15	2	492	100%
Share		87%	8%	0%	2%	3%	0%	100%	

Table 34 Year 2013 Weekday Tide LRT NHB Unlinked Trip Flows (ACTUAL)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	212	49	4	40	44	17	366	64%
Other Corridor	2	55	-	-	-	-	2	57	10%
ODU	3	3	4	-	2	4	-	13	2%
N/S Feed Area	4	29	-	1	7	7	8	53	9%
East Feed Area	5	33	-	-	8	-	5	45	8%
Other	6	14	7	-	2	6	10	40	7%
Total		347	61	6	59	61	41	574	100%
Share		60%	11%	1%	10%	11%	7%	100%	

Table 35
Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT NHB Unlinked Trips

		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	170	(31)	(4)	(37)	(34)	(16)	48
Other Corridor	2	(33)	8	1	4	3	(1)	(18)
ODU	3	(2)	(2)	-	(2)	(3)	-	(9)
N/S Feed Area	4	(25)	5	(1)	(7)	(6)	(8)	(41)
East Feed Area	5	(18)	3	0	(7)	0	(4)	(26)
Other	6	(12)	(6)	0	(2)	(6)	(10)	(36)
Total		79	(23)	(3)	(51)	(46)	(39)	(83)

Table 36
Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT NHB Unlinked Trips

		Attraction District						
Production District		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core	1	80%	-64%	-91%	-92%	-78%	-95%	13%
Other Corridor	2	-60%					-61%	-32%
ODU	3	-77%	-46%		-96%	-82%		-72%
N/S Feed Area	4	-84%		-97%	-97%	-80%	-99%	-78%
East Feed Area	5	-56%			-86%		-93%	-57%
Other	6	-84%	-80%		-94%	-93%	-99%	-89%
Total		23%	-38%	-59%	-86%	-75%	-95%	-14%

The predicted ridership included additional detail regarding household characteristics of travelers and mode of access for Home-Based Work Trips. Predictions of household auto ownership for HBW trips are presented in Tables 37 through 40. Although the forecasts underestimated actual ridership made by members of 0-car households by 300 trips per day (67 percent) it did properly represent the fact that the majority of HBW LRT trips are made by members of car-owning households. The predicted percentage of LRT trips made by car-owning households is 92 percent while the actual percentage is 74 percent. The error is generally distributed evenly across the region with travel to the core being somewhat more accurate (54 percent under-prediction) than travel to other locations.

Table 37 Opening Year (2011) Weekday Tide LRT HBW 0-Car Household Unlinked Trip Flows (PREDICTED)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	18	12	0	4	11	1	45	27%
Other Corridor	2	27	8	1	6	6	2	50	29%
ODU	3	4	5	-	1	3	0	13	8%
N/S Feed Area	4	8	10	0	2	8	0	28	17%
East Feed Area	5	7	0	0	0	0	0	9	5%
Other	6	11	6	0	2	4	0	25	14%
Total		74	42	2	15	33	4	170	100%
Share		44%	25%	1%	9%	19%	2%	100%	

Table 38 Year 2013 Weekday Tide LRT HBW 0-Car Household Unlinked Trip Flows (ACTUAL)									
		Attraction District							
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other		
Production District		1	2	3	4	5	6	Total	Share
Core	1	40	20	-	10	18	4	92	18%
Other Corridor	2	22	-	8	7	1	7	45	9%
ODU	3	16	4	-	-	21	10	51	10%
N/S Feed Area	4	21	30	6	5	30	16	109	21%
East Feed Area	5	39	19	11	25	-	11	105	21%
Other	6	23	38	1	6	30	8	106	21%
Total		161	110	26	54	100	55	507	100%
Share		32%	22%	5%	11%	20%	11%	100%	

Table 39
Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBW 0-Car Household Unlinked Trips

		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	(23)	(7)	0	(7)	(7)	(3)	(47)
Other Corridor	2	4	8	(7)	(1)	5	(5)	5
ODU	3	(12)	1	-	1	(18)	(10)	(38)
N/S Feed Area	4	(13)	(21)	(5)	(4)	(22)	(15)	(80)
East Feed Area	5	(31)	(18)	(11)	(25)	0	(10)	(96)
Other	6	(11)	(32)	(1)	(4)	(26)	(7)	(81)
Total		(86)	(69)	(24)	(39)	(67)	(51)	(337)

Table 40
Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBW 0-Car Household Unlinked Trips

		Attraction District						
		Core	Other Corridor	ODU	N/S Feed Area	East Feed Area	Other	
Production District		1	2	3	4	5	6	Total
Core	1	-57%	-38%		-65%	-40%	-73%	-51%
Other Corridor	2	20%		-82%	-15%	338%	-76%	10%
ODU	3	-76%	25%			-85%	-98%	-74%
N/S Feed Area	4	-63%	-68%	-96%	-66%	-73%	-98%	-74%
East Feed Area	5	-81%	-98%	-99%	-98%		-99%	-92%
Other	6	-50%	-83%	-91%	-68%	-86%	-94%	-77%
Total		-54%	-62%	-92%	-73%	-67%	-93%	-67%

Tables 41 through 44 present a comparison of HBW Park-and-Ride (PNR) access trips. Predictions of HBW PNR trips are higher than actual by nearly 600 trips per day (90%). The forecasts properly anticipated the fact that nearly all PNR demand would be attracted to the Core. The forecasts significantly overstated the attractiveness of the LRT PNR opportunities for residents of North/South and East Feeder areas. For these trips, PNR estimates are more than twice as high as actual ridership. This could be caused by the fact that the actual service plan provides more feeder bus opportunities in these areas than was assumed at the time the predictions were prepared. It may also suggest that the geographic attractiveness of PNR options is more limited than represented in the underlying forecast models.

At the time the forecasting models were developed, transit PNR was very limited and served only 120 trips out of 30,000 regional transit trips. Many of these trips were made by travelers to the Norfolk Naval Base. This meant that the models had very little information upon which to base forecasts of PNR activity. As such, the divergence between predicted and actual PNR activity is not surprising.

Table 41
Opening Year (2011) Weekday Tide LRT HBW PNR Access Unlinked Trip Flows (PREDICTED)

Production District		Attraction District							
		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	1	-	-	-	-	-	1	0%
Other Corridor	2	42	0	-	-	-	-	43	4%
ODU	3	8	-	-	-	-	-	8	1%
N/S Feed Area	4	236	1	-	-	-	-	237	20%
East Feed Area	5	525	3	-	-	-	-	529	45%
Other	6	352	0	-	-	-	-	352	30%
Total		1,164	6	-	-	-	-	1,169	100%
Share		100%	0%	0%	0%	0%	0%	100%	

Table 42
Year 2013 Weekday Tide LRT HBW PNR Access Unlinked Trip Flows (ACTUAL)

Production District		Attraction District							
		Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total	Share
Core	1	5	-	-	-	-	1	7	1%
Other Corridor	2	4	-	1	-	-	-	5	1%
ODU	3	-	-	-	-	-	-	-	0%
N/S Feed Area	4	96	27	-	-	7	-	130	21%
East Feed Area	5	196	-	6	12	-	2	215	35%
Other	6	241	4	-	-	-	13	258	42%
Total		542	31	6	12	7	16	614	100%
Share		88%	5%	1%	2%	1%	3%	100%	

Table 43 Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide LRT HBW PNR Access Unlinked Trips							
	Attraction District						
Production District	Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core 1	(4)	-	-	-	-	(1)	(6)
Other Corridor 2	38	0	(1)	-	-	-	38
ODU 3	8	-	-	-	-	-	8
N/S Feed Area 4	140	(26)	-	-	(7)	-	107
East Feed Area 5	329	3	(6)	(12)	-	(2)	314
Other 6	111	(3)	-	-	-	(13)	94
Total	621	(25)	(6)	(12)	(7)	(16)	555

Table 44 Percentage Difference Between Predicted Year 2011 and Actual 2013 Weekday Tide HBW PNR Access LRT Unlinked Trips							
	Attraction District						
Production District	Core 1	Other Corridor 2	ODU 3	N/S Feed Area 4	East Feed Area 5	Other 6	Total
Core 1	-84%					-100%	-87%
Other Corridor 2	849%		-100%				735%
ODU 3							
N/S Feed Area 4	147%	-95%			-100%		82%
East Feed Area 5	168%		-100%	-100%		-100%	146%
Other 6	46%	-88%				-100%	37%
Total	115%	-82%	-100%	-100%	-100%	-100%	90%

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix F: Land Use & Development

HAMPTON ROADS TRANSIT

Purpose of the Report

In the 2008 *Documentation of Conditions Before Project Implementation Report,* a list of planned developments was compiled to create a baseline of expected developments against which "realized" station area developments (what was actually constructed) could be measured. The purpose of this report is to determine which of the projects listed in the 2008 report have been constructed to date, identify station area developments that were not yet planned in 2008 but have subsequently been constructed, which of the station area developments can be attributed to LRT operations, and to identify developments that were planned in 2008 but have not been constructed. Because development activity is the result of multiple influences that can be difficult to untangle and isolate, the report begins with a summary of downtown Norfolk's big-picture development context before the Tide began operations.

Norfolk's Development Context

By the mid-1990s, downtown Norfolk has experienced a cycle of disinvestment that resulted in residential, retail and entertainment uses largely abandoning the downtown in favor of neighborhood and suburban locations. The development of MacArthur Mall – a large-scale regional mall – in Norfolk's central business district was a critical first step in reversing the cycle of 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. While market forces – rather than LRT operations – are responsible for this renaissance, there are limited examples (discussed below) where LRT operations can be credited with catalyzing specific developments.

All Station Area Development

Table 2 lists the projects that have been built (or have begun construction) since 2008 within a half-mile of Tide LRT stations (defined as the station area); Figures 1 and 2 map these developments. This list is a combination of completed projects from the 2008 report as well as projects that were not yet in development in 2008. As shown in Table 2 and Figures 1 and 2, 31 station area developments have been built (or are under construction) since 2008 within a half-mile of Tide LRT stations. As shown in the table and figures, the developments are a mixture of sizes, scales and uses, and the majority of the development has occurred in the station areas nearest the downtown.

Station Area Development That is Attributable to LRT

According to the City of Norfolk Department of Development and Hampton Roads Transit (HRT) staff, the station area developments shown in Table 1 and Figure 1 – which are a mix of commercial, institutional, and residential uses - was directly attributable to Tide LRT operations. According to the City and HRT staff, the closure of these three development deals was dependent on a number of factors and concessions, including LRT operations.

Table 1: Development since 2008 within a Half-Mile of Tide LRT Stations That is Directly Attributable to LRT Service

Map #	Name	LRT Station Area(s)	In 2008 Report?
1	Fort Norfolk Plaza	EVMC / Fort Norfolk	✔
6	Belmont at Freemason	York Street / Freemason Monticello MacArthur Square	✔
10	Wells Fargo (Wachovia) Tower	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔

Source: Norfolk Department of Development, HRT Planning Staff

These three projects represent more than $305 million and 500,000 square feet of investment attributed by the City to the Tide System. While other developments in Table 1 may be attributable to the Tide, there is no information available to make a direct connection.

Planned Development That Has Not Been Constructed to Date

Table 3 lists planned station area developments that were included in the 2008 report but were not constructed to date. Of the 33 planned developments listed in the 2008 report, 13 have been constructed (and are included in Table 2 and Figures 1 and 2), 12 have not been constructed (and are included in Table 3 and Figure 3), and eight fall outside of an LRT station area. The planned developments that were not constructed were – like the constructed developments - a mixture of sizes, scales and uses. There does not appear to be a pattern or common reason that these developments did not move into construction.

Conclusion

There is very little evidence to indicate that any development that has happened in Norfolk since 2008 can be directly attributed to LRT, with the exception of the three developments listed in Table 1. As previously discussed, market forces are responsible for the renaissance of downtown Norfolk, which was catalyzed be the development of the MacArthur Mall.

Table 2: Development since 2008 within a Half-Mile of Tide LRT Stations[1]

Map #	Name	LRT Station Area(s)	In 2008 Report?*	Details
2	Riverview Lofts	EVMC / Fort Norfolk		$16M development; 81 residential units
3	EVMS Education and Research Building	EVMC / Fort Norfolk		$80M development; 100,000 square feet
4	Chrysler Museum of Art	York Street / Freemason Monticello		$24M investment; updates and addition of two wings; new 7,000 square foot Glass Arts Building
5	220 West	York Street / Freemason Monticello MacArthur Square		6,000 square feet; 19 residential units
7	Residence Inn by Marriott	York Street / Freemason Monticello MacArthur Square		$35M development; 130,000 square feet; 160 extended stay units
8	The Wainwright	York Street / Freemason Monticello MacArthur Square		$20M conversion; 126 residential units
9	Metro on Granby	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔	$24M development; 8,100 square feet; 84 residential units
11	The James	York Street / Freemason Monticello MacArthur Square Civic Plaza		$13M conversion; 79 residential units; 2 retail spaces
12	Virginia Arts Festival Building	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔	$7.5M development; 17,440 square feet

[1] Note: There is no evidence to indicate that these developments occurred because of LRT operations.

Map #	Name	LRT Station Area(s)	In 2008 Report?*	Details
13	Tidewater Community College Student Center	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔	$17.6M development; 55,000 square feet
14	Urban Outfitters	York Street / Freemason Monticello MacArthur Square Civic Plaza		$2M renovation of historic building and conversion to retail; 10,500 square feet
15	Governor's School for the Arts	York Street / Freemason Monticello MacArthur Square Civic Plaza		$9.6M consolidation; 52,000 square feet
16	Rockefeller Apartments	York Street / Freemason Monticello MacArthur Square Civic Plaza		$17M conversion; 136 residential units
17	The Seaboard	York Street / Freemason Monticello MacArthur Square Civic Plaza		conversion from office use to 135 residential units
18	Norfolk Half Moone Cruise & Celebration Center	York Street / Freemason Monticello MacArthur Square	✔	80,000 square foot cruise terminal and event space
19	Hilton Norfolk at The Main	York Street / Freemason Monticello MacArthur Square Civic Plaza		$125M development; 300 hotel rooms; 50,000 square foot convention space; 3 restaurants
20	Town Point Park	Monticello MacArthur Square Civic Plaza		7-acre redevelopment

Map #	Name	LRT Station Area(s)	In 2008 Report?*	Details
21	Mo & O'Malley's	York Street / Freemason Monticello MacArthur Square Civic Plaza		$6M development; retail with residential units
22	Waterside Live	York Street / Freemason Monticello MacArthur Square Civic Plaza		$40M redevelopment; 110,00 square feet of retail and entertainment uses
23	Slover Memorial Library / Kirn Library Reuse	York Street / Freemason Monticello MacArthur Square Civic Plaza	✔	$64M development; 70,000 square feet
24	MacArthur Memorial Expansion	York Street / Freemason Monticello MacArthur Square Civic Plaza		$6M expansion; 16,000 square feet
25	The Rotunda	Monticello MacArthur Square Civic Plaza Harbor Park	✔	conversion from office to 66 residential units
26	Downtown Bus Transfer Facility	Monticello MacArthur Square Civic Plaza Harbor Park		$6M development; 3,700 square feet
27	Consolidated Courthouse Complex	Monticello MacArthur Square Civic Plaza Harbor Park	✔	$121.7M development; 315,000 square feet; General District, Circuit, and Juvenile and Domestic Relations Courts
28	Amtrak Passenger Rail Facility	Civic Plaza Harbor Park NSU		$3.75M development; 3,500 square foot
29	Marie V. McDemmond Center for Applied Research	Harbor Park NSU	✔	128,000 square foot research center

Map #	Name	LRT Station Area(s)	In 2008 Report?*	Details
30	NSU Nursing and Allied Health Building	NSU	✔	140,000 square foot building; laboratory and classroom space; cafes, lounges
31	Grandy Village rehab; Grandy Village Learning Center (GVLC)	Ballentine / Broad Creek	✔	363 residential units (rehab); $4.1M development, 15,000 square feet (GVLC)

Sources: Norfolk Virginia Project Updates, First Quarter 2014, City of Norfolk; Downtown Norfolk Transit Oriented Development, Norfolk Department of Development; conversations with the Norfolk Department of Development; web searches

**Note: the scale and character of built projects may vary from the scale anticipated in the 2008 Before Project Implementation Report*

Figure 1: Development Projects within a Half-Mile of Tide LRT Stations That Were Constructed After 2008: EVMC/Fort Norfolk Station to Ballentine Boulevard / Broad Creek Station

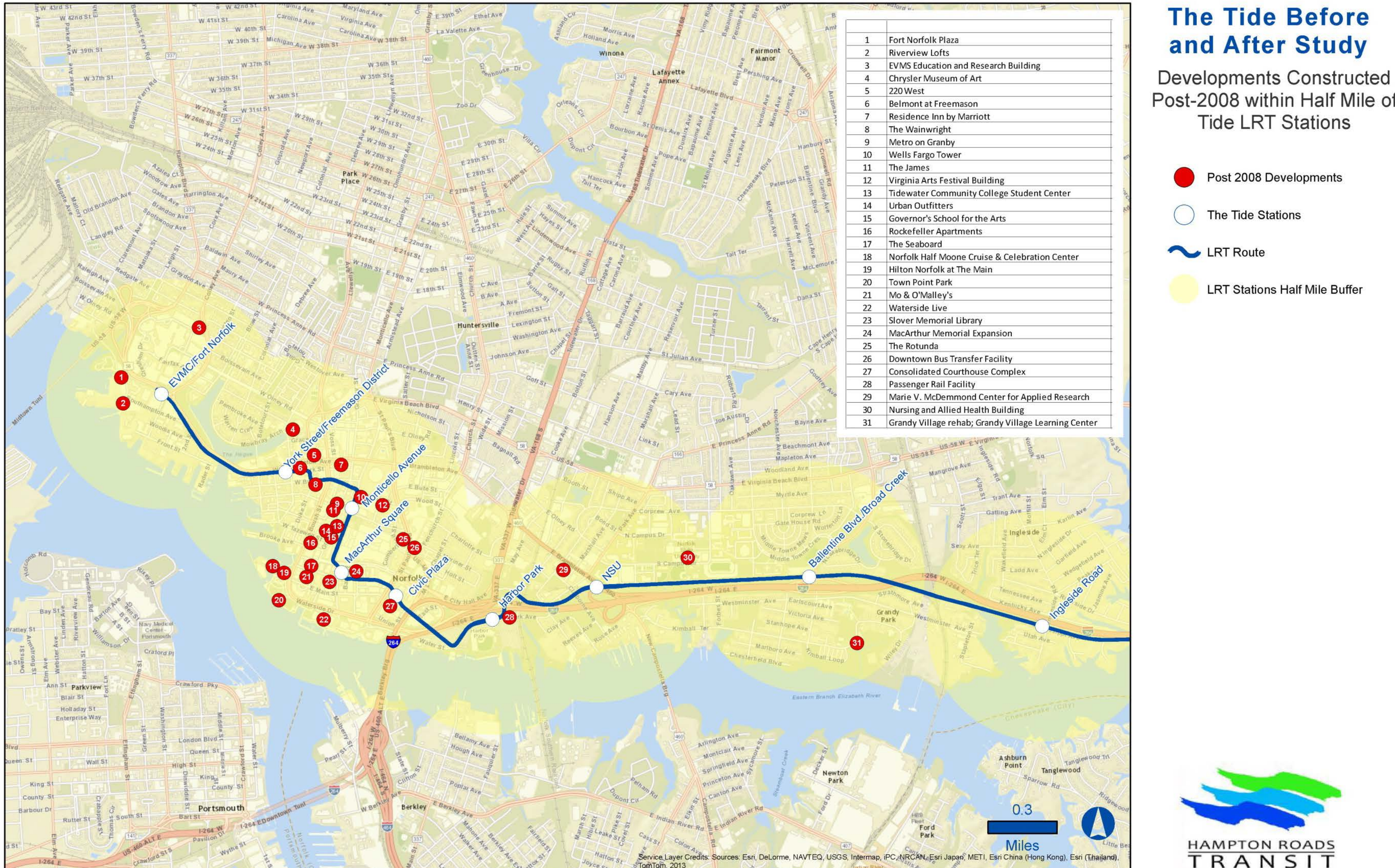


Figure 2: Development Projects within a Half-Mile of Tide LRT Stations That Were Constructed After 2008: Ballentine Boulevard / Broad Creek Station to Newtown Road Station

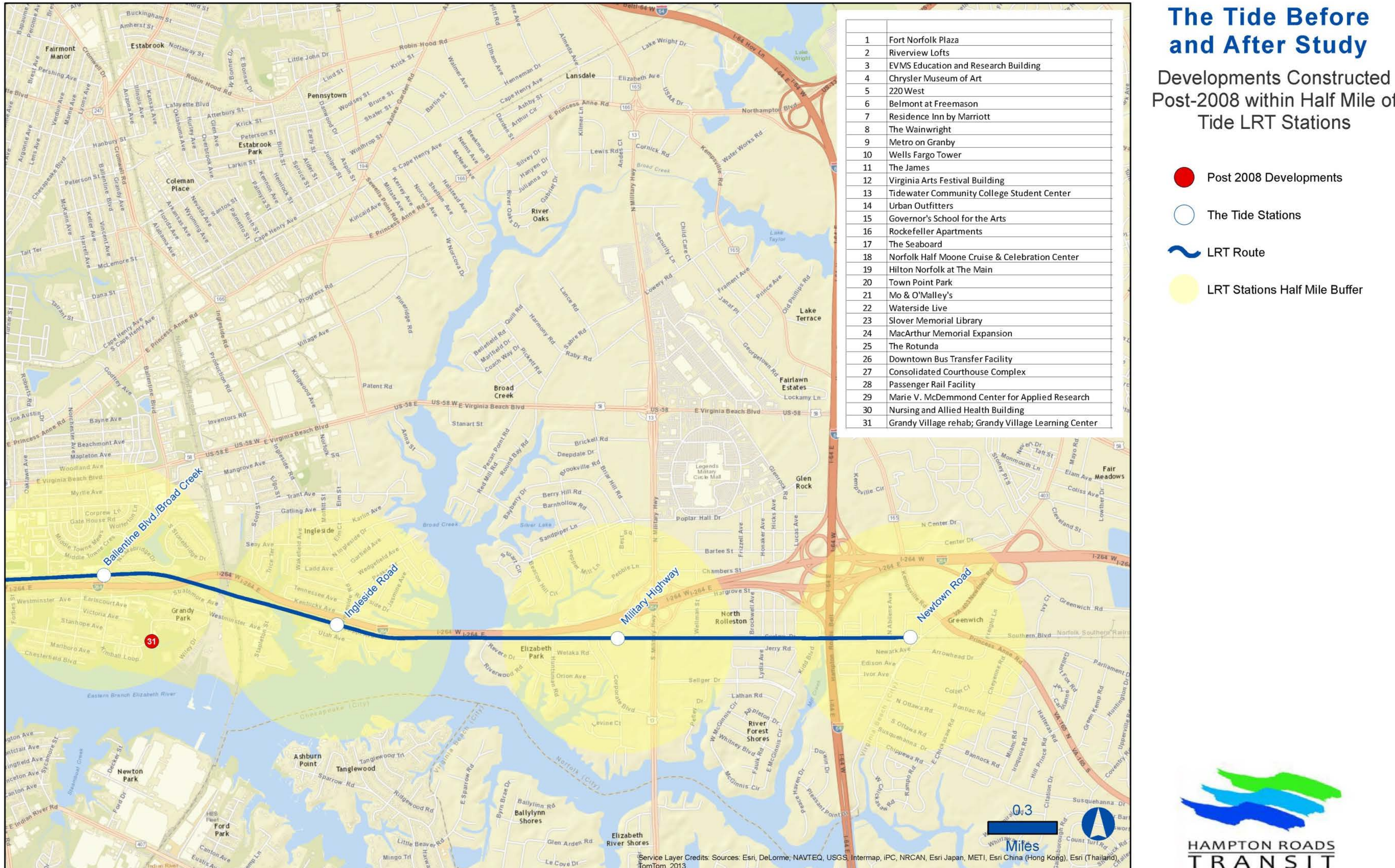
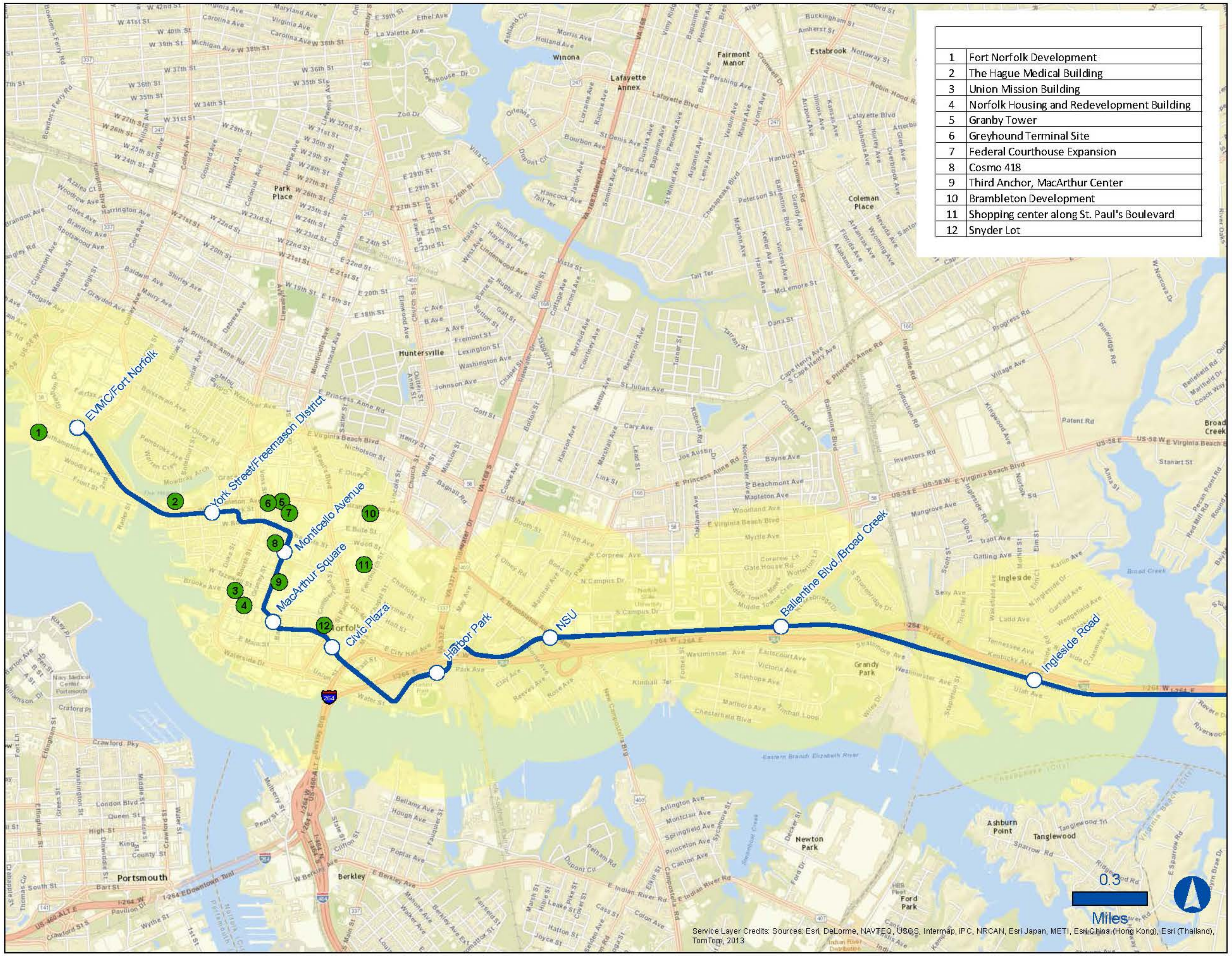


Table 3: Planned Station Area Developments listed in the 2008 *Before Project Implementation Report* within the Vicinity of Tide Station Areas That Were Not Constructed as of November 2014

Planned Development Name	Planned Station Area Development Details from 2008 Before Project Implementation Report
Granby Tower	Planned 31-story, $125M residential tower; 309 residential units; 15,000 square feet of retail
Federal Courthouse Expansion	$166M expansion of existing facility; addition of seven floors for a total of eleven floors
Fort Norfolk Development	$300M master planned development; 30 acres; 1,800 residential units, 85,000 square feet of office/research space.
Cosmo 418	11 floor residential building; 16 units; restaurant
Brambleton Development	$30M development; 35 to 40 floors; 300 residential units; 10,000 square feet of retail
Shopping center redevelopment along St. Paul's Boulevard	$5M mixed-use redevelopment; 12.5 acres
Third Anchor, MacArthur Center	No tenant identified; estimated to be same size and scale as other two anchor tenants
Snyder Lot	City-owned parking lot with developer interest
Greyhound Terminal Site	No redevelopment plan, but considered as location for the Kirn Library
Union Mission Building	Identified by Norfolk Department of Development as potential residential development site
Norfolk Housing and Redevelopment Building	13-floor building at 201 Granby Street identified as potential residential re-use
The Hague Medical Building	Potential high-density mixed-use redevelopment

Figure 3: Planned Station Area Developments listed in the 2008 Before Project Implementation Report within the Vicinity of Tide Station Areas That Were Not Constructed



The Tide Before and After Study

Documentation of Condition Before Project Implementation

Station Area Developments That Were Planned in 2008 But Have Not Been Constructed

- Planned Developments That Have Not Been Constructed
- The Tide Stations
- LRT Route
- LRT Stations Half Mile Buffer

HAMPTON ROADS TRANSIT

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix G: Parking

HAMPTON ROADS TRANSIT

Introduction

This purpose of this report is to review and compare City of Norfolk parking policies, parking supply, and parking utilization reports before and after the implementation of Light Rail service in the area in an attempt to determine the impact of LRT service on parking in the Central Business District (CBD) and fringe CBD. The number of spaces, utilization rates, and costs of City-controlled parking garages and parking lots in Norfolk's CBD) and fringe CBD were inventoried in the 2008 *Before Project Implementation Report*. This inventory, which relied on 2006/2008 data, has been updated to 2014 data as part of this *After Project Implementation Report* and is discussed below. Details of the City's parking policy and regulatory changes, and a comparison of between 2006/2008 and 2014 parking supply, demand, and cost for City-controlled lots and garages in Norfolk's CBD and fringe CBD can be found in the sections below.

A comparison of 2006/2008 and 2014 parking does not demonstrate a direct correlation between Tide LRT operations and parking supply, demand, and cost in Norfolk's CBD. The data does show that the supply of parking (number of spaces) in City-controlled parking garages and lots has increased by eight percent between 2006 and 2014 (two new garages have opened and five lots/garages have closed) while the utilization rate has declined by four percent. This means that the number of utilized City-controlled parking spaces has remained stable between 2006 and 2014. The price of parking has increased to some degree between 2008 and 2014 for all City-controlled parking garages and lots within the CBD, but the degree of increase is determined by the City's 2010 pricing restructure from tiered to flat pricing in City-controlled lots and garages.

City of Norfolk Parking Policy and Regulations

In addition to understanding the parking data discussed in the following two sections, it is helpful to understand the City parking policy and regulations because those policies and regulations guide the supply of, demand for (through pricing decisions), and cost of parking.

In October 2005, Norfolk City Council passed a Resolution to "adopt a parking policy to support a greater use of public transit," with an attached policy titled "Transit Oriented Downtown Parking Policy" (Resolution 1, 289). One of the policy goals within the Resolution encouraged "promotion of greater development density particularly near transit stations." As documented in the *Norfolk LRT Documentation of Conditions Before Project Implementation Report (2008),* this policy set the Maximum Downtown Parking Capacity at 3.7 privately-controlled parking spaces per 1,000 square feet of leasable office space within the CBD.

Beginning in 2010, City of Norfolk staff began researching and proposing parking policy changes to satisfy market demand for reduced parking requirements and reduce a perceived oversupply of downtown parking. In February 2014, Norfolk City Council members (based on research and recommendations by City staff) recommended a series of changes to the Zoning Ordinance, including a 25 percent reduction in required parking minimums for non-residential (including commercial) uses within 1,500 feet of a LRT station. The parking minimums vary by land use and location; details can be found in the revised ordinance, which is attached to this report as Appendix 1.

This policy change was partially catalyzed by the realization that "application of suburban parking standards in the Arts District and in Fort Norfolk has created a barrier to revitalization"[1] and to improve compliance with Character Districts defined in *plaNorfolk2030*, the city's General Plan. The City Council approved the amendments to the Zoning Ordinance on March 25, 2014.

It is too soon to quantitatively measure the impacts of this 2014 zoning change on the supply of downtown parking, but the adoption of the Transit Oriented Downtown Parking Policy and the 25 percent reduction in the required parking minimum for non-residential uses within 1,500 feet of an LRT station indicate the City's belief that Tide LRT can play a role in reducing demand for parking and the City's desire for transit-supportive land uses in LRT station areas.

Special Conditions Included in the Project Full Funding Grant Agreement

The City's recent parking and development policy changes are in alignment with the project Full Funding Grant Agreement, signed in October 2007, which includes two special conditions related to land use and transportation planning:

1. "The Grantee acknowledges that the Government's provision of Federal financial assistance to the Project is specifically conditioned upon the continuing enforcement of Resolution No. R-3, "Transit Oriented Downtown Parking Policy," adopted October 18, 2005, by the City of Norfolk's City Council, a true copy of which is affixed to this Attachment to this Agreement. The Grantee agrees and promises to take any and all actions, within its powers, as may be reasonable and necessary to ensure the continued enforcement of Resolution No. R-3 for a period of no less than five years following the completion of the Project, now estimated for January 1, 2010."
2. "The Grantee agrees and promises to take any and all actions, within its powers, as may be reasonable and necessary to ensure local adoption of policies that promote transit-oriented development adjacent to the stations on the light rail line; operation of "feeder" bus routes and services that optimize travel times between satellite parking facilities and the stations on the light rail line; and adoption of *value pricing* parking policies within the city limits of Norfolk."

Parking Supply

The number of spaces and utilization rates of City-controlled parking garages and parking lots in Norfolk's CBD were inventoried in the 2008 *Before Project Implementation Report*. This inventory, which relied on 2006 data, has been updated to 2014 data as part of this *After Project Implementation Report*.

Table 1 lists the 2006 / 2014 City-controlled parking lots and garages in Norfolk's CBD, which is defined as the area bound on the west by Boush Street, on the east by St. Paul's Boulevard, on the north by Brambleton Avenue, and on the south by Waterside Drive, and the fringe CBD, which is the area just outside of the CBD. Figure 1 shows the location of the 2014 parking facilities.

The City controls 90 percent of the parking in downtown Norfolk; the remaining 10 percent is privately-controlled. Privately-controlled parking facilities are not included in this inventory. Two of the garages included in Table 1, Bank and Charlotte Street Garages, were built in 2010, after the 2008 *Before Project*

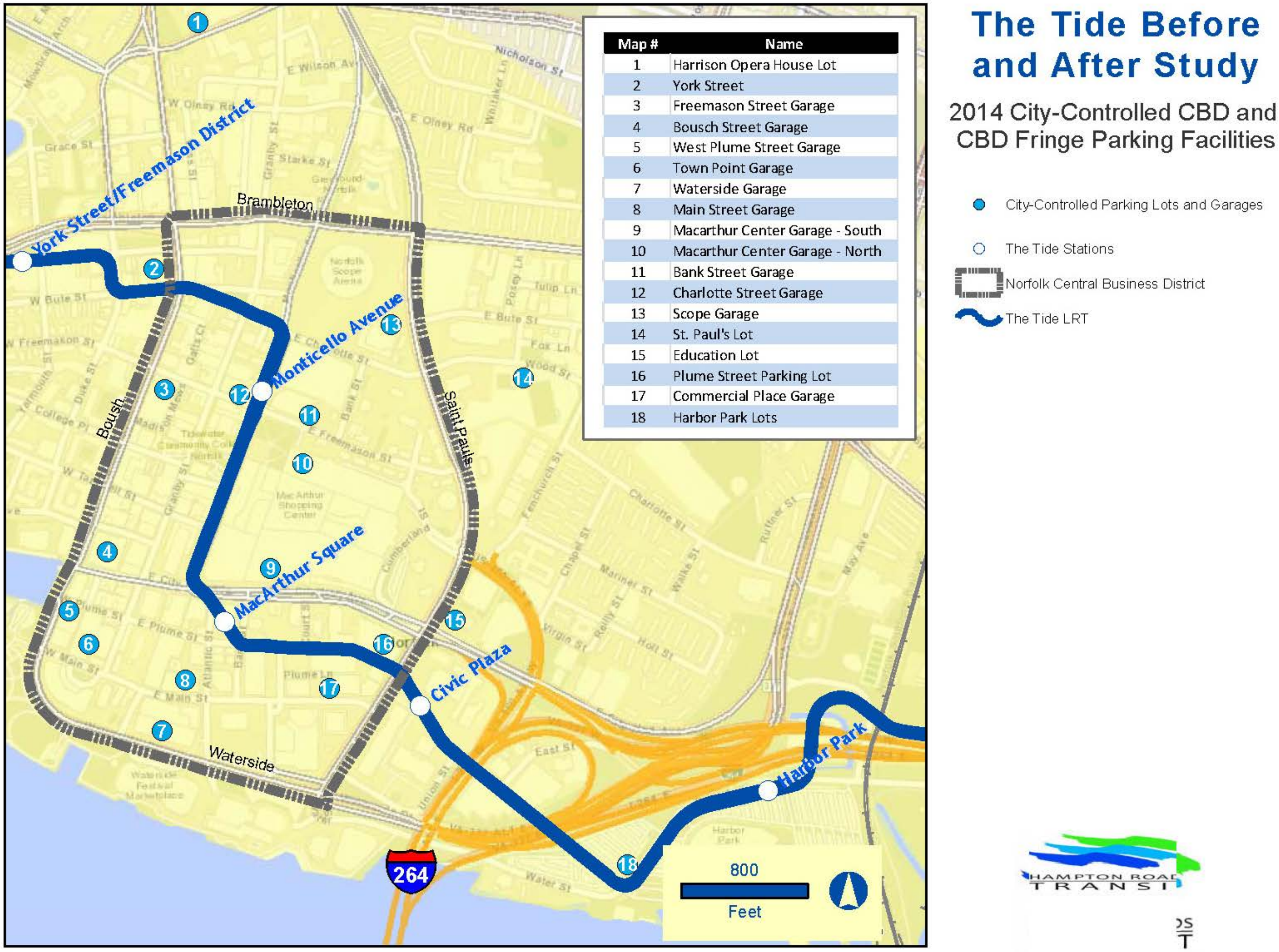
[1] "Getting the Parking Right," February 2014; http://www.norfolk.gov/DocumentCenter/View/13821

Implementation Report was completed. Their primary purpose was to accommodate demand that was generated by the construction of the Wells-Fargo Tower. These garages were opened just before the City started considering changes to its parking policy in 2010, as described in the previous section.

While the utilization rate of the City-controlled parking garages and lots has decreased four percent, the total number of parking spaces has increased over eight percent (from 16,418 to 17,925) between 2006 and 2014. This increase in the number of spaces reflects the construction of the Bank and Charlotte Street Garages, which added 1,858 additional parking spaces to the CBD. The majority of spaces in these two new garages (80 percent) are designated for monthly parking. Five lots/garages closed between 2006 and 2014, resulting in the loss of 1,390 spaces.

A comparison of 2006 and 2014 parking supply data does not demonstrate a direct correlation between Tide LRT operations and parking supply in Norfolk's CBD. Further, the data does not immediately indicate that parking policies have made a difference to parking utilization or construction. Additional time is needed to see if the policies will make long term changes to parking supplies in the CBD.

Figure 1: 2014 City-Controlled CBD Parking Facilities



Map #	Name
1	Harrison Opera House Lot
2	York Street
3	Freemason Street Garage
4	Bousch Street Garage
5	West Plume Street Garage
6	Town Point Garage
7	Waterside Garage
8	Main Street Garage
9	Macarthur Center Garage - South
10	Macarthur Center Garage - North
11	Bank Street Garage
12	Charlotte Street Garage
13	Scope Garage
14	St. Paul's Lot
15	Education Lot
16	Plume Street Parking Lot
17	Commercial Place Garage
18	Harbor Park Lots

Table 1. City-Controlled Parking Garages and Lots in Norfolk's Central Business District and Fringe Central Business District

City of Norfolk CBD and CBD Fringe Parking Facilities	2006				2014			
	Total Number of Parking Spaces*	Number of General Parking Spaces*	Number of Monthly Parking Spaces*	Utilization Rate*	Total Number of Parking Spaces	Number of General Parking Spaces	Number of Monthly Parking Spaces	Utilization Rate
Bank Street Garage	--	--	--	--	1,372	274	1,098	75%
Board of Trade Lot	15	--	15	100%	**Closed**			
Boush Street Garage	716	266	450	81%	716	266	450	81%
Cedar Grove Lot (special event / cruise parking only)	1,200	--	1,200	65%	1,200	--	1,200	n/a
Chamber of Commerce Lot	--	--	31	100%	**Closed**			
Charlotte Street Garage	--	--	--	--	486	100	386	86%
Commercial Place Garage	743	83	160	78%	743	83	660	78%
Freemason Street Garage	617	124	353	42%	617	44	573	42%
Education Lot	--	--	--	--	232	30	--	n/a
Harbor Park Lot	2,441	--	2,200	35%	2,441	--	2,441	35%
Harrison Opera House Lot	400	--	400	50%	400	--	400	50%
Lot 31	69	69	--	75%	**Closed**			
Lot 56	176	--	176	n/a	**Closed**			
Macarthur Center Garage - North	1,672	1,362	310	45%	1,672	1,173	499	45%
Macarthur Center Garage - South	2,932	1,760	1,172	45%	2,932	1,241	1,691	45%
Main Street Garage	707	192	515	70%	707	142	565	70%
Monticello Lot	333	77	256	60%	**Closed**			
Monticello Avenue Garage	766	153	613	55%	**Closed**			
Plume Street Parking Lot	169	--	169	82%	169	0	169	82%
Scope Garage	593	493	100	20%	593	393	200	20%
St. Paul's Lot	--	--	--	--	776	--	776	43%
Town Point Garage	880	90	790	80%	880	90	790	80%

City of Norfolk CBD and CBD Fringe Parking Facilities	2006				2014			
	Total Number of Parking Spaces*	Number of General Parking Spaces*	Number of Monthly Parking Spaces*	Utilization Rate*	Total Number of Parking Spaces	Number of General Parking Spaces	Number of Monthly Parking Spaces	Utilization Rate
Waterside Garage	561	291	270	70%	561	216	345	55%
West Plume Street Garage	835	184	651	65%	835	134	701	65%
York Street Garage	593	119	474	52%	593	119	447	69%
Total / Average Utilization Rate	**16,418**	**5,263**	**10,305**	**64%**	**17,925**	**4,305**	**13,391**	**60%**

Source: City of Norfolk website; Linda Davis, City of Norfolk Parking Division

** This data is drawn from the Before Project Implementation Report*

Parking Costs

In 2002, the City of Norfolk – in response to concerns that parking demand generated by CBD development would exceed the existing parking supply - established a three-tiered pricing structure for City-controlled parking garages and lots. The tiering of the garages was based on their proximity to prime demand generators: garages and lots closest to those generators were classified as Tier 1, which was the most expensive tier. Garages and lots that were located successively further away from those demand generators were classified in the less expensive Tiers 2 and 3. The intent was to use pricing as a means to more evenly distribute parking demand throughout City-owned garages and lots. Table 1 outlines the tiered parking rate structure. The location of City-controlled CBD parking lots and garages – and their tier classification – are shown in Figure 1.

In 2010, the City eliminated the tiered parking garage pricing structure because development was more evenly distributed throughout the city than anticipated, which resulted in a more even distribution of parking demand than anticipated. The City decided that the tiered structure was not necessary to balance demand among the City-controlled parking lots and garages. Table 2 shows the current parking rates for 2014.

A comparison of 2008 and 2014 parking cost data does not demonstrate a direct correlation between Tide LRT operations and parking costs in Norfolk's CBD.

Table 2. Downtown Norfolk Parking: Tiered-Pricing System, as of 2008

City of Norfolk Garage and Parking Lot Tiers	2008 City of Norfolk Garage and Parking Lot Costs										
	0-1 Hour	1-2 Hours	2-3 Hours	3-4 Hours	4-5 Hours	5-6 Hours	6-7 Hours	7-8 Hours	Max up to 24 Hours	Lost Ticket	Special Event/ Collect on Entry
Tier 1	$0.75	$1.50	$2.50	$4.50	$6.50	$8.50	$10.50	$12.50	$14.00	$14.00	$5.00
Tier 2	$0.50	$1.25	$2.25	$3.25	$4.25	$5.25	$6.25	$7.25	$8.00	$8.00	$4.00
Tier 3	$0.50	$1.00	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50	$4.50	$4.00

Source: City of Norfolk website; Norfolk LRT Project Documentation of Conditions before Project Implementation

Table 3. 2014 Parking Rates for City-Controlled Parking Facilities in City of Norfolk Central Business District and Fringe CBD

City of Norfolk CBD and CBD Fringe Facilities	2014 Parking Rates											2008 Tier
	0-1 Hour	1-2 Hours	2-3 Hours	3-4 Hours	4-5 Hours	5-6 Hours	6-7 Hours	7-8 Hours	Max up to 24 Hours	Lost Ticket	Special Event/ Collect on Entry	
Bank Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	--
Boush Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	1
Charlotte Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	--
Commercial Place Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	1
Education Lot	NA - City-controlled spaces are only metered up to two hours											--
Freemason Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	2
Harbor Park Lots	NA - Monthly Parking ($43 or $73 day/$20 or $25 night) or Special Event ($5)											--
Harrison Opera House Lot	NA - Monthly Parking ($37 or $67 day/$20 or $25 night) or Special Event ($5)											--
Macarthur Center Garage – North	$1.00	$1.00	$1.00	$3.00	$5.00	$7.00	$9.00	$10.00	$10.00	$10.00	--	1
Macarthur Center Garage – South	$1.00	$1.00	$1.00	$3.00	$5.00	$7.00	$9.00	$10.00	$10.00	$10.00	--	1
Main Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	1
Plume Street Parking Lot	NA - Monthly Parking Only ($69 or $99 day/$28 or $33 night) or Special Event ($5)											1
Saint Paul's Lot	NA - Monthly Parking Only ($43 day or night) or Special Event ($5)											--
Scope Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	2
Town Point Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	1
Waterside Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$12.00	$13.00	$13.00	$5.00	2
West Plume Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$11.00	$13.00	$13.00	$5.00	1
York Street Garage	$1.50	$3.00	$4.50	$6.00	$7.50	$9.00	$10.50	$11.00	$13.00	$13.00	$5.00	3

Source: City of Norfolk website; Norfolk LRT Project Documentation of Conditions before Project Implementation

Additional Transit Network Factors

The Norfolk NET Circulator (HRT Route 17) was a downtown circulator bus route that was established in 1999 to connect residents and visitors with employment, dining, entertainment, shopping, and other destinations within downtown. Operation of the route supported reduced parking demand, as riders could choose to circulate car-free throughout the downtown. The name NET, which is short for Norfolk Electric Transit, refers to the operation of electric-powered buses along the original route. Over the years, the routing of the NET has changed, including:

- Between 2011 and 2013, the downtown service operated as a bi-directional circulator route from the former Cedar Grove Transfer Center to Water Street, near the Waterside Festival Marketplace along the Elizabeth River, via Granby Street.
- When the Cedar Grove Transfer Center closed in July 2013, the NET was revised to operate as a one-directional loop around downtown, traversing Granby Street, Main Street, St Paul's Drive, and Brambleton Avenue, serving the interim Downtown Norfolk Transit Center.

The service, which originally was fare-free, was converted to the HRT bus fare structure in 2011 to reduce a perceived competition with the new LRT service that arose from their similar routes through downtown Norfolk. Due to low route ridership and duplication of transit service in the downtown, Route 17 was discontinued in July 2014.[2]

Free LRT park-and-ride lots (Harbor Park, Ballentine/Broad Creek, Military Highway, and Newtown Road) have increased transit system access by suburban users. Despite these free parking facilities, however, HRT planning staff report that some commuters have continued to choose to park at CBD fringe lots and garages and walk into the CBD as a means to more directly access to their final destination.

Conclusions

A comparison of 2006/2008 and 2014 parking does not demonstrate a direct correlation between Tide LRT operations and parking supply, demand, and cost in Norfolk's CBD. The data does show that the supply of parking (number of spaces) in City-controlled parking garages and lots has increased by eight percent between 2006 and 2014 (two new garages have opened and five lots/garages have closed) while the utilization rate has declined by four percent. This means that the number of utilized City-controlled parking spaces has remained stable between 2006 and 2014. The price of parking has increased to some degree between 2008 and 2014 for all City-controlled parking garages and lots within the CBD, but the degree of increase is determined by the City's 2010 pricing restructure from tiered to flat pricing in City-controlled lots and garages.

The City of Norfolk is making policy changes with the expressed belief that Tide LRT will play a role in reducing demand for parking within station areas; however, it is too soon to measure or predict the actual impacts of those 2014 policy changes on parking supply and demand at this time.

[2] https://hartride2012tampa.wordpress.com/transit_focus_pages/hampton-roads-area-virginia/hampton-roads-transit/norfolk-net-downtown-circulator/

Appendix 1

02/21/2014 tsv

Form and Correctness Approved: RAP

By Adam D. Melita
Office of the City Attorney.

Contents Approved: M. S.

By
DEPT.

NORFOLK, VIRGINIA

ORDINANCE NO: 45,496

PH-5

AN ORDINANCE TO AMEND AND REORDAIN ALL OF CHAPTER 15 AND PORTIONS OF SECTIONS 4-0.9, 10-15.5, AND 25-10 OF THE ZONING ORDINANCE OF THE CITY OF NORFOLK, 1992, IN ORDER TO REVISE THE REGULATIONS FOR REQUIRED PARKING.

- - -

BE IT ORDAINED by the Council of the City of Norfolk:

Section 1:- That the sections and tables in Chapter 15 and portions of sections 4, 10, and 25 of the Zoning Ordinance of the City of Norfolk, 1992 (as amended) that are specified hereinafter are hereby amended and reordained in the manner set forth below so as to revise and reorganize the regulations for required parking.

Section 2:- That Chapter 15, entitled "OFF-STREET PARKING AND LOADING," is hereby amended and reordained to include all new text and tables for the reasons stated above. The text and tables shall read as set forth in "Exhibit A," attached hereto.

Section 3:- That Section 4-0.9(a), entitled "Covered porches," is hereby amended and reordained for the reasons stated above. The text shall read as set forth in "Exhibit B," attached hereto.

Section 4:- That Section 10-15.5, entitled "Parking requirements," is hereby amended and reordained for the reasons stated above. The text shall read as set forth in "Exhibit C," attached hereto.

Section 5:- That Section 25-10.4, entitled "Off-lot parking," is hereby amended and reordained for the reasons stated above. The text shall read as set forth in "Exhibit D," attached hereto.

Section 6:- That Section 25-10.8(b), entitled "Traffic circulation requirements," is hereby amended and reordained by removing subsection (3) for the reasons stated above. The text shall read as set forth in "Exhibit E," attached hereto.

Section 7:- That Section 25-10.9, entitled "Tattoo parlor and tattoo school," is hereby amended and reordained by removing subsection (c) for the reasons stated above.

Section 8:- That Section 25-10.10, entitled "Bed and breakfast," is hereby amended and reordained for the reasons stated above. The portion of the section to be amended is found in subsection (h) and the text of the amended portion shall read as set forth in "Exhibit F," attached hereto.

Section 9:- That this ordinance shall be in effect from the date of its adoption.

ATTACHMENTS:
Exhibit A (22 pages)
Exhibit B (1 page)
Exhibit C (1 page)
Exhibit D (1 page)
Exhibit E (1 page)
Exhibit F (1 page)

Adopted by Council March 25, 2014
Effective March 25, 2014

TRUE COPY
TESTE:

____
R. BRECKENRIDGE DAUGHTREY, CITY CLERK

BY: ____________________________________
DEPUTY CITY CLERK

EXHIBIT A

CHAPTER 15: PARKING AND LOADING

15-0 Purpose

The purpose of this chapter is to reduce hazards to public safety and to ensure efficient traffic flow by establishing standards for motor vehicle parking, bicycle parking and loading areas. For the purpose of applying and enforcing this ordinance, "parking" shall refer to both motor vehicle parking and loading as well as parking for bicycles.

15-1 Applicability.

15-1.1 *General.* Except where expressly provided for otherwise, all uses in all zoning districts shall provide off-street parking as set forth in this chapter.

15-1.2 *Grandfathering of existing motor vehicle parking.*

(a) In order to encourage the reuse of existing buildings, any building serving a use which was lawfully established prior to March 3, 1992 shall be deemed to include one (1) parking space for each 250 square feet of gross area inside the building without regard to the number of parking spaces, if any, that actually exist on the site.

(b) All requirements and provisions of this chapter shall apply to such grandfathered uses, incorporating to the numerical adjustment set forth above.

(c) *Existing facilities.* Any improved portion of a zoning lot that has been used continuously to provide parking for a use which was lawfully established prior to March 3, 1992 shall not be reduced in area or dimension.

15-1.3 *Adjustments to general parking requirements.* Some zoning districts contain specific parking requirements that differ from those found in this chapter. In the event there is any conflict between the parking requirements set forth in the regulations of the applicable zoning district or overlay district and those found in this chapter, the regulations of the specific zoning district or overlay district shall apply.

15-2 General Provisions.

15-2.1 *Parking plan.* In the event that the zoning administrator determines that the evaluation of compliance with the parking requirements of this ordinance requires a parking plan, no new use may commence until a plan, drawn to scale and showing parking facilities and spaces, is provided and it has been determined that the parking provided is sufficient.

15-2.2 *Reserved for principal use.* Required parking spaces shall not be used for the storage or sale of merchandise, vehicles for sale, or vehicle repair. Spaces allocated for these activities shall be designated on a parking plan.

15-2.3 *Multiple uses on same zoning lot.* When computing the number of parking spaces required on a lot with more than one use, the total number of required spaces shall be the sum of the number of parking spaces required for each use evaluated individually, including any adjustments made under the alternative parking provisions of section 15-4.

15-2.4 *Residential garage.* For a single-family residential use in which one or more garage spaces are provided, all spaces located inside the garage shall only be considered to accommodate one (1) required motor vehicle parking space.

15-2.5 *Fractional spaces.* When determination of the number of parking or loading spaces required by this ordinance results in a fractional number, any fraction shall be rounded to the nearest whole number.

15-3 Motor Vehicle Parking Requirements.

15-3.1 *Minimum motor vehicle parking.*

(a) *General.* Every use shall include the number of motor vehicle parking spaces indicated under the classifications and formulae set forth in Table 15-A – Table of Minimum Parking Requirements, below. If a particular use is not specified on the table, then the number of spaces required shall be established by the zoning administrator.

(b) *Reduction for proximity to Light Rail Transit (LRT).* For any nonresidential use located within 1,500 feet of a LRT station, the required number of parking spaces determined under the general rule, above, shall be reduced by 25 percent (25%). This reduction shall not apply in Transit Oriented Development (TOD) zoning districts.

15-3.2 *Maximum motor vehicle parking.* In order to minimize the adverse impacts caused by improving large areas with impervious surfaces, including increased storm water run-off, urban heat island effects, and nonpoint source pollution, excess parking shall be limited as follows:

(a) *General limitation.* The total number of motor vehicle parking spaces serving a commercial use shall not exceed 125% of the minimum parking requirement, subject to the exemptions applicable in subsection (b), below.

(b) *Exemptions.* A commercial use shall be exempt from the general limitation set forth above if any of the following apply:

(1) Any spaces in excess of 125% of the minimum number required are located in a structured parking facility.

(2) An alternative landscape plan that provides additional pervious landscape surfaces and increases stormwater filtration has been reviewed and recommended by the Department of Recreation, Parks and Open Space and has been approved by the zoning administrator subject to the provisions of chapter 17, Landscape Plantings and Buffers

.

15-3.3 *Handicap accessible parking.* Every use shall include the number of handicap accessible motor vehicle parking spaces set forth in Table 15-C – Table of Handicap Accessible Parking Requirements, below. The location and design of such spaces shall conform to the requirements of the Virginia Uniform Statewide Building Code.

15-4 Motor Vehicle Parking Design Standards.

15-4.1 *Locational standards for parking areas.*

(a) *Single-family dwellings.* For any single-family dwelling, motor vehicle parking and maneuvering areas shall not be located in any required yard adjacent to a public street except in an access/driveway that complies with the provisions of section 15-4.2(b). Any structure that projects into any required yard designed to shield or shelter a motor vehicle or otherwise shall comply with the requirements of section 4-0.9.

(b) *Uses other than single-family dwellings.* For all uses other than single-family dwellings, all surface motor vehicle parking and maneuvering areas shall be located as follows:

(1) *Suburban.* In the Suburban Character District, parking shall not be located in any required yard adjacent to a public street, any required buffer yard, or any open space.

(2) *Traditional.* In the Traditional Character District, the following standards must be met:

(A) No parking shall be located in any required buffer yard or any open space.

(B) Parking shall not be located in any required yard adjacent to a public street except when a wall, hedge, or decorative fence is located along the property line abutting the street which is not less than three (3) feet in height, screens the parking area, and defines the edge of the pedestrian corridor.

(3) *Downtown.* In the Downtown Character District, the following standards must be met:

(A) At least 50% of all required parking shall be located to the side or rear of buildings.

(B) No parking shall be located in any required buffer yard or any open space.

(C) Parking shall not be located in any required yard adjacent to a public street except when a wall, hedge, or decorative fence is located along the property line abutting the street which is not less than three (3) feet in height, screens the parking area, and defines the edge of the pedestrian corridor.

15-4.2 *Design standards for parking areas.*

(a) *Zoning certificate.* No parking area, driveway, or access shall be constructed or expanded except in accordance with a zoning certificate without regard to whether it is used to provide required parking spaces.

(b) *Single-family dwellings.* For any single-family dwelling, the following design standards for the parking area must be met:

(1) *Surfacing.* Surfacing of parking areas, driveways, and accesses shall be designed to maintain proper drainage, shall consist of an improved surface, and shall not include gravel, dirt, or sand.

(2) *Driveway or access.* Any improved hard surface used for parking or maneuvering a vehicle and which is located in any required yard abutting a public street shall be limited to a driveway or access installed generally perpendicular to the abutting street. The width and number of such driveways or accesses per zoning lot shall be limited as follows:

(A) On lots at least 100 feet wide:

(i) No more than two (2), with a maximum width of 20 feet each and located on separate streets; or

(ii) No more than two (2), with a maximum width of 20 feet each if located on the same street and separated by at least 50 feet of street frontage.

(B) On lots at least 75 feet wide but less than 100 feet wide:

(i) No more than two (2), with a maximum width of 20 feet each and located on separate streets; or

(ii) No more than two (2), with a maximum width of 10 feet each if located on the same street and separated by at least 25 feet of street frontage.

(C) On lots at least 40 feet wide but less than 75 feet wide:

(i) No more than one (1), with a maximum width of 20 feet;

(ii) No more than two (2), with a maximum width of 10 feet each and located on separate streets; or

(iii) No more than two (2), with a maximum width of 10 feet each if located on the same street and separated by at least 15 feet of street frontage.

(D) On lots at least 30 feet wide but less than 40 feet wide, no more than one (1), with a maximum width of 10 feet.

(E) On lots less than 30 feet wide:

(i) For a corner lot, no more than one (1), with a maximum width of 10 feet and located along the longest street frontage and not in the front yard.

(ii) For any lot other than a corner lot, no more than one (1), with a maximum width of 10 feet.

(3) *Additional restrictions for nonstandard-width parcels.* Notwithstanding the provisions regarding the permissible width and number of such driveways or accesses per zoning lot set forth in subsection (b)(2), above, a driveway or access may nevertheless be prohibited under section 4-0.15(c) of this ordinance.

(c) *Uses other than single-family dwellings*:

(1) *Surfacing.* Surfacing of parking areas, driveways, and accesses shall consist of an improved surface, shall be designed to maintain proper drainage, and shall be striped and maintained in accordance with the dimensional standards set forth in Figure 15-1 – Minimum Parking Dimensions, below.

(2) *Landscaping and screening.* Landscaping and screening of parking areas shall be provided in accordance with the requirements of chapter 17, Landscape Plantings and Buffers.

(3) *Lighting.* Whenever development activity on a lot requires site plan review and approval, all parking area lighting shall be provided in accordance with the requirements of chapter 26, Site Plan Review.

(4) *Dimensions of parking spaces.*

(A) All minimum requirements as to size, angle, and placement of parking spaces located on surface lots shall be as set forth in Figure 15-1, Minimum Parking Dimensions, below, unless alternative parking dimensions indicated on a parking plan designed and sealed by a professional engineer have been approved by the director of public works.

(B) The minimum dimensional requirements of parking spaces in a particular structured parking facility and shown on a parking plan designed and sealed by a professional engineer shall be established by the director of public works.

(C) Any parking area may include spaces designed for compact vehicles, subject to the following limitations:

(i) No more than 15% of the number of minimum required parking spaces may be satisfied by providing compact spaces;

(ii) Compact spaces must be located only at the ends of parking rows with no more than two (2) compact spaces placed side-by-side.

(iii) Each compact space shall be clearly identified with markings placed on the surface of the parking space and with a sign restricting it for compact vehicles only.

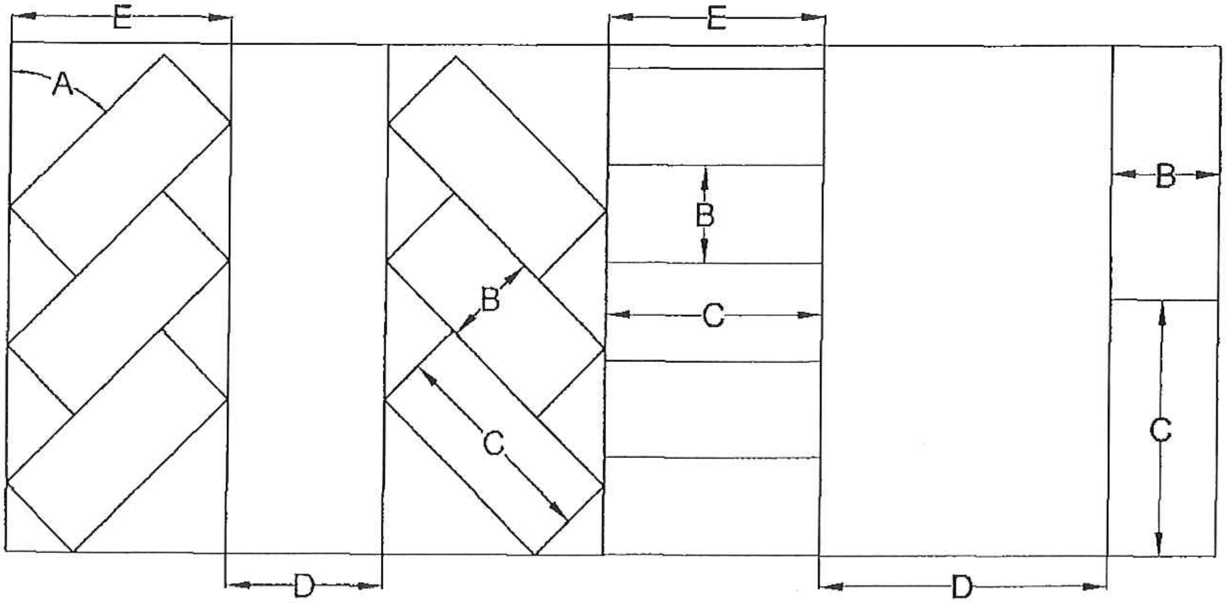
(5) *Stacking spaces.*

(A) *Drive-Through facilities.* Commercial Drive-Through facilities for which vehicle stacking spaces are required must meet the minimum dimensional standards set forth in section 25-10.8 of this ordinance.

(B) *Other commercial uses.* For automobiles awaiting service at any of the facilities indicated in the following table, space sufficient to accommodate the number of stacking spaces indicated therein shall be provided on the same zoning lot:

TYPE OF ACTIVITY	REQUIRED NUMBER OF STACKING SPACES	START POINT FOR STACKING SPACES
Automated teller machine	3	Teller machine
Bank teller lane	3	Teller window/tube
Dry-cleaning/laundry	3	Cleaner/laundry window
Pharmacy	3	Pharmacy window
Food service	6	Order box/speaker
	4*	Pick-up window
Other	To be determined by zoning administrator. Such determination shall consider any study prepared by a registered engineer having expertise in transportation engineering and provided by the special exception applicant.	
* These spaces are required in addition to the stacking spaces required to be located behind the order box/speaker and shall be located between the pickup window and the order box/speaker.		

FIGURE 15-1 – MINIMUM PARKING DIMENSIONS



STANDARD PARKING DIMENSIONAL REQUIREMENTS

Parking Angle (A)	Stall Width (B)	Stall Depth (C)	Aisle Width – parking on one side (D)	Aisle Width – parking on both sides (D)	Stall Distance – Curb to Aisle (E)
0⁰	9.0'	21.0'	12.0' (one-way) 20.0' (two-way)	12.0' (one-way) 20.0' (two-way)	9.0'
45⁰	8.0'	18.0'	13.0' (one-way)	13.0' (one-way)	18.4'
60⁰	8.0'	18.0'	18.0' (one-way)	18.0' (one-way)	19.6'
70⁰	8.0'	19.0'	20.0' (one-way)	20.0' (one-way)	20.6'
90⁰	8.0'	18.0'	22.0' (two-way)	24.0' (two-way)	18.0'

COMPACT PARKING DIMENSIONAL REQUIREMENTS

Parking Angle (A)	Stall Width (B)	Stall Depth (C)	Aisle Width – parking on one side (D)	Aisle Width – parking on both sides (D)	Stall Distance – Curb to Aisle (E)
0⁰	8.5'	18.0'	11.0' (one-way) 20.0' (two-way)	11.0' (one-way) 20.0' (two-way)	8.5'
45⁰	7.5'	16.5'	12.0' (one-way)	12.0' (one-way)	17.0'
60⁰	7.5'	16.5'	16.0' (one-way)	16.0' (one-way)	18.0'
70⁰	7.5'	17.0'	18.0' (one-way)	18.0' (one-way)	18.5'
90⁰	7.5'	16.5'	19.0' (two-way)	21.0' (two-way)	16.5'

15-5 Alternative Parking.

In order to accommodate infill development, redevelopment, and flexible parking practices within the built environment, the following parking alternatives may be utilized to satisfy specific parking needs. In order to utilize any of these forms of alternative parking, a parking plan designed and sealed by a design professional must be submitted to the Department of Planning for review and will not be effective until the zoning administrator approves the plan.

15-5.1 *Off-lot parking.* Required parking may be provided on a lot other than the lot upon which the use is located as follows:

(a) *Administrative process.* Where sufficient alternative parking is located no more than 500 feet from the property upon which the use is located, measured along a convenient pedestrian route, the parking shall satisfy the required parking requirements of this chapter provided that the parking plan is reviewed and approved by the zoning administrator. The review process shall include the location and condition of the alternative parking area and evidence of a legal right to use the alternative parking area, secured either by deed, long-term lease, or other documentation of sufficient license or possessory interest.

(b) *Special exception process.* Whenever an application for alternative parking at an off-lot location has been denied by the zoning administrator or where the alternative parking is located more than 500 feet from the property upon which the use is located, measured along a convenient pedestrian route, the parking shall satisfy the required parking requirements of this chapter only upon the grant of a Special Exception authorizing off-lot parking pursuant to the provisions of section 25-10.4.

15-5.2 *Shared parking.* Parking for multiple, separate uses may be provided collectively. A reduction in the parking required for each separate use may be allowed when the separate uses involve differing hours of operation, days of operation, or other circumstances that make it unlikely that the separate uses will experience peak-hours of usage simultaneously. In such cases, the reduction may be approved subject to the approval of the zoning administrator.

15-5.3 *Valet parking.* Any parking spaces that do not meet the minimum dimensional requirements set forth in Figure 15-1 may nevertheless be deemed sufficient to satisfy the dimensional provisions of this chapter if such spaces are reserved for valet parking. In order to qualify, all of the following criteria must be met:

(a) A scaled plan showing the dimensions and layout of all parking spaces, stacking, and maneuvering of vehicles in the valet parking area must be submitted and approved by the zoning administrator;

(b) The parking area is marked with signage indicating that it is reserved exclusively for valet parking; and

(c) A parking attendant is present at the property during all times that the use served by the valet parking area is operating.

15-6 Bicycle Parking.

15-6.1 *General requirements.*

(a) *Maneuvering areas.* All required bicycle parking must meet all of the following minimum criteria:

(1) The parking area must accommodate the maneuvering standards set forth in the Figure 15-2, below, or, for bicycle parking provided with vertical space-saving racks, as set forth in Figure 15-3, below.

(2) When in use, each parking space must be accessible without moving another, parked bicycle.

(3) The maneuvering area provided alongside or behind the bicycle parking spaces may extend into portions of a public right-of-way but not those portions established as a motor vehicle lane, motor vehicle drive aisle, motor vehicle parking space, or any landscaped area.

(b) *Surfacing.* The surface of the bicycle parking area shall be improved with a hard surface and shall not include any gravel, dirt, sand or turf.

(c) *Visibility.* Whenever the bicycle parking area is not visible from either the street or the entrance of the principal building, a sign shall be posted at the entrance of the principal building indicating the location of the bicycle parking.

15-6.2 *Standards for short-term bicycle parking.* All short-term bicycle parking facilities or racks shall meet the following construction and location standards:

(a) The facility or rack shall accommodate securing a bicycle using an industry-standard bike lock.

(b) The facility or rack shall be securely anchored to the ground or to a structural element of a building or structure.

(c) Each space on the facility or rack shall be sufficient to accommodate a bicycle at least six (6) feet in length.

(d) The parking area shall be located within 75 feet of the main entrance to the building as measured along the most direct pedestrian access route.

15-6.3 *Standards for long-term bicycle parking.* All long-term bicycle parking facilities or racks shall meet the following construction and location standards:

(a) The facility or rack shall be securely anchored to the ground or to a structural element of a building or structure.

(b) Each space on the facility or rack shall be sufficient to accommodate a bicycle at least six (6) feet in length.

(c) The parking area shall be located within 500 feet of the main entrance to the building as measured along the most direct pedestrian access route.

(d) The bicycle parking area shall be constructed with at least one of the following features:

(1) *Bicycle locker.* A structure, manufactured for the sole purpose of securing and protecting a standard size bicycle from rain, theft and tampering by fully securing the bicycle in a temporary enclosure.

(2) *Indoor storage.* A secured and dedicated bicycle parking area provided either inside the principal building on the lot or in a building located elsewhere on the lot and within 500 feet of a main entrance to the principal building.

(3) *Covered.* A secured and dedicated bicycle parking area that completely protects bicycles from rain with a minimum of eight (8) feet of clearance above the floor or ground improved with a hard surface.

15-6.4 *Minimum bicycle parking requirements.*

(a) *Parking spaces.* Except where indicated otherwise in this ordinance, every use shall include the number of bicycle vehicle parking spaces indicated under the classifications and formulae set forth in Table 15-B – Table of Bicycle Parking Requirements, below. If a particular use is not specified on the table, then the number of spaces required shall be established by the zoning administrator.

(b) *Exemptions.*

(1) No bicycle parking spaces are required for any of the following:

(A) Any single-family dwelling, two-family dwelling, or group home.

(B) Any industrial use.

(C) Any non-residential use located on property in the D-2, D-3, or D-4 zoning districts.

(2) No short-term bicycle spaces are required for any residential use located on property in the D-2, D-3, or D-4 zoning districts.

(c) *Bicycle commuter shower facilities.*

(1) *Limited applicability.* The requirement to provide bicycle commuter shower facilities as set forth below shall only apply on properties that meet all of the following criteria:

(A) The property is used for a Commercial, Office, or Public and Civic use;

(B) The property is located within the Traditional or Downtown Character District;

(C) The total square footage of the buildings related to the use exceeds 250,000 gross square feet in area; and

(D) The use is commenced after July 1, 2014.

(2) *Requirements.* At each property subject to this requirement:

(A) One shower per gender shall be provided for each 250,000 gross square feet of area in the buildings; and

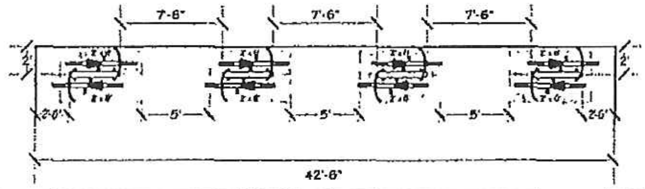
(B) Shower facilities shall be limited to use by employees or occupants of the building and shall be easily accessible to the bicycle parking area.

(d) *Clustered bicycle parking.* Locations for bicycle parking spaces required for more than one use on the same zoning lot may be clustered provide that the total number of required bicycle parking spaces for each use is satisfied and the parking area is located as follows:

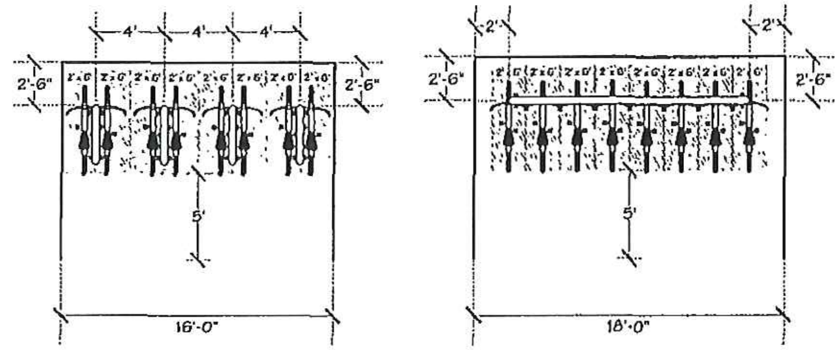
(1) For all required short-term bicycle parking, within 150 feet from the main entrance of the principal building for each use on the lot; and

(2) For all required long-term bicycle parking, within 750 feet from the main entrance of the principal building for each use on the lot.

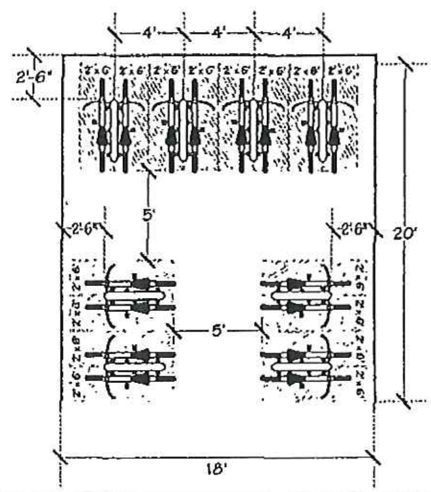
FIGURE 15-2
MINIMUM MANEUVERABILITY CRITERIA FOR BICYCLE PARKING



This area accommodates 8 bicycles.

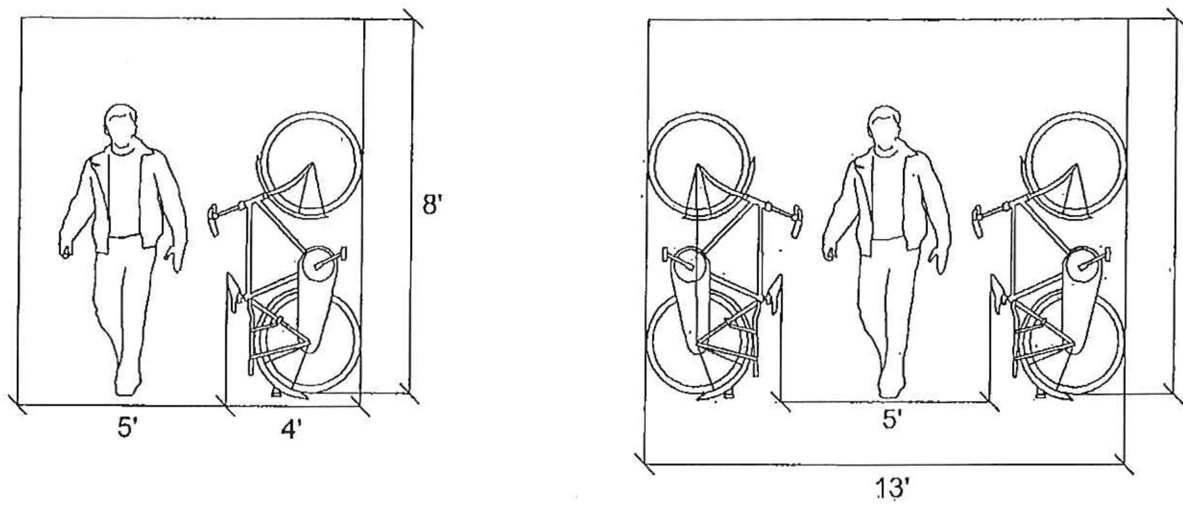


These areas accommodate eight bicycles.



This area accommodates sixteen bicycles.

FIGURE 15-3
MINIMUM MANEUVERABILITY CRITERIA FOR VERTICAL SPACE SAVER RACKS



15-7 Off-street loading.

15-7.1 *General requirements.*

(a) *Location of loading areas and berths.*

(1) All required loading areas and berths shall be located on the same zoning lot as the use served.

(2) All loading berths which abut a residential zoning district or are visible from a public right-of-way shall be completely screened therefrom by building walls, a solid concrete or masonry wall, or a door designed to be compatible with the principal building that it serves. The screening wall shall not be less than six (6) nor more than eight (8) feet in height.

(3) No loading berth shall be located within 30 feet of the nearest point of intersection of any two (2) streets.

(4) No loading areas or berths shall be located in a required front or side yard abutting a residential zoning district.

(b) *Dimensions of loading areas or berths.*

(1) *Short loading areas or berths.*

(A) Unless otherwise specified, a required short loading area or berth shall be at least ten (10) feet in width and 35 feet in length exclusive of aisle and maneuvering space and shall have a vertical clearance of at least 15 feet.

(B) Maneuvering aprons for short areas or berths shall be at least 35 feet in length.

(C) Access lanes for short areas or berths shall be 12 feet in width for one-way lanes and 22 feet in width for two-way lanes. Space dedicated for access lanes may also be considered as space for the maneuvering apron.

(2) *Long loading areas or berths.*

(A) Unless otherwise specified, a required long loading area or berth shall be at least 12 feet in width by at least 50 feet in length exclusive of aisle and maneuvering space, and shall have a vertical clearance of at least 15 feet.

(B) Maneuvering aprons for long areas or berths shall be at least 60 feet in length.

(C) Access lanes for long areas or berths, access lanes shall be 14 feet in width for one-way lanes and 24 feet in width for two-way lanes. Space dedicated for access lanes may also be considered as space for the maneuvering apron.

(c) *Access.* Each required loading area or berth shall be designed with appropriate means of vehicular access to a street or alley in a manner which will least interfere with traffic movement, shall be separated from customer and employee parking, and shall be subject to approval by the director of public works.

(d) *Surfacing.* All open loading areas or berths shall be surfaced with a dustless, all-weather material capable of bearing a live load of 200 pounds per square foot in accordance with standards established by the director of public works.

(e) *Utilization.* Space allocated to any loading use shall not be used to satisfy the space requirements for any motor vehicle parking area or portion thereof.

(f) *Central loading.* Central loading facilities may be substituted for loading areas or berths on individual zoning lots provided that the following criteria are met:

(1) Each zoning lot served shall have direct access to the central loading area or berths without crossing streets or alleys at-grade.

(2) The total number of loading areas or berths provided shall meet 75 percent (75%) of the minimum requirements herein specified for each of the uses served.

(3) The zoning lot served shall be located no more than 500 feet from the central loading area or berths.

(4) Any tunnel or ramp connecting the central loading area or berths with the zoning lot served shall be a minimum of seven (7) feet in width and have a vertical clearance of not less than seven (7) feet.

(g) *Minimum facilities.* Uses for which loading facilities are required but which are located in buildings with less floor area than the minimum prescribed for such required facilities shall provide adequate receiving facilities accessible by motor vehicle off any adjacent alley, service drive, or open space on the same zoning lot.

15-7.2 *Specific requirements.* Except where indicated otherwise in this ordinance, every use listed in Table 15-D – Table of Off-Street Loading Requirements, below, shall provide the number and size of loading areas or berths set forth in therein.

TABLE 15-A – TABLE OF MINIMUM PARKING REQUIREMENTS

LAND USES DU = Dwelling Unit LU = Lodging Unit BDRM = Bedroom SF = Building's Square Feet	**DOWNTOWN**	**TRADITIONAL**	**SUBURBAN**	**EXCEPTIONS/COMMENTS**
ALL LAND USES				
RESIDENTIAL USES (except as listed below)	**2 per DU** (1 per DU for adaptive reuse *of existing buildings*)	**2 per DU** (1 per DU for adaptive reuse *of existing buildings*)	**2 per DU**	No spaces required for lots less than 40 feet in width
Congregate Housing	0.33 per LU	0.33 per LU	0.33 per LU	
Continuing Care Retirement Community	0.5 per DU	1 per DU	1 per DU	
Dormitory	Zoning Administrator Determination	Zoning Administrator Determination	Zoning Administrator Determination	
Fraternity, Sorority House	2 per BDRM	2 per BDRM	2 per BDRM	
Mixed Uses	Depends on mix	Depends on mix	Depends on mix	
Multi-Family	1.5 per DU	1.6 per DU	1.75 per DU	
Nursing Home	0.67 per LU	0.67 per LU	0.67 per LU	
Rooming House	1 plus 1 per BDRM	1 plus 1 per BDRM	1 plus 1 per BDRM	
Townhouse	1.5 per DU	1.75 per DU	2 per DU	
Two-Family	2 per DU	2 per DU	2.5 per DU	
OFFICE USES All Office, except as listed below	**1 per 600 SF** (*max. parking = 125% of the min. requirement)	**1 per 300 SF** (*max. parking = 125% of the min. requirement)	**1 per 250 SF** (*max. parking = 125% of the min. requirement)	*No spaces required for* buildings <2,000 SF located on a separate zoning lot
Office/Clinic, Medical	1 per 500 SF	1 per 250 SF	1 per 250 SF	
COMMERCIAL USES (except as listed below)	**1 per 600 SF** (*max. parking = 125% of the min. requirement)	**1 per 300 SF** (*max. parking = 125% of the min. requirement)	**1 per 250 SF** (*max. parking = 125% of the min. requirement)	No spaces required for buildings located on a separate zoning lot with <2,000 SF of building floor space
Antique Store	1 per 1,250 SF	1 per 625 SF	1 per 500 SF	
Art Gallery	1 per 1,250 SF	1 per 625 SF	1 per 500 SF	

TABLE 15-A – TABLE OF MINIMUM PARKING REQUIREMENTS

LAND USES DU = Dwelling Unit LU = Lodging Unit BDRM = Bedroom SF = Building's Square Feet	DOWNTOWN	TRADITIONAL	SUBURBAN	EXCEPTIONS/COMMENTS
Automobile and Truck Rental	1 customer vehicle space per 500 SF	1 customer vehicle space per 500 SF	1 customer vehicle space per 500 SF	(Spaces for customer parking shall be marked separately)
Automobile and Truck Repair	3 per bay	3 per bay	3 per bay	
Automobile Sales and Service	1 per 500 SF plus 3 per bay	1 per 500 SF plus 3 per bay	1 per 500 SF plus 3 per bay	(Spaces for customer parking shall be marked separately)
Bed and Breakfast	0.67 per guest room plus resident spaces	1 per guest room plus resident spaces	1 per guest room plus resident spaces	
Boat Sales and Service	1 per 500 SF plus 3 per bay	1 per 500 SF plus 3 per bay	1 per 500 SF plus 3 per bay	
Car Wash (Self-Service)	1 per bay	1 per bay	1 per bay	
Convenience Store, 24-Hours (with fuel sales)	1 per 125 SF	1 per 125 SF	1 per 100 SF	
Eating/Eating & Drinking/ Entertainment Establishment	1 per 250 SF of enclosed building area	1 per 175 SF of enclosed building area	1 per 150 SF of enclosed building area	
Funeral Home	1 per 175 SF assembly area	1 per 175 SF assembly area	1 per 150 SF assembly area	
Gas Station	1 per 125 SF	1 per 125 SF	1 per 125 SF	
Health and Fitness Facility	1 per 250 SF	1 per 175 SF	1 per 150 SF	
Hotel/Motel	0.67 per room	1.0 per room	1.3 per room	
Kennel	1 per 400 SF	1 per 400 SF	1 per 400 SF	
Marina	½ per slip	½ per slip	½ per slip	
Mini-Warehouse	3 plus 1 per 100 units	3 plus 1 per 100 units	3 plus 1 per 100 units	
Recreational Sports, Outdoor	Zoning Administrator	Zoning Administrator	Zoning Administrator	
Studio, Arts/Dance	1 per 1,200 SF	1 per 600 SF	1 per 500 SF	
Taxicab Operation	n/a	1 per 500 SF plus 3 per bay	1 per 500 SF plus 3 per bay	
Theater	1 per 12 seats	1 per 6 seats	1 per 5 seats	
PUBLIC AND CIVIC USES (except as listed below)	**Zoning Administrator**	**Zoning Administrator**	**Zoning Administrator**	(*no max. parking required)

TABLE 15-A – TABLE OF MINIMUM PARKING REQUIREMENTS

LAND USES DU = Dwelling Unit LU = Lodging Unit BDRM = Bedroom SF = Building's Square Feet	DOWNTOWN	TRADITIONAL	SUBURBAN	EXCEPTIONS/COMMENTS
Airport	n/a	n/a	1 per 500 SF of passenger waiting and service area	
Broadcast Studio	1 per 1,000 SF	1 per 500 SF	1 per 400 SF	
Day Care Center, Adult	1 plus 1 per 12 attendees	1 plus 1 per 12 attendees	1 plus 1 per 10 attendees	
Day Care Center, Child	1 per 250 SF	1 per 250 SF	1 per 250 SF	
Day Care Home	1 plus resident spaces	1 plus resident spaces	1 plus resident spaces	
Hospital	1 per 300 SF	1 per 300 SF	1 per 250 SF	
Library	1 per 1,600 SF	1 per 800 SF	1 per 500 SF	
Membership Organization/Hiring Hall/ Religious Institution	1 per 65 SF assembly area	1 per 60 SF assembly area	1 per 50 SF assembly area	
INDUSTRIAL USES (except as listed below)	**1 per 850 SF**	**1 per 850 SF**	**1 per 850 SF**	(*no max. parking required)
Automobile Storage Yard	n/a	1 per 500 SF	1 per 500 SF	
Boat Dry Storage Facility	n/a	1 per 1,250 SF	1 per 1,250 SF	
Heavy Equipment Rental, Sales and Service	n/a	1 per 500 SF	1 per 500 SF	
Moving and Storage	n/a	1 per 2,000 SF	1 per 2,000 SF	
Recycling Collection Station	n/a	1 per 500 SF	1 per 500 SF	
Recycling Processing Center	n/a	1 per 500 SF	1 per 500 SF	
Ship Chandler	1 per 2,000 SF	1 per 2,000 SF	1 per 2,000 SF	
Trucking Terminal	n/a	1 per 2,000 SF	1 per 2,000 SF	
Warehouse/Wholesale	1 per 1,250 SF	1 per 1,250 SF	1 per 1,250 SF	

*All parking maximums are subject to the provisions of section 15-3.2 of this ordinance.

TABLE 15-B – TABLE OF BICYCLE PARKING REQUIREMENTS

LAND USES (All spaces are for short-term parking unless otherwise noted)	BICYCLE PARKING CALCULATIONS		
	DOWNTOWN CHARACTER DISTRICT	TRADITIONAL CHARACTER DISTRICT	SUBURBAN CHARACTER DISTRICT
RESIDENTIAL USES (only applicable to Multi-Family as listed below)			
Multi-Family Dwelling	1 per 4 dwelling units (at least 75% of required minimum shall be long-term)	1 per 5 dwelling units (at least 75% of required minimum shall be long-term)	1 per 6 dwelling units (at least 75% of required minimum shall be long-term)
OFFICE USES (unless otherwise listed below)	**1 per 1,200 gsf** (at least 25% of required minimum shall be long-term)	**1 per 1,500 gsf** (at least 25% of required minimum shall be long-term)	**1 per 2,000 gsf** (at least 25% of required minimum shall be long-term)
Office, Veterinary	2 (short-term) and 2 (long-term)	2 (short-term) and 2 (long-term)	2 (short-term) and 2 (long-term)
COMMERCIAL USES (unless otherwise listed below)	**1 per 1,200 gsf** (at least 10% of required minimum shall be long-term)	**1 per 1,500 gsf** (at least 10% of required minimum shall be long-term)	**1 per 2,000 gsf** (at least 10% of required minimum shall be long-term)
Kennel	N/A	2 (short-term) and 2 (long-term)	2 (short-term) and 2 (long-term)
Marina or Yacht Club	1 per 600 gsf of assembly area	1 per 750 gsf of assembly area	1 per 1,000 gsf of assembly area
Hotel/Motel	1 per 20 lodging units (at least 90% of required minimum shall be long-term)	1 per 30 lodging units (at least 90% of required minimum shall be long-term)	1 per 40 lodging units (at least 90% of required minimum shall be long-term)
Mini-Storage	2 (short-term) and 2 (long-term)	2 (short-term) and 2 (long-term)	2 (short-term) and 2 (long-term)
Auto-Dependent Uses: Auto Rental/Repair/Sales/ Car Wash	3 per 20,000 gsf (short-term) 3 per 20,000 gsf (long-term)	2 per 20,000 gsf (short-term) 2 per 20,000 gsf (long-term)	1 per 20,000 gsf (short-term 1 per 20,000 gsf (long-term)
PUBLIC AND CIVIC USES (unless otherwise listed below)	**1 per 1,200 gsf** (at least 25% of required minimum shall be long-term)	**1 per 1,500 gsf** (at least 25% of required minimum shall be long-term)	**1 per 2,000 gsf** (at least 25% of required minimum shall be long-term)
Airport	N/A	N/A	1 per 12,000 gsf of waiting/queuing area
Amphitheater, Arena, Stadium, Conference Center	1 per 35 seats and 1 space per 2,000 gsf of non-seated assembly area	1 per 40 seats and 1 space per 3,000 gsf of non-seated assembly area	1 per 75 seats and 1 space per 5,000 gsf of non-seated assembly area
Day Care Home	No spaces required	No spaces required	No spaces required
Religious Institution	1 per 1,200 gsf of assembly area	1 per 1,500 gsf of assembly area	1 per 2,000 gsf of assembly area

TABLE 15-C – TABLE OF HANDICAP ACCESSIBLE PARKING REQUIREMENTS

TOTAL PARKING SPACES IN LOTS AND GARAGES	REQUIRED MINIMUM NO. OF HANDICAP ACCESSIBLE PARKING SPACES
1—25	1
26—50	2
51—75	3
76—100	4
101—150	5
151—200	6
201—300	7
301—400	8
401—500	9
501-1,000	2% of total
over 1,000	20 plus one for each 100 over 1,000 spaces

TABLE 15-D – TABLE OF OFF-STREET LOADING REQUIREMENTS

LAND USES	GROSS FLOOR AREA (square feet)**	NO. AND SIZE OF LOADING AREAS*
***RESIDENTIAL USES* (only those listed below)**		
Nursing Home, and Continuing Care Retirement Community	10,000 – 100,000 100,000 – 200,000	1 Short 1 Short
OFFICE USES	10,000 – 100,000 Each additional 100,000 up to 500,000	1 Short 1 Short
***COMMERCIAL USES* (only those listed below)**	10,000 - 25,000 25-000 – 40,000 40,000 – 100,000 Each additional 200,000	2 Short 2 Long 3 Long 1 Long
Retail Goods Establishment, (wholesale)	5,000 – 10,000	1 Short
Hotel/Motel	10,000 – 100,000 each additional 100,000	1 Short 1 Short
Theater	10,000 – 25,000 each additional 50,000	1 Short 1 Short
***PUBLIC AND CIVIC USES* (only those listed below)**	10,000 – 100,000 Each additional 100,000 up to 500,000	1 Short 1 Short
Amphitheater, Arena, Stadium, Conference Center	10,000 – 20,000 20,000 – 100,000	1 Short 1 Short
Hospital, Educational Facility	10,000 – 100,000 Each additional 100,000	1 Short 1 Short
***INDUSTRIAL USES* (only those listed below)**	10,000 – 40,000 40,000 – 100,000 Each additional 100,000	1 Short 1 Long, 1 Short 1 Long
Manufacturing, Heavy and Light, and Warehouse/Wholesale	5,000 – 10,000 10,000 – 40,000 40,000 – 100,000	1 Short 1 Long 2 Long
* Loading Area Dimensions	Short: 10 ft. wide x 35 ft. deep	Long: 12 ft. wide x 50 ft. deep
** Gross Floor Area refers to buildings or structures on premises		

EXHIBIT B

CHAPTER 4: RESIDENTIAL DISTRICTS

4-0 General provisions.

...

4-0.9 *Projections into required yards.* The following projections into required yards are permitted.

(a) *Covered porches and carports.* No covered porch or carport, open on three (3) sides except for supporting columns and architectural features, shall be located closer than three (3) feet to any interior side lot line or project more than eight (8) feet into any required front or rear yard. The first floor of such porches or carports shall not extend beyond the first floor level of the building.

...

...

EXHIBIT C

CHAPTER 10: SPECIAL PURPOSE DISTRICTS

...

10-15 Transit-Oriented Development Districts.

...

10-15.5 *Parking requirements.* In order to reduce reliance on the personal automobile and foster greater reliance on mass transit and pedestrian activity, off-street parking in any TOD District shall be required as follows:

(a) *In the TOD-C District:* The minimum motor vehicle parking required shall equal 50 percent (50%) of the minimum computed under the regulations of chapter 15, Parking and Loading.

(b) *In the TOD-S District:* The minimum motor vehicle parking required shall equal 65 percent (65%) of the minimum computed under the regulations of chapter 15, Parking and Loading.

...

EXHIBIT D

CHAPTER 25: SPECIAL EXCEPTIONS

...

25-10.4 *Off-lot parking.* Pursuant to section 15-5.1 of this ordinance, off-lot parking may be permitted upon grant of a special exception provided that the following prerequisites to submitting an application for such special exception are satisfied:

(a) The off-lot parking shall be located within convenient pedestrian route from the principal use which it serves. An applicant may provide shuttle transit service between the off-lot parking area and the principal use it serves.

(b) Parking spaces shall be signed and reserved for the exclusive use of vehicles associated with the principal use that the off-lot parking area serves during all times that the principal use is operating.

EXHIBIT E

CHAPTER 25: SPECIAL EXCEPTIONS

...

25-10.8 *Commercial drive-through facility:*

...

(b) *Traffic circulation requirements.*

(1) Vehicular access to the drive-through windows or service area shall only be permitted from a public street when such street is an arterial or collector street.

(2) The driveway providing access to the drive-through windows shall be at least twenty-five (25) feet from any other driveway.

(3) Internal traffic circulation patterns on the lot shall be adequate to prevent vehicles from impeding street traffic or blocking access to any required parking spaces located on the lot.

...

EXHIBIT F

CHAPTER 25: SPECIAL EXCEPTIONS

...

25-10.10 *Bed and breakfast.* In districts which permit a bed and breakfast by special exception, the following additional requirements shall apply:

...

(h) The parking requirements for a bed and breakfast are set forth Chapter 15, Parking and Loading. Any parking, whether it be on-premises or off-lot, shall be appropriately screened from view.

...

Final Report from the Before-and-After Study of the Tide Light Rail Project

Appendix H: Traffic

HAMPTON ROADS TRANSIT

Traffic

Introduction

In the 2008 *Documentation of Conditions Before Project Implementation Report,* Average Daily Traffic (ADT) and intersection turn movement counts of major roadway segments and intersections were conducted in 2007 at the same locations as in the project Final Environmental Impact Statement. A subset of these segment and intersection locations was updated to 2014 count data. The methodology and results of this update, as well as reasons for changes in the count volumes, are included in the sections below.

Traffic Counts

In the 2008 *Documentation of Conditions Before Project Implementation Report,* ADT counts of 52 major roadway segments were conducted in 2007 at the same locations as in the project Final Environmental Impact Statement. A subset of these locations – seven locations, listed below – was updated to 2014 count data. ADT counts were taken over the course of week (including the weekend) at the following locations, which are mapped in Figure 1:

1. City Hall Avenue between Monticello and St. Paul's Boulevard
2. St. Paul's Boulevard between Waterside and City Hall Avenue
3. Eastbound City Hall Avenue between St. Paul's Boulevard and Berkeley Bridge
4. Westbound City Hall Avenue between St. Paul's Boulevard and Berkeley Bridge
5. Brambleton Avenue between Tidewater Drive and Park Avenue
6. Brambleton Avenue between Park Avenue and I-264
7. Ballentine Boulevard between I-264 and Virginia Beach Boulevard

A comparison of the 2007 and 2014 ADT data is shown in Table 1.

Table 1: 2007 / 2014 ADT Count Data with After (2014) Photos

Map #	Roadway Name	Segment From	Segment To	2007	2014	Difference	Percent Change
1	City Hall Avenue	Monticello Avenue	St. Paul's Boulevard	13,990	6,449	-7,541	-54%

Source: URS Team

City Hall between Monticello and St. Paul's, looking east (2014)

City Hall between Monticello and St. Paul's, looking east (2014)

City Hall between Monticello and St. Paul's, looking west (2014)

City Hall between Monticello and St. Paul's, looking west (2014)

Map #	Roadway Name	Segment From	Segment To	2007	2014	Difference	Percent Change
2	St. Paul's Boulevard	Waterside	City Hall Avenue	14,885	8,546	-6,339	-43%

Source: URS Team

St. Paul's between Waterside and City Hall, looking north (2014)

St. Paul's between Waterside and City Hall, looking south (2014)

<table>
<tr><th>Map #</th><th>Roadway Name</th><th>Segment From</th><th>Segment To</th><th>2007</th><th>2014</th><th>Difference</th><th>Percent Change</th></tr>
<tr><td>3</td><td>Eastbound City Hall Avenue</td><td>St. Paul’s Boulevard</td><td>Berkeley Bridge</td><td rowspan="2">42,410</td><td>13,522</td><td rowspan="2">-23,072</td><td rowspan="2">-154%</td></tr>
<tr><td>4</td><td>Westbound City Hall Avenue</td><td>St. Paul’s Boulevard</td><td>Berkeley Bridge</td><td>5,816</td></tr>
</table>

Source: URS Team

City Hall between St. Paul’s and Berkeley Bridge, looking east (2014)

City Hall between St. Paul’s and Berkeley Bridge, looking east (2014)

City Hall between St. Paul’s and Berkeley Bridge, looking west (2014)

Map #	Roadway Name	Segment From	Segment To	2007	2014	Difference	Percent Change
5	Brambleton Avenue	Tidewater Drive	Park Avenue	28,650	32,035	3,385	12%

Source: URS Team

Brambleton between Tidewater and Park, looking east (2014)

Brambleton between Tidewater and Park, looking east (2014)

Brambleton between Tidewater and Park, looking west (2014)

Brambleton between Tidewater and Park, looking west (2014)

Map #	Roadway Name	Segment From	Segment To	2007	2014	Difference	Percent Change
6	Brambleton Avenue	Park Avenue	I-264	39,630	34,216	-5,414	-14%

Source: URS Team

Brambleton between Park and I-264, looking east (2014)

Brambleton between Park and I-264, looking east (2014)

Brambleton between Park and I-264, looking west (2014)

Brambleton between Park and I-264, looking west (2014)

Map #	Roadway Name	Segment From	Segment To	2007	2014	Difference	Percent Change
7	Ballentine Boulevard	I-264	Virginia Beach Boulevard	29,935	14,859	-15,076	-50%

Source: URS Team

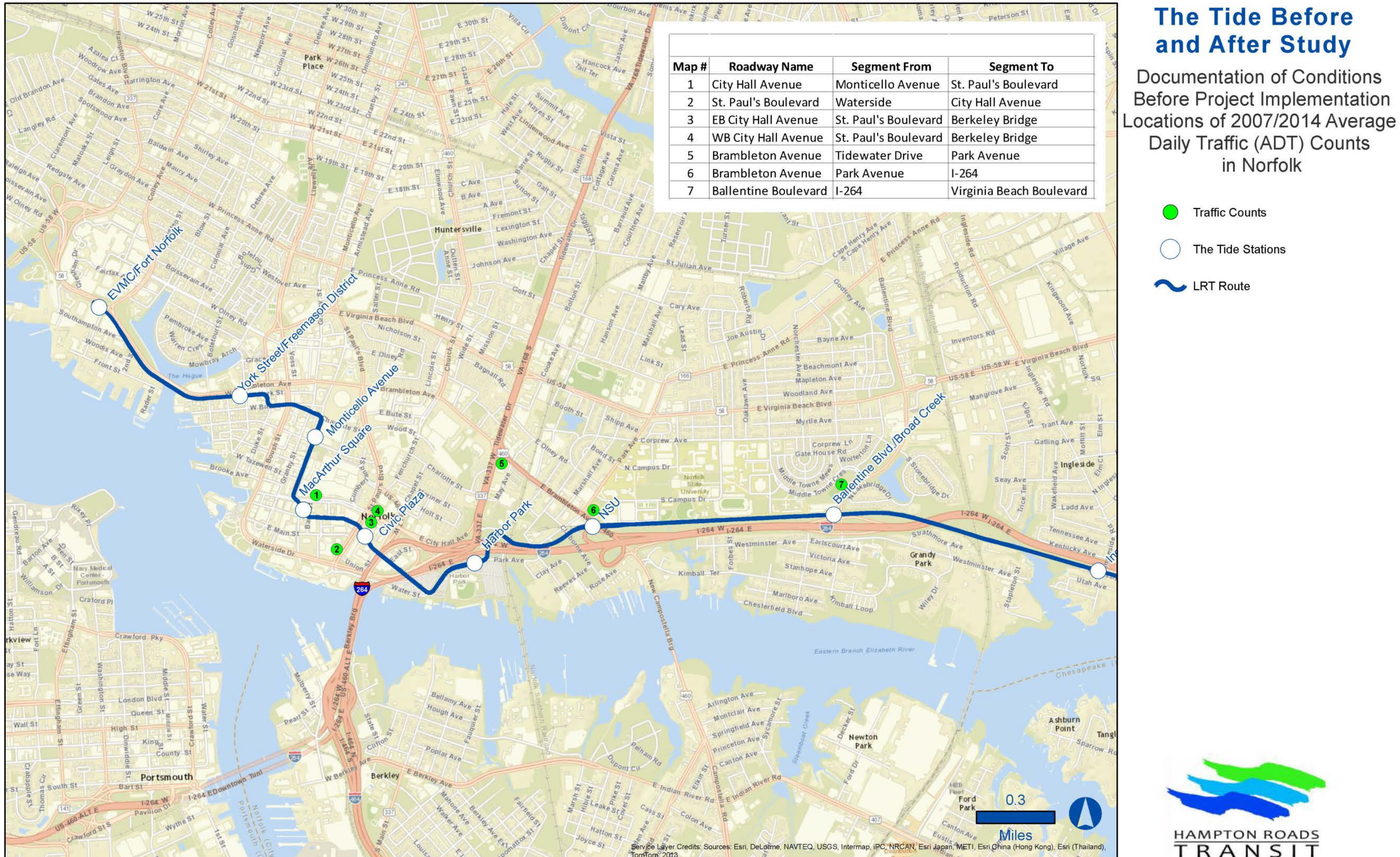
Ballentine between I-264 and Virginia Beach Boulevard, looking north (2014)

Ballentine between I-264 and Virginia Beach Boulevard, looking south (2014)

ADT counts have declined at six of the seven count locations between 2007 and 2014. Two main issues influenced the variation in ADT counts between 2007 and 2014 (with the exception of Ballentine Boulevard, which is discussed below):

- Construction of the new City Hall complex on the east side of St. Paul's Boulevard in the vicinity of City Hall Avenue has resulted in lane closures and various traffic impacts.
- Tolls have been added to the Downtown and Midtown Tunnels, with major shifts in traffic orientation and mixed impacts: people either avoid the tolls using alternate routes, or shift travel times to avoid peak-hour prices.

Figure 1: Locations of 2007/2014 ADT Counts



Map #	Roadway Name	Segment From	Segment To
1	City Hall Avenue	Monticello Avenue	St. Paul's Boulevard
2	St. Paul's Boulevard	Waterside	City Hall Avenue
3	EB City Hall Avenue	St. Paul's Boulevard	Berkeley Bridge
4	WB City Hall Avenue	St. Paul's Boulevard	Berkeley Bridge
5	Brambleton Avenue	Tidewater Drive	Park Avenue
6	Brambleton Avenue	Park Avenue	I-264
7	Ballentine Boulevard	I-264	Virginia Beach Boulevard

Intersection Counts

In the 2008 *Documentation of Conditions Before Project Implementation Report,* peak period turn movement counts were conducted in 2007 at 38 intersections. A subset of these locations – nine locations, listed below – was updated to 2014 count data. Intersection turn movement counts were taken during the AM peak period (6:00 am to 9:00 am) and PM peak period (3:00 pm to 6:00 pm) during a weekday at the following locations, which are mapped in Figure 2:

1. St. Paul's Boulevard and City Hall Avenue
2. Monticello Avenue and City Hall Avenue
3. Monticello Avenue and Freemason Street
4. Monticello Avenue and Charlotte Street
5. Boush Street and Bute Street / Charlotte Street
6. Duke Street and Bute Street
7. Brambleton Avenue and Duke Street
8. Ballentine Boulevard and I-264 Westbound Ramps
9. Ballentine Boulevard and I-264 Eastbound Ramps / Westminster Avenue

A summary comparison of the 2007 and 2014 turn movement count data is shown in Table 2; more detailed information can be found in Appendix 1.

Table 2: 2007 / 2014 Intersection Turn Movement Count Data with Before (2008) and After (2014) Photos, As Available

Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
1	St. Paul's Boulevard and City Hall Avenue	3,040	D	4,434	F	2,397	D	4,655	F	-643	221
	Comments: The 2014 volumes may be impacted by construction of the new City Hall building on the southeast corner and the implementation of tolls on the Downtown Tunnel. Before tolls, vehicles headed to the tunnel would block the City Hall Avenue ramp on westbound I-264.										

Source: URS Team

St. Paul's and City Hall, looking north (2014)

St. Paul's and City Hall, looking south (2014)

St. Paul's and City Hall, looking east (2014)

St. Paul's and City Hall, looking west (2014)

Map #	Intersection	2007 AM Peak Intersection Total	2007 AM LOS	2007 PM Peak Intersection Total	2007 PM LOS	2014 AM Peak Intersection Total	2014 AM LOS	2014 PM Peak Intersection Total	2014 PM LOS	Change, 2007 to 2014 AM Peak Intersection Total	Change, 2007 to 2014 PM Peak Intersection Total
2	**Monticello Avenue and City Hall Avenue***	1,198	B	1,495	B	516	B	1,024	B	-682	-471
	Comments: This intersection has an exclusive pedestrian phase. The pedestrian phase was mimicked by adding a northbound exclusive phase and the delay was recalculated excluding the northbound movement. For the "after" LRT condition w/pre-emption, the northbound phase was extended by the LRT pre-emption time and, consequently, represents the exclusive pedestrian phase and the pre-emption phase; then the delay was recalculated excluding the northbound movement.										

**Impacts of signal pre-emption in Appendix 1*

Source: URS Team

Monticello and City Hall, looking north (2008)

Monticello and City Hall, looking south (2008)

Monticello and City Hall, looking east (2008)

Monticello and City Hall, looking west (2008)

Monticello and City Hall, looking north (2014)

Monticello and City Hall, looking south (2014)

Monticello and City Hall, looking east (2014)

Monticello and City Hall, looking west (2014)

Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
3	**Monticello Avenue and Freemason Street**	663	A	1,018	A	387	C	611	C	-276	-407
	Comments: Monticello Avenue was narrowed from four lanes to two lanes with the installation of the LRT line. The LRT at this intersection is not pre-empted and moves with the signal operation.										

Source: URS Team

Monticello and Freemason, looking north (2008)

Monticello and Freemason, looking south (2008)

Monticello and Freemason, looking east (2008)

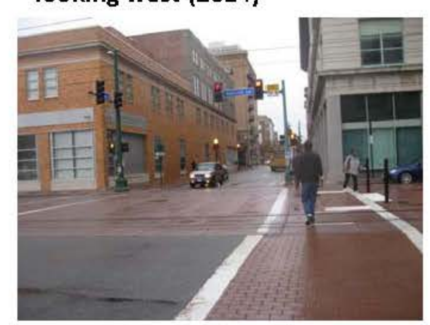
Monticello and Freemason, looking west (2008)

Monticello and Freemason, looking north (2014)

Monticello and Freemason, looking south (2014)

Monticello and Freemason, looking east (2014)

Monticello and Freemason, looking west (2014)



Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
4	**Monticello Avenue and Charlotte Street**	684	B	953	A	439	C	695	C	-245	-258
	Comments: Monticello Avenue was narrowed from four lanes to two lanes with the installation of the LRT line. The LRT at this intersection is not pre-empted and moves with the signal operation.										

Source: URS Team

Monticello and Charlotte, looking north (2008)

Monticello and Charlotte, looking south (2008)

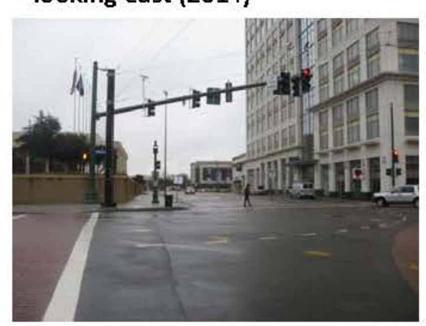
Monticello and Charlotte, looking east (2008)

Monticello and Charlotte, looking west (2008)

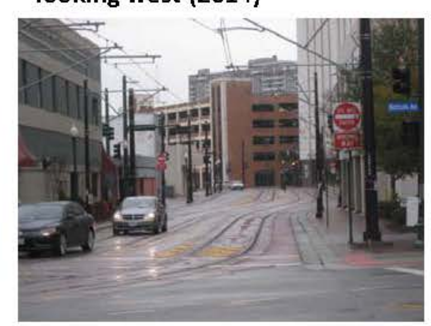
Monticello and Charlotte, looking north (2014)

Monticello and Charlotte, looking south (2014)

Monticello and Charlotte, looking east (2014)



Monticello and Charlotte, looking west (2014)



Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
5	**Boush Street and Charlotte Street / Bute Street***	2,042	B	2,458	B	2,248	B	2,272	B	206	-186
	Comments: The "after" LRT pre-emption was mimicked by adding an eastbound/westbound exclusive left phase (existing lefts were minimal and added to the through movement).										

**Impacts of signal pre-emption in Appendix 1*
Source: URS Team

Boush and Bute/Charlotte, looking north (2014)

Boush and Bute/Charlotte, looking south (2014)

Boush and Bute/Charlotte, looking east (2014)

Boush and Bute/Charlotte, looking west (2014)

Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
6	**Duke Street and Bute Street**	393	n/a	623	n/a	431	B	532	B	38	-91
	Comments: This intersection was un-signalized before the LRT was installed and was signalized as a part of the project. The LRT at this intersection is not pre-empted and moves with the signal operation.										

Source: URS Team

Duke and Bute, looking north (2014)

Duke and Bute, looking south (2014)

Duke and Bute, looking east (2014)

Duke and Bute, looking west (2014)

Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
7	**Duke Street and Brambleton Avenue**	4,536	B	4,972	F	3,882	D	4,102	D	-654	-870
	Comments: There were a few lane assignment changes for southbound Duke St; in 2007 there were duel left turn southbound lanes and now there are not.										

Source: URS Team

Brambleton and Duke, looking north (2014)

Brambleton and Duke, looking south (2014)

Brambleton and Duke, looking east (2014)

Brambleton and Duke, looking west (2014)

Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
8	**Ballentine Boulevard and Westbound Off/Westbound On Ramp***	2,667	C	2,805	C	2,090	B	2,408	B	-577	-397
	Comments: The westbound ramps, eastbound ramps, and Westminster Avenue operate on one controller with phasing set-up that can't be directly analyzed by Highway Capacity Software (HCS; the software tool used to analysis traffic operations). To provide a comparison, the movements on the north side of the interchange at the westbound ramps were analyzed as a stand-alone intersection. It is noted that traffic volumes may not be entirely representative at this intersection because of queuing from the south side of the interchange limiting movement. The "after" LRT pre-emption was mimicked by adding an exclusive eastbound phase and the delay was recalculated excluding the eastbound movement.										

**Impacts of signal pre-emption in Appendix 1*

Source: URS Team

Ballentine, looking north (2008)

Ballentine, looking south (2008)

Ballentine, looking east (2008)

Ballentine, looking west (2008)

Ballentine and I-264 WB, looking north (2014)

Ballentine and I-264 WB, looking south (2014)

Ballentine and I-264 WB, looking west (2014)

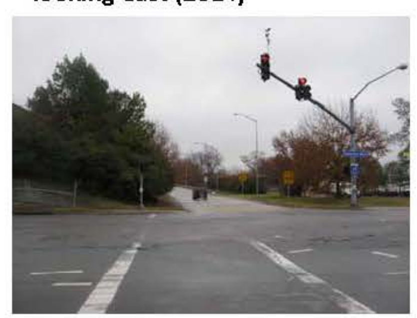
Map #	Intersection	2007				2014				Change, 2007 to 2014	
		AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	AM LOS	PM Peak Intersection Total	PM LOS	AM Peak Intersection Total	PM Peak Intersection Total
9	**Ballentine Boulevard and Eastbound Off/Eastbound On Ramp / Westminster Avenue**	1,872	F	2,195	F	1,559	F	2,113	F	-313	-82
	Comments: The westbound ramps, eastbound ramps, and Westminster Avenue operate on one controller with phasing set-up that can't be directly analyzed by HCS. To provide a comparison, the movements on the south side of the interchange at eastbound ramps and at Westminster Avenue were analyzed together as a stand-alone intersection. Due to geometric constraints, because it is a five-legged intersection, HSC can't directly analyze this intersection either. To provide some sort of before/after comparison, the intersection at the eastbound ramps was analyzed adding an exclusive movement representing Westminster Avenue. This is not exactly how the intersection operates, but since the same methodology was applied for the "before" and "after" LRT condition, the comparison is the same constraints. However, because the intersection cannot exactly be modeled, the intersection probably operates worse than was calculated here. Further, the LRT pre-emption does impact this intersection, but HCS can't analyze it because there are no available phases remaining to mimic that condition.										

Source: URS Team

Ballentine and I-264 EB, looking north (2014)

Ballentine and I-264 EB, looking south (2014)

Ballentine and I-264 EB, looking east (2014)



Ballentine and I-264 EB, looking west (2014)

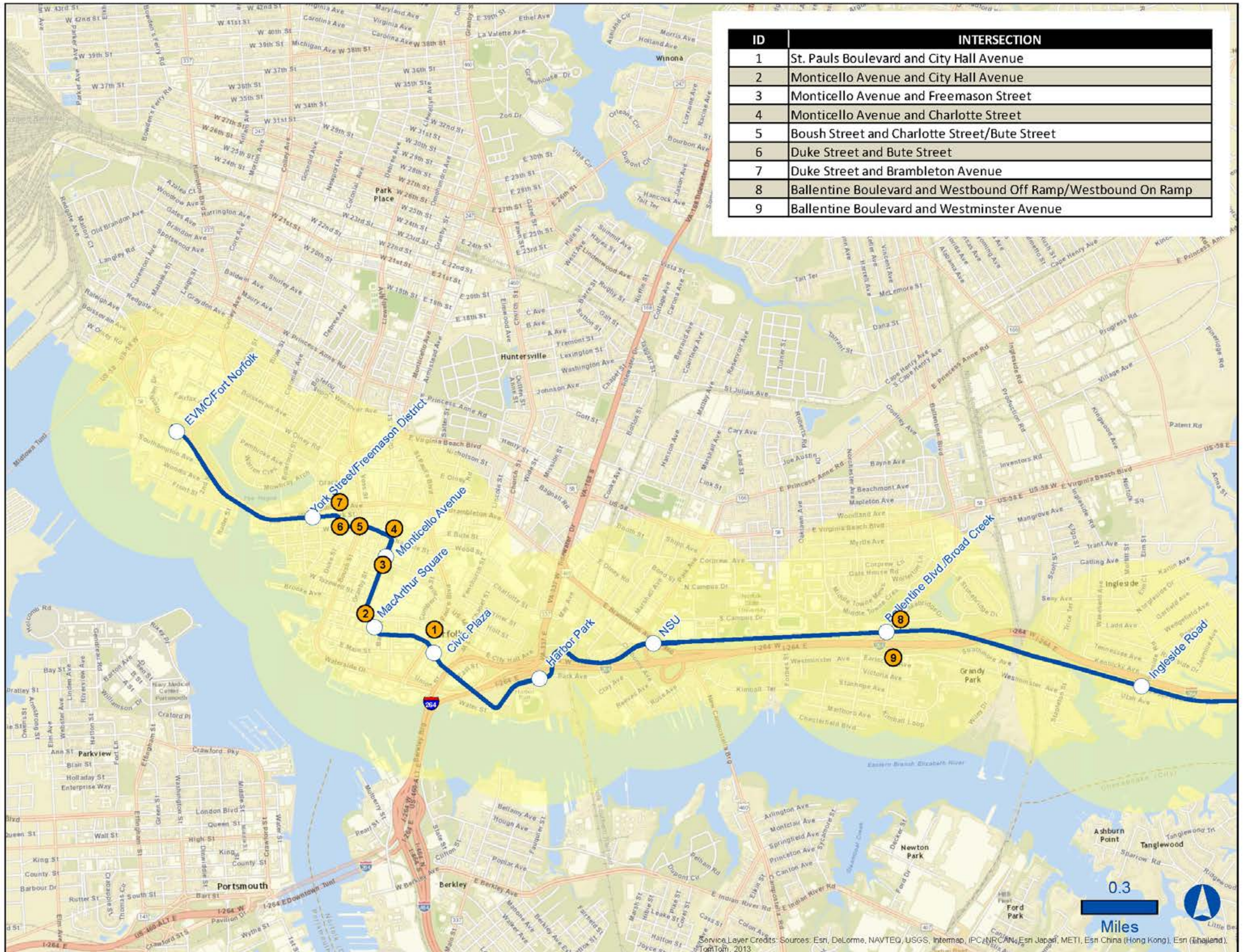
Ballentine and Westminster, looking north (2014)

Ballentine and Westminster, looking south (2014)

Ballentine and Westminster, looking east (2014)

Ballentine and Westminster, looking west (2014)

Figure 2: Locations of 2007/2014 Intersection Turn Movement Counts



ID	INTERSECTION
1	St. Pauls Boulevard and City Hall Avenue
2	Monticello Avenue and City Hall Avenue
3	Monticello Avenue and Freemason Street
4	Monticello Avenue and Charlotte Street
5	Boush Street and Charlotte Street/Bute Street
6	Duke Street and Bute Street
7	Duke Street and Brambleton Avenue
8	Ballentine Boulevard and Westbound Off Ramp/Westbound On Ramp
9	Ballentine Boulevard and Westminster Avenue

The Tide Before and After Study

Documentation of Condition Before Project Implementation

Locations of 2007/2014 Intersection Turn Movement Counts

- Count Locations
- The Tide Stations
- LRT Route
- LRT Stations Half Mile Buffer

HAMPTON ROADS TRANSIT

Conclusion

With a few exceptions, both ADT and intersection turn counts declined between 2007 and 2014; we do not have sufficient data to link these changes to LRT operations. A number of factors may have influenced the reduction in ADT and intersection turn counts, including LRT operations (which could include mode shift of drivers to transit, lane reductions and the impacts of signal pre-emption on driver behavior), new tunnel tolls, and new building construction (and related construction impacts), but we do not have evidence to definitively make that link.

Appendix 1

ST. PAULS BLVD & CITY HALL AVE

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	243	1,126	394	1,277	3,040
Delay	56.6	46.2	22.3	35.1	39.3
LOS	E	D	C	D	**D**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	1,419	328	1,255	1,432	4,434
Delay	319.6	43.0	114.9	64.5	158.8
LOS	F	D	F	E	**F**

2014 - AFTER ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	212	991	155	1,039	2,397
Delay	55.0	47.3	39.9	40.9	44.7
LOS	E	D	D	D	**D**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	1,032	550	1,885	1,188	4,655
Delay	56.6	61.1	340.2	51.2	170.6
LOS	E	E	F	D	**F**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-31	-135	-239	-238	**-643**
Delay	-1.6	1.1	17.6	5.8	**5.4**
LOS	-	-	decline	-	**-**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-387	222	630	-244	**221**
Delay	-263	18.1	225.3	-13.3	**11.8**
LOS	improve	improve	-	improve	**-**

COMMENTS:

The 2014 volumes may be impacted by construction of the new City Hall building on the ~~sou~~theast corner and the implementation of tolls on the Downtown Tunnel. Before tolls, vehicles headed to the tunnel would block the City Hall Avenue ramp on westbound I-264.

MONTICELLO AVENUE & CITY HALL AVE

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	351	654	-	193	1,198
Delay	7.7	13.4	-	21.6	13.1
LOS	A	B	-	C	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	714	454	-	327	1,495
Delay	10.7	12.1	-	20.6	13.3
LOS	B	B	-	C	**B**

2014 - AFTER ANALYSIS: without Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	202	275	-	39	516
Delay	7.7	13.1	-	15.7	11.2
LOS	A	B	-	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	533	344	-	147	1,024
Delay	8.5	13.4	-	20.5	11.9
LOS	A	B	-	C	**B**

2014 - AFTER ANALYSIS: with Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	202	275	-	39	516
Delay	7.7	13.1	-	15.7	11.2
LOS	A	B	-	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	533	344	-	147	1,024
Delay	8.7	13.7	-	19.9	12.0
LOS	A	B	-	C	**B**

LRT: 12 pre-emptions per hour

AM : 150s cycle length; 24 cycles/hour = 50% pre-empt/50% non-pre-empt

PM : 140s cycle length; 25.7 cycles/hour = 47% pre-empt/53% non-pre-empt

MONTICELLO AVENUE & CITY HALL AVE

2014 - AFTER ANALYSIS: Averaged

50% Pre-empted

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	202	275	-	39	516
Delay	7.7	13.1	-	15.7	11.2
LOS	A	B	-	B	**B**

47% Pre-empted

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	533	344	-	147	1,024
Delay	8.6	13.5	-	20.2	11.9
LOS	A	B	-	C	**B**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-149	-379	-	-154	-682
Delay	0.0	-0.3	-	-5.9	-1.9
LOS	-	-	-	improve	-

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-181	-110	-	-180	**-471**
Delay	-2.2	1.3	-	-0.1	**-1.4**
LOS	improve	-	-	-	-

COMMENTS:

This intersection has an exclusive pedestrian phase. The pedestrian phase was mimicked by adding a northbound exclusive phase and the delay was recalculated excluding the northbound movement. For the "after" LRT condition w/pre-emption, the northbound phase was extended by the LRT pre-emption time and, consequently, represents the exclusive pedestrian phase and the pre-emption phase; then the delay was recalulated excluding the northbound movement.

MONTICELLO AVENUE & FREEMASON STREET

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	48	123	254	238	663
Delay	24.2	26.4	2.5	2.4	8.5
LOS	C	C	A	A	**A**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	158	60	424	376	1,018
Delay	22.0	20.5	3.4	0.1	6.1
LOS	C	C	A	A	**A**

2014 - AFTER ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	77	96	75	139	387
Delay	18.6	19.2	23.4	26.6	22.6
LOS	B	B	C	C	**C**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	104	102	189	216	611
Delay	16.6	17.1	27.0	28.2	24.0
LOS	B	B	C	C	**C**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	29	-27	-179	-99	**-276**
Delay	-5.6	-7.2	20.9	24.2	**14.1**
LOS	improve	improve	decline	decline	decline

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-54	42	-235	-160	**-407**
Delay	-5.4	-3.4	23.6	28.1	**17.9**
LOS	improve	improve	decline	decline	decline

COMMENTS:

Monticello Avenue was narrowed from four lanes to two lanes with the installation of the LRT line. The LRT at this intersection is not pre-empted and moves with the signal operation.

MONTICELLO AVENUE & CHARLOTTE STREET

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	37	145	159	343	684
Delay	16.2	17.0	17.4	18.2	17.7
LOS	B	B	B	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	78	67	385	423	953
Delay	37.3	37.7	0.2	5.0	6.1
LOS	D	D	A	A	**A**

2014 - AFTER ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	26	125	112	176	439
Delay	18.4	19.9	29.7	15.5	20.6
LOS	B	B	C	B	**C**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	74	150	206	265	695
Delay	16.8	17.8	28.3	20.7	21.9
LOS	B	B	C	C	**C**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-11	-20	-47	-167	**-245**
Delay	2.2	2.9	12.3	-2.7	**2.9**
LOS	-	-	decline	-	decline

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-4	83	-179	-158	**-258**
Delay	-20.5	-19.9	28.1	15.7	**15.8**
LOS	improve	improve	decline	decline	decline

COMMENTS:

Monticello Avenue was narrowed from four lanes to two lanes with the installation of the LRT line. The LRT at this intersection is not pre-empted and moves with the signal operation.

BOUSH STREET & BUTE STREET/CHARLOTTE STREET

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	41	44	1,070	887	2,042
Delay	33.0	32.8	11.6	13.0	13.1
LOS	C	C	B	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	61	18	1,216	1,163	2,458
Delay	54.0	51.7	10.8	9.9	11.7
LOS	D	D	B	A	**B**

2014 - AFTER ANALYSIS: without Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	22	49	1,320	857	2,248
Delay	55.8	57.4	13.8	15.5	15.8
LOS	E	E	B	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	49	36	987	1,200	2,272
Delay	53.2	52.4	12.2	13.0	14.1
LOS	D	D	B	B	**B**

2014 - AFTER ANALYSIS: with Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	22	49	1,320	857	2,248
Delay	45.8	47.2	16.1	18.0	17.8
LOS	D	D	B	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	49	36	987	1,200	2,272
Delay	43.0	42.0	14.3	15.3	15.8
LOS	D	D	B	B	**B**

LRT: 12 pre-emptions per hour
AM : 150s cycle length; 24 cycles/hour = 50% pre-empt/50% non-pre-empt
PM : 140s cycle length; 25.7 cycles/hour = 47% pre-empt/53% non-pre-empt

BOUSH STREET & BUTE STREET/CHARLOTTE STREET

2014 - AFTER ANALYSIS: Averaged

50% Pre-empted

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	22	49	1,320	857	2,248
Delay	50.8	52.3	15.0	16.8	16.8
LOS	E	E	B	B	**B**

47% Pre-empted

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	49	36	987	1,200	2,272
Delay	48.4	47.5	13.2	14.1	14.9
LOS	D	D	B	B	**B**

CHANGE

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Volume	-19	5	250	-30	206
Delay	17.8	19.5	3.4	3.8	3.7
LOS	decline	decline	-	-	-

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Volume	-12	18	-229	37	**-186**
Delay	-0.8	0.7	1.4	3.1	**2.4**
LOS	-	-	-	decline	-

COMMENTS:

The "after" LRT pre-emption was mimicked by adding a eastbound/westbound exclusive left phase (existing lefts were minimal and added to the thru movement).

DUKE STREET & BUTE STREET

2007 - BEFORE ANALYSIS

Unsignalized

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	44	49	95	205	393
Delay	8.0	7.8	8.0	8.5	n/a
LOS	A	A	A	A	n/a

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	92	43	112	376	623
Delay	9.1	8.6	8.7	11.5	n/a
LOS	A	A	A	B	n/a

2014 - AFTER ANALYSIS

Signalized

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	78	47	132	174	431
Delay	15.0	14.5	11.3	19.7	15.7
LOS	B	B	B	B	**B**

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	132	39	121	240	532
Delay	17.2	15.5	9.1	18.3	15.7
LOS	B	B	A	B	**B**

CHANGE

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	34	-2	37	-31	**38**
Delay	7	6.7	3.3	11.2	**n/a**
LOS	decline	decline	decline	-	n/a

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	40	-4	9	-136	**-91**
Delay	8.1	6.9	0.4	6.8	**n/a**
LOS	decline	decline	-	decline	n/a

COMMENTS:

This intersection was unsignalized before the LRT was installed and was signalized as a part of the project. The LRT at this intersection is not pre-empted and moves with the signal operation.

BRAMBLETON AVENUE & DUKE STREET

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	1,338	2,267	139	792	4,536
Delay	14.2	3.2	50.3	50.7	16.2
LOS	B	A	D	D	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	1,784	1,122	282	1,784	4,972
Delay	19.8	2.2	53.3	1646.5	601.4
LOS	B	A	D	F	**F**

2014 - AFTER ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	977	2,240	266	399	3,882
Delay	20.4	5.1	77.9	249.1	39.0
LOS	C	A	E	F	**D**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	2,090	1,300	170	542	4,102
Delay	42.2	10.2	61.9	132.2	44.8
LOS	D	B	E	F	**D**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-361	-27	127	-393	**-654**
Delay	6.2	1.9	27.6	198.4	**22.8**
LOS	decline	-	decline	decline	decline

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	306	178	-112	-1242	**-870**
Delay	22.4	8	8.6	-1514.3	**-556.6**
LOS	decline	decline	decline	-	improve

COMMENTS:

BALLENTINE BLVD & I-264 WB RAMPS

2007 - BEFORE ANALYSIS

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	563	1,049	1,055	2,667
Delay	-	91.6	8.0	10.5	26.6
LOS	-	F	A	B	**C**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	563	788	1,454	2,805
Delay	-	110.4	6.2	11.6	29.9
LOS	-	F	A	B	**C**

2014 - AFTER ANALYSIS: without Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	429	820	841	2,090
Delay	-	33.8	6.8	12.2	14.5
LOS	-	C	A	B	**B**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	305	826	1,277	2,408
Delay	-	31.1	4.4	10.5	11.0
LOS	-	C	A	B	**B**

2014 - AFTER ANALYSIS: with Pre-emption

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	429	820	841	2,090
Delay	-	63.1	11.3	19.7	25.3
LOS	-	E	B	B	**C**

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	305	826	1,277	2,408
Delay	-	37.2	8.8	29.6	23.4
LOS	-	D	A	C	**C**

LRT: 15 pre-emptions per hour
AM & PM : 100s cycle length; 36 cycles/hour = 42% pre-empt/58% non-pre-empt

BALLENTINE BLVD & I-264 WB RAMPS

2014 - AFTER ANALYSIS: Averaged

42% Pre-empted

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	429	820	841	2,090
Delay	-	46.1	8.7	15.4	19.0
LOS	-	E	A	B	**B**

42% Pre-empted

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	305	826	1,277	2,408
Delay	-	33.7	6.2	18.5	16.2
LOS	-	D	A	B	**B**

CHANGE

AM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	-134	-229	-214	-577
Delay	-	-45.5	0.7	4.9	-7.6
LOS	-	improve	-	-	-

PM Peak	EB	WB	NB	SB	INT. TOTAL
Factored Volume	-	-258	38	-177	**-397**
Delay	-	-79.3	-1.8	-1.1	**-18.9**
LOS	-	improve	-	-	-

COMMENTS:

The westbound ramps, eastbound ramps, and Westminster Avenue operate on one controller with phasing set-up that can't be directly analyzed by HCS. To provide a comparison, the movements on the north side of the interchange at the westbound ramps were analyzed as a stand alone intersection. It is noted that traffic volumes may not be entirely representative at this intersection because of queuing from the south side of the interchange limiting movement. The "after" LRT pre-emption was mimicked by adding an exclusive eastbound phase and the delay was recalulated excluding the eastbound movement.

BALLENTINE BLVD & I-264 EB RAMPS/WESTMINSTER AVE

2007 - BEFORE ANALYSIS

Unsignalized

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	730	159	405	578	1,872
Delay	727.8	50.3	20.7	29.3	301.6
LOS	F	D	C	C	**F**

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	412	179	433	1,171	2,195
Delay	246.4	54.4	20.9	213.8	168.9
LOS	F	D	C	F	**F**

2014 - AFTER ANALYSIS

Signalized

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	516	125	404	514	1,559
Delay	408.2	44.9	20.6	30.9	154.2
LOS	F	D	C	C	**F**

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	489	251	639	734	2,113
Delay	370.5	96.1	23.2	63.2	126.1
LOS	F	F	C	E	**F**

CHANGE

AM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	-214	-34	-1	-64	**-313**
Delay	-319.6	-5.4	-0.1	1.6	**-147.4**
LOS	-	-	-	-	-

PM Peak	**EB**	**WB**	**NB**	**SB**	**INT. TOTAL**
Factored Volume	77	72	206	-437	**-82**
Delay	124.1	41.7	2.3	-150.6	**-42.8**
LOS	-	decline	-	improve	-

COMMENTS:

The westbound ramps, eastbound ramps, and Westminster Avenue operate on one controller with phasing set-up that can't be directly analyzed by HCS. To provide a comparison, the movements on the south side of the interchange at westbound ramps and at Westminster Avenue were were analyzed together as a stand alone intersection. Due to geometric contraints, because it is a five-legged intersection, HSC can't directly analyze this intersection either. To provide some sort of before/after comparison, the intersection at the eastbound ramps was analyzed adding an exclusive movement representing Westminster Avenue. This is not exactly how the intersection operates but since the same methodology was applied for the "before" and "after" LRT condition, the comparsison is the same constraints. However, because the intersection can not exactly be modeled, the intersection probably operates worse than was calculated here. Further, the LRT pre-emption does impact this intersection but HCS can't analyze it because there are no availble phases remaining to mimic that condition.

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	40	171	13	302	734	507	62	234	67	335	625	215
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	186.3	186.3	186.3	186.3	186.3	186.3	186.3	186.3	186.3	186.3	186.3	190.0
Adj Flow Rate, veh/h	43	186	14	328	798	0	67	254	73	364	679	234
Adj No. of Lanes	1	3	1	1	3	1	1	2	1	2	3	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	84	363	113	397	1259	392	233	1567	701	451	1662	564
Arrive On Green	0.05	0.07	0.07	0.22	0.25	0.00	0.13	0.44	0.44	0.13	0.44	0.43
Sat Flow, veh/h	1774	5085	1583	1774	5085	1583	1774	3539	1583	3442	3754	1274
Grp Volume(v), veh/h	43	186	14	328	798	0	67	254	73	364	612	301
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1583	1774	1770	1583	1721	1695	1638
Q Serve(g_s), s	2.9	4.3	1.0	21.5	17.1	0.0	4.2	5.3	1.4	12.5	15.0	15.5
Cycle Q Clear(g_c), s	2.9	4.3	1.0	21.5	17.1	0.0	4.2	5.3	1.4	12.5	15.0	15.5
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.78
Lane Grp Cap(c), veh/h	84	363	113	397	1259	392	233	1567	701	451	1501	725
V/C Ratio(X)	0.51	0.51	0.12	0.83	0.63	0.00	0.29	0.16	0.10	0.81	0.41	0.41
Avail Cap(c_a), veh/h	204	584	182	436	1259	392	233	1567	701	451	1501	725
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	56.7	54.6	53.1	45.1	41.0	0.0	47.9	20.4	3.5	51.5	23.1	23.8
Incr Delay (d2), s/veh	4.7	1.1	0.5	11.5	1.0	0.0	0.7	0.2	0.3	10.3	0.8	1.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.5	2.1	0.5	11.7	8.1	0.0	2.1	2.6	1.4	6.6	7.1	7.4
LnGrp Delay(d),s/veh	61.5	55.7	53.6	56.6	42.0	0.0	48.5	20.6	3.8	61.8	23.9	25.6
LnGrp LOS	E	E	D	E	D		D	C	A	E	C	C
Approach Vol, veh/h		243			1126			394			1277	
Approach Delay, s/veh		56.6			46.2			22.3			35.1	
Approach LOS		E			D			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	28.0	58.0	9.8	34.2	20.0	66.0	31.3	12.7
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	14.0	52.0	12.0	28.0	14.0	52.0	28.0	12.0
Max Q Clear Time (g_c+I1), s	6.2	17.5	4.9	19.1	14.5	7.3	23.5	6.3
Green Ext Time (p_c), s	1.1	4.8	0.0	3.8	0.0	1.8	1.8	0.4

Intersection Summary	
HCM 2010 Ctrl Delay	39.3
HCM 2010 LOS	D

Notes

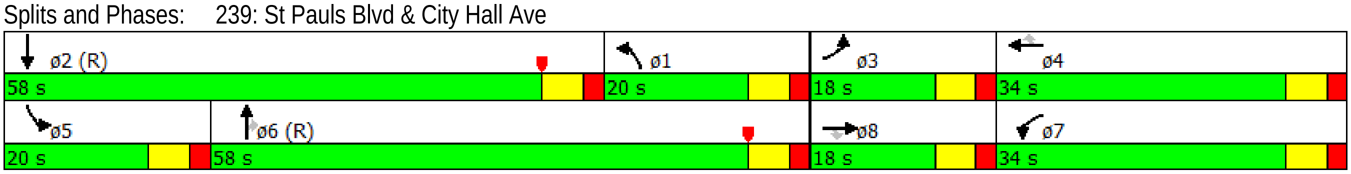
User approved pedestrian interval to be less than phase max green.

Timing Report, Sorted By Phase
239: St Pauls Blvd & City Hall Ave

Phase Number	1	2	3	4	5	6	7	8
Movement	NBL	SBT	EBL	WBT	SBL	NBT	WBL	EBT
Lead/Lag	Lag	Lead	Lead	Lag	Lead	Lag	Lag	Lead
Lead-Lag Optimize								
Recall Mode	None	C-Max	None	None	None	C-Max	None	None
Maximum Split (s)	20	58	18	34	20	58	34	18
Maximum Split (%)	15.4%	44.6%	13.8%	26.2%	15.4%	44.6%	26.2%	13.8%
Minimum Split (s)	22	33	10	24	22	33	10	24
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	4	4	4	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		5		7		5
Flash Dont Walk (s)		20		13		20		13
Dual Entry	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	64	6	84	102	6	26	102	84
End Time (s)	84	64	102	6	26	84	6	102
Yield/Force Off (s)	78	58	96	0	20	78	0	96
Yield/Force Off 170(s)	78	38	96	117	20	58	0	83
Local Start Time (s)	6	78	26	44	78	98	44	26
Local Yield (s)	20	0	38	72	92	20	72	38
Local Yield 170(s)	20	110	38	59	92	0	72	25

Intersection Summary	
Cycle Length	130
Control Type	Actuated-Coordinated
Natural Cycle	100
Offset: 58 (45%), Referenced to phase 2:SBT and 6:NBT, Start of Yellow	

Splits and Phases: 239: St Pauls Blvd & City Hall Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	103	1193	9	128	174	266	96	318	741	638	556	124
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1900
Adj Flow Rate, veh/h	112	1297	10	139	189	0	104	346	805	693	604	135
Adj No. of Lanes	1	3	1	1	3	1	1	2	1	2	3	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	171	786	245	216	917	285	526	1370	613	657	1176	258
Arrive On Green	0.10	0.15	0.15	0.12	0.18	0.00	0.30	0.39	0.39	0.19	0.28	0.26
Sat Flow, veh/h	1774	5085	1583	1774	5085	1583	1774	3539	1583	3442	4174	917
Grp Volume(v), veh/h	112	1297	10	139	189	0	104	346	805	693	489	250
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1583	1774	1770	1583	1721	1695	1701
Q Serve(g_s), s	6.7	17.0	0.6	8.2	3.5	0.0	4.8	7.3	26.5	21.0	13.3	13.7
Cycle Q Clear(g_c), s	6.7	17.0	0.6	8.2	3.5	0.0	4.8	7.3	26.5	21.0	13.3	13.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.54
Lane Grp Cap(c), veh/h	171	786	245	216	917	285	526	1370	613	657	955	479
V/C Ratio(X)	0.66	1.65	0.04	0.64	0.21	0.00	0.20	0.25	1.31	1.05	0.51	0.52
Avail Cap(c_a), veh/h	274	786	245	500	1433	446	526	1370	613	657	955	479
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	48.0	46.5	39.6	46.0	38.4	0.0	28.9	22.9	13.1	44.5	33.1	33.8
Incr Delay (d2), s/veh	4.2	298.3	0.1	3.2	0.1	0.0	0.2	0.4	152.3	50.4	2.0	4.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	3.5	29.6	0.3	4.2	1.6	0.0	2.4	3.6	37.3	14.5	6.5	7.0
LnGrp Delay(d),s/veh	52.2	344.8	39.6	49.2	38.5	0.0	29.1	23.3	165.4	94.9	35.1	37.8
LnGrp LOS	D	F	D	D	D		C	C	F	F	D	D
Approach Vol, veh/h		1419			328			1255			1432	
Approach Delay, s/veh		319.6			43.0			114.9			64.5	
Approach LOS		F			D			F			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	36.6	35.0	14.6	23.8	25.0	46.6	17.4	21.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	13.0	29.0	15.0	29.0	19.0	23.0	29.0	15.0
Max Q Clear Time (g_c+I1), s	6.8	15.7	8.7	5.5	23.0	28.5	10.2	19.0
Green Ext Time (p_c), s	3.4	2.9	0.2	1.4	0.0	0.0	1.4	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	158.8
HCM 2010 LOS	F

Notes

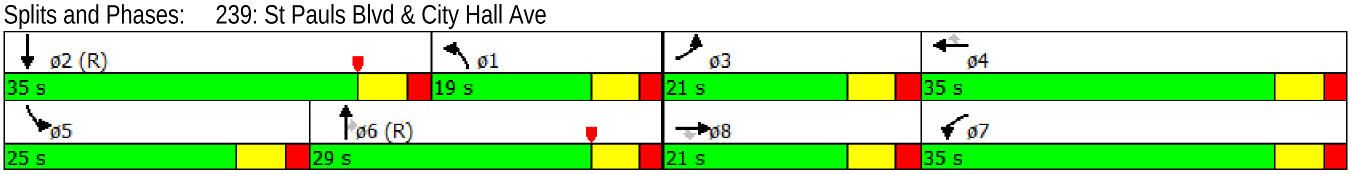
User approved pedestrian interval to be less than phase max green.

Timing Report, Sorted By Phase
239: St Pauls Blvd & City Hall Ave

Phase Number	1	2	3	4	5	6	7	8
Movement	NBL	SBT	EBL	WBT	SBL	NBT	WBL	EBT
Lead/Lag	Lag	Lead	Lead	Lag	Lead	Lag	Lag	Lead
Lead-Lag Optimize								
Recall Mode	None	C-Max	None	None	None	C-Max	None	None
Maximum Split (s)	19	35	21	35	25	29	35	21
Maximum Split (%)	17.3%	31.8%	19.1%	31.8%	22.7%	26.4%	31.8%	19.1%
Minimum Split (s)	22	33	10	24	22	33	10	24
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	4	4	4	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		5		7		5
Flash Dont Walk (s)		20		13		20		13
Dual Entry	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	102	67	11	32	67	92	32	11
End Time (s)	11	102	32	67	92	11	67	32
Yield/Force Off (s)	5	96	26	61	86	5	61	26
Yield/Force Off 170(s)	5	76	26	48	86	95	61	13
Local Start Time (s)	6	81	25	46	81	106	46	25
Local Yield (s)	19	0	40	75	100	19	75	40
Local Yield 170(s)	19	90	40	62	100	109	75	27

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	100
Offset: 96 (87%), Referenced to phase 2:SBT and 6:NBT, Start of Yellow	

Splits and Phases: 239: St Pauls Blvd & City Hall Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	49	274	0	0	367	235	0	100	0	124	0	53
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1881	1881	1881
Adj Flow Rate, veh/h	53	298	0	0	399	255	0	109	0	135	0	58
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	322	1703	0	0	581	695	153	161	137	225	236	201
Arrive On Green	0.04	0.48	0.00	0.00	0.31	0.31	0.00	0.08	0.00	0.13	0.00	0.13
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1792	1881	1599
Grp Volume(v), veh/h	53	298	0	0	399	255	0	109	0	135	0	58
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1792	1881	1599
Q Serve(g_s), s	0.9	2.3	0.0	0.0	8.9	5.1	0.0	2.7	0.0	3.4	0.0	1.6
Cycle Q Clear(g_c), s	0.9	2.3	0.0	0.0	8.9	5.1	0.0	2.7	0.0	3.4	0.0	1.6
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	322	1703	0	0	581	695	153	161	137	225	236	201
V/C Ratio(X)	0.16	0.17	0.00	0.00	0.69	0.37	0.00	0.68	0.00	0.60	0.00	0.29
Avail Cap(c_a), veh/h	434	2763	0	0	1022	1070	1437	1509	1282	749	786	668
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	10.4	7.2	0.0	0.0	14.5	9.1	0.0	21.3	0.0	19.8	0.0	19.0
Incr Delay (d2), s/veh	0.2	0.0	0.0	0.0	1.5	0.3	0.0	4.9	0.0	2.6	0.0	0.8
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.4	1.1	0.0	0.0	4.8	2.8	0.0	1.6	0.0	1.8	0.0	0.7
LnGrp Delay(d),s/veh	10.7	7.2	0.0	0.0	16.0	9.4	0.0	26.2	0.0	22.3	0.0	19.8
LnGrp LOS	B	A			B	A		C		C		B
Approach Vol, veh/h		351			654			109			193	
Approach Delay, s/veh		7.7			13.4			26.2			21.6	
Approach LOS		A			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		28.8		12.0	8.0	20.8		7.0
Change Period (Y+Rc), s		6.0		6.0	6.0	6.0		3.0
Max Green Setting (Gmax), s		37.0		20.0	5.0	26.0		38.0
Max Q Clear Time (g_c+I1), s		4.3		5.4	2.9	10.9		3.7
Green Ext Time (p_c), s		4.6		0.6	0.0	3.9		0.4

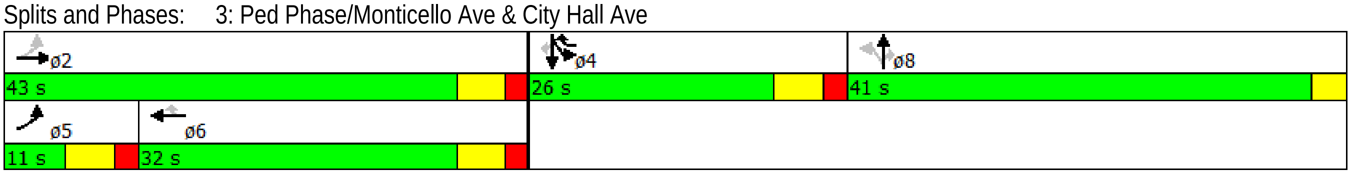
Intersection Summary		
HCM 2010 Ctrl Delay		14.2
HCM 2010 LOS		B

Timing Report, Sorted By Phase
3: Ped Phase/Monticello Ave & City Hall Ave

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	43	26	11	32	41
Maximum Split (%)	39.1%	23.6%	10.0%	29.1%	37.3%
Minimum Split (s)	22	22	10	22	20.5
Yellow Time (s)	4	4	4	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	43	0	11	69
End Time (s)	43	69	11	43	0
Yield/Force Off (s)	37	63	5	37	107
Yield/Force Off 170(s)	26	63	5	37	107
Local Start Time (s)	0	43	0	11	69
Local Yield (s)	37	63	5	37	107
Local Yield 170(s)	26	63	5	37	107

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped Phase/Monticello Ave & City Hall Ave



HCM 2010 Signalized Intersection Summary
3: Ped Phase/Monticello Ave & City Hall Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	107	550	0	0	162	256	0	100	0	243	0	58
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1881	1881	1881
Adj Flow Rate, veh/h	116	598	0	0	176	278	0	109	0	264	0	63
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	424	1479	0	0	462	716	151	159	135	362	380	323
Arrive On Green	0.07	0.41	0.00	0.00	0.25	0.25	0.00	0.08	0.00	0.20	0.00	0.20
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1792	1881	1599
Grp Volume(v), veh/h	116	598	0	0	176	278	0	109	0	264	0	63
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1792	1881	1599
Q Serve(g_s), s	2.2	5.9	0.0	0.0	3.9	5.8	0.0	2.8	0.0	6.9	0.0	1.6
Cycle Q Clear(g_c), s	2.2	5.9	0.0	0.0	3.9	5.8	0.0	2.8	0.0	6.9	0.0	1.6
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	424	1479	0	0	462	716	151	159	135	362	380	323
V/C Ratio(X)	0.27	0.40	0.00	0.00	0.38	0.39	0.00	0.69	0.00	0.73	0.00	0.20
Avail Cap(c_a), veh/h	446	2294	0	0	868	1060	1379	1448	1231	898	943	802
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	11.5	10.3	0.0	0.0	15.6	9.2	0.0	22.2	0.0	18.6	0.0	16.5
Incr Delay (d2), s/veh	0.3	0.2	0.0	0.0	0.5	0.3	0.0	5.2	0.0	2.8	0.0	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.1	2.9	0.0	0.0	2.1	3.5	0.0	1.7	0.0	3.7	0.0	0.7
LnGrp Delay(d),s/veh	11.9	10.5	0.0	0.0	16.2	9.6	0.0	27.4	0.0	21.5	0.0	16.8
LnGrp LOS	B	B			B	A		C		C		B
Approach Vol, veh/h		714			454			109			327	
Approach Delay, s/veh		10.7			12.1			27.4			20.6	
Approach LOS		B			B			C			C	

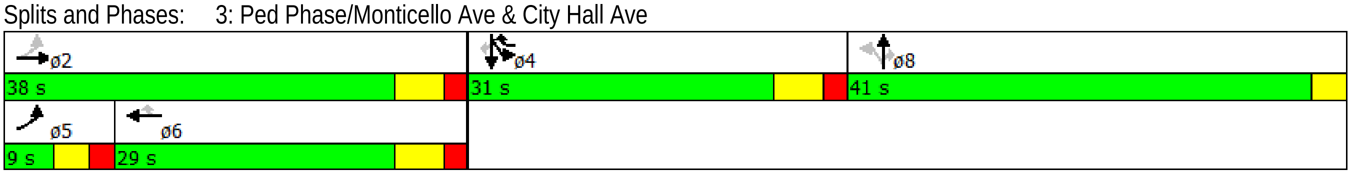
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		26.6		16.1	8.4	18.3		7.2
Change Period (Y+Rc), s		6.0		6.0	5.0	6.0		3.0
Max Green Setting (Gmax), s		32.0		25.0	4.0	23.0		38.0
Max Q Clear Time (g_c+I1), s		7.9		8.9	4.2	7.8		3.8
Green Ext Time (p_c), s		5.2		1.2	0.0	4.5		0.4

Intersection Summary		
HCM 2010 Ctrl Delay		14.2
HCM 2010 LOS		B

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	38	31	9	29	41
Maximum Split (%)	34.5%	28.2%	8.2%	26.4%	37.3%
Minimum Split (s)	22	22	8	22	20.5
Yellow Time (s)	4	4	3	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	2	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	38	0	9	69
End Time (s)	38	69	9	38	0
Yield/Force Off (s)	32	63	4	32	107
Yield/Force Off 170(s)	21	63	4	32	107
Local Start Time (s)	0	38	0	9	69
Local Yield (s)	32	63	4	32	107
Local Yield 170(s)	21	63	4	32	107

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped Phase/Monticello Ave & City Hall Ave



HCM 2010 Signalized Intersection Summary
166: Monticello Ave & Freemason St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	16	15	14	4	47	63	29	191	13	19	151	49
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1863	1863	1863
Adj Flow Rate, veh/h	17	16	15	4	51	68	32	208	14	21	164	53
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	135	100	71	64	99	128	324	2044	139	938	2597	1162
Arrive On Green	0.14	0.14	0.10	0.14	0.14	0.10	0.73	0.73	0.70	0.73	0.73	0.73
Sat Flow, veh/h	413	727	518	32	722	933	343	2785	189	1154	3539	1583
Grp Volume(v), veh/h	48	0	0	123	0	0	131	0	123	21	164	53
Grp Sat Flow(s),veh/h/ln	1659	0	0	1687	0	0	1655	0	1662	1154	1770	1583
Q Serve(g_s), s	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.3	0.3	0.8	0.6
Cycle Q Clear(g_c), s	1.5	0.0	0.0	4.2	0.0	0.0	1.2	0.0	1.3	1.7	0.8	0.6
Prop In Lane	0.35		0.31	0.03		0.55	0.24		0.11	1.00		1.00
Lane Grp Cap(c), veh/h	306	0	0	291	0	0	1287	0	1219	938	2597	1162
V/C Ratio(X)	0.16	0.00	0.00	0.42	0.00	0.00	0.10	0.00	0.10	0.02	0.06	0.05
Avail Cap(c_a), veh/h	810	0	0	846	0	0	1287	0	1219	938	2597	1162
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	1.00	0.99	0.99	0.99
Uniform Delay (d), s/veh	24.0	0.0	0.0	25.4	0.0	0.0	2.4	0.0	2.4	2.6	2.3	2.3
Incr Delay (d2), s/veh	0.2	0.0	0.0	1.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.7	0.0	0.0	2.0	0.0	0.0	0.7	0.0	0.6	0.1	0.4	0.3
LnGrp Delay(d),s/veh	24.2	0.0	0.0	26.4	0.0	0.0	2.5	0.0	2.6	2.7	2.3	2.3
LnGrp LOS	C			C			A		A	A	A	A
Approach Vol, veh/h		48			123			254			238	
Approach Delay, s/veh		24.2			26.4			2.5			2.4	
Approach LOS		C			C			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		49.5		12.5		49.5		12.5
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		23.0		27.0		23.0		27.0
Max Q Clear Time (g_c+I1), s		3.3		3.5		3.7		6.2
Green Ext Time (p_c), s		2.1		0.7		2.1		0.6

Intersection Summary	
HCM 2010 Ctrl Delay	8.5
HCM 2010 LOS	A

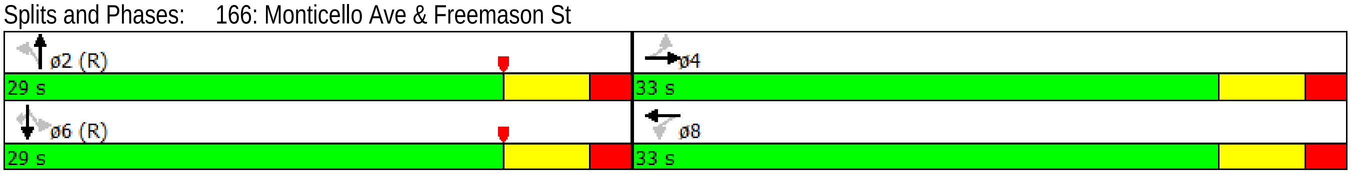
Notes

User approved pedestrian interval to be less than phase max green.

Phase Number	2	4	6	8
Movement	NBTL	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	C-Max	None	C-Max	None
Maximum Split (s)	29	33	29	33
Maximum Split (%)	46.8%	53.2%	46.8%	53.2%
Minimum Split (s)	22	33	22	33
Yellow Time (s)	4	4	4	4
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		6		6
Flash Dont Walk (s)		20		20
Dual Entry	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	29	0	29
End Time (s)	29	0	29	0
Yield/Force Off (s)	23	56	23	56
Yield/Force Off 170(s)	23	36	23	36
Local Start Time (s)	39	6	39	6
Local Yield (s)	0	33	0	33
Local Yield 170(s)	0	13	0	13

Intersection Summary	
Cycle Length	62
Control Type	Actuated-Coordinated
Natural Cycle	55
Offset: 23 (37%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 166: Monticello Ave & Freemason St



HCM 2010 Signalized Intersection Summary
166: Monticello Ave & Freemason St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	47	64	34	13	12	30	24	342	24	50	249	47
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1863	1863	1863
Adj Flow Rate, veh/h	51	70	37	14	13	33	26	372	26	54	271	51
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	160	137	64	122	83	152	162	2116	145	762	2431	1088
Arrive On Green	0.17	0.17	0.13	0.17	0.17	0.13	0.69	0.69	0.65	1.00	1.00	1.00
Sat Flow, veh/h	437	817	384	247	496	908	129	3080	212	983	3539	1583
Grp Volume(v), veh/h	158	0	0	60	0	0	220	0	204	54	271	51
Grp Sat Flow(s),veh/h/ln	1638	0	0	1651	0	0	1763	0	1658	983	1770	1583
Q Serve(g_s), s	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.2	0.0	0.0
Cycle Q Clear(g_c), s	4.8	0.0	0.0	1.7	0.0	0.0	2.3	0.0	2.4	2.7	0.0	0.0
Prop In Lane	0.32		0.23	0.23		0.55	0.12		0.13	1.00		1.00
Lane Grp Cap(c), veh/h	361	0	0	358	0	0	1284	0	1139	762	2431	1088
V/C Ratio(X)	0.44	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.18	0.07	0.11	0.05
Avail Cap(c_a), veh/h	734	0	0	717	0	0	1284	0	1139	762	2431	1088
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.2	0.0	0.0	20.2	0.0	0.0	3.1	0.0	3.1	0.1	0.0	0.0
Incr Delay (d2), s/veh	0.8	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.3	0.2	0.1	0.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	2.3	0.0	0.0	0.8	0.0	0.0	1.3	0.0	1.2	0.1	0.0	0.0
LnGrp Delay(d),s/veh	22.0	0.0	0.0	20.5	0.0	0.0	3.3	0.0	3.5	0.3	0.1	0.1
LnGrp LOS	C			C			A		A	A	A	A
Approach Vol, veh/h		158			60			424			376	
Approach Delay, s/veh		22.0			20.5			3.4			0.1	
Approach LOS		C			C			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		41.8		13.2		41.8		13.2
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		23.0		20.0		23.0		20.0
Max Q Clear Time (g_c+I1), s		4.4		6.8		4.7		3.7
Green Ext Time (p_c), s		3.5		0.7		3.5		0.8

Intersection Summary	
HCM 2010 Ctrl Delay	6.1
HCM 2010 LOS	A

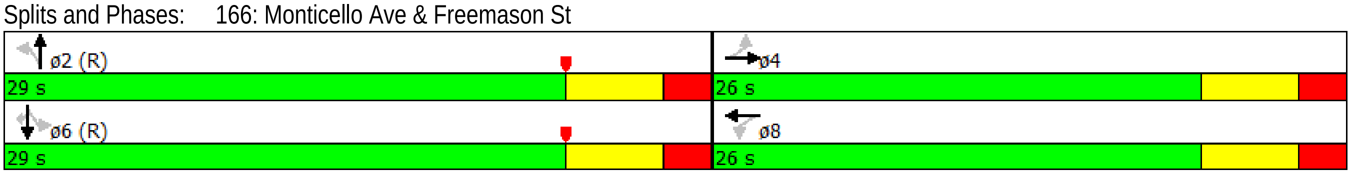
Notes

User approved pedestrian interval to be less than phase max green.

Phase Number	2	4	6	8
Movement	NBTL	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	C-Max	None	C-Max	None
Maximum Split (s)	29	26	29	26
Maximum Split (%)	52.7%	47.3%	52.7%	47.3%
Minimum Split (s)	22	33	22	33
Yellow Time (s)	4	4	4	4
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		6		6
Flash Dont Walk (s)		21		21
Dual Entry	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	27	1	27	1
End Time (s)	1	27	1	27
Yield/Force Off (s)	50	21	50	21
Yield/Force Off 170(s)	50	0	50	0
Local Start Time (s)	32	6	32	6
Local Yield (s)	0	26	0	26
Local Yield 170(s)	0	5	0	5

Intersection Summary	
Cycle Length	55
Control Type	Actuated-Coordinated
Natural Cycle	55
Offset: 50 (91%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 166: Monticello Ave & Freemason St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	5	9	20	61	0	73	0	128	18	36	280	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	0	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	5	10	22	66	0	79	0	139	20	39	304	0
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	2
Cap, veh/h	649	245	540	699	0	748	0	1415	200	589	1609	0
Arrive On Green	0.47	0.47	0.45	0.47	0.00	0.45	0.00	0.45	0.44	0.45	0.45	0.00
Sat Flow, veh/h	1314	519	1142	1372	0	1583	0	3207	441	1222	3632	0
Grp Volume(v), veh/h	5	0	32	66	0	79	0	78	81	39	304	0
Grp Sat Flow(s),veh/h/ln	1314	0	1661	1372	0	1583	0	1770	1785	1222	1770	0
Q Serve(g_s), s	0.2	0.0	1.2	3.0	0.0	3.1	0.0	2.8	2.9	2.1	5.6	0.0
Cycle Q Clear(g_c), s	3.4	0.0	1.2	4.2	0.0	3.1	0.0	2.8	2.9	4.9	5.6	0.0
Prop In Lane	1.00		0.69	1.00		1.00	0.00		0.25	1.00		0.00
Lane Grp Cap(c), veh/h	649	0	785	699	0	748	0	804	811	589	1609	0
V/C Ratio(X)	0.01	0.00	0.04	0.09	0.00	0.11	0.00	0.10	0.10	0.07	0.19	0.00
Avail Cap(c_a), veh/h	649	0	785	699	0	748	0	804	811	589	1609	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	17.1	0.0	16.0	16.7	0.0	16.7	0.0	17.1	17.3	18.6	17.9	0.0
Incr Delay (d2), s/veh	0.0	0.0	0.1	0.3	0.0	0.3	0.0	0.2	0.2	0.2	0.3	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.1	0.0	0.6	1.2	0.0	1.4	0.0	1.4	1.5	0.7	2.8	0.0
LnGrp Delay(d),s/veh	17.1	0.0	16.1	17.0	0.0	17.0	0.0	17.4	17.5	18.8	18.2	0.0
LnGrp LOS	B		B	B		B		B	B	B	B	
Approach Vol, veh/h		37			145			159			343	
Approach Delay, s/veh		16.2			17.0			17.4			18.2	
Approach LOS		B			B			B			B	

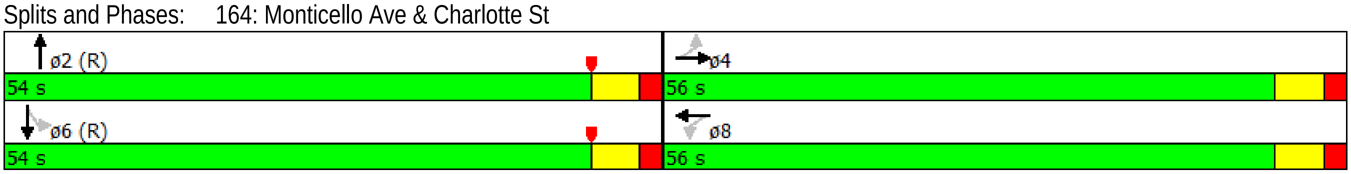
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		54.0		56.0		54.0		56.0
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		48.0		50.0		48.0		50.0
Max Q Clear Time (g_c+I1), s		4.9		5.4		7.6		6.2
Green Ext Time (p_c), s		2.4		0.8		2.4		0.8

Intersection Summary			
HCM 2010 Ctrl Delay			17.7
HCM 2010 LOS			B

Phase Number	2	4	6	8
Movement	NBT	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	C-Max	Max	C-Max	Max
Maximum Split (s)	54	56	54	56
Maximum Split (%)	49.1%	50.9%	49.1%	50.9%
Minimum Split (s)	27	27	27	27
Yellow Time (s)	4	4	4	4
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	10	10	10	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	6	3	6	3
Time Before Reduce (s)	3	3	3	3
Time To Reduce (s)	0	0	0	0
Walk Time (s)	5	5	5	5
Flash Dont Walk (s)	16	16	16	16
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	54	0	54
End Time (s)	54	0	54	0
Yield/Force Off (s)	48	104	48	104
Yield/Force Off 170(s)	32	88	32	88
Local Start Time (s)	62	6	62	6
Local Yield (s)	0	56	0	56
Local Yield 170(s)	94	40	94	40

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	55
Offset: 48 (44%), Referenced to phase 2:NBT and 6:SBTL, Start of Yellow	

Splits and Phases: 164: Monticello Ave & Charlotte St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	13	22	37	29	0	32	0	319	35	86	304	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	0	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	14	24	40	32	0	35	0	347	38	93	330	0
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	2
Cap, veh/h	326	132	219	302	0	331	0	2313	252	780	2542	0
Arrive On Green	0.21	0.21	0.19	0.21	0.00	0.19	0.00	1.00	1.00	0.72	0.72	0.00
Sat Flow, veh/h	1368	629	1049	1332	0	1583	0	3313	350	994	3632	0
Grp Volume(v), veh/h	14	0	64	32	0	35	0	190	195	93	330	0
Grp Sat Flow(s),veh/h/ln	1368	0	1678	1332	0	1583	0	1770	1801	994	1770	0
Q Serve(g_s), s	0.9	0.0	3.5	2.2	0.0	2.0	0.0	0.0	0.0	3.2	3.2	0.0
Cycle Q Clear(g_c), s	2.9	0.0	3.5	5.7	0.0	2.0	0.0	0.0	0.0	3.2	3.2	0.0
Prop In Lane	1.00		0.63	1.00		1.00	0.00		0.19	1.00		0.00
Lane Grp Cap(c), veh/h	326	0	351	302	0	331	0	1271	1293	780	2542	0
V/C Ratio(X)	0.04	0.00	0.18	0.11	0.00	0.11	0.00	0.15	0.15	0.12	0.13	0.00
Avail Cap(c_a), veh/h	326	0	351	302	0	331	0	1271	1293	780	2542	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	0.00	0.99	0.99	1.00	1.00	0.00
Uniform Delay (d), s/veh	36.4	0.0	36.3	38.1	0.0	36.0	0.0	0.0	0.0	4.8	4.8	0.0
Incr Delay (d2), s/veh	0.2	0.0	1.1	0.7	0.0	0.6	0.0	0.2	0.2	0.3	0.1	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.4	0.0	1.7	0.9	0.0	0.9	0.0	0.1	0.1	0.9	1.6	0.0
LnGrp Delay(d),s/veh	36.6	0.0	37.4	38.8	0.0	36.6	0.0	0.2	0.2	5.1	4.9	0.0
LnGrp LOS	D		D	D		D		A	A	A	A	
Approach Vol, veh/h		78			67			385			423	
Approach Delay, s/veh		37.3			37.7			0.2			5.0	
Approach LOS		D			D			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		83.0		27.0		83.0		27.0
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		77.0		21.0		77.0		21.0
Max Q Clear Time (g_c+I1), s		2.0		5.5		5.2		7.7
Green Ext Time (p_c), s		4.2		0.5		4.2		0.4

Intersection Summary	
HCM 2010 Ctrl Delay	8.0
HCM 2010 LOS	A

Timing Report, Sorted By Phase
164: Monticello Ave & Charlotte St

Phase Number	2	4	6	8
Movement	NBT	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	C-Max	Max	C-Max	Max
Maximum Split (s)	83	27	83	27
Maximum Split (%)	75.5%	24.5%	75.5%	24.5%
Minimum Split (s)	27	27	27	27
Yellow Time (s)	4	4	4	4
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	10	10	10	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	6	3	6	3
Time Before Reduce (s)	3	3	3	3
Time To Reduce (s)	0	0	0	0
Walk Time (s)	5	5	5	5
Flash Dont Walk (s)	16	16	16	16
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	33	6	33	6
End Time (s)	6	33	6	33
Yield/Force Off (s)	0	27	0	27
Yield/Force Off 170(s)	94	11	94	11
Local Start Time (s)	33	6	33	6
Local Yield (s)	0	27	0	27
Local Yield 170(s)	94	11	94	11

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	55
Offset: 0 (0%), Referenced to phase 2:NBT and 6:SBTL, Start of Yellow	

Splits and Phases: 164: Monticello Ave & Charlotte St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	9	6	22	2	26	13	108	869	7	7	809	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	10	7	24	2	28	14	117	945	8	8	879	0
Adj No. of Lanes	0	1	0	0	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	113	89	228	40	289	137	454	2228	19	395	2073	0
Arrive On Green	0.25	0.25	0.23	0.25	0.25	0.23	0.06	0.62	0.60	0.03	0.59	0.00
Sat Flow, veh/h	295	364	930	22	1176	559	1774	3597	30	1774	3632	0
Grp Volume(v), veh/h	41	0	0	44	0	0	117	465	488	8	879	0
Grp Sat Flow(s),veh/h/ln	1589	0	0	1756	0	0	1774	1770	1857	1774	1770	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	2.6	14.9	14.9	0.2	15.1	0.0
Cycle Q Clear(g_c), s	2.1	0.0	0.0	2.1	0.0	0.0	2.6	14.9	14.9	0.2	15.1	0.0
Prop In Lane	0.24		0.59	0.05		0.32	1.00		0.02	1.00		0.00
Lane Grp Cap(c), veh/h	431	0	0	465	0	0	454	1096	1150	395	2073	0
V/C Ratio(X)	0.10	0.00	0.00	0.09	0.00	0.00	0.26	0.42	0.42	0.02	0.42	0.00
Avail Cap(c_a), veh/h	431	0	0	465	0	0	509	1096	1150	510	2073	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.82	0.82	0.00
Uniform Delay (d), s/veh	32.6	0.0	0.0	32.4	0.0	0.0	8.3	10.8	10.8	8.9	12.6	0.0
Incr Delay (d2), s/veh	0.4	0.0	0.0	0.4	0.0	0.0	0.1	1.2	1.1	0.0	0.5	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.0	0.0	0.0	1.1	0.0	0.0	1.3	7.6	8.0	0.1	7.5	0.0
LnGrp Delay(d),s/veh	33.0	0.0	0.0	32.8	0.0	0.0	8.4	12.0	12.0	8.9	13.1	0.0
LnGrp LOS	C			C			A	B	B	A	B	
Approach Vol, veh/h		41			44			1070			887	
Approach Delay, s/veh		33.0			32.8			11.6			13.0	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	6.9	72.1		31.0	10.6	68.4		31.0
Change Period (Y+Rc), s	6.0	6.0		6.0	6.0	6.0		6.0
Max Green Setting (Gmax), s	8.0	59.0		25.0	8.0	59.0		25.0
Max Q Clear Time (g_c+I1), s	2.2	16.9		4.1	4.6	17.1		4.1
Green Ext Time (p_c), s	0.0	19.2		0.3	0.1	19.2		0.3

Intersection Summary	
HCM 2010 Ctrl Delay	13.1
HCM 2010 LOS	B

Phase Number	1	2	4	5	6	8
Movement	SBL	NBTL	EBTL	NBL	SBTL	WBTL
Lead/Lag	Lead	Lag		Lead	Lag	
Lead-Lag Optimize	Yes	Yes		Yes	Yes	
Recall Mode	None	C-Max	Max	None	C-Max	Max
Maximum Split (s)	14	65	31	14	65	31
Maximum Split (%)	12.7%	59.1%	28.2%	12.7%	59.1%	28.2%
Minimum Split (s)	10	28	28	10	28	28
Yellow Time (s)	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2
Minimum Initial (s)	4	15	10	4	15	10
Vehicle Extension (s)	2	4	3	2	4	3
Minimum Gap (s)	2	4	3	2	4	3
Time Before Reduce (s)	2	4	3	2	4	3
Time To Reduce (s)	0	0	0	0	0	0
Walk Time (s)		7	7		7	7
Flash Dont Walk (s)		15	15		15	15
Dual Entry	No	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	77	91	46	77	91	46
End Time (s)	91	46	77	91	46	77
Yield/Force Off (s)	85	40	71	85	40	71
Yield/Force Off 170(s)	85	25	56	85	25	56
Local Start Time (s)	37	51	6	37	51	6
Local Yield (s)	45	0	31	45	0	31
Local Yield 170(s)	45	95	16	45	95	16

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	70
Offset: 40 (36%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	21	10	25	2	6	8	37	1074	8	42	1028	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	23	11	27	2	7	9	40	1167	9	46	1117	0
Adj No. of Lanes	0	1	0	0	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	125	65	125	44	134	151	396	2534	20	379	2495	0
Arrive On Green	0.18	0.18	0.17	0.18	0.18	0.17	0.03	0.70	0.69	0.04	0.71	0.00
Sat Flow, veh/h	511	362	694	97	743	840	1774	3600	28	1774	3632	0
Grp Volume(v), veh/h	61	0	0	18	0	0	40	574	602	46	1117	0
Grp Sat Flow(s),veh/h/ln	1567	0	0	1679	0	0	1774	1770	1858	1774	1770	0
Q Serve(g_s), s	1.4	0.0	0.0	0.0	0.0	0.0	0.9	21.3	21.3	1.0	20.4	0.0
Cycle Q Clear(g_c), s	4.7	0.0	0.0	1.3	0.0	0.0	0.9	21.3	21.3	1.0	20.4	0.0
Prop In Lane	0.38		0.44	0.11		0.50	1.00		0.01	1.00		0.00
Lane Grp Cap(c), veh/h	315	0	0	329	0	0	396	1246	1308	379	2495	0
V/C Ratio(X)	0.19	0.00	0.00	0.05	0.00	0.00	0.10	0.46	0.46	0.12	0.45	0.00
Avail Cap(c_a), veh/h	315	0	0	329	0	0	452	1246	1308	433	2495	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.85	0.85	0.00
Uniform Delay (d), s/veh	52.7	0.0	0.0	51.4	0.0	0.0	6.7	9.7	9.7	6.9	9.5	0.0
Incr Delay (d2), s/veh	1.4	0.0	0.0	0.3	0.0	0.0	0.0	1.2	1.2	0.0	0.5	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	2.3	0.0	0.0	0.7	0.0	0.0	0.4	10.8	11.3	0.5	10.1	0.0
LnGrp Delay(d),s/veh	54.0	0.0	0.0	51.7	0.0	0.0	6.8	11.0	10.9	6.9	10.0	0.0
LnGrp LOS	D			D			A	B	B	A	B	
Approach Vol, veh/h		61			18			1216			1163	
Approach Delay, s/veh		54.0			51.7			10.8			9.9	
Approach LOS		D			D			B			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	9.4	109.6		31.0	9.2	109.8		31.0
Change Period (Y+Rc), s	6.0	6.0		6.0	6.0	6.0		6.0
Max Green Setting (Gmax), s	8.0	99.0		25.0	8.0	99.0		25.0
Max Q Clear Time (g_c+I1), s	3.0	23.3		6.7	2.9	22.4		3.3
Green Ext Time (p_c), s	0.0	35.7		0.2	0.0	35.9		0.2

Intersection Summary	
HCM 2010 Ctrl Delay	11.7
HCM 2010 LOS	B

Phase Number	1	2	4	5	6	8
Movement	SBL	NBTL	EBTL	NBL	SBTL	WBTL
Lead/Lag	Lead	Lag		Lead	Lag	
Lead-Lag Optimize	Yes	Yes		Yes	Yes	
Recall Mode	None	C-Max	Max	None	C-Max	Max
Maximum Split (s)	14	105	31	14	105	31
Maximum Split (%)	9.3%	70.0%	20.7%	9.3%	70.0%	20.7%
Minimum Split (s)	10	28	28	10	28	28
Yellow Time (s)	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2
Minimum Initial (s)	4	15	10	4	15	10
Vehicle Extension (s)	2	4	3	2	4	3
Minimum Gap (s)	2	4	3	2	4	3
Time Before Reduce (s)	2	4	3	2	4	3
Time To Reduce (s)	0	0	0	0	0	0
Walk Time (s)		7	7		7	7
Flash Dont Walk (s)		15	15		15	15
Dual Entry	No	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	77	91	46	77	91	46
End Time (s)	91	46	77	91	46	77
Yield/Force Off (s)	85	40	71	85	40	71
Yield/Force Off 170(s)	85	25	56	85	25	56
Local Start Time (s)	37	51	6	37	51	6
Local Yield (s)	45	0	31	45	0	31
Local Yield 170(s)	45	135	16	45	135	16

Intersection Summary	
Cycle Length	150
Control Type	Actuated-Coordinated
Natural Cycle	70
Offset: 40 (27%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

Intersection	
Intersection Delay, s/veh	8.2
Intersection LOS	A

Movement	EBU	EBL	EBT	EBR	WBU	WBL	WBT	WBR	NBU	NBL	NBT	NBR
Vol, veh/h	0	24	12	8	0	2	28	19	0	11	77	7
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	26	13	9	0	2	30	21	0	12	84	8
Number of Lanes	0	0	1	0	0	0	1	0	0	0	1	0

Approach	EB	WB	NB
Opposing Approach	WB	EB	SB
Opposing Lanes	1	1	1
Conflicting Approach Left	SB	NB	EB
Conflicting Lanes Left	1	1	1
Conflicting Approach Right	NB	SB	WB
Conflicting Lanes Right	1	1	1
HCM Control Delay	8	7.8	8
HCM LOS	A	A	A

Lane	NBLn1	EBLn1	WBLn1	SBLn1
Vol Left, %	12%	55%	4%	19%
Vol Thru, %	81%	27%	57%	44%
Vol Right, %	7%	18%	39%	37%
Sign Control	Stop	Stop	Stop	Stop
Traffic Vol by Lane	95	44	49	205
LT Vol	11	24	2	39
Through Vol	77	12	28	91
RT Vol	7	8	19	75
Lane Flow Rate	103	48	53	223
Geometry Grp	1	1	1	1
Degree of Util (X)	0.125	0.062	0.066	0.248
Departure Headway (Hd)	4.374	4.704	4.474	4.112
Convergence, Y/N	Yes	Yes	Yes	Yes
Cap	823	765	804	878
Service Time	2.382	2.712	2.481	2.112
HCM Lane V/C Ratio	0.125	0.063	0.066	0.254
HCM Control Delay	8	8	7.8	8.5
HCM Lane LOS	A	A	A	A
HCM 95th-tile Q	0.4	0.2	0.2	1

Intersection	
Intersection Delay, s/veh	
Intersection LOS	

Movement	SBU	SBL	SBT	SBR
Vol, veh/h	0	39	91	75
Peak Hour Factor	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2
Mvmt Flow	0	42	99	82
Number of Lanes	0	0	1	0

Approach	SB
Opposing Approach	NB
Opposing Lanes	1
Conflicting Approach Left	WB
Conflicting Lanes Left	1
Conflicting Approach Right	EB
Conflicting Lanes Right	1
HCM Control Delay	8.5
HCM LOS	A

Lane

Intersection	
Intersection Delay, s/veh	10.4
Intersection LOS	B

Movement	EBU	EBL	EBT	EBR	WBU	WBL	WBT	WBR	NBU	NBL	NBT	NBR
Vol, veh/h	0	45	25	22	0	5	28	10	0	18	86	8
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	49	27	24	0	5	30	11	0	20	93	9
Number of Lanes	0	0	1	0	0	0	1	0	0	0	1	0

Approach	EB	WB	NB
Opposing Approach	WB	EB	SB
Opposing Lanes	1	1	1
Conflicting Approach Left	SB	NB	EB
Conflicting Lanes Left	1	1	1
Conflicting Approach Right	NB	SB	WB
Conflicting Lanes Right	1	1	1
HCM Control Delay	9.1	8.6	8.7
HCM LOS	A	A	A

Lane	NBLn1	EBLn1	WBLn1	SBLn1
Vol Left, %	16%	49%	12%	15%
Vol Thru, %	77%	27%	65%	57%
Vol Right, %	7%	24%	23%	28%
Sign Control	Stop	Stop	Stop	Stop
Traffic Vol by Lane	112	92	43	376
LT Vol	18	45	5	55
Through Vol	86	25	28	216
RT Vol	8	22	10	105
Lane Flow Rate	122	100	47	409
Geometry Grp	1	1	1	1
Degree of Util (X)	0.16	0.143	0.067	0.49
Departure Headway (Hd)	4.738	5.133	5.146	4.314
Convergence, Y/N	Yes	Yes	Yes	Yes
Cap	754	695	692	834
Service Time	2.786	3.188	3.207	2.349
HCM Lane V/C Ratio	0.162	0.144	0.068	0.49
HCM Control Delay	8.7	9.1	8.6	11.5
HCM Lane LOS	A	A	A	B
HCM 95th-tile Q	0.6	0.5	0.2	2.7

Intersection	
Intersection Delay, s/veh	
Intersection LOS	

Movement	SBU	SBL	SBT	SBR
Vol, veh/h	0	55	216	105
Peak Hour Factor	0.92	0.92	0.92	0.92
Heavy Vehicles, %	2	2	2	2
Mvmt Flow	0	60	235	114
Number of Lanes	0	0	1	0

Approach	SB
Opposing Approach	NB
Opposing Lanes	1
Conflicting Approach Left	WB
Conflicting Lanes Left	1
Conflicting Approach Right	EB
Conflicting Lanes Right	1
HCM Control Delay	11.5
HCM LOS	B

Lane

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	58	1132	41	71	1913	102	55	62	11	519	166	44
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1863	1863	1900	1827	1827	1900
Adj Flow Rate, veh/h	63	1230	45	77	2079	111	60	67	12	564	180	48
Adj No. of Lanes	1	4	0	1	3	0	1	1	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	4	4	4
Cap, veh/h	264	3504	128	361	2721	145	211	126	23	689	230	61
Arrive On Green	0.06	0.55	0.53	0.12	1.00	1.00	0.08	0.08	0.06	0.17	0.17	0.15
Sat Flow, veh/h	1774	6394	233	1774	4944	263	1774	1539	276	3375	1391	371
Grp Volume(v), veh/h	63	924	351	77	1423	767	60	0	79	564	0	228
Grp Sat Flow(s),veh/h/ln	1774	1602	1822	1774	1695	1816	1774	0	1814	1688	0	1761
Q Serve(g_s), s	1.6	11.8	11.9	1.9	0.0	0.0	3.5	0.0	4.6	13.3	0.0	13.7
Cycle Q Clear(g_c), s	1.6	11.8	11.9	1.9	0.0	0.0	3.5	0.0	4.6	13.3	0.0	13.7
Prop In Lane	1.00		0.13	1.00		0.14	1.00		0.15	1.00		0.21
Lane Grp Cap(c), veh/h	264	2634	998	361	1866	1000	211	0	148	689	0	291
V/C Ratio(X)	0.24	0.35	0.35	0.21	0.76	0.77	0.28	0.00	0.53	0.82	0.00	0.78
Avail Cap(c_a), veh/h	308	2634	998	433	1866	1000	243	0	379	689	0	368
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	0.75	0.75	0.75	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	8.9	13.9	14.0	9.0	0.0	0.0	47.9	0.0	48.6	42.3	0.0	44.2
Incr Delay (d2), s/veh	0.5	0.4	1.0	0.2	2.3	4.3	0.7	0.0	2.9	7.7	0.0	8.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.8	5.3	6.2	0.9	0.6	1.2	1.8	0.0	2.4	9.0	0.0	7.3
LnGrp Delay(d),s/veh	9.4	14.3	15.0	9.2	2.3	4.3	48.6	0.0	51.6	50.0	0.0	52.5
LnGrp LOS	A	B	B	A	A	A	D		D	D		D
Approach Vol, veh/h		1338			2267			139			792	
Approach Delay, s/veh		14.2			3.2			50.3			50.7	
Approach LOS		B			A			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.5	64.3	22.2	13.0	10.3	64.5	13.0	22.2
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	9.0	47.0	9.0	21.0	7.0	49.0	9.0	21.0
Max Q Clear Time (g_c+I1), s	3.9	13.9	15.3	6.6	3.6	2.0	5.5	15.7
Green Ext Time (p_c), s	0.1	30.3	0.0	0.2	0.0	41.6	0.0	0.5

Intersection Summary	
HCM 2010 Ctrl Delay	16.2
HCM 2010 LOS	B

Notes

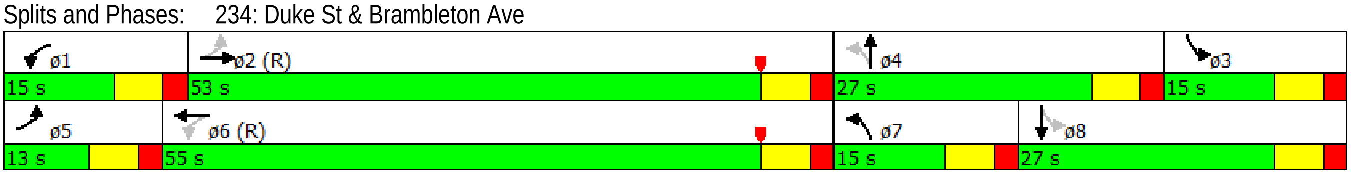
User approved pedestrian interval to be less than phase max green.

Phase Number	1	2	3	4	5	6	7	8
Movement	WBL	EBTL	SBL	NBTL	EBL	WBTL	NBL	SBTL
Lead/Lag	Lead	Lag	Lag	Lead	Lead	Lag	Lead	Lag
Lead-Lag Optimize	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	C-Max	None	None	None	C-Max	None	None
Maximum Split (s)	15	53	15	27	13	55	15	27
Maximum Split (%)	13.6%	48.2%	13.6%	24.5%	11.8%	50.0%	13.6%	24.5%
Minimum Split (s)	11	30	13	20	11	30	13	20
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	7	7	5	10	7	7
Vehicle Extension (s)	3	4	3	3	3	4	3	3
Minimum Gap (s)	3	4	3	3	3	4	3	3
Time Before Reduce (s)	3	4	3	3	3	4	3	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		6		6		6		6
Flash Dont Walk (s)		11		19		11		19
Dual Entry	No	No	No	Yes	No	No	Yes	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	62	77	47	20	62	75	20	35
End Time (s)	77	20	62	47	75	20	35	62
Yield/Force Off (s)	71	14	56	41	69	14	29	56
Yield/Force Off 170(s)	71	3	56	22	69	3	29	37
Local Start Time (s)	48	63	33	6	48	61	6	21
Local Yield (s)	57	0	42	27	55	0	15	42
Local Yield 170(s)	57	99	42	8	55	99	15	23

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	90

Offset: 14 (13%), Referenced to phase 2:EBTL and 6:WBTL, Start of Yellow

Splits and Phases: 234: Duke St & Brambleton Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	50	1562	29	110	865	57	93	125	41	50	1562	29
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	54	1698	32	120	940	62	101	136	45	54	1698	32
Adj No. of Lanes	1	4	0	1	3	0	1	1	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	441	3237	61	274	2480	163	227	181	60	668	364	7
Arrive On Green	0.05	0.50	0.48	0.13	1.00	0.98	0.09	0.13	0.12	0.16	0.20	0.18
Sat Flow, veh/h	1774	6524	123	1774	4875	321	1774	1341	444	3442	1822	34
Grp Volume(v), veh/h	54	1251	479	120	653	349	101	0	181	54	0	1730
Grp Sat Flow(s),veh/h/ln	1774	1602	1841	1774	1695	1806	1774	0	1784	1721	0	1857
Q Serve(g_s), s	1.6	19.5	19.5	3.5	0.0	0.1	5.9	0.0	10.8	0.0	0.0	22.0
Cycle Q Clear(g_c), s	1.6	19.5	19.5	3.5	0.0	0.1	5.9	0.0	10.8	0.0	0.0	22.0
Prop In Lane	1.00		0.07	1.00		0.18	1.00		0.25	1.00		0.02
Lane Grp Cap(c), veh/h	441	2384	913	274	1725	919	227	0	241	668	0	371
V/C Ratio(X)	0.12	0.52	0.52	0.44	0.38	0.38	0.45	0.00	0.75	0.08	0.00	4.66
Avail Cap(c_a), veh/h	505	2384	913	316	1725	919	323	0	260	819	0	371
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	0.91	0.91	0.91	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	11.4	18.9	18.9	13.1	0.0	0.1	45.5	0.0	46.1	39.2	0.0	44.0
Incr Delay (d2), s/veh	0.1	0.8	2.2	1.0	0.6	1.1	1.4	0.0	10.9	0.1	0.0	1652.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.8	8.8	10.4	1.7	0.1	0.3	2.9	0.0	6.0	0.7	0.0	181.7
LnGrp Delay(d),s/veh	11.6	19.7	21.1	14.1	0.6	1.2	46.9	0.0	56.9	39.2	0.0	1696.6
LnGrp LOS	B	B	C	B	A	A	D		E	D		F
Approach Vol, veh/h		1784			1122			282			1784	
Approach Delay, s/veh		19.8			2.2			53.3			1646.5	
Approach LOS		B			A			D			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.4	58.6	21.2	18.8	10.0	60.0	14.0	26.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	8.0	44.0	20.0	14.0	8.0	44.0	14.0	20.0
Max Q Clear Time (g_c+I1), s	5.5	21.5	2.0	12.8	3.6	2.1	7.9	24.0
Green Ext Time (p_c), s	0.1	18.8	15.5	0.1	0.0	31.0	0.1	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	601.4
HCM 2010 LOS	F

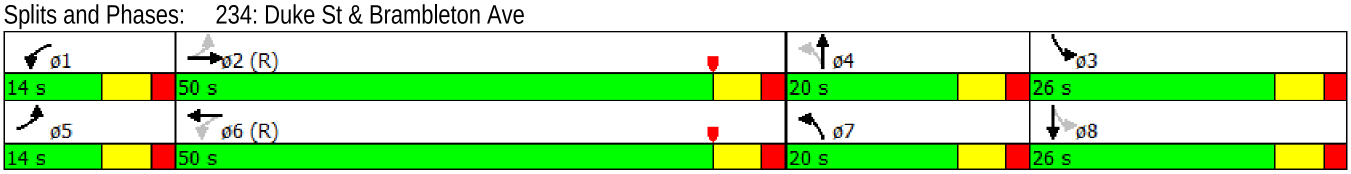
Notes

User approved pedestrian interval to be less than phase max green.

Phase Number	1	2	3	4	5	6	7	8
Movement	WBL	EBTL	SBL	NBTL	EBL	WBTL	NBL	SBTL
Lead/Lag	Lead	Lag	Lag	Lead	Lead	Lag	Lead	Lag
Lead-Lag Optimize	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	C-Max	None	None	None	C-Max	None	None
Maximum Split (s)	14	50	26	20	14	50	20	26
Maximum Split (%)	12.7%	45.5%	23.6%	18.2%	12.7%	45.5%	18.2%	23.6%
Minimum Split (s)	11	30	13	20	11	30	13	20
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	7	7	5	10	7	7
Vehicle Extension (s)	3	4	3	3	3	4	3	3
Minimum Gap (s)	3	4	3	3	3	4	3	3
Time Before Reduce (s)	3	4	3	3	3	4	3	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		6		6		6		6
Flash Dont Walk (s)		11		19		11		19
Dual Entry	No	No	No	Yes	No	No	Yes	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	77	91	51	31	77	91	31	51
End Time (s)	91	31	77	51	91	31	51	77
Yield/Force Off (s)	85	25	71	45	85	25	45	71
Yield/Force Off 170(s)	85	14	71	26	85	14	45	52
Local Start Time (s)	52	66	26	6	52	66	6	26
Local Yield (s)	60	0	46	20	60	0	20	46
Local Yield 170(s)	60	99	46	1	60	99	20	27

Intersection Summary	
Cycle Length	110
Control Type	Actuated-Coordinated
Natural Cycle	150
Offset: 25 (23%), Referenced to phase 2:EBTL and 6:WBTL, Start of Yellow	

Splits and Phases: 234: Duke St & Brambleton Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	81	0	437	12	953	0	0	542	429
Number				3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1881	0	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h				88	0	475	13	1036	0	0	589	466
Adj No. of Lanes				1	0	1	1	2	0	0	2	1
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				1	0	1	0	0	0	0	1	1
Cap, veh/h				472	0	422	355	2063	0	0	1761	788
Arrive On Green				0.26	0.00	0.26	0.01	0.57	0.00	0.00	0.49	0.49
Sat Flow, veh/h				1792	0	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h				88	0	475	13	1036	0	0	589	466
Grp Sat Flow(s),veh/h/ln				1792	0	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s				2.3	0.0	16.0	0.2	10.5	0.0	0.0	6.1	12.7
Cycle Q Clear(g_c), s				2.3	0.0	16.0	0.2	10.5	0.0	0.0	6.1	12.7
Prop In Lane				1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h				472	0	422	355	2063	0	0	1761	788
V/C Ratio(X)				0.19	0.00	1.13	0.04	0.50	0.00	0.00	0.33	0.59
Avail Cap(c_a), veh/h				472	0	422	809	4581	0	0	3181	1423
HCM Platoon Ratio				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				17.3	0.0	22.3	7.1	7.8	0.0	0.0	9.4	11.0
Incr Delay (d2), s/veh				0.2	0.0	83.0	0.0	0.2	0.0	0.0	0.1	0.7
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				1.1	0.0	16.7	0.1	5.2	0.0	0.0	3.0	5.7
LnGrp Delay(d),s/veh				17.5	0.0	105.3	7.1	8.0	0.0	0.0	9.5	11.7
LnGrp LOS				B		F	A	A			A	B
Approach Vol, veh/h					563			1049			1055	
Approach Delay, s/veh					91.6			8.0			10.5	
Approach LOS					F			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2				6		8
Phs Duration (G+Y+Rc), s	4.8	35.9				40.7		20.0
Change Period (Y+Rc), s	4.0	6.0				* 6		4.0
Max Green Setting (Gmax), s	16.0	54.0				* 77		16.0
Max Q Clear Time (g_c+I1), s	2.2	14.7				11.5		18.0
Green Ext Time (p_c), s	0.0	15.2				17.1		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	26.6
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Timing Report, Sorted By Phase
3: I-264 WB Off-ramp & Ballentine Blvd

Phase Number	1	2	3	6
Movement	NBL	SBT	WBL	NBTL
Lead/Lag	Lead	Lag		
Lead-Lag Optimize	Yes	Yes		
Recall Mode	None	Min	None	Min
Maximum Split (s)	20	60	20	80
Maximum Split (%)	20.0%	60.0%	20.0%	80.0%
Minimum Split (s)	8	22	8	20.5
Yellow Time (s)	3.5	4	3.5	3
All-Red Time (s)	0.5	2	0.5	0
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		5		5
Flash Dont Walk (s)		11		11
Dual Entry	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	20	80	0
End Time (s)	20	80	0	80
Yield/Force Off (s)	16	74	96	77
Yield/Force Off 170(s)	16	74	96	77
Local Start Time (s)	80	0	60	80
Local Yield (s)	96	54	76	57
Local Yield 170(s)	96	54	76	57

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	50

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

HCM 2010 Signalized Intersection Summary
3: I-264 WB Off-ramp & Ballentine Blvd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	119	0	399	54	671	0	0	773	565
Number				3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1881	0	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h				129	0	434	59	729	0	0	840	614
Adj No. of Lanes				1	0	1	1	2	0	0	2	1
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				1	0	1	0	0	0	0	1	1
Cap, veh/h				409	0	365	318	2271	0	0	1905	852
Arrive On Green				0.23	0.00	0.23	0.04	0.63	0.00	0.00	0.53	0.53
Sat Flow, veh/h				1792	0	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h				129	0	434	59	729	0	0	840	614
Grp Sat Flow(s),veh/h/ln				1792	0	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s				4.2	0.0	16.0	0.9	6.6	0.0	0.0	10.1	20.4
Cycle Q Clear(g_c), s				4.2	0.0	16.0	0.9	6.6	0.0	0.0	10.1	20.4
Prop In Lane				1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h				409	0	365	318	2271	0	0	1905	852
V/C Ratio(X)				0.32	0.00	1.19	0.19	0.32	0.00	0.00	0.44	0.72
Avail Cap(c_a), veh/h				409	0	365	660	3965	0	0	2753	1232
HCM Platoon Ratio				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				22.5	0.0	27.1	7.0	6.0	0.0	0.0	10.0	12.4
Incr Delay (d2), s/veh				0.4	0.0	109.3	0.3	0.1	0.0	0.0	0.2	1.2
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				2.1	0.0	18.1	0.5	3.3	0.0	0.0	4.9	9.1
LnGrp Delay(d),s/veh				22.9	0.0	136.4	7.3	6.1	0.0	0.0	10.1	13.6
LnGrp LOS				C		F	A	A			B	B
Approach Vol, veh/h					563			788			1454	
Approach Delay, s/veh					110.4			6.2			11.6	
Approach LOS					F			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2				6		8
Phs Duration (G+Y+Rc), s	6.7	43.4				50.1		20.0
Change Period (Y+Rc), s	4.0	6.0				* 6		4.0
Max Green Setting (Gmax), s	16.0	54.0				* 77		16.0
Max Q Clear Time (g_c+I1), s	2.9	22.4				7.6		18.0
Green Ext Time (p_c), s	0.1	15.0				18.8		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	29.9
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Phase Number	1	2	3	6
Movement	NBL	SBT	WBL	NBTL
Lead/Lag	Lead	Lag		
Lead-Lag Optimize	Yes	Yes		
Recall Mode	None	Min	None	Min
Maximum Split (s)	20	60	20	80
Maximum Split (%)	20.0%	60.0%	20.0%	80.0%
Minimum Split (s)	8	22	8	20.5
Yellow Time (s)	3.5	4	3.5	3
All-Red Time (s)	0.5	2	0.5	0
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		5		5
Flash Dont Walk (s)		11		11
Dual Entry	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	20	80	0
End Time (s)	20	80	0	80
Yield/Force Off (s)	16	74	96	77
Yield/Force Off 170(s)	16	74	96	77
Local Start Time (s)	80	0	60	80
Local Yield (s)	96	54	76	57
Local Yield 170(s)	96	54	76	57

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	45

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	607	0	64	5	0	142	0	287	86	229	303	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1937	1900	1900	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	660	0	70	5	0	154	0	312	93	249	329	0
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	264	0	28	8	0	246	0	1107	325	379	1043	0
Arrive On Green	0.16	0.00	0.16	0.16	0.00	0.16	0.00	0.41	0.41	0.11	0.56	0.00
Sat Flow, veh/h	1649	0	175	50	0	1539	0	2794	792	3442	1863	0
Grp Volume(v), veh/h	730	0	0	159	0	0	0	203	202	249	329	0
Grp Sat Flow(s),veh/h/ln	1824	0	0	1589	0	0	0	1770	1723	1721	1863	0
Q Serve(g_s), s	16.0	0.0	0.0	9.3	0.0	0.0	0.0	7.6	7.9	6.9	9.4	0.0
Cycle Q Clear(g_c), s	16.0	0.0	0.0	9.3	0.0	0.0	0.0	7.6	7.9	6.9	9.4	0.0
Prop In Lane	0.90		0.10	0.03		0.97	0.00		0.46	1.00		0.00
Lane Grp Cap(c), veh/h	292	0	0	254	0	0	0	726	706	379	1043	0
V/C Ratio(X)	2.50	0.00	0.00	0.63	0.00	0.00	0.00	0.28	0.29	0.66	0.32	0.00
Avail Cap(c_a), veh/h	292	0	0	254	0	0	0	726	706	379	1043	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	42.0	0.0	0.0	39.2	0.0	0.0	0.0	19.7	19.7	42.7	11.8	0.0
Incr Delay (d2), s/veh	685.8	0.0	0.0	11.1	0.0	0.0	0.0	1.0	1.0	8.7	0.8	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	63.6	0.0	0.0	4.9	0.0	0.0	0.0	3.9	3.9	3.7	5.1	0.0
LnGrp Delay(d),s/veh	727.8	0.0	0.0	50.3	0.0	0.0	0.0	20.6	20.7	51.3	12.5	0.0
LnGrp LOS	F			D				C	C	D	B	
Approach Vol, veh/h		730			159			405			578	
Approach Delay, s/veh		727.8			50.3			20.7			29.3	
Approach LOS		F			D			C			C	

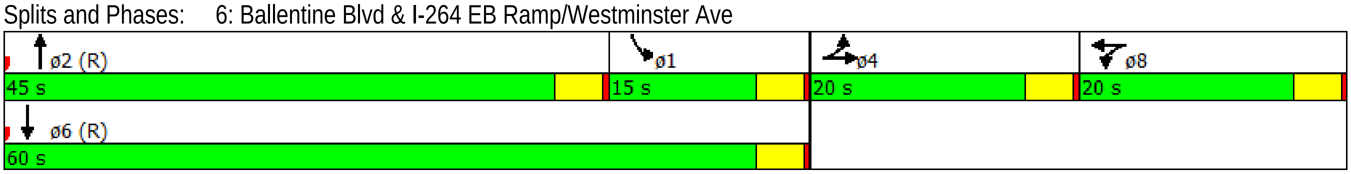
Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	15.0	45.0		20.0		60.0		20.0
Change Period (Y+Rc), s	4.0	4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s	11.0	41.0		16.0		56.0		16.0
Max Q Clear Time (g_c+I1), s	8.9	9.9		18.0		11.4		11.3
Green Ext Time (p_c), s	0.6	2.6		0.0		3.1		0.3

Intersection Summary	
HCM 2010 Ctrl Delay	301.6
HCM 2010 LOS	F

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lag	Lead			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	15	45	20	60	20
Maximum Split (%)	15.0%	45.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	20	20	20	20
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	30	85	45	85	65
End Time (s)	45	30	65	45	85
Yield/Force Off (s)	41	26	61	41	81
Yield/Force Off 170(s)	41	15	50	30	70
Local Start Time (s)	45	0	60	0	80
Local Yield (s)	56	41	76	56	96
Local Yield 170(s)	56	30	65	45	85

Intersection Summary	
Cycle Length	100
Control Type	Pretimed
Natural Cycle	80
Offset: 85 (85%), Referenced to phase 2:NBT and 6:SBT, Start of Green	

Splits and Phases: 6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave



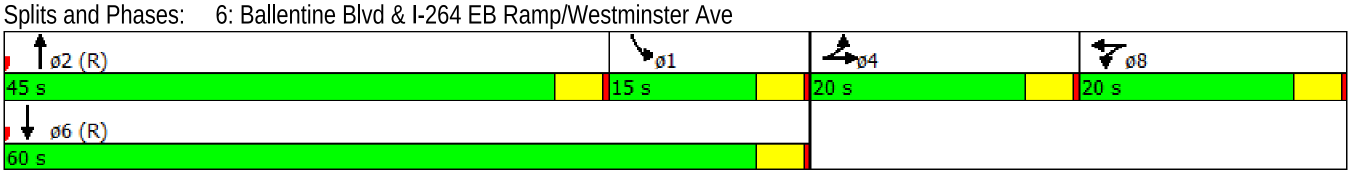
HCM 2010 Signalized Intersection Summary
6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	343	0	36	17	0	148	0	345	53	595	482	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1937	1900	1900	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	373	0	39	18	0	161	0	375	58	647	524	0
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	264	0	28	26	0	230	0	1262	194	379	1043	0
Arrive On Green	0.16	0.00	0.16	0.16	0.00	0.16	0.00	0.41	0.41	0.11	0.56	0.00
Sat Flow, veh/h	1652	0	173	161	0	1440	0	3170	472	3442	1863	0
Grp Volume(v), veh/h	412	0	0	179	0	0	0	214	219	647	524	0
Grp Sat Flow(s),veh/h/ln	1824	0	0	1601	0	0	0	1770	1779	1721	1863	0
Q Serve(g_s), s	16.0	0.0	0.0	10.6	0.0	0.0	0.0	8.1	8.3	11.0	17.2	0.0
Cycle Q Clear(g_c), s	16.0	0.0	0.0	10.6	0.0	0.0	0.0	8.1	8.3	11.0	17.2	0.0
Prop In Lane	0.91		0.09	0.10		0.90	0.00		0.27	1.00		0.00
Lane Grp Cap(c), veh/h	292	0	0	256	0	0	0	726	730	379	1043	0
V/C Ratio(X)	1.41	0.00	0.00	0.70	0.00	0.00	0.00	0.30	0.30	1.71	0.50	0.00
Avail Cap(c_a), veh/h	292	0	0	256	0	0	0	726	730	379	1043	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	42.0	0.0	0.0	39.7	0.0	0.0	0.0	19.8	19.8	44.5	13.5	0.0
Incr Delay (d2), s/veh	204.4	0.0	0.0	14.7	0.0	0.0	0.0	1.0	1.1	330.1	1.7	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	24.6	0.0	0.0	5.7	0.0	0.0	0.0	4.1	4.3	22.6	9.2	0.0
LnGrp Delay(d),s/veh	246.4	0.0	0.0	54.4	0.0	0.0	0.0	20.8	20.9	374.6	15.2	0.0
LnGrp LOS	F			D				C	C	F	B	
Approach Vol, veh/h		412			179			433			1171	
Approach Delay, s/veh		246.4			54.4			20.9			213.8	
Approach LOS		F			D			C			F	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2		4		6		8				
Phs Duration (G+Y+Rc), s	15.0	45.0		20.0		60.0		20.0				
Change Period (Y+Rc), s	4.0	4.0		4.0		4.0		4.0				
Max Green Setting (Gmax), s	11.0	41.0		16.0		56.0		16.0				
Max Q Clear Time (g_c+I1), s	13.0	10.3		18.0		19.2		12.6				
Green Ext Time (p_c), s	0.0	2.8		0.0		7.0		0.3				
Intersection Summary												
HCM 2010 Ctrl Delay			168.9									
HCM 2010 LOS			F									

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lag	Lead			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	15	45	20	60	20
Maximum Split (%)	15.0%	45.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	20	20	20	20
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	30	85	45	85	65
End Time (s)	45	30	65	45	85
Yield/Force Off (s)	41	26	61	41	81
Yield/Force Off 170(s)	41	15	50	30	70
Local Start Time (s)	45	0	60	0	80
Local Yield (s)	56	41	76	56	96
Local Yield 170(s)	56	30	65	45	85

Intersection Summary	
Cycle Length	100
Control Type	Pretimed
Natural Cycle	80
Offset: 85 (85%), Referenced to phase 2:NBT and 6:SBT, Start of Green	

Splits and Phases: 6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	25	143	16	215	645	858	16	86	33	350	433	119
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1900
Adj Flow Rate, veh/h	29	165	18	248	743	0	18	99	38	403	499	137
Adj No. of Lanes	1	3	1	1	3	1	1	2	1	2	3	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	118	915	285	367	1627	507	118	802	686	780	1546	413
Arrive On Green	0.07	0.18	0.18	0.21	0.32	0.00	0.07	0.23	0.23	0.23	0.39	0.39
Sat Flow, veh/h	1774	5085	1583	1774	5085	1583	1774	3539	1583	3442	3997	1067
Grp Volume(v), veh/h	29	165	18	248	743	0	18	99	38	403	421	215
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1583	1774	1770	1583	1721	1695	1674
Q Serve(g_s), s	2.3	4.1	1.4	19.3	17.5	0.0	1.4	3.3	1.0	15.4	13.0	13.5
Cycle Q Clear(g_c), s	2.3	4.1	1.4	19.3	17.5	0.0	1.4	3.3	1.0	15.4	13.0	13.5
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.64
Lane Grp Cap(c), veh/h	118	915	285	367	1627	507	118	802	686	780	1311	647
V/C Ratio(X)	0.25	0.18	0.06	0.68	0.46	0.00	0.15	0.12	0.06	0.52	0.32	0.33
Avail Cap(c_a), veh/h	118	915	285	367	1627	507	118	802	686	780	1311	647
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	66.4	52.1	51.0	54.9	40.6	0.0	66.0	46.1	9.2	50.8	32.2	32.4
Incr Delay (d2), s/veh	4.9	0.4	0.4	9.6	0.9	0.0	2.7	0.3	0.2	2.4	0.6	1.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.3	2.0	0.7	10.5	8.3	0.0	0.8	1.7	0.5	7.6	6.2	6.5
LnGrp Delay(d),s/veh	71.3	52.6	51.4	64.5	41.5	0.0	68.7	46.5	9.3	53.2	32.9	33.7
LnGrp LOS	E	D	D	E	D		E	D	A	D	C	C
Approach Vol, veh/h		212			991			155			1039	
Approach Delay, s/veh		55.0			47.3			39.9			40.9	
Approach LOS		E			D			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	16.0	64.0	16.0	54.0	40.0	40.0	37.0	33.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	10.0	58.0	10.0	48.0	34.0	34.0	31.0	27.0
Max Q Clear Time (g_c+I1), s	3.4	15.5	4.3	19.5	17.4	5.3	21.3	6.1
Green Ext Time (p_c), s	0.3	3.1	0.0	5.3	1.7	0.6	3.5	0.8

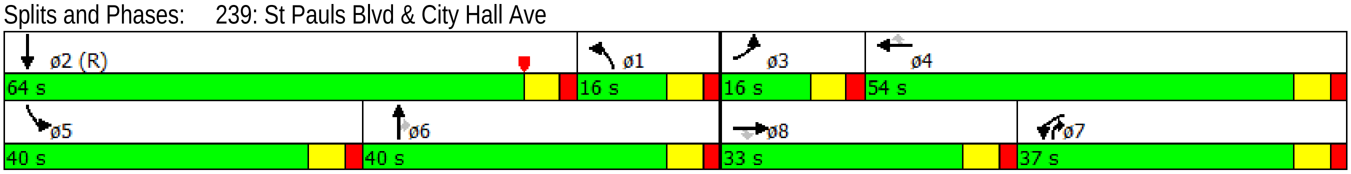
Intersection Summary		
HCM 2010 Ctrl Delay		44.7
HCM 2010 LOS		D

Timing Report, Sorted By Phase
239: St Pauls Blvd & City Hall Ave

Phase Number	1	2	3	4	5	6	7	8
Movement	NBL	SBT	EBL	WBT	SBL	NBT	WBL	EBT
Lead/Lag	Lag	Lead	Lead	Lag	Lead	Lag	Lag	Lead
Lead-Lag Optimize								
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	16	64	16	54	40	40	37	33
Maximum Split (%)	10.7%	42.7%	10.7%	36.0%	26.7%	26.7%	24.7%	22.0%
Minimum Split (s)	11	33	11	33	11	33	11	33
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	5	10	5	10	5	10
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		7		7		7
Flash Dont Walk (s)		20		20		20		20
Dual Entry	No	No	No	No	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	6	92	22	38	92	132	55	22
End Time (s)	22	6	38	92	132	22	92	55
Yield/Force Off (s)	16	0	32	86	126	16	86	49
Yield/Force Off 170(s)	16	130	32	66	126	146	86	29
Local Start Time (s)	6	92	22	38	92	132	55	22
Local Yield (s)	16	0	32	86	126	16	86	49
Local Yield 170(s)	16	130	32	66	126	146	86	29

Intersection Summary	
Cycle Length	150
Control Type	Pretimed
Natural Cycle	100
Offset: 0 (0%), Referenced to phase 2:SBT, Start of Yellow	

Splits and Phases: 239: St Pauls Blvd & City Hall Ave



HCM 2010 Signalized Intersection Summary
239: St Pauls Blvd & City Hall Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	45	846	4	127	351	617	76	442	1118	499	452	80
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1900
Adj Flow Rate, veh/h	52	975	5	146	404	0	88	509	1288	575	521	92
Adj No. of Lanes	1	3	1	1	3	1	1	2	1	2	3	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	228	1199	373	177	1053	328	177	1087	645	639	1714	297
Arrive On Green	0.13	0.24	0.24	0.10	0.21	0.00	0.10	0.31	0.31	0.19	0.39	0.39
Sat Flow, veh/h	1774	5085	1583	1774	5085	1583	1774	3539	1583	3442	4363	756
Grp Volume(v), veh/h	52	975	5	146	404	0	88	509	1288	575	403	210
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1583	1774	1770	1583	1721	1695	1729
Q Serve(g_s), s	3.7	25.4	0.3	11.3	9.6	0.0	6.6	16.3	34.8	22.9	11.5	11.8
Cycle Q Clear(g_c), s	3.7	25.4	0.3	11.3	9.6	0.0	6.6	16.3	34.8	22.9	11.5	11.8
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.44
Lane Grp Cap(c), veh/h	228	1199	373	177	1053	328	177	1087	645	639	1332	679
V/C Ratio(X)	0.23	0.81	0.01	0.82	0.38	0.00	0.50	0.47	2.00	0.90	0.30	0.31
Avail Cap(c_a), veh/h	228	1199	373	177	1053	328	177	1087	645	639	1332	679
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	54.8	50.6	41.0	61.8	47.8	0.0	59.7	39.2	22.5	55.7	29.3	29.4
Incr Delay (d2), s/veh	2.3	6.1	0.1	33.3	1.1	0.0	9.6	1.4	454.6	18.0	0.6	1.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	2.0	12.6	0.2	7.2	4.6	0.0	3.7	8.2	96.6	12.5	5.5	5.8
LnGrp Delay(d),s/veh	57.1	56.7	41.1	95.1	48.9	0.0	69.2	40.7	477.1	73.8	29.9	30.6
LnGrp LOS	E	E	D	F	D		E	D	F	E	C	C
Approach Vol, veh/h		1032			550			1885			1188	
Approach Delay, s/veh		56.6			61.1			340.2			51.2	
Approach LOS		E			E			F			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	20.0	61.0	24.0	35.0	32.0	49.0	20.0	39.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	14.0	55.0	18.0	29.0	26.0	43.0	14.0	33.0
Max Q Clear Time (g_c+I1), s	8.6	13.8	5.7	11.6	24.9	36.8	13.3	27.4
Green Ext Time (p_c), s	4.5	2.9	0.1	2.4	0.4	5.1	0.2	2.5

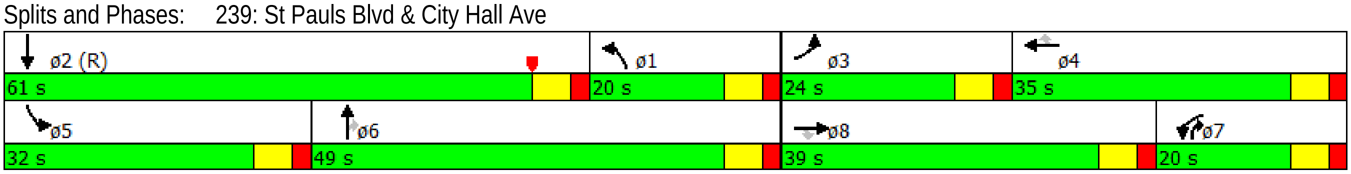
Intersection Summary		
HCM 2010 Ctrl Delay		170.6
HCM 2010 LOS		F

Timing Report, Sorted By Phase
239: St Pauls Blvd & City Hall Ave

Phase Number	1	2	3	4	5	6	7	8
Movement	NBL	SBT	EBL	WBT	SBL	NBT	WBL	EBT
Lead/Lag	Lag	Lead	Lead	Lag	Lead	Lag	Lag	Lead
Lead-Lag Optimize	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	20	61	24	35	32	49	20	39
Maximum Split (%)	14.3%	43.6%	17.1%	25.0%	22.9%	35.0%	14.3%	27.9%
Minimum Split (s)	11	33	11	33	11	33	11	33
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	5	10	5	10	5	10
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		7		7		7
Flash Dont Walk (s)		20		20		20		20
Dual Entry	No	No	No	No	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	65	4	85	109	4	36	124	85
End Time (s)	85	65	109	4	36	85	4	124
Yield/Force Off (s)	79	59	103	138	30	79	138	118
Yield/Force Off 170(s)	79	39	103	118	30	59	138	98
Local Start Time (s)	6	85	26	50	85	117	65	26
Local Yield (s)	20	0	44	79	111	20	79	59
Local Yield 170(s)	20	120	44	59	111	0	79	39

Intersection Summary	
Cycle Length	140
Control Type	Pretimed
Natural Cycle	150
Offset: 59 (42%), Referenced to phase 2:SBT, Start of Yellow	

Splits and Phases: 239: St Pauls Blvd & City Hall Ave



HCM 2010 Signalized Intersection Summary
3: Ped & LRT Phases/Monticello Ave & City Hall Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	10	176	0	0	195	58	0	100	0	23	0	13
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1900	1881	1900
Adj Flow Rate, veh/h	11	191	0	0	212	63	0	109	0	25	0	14
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	333	1361	0	0	390	504	195	205	174	119	0	66
Arrive On Green	0.01	0.38	0.00	0.00	0.21	0.21	0.00	0.11	0.00	0.11	0.00	0.11
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1101	0	616
Grp Volume(v), veh/h	11	191	0	0	212	63	0	109	0	39	0	0
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1717	0	0
Q Serve(g_s), s	0.2	1.3	0.0	0.0	3.7	1.0	0.0	2.0	0.0	0.8	0.0	0.0
Cycle Q Clear(g_c), s	0.2	1.3	0.0	0.0	3.7	1.0	0.0	2.0	0.0	0.8	0.0	0.0
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	0.64		0.36
Lane Grp Cap(c), veh/h	333	1361	0	0	390	504	195	205	174	185	0	0
V/C Ratio(X)	0.03	0.14	0.00	0.00	0.54	0.12	0.00	0.53	0.00	0.21	0.00	0.00
Avail Cap(c_a), veh/h	795	4620	0	0	1621	1550	3167	3326	2827	1017	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	10.3	7.5	0.0	0.0	13.1	9.1	0.0	15.7	0.0	15.1	0.0	0.0
Incr Delay (d2), s/veh	0.0	0.0	0.0	0.0	1.2	0.1	0.0	2.1	0.0	0.6	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.1	0.6	0.0	0.0	2.1	0.5	0.0	1.2	0.0	0.4	0.0	0.0
LnGrp Delay(d),s/veh	10.4	7.6	0.0	0.0	14.3	9.2	0.0	17.8	0.0	15.7	0.0	0.0
LnGrp LOS	B	A			B	A		B		B		
Approach Vol, veh/h		202			275			109			39	
Approach Delay, s/veh		7.7			13.1			17.8			15.7	
Approach LOS		A			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		20.1		10.0	6.4	13.7		7.0
Change Period (Y+Rc), s		6.0		6.0	6.0	6.0		3.0
Max Green Setting (Gmax), s		48.0		22.0	10.0	32.0		65.0
Max Q Clear Time (g_c+I1), s		3.3		2.8	2.2	5.7		3.0
Green Ext Time (p_c), s		2.1		0.1	0.0	2.0		0.4

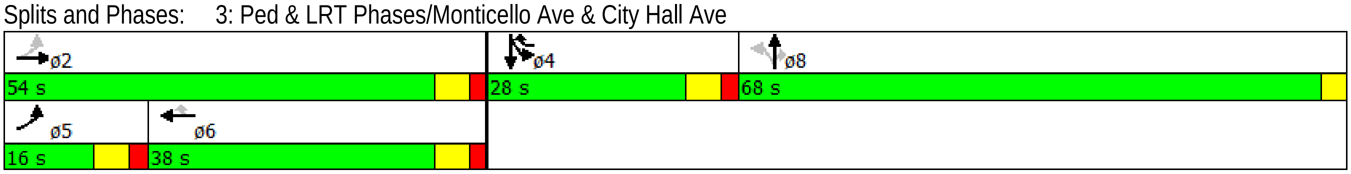
Intersection Summary		
HCM 2010 Ctrl Delay		12.4
HCM 2010 LOS		B

Timing Report, Sorted By Phase
3: Ped & LRT Phases/Monticello Ave & City Hall Ave

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	54	28	16	38	68
Maximum Split (%)	36.0%	18.7%	10.7%	25.3%	45.3%
Minimum Split (s)	22	22	10	22	20.5
Yellow Time (s)	4	4	4	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	54	0	16	82
End Time (s)	54	82	16	54	0
Yield/Force Off (s)	48	76	10	48	147
Yield/Force Off 170(s)	37	76	10	48	147
Local Start Time (s)	0	54	0	16	82
Local Yield (s)	48	76	10	48	147
Local Yield 170(s)	37	76	10	48	147

Intersection Summary	
Cycle Length	150
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped & LRT Phases/Monticello Ave & City Hall Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑			↑	↱	↰	↑	↱		✣	
Volume (veh/h)	10	176	0	0	195	58	0	100	0	23	0	13
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1900	1881	1900
Adj Flow Rate, veh/h	11	191	0	0	212	63	0	109	0	25	0	14
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	335	1366	0	0	394	507	194	204	174	118	0	66
Arrive On Green	0.01	0.38	0.00	0.00	0.21	0.21	0.00	0.11	0.00	0.11	0.00	0.11
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1101	0	616
Grp Volume(v), veh/h	11	191	0	0	212	63	0	109	0	39	0	0
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1717	0	0
Q Serve(g_s), s	0.2	1.3	0.0	0.0	3.7	1.0	0.0	2.0	0.0	0.8	0.0	0.0
Cycle Q Clear(g_c), s	0.2	1.3	0.0	0.0	3.7	1.0	0.0	2.0	0.0	0.8	0.0	0.0
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	0.64		0.36
Lane Grp Cap(c), veh/h	335	1366	0	0	394	507	194	204	174	185	0	0
V/C Ratio(X)	0.03	0.14	0.00	0.00	0.54	0.12	0.00	0.53	0.00	0.21	0.00	0.00
Avail Cap(c_a), veh/h	796	7585	0	0	3184	2878	1653	1735	1475	1015	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	10.3	7.5	0.0	0.0	13.1	9.0	0.0	15.7	0.0	15.2	0.0	0.0
Incr Delay (d2), s/veh	0.0	0.0	0.0	0.0	1.1	0.1	0.0	2.2	0.0	0.6	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.1	0.6	0.0	0.0	2.1	0.5	0.0	1.2	0.0	0.4	0.0	0.0
LnGrp Delay(d),s/veh	10.3	7.6	0.0	0.0	14.3	9.2	0.0	17.9	0.0	15.7	0.0	0.0
LnGrp LOS	B	A			B	A		B		B		
Approach Vol, veh/h		202			275			109			39	
Approach Delay, s/veh		7.7			13.1			17.9			15.7	
Approach LOS		A			B			B			B	

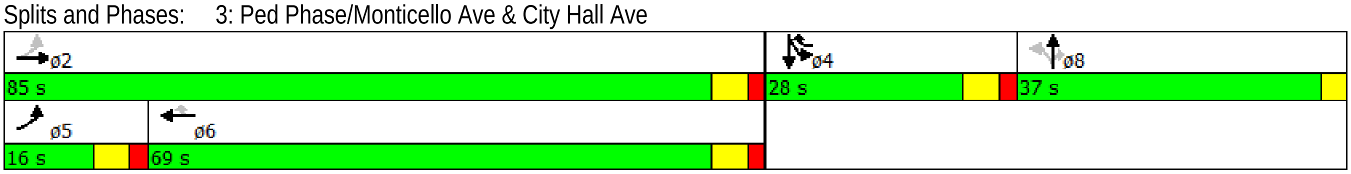
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		20.2		10.0	6.4	13.8		7.0
Change Period (Y+Rc), s		6.0		6.0	6.0	6.0		3.0
Max Green Setting (Gmax), s		79.0		22.0	10.0	63.0		34.0
Max Q Clear Time (g_c+I1), s		3.3		2.8	2.2	5.7		3.0
Green Ext Time (p_c), s		2.1		0.1	0.0	2.1		0.4

Intersection Summary		
HCM 2010 Ctrl Delay		12.3
HCM 2010 LOS		B

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	85	28	16	69	37
Maximum Split (%)	56.7%	18.7%	10.7%	46.0%	24.7%
Minimum Split (s)	22	22	10	22	20.5
Yellow Time (s)	4	4	4	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	85	0	16	113
End Time (s)	85	113	16	85	0
Yield/Force Off (s)	79	107	10	79	147
Yield/Force Off 170(s)	68	107	10	79	147
Local Start Time (s)	0	85	0	16	113
Local Yield (s)	79	107	10	79	147
Local Yield 170(s)	68	107	10	79	147

Intersection Summary	
Cycle Length	150
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped Phase/Monticello Ave & City Hall Ave



HCM 2010 Signalized Intersection Summary
3: Ped & LRT Phases/Monticello Ave & City Hall Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↑			↑	↱	↰	↑	↱		✣	
Volume (veh/h)	53	437	0	0	225	91	0	100	0	114	0	21
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1900	1881	1900
Adj Flow Rate, veh/h	58	475	0	0	245	99	0	109	0	124	0	23
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	376	1502	0	0	440	593	169	177	151	203	0	38
Arrive On Green	0.05	0.42	0.00	0.00	0.23	0.23	0.00	0.09	0.00	0.14	0.00	0.14
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1483	0	275
Grp Volume(v), veh/h	58	475	0	0	245	99	0	109	0	147	0	0
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1758	0	0
Q Serve(g_s), s	1.0	3.8	0.0	0.0	4.9	1.8	0.0	2.4	0.0	3.4	0.0	0.0
Cycle Q Clear(g_c), s	1.0	3.8	0.0	0.0	4.9	1.8	0.0	2.4	0.0	3.4	0.0	0.0
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	0.84		0.16
Lane Grp Cap(c), veh/h	376	1502	0	0	440	593	169	177	151	241	0	0
V/C Ratio(X)	0.15	0.32	0.00	0.00	0.56	0.17	0.00	0.62	0.00	0.61	0.00	0.00
Avail Cap(c_a), veh/h	459	2499	0	0	877	964	2910	3055	2597	1065	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	10.6	8.3	0.0	0.0	14.5	9.1	0.0	18.7	0.0	17.4	0.0	0.0
Incr Delay (d2), s/veh	0.2	0.1	0.0	0.0	1.1	0.1	0.0	3.4	0.0	2.5	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	1.9	0.0	0.0	2.7	1.0	0.0	1.4	0.0	1.8	0.0	0.0
LnGrp Delay(d),s/veh	10.8	8.4	0.0	0.0	15.6	9.2	0.0	22.2	0.0	19.9	0.0	0.0
LnGrp LOS	B	A			B	A		C		B		
Approach Vol, veh/h		533			344			109			147	
Approach Delay, s/veh		8.7			13.7			22.2			19.9	
Approach LOS		A			B			C			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		24.0		11.9	8.0	16.0		7.0
Change Period (Y+Rc), s		6.0		6.0	6.0	6.0		3.0
Max Green Setting (Gmax), s		30.0		26.0	4.0	20.0		69.0
Max Q Clear Time (g_c+I1), s		5.8		5.4	3.0	6.9		3.4
Green Ext Time (p_c), s		3.8		0.5	0.0	3.1		0.4

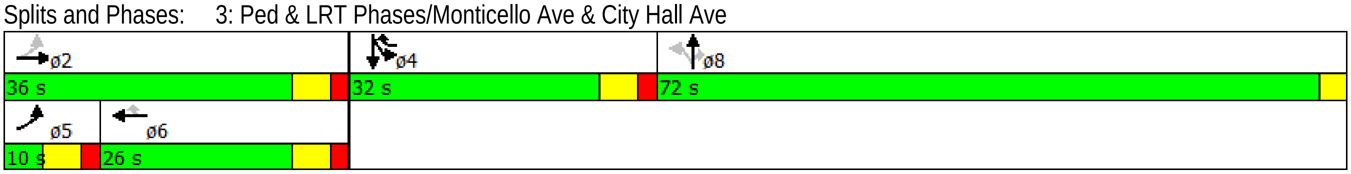
Intersection Summary			
HCM 2010 Ctrl Delay			13.0
HCM 2010 LOS			B

Timing Report, Sorted By Phase
3: Ped & LRT Phases/Monticello Ave & City Hall Ave

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	36	32	10	26	72
Maximum Split (%)	25.7%	22.9%	7.1%	18.6%	51.4%
Minimum Split (s)	22	22	10	22	20.5
Yellow Time (s)	4	4	4	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	36	0	10	68
End Time (s)	36	68	10	36	0
Yield/Force Off (s)	30	62	4	30	137
Yield/Force Off 170(s)	19	62	4	30	137
Local Start Time (s)	0	36	0	10	68
Local Yield (s)	30	62	4	30	137
Local Yield 170(s)	19	62	4	30	137

Intersection Summary	
Cycle Length	140
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped & LRT Phases/Monticello Ave & City Hall Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	53	437	0	0	225	91	0	100	0	114	0	21
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	0	0	1881	1881	1900	1900	1900	1900	1881	1900
Adj Flow Rate, veh/h	58	475	0	0	245	99	0	109	0	124	0	23
Adj No. of Lanes	1	2	0	0	1	1	1	1	1	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	0	0	1	1	0	0	0	1	1	1
Cap, veh/h	389	1542	0	0	468	615	165	173	147	201	0	37
Arrive On Green	0.05	0.43	0.00	0.00	0.25	0.25	0.00	0.09	0.00	0.14	0.00	0.14
Sat Flow, veh/h	1792	3668	0	0	1881	1599	1810	1900	1615	1483	0	275
Grp Volume(v), veh/h	58	475	0	0	245	99	0	109	0	147	0	0
Grp Sat Flow(s),veh/h/ln	1792	1787	0	0	1881	1599	1810	1900	1615	1758	0	0
Q Serve(g_s), s	1.0	3.8	0.0	0.0	4.9	1.8	0.0	2.4	0.0	3.5	0.0	0.0
Cycle Q Clear(g_c), s	1.0	3.8	0.0	0.0	4.9	1.8	0.0	2.4	0.0	3.5	0.0	0.0
Prop In Lane	1.00		0.00	0.00		1.00	1.00		1.00	0.84		0.16
Lane Grp Cap(c), veh/h	389	1542	0	0	468	615	165	173	147	239	0	0
V/C Ratio(X)	0.15	0.31	0.00	0.00	0.52	0.16	0.00	0.63	0.00	0.62	0.00	0.00
Avail Cap(c_a), veh/h	469	4966	0	0	2185	2074	1566	1644	1398	1041	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	10.4	8.2	0.0	0.0	14.2	8.9	0.0	19.2	0.0	17.9	0.0	0.0
Incr Delay (d2), s/veh	0.2	0.1	0.0	0.0	0.9	0.1	0.0	3.7	0.0	2.6	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	1.9	0.0	0.0	2.6	1.0	0.0	1.5	0.0	1.8	0.0	0.0
LnGrp Delay(d),s/veh	10.6	8.3	0.0	0.0	15.2	9.0	0.0	23.0	0.0	20.5	0.0	0.0
LnGrp LOS	B	A			B	A		C		C		
Approach Vol, veh/h		533			344			109			147	
Approach Delay, s/veh		8.5			13.4			2[illegible]0			20.5	
Approach LOS		A			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		24.9		12.0	8.0	16.9		7.0
Change Period (Y+Rc), s		6.0		6.0	6.0	6.0		3.0
Max Green Setting (Gmax), s		61.0		26.0	4.0	51.0		38.0
Max Q Clear Time (g_c+I1), s		5.8		5.5	3.0	6.9		3.4
Green Ext Time (p_c), s		4.0		0.5	0.0	4.0		0.4

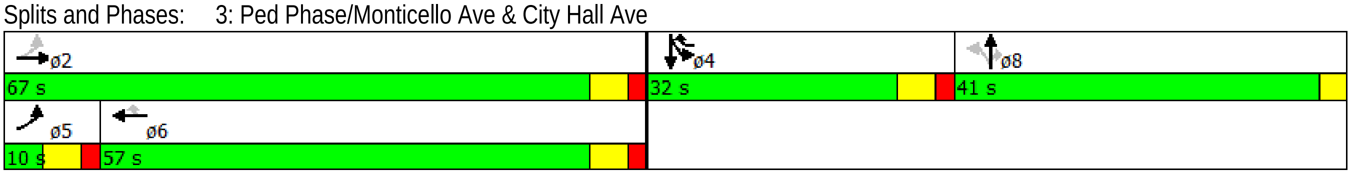
Intersection Summary	
HCM 2010 Ctrl Delay	12.9
HCM 2010 LOS	B

Timing Report, Sorted By Phase
3: Ped Phase/Monticello Ave & City Hall Ave

Phase Number	2	4	5	6	8
Movement	EBTL	SBTL	EBL	WBT	NBTL
Lead/Lag			Lead	Lag	
Lead-Lag Optimize			Yes	Yes	
Recall Mode	None	Min	None	Min	Min
Maximum Split (s)	67	32	10	57	41
Maximum Split (%)	47.9%	22.9%	7.1%	40.7%	29.3%
Minimum Split (s)	22	22	10	22	20.5
Yellow Time (s)	4	4	4	4	3
All-Red Time (s)	2	2	2	2	0
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)	5	5		5	5
Flash Dont Walk (s)	11	11		11	11
Dual Entry	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	67	0	10	99
End Time (s)	67	99	10	67	0
Yield/Force Off (s)	61	93	4	61	137
Yield/Force Off 170(s)	50	93	4	61	137
Local Start Time (s)	0	67	0	10	99
Local Yield (s)	61	93	4	61	137
Local Yield 170(s)	50	93	4	61	137

Intersection Summary	
Cycle Length	140
Control Type	Actuated-Uncoordinated
Natural Cycle	75

Splits and Phases: 3: Ped Phase/Monticello Ave & City Hall Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	11	49	7	8	44	31	0	34	31	57	41	23
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1900	1863	1900
Adj Flow Rate, veh/h	13	56	8	9	51	36	0	39	36	66	47	26
Adj No. of Lanes	0	1	0	0	1	0	0	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	115	444	58	74	323	207	0	214	198	190	135	75
Arrive On Green	0.32	0.32	0.31	0.29	0.32	0.31	0.00	0.24	0.25	0.23	0.23	0.24
Sat Flow, veh/h	183	1387	182	66	1010	646	0	893	824	837	596	330
Grp Volume(v), veh/h	77	0	0	96	0	0	0	0	75	139	0	0
Grp Sat Flow(s),veh/h/ln	1752	0	0	1722	0	0	0	0	1717	1763	0	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	5.0	0.0	0.0
Cycle Q Clear(g_c), s	2.2	0.0	0.0	3.0	0.0	0.0	0.0	0.0	2.6	5.0	0.0	0.0
Prop In Lane	0.17		0.10	0.09		0.37	0.00		0.48	0.47		0.19
Lane Grp Cap(c), veh/h	617	0	0	558	0	0	0	0	412	400	0	0
V/C Ratio(X)	0.12	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.18	0.35	0.00	0.00
Avail Cap(c_a), veh/h	617	0	0	558	0	0	0	0	412	400	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	18.1	0.0	0.0	18.6	0.0	0.0	0.0	0.0	22.5	24.3	0.0	0.0
Incr Delay (d2), s/veh	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.0	1.0	2.4	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.2	0.0	0.0	1.6	0.0	0.0	0.0	0.0	1.3	2.7	0.0	0.0
LnGrp Delay(d),s/veh	18.6	0.0	0.0	19.2	0.0	0.0	0.0	0.0	23.4	26.6	0.0	0.0
LnGrp LOS	B			B					C	C		
Approach Vol, veh/h		77			96			75			139	
Approach Delay, s/veh		18.6			19.2			23.4			26.6	
Approach LOS		B			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		24.0		28.0		23.0		28.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		19.0		23.0		18.0		23.0
Max Q Clear Time (g_c+I1), s		4.6		4.2		7.0		5.0
Green Ext Time (p_c), s		0.2		0.9		0.3		0.9

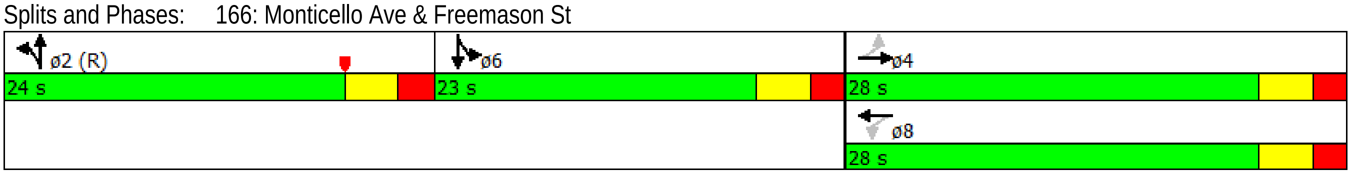
Intersection Summary	
HCM 2010 Ctrl Delay	22.6
HCM 2010 LOS	C

Timing Report, Sorted By Phase
166: Monticello Ave & Freemason St

Phase Number	2	4	6	8
Movement	NBTL	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	Max	Max	Max	Max
Maximum Split (s)	24	28	23	28
Maximum Split (%)	32.0%	37.3%	30.7%	37.3%
Minimum Split (s)	21	28	17	28
Yellow Time (s)	3	3	3	3
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	10	10	10	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)	7	7	7	7
Flash Dont Walk (s)	9	16	5	16
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	32	4	56	4
End Time (s)	56	32	4	32
Yield/Force Off (s)	51	27	74	27
Yield/Force Off 170(s)	42	11	69	11
Local Start Time (s)	56	28	5	28
Local Yield (s)	0	51	23	51
Local Yield 170(s)	66	35	18	35

Intersection Summary	
Cycle Length	75
Control Type	Pretimed
Natural Cycle	70
Offset: 51 (68%), Referenced to phase 2:NBTL, Start of Yellow	

Splits and Phases: 166: Monticello Ave & Freemason St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	6	74	10	25	25	38	6	115	43	80	92	16
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1900	1863	1900
Adj Flow Rate, veh/h	7	85	12	29	29	44	7	132	50	92	106	18
Adj No. of Lanes	0	1	0	0	1	0	0	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	69	534	72	183	193	235	15	284	107	153	176	30
Arrive On Green	0.34	0.34	0.33	0.31	0.34	0.33	0.26	0.23	0.24	0.33	0.33	0.36
Sat Flow, veh/h	41	1559	209	343	562	686	66	1241	470	766	882	150
Grp Volume(v), veh/h	104	0	0	102	0	0	189	0	0	216	0	0
Grp Sat Flow(s),veh/h/ln	1809	0	0	1591	0	0	1777	0	0	1798	0	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0	7.0	0.0	0.0
Cycle Q Clear(g_c), s	2.8	0.0	0.0	3.0	0.0	0.0	6.4	0.0	0.0	7.0	0.0	0.0
Prop In Lane	0.07		0.12	0.28		0.43	0.04		0.26	0.43		0.08
Lane Grp Cap(c), veh/h	675	0	0	566	0	0	406	0	0	360	0	0
V/C Ratio(X)	0.15	0.00	0.00	0.18	0.00	0.00	0.47	0.00	0.00	0.60	0.00	0.00
Avail Cap(c_a), veh/h	675	0	0	566	0	0	406	0	0	360	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.67	1.67	1.67
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	16.1	0.0	0.0	16.4	0.0	0.0	23.2	0.0	0.0	20.9	0.0	0.0
Incr Delay (d2), s/veh	0.5	0.0	0.0	0.7	0.0	0.0	3.8	0.0	0.0	7.2	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.5	0.0	0.0	1.6	0.0	0.0	3.6	0.0	0.0	4.1	0.0	0.0
LnGrp Delay(d),s/veh	16.6	0.0	0.0	17.1	0.0	0.0	27.0	0.0	0.0	28.2	0.0	0.0
LnGrp LOS	B			B			C			C		
Approach Vol, veh/h		104			102			189			216	
Approach Delay, s/veh		16.6			17.1			27.0			28.2	
Approach LOS		B			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		22.0		28.0		20.0		28.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		17.0		23.0		15.0		23.0
Max Q Clear Time (g_c+I1), s		8.4		4.8		9.0		5.0
Green Ext Time (p_c), s		0.4		1.1		0.4		1.1

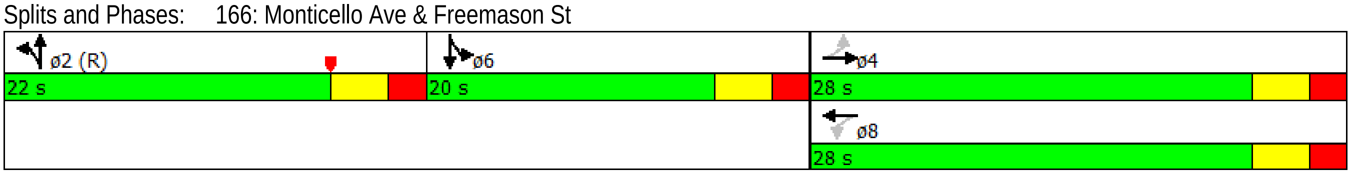
Intersection Summary	
HCM 2010 Ctrl Delay	24.0
HCM 2010 LOS	C

Timing Report, Sorted By Phase
166: Monticello Ave & Freemason St

Phase Number	2	4	6	8
Movement	NBTL	EBTL	SBTL	WBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	Max	Max	Max	Max
Maximum Split (s)	22	28	20	28
Maximum Split (%)	31.4%	40.0%	28.6%	40.0%
Minimum Split (s)	21	28	17	28
Yellow Time (s)	3	3	3	3
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	10	10	10	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)	7	7	7	7
Flash Dont Walk (s)	9	16	5	16
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	58	30	10	30
End Time (s)	10	58	30	58
Yield/Force Off (s)	5	53	25	53
Yield/Force Off 170(s)	66	37	20	37
Local Start Time (s)	53	25	5	25
Local Yield (s)	0	48	20	48
Local Yield 170(s)	61	32	15	32

Intersection Summary	
Cycle Length	70
Control Type	Pretimed
Natural Cycle	70
Offset: 5 (7%), Referenced to phase 2:NBTL, Start of Yellow	

Splits and Phases: 166: Monticello Ave & Freemason St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	2	16	5	23	0	86	0	76	21	62	91	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1863	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	2	18	6	26	0	99	0	88	24	71	105	0
Adj No. of Lanes	0	1	0	1	1	0	0	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	67	402	125	524	0	443	0	338	92	378	993	0
Arrive On Green	0.31	0.31	0.31	0.31	0.00	0.33	0.00	0.08	0.08	0.21	0.53	0.00
Sat Flow, veh/h	50	1311	408	1381	0	1583	0	1410	385	1774	1863	0
Grp Volume(v), veh/h	26	0	0	26	0	99	0	0	112	71	105	0
Grp Sat Flow(s),veh/h/ln	1769	0	0	1381	0	1583	0	0	1795	1774	1863	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	4.4	2.5	2.1	0.0
Cycle Q Clear(g_c), s	0.8	0.0	0.0	0.8	0.0	3.4	0.0	0.0	4.4	2.5	2.1	0.0
Prop In Lane	0.08		0.23	1.00		1.00	0.00		0.21	1.00		0.00
Lane Grp Cap(c), veh/h	594	0	0	524	0	443	0	0	431	378	993	0
V/C Ratio(X)	0.04	0.00	0.00	0.05	0.00	0.22	0.00	0.00	0.26	0.19	0.11	0.00
Avail Cap(c_a), veh/h	594	0	0	524	0	443	0	0	431	378	993	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	18.3	0.0	0.0	18.3	0.0	19.1	0.0	0.0	28.3	24.2	8.7	0.0
Incr Delay (d2), s/veh	0.1	0.0	0.0	0.2	0.0	1.2	0.0	0.0	1.5	1.1	0.2	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.4	0.0	0.0	0.4	0.0	1.6	0.0	0.0	2.4	1.3	1.1	0.0
LnGrp Delay(d),s/veh	18.4	0.0	0.0	18.5	0.0	20.3	0.0	0.0	29.7	25.3	8.9	0.0
LnGrp LOS	B			B		C			C	C	A	
Approach Vol, veh/h		26			125			112			176	
Approach Delay, s/veh		18.4			19.9			29.7			15.5	
Approach LOS		B			B			C			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	22.0	24.0		29.0		46.0		29.0
Change Period (Y+Rc), s	6.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	16.0	18.0		23.0		40.0		23.0
Max Q Clear Time (g_c+I1), s	4.5	6.4		2.8		4.1		5.4
Green Ext Time (p_c), s	0.1	0.6		0.5		0.9		0.5

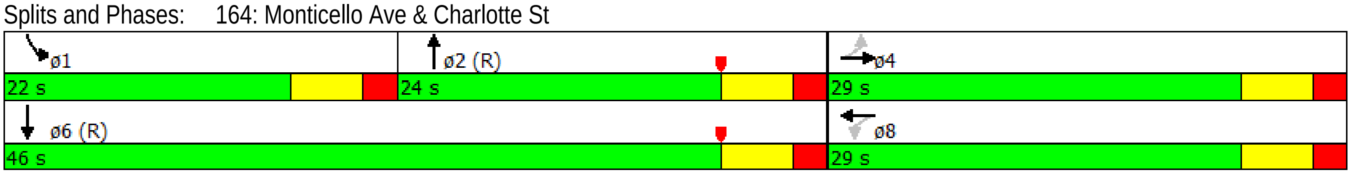
Intersection Summary	
HCM 2010 Ctrl Delay	20.6
HCM 2010 LOS	C

Timing Report, Sorted By Phase
164: Monticello Ave & Charlotte St

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lead	Lag			
Lead-Lag Optimize					
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	22	24	29	46	29
Maximum Split (%)	29.3%	32.0%	38.7%	61.3%	38.7%
Minimum Split (s)	11	23	29	23	29
Yellow Time (s)	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2
Minimum Initial (s)	5	10	10	10	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	3	3	3	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		7	7	7	5
Flash Dont Walk (s)		10	16	10	11
Dual Entry	No	No	No	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	26	48	72	26	72
End Time (s)	48	72	26	72	26
Yield/Force Off (s)	42	66	20	66	20
Yield/Force Off 170(s)	42	56	4	56	9
Local Start Time (s)	35	57	6	35	6
Local Yield (s)	51	0	29	0	29
Local Yield 170(s)	51	65	13	65	18

Intersection Summary	
Cycle Length	75
Control Type	Pretimed
Natural Cycle	65
Offset: 66 (88%), Referenced to phase 2:NBT and 6:SBT, Start of Yellow	

Splits and Phases: 164: Monticello Ave & Charlotte St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	6	47	11	27	0	103	0	152	27	96	134	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1863	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	7	54	13	31	0	119	0	175	31	111	154	0
Adj No. of Lanes	0	1	0	1	1	0	0	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	80	457	102	552	0	475	0	440	78	228	931	0
Arrive On Green	0.33	0.33	0.33	0.33	0.00	0.36	0.00	0.09	0.09	0.13	0.50	0.00
Sat Flow, veh/h	71	1392	312	1329	0	1583	0	1541	273	1774	1863	0
Grp Volume(v), veh/h	74	0	0	31	0	119	0	0	206	111	154	0
Grp Sat Flow(s),veh/h/ln	1774	0	0	1329	0	1583	0	0	1815	1774	1863	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	3.7	0.0	0.0	7.5	4.1	3.2	0.0
Cycle Q Clear(g_c), s	2.0	0.0	0.0	0.8	0.0	3.7	0.0	0.0	7.5	4.1	3.2	0.0
Prop In Lane	0.09		0.18	1.00		1.00	0.00		0.15	1.00		0.00
Lane Grp Cap(c), veh/h	639	0	0	552	0	475	0	0	518	228	931	0
V/C Ratio(X)	0.12	0.00	0.00	0.06	0.00	0.25	0.00	0.00	0.40	0.49	0.17	0.00
Avail Cap(c_a), veh/h	639	0	0	552	0	475	0	0	518	228	931	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	16.5	0.0	0.0	16.1	0.0	16.9	0.0	0.0	26.0	28.4	9.5	0.0
Incr Delay (d2), s/veh	0.4	0.0	0.0	0.2	0.0	1.3	0.0	0.0	2.3	7.3	0.4	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.1	0.0	0.0	0.4	0.0	1.8	0.0	0.0	4.1	2.5	1.7	0.0
LnGrp Delay(d),s/veh	16.8	0.0	0.0	16.3	0.0	18.2	0.0	0.0	28.3	35.6	9.9	0.0
LnGrp LOS	B			B		B			C	D	A	
Approach Vol, veh/h		74			150			206			265	
Approach Delay, s/veh		16.8			17.8			28.3			20.7	
Approach LOS		B			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	15.0	26.0		29.0		41.0		29.0
Change Period (Y+Rc), s	6.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	9.0	20.0		23.0		35.0		23.0
Max Q Clear Time (g_c+I1), s	6.1	9.5		4.0		5.2		2.8
Green Ext Time (p_c), s	0.1	1.1		0.1		1.5		0.1

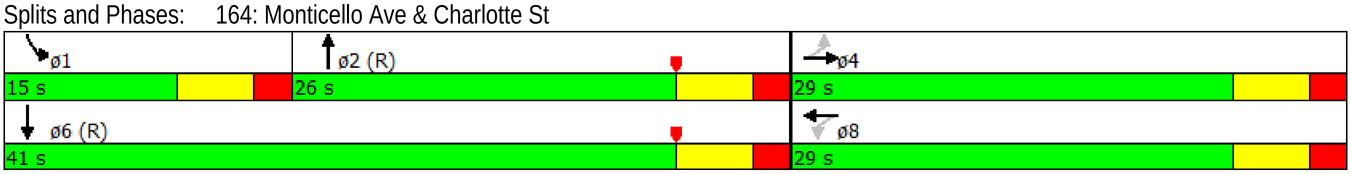
Intersection Summary			
HCM 2010 Ctrl Delay			21.9
HCM 2010 LOS			C

Timing Report, Sorted By Phase
164: Monticello Ave & Charlotte St

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lead	Lag			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	15	26	29	41	29
Maximum Split (%)	21.4%	37.1%	41.4%	58.6%	41.4%
Minimum Split (s)	11	23	29	23	29
Yellow Time (s)	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2
Minimum Initial (s)	5	10	10	10	10
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	3	3	3	3
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		7	7	7	7
Flash Dont Walk (s)		10	16	10	16
Dual Entry	No	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	55	0	26	55	26
End Time (s)	0	26	55	26	55
Yield/Force Off (s)	64	20	49	20	49
Yield/Force Off 170(s)	64	10	33	10	33
Local Start Time (s)	35	50	6	35	6
Local Yield (s)	44	0	29	0	29
Local Yield 170(s)	44	60	13	60	13

Intersection Summary	
Cycle Length	70
Control Type	Pretimed
Natural Cycle	65
Offset: 20 (29%), Referenced to phase 2:NBT and 6:SBT, Start of Yellow	

Splits and Phases: 164: Monticello Ave & Charlotte St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	17	2	0	25	17	33	1106	7	12	726	6
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	0	20	2	0	29	20	38	1274	8	14	836	7
Adj No. of Lanes	1	1	0	1	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	1	282	28	1	174	120	568	2247	14	354	1992	17
Arrive On Green	0.00	0.17	0.18	0.00	0.17	0.18	0.14	0.62	0.62	0.07	0.55	0.55
Sat Flow, veh/h	1774	1667	167	1774	1028	709	1774	3606	23	1774	3597	30
Grp Volume(v), veh/h	0	0	22	0	0	49	38	625	657	14	411	432
Grp Sat Flow(s),veh/h/ln	1774	0	1833	1774	0	1738	1774	1770	1859	1774	1770	1857
Q Serve(g_s), s	0.0	0.0	1.3	0.0	0.0	3.1	0.9	26.8	26.8	0.4	17.6	17.6
Cycle Q Clear(g_c), s	0.0	0.0	1.3	0.0	0.0	3.1	0.9	26.8	26.8	0.4	17.6	17.6
Prop In Lane	1.00		0.09	1.00		0.41	1.00		0.01	1.00		0.02
Lane Grp Cap(c), veh/h	1	0	310	1	0	294	568	1103	1158	354	980	1029
V/C Ratio(X)	0.00	0.00	0.07	0.00	0.00	0.17	0.07	0.57	0.57	0.04	0.42	0.42
Avail Cap(c_a), veh/h	177	0	310	191	0	294	568	1103	1158	354	980	1029
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	0.0	0.0	45.4	0.0	0.0	46.0	7.5	14.3	14.3	10.9	16.9	16.9
Incr Delay (d2), s/veh	0.0	0.0	0.4	0.0	0.0	1.2	0.2	2.1	2.0	0.2	1.3	1.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.0	0.0	0.7	0.0	0.0	1.6	0.4	13.7	14.3	0.2	8.9	9.4
LnGrp Delay(d),s/veh	0.0	0.0	45.8	0.0	0.0	47.2	7.8	16.4	16.3	11.2	18.2	18.1
LnGrp LOS			D			D	A	B	B	B	B	B
Approach Vol, veh/h		22			49			1320			857	
Approach Delay, s/veh		45.8			47.2			16.1			18.0	
Approach LOS		D			D			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	15.0	87.0	0.0	28.0	24.0	78.0	0.0	28.0
Change Period (Y+Rc), s	5.0	6.0	5.0	5.0	5.0	6.0	6.0	5.0
Max Green Setting (Gmax), s	10.0	81.0	15.0	23.0	19.0	72.0	14.0	23.0
Max Q Clear Time (g_c+I1), s	2.4	28.8	0.0	3.3	2.9	19.6	0.0	5.1
Green Ext Time (p_c), s	0.0	15.4	0.0	0.2	0.1	15.4	0.0	0.2

Intersection Summary	
HCM 2010 Ctrl Delay	17.8
HCM 2010 LOS	B

Phase Number	1	2	3	4	5	6	7	8
Movement	SBL	NBTL	WBL	EBT	NBL	SBTL	EBL	WBT
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize								
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	15	87	20	28	24	78	20	28
Maximum Split (%)	10.0%	58.0%	13.3%	18.7%	16.0%	52.0%	13.3%	18.7%
Minimum Split (s)	10	28	15	27	10	28	10	27
Yellow Time (s)	3	4	3	3	3	4	4	3
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	4	15	10	5	4	15	4	5
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	2	4	0	3	2	4	0	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		7		7		7
Flash Dont Walk (s)		15		15		15		15
Dual Entry	No	Yes	No	Yes	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	130	145	82	102	130	4	82	102
End Time (s)	145	82	102	130	4	82	102	130
Yield/Force Off (s)	140	76	97	125	149	76	96	125
Yield/Force Off 170(s)	140	61	97	110	149	61	96	110
Local Start Time (s)	54	69	6	26	54	78	6	26
Local Yield (s)	64	0	21	49	73	0	20	49
Local Yield 170(s)	64	135	21	34	73	135	20	34

Intersection Summary	
Cycle Length	150
Control Type	Pretimed
Natural Cycle	90
Offset: 76 (51%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	4	13	2	4	21	17	33	1106	7	12	726	6
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	5	15	2	5	24	20	38	1274	8	14	836	7
Adj No. of Lanes	0	1	0	0	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	69	191	23	38	138	103	579	2428	15	364	2206	18
Arrive On Green	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.67	0.67	0.06	0.61	0.61
Sat Flow, veh/h	273	1303	158	76	938	699	1774	3606	23	1774	3597	30
Grp Volume(v), veh/h	22	0	0	49	0	0	38	625	657	14	411	432
Grp Sat Flow(s),veh/h/ln	1733	0	0	1713	0	0	1774	1770	1859	1774	1770	1857
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	0.9	26.8	26.8	0.4	17.6	17.6
Cycle Q Clear(g_c), s	1.6	0.0	0.0	3.7	0.0	0.0	0.9	26.8	26.8	0.4	17.6	17.6
Prop In Lane	0.23		0.09	0.10		0.41	1.00		0.01	1.00		0.02
Lane Grp Cap(c), veh/h	284	0	0	278	0	0	579	1192	1252	364	1085	1139
V/C Ratio(X)	0.08	0.00	0.00	0.18	0.00	0.00	0.07	0.52	0.52	0.04	0.38	0.38
Avail Cap(c_a), veh/h	284	0	0	278	0	0	579	1192	1252	364	1085	1139
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	55.2	0.0	0.0	56.0	0.0	0.0	6.5	12.4	12.4	9.5	14.6	14.6
Incr Delay (d2), s/veh	0.5	0.0	0.0	1.4	0.0	0.0	0.2	1.7	1.6	0.2	1.0	1.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.8	0.0	0.0	1.9	0.0	0.0	0.4	13.6	14.2	0.2	8.9	9.3
LnGrp Delay(d),s/veh	55.8	0.0	0.0	57.4	0.0	0.0	6.8	14.0	14.0	9.7	15.6	15.6
LnGrp LOS	E			E			A	B	B	A	B	B
Approach Vol, veh/h		22			49			1320			857	
Approach Delay, s/veh		55.8			57.4			13.8			15.5	
Approach LOS		E			E			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	15.0	107.0		28.0	24.0	98.0		28.0
Change Period (Y+Rc), s	5.0	6.0		5.0	5.0	6.0		5.0
Max Green Setting (Gmax), s	10.0	101.0		23.0	19.0	92.0		23.0
Max Q Clear Time (g_c+I1), s	2.4	28.8		3.6	2.9	19.6		5.7
Green Ext Time (p_c), s	0.0	16.1		0.2	0.1	16.1		0.2

Intersection Summary			
HCM 2010 Ctrl Delay			15.8
HCM 2010 LOS			B

Phase Number	1	2	4	5	6	8
Movement	SBL	NBTL	EBTL	NBL	SBTL	WBTL
Lead/Lag	Lead	Lag		Lead	Lag	
Lead-Lag Optimize						
Recall Mode	Max	Max	Max	Max	Max	Max
Maximum Split (s)	15	107	28	24	98	28
Maximum Split (%)	10.0%	71.3%	18.7%	16.0%	65.3%	18.7%
Minimum Split (s)	10	28	27	10	28	27
Yellow Time (s)	3	4	3	3	4	3
All-Red Time (s)	2	2	2	2	2	2
Minimum Initial (s)	4	15	5	4	15	5
Vehicle Extension (s)	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3
Time Before Reduce (s)	2	4	3	2	4	3
Time To Reduce (s)	0	0	0	0	0	0
Walk Time (s)		7	7		7	7
Flash Dont Walk (s)		15	15		15	15
Dual Entry	No	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	34	49	6	34	58	6
End Time (s)	49	6	34	58	6	34
Yield/Force Off (s)	44	0	29	53	0	29
Yield/Force Off 170(s)	44	135	14	53	135	14
Local Start Time (s)	34	49	6	34	58	6
Local Yield (s)	44	0	29	53	0	29
Local Yield 170(s)	44	135	14	53	135	14

Intersection Summary	
Cycle Length	150
Control Type	Pretimed
Natural Cycle	70
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	25	17	0	9	17	18	825	13	23	1019	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1900	1863	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	0	29	20	0	10	20	21	951	15	26	1174	0
Adj No. of Lanes	1	1	0	1	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	1	180	124	1	97	194	380	2140	34	452	2124	0
Arrive On Green	0.00	0.17	0.18	0.00	0.17	0.18	0.08	0.60	0.60	0.08	0.60	0.00
Sat Flow, veh/h	1774	1028	709	1774	556	1111	1774	3566	56	1774	3632	0
Grp Volume(v), veh/h	0	0	49	0	0	30	21	472	494	26	1174	0
Grp Sat Flow(s),veh/h/ln	1774	0	1738	1774	0	1667	1774	1770	1853	1774	1770	0
Q Serve(g_s), s	0.0	0.0	2.9	0.0	0.0	1.8	0.5	17.5	17.5	0.6	23.8	0.0
Cycle Q Clear(g_c), s	0.0	0.0	2.9	0.0	0.0	1.8	0.5	17.5	17.5	0.6	23.8	0.0
Prop In Lane	1.00		0.41	1.00		0.67	1.00		0.03	1.00		0.00
Lane Grp Cap(c), veh/h	1	0	304	1	0	292	380	1062	1112	452	2124	0
V/C Ratio(X)	0.00	0.00	0.16	0.00	0.00	0.10	0.06	0.44	0.44	0.06	0.55	0.00
Avail Cap(c_a), veh/h	192	0	304	192	0	292	380	1062	1112	452	2124	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	0.0	0.0	41.8	0.0	0.0	41.3	9.2	13.1	13.1	8.1	14.4	0.0
Incr Delay (d2), s/veh	0.0	0.0	1.1	0.0	0.0	0.7	0.3	1.3	1.3	0.2	1.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.0	0.0	1.5	0.0	0.0	0.9	0.3	8.9	9.3	0.3	11.9	0.0
LnGrp Delay(d),s/veh	0.0	0.0	43.0	0.0	0.0	42.0	9.5	14.4	14.4	8.3	15.4	0.0
LnGrp LOS			D			D	A	B	B	A	B	
Approach Vol, veh/h		49			30			987			1200	
Approach Delay, s/veh		43.0			42.0			14.3			15.3	
Approach LOS		D			D			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	15.0	78.0	0.0	27.0	15.0	78.0	0.0	27.0
Change Period (Y+Rc), s	5.0	6.0	6.0	5.0	5.0	6.0	6.0	5.0
Max Green Setting (Gmax), s	10.0	72.0	14.0	22.0	10.0	72.0	14.0	22.0
Max Q Clear Time (g_c+I1), s	2.6	19.5	0.0	4.9	2.5	25.8	0.0	3.8
Green Ext Time (p_c), s	0.0	17.1	0.0	0.2	0.0	16.6	0.0	0.2

Intersection Summary		
HCM 2010 Ctrl Delay		15.8
HCM 2010 LOS		B

Phase Number	1	2	3	4	5	6	7	8
Movement	SBL	NBTL	WBL	EBT	NBL	SBTL	EBL	WBT
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	15	78	20	27	15	78	20	27
Maximum Split (%)	10.7%	55.7%	14.3%	19.3%	10.7%	55.7%	14.3%	19.3%
Minimum Split (s)	10	28	10	27	10	28	10	27
Yellow Time (s)	3	4	4	3	3	4	4	3
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	4	15	4	5	4	15	4	5
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	2	4	0	3	2	4	0	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		7		7		7		7
Flash Dont Walk (s)		15		15		15		15
Dual Entry	No	Yes	No	Yes	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	53	68	6	26	53	68	6	26
End Time (s)	68	6	26	53	68	6	26	53
Yield/Force Off (s)	63	0	20	48	63	0	20	48
Yield/Force Off 170(s)	63	125	20	33	63	125	20	33
Local Start Time (s)	53	68	6	26	53	68	6	26
Local Yield (s)	63	0	20	48	63	0	20	48
Local Yield 170(s)	63	125	20	33	63	125	20	33

Intersection Summary	
Cycle Length	140
Control Type	Pretimed
Natural Cycle	80
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

HCM 2010 Signalized Intersection Summary
18: Boush St & Bute St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	7	18	17	5	9	17	18	825	13	23	1019	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	8	21	20	6	10	20	21	951	15	26	1174	0
Adj No. of Lanes	0	1	0	0	1	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	54	126	103	54	86	137	394	2343	37	470	2326	0
Arrive On Green	0.15	0.15	0.16	0.15	0.15	0.16	0.06	0.66	0.66	0.06	0.66	0.00
Sat Flow, veh/h	158	839	688	159	571	913	1774	3566	56	1774	3632	0
Grp Volume(v), veh/h	49	0	0	36	0	0	21	472	494	26	1174	0
Grp Sat Flow(s),veh/h/ln	1685	0	0	1643	0	0	1774	1770	1853	1774	1770	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	0.5	17.5	17.5	0.6	23.8	0.0
Cycle Q Clear(g_c), s	3.4	0.0	0.0	2.6	0.0	0.0	0.5	17.5	17.5	0.6	23.8	0.0
Prop In Lane	0.16		0.41	0.17		0.56	1.00		0.03	1.00		0.00
Lane Grp Cap(c), veh/h	283	0	0	276	0	0	394	1163	1218	470	2326	0
V/C Ratio(X)	0.17	0.00	0.00	0.13	0.00	0.00	0.05	0.41	0.41	0.06	0.50	0.00
Avail Cap(c_a), veh/h	283	0	0	276	0	0	394	1163	1218	470	2326	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	51.9	0.0	0.0	51.4	0.0	0.0	7.9	11.2	11.2	6.9	12.3	0.0
Incr Delay (d2), s/veh	1.3	0.0	0.0	1.0	0.0	0.0	0.3	1.1	1.0	0.2	0.8	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.8	0.0	0.0	1.3	0.0	0.0	0.3	8.9	9.3	0.3	11.8	0.0
LnGrp Delay(d),s/veh	53.2	0.0	0.0	52.4	0.0	0.0	8.2	12.3	12.2	7.2	13.1	0.0
LnGrp LOS	D			D			A	B	B	A	B	
Approach Vol, veh/h		49			36			987			1200	
Approach Delay, s/veh		53.2			52.4			12.2			13.0	
Approach LOS		D			D			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	15.0	98.0		27.0	15.0	98.0		27.0
Change Period (Y+Rc), s	5.0	6.0		5.0	5.0	6.0		5.0
Max Green Setting (Gmax), s	10.0	92.0		22.0	10.0	92.0		22.0
Max Q Clear Time (g_c+I1), s	2.6	19.5		5.4	2.5	25.8		4.6
Green Ext Time (p_c), s	0.0	18.1		0.2	0.0	17.9		0.2

Intersection Summary			
HCM 2010 Ctrl Delay			14.1
HCM 2010 LOS			B

Phase Number	1	2	4	5	6	8
Movement	SBL	NBTL	EBTL	NBL	SBTL	WBTL
Lead/Lag	Lead	Lag		Lead	Lag	
Lead-Lag Optimize	Yes	Yes		Yes	Yes	
Recall Mode	Max	Max	Max	Max	Max	Max
Maximum Split (s)	15	98	27	15	98	27
Maximum Split (%)	10.7%	70.0%	19.3%	10.7%	70.0%	19.3%
Minimum Split (s)	10	28	27	10	28	27
Yellow Time (s)	3	4	3	3	4	3
All-Red Time (s)	2	2	2	2	2	2
Minimum Initial (s)	4	15	5	4	15	5
Vehicle Extension (s)	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3
Time Before Reduce (s)	2	4	3	2	4	3
Time To Reduce (s)	0	0	0	0	0	0
Walk Time (s)		7	7		7	7
Flash Dont Walk (s)		15	15		15	15
Dual Entry	No	Yes	Yes	No	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	33	48	6	33	48	6
End Time (s)	48	6	33	48	6	33
Yield/Force Off (s)	43	0	28	43	0	28
Yield/Force Off 170(s)	43	125	13	43	125	13
Local Start Time (s)	33	48	6	33	48	6
Local Yield (s)	43	0	28	43	0	28
Local Yield 170(s)	43	125	13	43	125	13

Intersection Summary	
Cycle Length	140
Control Type	Pretimed
Natural Cycle	65
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	

Splits and Phases: 18: Boush St & Bute St

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	26	19	23	5	29	7	11	89	14	22	88	42
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1900	1863	1900
Adj Flow Rate, veh/h	30	22	26	6	33	8	13	103	16	25	101	48
Adj No. of Lanes	0	1	0	0	1	0	0	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	272	201	203	106	512	116	100	702	103	133	515	226
Arrive On Green	0.39	0.39	0.40	0.41	0.39	0.40	0.48	0.48	0.47	0.15	0.16	0.15
Sat Flow, veh/h	531	519	525	135	1324	299	98	1462	215	162	1072	470
Grp Volume(v), veh/h	78	0	0	47	0	0	132	0	0	174	0	0
Grp Sat Flow(s),veh/h/ln	1574	0	0	1759	0	0	1775	0	0	1704	0	0
Q Serve(g_s), s	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cycle Q Clear(g_c), s	2.1	0.0	0.0	1.2	0.0	0.0	3.1	0.0	0.0	6.4	0.0	0.0
Prop In Lane	0.38		0.33	0.13		0.17	0.10		0.12	0.14		0.28
Lane Grp Cap(c), veh/h	675	0	0	781	0	0	905	0	0	827	0	0
V/C Ratio(X)	0.12	0.00	0.00	0.06	0.00	0.00	0.15	0.00	0.00	0.21	0.00	0.00
Avail Cap(c_a), veh/h	675	0	0	781	0	0	905	0	0	827	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	0.33
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	14.6	0.0	0.0	14.3	0.0	0.0	11.0	0.0	0.0	19.2	0.0	0.0
Incr Delay (d2), s/veh	0.3	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.6	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	1.1	0.0	0.0	0.6	0.0	0.0	1.6	0.0	0.0	3.4	0.0	0.0
LnGrp Delay(d),s/veh	15.0	0.0	0.0	14.5	0.0	0.0	11.3	0.0	0.0	19.7	0.0	0.0
LnGrp LOS	B			B			B			B		
Approach Vol, veh/h		78			47			132			174	
Approach Delay, s/veh		15.0			14.5			11.3			19.7	
Approach LOS		B			B			B			B	

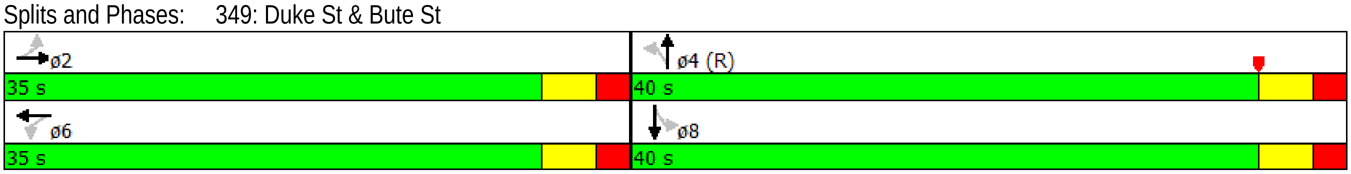
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		35.0		40.0		35.0		40.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		30.0		35.0		30.0		35.0
Max Q Clear Time (g_c+I1), s		4.1		5.1		3.2		8.4
Green Ext Time (p_c), s		0.5		2.0		0.5		2.0

Intersection Summary		
HCM 2010 Ctrl Delay		15.7
HCM 2010 LOS		B

Phase Number	2	4	6	8
Movement	EBTL	NBTL	WBTL	SBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	Max	Max	Max	Max
Maximum Split (s)	35	40	35	40
Maximum Split (%)	46.7%	53.3%	46.7%	53.3%
Minimum Split (s)	27	24	27	24
Yellow Time (s)	3	3	3	3
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	15	10	15	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)	7	7	7	7
Flash Dont Walk (s)	15	12	15	12
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	70	30	70	30
End Time (s)	30	70	30	70
Yield/Force Off (s)	25	65	25	65
Yield/Force Off 170(s)	10	53	10	53
Local Start Time (s)	5	40	5	40
Local Yield (s)	35	0	35	0
Local Yield 170(s)	20	63	20	63

Intersection Summary	
Cycle Length	75
Control Type	Pretimed
Natural Cycle	55
Offset: 65 (87%), Referenced to phase 4:NBTL, Start of Yellow	

Splits and Phases: 349: Duke St & Bute St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✣			✣			✣			✣	
Volume (veh/h)	69	26	19	2	20	12	13	88	4	16	145	48
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1863	1900	1900	1863	1900	1900	1863	1900	1900	1863	1900
Adj Flow Rate, veh/h	80	30	22	2	23	14	15	101	5	18	167	55
Adj No. of Lanes	0	1	0	0	1	0	0	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	375	138	86	63	374	214	128	800	38	87	668	208
Arrive On Green	0.34	0.34	0.36	0.37	0.34	0.36	0.51	0.51	0.50	0.16	0.17	0.17
Sat Flow, veh/h	854	402	251	26	1091	625	137	1556	73	61	1299	404
Grp Volume(v), veh/h	132	0	0	39	0	0	121	0	0	240	0	0
Grp Sat Flow(s),veh/h/ln	1507	0	0	1742	0	0	1766	0	0	1764	0	0
Q Serve(g_s), s	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cycle Q Clear(g_c), s	4.2	0.0	0.0	1.0	0.0	0.0	2.4	0.0	0.0	8.2	0.0	0.0
Prop In Lane	0.61		0.17	0.05		0.36	0.12		0.04	0.07		0.23
Lane Grp Cap(c), veh/h	599	0	0	701	0	0	966	0	0	912	0	0
V/C Ratio(X)	0.22	0.00	0.00	0.06	0.00	0.00	0.13	0.00	0.00	0.26	0.00	0.00
Avail Cap(c_a), veh/h	599	0	0	701	0	0	966	0	0	912	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	0.33
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	16.4	0.0	0.0	15.3	0.0	0.0	8.8	0.0	0.0	17.6	0.0	0.0
Incr Delay (d2), s/veh	0.8	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0	0.7	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	2.0	0.0	0.0	0.5	0.0	0.0	1.3	0.0	0.0	4.5	0.0	0.0
LnGrp Delay(d),s/veh	17.2	0.0	0.0	15.5	0.0	0.0	9.1	0.0	0.0	18.3	0.0	0.0
LnGrp LOS	B			B			A			B		
Approach Vol, veh/h		132			39			121			240	
Approach Delay, s/veh		17.2			15.5			9.1			18.3	
Approach LOS		B			B			A			B	

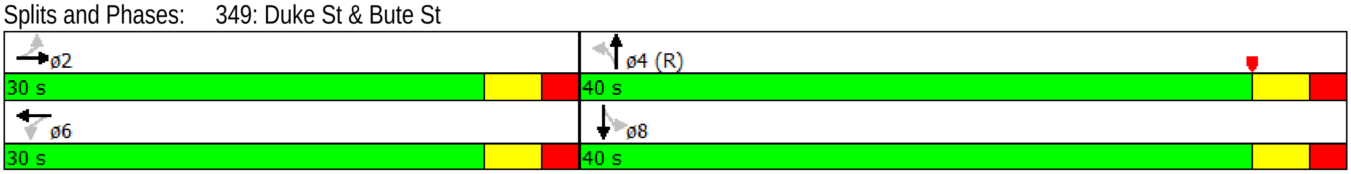
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		30.0		40.0		30.0		40.0
Change Period (Y+Rc), s		5.0		5.0		5.0		5.0
Max Green Setting (Gmax), s		25.0		35.0		25.0		35.0
Max Q Clear Time (g_c+I1), s		6.2		4.4		3.0		10.2
Green Ext Time (p_c), s		0.6		2.4		0.6		2.3

Intersection Summary		
HCM 2010 Ctrl Delay		15.7
HCM 2010 LOS		B

Phase Number	2	4	6	8
Movement	EBTL	NBTL	WBTL	SBTL
Lead/Lag				
Lead-Lag Optimize				
Recall Mode	Max	Max	Max	Max
Maximum Split (s)	30	40	30	40
Maximum Split (%)	42.9%	57.1%	42.9%	57.1%
Minimum Split (s)	27	24	27	24
Yellow Time (s)	3	3	3	3
All-Red Time (s)	2	2	2	2
Minimum Initial (s)	15	10	15	10
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)	7	7	7	7
Flash Dont Walk (s)	15	12	15	12
Dual Entry	No	No	No	No
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	23	53	23	53
End Time (s)	53	23	53	23
Yield/Force Off (s)	48	18	48	18
Yield/Force Off 170(s)	33	6	33	6
Local Start Time (s)	5	35	5	35
Local Yield (s)	30	0	30	0
Local Yield 170(s)	15	58	15	58

Intersection Summary	
Cycle Length	70
Control Type	Pretimed
Natural Cycle	55
Offset: 18 (26%), Referenced to phase 4:NBTL, Start of Yellow	

Splits and Phases: 349: Duke St & Bute St



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	15	809	24	54	1783	108	50	165	16	210	112	24
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1900	1863	1863	1900	1827	1827	1900
Adj Flow Rate, veh/h	17	932	28	62	2054	124	58	190	18	242	129	28
Adj No. of Lanes	1	3	1	1	3	0	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	4	4	4
Cap, veh/h	249	2678	855	399	2584	155	154	279	26	151	243	53
Arrive On Green	0.06	0.53	0.54	0.12	1.00	1.00	0.03	0.06	0.06	0.09	0.17	0.17
Sat Flow, veh/h	1774	5085	1583	1774	4906	295	1774	1676	159	1740	1455	316
Grp Volume(v), veh/h	17	932	28	62	1416	762	58	0	208	242	0	157
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1811	1774	0	1835	1740	0	1771
Q Serve(g_s), s	0.6	15.9	0.8	2.2	0.0	0.0	4.8	0.0	16.7	13.0	0.0	12.2
Cycle Q Clear(g_c), s	0.6	15.9	0.8	2.2	0.0	0.0	4.8	0.0	16.7	13.0	0.0	12.2
Prop In Lane	1.00		1.00	1.00		0.16	1.00		0.09	1.00		0.18
Lane Grp Cap(c), veh/h	249	2678	855	399	1786	954	154	0	306	151	0	295
V/C Ratio(X)	0.07	0.35	0.03	0.16	0.79	0.80	0.38	0.00	0.68	1.60	0.00	0.53
Avail Cap(c_a), veh/h	249	2678	855	399	1786	954	154	0	306	151	0	295
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	0.33	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	12.9	20.6	6.0	13.3	0.0	0.0	68.9	0.0	67.0	68.5	0.0	57.1
Incr Delay (d2), s/veh	0.5	0.4	0.1	0.8	3.7	7.0	6.9	0.0	11.6	300.8	0.0	6.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.3	7.5	0.3	1.1	0.9	1.8	2.7	0.0	9.5	18.8	0.0	6.5
LnGrp Delay(d),s/veh	13.5	20.9	6.1	14.1	3.7	7.0	75.8	0.0	78.5	369.3	0.0	63.9
LnGrp LOS	B	C	A	B	A	A	E		E	F		E
Approach Vol, veh/h		977			2240			266			399	
Approach Delay, s/veh		20.4			5.1			77.9			249.1	
Approach LOS		C			A			E			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	15.0	85.0	19.0	31.0	15.0	85.0	19.0	31.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	9.0	79.0	13.0	25.0	9.0	79.0	13.0	25.0
Max Q Clear Time (g_c+I1), s	4.2	17.9	15.0	18.7	2.6	2.0	6.8	14.2
Green Ext Time (p_c), s	0.1	35.2	0.0	0.4	0.0	39.4	0.1	1.3

Intersection Summary	
HCM 2010 Ctrl Delay	39.0
HCM 2010 LOS	D

Phase Number	1	2	3	4	5	6	7	8
Movement	WBL	EBTL	SBL	NBT	EBL	WBTL	NBL	SBT
Lead/Lag	Lead	Lag	Lag	Lead	Lead	Lag	Lead	Lag
Lead-Lag Optimize								
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	15	85	19	31	15	85	19	31
Maximum Split (%)	10.0%	56.7%	12.7%	20.7%	10.0%	56.7%	12.7%	20.7%
Minimum Split (s)	11	23	13	31	11	23	13	31
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	7	7	5	10	7	7
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	3	4	3	3	3	4	3	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		6		6		6		6
Flash Dont Walk (s)		11		19		11		19
Dual Entry	No	No	No	Yes	No	No	Yes	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	57	72	38	7	57	72	7	26
End Time (s)	72	7	57	38	72	7	26	57
Yield/Force Off (s)	66	1	51	32	66	1	20	51
Yield/Force Off 170(s)	66	140	51	13	66	140	20	32
Local Start Time (s)	56	71	37	6	56	71	6	25
Local Yield (s)	65	0	50	31	65	0	19	50
Local Yield 170(s)	65	139	50	12	65	139	19	31

Intersection Summary	
Cycle Length	150
Control Type	Pretimed
Natural Cycle	120
Offset: 1 (1%), Referenced to phase 2:EBTL and 6:WBTL, Start of Yellow	

Splits and Phases: 234: Duke St & Brambleton Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	26	1741	47	102	946	80	35	97	16	246	179	46
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1900	1863	1863	1900	1827	1827	1900
Adj Flow Rate, veh/h	30	2006	54	118	1090	92	40	112	18	283	206	53
Adj No. of Lanes	1	3	1	1	3	0	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	4	4	4
Cap, veh/h	371	2216	712	205	2082	176	241	280	45	236	250	64
Arrive On Green	0.08	0.44	0.45	0.16	0.87	0.87	0.04	0.06	0.06	0.14	0.18	0.18
Sat Flow, veh/h	1774	5085	1583	1774	4779	403	1774	1567	252	1740	1402	361
Grp Volume(v), veh/h	30	2006	54	118	773	409	40	0	130	283	0	259
Grp Sat Flow(s),veh/h/ln	1774	1695	1583	1774	1695	1792	1774	0	1818	1740	0	1763
Q Serve(g_s), s	1.2	51.5	1.6	4.8	7.5	7.6	3.0	0.0	9.6	19.0	0.0	19.8
Cycle Q Clear(g_c), s	1.2	51.5	1.6	4.8	7.5	7.6	3.0	0.0	9.6	19.0	0.0	19.8
Prop In Lane	1.00		1.00	1.00		0.22	1.00		0.14	1.00		0.20
Lane Grp Cap(c), veh/h	371	2216	712	205	1477	781	241	0	325	236	0	315
V/C Ratio(X)	0.08	0.91	0.08	0.58	0.52	0.52	0.17	0.00	0.40	1.20	0.00	0.82
Avail Cap(c_a), veh/h	371	2216	712	205	1477	781	241	0	325	236	0	315
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	0.33	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	17.0	36.8	7.2	27.8	5.6	5.6	59.2	0.0	58.7	60.5	0.0	55.4
Incr Delay (d2), s/veh	0.4	6.7	0.2	11.3	1.3	2.5	1.5	0.0	3.7	122.8	0.0	21.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(-26165%),veh/ln	0.6	25.3	0.7	2.9	3.5	4.0	1.6	0.0	5.2	17.2	0.0	11.5
LnGrp Delay(d),s/veh	17.4	43.5	7.4	39.1	6.9	8.1	60.7	0.0	62.3	183.3	0.0	76.4
LnGrp LOS	B	D	A	D	A	A	E		E	F		E
Approach Vol, veh/h		2090			1300			170			542	
Approach Delay, s/veh		42.2			10.2			61.9			132.2	
Approach LOS		D			B			E			F	

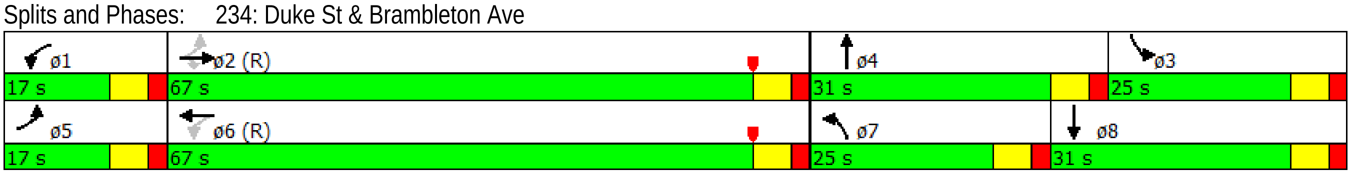
Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	17.0	67.0	25.0	31.0	17.0	67.0	25.0	31.0
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	11.0	61.0	19.0	25.0	11.0	61.0	19.0	25.0
Max Q Clear Time (g_c+I1), s	6.8	53.5	21.0	11.6	3.2	9.6	5.0	21.8
Green Ext Time (p_c), s	0.1	6.9	0.0	0.3	0.0	33.6	0.1	0.8

Intersection Summary			
HCM 2010 Ctrl Delay			44.8
HCM 2010 LOS			D

Phase Number	1	2	3	4	5	6	7	8
Movement	WBL	EBTL	SBL	NBT	EBL	WBTL	NBL	SBT
Lead/Lag	Lead	Lag	Lag	Lead	Lead	Lag	Lead	Lag
Lead-Lag Optimize	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	Max	Max	Max	Max	Max	Max	Max	Max
Maximum Split (s)	17	67	25	31	17	67	25	31
Maximum Split (%)	12.1%	47.9%	17.9%	22.1%	12.1%	47.9%	17.9%	22.1%
Minimum Split (s)	11	23	13	31	11	23	13	31
Yellow Time (s)	4	4	4	4	4	4	4	4
All-Red Time (s)	2	2	2	2	2	2	2	2
Minimum Initial (s)	5	10	7	7	5	10	7	7
Vehicle Extension (s)	3	3	3	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3	3	3	3
Time Before Reduce (s)	3	4	3	3	3	4	3	3
Time To Reduce (s)	0	0	0	0	0	0	0	0
Walk Time (s)		6		6		6		6
Flash Dont Walk (s)		11		19		11		19
Dual Entry	No	No	No	Yes	No	No	Yes	No
Inhibit Max	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start Time (s)	1	18	116	85	1	18	85	110
End Time (s)	18	85	1	116	18	85	110	1
Yield/Force Off (s)	12	79	135	110	12	79	104	135
Yield/Force Off 170(s)	12	68	135	91	12	68	104	116
Local Start Time (s)	62	79	37	6	62	79	6	31
Local Yield (s)	73	0	56	31	73	0	25	56
Local Yield 170(s)	73	129	56	12	73	129	25	37

Intersection Summary	
Cycle Length	140
Control Type	Pretimed
Natural Cycle	110
Offset: 79 (56%), Referenced to phase 2:EBTL and 6:WBTL, Start of Yellow	

Splits and Phases: 234: Duke St & Brambleton Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	100	0	65	0	329	94	661	0	0	328	445
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	1900	1881	1881	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h	0	109	0	71	0	358	102	718	0	0	357	484
Adj No. of Lanes	1	1	0	1	1	1	1	2	0	0	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	1	1	1	1	0	0	0	0	1	1
Cap, veh/h	139	146	0	406	426	362	412	1796	0	0	1381	618
Arrive On Green	0.00	0.08	0.00	0.23	0.00	0.23	0.05	0.50	0.00	0.00	0.39	0.39
Sat Flow, veh/h	1792	1881	0	1792	1881	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h	0	109	0	71	0	358	102	718	0	0	357	484
Grp Sat Flow(s),veh/h/ln	1792	1881	0	1792	1881	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s	0.0	4.0	0.0	2.3	0.0	15.8	2.2	8.8	0.0	0.0	4.8	18.8
Cycle Q Clear(g_c), s	0.0	4.0	0.0	2.3	0.0	15.8	2.2	8.8	0.0	0.0	4.8	18.8
Prop In Lane	1.00		0.00	1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h	139	146	0	406	426	362	412	1796	0	0	1381	618
V/C Ratio(X)	0.00	0.75	0.00	0.17	0.00	0.99	0.25	0.40	0.00	0.00	0.26	0.78
Avail Cap(c_a), veh/h	406	426	0	406	426	362	723	2913	0	0	1721	770
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh	0.0	31.9	0.0	22.0	0.0	27.2	10.9	11.1	0.0	0.0	14.8	19.1
Incr Delay (d2), s/veh	0.0	7.3	0.0	0.2	0.0	44.0	0.3	0.1	0.0	0.0	0.1	4.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	2.4	0.0	1.1	0.0	11.4	1.1	4.4	0.0	0.0	2.4	8.9
LnGrp Delay(d),s/veh	0.0	39.2	0.0	22.2	0.0	71.2	11.2	11.3	0.0	0.0	14.9	23.3
LnGrp LOS		D		C		E	B	B			B	C
Approach Vol, veh/h		109			429			820			841	
Approach Delay, s/veh		39.2			63.1			11.3			19.7	
Approach LOS		D			E			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	7.9	33.3		9.5		41.1		20.0
Change Period (Y+Rc), s	4.0	6.0		4.0		* 6		4.0
Max Green Setting (Gmax), s	16.0	34.0		16.0		* 57		16.0
Max Q Clear Time (g_c+I1), s	4.2	20.8		6.0		9.8		17.8
Green Ext Time (p_c), s	0.2	6.5		0.2		10.0		0.0

Intersection Summary		
HCM 2010 Ctrl Delay		26.0
HCM 2010 LOS		C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Phase Number	1	2	4	6	8
Movement	NBL	SBT	EBTL	NBTL	WBTL
Lead/Lag	Lead	Lag			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	None	Min	None	Min	None
Maximum Split (s)	20	40	20	60	20
Maximum Split (%)	20.0%	40.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	22	20	20.5	20
Yellow Time (s)	3.5	4	3.5	3	3.5
All-Red Time (s)	0.5	2	0.5	0	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	20	60	0	80
End Time (s)	20	60	80	60	0
Yield/Force Off (s)	16	54	76	57	96
Yield/Force Off 170(s)	16	54	65	57	85
Local Start Time (s)	80	0	40	80	60
Local Yield (s)	96	34	56	37	76
Local Yield 170(s)	96	34	45	37	65

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	70

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	65	0	329	94	661	0	0	328	445
Number				3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1881	0	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h				71	0	358	102	718	0	0	357	484
Adj No. of Lanes				1	0	1	1	2	0	0	2	1
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				1	0	1	0	0	0	0	1	1
Cap, veh/h				458	0	409	481	2059	0	0	1590	711
Arrive On Green				0.26	0.00	0.26	0.06	0.57	0.00	0.00	0.44	0.44
Sat Flow, veh/h				1792	0	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h				71	0	358	102	718	0	0	357	484
Grp Sat Flow(s),veh/h/ln				1792	0	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s				1.8	0.0	12.3	1.6	6.1	0.0	0.0	3.5	13.8
Cycle Q Clear(g_c), s				1.8	0.0	12.3	1.6	6.1	0.0	0.0	3.5	13.8
Prop In Lane				1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h				458	0	409	481	2059	0	0	1590	711
V/C Ratio(X)				0.16	0.00	0.88	0.21	0.35	0.00	0.00	0.22	0.68
Avail Cap(c_a), veh/h				499	0	445	884	4837	0	0	3359	1503
HCM Platoon Ratio				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				16.6	0.0	20.5	6.9	6.6	0.0	0.0	9.8	12.7
Incr Delay (d2), s/veh				0.2	0.0	16.6	0.2	0.1	0.0	0.0	0.1	1.2
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				0.9	0.0	7.3	0.8	3.0	0.0	0.0	1.8	6.3
LnGrp Delay(d),s/veh				16.7	0.0	37.2	7.1	6.7	0.0	0.0	9.9	13.9
LnGrp LOS				B		D	A	A			A	B
Approach Vol, veh/h					429			820			841	
Approach Delay, s/veh					33.8			6.8			12.2	
Approach LOS					C			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2				6		8
Phs Duration (G+Y+Rc), s	7.2	31.6				38.8		18.7
Change Period (Y+Rc), s	4.0	6.0				* 6		4.0
Max Green Setting (Gmax), s	16.0	54.0				* 77		16.0
Max Q Clear Time (g_c+I1), s	3.6	15.8				7.1		14.3
Green Ext Time (p_c), s	0.2	9.7				10.3		0.4

Intersection Summary	
HCM 2010 Ctrl Delay	14.5
HCM 2010 LOS	B

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Timing Report, Sorted By Phase
3: I-264 WB Off-ramp & Ballentine Blvd

Phase Number	1	2	3	6
Movement	NBL	SBT	WBL	NBTL
Lead/Lag	Lead	Lag		
Lead-Lag Optimize	Yes	Yes		
Recall Mode	None	Min	None	Min
Maximum Split (s)	20	60	20	80
Maximum Split (%)	20.0%	60.0%	20.0%	80.0%
Minimum Split (s)	8	22	8	20.5
Yellow Time (s)	3.5	4	3.5	3
All-Red Time (s)	0.5	2	0.5	0
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		5		5
Flash Dont Walk (s)		11		11
Dual Entry	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	20	80	0
End Time (s)	20	80	0	80
Yield/Force Off (s)	16	74	96	77
Yield/Force Off 170(s)	16	74	96	77
Local Start Time (s)	80	0	60	80
Local Yield (s)	96	54	76	57
Local Yield 170(s)	96	54	76	57

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	40

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	100	0	84	0	197	113	647	0	0	529	646
Number	7	4	14	3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1881	1881	1900	1881	1881	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h	0	109	0	91	0	214	123	703	0	0	575	702
Adj No. of Lanes	1	1	0	1	1	1	1	2	0	0	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	1	1	1	1	1	0	0	0	0	1	1
Cap, veh/h	139	146	0	292	307	261	360	2060	0	0	1636	732
Arrive On Green	0.00	0.08	0.00	0.16	0.00	0.16	0.06	0.57	0.00	0.00	0.46	0.46
Sat Flow, veh/h	1792	1881	0	1792	1881	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h	0	109	0	91	0	214	123	703	0	0	575	702
Grp Sat Flow(s),veh/h/ln	1792	1881	0	1792	1881	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s	0.0	4.2	0.0	3.3	0.0	9.6	2.5	7.7	0.0	0.0	7.7	31.5
Cycle Q Clear(g_c), s	0.0	4.2	0.0	3.3	0.0	9.6	2.5	7.7	0.0	0.0	7.7	31.5
Prop In Lane	1.00		0.00	1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h	139	146	0	292	307	261	360	2060	0	0	1636	732
V/C Ratio(X)	0.00	0.75	0.00	0.31	0.00	0.82	0.34	0.34	0.00	0.00	0.35	0.96
Avail Cap(c_a), veh/h	387	406	0	387	406	345	643	2777	0	0	1640	734
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	0.00	1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh	0.0	33.5	0.0	27.3	0.0	30.0	9.2	8.5	0.0	0.0	13.0	19.4
Incr Delay (d2), s/veh	0.0	7.5	0.0	0.6	0.0	11.2	0.6	0.1	0.0	0.0	0.1	23.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	2.5	0.0	1.7	0.0	5.0	1.3	3.8	0.0	0.0	3.8	18.4
LnGrp Delay(d),s/veh	0.0	40.9	0.0	27.9	0.0	41.2	9.7	8.6	0.0	0.0	13.1	43.0
LnGrp LOS		D		C		D	A	A			B	D
Approach Vol, veh/h		109			305			826			1277	
Approach Delay, s/veh		40.9			37.2			8.8			29.6	
Approach LOS		D			D			A			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	8.4	39.9		9.7		48.3		16.1
Change Period (Y+Rc), s	4.0	6.0		4.0		* 6		4.0
Max Green Setting (Gmax), s	16.0	34.0		16.0		* 57		16.0
Max Q Clear Time (g_c+I1), s	4.5	33.5		6.2		8.7		11.6
Green Ext Time (p_c), s	0.3	0.5		0.2		15.2		0.5

Intersection Summary	
HCM 2010 Ctrl Delay	24.2
HCM 2010 LOS	C

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Phase Number	1	2	4	6	8
Movement	NBL	SBT	EBTL	NBTL	WBTL
Lead/Lag	Lead	Lag			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	None	Min	None	Min	None
Maximum Split (s)	20	40	20	60	20
Maximum Split (%)	20.0%	40.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	22	20	20.5	20
Yellow Time (s)	3.5	4	3.5	3	3.5
All-Red Time (s)	0.5	2	0.5	0	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	0	20	60	0	80
End Time (s)	20	60	80	60	0
Yield/Force Off (s)	16	54	76	57	96
Yield/Force Off 170(s)	16	54	65	57	85
Local Start Time (s)	80	0	40	80	60
Local Yield (s)	96	34	56	37	76
Local Yield 170(s)	96	34	45	37	65

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	70

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	0	0	0	84	0	197	113	647	0	0	529	646
Number				3	8	18	1	6	16	5	2	12
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1881	0	1881	1900	1900	0	0	1881	1881
Adj Flow Rate, veh/h				91	0	214	123	703	0	0	575	702
Adj No. of Lanes				1	0	1	1	2	0	0	2	1
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				1	0	1	0	0	0	0	1	1
Cap, veh/h				300	0	268	420	2459	0	0	2024	906
Arrive On Green				0.17	0.00	0.17	0.05	0.68	0.00	0.00	0.57	0.57
Sat Flow, veh/h				1792	0	1599	1810	3705	0	0	3668	1599
Grp Volume(v), veh/h				91	0	214	123	703	0	0	575	702
Grp Sat Flow(s),veh/h/ln				1792	0	1599	1810	1805	0	0	1787	1599
Q Serve(g_s), s				2.9	0.0	8.5	1.7	5.1	0.0	0.0	5.5	22.4
Cycle Q Clear(g_c), s				2.9	0.0	8.5	1.7	5.1	0.0	0.0	5.5	22.4
Prop In Lane				1.00		1.00	1.00		0.00	0.00		1.00
Lane Grp Cap(c), veh/h				300	0	268	420	2459	0	0	2024	906
V/C Ratio(X)				0.30	0.00	0.80	0.29	0.29	0.00	0.00	0.28	0.78
Avail Cap(c_a), veh/h				434	0	387	760	4208	0	0	2922	1307
HCM Platoon Ratio				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				24.1	0.0	26.4	4.9	4.2	0.0	0.0	7.4	11.1
Incr Delay (d2), s/veh				0.6	0.0	7.4	0.4	0.1	0.0	0.0	0.1	1.8
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				1.5	0.0	4.3	0.9	2.5	0.0	0.0	2.7	10.1
LnGrp Delay(d),s/veh				24.7	0.0	33.8	5.3	4.2	0.0	0.0	7.5	12.9
LnGrp LOS				C		C	A	A			A	B
Approach Vol, veh/h					305			826			1277	
Approach Delay, s/veh					31.1			4.4			10.5	
Approach LOS					C			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2				6		8
Phs Duration (G+Y+Rc), s	7.6	43.4				51.0		15.1
Change Period (Y+Rc), s	4.0	6.0				* 6		4.0
Max Green Setting (Gmax), s	16.0	54.0				* 77		16.0
Max Q Clear Time (g_c+I1), s	3.7	24.4				6.1		10.5
Green Ext Time (p_c), s	0.3	13.0				16.1		0.6

Intersection Summary	
HCM 2010 Ctrl Delay	11.0
HCM 2010 LOS	B

Notes

* HCM 2010 computational engine requires equal clearance times for the phases crossing the barrier.

Timing Report, Sorted By Phase
3: I-264 WB Off-ramp & Ballentine Blvd

Phase Number	1	2	3	6
Movement	NBL	SBT	WBL	NBTL
Lead/Lag	Lead	Lag		
Lead-Lag Optimize	Yes	Yes		
Recall Mode	None	Min	None	Min
Maximum Split (s)	20	60	20	80
Maximum Split (%)	20.0%	60.0%	20.0%	80.0%
Minimum Split (s)	8	22	8	20.5
Yellow Time (s)	3.5	4	3.5	3
All-Red Time (s)	0.5	2	0.5	0
Minimum Initial (s)	4	4	4	4
Vehicle Extension (s)	3	3	3	3
Minimum Gap (s)	3	3	3	3
Time Before Reduce (s)	0	0	0	0
Time To Reduce (s)	0	0	0	0
Walk Time (s)		5		5
Flash Dont Walk (s)		11		11
Dual Entry	No	Yes	No	Yes
Inhibit Max	Yes	Yes	Yes	Yes
Start Time (s)	0	20	80	0
End Time (s)	20	80	0	80
Yield/Force Off (s)	16	74	96	77
Yield/Force Off 170(s)	16	74	96	77
Local Start Time (s)	80	0	60	80
Local Yield (s)	96	54	76	57
Local Yield 170(s)	96	54	76	57

Intersection Summary	
Cycle Length	100
Control Type	Actuated-Uncoordinated
Natural Cycle	45

Splits and Phases: 3: I-264 WB Off-ramp & Ballentine Blvd

HCM 2010 Signalized Intersection Summary
6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	395	0	80	4	0	111	0	315	57	228	245	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1937	1900	1900	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	429	0	87	4	0	121	0	342	62	248	266	0
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	241	0	49	8	0	246	0	1230	221	379	1043	0
Arrive On Green	0.16	0.00	0.16	0.16	0.00	0.16	0.00	0.41	0.41	0.11	0.56	0.00
Sat Flow, veh/h	1503	0	305	51	0	1538	0	3092	538	3442	1863	0
Grp Volume(v), veh/h	516	0	0	125	0	0	0	200	204	248	266	0
Grp Sat Flow(s),veh/h/ln	1808	0	0	1589	0	0	0	1770	1768	1721	1863	0
Q Serve(g_s), s	16.0	0.0	0.0	7.2	0.0	0.0	0.0	7.5	7.7	6.9	7.3	0.0
Cycle Q Clear(g_c), s	16.0	0.0	0.0	7.2	0.0	0.0	0.0	7.5	7.7	6.9	7.3	0.0
Prop In Lane	0.83		0.17	0.03		0.97	0.00		0.30	1.00		0.00
Lane Grp Cap(c), veh/h	289	0	0	254	0	0	0	726	725	379	1043	0
V/C Ratio(X)	1.78	0.00	0.00	0.49	0.00	0.00	0.00	0.28	0.28	0.66	0.25	0.00
Avail Cap(c_a), veh/h	289	0	0	254	0	0	0	726	725	379	1043	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	42.0	0.0	0.0	38.3	0.0	0.0	0.0	19.6	19.7	42.7	11.3	0.0
Incr Delay (d2), s/veh	366.2	0.0	0.0	6.7	0.0	0.0	0.0	0.9	1.0	8.6	0.6	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	37.4	0.0	0.0	3.6	0.0	0.0	0.0	3.9	3.9	3.7	3.9	0.0
LnGrp Delay(d),s/veh	408.2	0.0	0.0	44.9	0.0	0.0	0.0	20.6	20.6	51.2	11.9	0.0
LnGrp LOS	F			D				C	C	D	B	
Approach Vol, veh/h		516			125			404			514	
Approach Delay, s/veh		408.2			44.9			20.6			30.9	
Approach LOS		F			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	15.0	45.0		20.0		60.0		20.0
Change Period (Y+Rc), s	4.0	4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s	11.0	41.0		16.0		56.0		16.0
Max Q Clear Time (g_c+I1), s	8.9	9.7		18.0		9.3		9.2
Green Ext Time (p_c), s	0.6	2.6		0.0		2.6		0.3

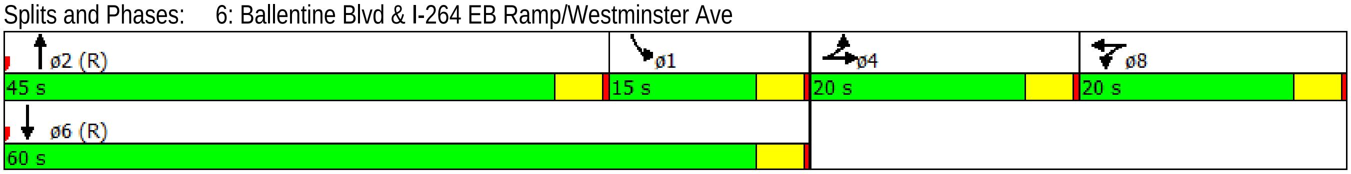
Intersection Summary	
HCM 2010 Ctrl Delay	154.2
HCM 2010 LOS	F

Timing Report, Sorted By Phase
6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lag	Lead			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	15	45	20	60	20
Maximum Split (%)	15.0%	45.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	20	20	20	20
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	30	85	45	85	65
End Time (s)	45	30	65	45	85
Yield/Force Off (s)	41	26	61	41	81
Yield/Force Off 170(s)	41	15	50	30	70
Local Start Time (s)	45	0	60	0	80
Local Yield (s)	56	41	76	56	96
Local Yield 170(s)	56	30	65	45	85

Intersection Summary	
Cycle Length	100
Control Type	Pretimed
Natural Cycle	70
Offset: 85 (85%), Referenced to phase 2:NBT and 6:SBT, Start of Green	

Splits and Phases: 6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (veh/h)	357	0	93	1	0	230	0	488	100	367	308	0
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1900	1937	1900	1900	1863	1900	0	1863	1900	1863	1863	0
Adj Flow Rate, veh/h	388	0	101	1	0	250	0	530	109	399	335	0
Adj No. of Lanes	0	1	0	0	1	0	0	2	0	2	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	0	2	2	2	2	0
Cap, veh/h	229	0	59	1	0	252	0	1200	246	379	1043	0
Arrive On Green	0.16	0.00	0.16	0.16	0.00	0.16	0.00	0.41	0.41	0.11	0.56	0.00
Sat Flow, veh/h	1428	0	372	6	0	1578	0	3020	600	3442	1863	0
Grp Volume(v), veh/h	489	0	0	251	0	0	0	320	319	399	335	0
Grp Sat Flow(s),veh/h/ln	1800	0	0	1584	0	0	0	1770	1757	1721	1863	0
Q Serve(g_s), s	16.0	0.0	0.0	15.8	0.0	0.0	0.0	13.0	13.1	11.0	9.6	0.0
Cycle Q Clear(g_c), s	16.0	0.0	0.0	15.8	0.0	0.0	0.0	13.0	13.1	11.0	9.6	0.0
Prop In Lane	0.79		0.21	0.00		1.00	0.00		0.34	1.00		0.00
Lane Grp Cap(c), veh/h	288	0	0	253	0	0	0	726	720	379	1043	0
V/C Ratio(X)	1.70	0.00	0.00	0.99	0.00	0.00	0.00	0.44	0.44	1.05	0.32	0.00
Avail Cap(c_a), veh/h	288	0	0	253	0	0	0	726	720	379	1043	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	42.0	0.0	0.0	41.9	0.0	0.0	0.0	21.2	21.3	44.5	11.8	0.0
Incr Delay (d2), s/veh	328.5	0.0	0.0	54.1	0.0	0.0	0.0	1.9	2.0	61.1	0.8	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	34.2	0.0	0.0	10.7	0.0	0.0	0.0	6.7	6.7	8.4	5.2	0.0
LnGrp Delay(d),s/veh	370.5	0.0	0.0	96.1	0.0	0.0	0.0	23.2	23.2	105.6	12.6	0.0
LnGrp LOS	F			F				C	C	F	B	
Approach Vol, veh/h		489			251			639			734	
Approach Delay, s/veh		370.5			96.1			23.2			63.2	
Approach LOS		F			F			C			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	15.0	45.0		20.0		60.0		20.0
Change Period (Y+Rc), s	4.0	4.0		4.0		4.0		4.0
Max Green Setting (Gmax), s	11.0	41.0		16.0		56.0		16.0
Max Q Clear Time (g_c+I1), s	13.0	15.1		18.0		11.6		17.8
Green Ext Time (p_c), s	0.0	4.2		0.0		3.8		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	126.1
HCM 2010 LOS	F

Phase Number	1	2	4	6	8
Movement	SBL	NBT	EBTL	SBT	WBTL
Lead/Lag	Lag	Lead			
Lead-Lag Optimize	Yes	Yes			
Recall Mode	Max	Max	Max	Max	Max
Maximum Split (s)	15	45	20	60	20
Maximum Split (%)	15.0%	45.0%	20.0%	60.0%	20.0%
Minimum Split (s)	8	20	20	20	20
Yellow Time (s)	3.5	3.5	3.5	3.5	3.5
All-Red Time (s)	0.5	0.5	0.5	0.5	0.5
Minimum Initial (s)	4	4	4	4	4
Vehicle Extension (s)	3	3	3	3	3
Minimum Gap (s)	3	3	3	3	3
Time Before Reduce (s)	0	0	0	0	0
Time To Reduce (s)	0	0	0	0	0
Walk Time (s)		5	5	5	5
Flash Dont Walk (s)		11	11	11	11
Dual Entry	No	Yes	Yes	Yes	Yes
Inhibit Max	Yes	Yes	Yes	Yes	Yes
Start Time (s)	30	85	45	85	65
End Time (s)	45	30	65	45	85
Yield/Force Off (s)	41	26	61	41	81
Yield/Force Off 170(s)	41	15	50	30	70
Local Start Time (s)	45	0	60	0	80
Local Yield (s)	56	41	76	56	96
Local Yield 170(s)	56	30	65	45	85

Intersection Summary	
Cycle Length	100
Control Type	Pretimed
Natural Cycle	75
Offset: 85 (85%), Referenced to phase 2:NBT and 6:SBT, Start of Green	

Splits and Phases: 6: Ballentine Blvd & I-264 EB Ramp/Westminster Ave