NHHIP ALTERNATIVES ANALYSIS: ENGINEERING AND TRAFFIC CRITERIA

A detailed summary of the alternative evaluation process for build alternatives along the Interstate 45 (I-45) corridor beginning with the Universe of Alternatives.

Updated July 2018





Table of Contents

1.0	Introduction and Background	1
1.1	Need and Purpose for Proposed Project	3
1.2	Existing Conditions	3
2.0	Development of Alternatives	10
2.1	Alternative Development Process	11
2.2	Assumptions and Design Criteria	12
3.0	Universe of Alternatives	15
3.1	Description of Universe of Alternatives	15
3.2	Initial Alternative Screening Process	35
3.3	Initial Alternative Screening Results	35
4.0	Preliminary Alternatives	39
4.1	Segment 2 Preliminary Alternatives	39
4.2	Segment 3 Preliminary Alternatives	48
4.3	Secondary Alternative Screening Process	59
4.4	Secondary Alternative Screening Results	63
5.0	Reasonable Alternatives	66
5.1	DEIS Analysis and Evaluation Process	80
5.2	DEIS Analysis and Evaluation Results	81
6.0	Recommended Alternatives	84
6.1	Segment 2 – Alternative 10	85
6.2	Segment 3 – Alternative 11	87
7.0	Next Steps	95
List	of Tables	
Table	1: I-45 Typical Lane and Shoulder Widths	5
	2: NHHIP Design Criteria	
	3: Segment 2 Universe of Alternatives	
	4: Segment 3 Universe of Alternatives 5: Initial Alternative Screening Engineering and Traffic Criteria	
	6: Segment 2 Initial Screening Results	
	7: Segment 3 Universe of Alternatives Screening Results	
	8: Segment 3, Alternative 3 Detailed Initial Alternative Screening	
	9: Segment 2 Preliminary Alternatives	
Table	10: Alternative 3 Access Points	48

Table 11: Alternative 10 Access Points	51
Table 12: Segment 3 Preliminary Alternatives	59
Table 13: Traffic Model Alternatives vs. Engineering Preliminary Alternatives	60
Table 14: Engineering and Traffic Criteria for the Secondary Alternative Screening	61
Table 15: Segment 2 Engineering and Traffic Screening Results	63
Table 16: Segment 3 Engineering Screening Results	64
Table 17: Segment 2 Reasonable Alternatives	66
Table 18: Segment 3 Reasonable Alternatives	
Table 19: DEIS Analysis and Evaluation – Engineering and Traffic Evaluation Criteria	80
Table 20: Segment 2 DEIS Engineering and Traffic Evaluation Results	82
Table 21: Segment 3 DEIS Engineering and Traffic Evaluation Results	82
Table 22: Segment 2 Percent Change in VHT	
Table 23: Segment 3 Percent Change in VHT	83
Table 24: Segment 2 Percent Change in Model Speeds	83
Table 25: Segment 3 Percent Change in Model Speeds	84
List of Figures	
List of Figures	
Figure 1: Study Area	
Figure 2: I-45 Existing Typical Section from I-610 to Patton	
Figure 4: I-45 Existing Typical Section from I-10 to Allen Parkway	
Figure 5: I-45 Existing Typical Section from Allen Park to US 59/I-69	
Figure 6: Historic Traffic Growth	
Figure 7: 2011 Daily Traffic Volumes on Other Study Corridors	
Figure 8: 2011 Peak Hour Level of Service	
Figure 9: Alternative Screening Process	
Figure 10: Segment 2 Alternatives 3 and 4	
Figure 11: Segment 2 Alternatives 5 and 6	
Figure 12: Segment 2 Alternatives 7 and 8	
Figure 13: Segment 2 Alternatives 9 and 10	
Figure 14: Segment 2 Alternatives 11 and 12	
Figure 15: Segment 2 Alternatives 13 and 14	
Figure 16: Segment 2 Alternatives 15 and 16	
Figure 17: Segment 3 Alternative 3 – I-45	
Figure 18: Segment 3 Alternative 3 – US 59	
Figure 19: Segment 3 Alternative 3 – I-10	
Figure 20: Segment 3 Alternative 4	
Figure 21: Segment 3 Alternative 5	
Figure 22: Segment 3 Alternative 6	
Figure 24: Segment 3 Alternative 7.	
Figure 24: Segment 3 Alternative 8	
Figure 25: Segment 3 Alternative 9	
Figure 26: Segment 3 Alternative 10	
Figure 28: Preliminary Alternative 10, Segment 2	
rigure 20. Fremilinary Arternative 10, Segment 2	43

Figure 29: Preliminary Alternative 11, Segment 2	44
Figure 30: Preliminary Alternative 12, Segment 2	45
Figure 31: Preliminary Alternative 14, Segment 2	46
Figure 32: Preliminary Alternative 15, Segment 2	47
Figure 33: Preliminary Alternative 3, Segment 3	53
Figure 34: Alternative 5	54
Figure 35: Alternative 6	55
Figure 36: Alternative 10	56
Figure 37: Alternative 11	57
Figure 38: Alternative 12	58
Figure 39: Segment 2 Alternative 10	68
Figure 40: Segment 2 Alternative 10 Typical Section and Rendering	69
Figure 41: Segment 2 Alternative 11	70
Figure 42: Segment 2 Alternative 11 Typical Section and Rendering	71
Figure 43: Segment 2 Alternative 12	72
Figure 44: Segment 2 Alternative 12 Typical Section and Rendering	73
Figure 45: Segment 3 Alternative 10	74
Figure 46: Segment 3 Alternative 10 Rendering	75
Figure 47: Segment 3 Alternative 11	76
Figure 48: Segment 3 Alternative 11 Renderings	77
Figure 49: Segment 3 Alternative 12	78
Figure 50: Segment 3 Alternative 12 Renderings	79
Figure 51: Segment 2 Depressed Section	85
Figure 52: Proposed Recommended Alternative for Downtown AreaArea	88
Figure 53: I-45/I-69 Interchange, looking Northwest	89
Figure 54: Klyde Warren Park in Dallas	89
Figure 55: I-10/I-69 Interchange, looking Southwest	90
Figure 56: I-45/I-10 Interchange Looking South towards Downtown	92
Figure 57: I-69/US 59 at SH 288 Interchange, Looking North	94
Figure 58: Allen Parkway at Downtown Connector (Looking East)	95

Appendices

Appendix A:	Existing	Conditions	Report
Appendix A.	LAISUIIG	Containons	Report

- Appendix B: Initial Screening Detailed Evaluation Matrices
- Appendix C: Detailed Secondary Screening Matrices
- Appendix D: Preliminary Alternatives Traffic Screening Methodology and Results
- Appendix E: White Paper: NHHIP Engineering Aspects of Tunnel Alternatives
- Appendix F: Reasonable Alternative Exhibits
- Appendix G: DEIS Evaluation Traffic and Engineering Evaluation Matrices
- $Appendix\,H:\,Reasonable\,Alternatives\,Traffic\,Screening\,Methodology\,and\,Results$

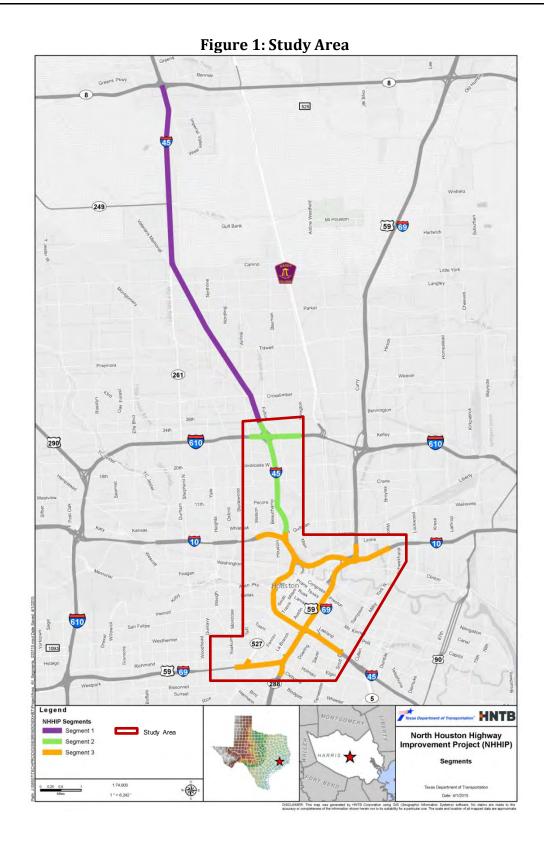
1.0 Introduction and Background

This report considers the alternative development and evaluation process for improvements to Interstate 45 (I-45), just north of I-610 and Spur 527, in Houston, Texas. These improvements are part of the North Houston Highway Improvement Project (NHHIP). I-45 is a highly utilized north-south interstate facility within the Houston metropolitan area and is a primary commuter and through facility for regional traffic. The facility is also an official Texas Evacuation Route from Galveston to FM 1314 (north of the Woodlands) in Montgomery County. As a result of the evacuation problems experienced by residents in the region in response to Hurricane Rita in September 2005, plans are currently underway to develop efficient and safe methods for a more systematic and improved evacuation.

The I-45 corridor has been divided into three segments, as described below and illustrated in Figure 1.

- Segment 1 Beltway 8 to I-610
- Segment 2 I-610 to I-10
- Segment 3 Downtown Loop System (I-10, US 59/I-69 and I-45) including US 59/I-69, from Spur 527 to I-45

Within the limits of the study, I-45 provides between four to eleven travel lanes (10 main lanes and one HOV lane) between north of Sam Houston Tollway/Beltway 8 to the southern terminus at US 59/I-69/SH 288. The posted speed limit is 60 miles per hour. The facility has one-way two-lane frontage roads on both sides for most of its length. This report considers the alternatives developed and evaluated for Segments 2 and 3. Improvements to Segment 1 (I-45 between Beltway 8 and I-610) are being evaluated by others.



1.1 Need and Purpose for Proposed Project

The following summarizes the need and purpose of the I-45 improvements.

- Need for Proposed Project
 - o Population and employment increases
 - o Existing and future I-45 traffic
 - o Current design standards and improved safety
 - o Efficient traffic movement, including during evacuation events
- Purpose of Proposed Project
 - Manage congestion and enhance safety
 - o Improve mobility and operational efficiency

1.2 Existing Conditions

As a precursor to developing a Universe of Alternatives for potential improvements in the I-45 corridor, the existing conditions of study corridor were collected and evaluated. The results of this effort are summarized in the *Evaluation of Existing Conditions Report* (2015), included as **Appendix A**. The report considered two primary analyses: (1) existing engineering elements and (2) existing traffic conditions. Analysis of existing engineering elements included evaluation of roadway geometry, right-of-way, utilities, and high occupancy vehicle (HOV) facilities. Analysis of existing traffic conditions was performed by other consultants; the comprehensive results of the traffic evaluation are documented in the *I-45/Hardy Corridor Study Update*, dated August 2014. The traffic analysis resulted in the determination that improving the Hardy Toll Road was not sufficient to improve mobility in the region.

Description of Major Transportation Facilities within Study Area

I-45 is a major north-south freeway within the Houston metropolitan region. The northern portion of I-45 within the region is commonly referred to as the "North Freeway", and the southern portion connecting Downtown Houston with Galveston is referred to as the "Gulf Freeway". Within the study area, I-45 generally carries three to five general purpose lanes in each direction with one-lane reversible barrier-separated High Occupancy Vehicle (HOV) lane in the center. North of Sam Houston Tollway/Beltway 8, I-45 is an 11-lane section with 10 general purpose lanes plus one HOV lane, between Sam Houston Tollway/Beltway 8 and I-10, I-45 is a nine-lane section with eight general purpose lanes and one HOV lane, and in the Downtown area there are six general purpose lanes between Allen Parkway and US 59.

The posted speed limit along I-45 in the study area is 60 miles per hour (mph). Within the study area, I-45 has one-way two-lane frontage roads on both sides from north of Sam Houston Tollway/Beltway 8 to North Main Street. Currently there are no frontage roads through the I-610 North interchange. I-45 serves as a major route and provides access to major destinations in the region such as Downtown Houston, Bush Intercontinental airport, Texas Medical Center, The Woodlands, and The Port of Houston. In addition, this freeway serves long distance travel from Houston north to Dallas and south to Galveston.

Hardy Toll Road is a four-lane section north of Beltway 8 and a six-lane section between Beltway 8 and I-610. It generally runs parallel to I-45 corridor connecting to I-45 south of The Woodlands. The posted speed limit along this facility is 55 mph. There are Union Pacific Railroad tracks along the Hardy Toll Road corridor. The road is named for the nearby Hardy Street, which in some areas serves as the frontage road for the Toll Road. Inside the study area, Hardy Street serves as the frontage road between Greens Road and Crosstimbers Street. There is one main lane toll collection plaza located inside the study area, just south of Aldine Bender Road. South of this toll plaza, in the southbound direction, all entrance ramps are tolled and exit ramps are free (no toll). In the northbound direction, it's the reverse, with all entrance ramps free and exit ramps tolled.

The Harris County Toll Road Authority (HCTRA) has proposed Hardy Toll Road Downtown Connector project, which is currently in the design phase and will extend the Hardy Toll Road from its current terminus at I-610 to Downtown Houston and will consist of a four-lane toll facility with two lanes in each direction.

The **Sam Houston Tollway** currently serves as the second circumferential facility in the Houston region. The other two circumferential loops are I-610 around Downtown Houston and the Grand Parkway (SH 99) which is the outer most loop facility. The tolled portion of this facility is operated and maintained by HCTRA and is referred to as the Sam Houston Tollway. The frontage roads along Sam Houston Tollway and the non-tolled sections of this facility are known as Beltway 8 (BW 8) and are maintained by TxDOT. Within the study area between I-45 North and US 59 North, this facility is an access controlled non-tolled freeway referred to as Beltway 8. Within the study limits, between I-45 and Hardy Toll Road, this facility is a six-lane non tolled section with one-way two-lane frontage roads on either side and has a posted speed limit of 65 mph.

I-610 is a heavily traveled circumferential (loop) freeway primarily serving the inner Houston metropolitan area. I-610 along with Beltway 8 currently provides the only access-controlled connectivity between the I-45 and Hardy Toll Road corridors. Within the study area, I-610 is a 10-lane section with five general purpose lanes in each direction with a 60 mph posted speed limit, and has one-way frontage roads that primarily include three travel lanes on either side.

I-10 is the major east-west interstate highway in the southern United States extending from Florida to California. Within the Houston region, this facility is known as Katy Freeway and serves both regional as well as interstate travel. The study limit of this corridor is from west of I-45 to east of US 59. Within the study limits, I-10 is an eight-lane section with four general purpose lanes in each direction and has a posted speed limit of 60 mph. Currently along I-10, there is a bidirectional two-lane direct connector for high-occupancy vehicles from west of I-45 connecting to Franklin Street in the Downtown area. Within the study area, there are intermittent one-way two-lane frontage roads on either side of I-10.

US 59 is a major controlled-access highway traversing the Houston region generally in a north-south direction. North of Downtown Houston, US 59 is referred to as the Eastex Freeway and south of Downtown it is known as the Southwest Freeway. Within the study area, this corridor extends from north of I-10/US 59 interchange to just south of Spur 527. There is one reversible HOV lane along this facility from Smith Street in the Downtown area that follows Spur 527 as it connects to US 59. There are no frontage roads through the Downtown area. North of I-10, US 59 is an 11-lane section with five general purpose lanes in each direction plus one reversible HOV lane in the center connecting to Jackson Street in Downtown Houston. Between I-10 and I-45, it is generally an eight-lane section with four general purpose lanes in each direction and from I-45 to Spur 527 there are three general purpose lanes in each direction. The posted speed limit along this facility is 60 mph. Hazardous materials are prohibited on US 59 from its intersection with I-45 to just south of its intersection with I-10.

SH 288 is a major north–south highway that extends from Downtown Houston to Freeport. The study limit of this corridor includes the section between US 59/SH 288 and I-45/US 59 interchanges. Within the study area, SH 288 has three general purpose lanes in each direction with no frontage roads and has a posted speed limit of 60 mph.

Spur 527 is a controlled-access facility that spurs off from US 59 serving the Midtown and Downtown areas of Houston. Spur 527 is a five-lane section that includes two general purpose lanes in each direction and one reversible HOV lane. This facility has a posted speed limit of 60 mph.

Major arterials that provide access to I-45 between I-610 and I-10 include:

• W. Calvacade Street/Calvacade Street

N. Main Street

• W. Patton Street

• Quitman Street

There are three freight rail lines, as shown on Figure 1-3, that traverse the study area:

- The **Union Pacific Railroad (UPRR)** parallels the Hardy Toll Road from north of BW 8 to I-610, parallels the Elysian Viaduct, continues to I-10 and US 59 where it is an underpass, and then veers in an easterly direction near Franklin Street west of US 59.
- The **Southern Pacific Railroad** has two lines entering the study area. One north-south line enters just south of I-610 to the west of US 59 and runs parallel to the UPRR tracks. It has an underpass with I-10 and veers west paralleling Washington Avenue to outside the study area. Another line enters the study area approximately half a mile north of I-10/US 59 and continues westward north of I-10.
- The **Chicago Rock Island and Pacific Railroad** is an east-west rail line paralleling I-610 just to the north.

I-45 Typical Sections

Existing typical sections were determined using TxDOT as-built drawings and were verified through field visits. **Table 1**, below, summarizes details of interest for each section including width of HOV lane (barrier to barrier), number and width of main lanes and shoulder widths. Following the table, a graphical representation of each location's typical section is presented in **Figures 2** through **5**.

Table 1: I-45 Typical Lane and Shoulder Widths

Segment	Location	ROW	HOV Facility Width (ft-in)	Main Lane Width (NB/SB)	No. of Main Lanes in Each Direction	Shoulder Width (Outside/ Inside)
2	I-610 to Patton	Varies 290- 364 '	18'-8"	12'/12'	4	10'/0'
2	Patton to I-10	Varies 292-320'	18'-8" to 23'-4"	12'/11'	4	6'/0'
3	I-10 to Allen Pkwy	Varies 235-265'	N/A	12'/12'	5	10'/10'
3	US 59/I-69 to Allen Pkwy	120'	N/A	12'/12'	3	10'/3'

Figure 2: I-45 Existing Typical Section from I-610 to Patton



Figure 3: I-45 Existing Typical Section from Patton to I-10



Figure 4: I-45 Existing Typical Section from I-10 to Allen Parkway

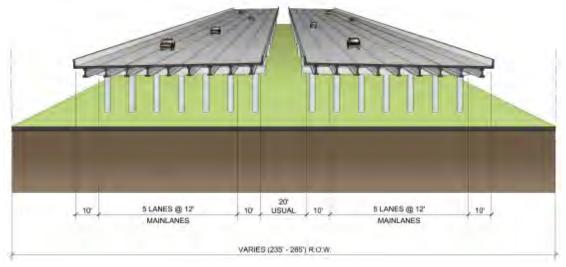


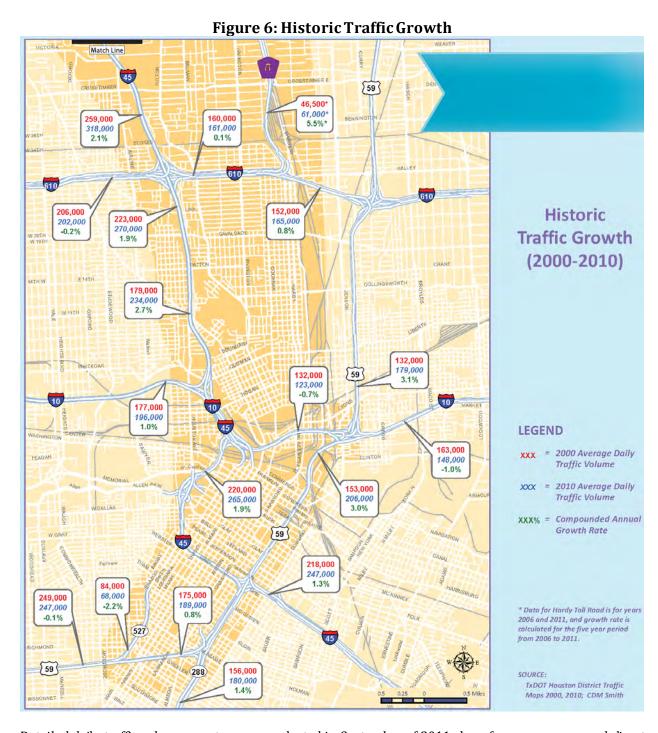
Figure 5: I-45 Existing Typical Section from Allen Parkway to US 59/I-69



Existing Traffic Conditions

In the past decade (2000–2010), the Houston metropolitan area has experienced one of the highest population growths in the nation. The population of the metropolitan area grew from 4,715,407 in 2000 to 5,946,800 in 2010 (U.S. Census), which equates to an average annual growth rate of 2.4 percent. This has resulted in significant increase in travel demand on roadways in the region which is directly related to population growth and in turn land use development.

Annual average daily traffic (AADT) volumes for 2000 and 2010 collected from the TxDOT Houston District's traffic maps, along with the resulting compounded annual growth rates are presented in **Figure 6**.

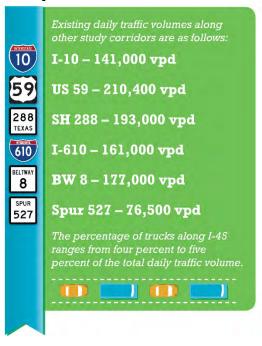


Detailed daily traffic volume counts were conducted in September of 2011 along freeways, ramps and direct connectors along the Downtown loop system (I-45/I-10/US 59) and US 59 from I-45/US 59 Interchange to Spur 527. Daily traffic volumes along I-45 ranges from approximately 301,000 vpd south of Sam Houston Tollway/Beltway 8 to 163,000 vpd west of US 59, along Pierce Elevated in Downtown Houston. Hardy Toll Road experienced traffic volumes ranging from 68,000 vpd south of Beltway 8 to 61,000 vpd north of I-610.

Daily traffic volumes range on I-45 range from 282,000 vpd to 306,000 vpd between Sam Houston Tollway/Beltway 8 and I-610; from 249,000 vpd to 257,000 vpd between I-610 and and I-10; and from

163,000 vpd to 248,000 vpd between I-10 and US 59 in Downtown Houston. Daily traffic volumes collected in 2011 along other study corridors is presented in **Figure 7**.

Figure 7: 2011 Daily Traffic Volumes on Other Study Corridors



Source: I-45/Hardy Corridor Study Update, CDM Smith, August 2014

I-45 experiences significant congestion during peak hours with level-of-service (LOS) unacceptable at E/F. Hardy Toll Road experiences daily traffic volume between 68,000 and 42,000 with operating conditions generally acceptable with LOS at D. The 2011 level of service for study area corridors during the peak period is illustrated on **Figure 8**.



Figure 8: 2011 Peak Hour Level of Service

Development of Alternatives

This section describes the alternative development process for Segments 2 and 3 of the NHHIP. Alternatives were developed to meet the needs of the study area and included roadway widening, Transportation Systems Management (TSM) alternatives, and freeway reconfiguration.

2.1 Alternative Development Process

The Study Team developed alternatives for I-45 from I-610 to downtown, including the downtown loop, using various sources of previously identified alternatives (Segments 2 and 3). Alternatives were identified and evaluated for Segment 1, I-45 between Beltway 8 and I-610, by others.

The alternative development process, used to identify the Universe of Alternatives, is summarized below.

- Alternatives previously identified from the following previous studies and reports:
 - o 2004 North-Hardy Corridor Alternatives Analysis Report (Transit Component);
 - o 2005 North-Hardy Planning Studies, Alternatives Analysis Report (Highway Component);
 - o Downtown District Study; and
 - o 2005 US 59/I-69/SH 288 Corridor Feasibility Study (from Spur 527 to I-45).
- Alternatives identified by the public and stakeholders include alternatives brought forward by stakeholders at the first scoping meeting held in November 2011.
- Alternatives developed by the Study Team which includes a set of alternatives identified to address needed additional capacity to the corridor. Alternatives identified by the Study Team were developed using a set of general assumptions and design criteria, described below.

The alternative screening process was utilized to narrow down the number of alternatives from the Universe of Alternatives to the final outcome of the Preferred Alternative for each analysis segment. The evaluation of the remaining alternatives was done in greater detail as the study progressed to subsequent levels of screening Definitions of the various screening levels and the alternative screening process are shown graphically in **Figure 9**.

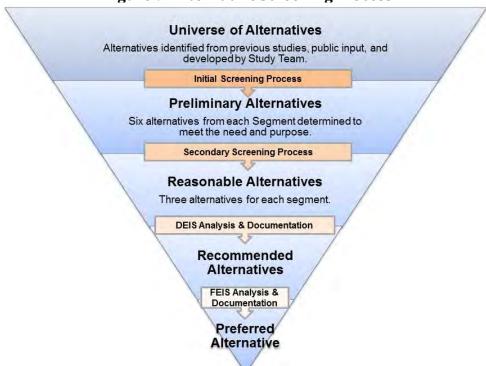


Figure 9: Alternative Screening Process

Note: DEIS – Draft Environmental Impact Statement; FEIS – Final Environmental Impact Statement

2.2 Assumptions and Design Criteria

The design team utilized the latest design standards and methodologies from TxDOT, A Policy on Geometric Design of Highway and Streets (AASHTO), and other sources to develop the alternative designs. The design criteria utilized is presented in **Table 2**.

Table 2: NHHIP Design Criteria

Table 2. Willing Design Criteria							
Design Element Reference	Freeway and Managed Lanes	Ramps and Collector- Distributor	Direct Connectors	Frontage Road	Cross Roads – SH/FM	Local Streets	
	(General Eleme	ents				
Design Speed RDM table 3-1, pg 3-4; RDM table 3-17, pg 3-60; RDM table 3-20, pg 3-90	60 mph 50 mph ¹	45 mph 40 mph¹	45 mph 40 mph ¹	45 mph 35 mph		35 mph ⁷	
Design Vehicle RDM Pg 7-25 and 7-26		N/A			WB-62 ²		
	Cro	ss Section Ele	ements				
Lane Widths RDM table 3-1, pg 3-4; RDM table 3-18, pg 3-65; RDM pg 2-33	12 ft	14 ft	14 ft (one) 24 ft (two)	12 ft			
Shoulder Width (Inside/Left) RDM table 3-18, pg 3-65	10 ft	4 ft³	4 ft³	N/A			
Shoulder Width (Outside/Right) RDM table 3-1, pg 3-4; RDM table 3-18, pg 3-65	10 ft	6 ft to 10 ft	8 ft to 12 ft	N/A			
Offset to Face of Curb RDM table 3-1, pg 3-4		N/A		1 ft (min)			
Normal Cross-Slope (Pavement) RDM pg 2-31 and TxDOT Houston District Memo (9-17-2005)	Inside shoulder and 4 inside lanes: 2% Remaining: 3%	2% to 3%	2%				
Border Width (measured from face of curb) RDM table 3-1, pg 3-4	20 ft	N.	/A 15 ft (min) Match Exis		Match Exist		

Design Element <i>Reference</i>	Freeway and Managed Lanes	Ramps and Collector- Distributor	Direct Connectors	Frontage Road	Cross Roads – SH/FM	Local Streets	
Sidewalk Width RDM table 3-1, pg 3-4		N/A		6 ft (a	5 ft (min) igainst back of	curb)	
Normal Sidewalk Slope RDM pg 2-39		N/A		1.5% Desirable 2% Max			
Maximum Side Slope RDM pg 2-41			4:1 De: 3:11				
Maximum Algebraic Difference in Cross Slope at Crossover Line RDM table 3-22, pg 3-94		4% to 5%			N/A		
	Horizoi	ntal Alignmen	tElements				
Horizontal Clearance RDM table 2-12, pg 2-44	30 ft	16	oft	4 ft (curb) 20 ft (no curb)		; 3 ft (min) urb face	
Minimum Horizontal Clearance from Face of Curb to Face of Bridge Column/Obstruction RDM fig 3-38, pg 3-96	N/A	N.	/A	6 ft			
Minimum Radius of Curvature (with max. superelevation) RDM table 2-3, pg 2-12	2195 ft 1050 ft ¹	810 ft 485 ft¹	810 ft 485 ft¹	N/A			
Minimum Radius (without superelevation) RDM table 2-6, pg 2-15; RDM table 3-21, pg 3-92	11100 ft 7870 ft ¹	6480 ft 5230 ft ¹	6480 ft 5230 ft ¹	N/A			
Maximum Superelevation RDM pg 2-14; AASHTO pg 3-31		6%		N/A			
Superelevation Attainment - Roadway RDM pg 2-18 and 2-20	Reverse Parabola			N/A			
Superelevation Attainment - Structures	Linear Rotation			N/A			
Vertical Alignment Elements							
Stopping Sight Distance RDM figure 2-2, pg 2-21	570 ft 425 ft¹	360 ft 305 ft ¹	360 ft 305 ft ¹	360 ft	250 ft	250 ft	

Design Element <i>Referenc</i> e	Freeway and Managed Lanes	Ramps and Collector- Distributor	Direct Connectors	Frontage Road	Cross Roads – SH/FM	Local Streets
Maximum Gradient RDM table 2-11, pg 2-25	3% 4%¹	69	%	6%	64	6% ⁵
Minimum Gradient for Widening Area	Match Existing					
Minimum Gradient with Curb or Concrete Barrier RDM pg 2-25	0.35%					
K Value (Crest) RDM fig 2-5, pg 2-28	151 84¹	61 44 ¹	61 44 ¹	6	1	29-44
K Value (Sag) RDM fig 2-6, pg 2-29	136 96¹	79 64 ¹	79 64¹	79 49-64		49-64
Vertical Clearance ⁶ RDM table 3-1, Pg 3-4	16.5 ft					
Vertical Clearance (Railroad and High Capacity Transit Overpasses) RDM fig 3-16, pg 3-64	23'-4"					

Notes:

- 1. The values shown apply to the highways that encompass Downtown I-45 south of N. Main, US 59/I-69, I-10, and SH 288. Use higher design speed where practical.
- 2. Adjacent lane encroachment allowed (departure only)
- 3. In those areas where sight distance criteria is not met, use inside shoulder width of 8 ft and outside shoulder width of 4 ft
- 4. Use flatter gradient where practical
- 5. Must maintain 2% at sidewalk locations
- 6. Use 16.75 ft for design to allow 16.5 ft for sign
- 7. Surface streets that are considered as part of the Downtown Houston grid system shall follow City of Houston design standards

Sources: A Policy on Geometric Design of Highway and Streets (AASHTO), 2011 and TxDOT Roadway Design Manual (RDM), 2014

The assumptions used during the alternative development process include the following:

- LOSE will be used as acceptable for general purpose lanes and LOSD for managed lanes.
- All planned/committed projects, identified in the updated 2035 Regional Transportation Plan (RTP) will be included in existing conditions.
- Transit (bus or light rail alternatives) will not be considered since the North Line is under construction.
- Initial assumption is no additional general purpose lanes only consider adding four (4) managed lanes.
- Proposed managed lanes will also carry HOV traffic (same as I-10 managed lanes).

- Hardy Toll Road will be an express toll facility (all electronic).
- Total reconstruction of I-45.
- No additional ROW between Quitman and Cavalcade except at intersections to improve operations.
- Continuous frontage roads will be maintained along I-45.
- Frontage road connectivity through the I-610/I-45 interchange was considered.
- Maximum of six (6) reasonable alternatives will move forward for further consideration and evaluation.

The following identifies the guidelines for alternatives development:

- Stay within the existing I-45 right of way between Quitman Street and Cavalcade Street, except at intersections where turn lanes may be needed.
- Minimize adverse effects on quality of life issues of the residents and neighborhoods in the project area.
- Study Hardy Toll Road as an alternative route for additional lanes.
- Evaluate use of tunnels as an alternative in areas of constrained right-of-way.

3.0 Universe of Alternatives

The Universe of Alternatives was developed using the results of previous studies and reports, public and stakeholder input, and alternatives developed by the Study Team to meet the need and purpose of the proposed project.

3.1 Description of Universe of Alternatives

Table 3 and **Table 4** provide a description of the Universe of Alternatives for Segments 2 and 3, respectively. The tables also provide the previous study or report where the alternative originated, if applicable. The Universe of Alternatives for Segment 2 are illustrated on **Figures 10** through **17** (Alternatives 3 through 15). The Universe of Alternatives for Segment 3 are illustrated on **Figures 18** through **26** (Alternatives 3 through 10).

In December 2005, an independent corridor feasibility study was completed on alternatives for the section of US 59/I-69 between I-45 to Spur 527. The alternatives evaluated and the results of the study can be found in the *US 59: Spur 527 to I-45 Corridor Feasibility Study Informational Package* (TxDOT 2005). The study evaluated impacts of various alternative transportation improvement and recommended the Most Feasible Alternative, identified to improve existing and future mobility and safety conditions on US 59/I-69 between Spur 527 and just north of I-45. The various alternatives were evaluated with regard to traffic/mobility, engineering/cost, environmental/land use, cost effectiveness, and public input. The alternatives evaluated included:

- No Build, which considered existing conditions plus the committed transportation improvements;
- TSM/Access improvements:
- Adding additional general purpose lanes; and
- Adding additional HOV lanes.

The results of this study were incorporated into the alternatives evaluated for Segment 3.

Table 3: Segment 2 Universe of Alternatives

Alternative No.	Alternative Type	Description	Previous Study/Report
1	Existing Configuration	No Build	N/A
2	TSM Upgrades	Various TSM projects	N/A
3	Widen existing	12 lane section - includes 10 general purpose lanes and 2 reversible, special purpose lanes.	North-Hardy Planning Study (2005)
4	Widen existing	12 lane section - includes 8 general purpose lanes and 4 managed lanes.	North-Hardy Planning Study (2005)
5	Elevated High Occupancy/Toll (HOT) ¹ Lanes	12 lane section - includes 10 general purpose lanes and 2 elevated HOT¹ lanes.	North-Hardy Planning Study (2005)
6	Widen existing	12 lane section - includes 10 general purpose lanes and 2 non-barrier separated HOT¹ lanes.	North-Hardy Planning Study (2005)
7	Widen existing	10 lane section - includes 8 general purpose lanes and 2 barrier separated HOT¹ lanes.	North-Hardy Planning Study (2005)
8	Widen existing	10 lane section - includes 8 general purpose lanes and 2 non-barrier separated HOT¹ lanes.	North-Hardy Planning Study (2005)
9	Widen existing	12 lane section - includes 8 general purpose lanes and 2 reversible managed lanes.	I-45N Alternatives Analysis (2012)
10	Widen existing	12 lane section - includes 8 general purpose lanes and 4 managed lanes.	I-45N Alternatives Analysis (2012)
11	Widen existing with elevated managed lanes	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on a single structure at center.	I-45N Alternatives Analysis (2012)
12	Widen existing with elevated managed lanes	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on double decker structure at center.	I-45N Alternatives Analysis (2012)
13	Widen existing with elevated managed lanes	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on 2 separate structures on left and right sides of centerline.	I-45N Alternatives Analysis (2012)
14	Add tunnel to existing	Tunneled roadway underneath I-45. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
15	Add direct connector	Addition of direct connectors along I-610 corridor from I-45 to Hardy Toll Road includes 4 managed lanes. This alternative also includes widening of Hardy Toll Road to provide one additional lane inbound and outbound. Illow lower occupancy vehicles to gain access to the lanes by	I-45N Alternatives Analysis (2012)

 $Note: 1.\,HOT\,lanes\,are\,HOV\,lanes\,that\,also\,allow\,lower\,occupancy\,vehicles\,to\,gain\,access\,to\,the\,lanes\,by\,paying\,a\,toll.$

 Table 4: Segment 3 Universe of Alternatives

Alternative No.	Alternative Type	Description	Previous Study/Report
1	Existing Configuration	No build	N/A
2	TSM Upgrades	Various TSM projects	N/A
3	Convert downtown loop to one way loop	Convert existing downtown loop roadway network to a one-way loop.	I-45N Alternatives Analysis (2012)
4	Add tunnel to existing	Tunneled roadway underneath La Branch St. and terminates at the US 59/I-69/SH 288 interchange. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
5	Add tunnel to existing	Tunneled roadway underneath I-45, continues underneath Bagby St. and terminates at Spur 527. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
6	Add tunnel to existing	Tunneled roadway underneath I-45, continues to Jefferson St. and terminates at I-45 south of the I-45/US 59/I-69 interchange. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
7	Add tunnel to existing	Tunneled roadway underneath Houston Ave. and splits to Jefferson St. and Bagby St. Tunnel terminates at I-45 south of the I-45/US 59/I-69 interchange and Spur 527. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
8	Elevated managed lanes	Elevated roadway along Houston Ave and terminates at I-45 near Allen Parkway. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
9	Add tunnel to existing	Utilizes existing I-10 HOV bridge into downtown and then becomes tunneled roadway underneath I-45 and Jefferson St. and terminates at I-45 south of the I-45/US 59/I-69 interchange. Includes 4 managed lanes.	I-45N Alternatives Analysis (2012)
10	Widen existing	8 lane section from I-10 to I-45/US 59/I-69 interchange includes 8 general purpose lanes.	I-45N Alternatives Analysis (2012)

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH 24' NB FR 2-12' LN SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 3) PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 4) 245' EXIST R.O.W. WIDTH 5' BDR WIDTH 24' SB FF 2-12' LN 24' NB FR 5' BDR WIDTH CROCKETT ST Roadway & Bridge Reconstruct Section Location **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 10: Segment 2 Alternatives 3 and 4

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH 2-12' LN PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 5) 5' BOR WIDTH 5' BDR WIDTH 10' SHLD-PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 6) 24' NB FR 5' BDR WIDTH 2-12' LN 5' BDR WIDTH CROCKETT ST 1'-9"-OVERHANG 1'-9" OVERHANG Roadway & Bridge Improvements Reconstruct Interchange **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 11: Segment 2 Alternatives 5 and 6

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH 2-12' LN PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 7) 10' SHLD PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 8) 245' EXIST R.O.W. WIDTH 24' NB FR 5' BDR WIDTH 10' SHLD CROCKETT ST Roadway & Bridge Reconstruct Interchange **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 12: Segment 2 Alternatives 7 and 8

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH 24' NB FR 2-12' LN PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 9) 245' EXIST R.O.W. WIDTH 10' SHLD SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 10) 245' EXIST R.O.W. WIDTH CROCKETT ST 10" SHLD-4' SHLD 4' SHLD -10" SHLD -10" SHLD 10' SHLD 15' OUTSIDE LANE FOR SHARED USE WITH BICYCLES 1 1 Roadway & Bridge Improvements Reconstruct Interchange **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 13: Segment 2 Alternatives 9 and 10

PRELIMINARY: SUBJECT TO CHANGE **IH 45 NORTH - UNIVERSE OF ALTERNATIVES** SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 11) 4' SHLD 4' SHLD 4' MNG LN 24' MNG LV 2-12' LN 2-12' LN SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 12) Roadway & Bridge Reconstruct Interchange Section Location **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 14: Segment 2 Alternatives 11 and 12

PRELIMINARY: SUBJECT TO CHANGE **IH 45 NORTH - UNIVERSE OF ALTERNATIVES** SEGMENT 2 LIMITS: IH 610 TO IH 10 LENGTH: 2.75 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 245' EXIST R.O.W. WIDTH 30' SB FR 3-10' LN 24' NB FR 100 PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 13) -10' SHLD 27' SB FR 27' NB FR -10' SHLD 10' SHLD-8.67° COLUMN--8.67 COLUMN SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 14) 分分 Roadway & Bridge Reconstruct Interchange Section Location **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 15: Segment 2 Alternatives 13 and 14

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 2 LIMITS: IH 610 FROM IH 45 TO HARDY TOLL ROAD AND HARDY TOLL ROAD FROM IH 610 TO IH 10 LENGTH: 4.5 MILES **EXISTING TYPICAL SECTION - IH 610** ESTIMATED COST (CONSTRUCTION & DESIGN): SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 610 (ALTERNATIVE 15) EXIST R.O.W. WIDTH VARIES (300' USUAL) **EXISTING TYPICAL SECTION - HARDY TOLL ROAD** EXIST R.O.W. WIDTH VARIES C HARDY TOLL RD PECORE ST 4' SHLD - ! -4' SHLD RAILROAD TRACKS **SELECTED AS PRELIMINARY ALTERNATIVE** PROPOSED TYPICAL SECTION - HARDY TOLL ROAD (ALTERNATIVE 15) EXIST R.O.W. WIDTH VARIES & HARDY TOLL RD -10' SHLD 10' SHLD 4' SHLD-4' SHLD Roadway & Bridge Improvements RAILROAD TRACKS Reconstruct Interchange **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 16: Segment 2 Alternatives 15 and 16

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE SEGMENT 3 LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 206' EXIST R.O.W. WIDTH -10' SHLD 4' SHLD - 4' SHLD 10' SHLD-CROCKETT ST 36' NB ML 3-12' LANES 111111111 SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 3) 205' EXIST R.O.W. WIDTH 10' SHLD-GRAY ST Roadway & Bridge Reconstruct Interchange **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 17: Segment 3 Alternative 3 - I-45

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - US 59** EXIST R.O.W. WIDTH VARIES € US 59 12' SHLD | 12' SHLD 10' SHLD CROCKETT ST 2 **SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - US 59 (ALTERNATIVE 3)** DALLAS ST 1111111111 OVETT BLVD Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 18: Segment 3 Alternative 3 - US 59

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 10** EXIST R.O.W. WIDTH VARIES (330' MAX.) 12' SHLD | 12' SHLD 10' SHLD-1 1 1 1 PROVIDENCE ST **SELECTED AS PRELIMINARY ALTERNATIVE** PROPOSED TYPICAL SECTION - IH 10 (ALTERNATIVE 3) EXIST R.O.W. WIDTH VARIES (330' MAX.) DALLAS ST TO IH 45 NORTH/IH 10 WEST TO IH 45 SOUTH TO IH 10 EAST 10' SHLD -10' SHLD 10' SHLD-OVETT BLVD Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 19: Segment 3 Alternative 3 – I-10

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - LA BRANCH (ALTERNATIVE 4) **QLA BRANCH ST** CROCKETT ST 54.5' DIAMETER DALLAS ST PROPOSED TYPICAL SECTION - CRAWFORD (ALTERNATIVE 4) CCRAWFORD ST OVETT BLVD 54.5' DIAMETER Roadway & Bridge Improvements

Figure 20: Segment 3 Alternative 4

IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT

HARRIS COUNTY

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 5) DALLAS ST PROPOSED TYPICAL SECTION - BAGBY (ALTERNATIVE 5) OVETT BLVD 54.5' DIAMETER Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 21: Segment 3 Alternative 5

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 6) B IH 45 NB B IH 45 SB -10' SHLD DALLAS ST PROPOSED TYPICAL SECTION - JEFFERSON (ALTERNATIVE 6) OVETT BLVD 11111 54.5' DIAMETER Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 22: Segment 3 Alternative 6

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): SELECTED AS PRELIMINARY ALTERNATIVE PROPOSED TYPICAL PROPOSED TYPICAL **SECTION - HOUSTON (ALTERNATIVE 7)** SECTION - JEFFERSON (ALTERNATIVE 7) 100' EXIST R.O.W. WIDTH 80' EXIST R.O.W. WIDTH © HOUSTON AVE & JEFFERSON AVE 11111 GTON AVE 54.5' DIAMETER TUNNEL DALLAS ST PROPOSED TYPICAL SECTION - BAGBY (ALTERNATIVE 7) 80' EXIST R.O.W. WIDTH OVETT BLVD POLKST 59 54.5' DIAMETER TUNNEL Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 23: Segment 3 Alternative 7

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL** PROPOSED TYPICAL **SECTION - HOUSTON SECTION - HOUSTON (ALTERNATIVE 8A)** 100' EXIST R.O.W. WIDTH 100' EXIST R.O.W. WIDTH € HOUSTON AVE 4' SHLD- 1-4' SHLD IGTON AVE 22' 介介 20'-22' COLUMN DALLAS ST PROPOSED TYPICAL **SECTION - HOUSTON (ALTERNATIVE 8B)** 100' EXIST R.O.W. WIDTH 10' SHLD -10' SHLD OVETT BLVD POLKST 527 3 8.67' COLUMN -8.67' COLUMN 59 Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 24: Segment 3 Alternative 8

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 9) EXIST R.O.W. WIDTH VARIES B IH 45 NB \$ IH 45 SB 10' SHLD 10' SHLD-DALLAS ST PROPOSED TYPICAL SECTION - JEFFERSON (ALTERNATIVE 9) 80' EXIST R.O.W. WIDTH & JEFFERSON AVE OVETT BLVD POLKST 11111 Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT** HARRIS COUNTY

Figure 25: Segment 3 Alternative 9

IH 45 NORTH - UNIVERSE OF ALTERNATIVES PRELIMINARY: SUBJECT TO CHANGE LIMITS: IH 10 TO IH 45/US 59 INTERCHANGE LENGTH: 2.8 MILES ESTIMATED COST (CONSTRUCTION & DESIGN): **EXISTING TYPICAL SECTION - IH 45** 205' EXIST R.O.W. WIDTH € IH 45 CROCKETT ST 2 **SELECTED AS PRELIMINARY ALTERNATIVE** PROPOSED TYPICAL SECTION - IH 45 (ALTERNATIVE 10) DALLAS ST 10' SHLD- 1.21' OVETT BLVD Roadway & Bridge Improvements **IH 45 NORTH HOUSTON HIGHWAY IMPROVEMENT PROJECT**

Figure 26: Segment 3 Alternative 10

HARRIS COUNTY

3.2 Initial Alternative Screening Process

The initial alternative screening process was used to reduce the Universe of Alternatives to six preliminary build alternatives for each segment. This initial screening of alternatives was accomplished by assessing the Universe of Alternatives according to general qualitative criteria. The evaluation criteria for the initial screening process was developed using the project need and purpose statement, the project goals, and the feedback received from the agencies and public at the first scoping meeting, and during the comment period.

Table 5 presents the engineering and traffic criteria used during the initial screening process which was utilized to evaluate the Universe of Alternatives.

Table 5: Initial Alternative Screening Engineering and Traffic Criteria

Category	Evaluation Criteria	Rating
Engineering	Meets Current Design Criteria?	Yes/No
Lingineering	Additional Right-of-Way (ROW) required between Cavalcade and Quitman?	Yes/No
Traffic	Traffic/Mobility Improvements 1	High/Medium/Low

Note: 1. Traffic/Mobility Improvements is a rating determined using outputs from the travel demand models. The model provides information on how many drivers will use the highway if improved, how this compares among various alternative improvements, and how many hours drivers can expect to save traveling on the highway if improved, also known as Vehicle-Hours Traveled (VHT).

Using the engineering and traffic criteria presented in **Table 1**, the Study Team conducted a two-day workshop with a multi-disciplinary team to review the alternatives. Proposed typical sections were developed at critical sections (limited to 5 sections per alternative) for the various alternatives and included the number of travel lanes, shoulders, type and range of median width, frontage road as applicable, clear zone width and border width.

Six preliminary alternatives were selected as the best alternatives from the universe of alternatives that included a full range of reasonable and feasible alternatives.

3.3 Initial Alternative Screening Results

Table 6 and **Table 7** present the results of the screening process for Segment 2 and Segment 3, respectively. Build alternatives that were identified to move into the next alternative evaluation level were selected as preliminary alternatives. The detailed initial screening matrices, for Segment 2 and Segment 3, are included in **Appendix B**.

Table 6: Segment 2 Initial Screening Results

			Engineering		Move
Alt. No.	Description	Meets Current Design Criteria	Additional ROW (Cavalcade to Quitman)	Traffic Mobility Improvements	Forward as Preliminary Alternative
1	No Build	No	No	N/A	Yes
2	Various TSM projects	No	No	N/A	No
3	12 lane section - includes 10 general purpose lanes and 2 reversible, special purpose lanes.	Yes	No	Medium	Yes
4	12 lane section - includes 8 general purpose lanes and 4 managed lanes.	No	No	High	No

		Engii	neering	Traffic	Move
Alt. No.	Description	Meets Current Design Criteria	Additional ROW (Cavalcade to Quitman)	Traffic Mobility Improvements	Forward as Preliminary Alternative
5	12 lane section - includes 10 general purpose lanes and 2 elevated HOT lanes.	Yes	No	Low	No
6	12 lane section - includes 10 general purpose lanes and 2 non-barrier separated HOT lanes.	Yes	No	Low	No
7	10 lane section - includes 8 general purpose lanes and 2 barrier separated HOT lanes.	No	No	Low	No
8	10 lane section - includes 8 general purpose lanes and 2 non-barrier separated HOT lanes.	Yes	No	Low	No
9	12 lane section - includes 8 general purpose lanes and 2 reversible managed lanes.	Yes	No	Low	No
10	12 lane section - includes 8 general purpose lanes and 4 managed lanes.	Yes	No	High	Yes
11	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on a single structure at center.	Yes	No	High	Yes
12	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on double decker structure at center.	Yes	No	High	Yes
13	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on 2 separate structures on left and right sides of centerline.	Yes	No	High	No
14	Tunneled roadway underneath I-45. Includes 4 managed lanes.	Yes	No	High	Yes
15	Addition of direct connectors along I-610 corridor from I-45 to Hardy Toll Road includes 4 managed lanes. This alternative also includes widening of Hardy Toll Road to provide one additional lane inbound and outbound.	Yes	No	Medium	Yes

Eight alternatives from the Universe of Alternatives for Segment 2 were eliminated from further evaluation during the initial screening process. The rationale for eliminating these alternatives is described below.

- Alternative 2: TSM projects are programmed to provide short term mobility improvements and therefore do not meet the need and purpose of the project.
- Alternative 4: Alternative does not provide sufficient shoulder widths for I-45 main lanes.
- Alternative 5: Alternative would provide two additional HOT lanes and two general purpose lanes on I-45. The *I-45/Hardy Corridor Traffic Study* recommended four additional managed lanes within the project limits; therefore, this alternative does not meet need and purpose for the project.
- Alternative 6: Alternative would provide two additional HOT lanes and two general purpose lanes on I-45. The *I-45/Hardy Corridor Traffic Study* recommends four additional lanes within the project limits; therefore, this alternative does not meet need and purpose for the project.

- Alternative 7: Alternative would only provide two additional lanes on I-45. The *I-45/Hardy Corridor Traffic Study* recommends four additional lanes within the project limits. In addition, this alternative would not provide sufficient shoulder widths for the I-45 corridor. Therefore, this alternative does not meet need and purpose for the project.
- Alternative 8: Alternative would only provide two additional lanes on I-45. The *I-45/Hardy Corridor Traffic Study* recommends four additional lanes within the project limits; therefore this alternative does not meet need and purpose for the project.
- Alternative 9: Alternative would only provide two additional reversible lanes on I-45. The *I-45/Hardy Corridor Traffic Study* recommends four additional managed lanes within the project limits; therefore this alternative does not meet need and purpose for the project.
- Alternative 13: The elevated structures associated with the alternative would be within proximity of existing residential properties.

Table 7: Segment 3 Universe of Alternatives Screening Results

		Engi	neering	Traffic	Move
Alt. No.	Description	Meets Current Design Criteria	Additional ROW (Cavalcade to Quitman)	Traffic Mobility Improvements	Forward as Preliminary Alternative
1	No build	No	N/A	N/A	Yes
2	Various TSM projects	No	N/A	N/A	No
3	Convert existing downtown loop roadway network to a one-way loop.	Yes	N/A	Medium	Yes ¹
4	Tunneled roadway underneath La Branch St. and terminates at the US 59/I-69/SH 288 interchange. Includes 4 managed lanes.	Yes	N/A	Medium	Yes
5	Tunneled roadway underneath I-45 continues underneath Bagby St. and terminates at Spur 527. Includes 4 managed lanes.	Yes	N/A	Medium	Yes
6	Tunneled roadway underneath I-45 continues to Jefferson St. and terminates at I-45 south of the I-45/US 59/I-69 interchange. Includes 4 managed lanes.	Yes	N/A	Medium	Yes
7	Tunneled roadway underneath Houston Ave. and splits to Jefferson St. and Bagby St. Tunnel terminates at I-45 south of the I- 45/US 59/I-69 interchange and Spur 527. Includes 4 managed lanes.	Yes	N/A	High	Yes
8	Elevated roadway along Houston Ave and terminates at I-45 near Allen Parkway. Includes 4 managed lanes.	Yes	N/A	Low	No
9	Utilizes existing I-10 HOV bridge into downtown and then becomes tunneled roadway underneath I-45 and Jefferson St. and terminates at I-45 south of the I-45/US 59/I-69 interchange. Includes 4 managed lanes.	Yes	N/A	Low	No

		Engineering		Traffic	Move
Alt. No.	Description	Meets Current Design Criteria	Additional ROW (Cavalcade to Quitman)	Traffic Mobility Improvements	Forward as Preliminary Alternative
10	8 lane section from I-10 to I-45/US 59/I-69 interchange includes 8 general purpose lanes.	Yes	N/A	Medium	Yes

Note: 1. Alternative 3 for Segment 3 was evaluated in further detail during the initial alternative screening process. The results of this evaluation are presented in **Table 8**.

Because of the complexity of Alternative 3 for Segment 3, the Study Team conducted a more detailed initial alternative screening of the one-way Downtown Loop alternative. **Table 8** summarizes the detailed approach and results of the initial screening. After this detailed screening, it was determined that Alternative 3 for Segment 3 would move forward as a Preliminary Alternative due to the potential traffic mobility improvements that this alternative would offer. The alternative will be developed and evaluated further in the next phase of the alternatives analysis.

Table 8: Segment 3, Alternative 3 Detailed Initial Alternative Screening

		tanea miciai / nice native ser cening
Evaluation Criteria	Detailed Measure	Alternative 3 Screening Results
Lane Balance	The Study Team evaluated the number of lanes, as shown on the original conceptual design provided by TxDOT, to ensure that no lane balance violations occurred.	The analysis concluded that the lanes throughout the loop were not balanced and also required the addition of a direct connector on the northwest corner in order to complete the loop to provide movement in all directions and obtain a true loop. Adjustments were made to the original conceptual design in order to create a proper lane balance throughout the system.
Required Number of Lanes	The Study Team worked with the traffic demand model to estimate the future number of lanes needed based on the design year.	The traffic demand model indicated that future freeway to freeway demand is high, but the future demand is low for traffic traveling from I-45S to US 59N/I-69 and US 59N/I-69 to I-10W.
Geometric Elements	Vertical and Horizontal Alignments	The current design has few fatal flaws in terms of vertical clearance for some of the ramps. In the original conceptual design, there is not enough distance to change levels and connect the various freeways. In order to make the current design work, some city street closures and major re-construction would be required to provide adequate vertical clearance
Access to and from Downtown	Access to and from downtown is very challenging with the one-way loop and the current one-way grid surface street system. Access can be assessed by evaluating the entrance and exit ramps provided with the conceptual design.	Entrance Ramps: Most of the current entrance ramps would be eliminated; only 2 of the existing 7 ramps could be reconstructed. It is more challenging to accommodate the entrance ramps for the one-way loop from the downtown area. Exit Ramps: With the original conceptual design, vehicles exiting the freeway would have to weave across multiple travel lanes. This design could be improved by providing exit ramps on both sides of the one-way freeway. In the design year, there would be demand for approximately 14 exit ramps, while the conceptual design can only accommodate 10 exit ramps. Traffic accessing downtown from I-10 and US 59/I-69 are twice as high as those from I-45S. The highest demands come from I-45N and I-10W.
Signing	Adequate Distances for Signage	The loop does not provide adequate distances to provide signing for the various destinations, it will not meet design criteria for signing.

Evaluation Criteria	Detailed Measure	Alternative 3 Screening Results
Constructability	Complexity and Duration of Construction	With the sheer volume of traffic that is generated in the downtown area, it will be almost impossible to completely reconstruct the downtown freeway system without major disruption to the traffic in the downtown area. The complexity of construction and future traffic volume will also affect the duration of construction which may extend for more than 10 years. There may be strong opposition to this alternative by the businesses in the area.

Three alternatives from the Universe of Alternatives for Segment 3 were eliminated from further evaluation during the initial screening process. The rationale for eliminating these alternatives is described below.

- Alternative 2: Upgrade facility with planned TSM projects.
- Alternative 8: The elevated structures associated with the alternative would be within proximity of existing residential properties.
- Alternative 9: Alternative had low demand for this route per travel demand model.

The six build alternatives for each segment were carried forward as the set of Preliminary Alternatives. Alternative 1, the "No Build" Alternative, for each segment will advance with the build alternative through the alternative evaluation process.

4.0 Preliminary Alternatives

4.1 Description of Segment 2 Preliminary Alternatives

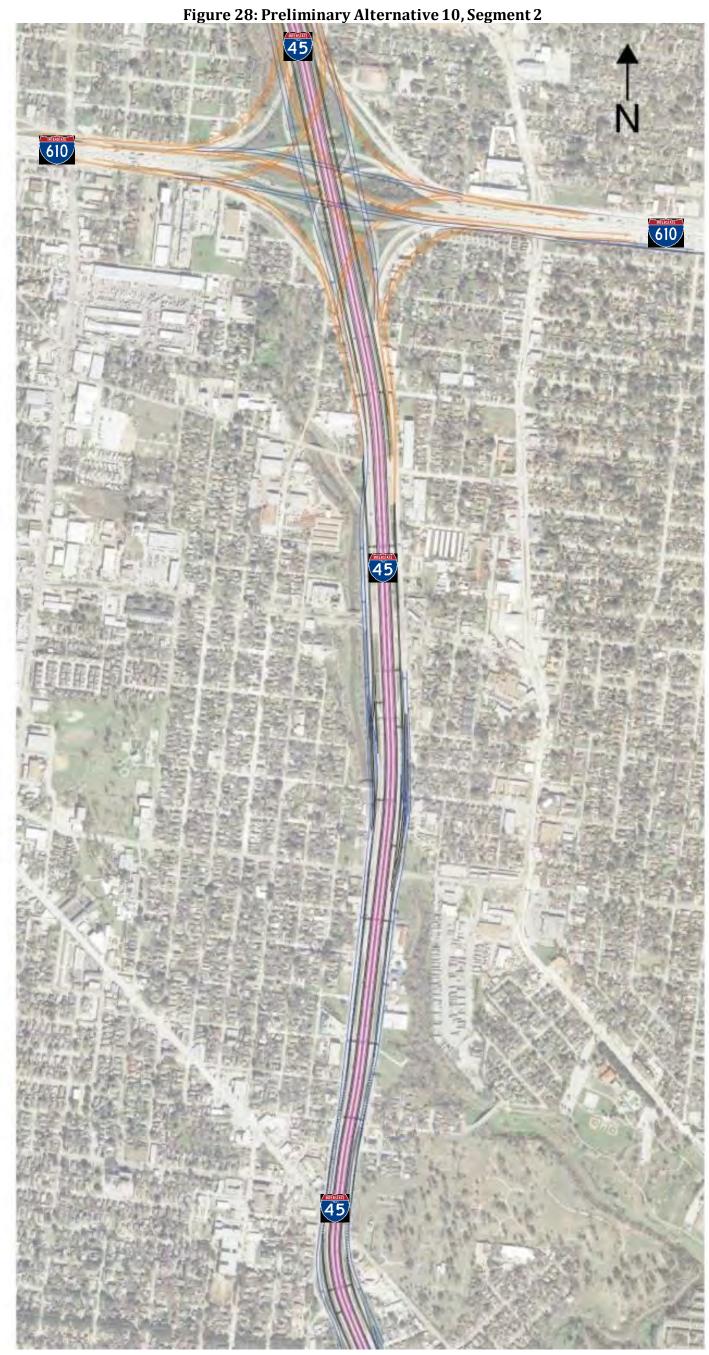
Table 9 provides a more detailed description of the Preliminary Alternatives for Segment 2. The table presents the objective and the proposed geometry for the alternatives. The Preliminary Alternatives were further developed to allow for the more detailed screening process. The Preliminary Alternatives for Segment 2 are illustrated on **Figure 27** through **32**.

 Table 9: Segment 2 Preliminary Alternatives

Alt. No.	Alternative Type	Description	Objective
1	Existing conditions	No build	Maintain existing conditions.
3	Widen existing	12 lane section - includes 10 general purpose lanes and 2 reversible, special purpose lanes.	Widen existing I-45 and utilize reversible, special purpose lanes: Compatible with Segment 1 Alternatives 4, 5, 6, 7, and 8 Approximately 13 foot overhang for cantilevered frontage roads No additional ROW required except at I-45/I-610 interchange Similar frontage road ramping; access points maintained Alternative 3 would involve widening the existing I-45 pavement to accommodate more lanes: ten general purpose and two reversible, special purpose lanes. All existing access points will be maintained. In order to fit the additional general purpose lanes, the frontage roads will have a cantilever design with an approximately 13 foot overhang.
10	Widen existing	12 lane section - includes 8 general purpose lanes and 4 managed lanes.	 Widen existing I-45: Compatible with Segment 1 Alternatives 4, 5, 6, 7, and 8 Cantilevered frontage roads south of Cavalcade Street Include a shared bike lane along the frontage road No additional ROW required except at I-45/I-610 interchange Improve connectivity with adjacent street grid Alternative 10 would involve widening the existing I-45 pavement to accommodate more lanes: eight general purpose and four managed lanes. Existing access points would not be maintained for this alternative because of ROW constraints south of Cavalcade Street. Braided ramps are proposed between Cavalcade Street and Patton Street for both directions – to access North Main Street from I-45 South and to access Cavalcade from I-45 North. There would also be an exit ramp before N. Main Street from I-45 North and toward Quitman Street from I-45 South.
11	Widen existing with elevated managed lanes	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on a single structure at center.	Widen existing I-45 with elevated managed lanes: Compatible with Segment 1 Alternatives 4, 5, 6, 7, and 8 No additional ROW required except at I-45/I-610 interchange Similar frontage road ramping; access points maintained Includes a shared use bike lane along the frontage road Maintains similar footprint width to existing main lanes Alternative 11 would involve widening the existing I-45 pavement to accommodate more lanes: eight general purpose and four elevated managed lanes with a single structure at the center. All existing access points would be maintained, however, there would be no access to or from the managed lanes south of I-610 until Downtown.

Alt. No.	Alternative Type	Description	Objective
12	Widen existing with elevated managed lanes	12 lane section - includes 8 general purpose lanes and 4 elevated managed lanes on double decker structure at center.	 Widen existing I-45 with elevated managed lanes: Compatible with Segment 1 Alternatives 4, 5, 6, 7, and 8 No additional ROW required except at I-45/I-610 interchange Approximately 19 foot overhang for cantilever frontage roads Similar frontage road ramping; access points maintained Include a shared use bike lane along the frontage road Alternative 12 would involve widening the existing I-45 pavement to accommodate more lanes: eight general purpose and four managed lanes on a double decker structure at the center (two lanes on the top deck and two lanes on the bottom deck). The top deck of the double decker structure would be for inbound traffic, and the bottom deck would support outbound traffic. Similar access points would be maintained, however, there would be no access to or from the managed lanes south of I-610 until Downtown.
14	Add tunnel to existing	Tunneled roadway underneath I-45. Includes 4 managed lanes.	Construct a tunnel parallel to I-45: Compatible with Segment 1 Alternatives 4, 5, 6, 7, and 8 Tunnel portal located just south of I-45/I-610 interchange Alternative 14 would include the removal of the I-45 HOV lane.
15	Add direct connector	Addition of direct connectors along I-610 corridor from I-45 to Hardy Toll Road includes 4 managed lanes. This alternative also includes widening of Hardy Toll Road to provide one additional lane inbound and outbound.	Construct a direct connector to Hardy Toll Road: • Compatible with Segment 1 Alternative 3 Alternative 15 would involve constructing direct connectors between I-45 and the Hardy Toll Road parallel to I-610. The connectors would be four lanes wide and would require Hardy Toll Road to be widened by one lane in each direction.





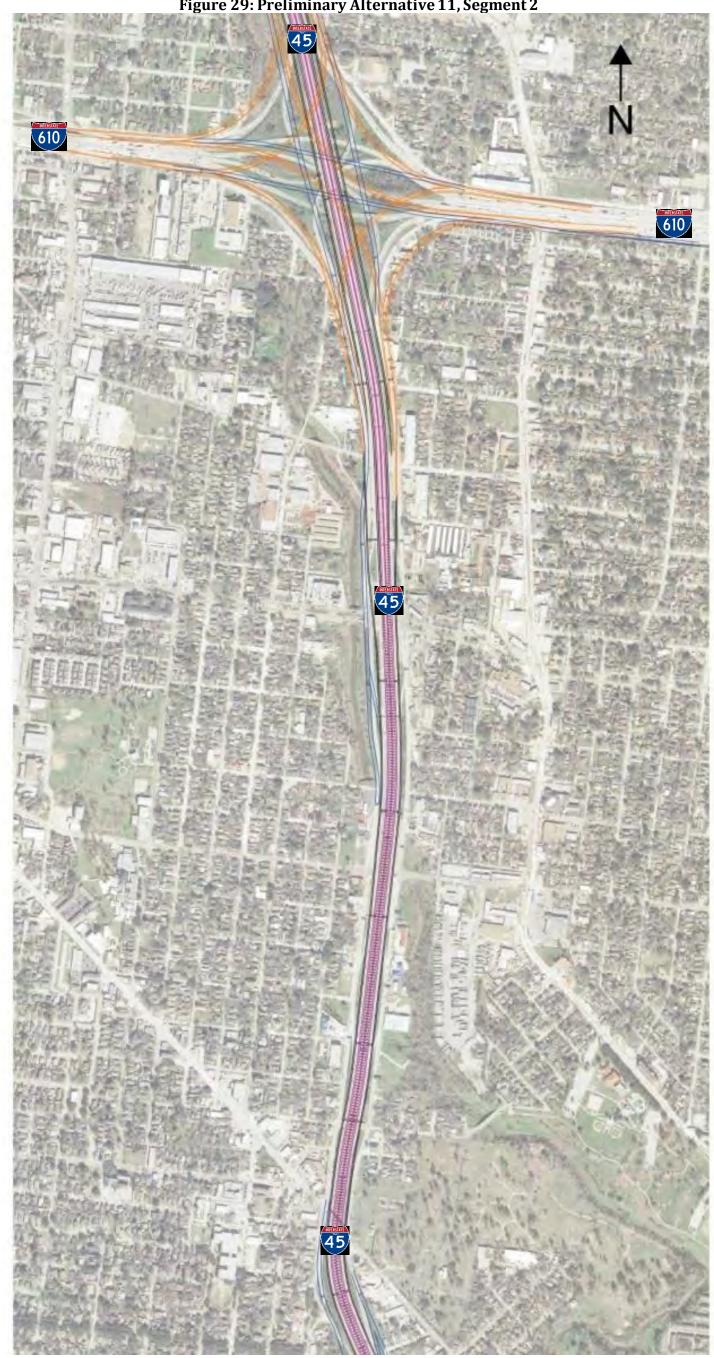
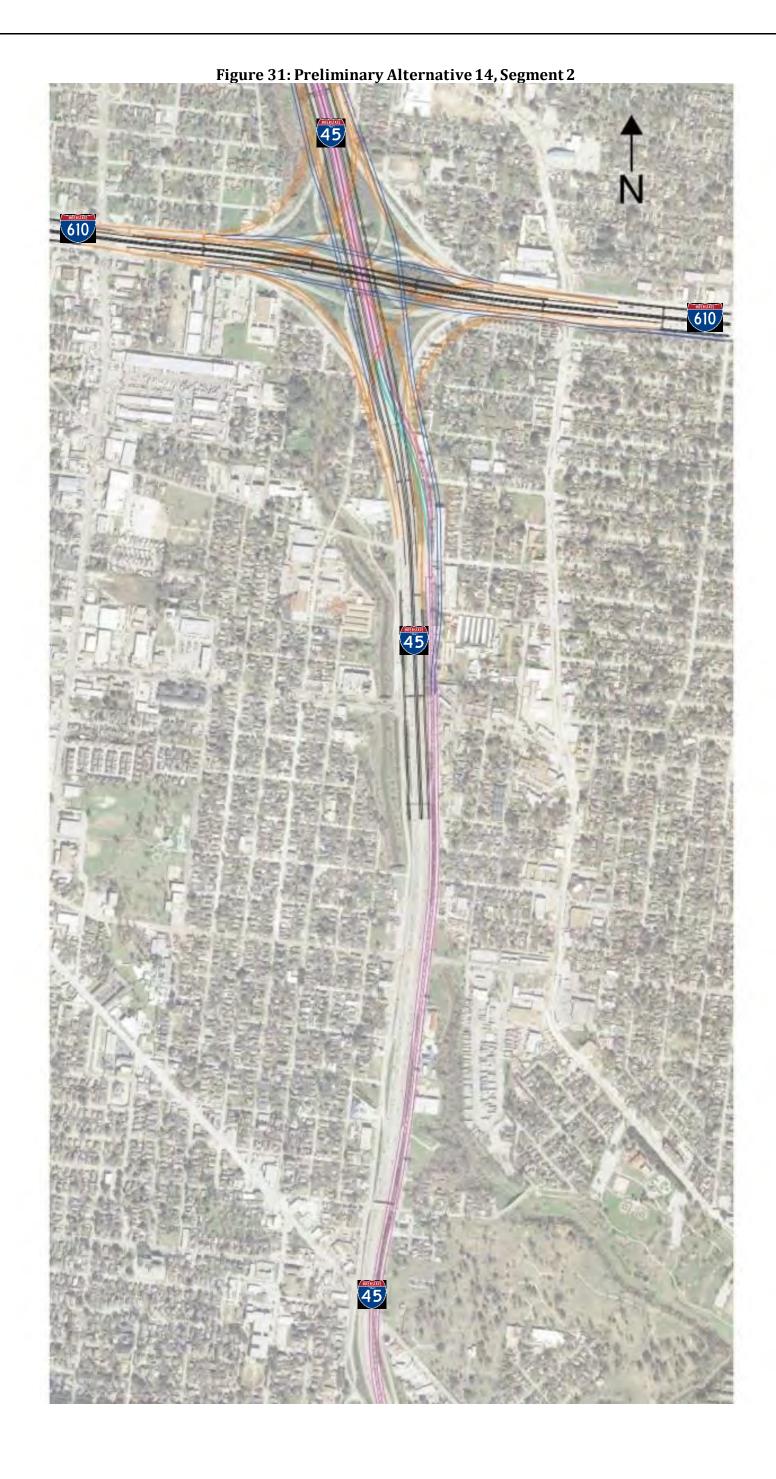
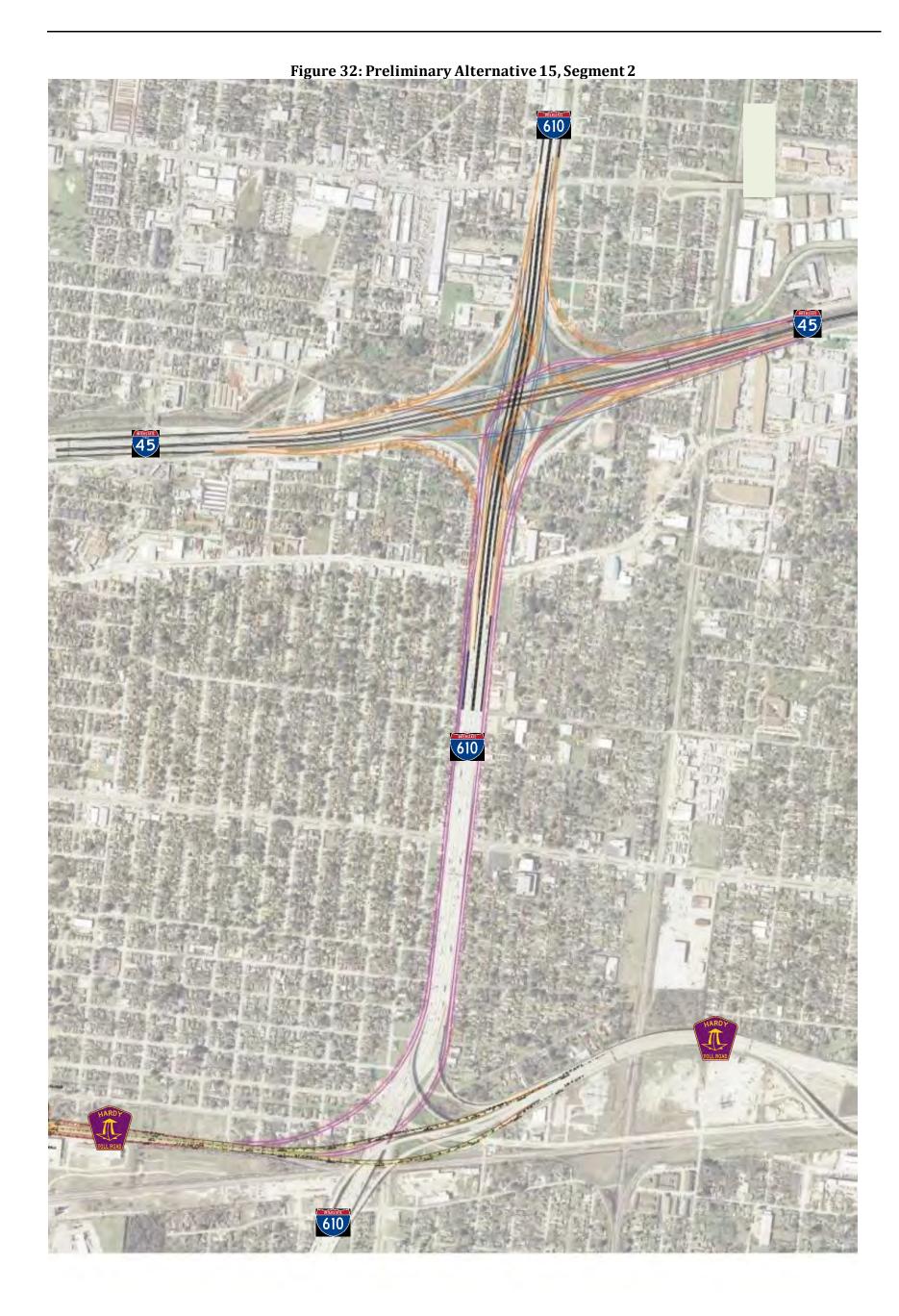


Figure 29: Preliminary Alternative 11, Segment 2







4.2 Description of Segment 3 Preliminary Alternatives

The detailed descriptions of the Preliminary Alternatives for Segment 3 are described below.

Details of the Segment 3, Alternative 3 (The One-Way Loop)

Objective: Combine I-45 and US 59/I-69 to create a "One-way Loop" around downtown:

- Compatible with Segment 2 Alternatives 3, 10, 11, and 12
- Barrier along entrance ramp from Travis to I45N to prevent movement to I-10
- I-45 South after I-10 interchange becomes two-five lane segments separated by a barrier (I-45 S Inner and I-45 S Outer)
- Traffic on US 59/I-69 and SH 288 are separated so that the existing weaving movements are removed
- Replaces broken back curve from SH 288 North to US 59/I-69 South has been improved to a single radius direct connector (DC); however, the DC still remains only 1 lane
- Adds fifth lane on US 59/I-69 South after SH 288 interchange
- The radius of the DC from US 59/I-69N to SH 288 S has been improved; however, the DC still remains only 1 lane
- US 59/I-69 South existing pavement will be used for the entrance ramp from Clay Street
- US 59/I-69 North near George R. Brown Convention Center will be 10 lanes wide separated by a barrier that divides the segment into 7 lanes and 3 lanes until the proposed Hamilton Street exit ramp
- Hamilton Street will support two-way traffic flow
- Hamilton Street will no longer provide parallel parking
- US 59/I-69 Expressway proposed adjacent to I-10 elevated over Providence Street
- Lane merges at:
 - o I-45 South to I-10 West DC to avoid reconstruction of Houston Avenue bridge
 - Nance Street entrance ramp to avoid reconstruction of McKee Street, Hardy Street, Elysian Street, and railroad bridges
 - o US 59/I-69 North and I-10 West DC convergence to support I-10 capacity while meeting the minimum two-lane DC width preference
 - US 59/I-69 North to I-45 South to avoid reconstruction of entrance ramp bridge from Jefferson Street
- List of access points identified in **Table 10**.

Table 10: Alternative 3 Access Points

Туре	From	То	No. of Lanes
Entrance	Travis	I-45N	2
Entrance	Louisiana	I-10W	1
Exit	I-10E	Smith	1
Exit	I-45S	Milam	2
Exit	I-45 HOV	Milam	2
Exit	I-10E	Nance	1
Entrance	Nance	I-10E	1
Exit	I-45S	Bagby/Allen Pkwy	1
Entrance	Walker	I-45S Outer	1
Exit	I-45S Inner	McKinney	1
Exit	I-45S Outer	McKinney	1
Exit	I-45S Outer	Brazos	1

Туре	From	То	No. of Lanes
Entrance	Allen Pkwy	I-45S Outer	1
Entrance	Houston Ave	I-45S Inner	1
Entrance	Hamilton	SH 288	1
Entrance	Clay	US 59/I-69S	1
Exit	US 59/I-69N	Polk	1
Exit	US 59/I-69N	Hamilton	1
Entrance	Chartres	US 59/I-69N	1
Entrance	Hamilton	I-10 W	2
Exit	I-10 W	Jackson	1
Exit	US 59/I-69S	Jackson	2
Exit	US 59/I-69HOV	Chenevert	1
Entrance	Elysian	Hardy Toll Road	1
Exit	Hardy Toll Road	Élysian	1
Exit	US 59/I-69N	Providence	1
Exit	I-10 W	Providence	1
Entrance	Providence	I-10 W	1

Alternative 3 for Segment 3 involves creating a one-way loop around downtown using I-45 and US-59. The design involves discontinuing north flowing traffic on I-45 between the I-10 interchange and the US 59/I-69 interchange and south flowing traffic on US 59/I-69 between the I-10 interchange and the I-45 interchange. The existing lane traffic direction will be reversed to compile the one-way travel sections.

On I-45 South at the beginning of Segment 3, from five lanes, one lane exits toward I-10 West and Quitman Street resulting in four travel lanes. Two lanes (one optional) exit toward I-10 East and Milam Street and two lanes from I-10 East are added to increase the total back to five lanes. This segment is designated as I-45 South Outer. Two "exit only" lanes will drop for Allen Parkway on the right and McKinney Street on the left similar to existing conditions. One lane is added from a proposed entrance ramp at Walker Street and an optional exitlane is provided for access to Pierce Street.

I-45 South Inner is a five-lane segment formed from the convergence of the US 59/I-69 Expressway (two-lanes) and the I-10 West DC (four-lanes). One merge is present at this location because estimated traffic utilizing the US 59/I-69 Expressway will be minimal, because it is provided to complete the loop from US 59/I-69 to I-45 and most traffic is expected to exit before reaching the Expressway. An "exit only" lane is provided for access to McKinney Street and a designated entrance lane is provided for Houston Avenue.

I-45 South Inner and Outer converge after the W. Dallas Street overpass to become a 10-lane section until the US 59/I-69 interchange. At this point, traffic may continue to I-45 South on four-lanes, SH 288 on three-lanes, US 59/I-69 South on three lanes, or US 59/I-69 North on two lanes.

Along US 59/I-69 North just past the I-45 interchange, six lanes are proposed instead of the existing three. The exit for Polk Street is preserved as an optional exit lane. The DC from I-45 South merges down to one lane before connecting with US 59/I-69 and three lanes connect from the DC from I-45 North to create a 10-lane section. The 10-lanes shall remain separated by a barrier to segregate the three lanes from I-45 South. The intention is to minimize weaving from US 59/I-69 North to a proposed exit to Hamilton Street and force that traffic to utilize the Polk Street exit to access the east side of Downtown. Hamilton Street shall become two-way with parallel parking removed. After the Hamilton Street exit, US 59/I-69 North becomes an undivided nine-lane section.

Three lanes of US 59/I-69 North diverge and combine with two entrance lanes from Hamilton Street to begin the DC toward the US 59/I-69 Expressway (four lanes) and Providence Street (one lane) exit ramp. The remaining six lanes of US 59/I-69 North converge with the entrance ramp from Chartres Street. One lane is merged down to decrease the total width to six lanes – four continue along US 59/I-69 North and two veer toward I-10 East.

The US 59/I-69 Expressway is four lanes wide and remains elevated over Providence Street adjacent to I-10 with no access ramps. Three lanes continue to I-45 North and two lanes complete the loop by veering off to I-45 South.

Other enhancements were needed for the US 59/I-69 and SH 288 interchange to help the design operate efficiently. An entrance ramp with one lane from Clay Street is proposed to provide access from Downtown to US 59/I-69 South and merges with the proposed three lanes. A DC from I-45 North adds two lanes to this segment resulting in five total lanes. One lane is then merged down before the Elgin Street overpass to create a four lane segment. The existing broken back curve from the DC from SH 288 North and US 59/I-69 South has been improved and adds another lane to US 59/I-69 South via a designated entrance lane. US 59/I-69 will have to be improved to five lanes wide until Spur 527 to support the increased demand on the freeway.

A SH 288 access is provided from a proposed entrance ramp along Hamilton Street at Tuam Street which will be closed due to low traffic volume. For improved operational elements, the existing weaving movements between SH 288 and US 59/I-69 have been removed in favor of two separated highways.

Details of the Segment 3, Alternative 4:

Objective: Construct a tunnel under I-45 and La Branch Street

- Compatible with Segment 2, Alternative 15
- Tunnel connects to Segment 2 under Elysian Street, transfers to La Branch Street, then to Crawford Street past I-45
- Exit portal provides access to Almeda Road and SH 288 South
- Entrance portal from Almeda Road and SH 288 North
- Possible conflicts with underground facilities at the Toyota Center and other downtown buildings

Details of the Segment 3, Alternative 5:

Objective: Construct a tunnel under Bagby Street

- Compatible with Segment 2, Alternative 14
- Tunnel connects to Segment 2 under I-45 South then curves to follow Bagby Street
- Exit portal provides access to Spur 527
- Entrance portal from Berry Street and Spur 527

Details of the Segment 3, Alternative 5A:

Objective: Construct a tunnel along White Oak Bayou

Compatible with Segment 2, Alternative 14

- Tunnel connects to Segment 2 under I-45 South then curves to follow White Oak Bayou
- Exit portal provides access to Milam Street and I-45 South
- Entrance portal from Travis Street and I-45 North
- Exit portal can provide direct access to future Metro Burnett LRT Station
- Portal site potential for parking garage on outskirts of Downtown

Details of the Segment 3, Alternative 6:

Objective: Construct a tunnel under Jefferson Street

- Compatible with Segment 2, Alternative 14
- Tunnel connects to Segment 2 under I-45 South then curves to follow Jefferson Street.
- Exit portal provides access to Jefferson Street at the Dowling Street intersection which allows access to I-45 South
- Entrance portal from I-45 North and Jefferson Street

Details of the Segment 3, Alternative 7:

Objective: Construct a tunnel under I-45 and Jefferson and Bagby Street

- Compatible with Segment 2, Alternative 14
- Tunnel connects to Segment 2 under I-45 South then curves to follow Bagby Street and curves to follow Jefferson Street
- Exit portal provides access to Jefferson Street at the Dowling Street intersection which allows access to I-45 South
- Entrance portal from I-45 North and Jefferson Street
- Exit portal provides access to Spur 527
- Entrance portal from Berry Street and Spur 527

Details of the Segment 3, Alternative 10 (Bypass)

Objective: Offer managed lanes for I-45 and I-10 that bypass Downtown:

- Compatible with Segment 2 Alternatives 3, 10, 11, and 12
- Maintains existing access ramps
- Right lane exit and entry ramps
- Minimal merging; one lane merge at US 59/I-69 South and I-45 North DC convergence to avoid need for extra ROW along Pierce Elevated and because traffic use is low
- Improved safety on exit and entrance ramps and direct connectors
- Retains use of existing roadway pavement for sections of I-45
- List of access points identified in **Table 11**.

Table 11: Alternative 10 Access Points

Ramp Type	From	То	No. of Lanes
Entrance	Travis	I-45N	1
Entrance	Travis	I-45N Managed	1
Entrance	Louisiana	I-10W	1
Exit	I-45S	Smith	1
Exit	I-45S	Milam	1
Exit	I-45 Managed	Milam	1
Exit	I-10 Managed	Milam	1
Entrance	Travis	I-10 Managed	1
Exit	I-45S	Allen Pkwy	1
Entrance	Walker	I-45N	1
Exit	I-45S	McKinney	1
Exit	I-45N	McKinney	1
Exit	I-45N	Houston	1
Entrance	Allen Pkwy	I-45S	1

Ramp Type	From	То	No. of Lanes
Entrance	Houston Ave	I-45S	1
Exit	I-45S	Bagby	1

Alternative 10 for Segment 3 aims to provide an option for traffic to bypass entering/exiting Downtown traffic on I-45 by using exclusive managed lanes through Downtown that would terminate into the existing I-45 Gulf Freeway HOV system south of Downtown. Traffic along I-10 will be provided dedicated express lanes to bypass entering/exiting traffic as well.

Beginning on I-45 South just before the I-10 interchange, four lanes continue from Segment 2 with an optional exit lane for a DC toward I-10 West. Four lanes become five after converging with the DC from I-10 East and the fifth lane is soon dropped as an exit lane toward I-10 East and Milam Street. One lane from the I-10 West to I-45 South DC is added back to the four lanes and dropped again for the exit lane toward McKinney Street. An optional exit lane is provided for access to Allen Parkway. An auxiliary lane is provided for Allen Parkway traffic wishing to access I-45 South and the lane also allows I-45 South traffic to exit to Bagby Street. Four lanes continue to the US 59/I-69 interchange. A lane is opened and used to enter the DC from I-45 South to US 59/I-69 North. Two lanes diverge for the DC towards US 59/I-69 South – one designated and one optional. Three lanes continue to I-45 South and connect to the existing pavement.

Traveling along I-45 North just before the US 59/I-69 interchange, four lanes open to five with one of those lanes diverging for the DC toward US 59/I-69 North, two (one optional) diverging to US 59/I-69 South, and three continuing through the interchange. Two lanes from US 59/I-69 North meet with I-45 North as well as one merging lane from US 59/I-69 South. This merge is being allowed because of ROW restrictions and because the daily traffic utilizing the movement is minimal. One lane is merged down to result in four lanes.

Just before Allen Parkway, one lane is forced to exit for Houston Avenue and McKinney Street. A lane is added from Allen Parkway with a much-improved radius of curvature than the existing conditions. Another lane is added from an entrance ramp from Walker Street that also has an improved radius of curvature. The fifth lane is dropped toward the DC from I-45 North to I-10 East. A proposed Louisiana Street entrance ramp will converge with the DC from I-10 West to I-45 North and add two lanes to I-45 North, resulting in six total lanes. Two of those six lanes are designated for a DC toward I-10 West. The four remaining lanes are then met by the DC from I-10 East to create a five-lane section to continue into Segment 2.

All I-45 managed lanes maintain a minimum of two lanes until Main Street when one lane is dropped in each direction. The I-45 managed lanes provide inbound Downtown access via Milam Street and outbound Downtown access via Travis Street. There are no other planned access points from or to the I-45 managed lanes beyond those mentioned.

All I-10 managed lanes maintain a minimum of two lanes until the connection with the existing I-10 HOV lanes when the lanes are reduced to one in each direction. Downtown can be accessed from the managed lanes via Milam Street, and traffic from Downtown can use Travis Street to access the managed lanes.

Figure 33: Preliminary Alternative 3, Segment 3

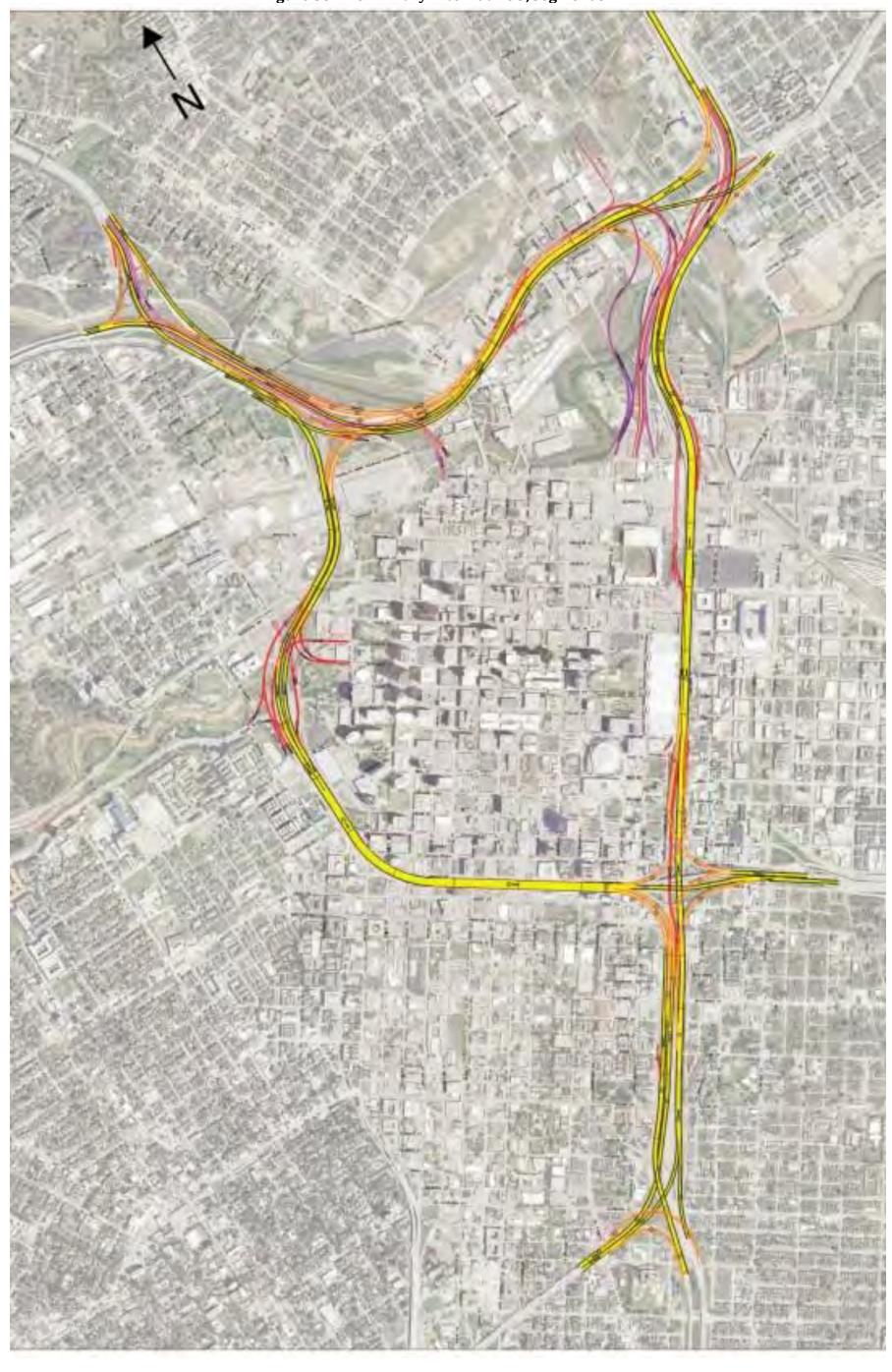


Figure 34: Preliminary Alternative 5, Segment 3



Figure 35: Preliminary Alternative 6, Segment 3

Figure 36: Preliminary Alternative 10, Segment 3

Figure 37: Preliminary Alternative 11, Segment 3

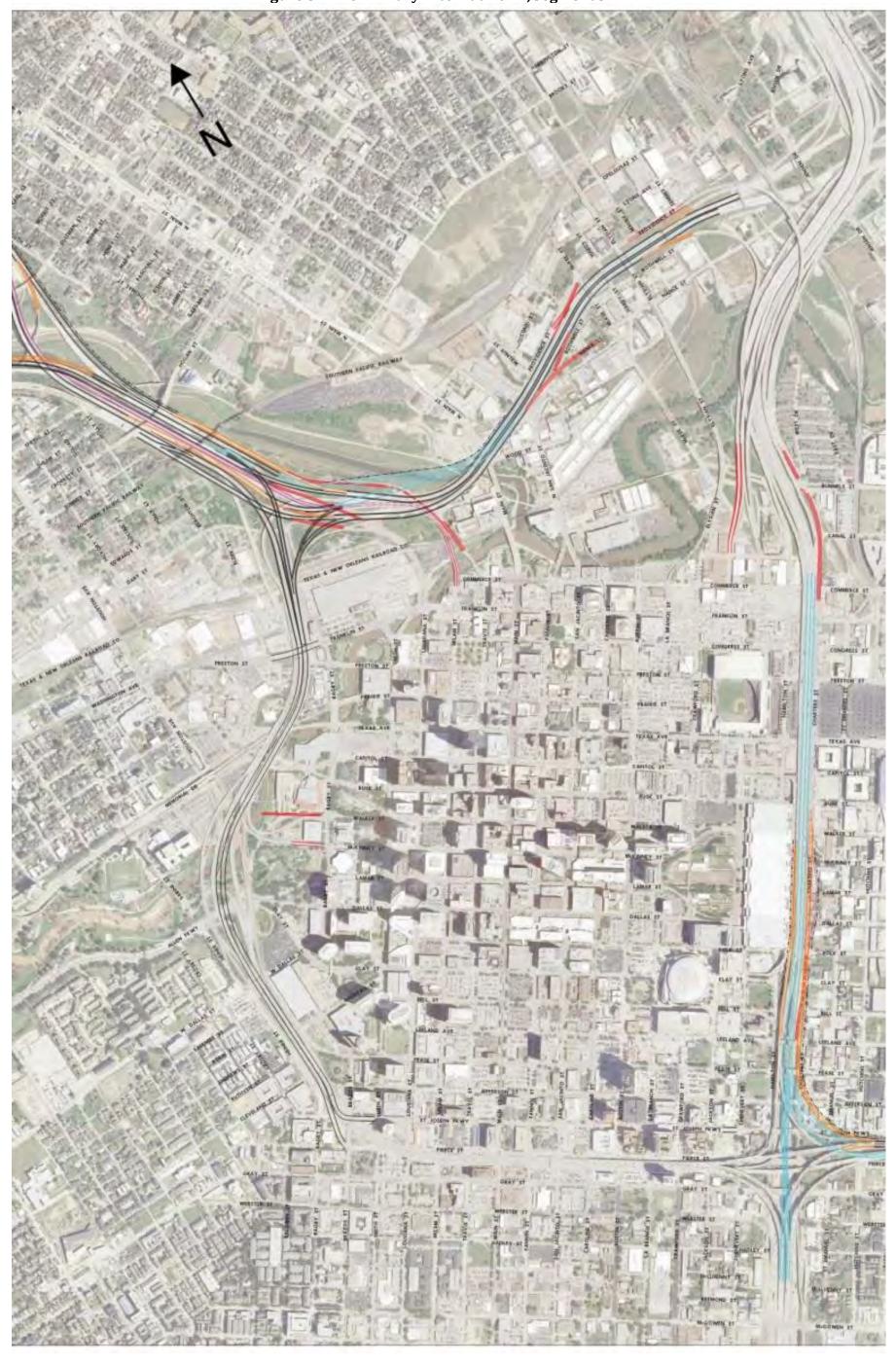


Figure 38: Preliminary Alternative 12, Segment 3

During a Study Team meeting in July 2013, the structural feasibility of the Preliminary Alternatives for Segment 3 were was discussed. During the evaluation, it was determined that two of the Preliminary Alternatives (Alternative 4 and Alternative 7) would not be structurally feasible due to the complexity of the tunnel connections being proposed for these alternatives. Also, accommodating proper ventilation for each of these tunnels was found to be a design constraint as tunnel can primarily be vented in one direction and providing the connections that were being proposed in these alternatives would introduce turbulent wind conditions that would not allow the tunnels to be properly ventilated. During the alternatives analysis process, two additional alternatives (Alternatives 11 and 12) were developed and incorporated into the study.

Table 12: Segment 3 Preliminary Alternatives

Alt. No.	Alternative Type	Description	Comments
1	Existing conditions	No build	
3	Convert downtown loop to one way loop	Convert existing downtown loop roadway network to a one-way loop.	
4	Add tunnel to existing	Tunneled roadway underneath La Branch St. and terminates at the US 59/I-69/SH 288 interchange. Includes 4 managed lanes.	Alternative was eliminated because it was determined to be not structurally feasible.1
5	Add tunnel to existing	Tunneled roadway underneath I-45, continues underneath Bagby St. and terminates at Spur 527. Includes 4 managed lanes.	
6	Add tunnel to existing	Tunneled roadway underneath I-45, continues to Jefferson St. and terminates at I-45 south of the I-45/US 59/I-69 interchange. Includes 4 managed lanes.	
7	Add tunnel to existing	Tunneled roadway underneath Houston Ave. and splits to Jefferson St. and Bagby St. Tunnel terminates at I-45 south of the I-45/US 59/I-69 interchange and Spur 527. Includes 4 managed lanes.	Alternative was eliminated because it was determined to be not structurally feasible. 1
10	Widen existing	8 lane section from I-10 to I-45/US 59/I-69 interchange includes 8 general purpose lanes.	
11	Realignment of I-45	Realign I-45 to the east along US 59/I-69 for the through movement. Existing I-45 on the west side will be converted to a parkway/boulevard type roadway for downtown access.	Added as a Preliminary Alternative in July 2013
12	Convert Downtown Loop to One Way Loop (Hybrid)	Hybrid of Alternative 3 which includes I-45 downtown loop with US 59/I-69 and I-10 maintaining existing directional flow.	Added as a Preliminary Alternative in July 2013

Note: 1. TxDOT and HNTB held in a meeting on July 24, 2013 to discuss the constructability and structural feasibility of various alternatives. It was determined that the tunnel options for the Downtown Loop were not structurally feasible.

4.3 Secondary Alternative Screening Process

The secondary alternative screening process was used to reduce the six Preliminary Alternatives for each segment to three Reasonable (build) Alternatives for each segment. This secondary screening of alternatives was accomplished by assessing the Preliminary Alternatives with more detailed and quantifiable evaluation criteria. The Preliminary Alternatives were developed to more detail to allow for this level of screening, as described above. The evaluation criteria for the secondary screening process was developed using the project need and purpose statement, specific project goals, and engineering traffic and environmental considerations. The Preliminary Alternatives were assessed from impacts on the future traffic and mobility conditions along I-45, Hardy Toll Road, and the study corridors within the Downtown Loop.

The assumptions considered at this level of alternative evaluation included the following:

- All alternatives compared include managed lanes that would be accessible by personal vehicles, buses and large trucks (non-hazardous cargo). All hazardous cargo would be required to utilize the existing I-610 Loop and will not be allowed access into Downtown Houston.
- Regional projections for traffic growth were determined to be acceptable to project stakeholders.
- National traffic emissions inventory models were determined to be acceptable to project stakeholders.
- Regional air quality standards remain the same for the operational life of the project.

Traffic Evaluation Methodology for Secondary Screening

The traffic demand along the corridors was evaluated based upon the Houston-Galveston Area Council (HGAC)'s regional travel demand model. The network considered the existing highway system and committed and programmed transportation improvements included in the *2035 Regional Transportation Plan*. The No Build Alternative model was run for the year 2035 to determine the impact of these future projects and projected growth in the region. The model was then modified to include the Preliminary Alternatives, and the model runs were compared to the 2035 No Build Alternative; thus transportation deficiencies along the study corridors were able to be identified.

Each of the three segments has a number of alternatives; however, only certain alternatives on each segment are compatible with others. For travel demand modeling purposes, many of the alternatives were considered identical. For example, in Segment 2, Alternatives 10, 11, and 12 are identical from a modeling perspective because those alternatives all involve adding managed lanes, either elevated or depressed.

Segment 2, the specific freeways of concern included the managed lanes along I-45, I-610, BW 8 and/or the Hardy Toll Road, and the general purpose lanes along I-45. For Segment 3, the specific roadways evaluated included the downtown street network, I-45, and the downtown freeway loop system, including I-10 and US 59.

Based on compatibility between the various alternatives in each segment, the 17 alternatives across all three segments can be condensed into 9 alternatives for modeling purposes. The engineering alternatives grouped for modeling purposes are presented in **Table 13** below. The HGAC's regional travel demand model was run 10 times for this analysis: one for each of the following model alternatives and one No Build Alternative. The results were used to analyze the traffic and mobility impacts of the Preliminary Alternatives.

Table 13: Traffic Model Alternatives vs. Engineering Preliminary Alternatives

Traffic Model	Engineering Preliminary Alternatives				
Alternatives	Segment 1	Segment 2	Segment 3		
No Build	-	-	-		
А	3	15	3		
В	3	15	12		
С	4,5,6,7,8	10,11,12	3		
D	4,5,6,7,8	10,11,12	10		
Е	4,5,6,7,8	10,11,12	11		
F	4,5,6,7,8	10,11,12	12		
G	4,5,6,7,8	14	5		
Н	4,5,6,7,8	14	6		
J	4,5,6,7,8	15	No Build		

Table 14 Summarizes the secondary engineering and traffic screening criteria used to evaluate the Preliminary Alternatives.

Table 14: Engineering and Traffic Criteria for the Secondary Alternative Screening

Evaluation Criteria	Evaluation Sub-Criteria	Description	Rating ¹			
Engineering						
	Construction Duration	Estimated period of time to construct the alternative.	D/N/U			
	Contractor Availability	Availability of a general construction contractor, can a local contractor be utilized or will a specialty contractor need to be mobilized.	D/N/U			
	Construction Risk	Potential risks (unforeseen conditions, schedule/cost overrun, etc.) associated with the construction of the various alternatives.	D/N/U			
Constructability	Construction Staging/ Sequencing Complexity	Complexity of the contractor's staging requirements as well as the phasing of the overall project and impact to the existing highway system.	D/N/U			
	Permanent ROW Acquisition	Addresses the alternative's required permanent ROW acquisition.	D/N/U			
	Utility Relocations	Impacts to existing major utilities for the alternative.	D/N/U			
	Long Term Geotechnical Risk	Addresses the alternative's susceptibility to existing fault lines, anticipated settlement, potential water infiltration and potential of major structural repair associate with such risks.	D/N/U			
	Design Life Expectancy	Anticipated design life expectancy of the alternative's proposed improvements.	D/N/U			
Functionality	Design Criteria Limitations	Addresses the various design elements and any limitations associated with the alternative including design speed, vertical clearance, roadway typical sections, roadway alignment, and roadway profile.	D/N/U			
Functionality Requirements	Opportunity for Future Expansion	The alternative's opportunity/potential for future infrastructure expansion to address a potential increase in traffic demand as well as changing traffic patterns.	D/N/U			
	Incident Management (Design Factors)	Addresses the alternative's requirement for additional design features/facilities including breakdown lanes, emergency exits, ventilation shafts and traffic control features.	D/N/U			
	Traffic and Systems Control	The alternative's type of traffic and systems control required including personnel and equipment needed to monitor daily traffic conditions.	D/N/U			
Operational and Maintenance	Incident Management (Operations)	The alternative's ability to handle incidents as they occur and the needed equipment and personnel to clear/manage the incident.	D/N/U			
	Maintenance Requirements	The alternative's special maintenance requirements that are not typical to TXDOT maintenance staff.	D/N/U			
	Incident Recovery (Recovery Time)	The alternative's estimated amount of time to recover from common incidents that are anticipated during the life expectancy of the roadway system.	D/N/U			
		Traffic				

61

Evaluation Criteria	Evaluation Sub-Criteria	Description	Rating ¹
Managed Lane U Managed Lane F	tilization along New acility ²	Capacity utilization provides a measure of the anticipated return on investment required for each alternative. If the added capacity is underutilized, then capacity exceeds demand. If the added capacity is over utilized, then demand exceeds capacity. Optimal utilization is achieved by balancing capacity and demand. The maximum peak hour capacity of the managed lanes was assumed to be 1,800 vehicles per lane per hour. Using the peak hour factors and the number of proposed managed lanes, the maximum daily capacity for 4 managed lanes is 72,000. Optimal lane utilization was considered to be less than 110% (desirable). Utilization between 30% and 70% was considered neutral. Utilization of 30% or less was considered to be the least ideal (undesirable).	D/N/U
Travel Demand a	long I-45 ²	A reduction in vehicles on the general purpose lanes means that traffic is being diverted to managed lanes or other routes, alleviating congestion and demand on I-45. The traffic reduction for the Preliminary Alternatives was compared to the nobuild scenarios and the thresholds for ratings were developed accordingly. Alternatives that increased traffic volumes on I-45, compared to the no-build, were rated undesirable. Alternatives that reduced traffic by 12,000 vehicles daily or less were rated neutral. Alternatives that reduced traffic by more than 12,000 vehicles daily were rated desirable.	D/N/U
Vehicle Hours Tra	aveled (VHT) along	Total daily VHT is a function of traffic volume, travel speed, and travel distance and is representative of the total amount of motorists travel time for each alternative. The fewer miles traveled and the less time spent getting to a destination is preferred. For Segment 2, the analysis considered travel	D/N/U
VHT along Study System	Area Freeway	times on I-45, Hardy Toll Road, and Beltway 8. The thresholds and ratings were relative to each segment and roadway, based upon the 2035 No Build Alternative VHT.	D/N/U
VHT along the Do System ³	owntownStreet	For Segment 3, the system was defined differently: VHT was considered on I-45, I-10, and US 59. The VHT on the downtown street system was also considered due to the significant reconfiguration of the system. The thresholds for ratings were based upon the changes in VHT from the 2035 No Build Alternative. The criteria for VHT reduction was the same across all three freeway segments. Any alternative that reduced VHT by 1,000 or less was rated undesirable, an increase of 1,000 to a reduction of 1,000 VHT was rated neutral, and the alternatives that had a reduction of greater than 1,000 VHT was rated desirable.	D/N/U
Volume to Capac	ity Ratio along I-45	Volume to capacity ratio (V/C) is a measure of the amount to traffic on a given roadway in relationship to the amount of traffic the roadway was designed to accommodate. V/C is a way to measure congestion; a V/C greater than 1 indicates that the roadway is over capacity and V/Cs of 0.75 or 0.8 indicates heavy congestion. For Segments 2 and 3, the V/C along I-45 was the only consideration. The Preliminary Alternatives were compared to the No Build Alternative to determine ratings. For Segments 2 and 3, an increase in V/C resulted in an undesirable rating. For Segment 2, the threshold of a 5% reduction in V/C and a 14% reduction resulted in a rating of neutral or desirable, respectively. The changes in Segment 3 were more varied and therefore had different thresholds. Preliminary Alternatives that resulted in up to a 10% reduction in V/c were rated neutral and alternatives that resulted in greater than a 10%, but less than 70%, were rated desirable.	D/N/U

Notes: 1. All criteria were rated using the Desirable (D)/Neutral (N)/Undesirable (U)

 $^{2.\,}Criteria\,considered\,for\,Segment\,2\,\,only.$

 $^{3.\,}Criteria\,considered\,for\,Segment\,3\,\,only.$

4.4 Secondary Alternative Screening Results

Table 15 and **Table 16** present the results of the secondary screening process for Segment 2 and Segment 3, respectively. Build alternatives that were identified to move into the next alternative evaluation level were selected as Reasonable Alternatives. The detailed secondary screening matrices, for Segment 2 and Segment 3, are included in **Appendix C**. The detailed screening results related to the traffic criteria are included in **Appendix D**.

Table 15: Segment 2 Engineering and Traffic Screening Results

	Alt 3	Alt 10	Alt 11	Alt 12	Alt 14	Alt 15
Sub-Criteria	Reversible Managed Lanes	Depressed Managed Lanes	Elevated Managed Lanes	Stacked Managed Lanes	Tunneled Managed Lane	Elevated Managed Lanes to Hardy Toll Road
			Ingineering			
		Со	nstructability			
Construction Duration	D	D	D	D	U	D
Contractor Availability	D	D	D	D	U	D
Construction Risk	D	D	D	D	U	D
Construction Staging/ Sequencing Complexity	N	N	N	N	U	U
Permanent ROW Acquisition	N	N	N	N	N	N
Utility Relocations	U	U	U	U	U	U
Long Term Geotechnical Risk	D	D	D	D	N	D
Constructability Rating	D	D	D	D	U	N
		Fi	unctionality			
Design Life Expectancy	N	Ν	N	N	D	N
Design Criteria Limitations	U	D	D	D	U	D
Opportunity for Future Expansion	U	U	U	U	N	N
Incident Management (Design Factors)	N	N	Ν	N	U	N
Functionality Rating	U	N	N	N	U	N
Operations and Maintenance						
Traffic and Systems Control	U	D	D	D	U	D
Incident Management (Operations)	N	N	N	N	U	N
Maintenance Requirements	D	D	D	D	U	D
Incident Recovery (Recovery Time)	D	N	D	N	U	D
Operations and Maintenance Rating	N	N	D	N	U	D

	Alt 3	Alt 10	Alt 11	Alt 12	Alt 14	Alt 15
Sub-Criteria	Reversible Managed Lanes	Depressed Managed Lanes	Elevated Managed Lanes	Stacked Managed Lanes	Tunneled Managed Lane	Elevated Managed Lanes to Hardy Toll Road
			Traffic			
Managed Lane Utilization	U	D	D	D	D	U
Travel Demand (along I-45)	U	D	D	D	D	N
VHT (along I-45)	U	D	D	D	D	Ν
VHT (along study area freeway system)	U	D	D	D	D	N
VHT (along downtown street system)	N/A	N/A	N/A	N/A	N/A	N/A
Volume to Capacity Ratio (along I-45)	U	D	D	D	D	N
Alternative to Move Forward	N	Y	Y	Y	N	Y

Notes: Roadway Design Speed: 60 mph; Tunnel Design Speed: 45 mph; D = Desirable, N = Neutral, U = Undesirable

The three Reasonable Alternatives selected for Segment 2 include Alternative 10, Alternative 11, and Alternative 12. The alternatives selected had "Desirable" or "Neutral" ratings for the engineering criteria and "Desirable" ratings for traffic criteria. Right-of-way would be required in selected areas for the three Reasonable Alternatives.

Table 16: Segment 3 Engineering Screening Results

	Alt 3	Alt 5	Alt 6	Alt 10	Alt 11	Alt 12
Sub-Criteria	One-way Downtown Loop	Tunneled Managed Lanes (North of Downtown)	Tunneled Managed Lanes (South of Downtown)	I-45 Pierce Widening	I-45 East Shift	I-45 Split
			Ingineering			
		Со	nstructability			
Construction Duration	N	U	U	N	N	D
Contractor Availability	D	U	U	D	D	D
Construction Risk	D	U	U	D	D	D
Construction Staging/ Sequencing Complexity	U	U	U	U	U	U
Permanent ROW Acquisition	N	U	N	U	U	N
Utility Relocations	U	U	U	U	U	U
Long Term Geotechnical Risk	D	N	N	D	D	D
Constructability Rating	N	U	U	N	N	D
	Functionality					
Design Life Expectancy	N	D	D	N	N	N

	Alt 3	Alt 5	Alt 6	Alt 10	Alt 11	Alt 12
Sub-Criteria	One-way Downtown Loop	Tunneled Managed Lanes (North of Downtown)	Tunneled Managed Lanes (South of Downtown)	I-45 Pierce Widening	I-45 East Shift	I-45 Split
Design Criteria Limitations	U	U	U	D	D	D
Opportunity for Future Expansion	U	D	N	U	N	N
Incident Management (Design Factors)	N	U	U	N	N	N
Functionality Rating	U	N	U	N	N	N
		Operatio	ns and Maintenan	ce		
Traffic and Systems Control	U	U	U	D	D	N
Incident Management (Operations)	N	U	U	N	N	N
Maintenance Requirements	D	U	U	D	D	D
Incident Recovery (Recovery Time)	N	U	U	N	N	N
Operations and Maintenance Rating	N	U	U	N	N	N
			Traffic			
Managed Lane Utilization	N/A	N/A	N/A	N/A	N/A	N/A
Travel Demand (along I-45)	N/A	N/A	N/A	N/A	N/A	N/A
VHT (along I-45)	U	U	U	N	D	N
VHT (along study area freeway system)	D	N	D	D	D	D
VHT (along downtown street system)	U	N	N	N	U	D
Volume to Capacity Ratio (along I-45)	D	U	D	N	D	D
Alternative to Move Forward	N	N	N	Y	Υ	Y

Notes: Roadway Design Speed: 50 mph; Tunnel Design Speed: 45 mph; D = Desirable, N = Neutral, U = Undesirable

The three Reasonable Alternatives selected for Segment 3 include Alternative 10, Alternative 11, and Alternative 12. The alternatives selected generally had "Desirable" or "Neutral" ratings for the engineering and traffic criteria. Right-of-way would be required in selected areas for the three Reasonable Alternatives.

The tunnel alternatives for both segments did not score well in engineering and traffic criteria. Internal characteristics of a tunnel are constrained by the diameter and therefore introduce functionality issues such as reduced shoulder widths and reduced vertical clearances. The tunnel alternatives would also have operational deficiencies such as increased incident management and emergency response times. Tunnel evaluations concluded that tunnels would also have several constructability issues. **Appendix E** includes a white paper detailing the engineering aspects of the tunnel alternatives that was completed in September 2013.

The Hardy Toll Road alternatives for Segment 2 did not score well in traffic criteria, primarily due to low utilization of managed lanes along Beltway 8 and I-610. Also, not enough traffic would be diverted to Hardy Toll Road to improve mobility and reduce congestion on I-45, as compared to other alternatives.

Three alternatives were identified for each Segment to be carried forward as the set of Reasonable Alternatives.

5.0 Reasonable Alternatives

The Reasonable Alternatives were presented to the public in November 2013 at the Public Meeting No. 3. **Table 17** and **Table 18** provide a description of the Reasonable Alternatives for Segments 2 and 3, respectively. The overall layouts and the typical sections for the Reasonable Alternatives are presented in **Figures 40** through **50**. The layouts presented at Public Meeting No. 3 are included in **Appendix F**. The drainage analyses related to each alternative are being performed by a different consultant and are not part of the evaluation criteria presented in the report.

Table 17: Segment 2 Reasonable Alternatives

Alt. No.	Alternative Type	Description
1	Existing conditions	No build
10	Widen existing	Complete reconstruction of I-45 to provide: Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads New ROW required on both sides of I-45 from I-610 to Cavalcade St. Reconstructed interchange with I-45/I-610 Eight general purpose lanes Addition of four depressed managed lanes
11	Widen existing with elevated managed lanes	 Complete reconstruction of I-45 to provide: Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads New ROW required on both sides of I-45 from I-610 to Cavalcade St. Reconstructed interchange with I-45/I-610 Eight general purpose lanes Addition of four elevated managed lanes (on a single structure)
12	Widen existing with elevated managed lanes	Complete reconstruction of I-45 to provide: Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads New ROW required on both sides of I-45 from I-610 to Cavalcade St. Reconstructed interchange with I-45/I-610 Eight general purpose lanes Addition of four elevated managed lanes (on a double-decked structure)

 Table 18: Segment 3 Reasonable Alternatives

Alt. No.	Alternative Type	Description
1	Existing conditions	No build
10	Widen existing	Complete reconstruction of I-45, I-10 and US 59/I-69 to provide: Addition of four at-grade managed lane connections into Downtown Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads Addition of I-10 express lanes from I-45 to US 59/I-69 New ROW required in various areas along the Downtown loop Addition of one I-45 main lane in each direction
11	Realignment of I-45	 Complete reconstruction of I-45, I-10 and US 59/I-69 to provide: Addition of four at-grade managed lane connections into Downtown Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads Addition of I-10 express lanes from I-45 to US 59/I-69 New ROW required in various areas along the Downtown loop Realign I-45 NB and SB lanes to be parallel with I-10 and US 59/I-69 US 59/I-69 would be below grade from Spur 527 to Downtown Remove existing I-45 Pierce Elevated structure
12	I-45 Split	 Complete reconstruction of I-45, I-10 and US 59/I-69 to provide: Addition of four at-grade managed lane connections into Downtown Addition of full-width shoulders Addition of bike/pedestrian features along frontage roads Addition of I-10 express lanes from I-45 to US 59/I-69 New ROW required in various areas along the Downtown loop Realign I-45 NB lanes to be parallel with I-10 and US 59/I-69



Figure 39: Segment 2Reasonable Alternative 10

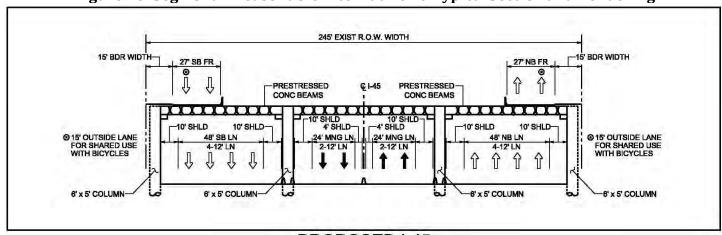
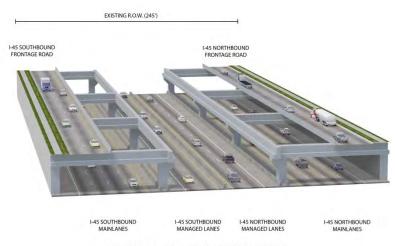


Figure 40: Segment 2 Reasonable Alternative 10 Typical Section and Rendering

PROPOSED I-45 SEGMENT 2 - ALT 10



SEGMENT 2 - ALTERNATIVE 10 (AT-GRADE)



SEGMENT 2 - ALTERNATIVE 10 (DEPRESSED)



Figure 41: Segment 2 Reasonable Alternative 11

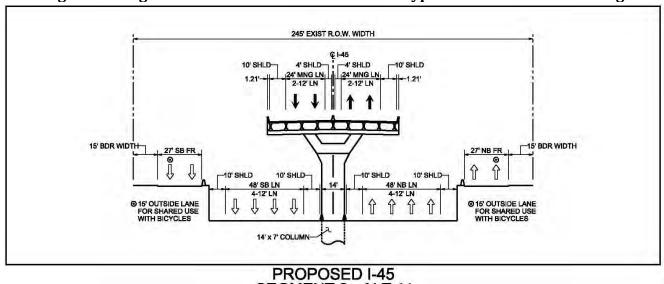
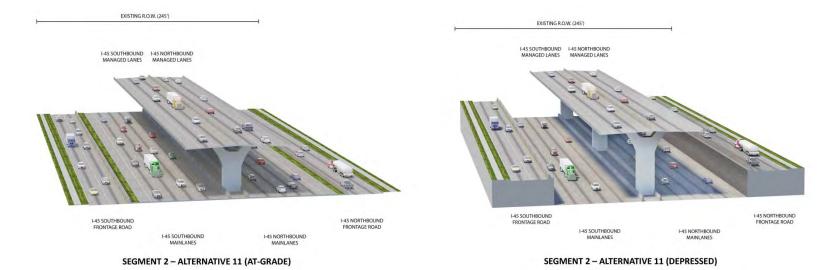
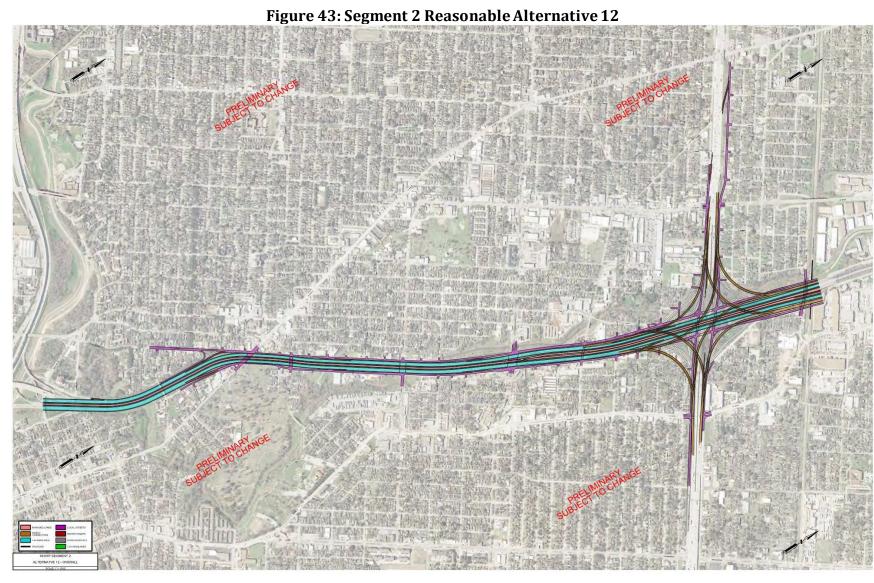


Figure 42: Segment 2 Reasonable Alternative 11 Typical Section and Rendering

PROPOSED I-45 SEGMENT 2 - ALT 11





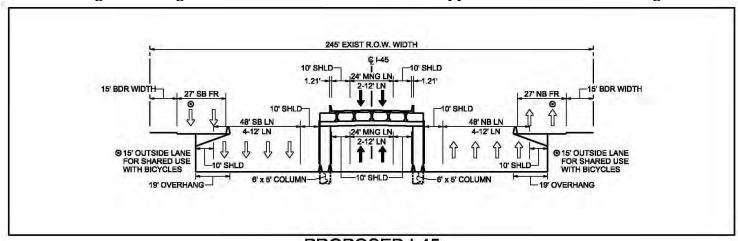


Figure 44: Segment 2 Reasonable Alternative 12 Typical Section and Rendering

PROPOSED I-45 SEGMENT 2 - ALT 12



SEGMENT 2 - ALTERNATIVE 12 (AT-GRADE)

SEGMENT 2 - ALTERNATIVE 12 (DEPRESSED)

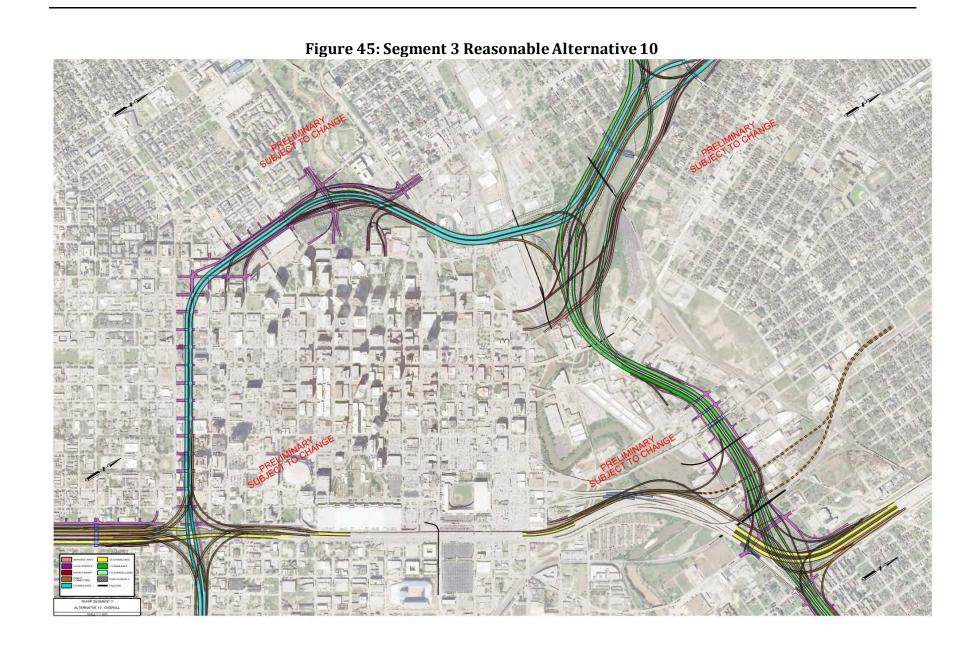


Figure 46: Segment 3 Alternative 10 Rendering



SEGMENT 3 - ALTERNATIVE 10 (I-10)



SEGMENT 3 – ALTERNATIVE 10 (I-45)

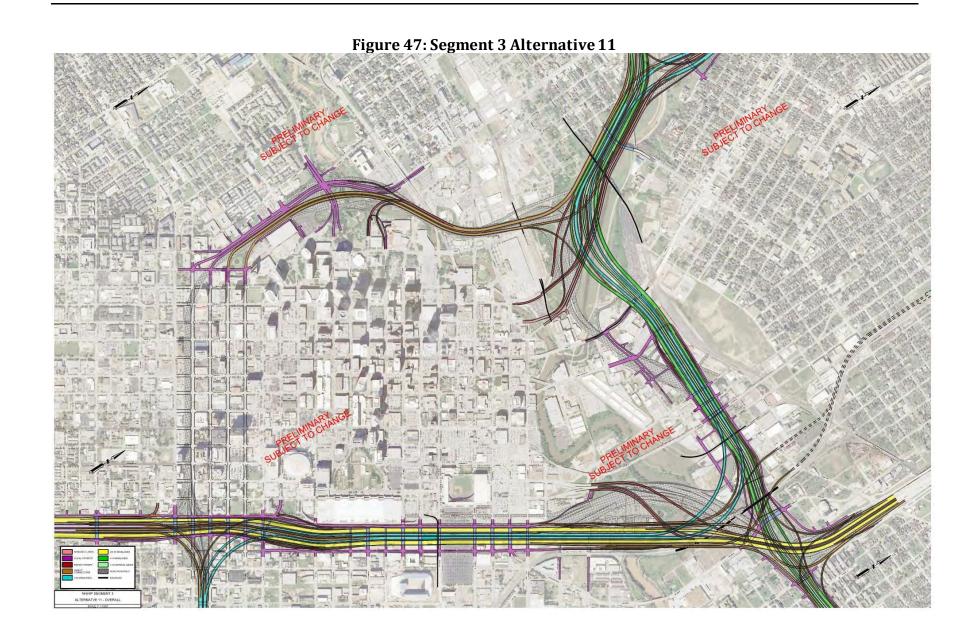
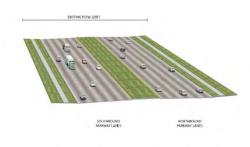


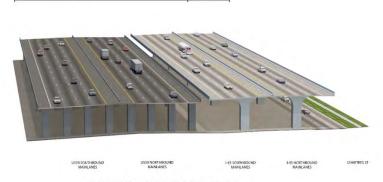
Figure 48: Segment 3 Reasonable Alternative 11 Renderings



SEGMENT 3 - ALTERNATIVE 11 (I-10)



SEGMENT 3 - ALTERNATIVE 11 (I-45/PARKWAY)



SEGMENT 3 - ALTERNATIVE 11 (US 59)

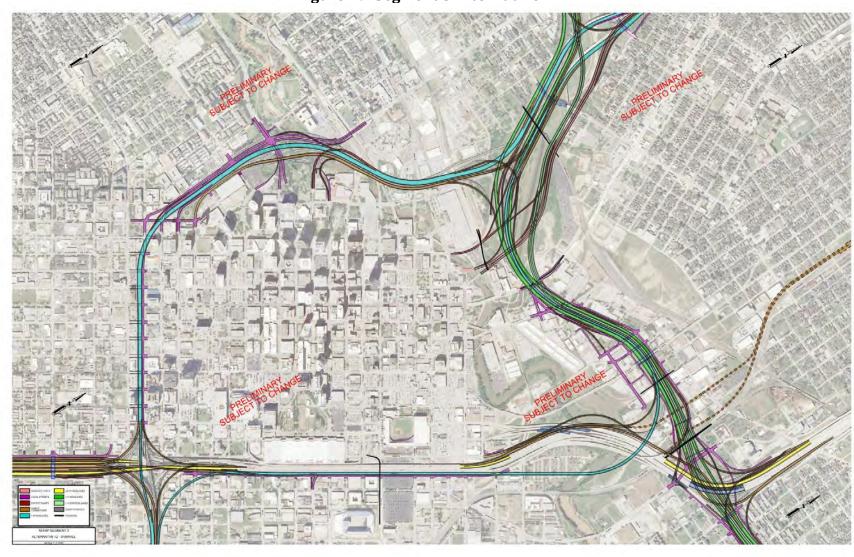
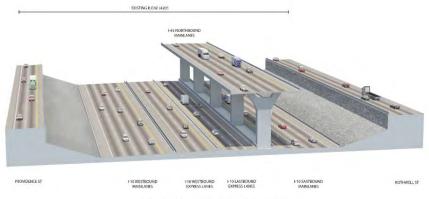
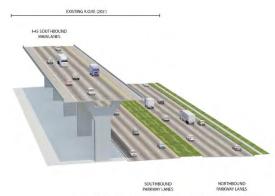


Figure 49: Segment 3 Alternative 12

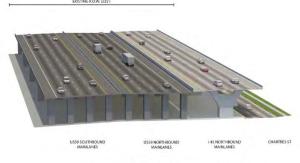
Figure 50: Segment 3 Alternative 12 Renderings



SEGMENT 3 - ALTERNATIVE 12 (I-10)



SEGMENT 3 – ALTERNATIVE 12 (I-45/PARKWAY)



SEGMENT 3 – ALTERNATIVE 12 (US 59)

5.1 DEIS Analysis and Evaluation Process

The DEIS Analysis and Evaluation process was used to determine the Proposed Recommended Alternative out of the set of the three Reasonable Alternatives. Three criteria with associated detailed sub-criteria were used to assess the engineering and traffic functionality of the three Reasonable Alternatives for Segments 2 and 3. The engineering and traffic criteria are detailed in **Table 19**.

Table 19: DEIS Analysis and Evaluation - Engineering and Traffic Evaluation Criteria

		8 8			
Criteria	Sub-Criteria	Description	Rating ¹		
Engineering					
	Ramping	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	D/N/U		
Improvement to	Access to Local Streets	Direct and indirect access to major arterials and minor arterials. This criterion will assess roadway closures, circulation and access to local land use within the corridor.	D/N/U		
Freeway Ramping/Access	Connectivity to Points of Interest	This criterion will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	D/N/U		
Traffic					
Reduction in Systemwide Delay	VHT	Total daily VHT is a function of traffic volume, travel speed and travel distance. This measure is representative of the total amount of travel time in hours that motorists spend traveling in their vehicles. The lower the VHT, the less time drivers are spending getting to their destinations.	D/N/U		
Increase in Systemwide Travel Speed	Model Speed	Speed is a function of the vehicle miles traveled divided by the vehicle hours of travel. This measure is an indicator of the delay on the system – higher speeds reflect better system performance.	D/N/U		

Note: 1. All criteria were rated using the Desirable (D)/Neutral (N)/Undesirable (U)

Engineering Evaluation Criteria and Methodology

The *Improvement to Freeway Ramping/Access* criteria assessed three separate considerations including: freeway to frontage and freeway to freeway ramping access to and from the local street system, and connectivity to major traffic generators. The goal of these three sub-criteria is to evaluate the quality of travel with consideration given to the community and to the local level. Mobility and accessibility have been discussed and studied in details throughout the years, the need to improve one usually negatively impact the other and visa-versa. One of the objectives of these Reasonable Alternatives is to increase the overall mobility along the freeway system without compromising ease of access.

Traffic Evaluation Criteria and Methodology

Traffic volume is steadily increasing in the Houston region, as significant development growth continues in the region. Travel demand modeling is a necessary component in evaluating the need for and usage of any transportation improvements, such as widening existing roadways or constructing new freeways.

The Reasonable Alternatives were evaluated with regards to the potential for each of them to alleviate traffic conditions in the area. As presented in **Table 19**, the evaluation criteria used for traffic and mobility impacts were reduction in systemwide delay, a measure of Vehicle Hours Traveled (VHT), and increase in systemwide

travel speed, a measure of model speeds. To evaluate the effectiveness of each alternative in improving traffic and mobility conditions, they were compared to the 2035 no build scenario.

For this study, the Houston-Galveston Area Council's (H-GAC) 2014 (base year) and 2035 (future year) Travel Demand Model (TDM) in *Cube Voyager* was utilized. The regional travel demand models are developed and maintained by H-GAC, TxDOT and METRO. The existing and future year networks were both refined to better reflect the existing access and connectivity in the downtown area. The regional model was also coded for each of the 2035 alternatives, and the Quarter 3 2014 demographics were used as the socioeconomic inputs for each network.

In addition to a regional level travel demand model analysis which was used to conduct daily model runs for existing and future years to evaluate future travel patterns and demand on various sections of the study corridors, a detailed micro-simulation analysis (using VISSIM simulation software) was also completed for Segment 3. VISSIM is a time step and behavior based simulation tool to model urban traffic conditions. The VISSIM model was developed for both AM and PM peak period conditions and was utilized to evaluate the operational impacts associated with the transportation improvements in the downtown loop system. The speeds in Segment 3 were based upon a VISSIM analysis.

Inputs to the VISSIM model included detailed field conducted traffic counts and actual traffic signal timing plans. The study area for VISSIM incorporates the freeways, access points in the downtown loop area, as well as the following freeway to freeway interchanges:

- I-10 and I-45,
- I-45 and US 59/I-69,
- US 59/I-69 and I-10,
- Spur 527 and US 59/I-69, and
- US 59/I-69 and US 288.

The two criteria listed under traffic in **Table 19** consider specific VISSIM model network performance measures for each Reasonable Alternative.

5.2 DEIS Analysis and Evaluation Results

Table 20 and **Table 21** present the results of the screening process conducted for the traffic and engineering criteria during the DEIS analysis for Segment 2 and Segment 3, respectively. With regard to the engineering sub-criteria, I-45 main lanes and frontage roads were assessed for Segment 2 and for Segment 3, the Downtown Loop, comprised of three major freeways (I-45, I-10, and US 59/I-69) were assessed. The result of the DEIS analysis was to determine the Proposed Recommended Alternative for each segment. The engineering and traffic evaluation criteria presented above were some of the many criteria considered during this detailed evaluation process.

The detailed engineering and traffic screening matrices developed during this phase of alternative evaluation, for Segment 2 and Segment 3, are included in **Appendix G**. The detailed screening results and model output related to the traffic evaluation performed at this level are included in **Appendix H**.

 $Table\,20:\,Segment\,2\,\,DEIS\,Engineering\,and\,Traffic\,Evaluation\,Results$

	0	0				
		Alt 10	Alt 11	Alt 12		
Criteria	Sub-Criteria	Depressed Managed Lanes	Elevated Managed Lanes	Stacked Managed Lanes		
	Traffi	С				
Reduction in Systemwide Delay	VHT	N	Ν	N		
Increase in Systemwide Travel Speed	Model Speed	N	Ν	N		
	Engineering					
	Ramping	N	Ν	N		
Improvement to Freeway Ramping/Access	Access to Local Streets	N	N	N		
. ,	Connectivity to Points of Interest	N	N	N		
Improvement to Freeway Ramping/Ac	N	Ν	N			
Proposed Recommended A	Υ	N	N			

Notes: D = Desirable, N = Neutral, U = Undesirable

Table 21: Segment 3 DEIS Engineering and Traffic Evaluation Results

14510 = 11	Jegment J Di	110 211	B	8	u 11u1					
			Alt 10			Alt 11			Alt 12	
Criteria	Sub-Criteria	I-45 Pierce Widening		I-45 East Shift		I-45 Split				
		I-45	I-10	US 59/ I-69	I-45	I-10	US 59/ I-69	I-45	I-10	US 59/ I-69
			Traf	fic						
Reduction in Systemwide Delay	VHT	N	N	U	D	U	N	N	N	U
Reduction in Syster Alternative R			N			D			N	
Increase in Systemwide Travel Speed	Model Speed	U	D	D	D	D	D	D	U	Ν
Increase in Systemwic Alternative R			N			D			U	
			Engine	eering						
	Ramping	Ν	N	Ν	N	D	Ν	U	Ν	N
Improvement to Freeway Ramping/Access	Access to Local Streets	Ν	N	U	D	D	U	U	Ζ	U
, J. J.	Connectivity to Points of Interest	N	N	Ν	D	D	Ν	U	Ν	Ν
Improvement to Freeway Ramping/Access Highway Rating		N	N	U	D	D	U	U	N	U
Improvement to Freeway Ramping/Access Alternative Rating			U			D			U	
Proposed Recommended Alternative			Ν			Υ			Ν	

Notes: D = Desirable, N = Neutral, U = Undesirable

The Proposed Recommended Alternatives identified for Segments 2 and 3, Alternative 10 and Alternative 11, respectively, were presented to the public during the fourth series of public meetings held in April 2015. The

public was encouraged to submit comments on the Proposed Recommended Alternatives. These comments will be part of the public record and will be incorporated into the next phase of the DEIS evaluation process.

Traffic Evaluation Results for DEIS Screening

Vehicle Hours Traveled (VHT)

As shown in **Table 22**, the alternatives showed a decrease in VHT on the I-45 main lanes of about 8 percent for Segment 2.

Table 22: Segment 2 Percent Change in VHT

Freeway System	No Build	Alternative	% change
	VHT	VHT	from No Build
I-45 (Main lanes only)	11,700	10,735	-8%

As shown in **Table 23**, Alternative 11 performed the best out of the three alternatives for Segment 3. Overall, Alternative 11 showed a systemwide decrease of 3 percent as compared to the no build alternative. While I-10, US 59/I-69 show a slight increase in VHT for Alternative 11, the VHT for I-45 showed a decrease of 20 percent. The other alternatives for Segment 3 both showed an increase systemwide.

Table 23: Segment 3 Percent Change in VHT

Freeway Segment	Alt. 10	Alt. 11	Alt. 12
I-45	0%	-20%	-3%
I-10	3%	11%	3%
US 59/I-69	7%	3%	5%
I-45, I-10, US 59/I-69	4%	-3%	2%

Average Travel Speed

The alternative speeds for Segment 2 were determined by using the output metrics from the H-GAC TDM. As shown in **Table 24**, the Segment 2 alternatives showed a slight improvement over the 2035 No Build condition. The average travel speed for Segments 2 alternatives changed only marginally, about 1 or 2 miles per hour (mph) on both I-45 and systemwide, as compared to the no build alternative.

Table 24: Segment 2 Percent Change in Model Speeds

Freeway System	No Build Speed (mph)	Alternative Speed (mph)	% change from No Build
I-45 (Main lanes only)	48	49	1%
I-45, I-610, Hardy Extension, I-45 HOV/ML	51	52	2%

The alternative speeds for Segment 3 were determined from the VISSIM model output, which provides detailed information about delay. To determine the model speeds, traffic count data collected from the field in 2011 and growth rates calculated from the H-GAC TDM were used. The year 2011 traffic volumes were used as a base and then extrapolated to the future year (2035) using the growth rates determined from the future year H-GAC TDM to estimate future traffic volumes. The future year traffic volumes were used as one of the

many inputs into the VISSIM model, used to determine the alternative's speed on each freeway evaluated. **Table 25** presents the percent change from the No Build Alternative to the build alternative scenario.

Table 25: Segment 3 Percent Change in Model Speeds

Freeway System	Alt. 10	Alt. 11	Alt. 12
I-45	-10%	24%	19%
I-10	19%	63%	-11%
US 59/I-69	52%	138%	12%
I-45, I-10, US 59/I-69	31%	88%	-4%

Under Alternative 10, the speed is projected to decrease slightly on I-45, and under Alternative 12, speeds are projected to decrease on I-10. However, all other highways are projected to show an improvement in speed across the other alternatives. The biggest change can be seen on US 59/I-69 under Alternative 11, where speeds increase from 21 mph under the 2035 No Build Alternative to a projected 50 mph. Other notable improvements are along I-10, where speeds are projected to increase from 27 mph to 44 mph under Alternative 11, and an increase from 21 to 50 mph on US 59/I-69 under Alternative 10.

Alternative 11 is projected to show the greatest improvement in speeds for various reasons, including:

- The proposed capacity increases on main lanes improve congestion.
- The separation of I-45 into local and through traffic helps with the distribution of traffic; this split of traffic also eliminates merges and vehicles switching lanes when entering and exiting the roadway. In particular, the congestion at the Allen Parkway ramp would be eliminated with Alternative 11, as the merging movement is removed.
- The reconfiguration of the direct connectors between I-10 and I-45 would also increase systemwide speeds; the direct connector to I-45 southbound (from I-10 westbound) would be eliminated and with the three westbound I-10 lanes east of the I-45 connection there would be little congestion on that segment, as compared to the No Build Alternative.
- The roadway which would have the greatest improvement to the system is US 59/I-69, which would have an almost 140 percent increase in travel speeds. The main reason for this is the elimination of the "chicken merge" where the traffic bottlenecks on US 59/I-69 between SH 288 and I-45. Additionally, the enhanced capacity also helps increase the travel speeds along US 59.

Alternative 11 performed better than the other two alternatives when evaluating systemwide speeds within Segment 3 because it fundamentally changes traffic patterns such that critical bottleneck points are eliminated, thus reducing systemwide delay.

6.0 Recommended Alternatives

The Proposed Recommended Alternatives were further developed between Public Meeting #4 (April 2015) and the public hearing (May 2017).

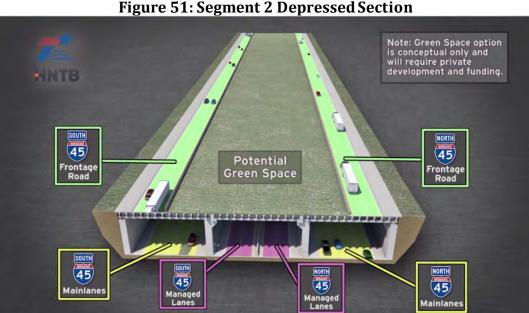
The following sections describe the Proposed Recommended Alternatives as presented to the public during the series of meetings held in April 2015.

6.1 Description of Segment 2 Proposed Recommended Alternative

Alternative 10

Alternative 10, the Proposed Recommended Alternative, for Segment 2 begins just north of the I-45/I-610 interchange, where it connects to Segment 1 and terminates near Quitman Street where it connects to Segment 3. The Proposed Recommended Alternative includes complete reconstruction of the I-45 general purpose lanes, managed lanes, and frontage roads. The project increases roadway capacity while improving safety by redesigning ramps to current design standards and redesign the horizontal and vertical curves to current design standards. Due to ROW constraints between Cottage Street and the Little White Oak Bayou crossing including the area adjacent to the Hollywood Cemetery, the Proposed Recommended Alternative includes a depressed section for the general purpose and managed lanes with the frontage roads located over the general purpose lanes, as further described below and illustrated on Figure 51. To maintain the same level of access on the local street network as existing conditions, local street bridges over the highway would need to be reconstructed.

The Proposed Recommended Alternative also includes the complete reconstruction of the fully directional I-45/I-610 interchange, addition of continuous frontage roads along I-610 and I-45, and a portion of I-610 reconstruction in the vicinity of the interchange. Local circulation would also be enhanced through the addition of the continuous frontage roads along I-610 and I-45.



I-45 General Purpose Lanes

Northbound: Beginning at the connection to Segment 3, there would be six northbound general purpose lanes with a two lane exit ramp to N. Main Street/Houston Avenue. Four general purpose lanes would continue northbound to the entrance ramp at Patton Street. Within this four lane section, the general purpose and managed lanes would be depressed and between Cottage Street and N. Main Street there would the possibility to add a decked park or greenbelt cap over the freeway. Also in this section, the northbound frontage road would be located at-grade and would continue over the general purpose lanes. Following the Patton Street entrance ramp, five general purpose lanes would continue to the split with the three lane (two forced, one optional) I-45 general purpose lanes and the three lane (two forced, one optional) ramp for the

eastbound and westbound I-610 direct connectors. The Link Road entrance ramp follows this split and adds the fourth lane.

The northbound frontage road would begin on Mainford Street near E. Woodland Street and would continue north towards Beltway 8. The northbound frontage road would vary between two and three lanes in Segment 2.

Southbound: Beginning at the connection to Segment 1, there would be four southbound I-45 general purpose lanes that would parallel the three-lane direct connector to eastbound and westbound I-610. Four main lanes would continue with full shoulders until the fourth outside lane ends at the Link Road exit ramp. Following the Link Road exit ramp is the two-lane merge of the direct connector from eastbound and westbound I-610. Four general purpose lanes continue and include a merge of the Cavalcade entrance ramp. Beginning at Temple Street, the general purpose lanes and the managed lanes begin to depress and the frontage roads continue at-grade over the general purpose lanes until N. Main Street. In this depressed section, between Cottage Street and N. Main Street there would the possibility to add a decked park or greenbelt cap over the general purpose and managed lanes. There would be a southbound entrance ramp from N. Main Street/Houston Avenue which would enter onto a fifth lane. There would be an optional exit to Quitman Street after crossing Little While Oak Bayou.

The southbound frontage road would have between two and three lanes, until it connects with existing Houston Avenue.

I-45 Managed Lanes - Northbound and Southbound

Beginning at the connection to Segment 1, the I-45 managed lanes would be located between the north and southbound general purpose lanes and would generally follow the general purpose lanes profile. The managed lanes would have two travel lanes in each direction with 4-footinside and 10-foot outside shoulders and would be separated by a barrier. The managed lanes would have connectivity to and from the proposed METRO T-Ramp south of Crosstimbers located in Segment 1.

I-45 managed lanes would begin and terminate at their existing location in northern downtown at Milam Street/Travis Street; managed lane traffic with a destination different than downtown would have the opportunity to exit to the southbound I-45 general purpose lanes near Quitman.

I-610 Main Lanes and Frontage Roads

Eastbound: Main lane reconstruction for I-610 eastbound would begin just east of the existing N. Main Street entrance ramp. Consistent with existing conditions, there would be five main lanes with full shoulders. The existing Airline Drive exit ramp would be maintained, which would connect to the two lane eastbound frontage road.

Following the optional Airline Drive exit is the connection to the I-45 general purpose lanes. Of the five main lanes on I-610, three lanes (two forced and one optional) split to the northbound and southbound I-45 general purpose lanes via two-lane direct connectors and three lanes (two forced and one optional) remain on eastbound I-610. The southbound I-45 DC merges to one lane, although the ramp would be wide enough to support two lanes in the future. The northbound I-45 DC would be two-lanes until the connection to the I-45 general purpose lanes. Following the split to I-45, there is a one-lane entrance ramp from Airline Drive which enters I-45 on an auxiliary lane. The auxiliary lane ends at the one-lane Fulton Street/Irvington Boulevard exit ramp and three main lanes continue eastbound until the three-lane merge from the I-45 direct connectors. The six-lane section connects to existing eastbound I-610 just west of Irvington Boulevard.

Westbound: Main lane reconstruction for I-610 westbound would begin just west of Irvington Boulevard. Consistent with existing conditions, there would six main lanes with full shoulders. Just east of Fulton Street, three lanes split to the northbound and southbound I-45 general purpose lanes via two-lane direct connectors and three lanes remain on westbound I-610. The southbound I-45 DC merges to one lane, although the ramp would be wide enough to support two lanes in the future. The northbound I-45 DC would be two-lanes until the connection to the I-45 general purpose lanes.

The existing entrance ramp west of Irvington Boulevard would be relocated west of Fulton Street, following the split to I-45. The one-lane westbound entrance ramp would add an auxiliary lane to westbound I-610 which would terminate at the Airline Drive exit ramp. The direct connectors from I-45 (three lanes) would merge with the three I-610 main lanes near Airline Drive. The three lanes of direct connectors from I-45 would include two lanes from I-45 southbound and one lane from I-45 northbound. The sixth, outside lane on I-610 terminates at the N. Main Street exit ramp. Following the exit ramp, the outside lane is merged to four lanes to connect to the existing westbound I-610 at the N. Main Street overpass.

N. Loop Freeway frontage roads would parallel I-610 and would intersect the proposed I-45 frontage roads with a series of four at-grade intersections. For the two-lane eastbound frontage road, construction would begin at the Airline Drive exit ramp and would continue east to Helmers Street where the proposed frontage road would connect to the existing frontage road. For the two-lane westbound frontage road, construction would begin just east of Fulton Street and would continue west to N. Main Street where the proposed frontage road would connect to the existing frontage road.

6.2 Description of Segment 3 Proposed Recommended Alternative

Alternative 11

The Proposed Recommended Alternative for Segment 3 includes the complete reconstruction and reconfiguration of the highways that comprise the "Downtown Loop." The Proposed Recommended Alternative would include the removal of the existing Pierce Elevated and would be replaced by a spur or downtown connector that would provide local access and connectivity from and to downtown via the highway system. A general concept of Alternative 11 is presented on **Figure 52**. As shown, I-10 and I-45 would be parallel north of downtown; at the interchange with I-69/US 59, I-45 would turn south and would be parallel to I-69/US 59 until it connects to the existing I-45(S). A portion of the Pierce Elevated would be replaced by the Downtown Connector which would provide local access to the west side of downtown. The redesign of the highways would be done to current design standards, improving horizontal curvature on the main lanes and ramp design. The proposed design would also include the addition of a pair of express lanes on I-10 and the addition of a pair of managed lanes on I-45 that terminate into north Downtown.

A more detailed description of each of the highways is provided on the next page.

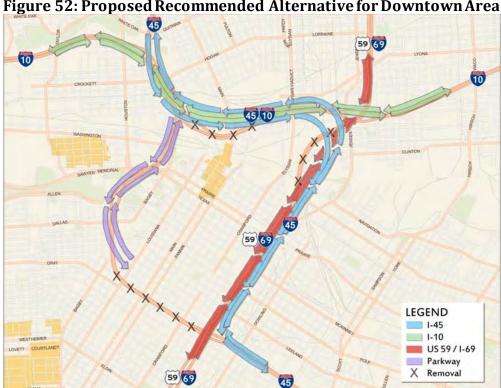


Figure 52: Proposed Recommended Alternative for Downtown Area

I-45 General Purpose Lanes

Beginning at the I-45 interchange with I-69/US 59 on the east side of downtown, the proposed I-45 would connect to the existing highway near Sauer Street and would also would incorporate TxDOT current planned modifications for the Pease/St. Joseph Street exit in this vicinity. The proposed improvements would abandon a portion of the Pierce Elevated, and three I-45 general purpose lanes in each direction would be rerouted to run parallel to the existing location of I-69/US 59 on the east side of downtown, as shown in **Figure 53**. The main lanes for both freeways, I-45 and I-69/US 59, would be depressed to allow for local arterial connections at ground level. Connections between the freeways would be provided to allow traffic to flow between the two concurrent facilities.

Figure 53: I-45/I-69 Interchange, looking Northwest



The configuration resulting from the removal of the elevated freeways and replacing with depressed freeways, would enhance the connectivity between downtown and the East Downtown Houston (EaDo) neighborhood. This depressed area would allow for the installation of a decked park similar to the Klyde Warren Park in Dallas, TX, as depicted in **Figure 54**.

Figure 54: Klyde Warren Park in Dallas



I-69/US 59, concurrent with the proposed I-45, would be realigned north of Commerce Street (near Minute Maid Park) to eliminate the horizontal curvature over Buffalo Bayou. The I-69/US 59 interchange with I-10 would also be reconfigured with new direct connectors, as illustrated in **Figure 55**. The I-45 general purpose lanes begin to ascend north of Commerce Street and curve towards the west to parallel and run between the realigned I-10. Connections between I-45 and I-10 would be provided so traffic would be able to flow between the facilities. The general purpose lanes continue to be elevated until the connection with the Downtown Connector. Just west of the Hogan Street bridge, the I-45 general purpose lanes curve north to

connect to Segment 2. The I-45 managed lanes would be located between the I-45 general purpose lanes, beginning just north of the White Oak Bayou crossing.

Minute Maid Park

September 10

West Hardy Connector SB

Jensen Dr 10

Express Lanes

Meadow St

Figure 55: I-10/I-69 Interchange, looking Southwest

Although access between I-69/US 59, I-10, and SH 288 provided through direct connectors, the proposed improvements would make I-45 into a downtown bypass with limited access to the surface street network from the I-45 general purpose lanes.

I-45 Managed Lanes

Near the terminus of Segment 2, before the I-10 interchange, the southbound I-45 managed lanes would have a split to the I-45 southbound general purpose lanes or to continue to the managed lane terminus in downtown at Milam Street. The northbound managed lanes would begin at Travis Street. Near the White Oak Bayou crossing there would be an optional connection the I-45 northbound general purpose lanes. The terminus in downtown for the I-45 managed lanes would be the same as existing conditions. The managed lanes would pass under the Union Pacific Railroad near the White Oak Bayou crossing.

I-10 General Purpose Lanes

At the western limit of the I-10 realignment, the Proposed Recommended Alternative would connect to existing I-10 just west of Houston Avenue. For the eastern limit of the I-10 realignment, the Proposed Recommended Alternative would connect to existing I-10 just west of Waco Street. The alignment of I-10 would shift north, between Bagby Street and McKee Street, of the existing location to run parallel to the Union Pacific Railroad north of Downtown. This shift north would improve the horizontal curvature of the facility. In this location, the I-10 general purpose lanes would be the outside highway, followed by the I-45 general purpose lanes, and the I-10 express lanes in the center. In this section of realignment, the highway facilities would be elevated due to the White Oak Bayou crossing and the N. Main Street METRO rail line. Between Jenson Drive and Naylor Street, Providence Street would serve as the westbound frontage road and Rothwell Street would serve as the eastbound frontage road.

The I-10 general purpose lanes vary between two and five lanes depending on the lane balancing with direct connectors and ramp terminals. The east and west limits of the project would connect to existing I-10.

Eastbound: For eastbound I-10, beginning near Houston Avenue, there would be a two inside lane split to northbound and southbound I-45 (the I-45 northbound direct connector would be one-lane and the I-45 southbound direct connector would be two-lanes) and four general purpose lanes would continue on eastbound I-10. Following the Houston Avenue overpass, there would be a two-lane exit to the Downtown Connector and three general purpose lanes would continue eastbound, as shown on Figure 56. After the interchange with I-45, the I-10 general purpose lanes would be flanked by the Downtown Connector to the south and the I-45 managed lanes to north and between the I-10 general purpose lanes, there would be the I-45 managed lanes and the I-10 Express Lanes. Between the I-45 interchange and White Oak Bayou, the I-10 and the I-45 general purpose lanes and the I-45 managed lanes would be located at-grade, the I-10 Express Lanes would be elevated to connect to the exiting METRO HOT lane. Following the exit to the Downtown Connector, there would be an exit to Smith Street, an entrance from the Downtown Connector, and an entrance from southbound I-45. This four lane section would continue over Main Street, provide an exit to McKee Street, and entrance ramp from San Jacinto Street/Naylor Street which would add a fifth lane that would have an optional exit to southbound I-69/US 59. In this vicinity, I-10 would be depressed and McKee Street, Hardy Street, and Elysian Street would pass over the I-10 general purpose lanes and managed lanes. In this section, the I-45 lanes would be elevated. There would be an exit to Jenson Drive with connectivity to the two-lane eastbound frontage road, followed by a two-lane exit to northbound I-69/US 59. This would leave two general purpose lanes that would connect to the three-lane director connector from northbound and southbound I-69/US 59. Before the terminus of the project at the eastern limit, the exit ramp to Waco Street would be reconstructed and four general purpose lanes would connect to existing I-10. The existing eastbound entrance ramp from Gregg Street would be removed; traffic would need to enter I-10 at Waco Street under the Proposed Recommended Alternative.

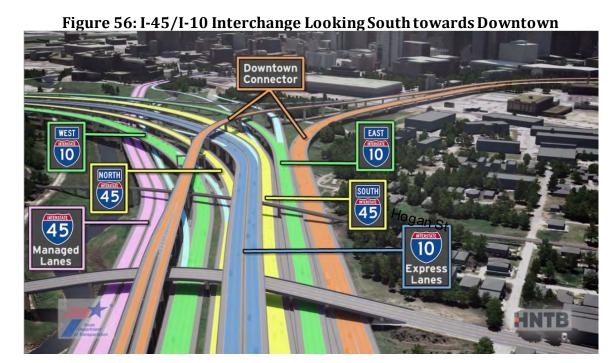
Westbound: At the eastern limit of the I-10 realignment, the Proposed Recommended Alternative would connect to existing I-10 just west of Waco Street with four westbound general purpose lanes. The Proposed Recommended Alternative would include the reconstruction of the westbound entrance ramp from Waco Street, which would be followed by the initiation of the two westbound Express Lanes and an exit ramp to Gregg Street. The exit ramp would connect to a two-lane westbound frontage road. Four general purpose lanes would continue with an optional one-lane connection to the northbound I-69/US 59 direct connector on the right and to the left would be a two-lane direct connector to southbound I-69/US 59 and to southbound I-45. Near the Meadow Street overpass, there is an exit ramp to the westbound frontage road that goes under the I-69/US 59 general purpose and managed lanes followed by the entrance of the southbound US 59/I-69 direct connector. In the depressed section of the highway near Elysian Street, the direct connector from US 59/I-69 northbound would add an additional travel lane which would be followed by the McKee Street entrance ramp and the two-lane connection from northbound I-45. In this section the I-10 general purpose lanes, I-45 general purpose lanes, and the I-10 Express Lanes would be elevated to pass over Main Street, White Oak Bayou, and the I-45 managed lanes. From I-10 there would be a left exit to the northbound I-45 general purpose lanes followed by the one-lane connection from the Downtown Connector and the one-lane connection from the southbound I-45 general purpose lanes. After going under the Houston Avenue overpass, westbound I-10 would connect to existing conditions with six lanes.

I-10 Express Lanes

The I-10 Express Lanes would connect to the existing METRO HOT structure on the west side of the project limits near Houston Avenue and would begin near Granger Street on the east side of the project limits. At the connection to the existing METRO HOT structure, the travel lanes would reduce to one lane in each direction. The I-10 Express Lanes, two lanes in each direction (with 4-footinside and 10-foot outside shoulders) within the project limits, are intended to facilitate the movement of traffic bypassing downtown. The I-10 Express

Lanes would be located between the I-10 general purpose lanes and would follow the same profile, until the Express Lanes begin to elevate to connect to the METRO HOT structure.

Since the proposed structure would replace and connect to the existing METRO T-ramp, access to and from downtown would be maintained to support HOV and transit operations for METRO. The existing METRO facility has access via Preston Street; the proposed design allows access to and from downtown from Smith Street and Louisiana Street, respectively. The Louisiana entrance ramp to westbound I-10 would have a connection to the I-10 Express Lanes and I-10 general purpose lanes.



I-69/US 59 General Purpose Lanes

The proposed I-69/US 59 general purpose lanes would connect to the existing facility just north of Lyons Avenue at the northern limit of the project and at Montrose Boulevard at the southern limit of the project. The general purpose lanes would vary between four and six lanes and follow the existing alignment, but would be reconstructed to maintain the depressed profile for the entire length of the corridor in the project limits until the I-10 interchange. Changing the profile of the freeway would require changes in the connectivity across the main lanes. The improvements propose to close a number of bridges spanning over the depressed section, including Blodgett, Caroline, Austin, Eagle, Cleburne, and Crawford. Although the access provided by Spur 527 would remain unchanged, a portion of Spur 527 (between I-69/US 59 and Richmond Avenue) would have to be reconstructed to accommodate the proposed changes in roadway profile.

In the location where I-69/US 59 is currently elevated, near the George R. Brown Convention Center, additional roads would have to be closed due to the proposed depressed profile, including Polk, Ruiz, and Runnels. Between the I-69/SH 288 interchange and the I-69/I-45 interchange, the I-69/US 59 general purpose lanes would be located outside of the SH 288 general purpose lanes. Access would be provided between the two facilities for traffic to flow between them. The I-69/US 59 general purpose lanes would remain depressed, while the SH 288 general purpose lanes begin would to elevate to go over the I-69/US 59 general purpose lanes and to connect to with the existing facility.

Between the I-69/I-45 interchange and the I-69/I-10 interchange, the I-69/US 59 general purpose lanes would be located outside of the I-45 general purpose lanes. Access would be provided between the two facilities for traffic to flow between them. In this vicinity, the I-69/US 59 HOV lane would begin/terminate at Chenevert Street/Jackson Street in northern downtown, which is the same as existing access. The HOV lane would weave through the I-69/I-10 interchange to align down the center of the I-69/US 59 general purpose lanes. Ramps beginning and terminating at Chenevert Street and Jackson Street would also provide access to and from northeastern downtown to the I-69/US 59 general purpose lanes.

The proposed improvements would include reconstructing the I-69/I-10 interchange with fully directional connectors. Additionally, access to the future Hardy Toll Road extension would be provided from the I-69/US 59 general purpose lanes and from St. Emanuel Street. The existing southbound exit ramp to Fannin Street would be relocated to Almeda Road and the northbound entrance ramp at San Jacinto would be also relocated to Almeda Road. A northbound frontage road would be located between Wheeler Avenue and Almeda Road. The northbound exit ramp to Main Street would be reconstructed but would remain the same level of access.

Midtown and East Downtown would have access to and from I-69/US 59 from Leeland Street and Bell Street which would vary from existing conditions where the ramps are located at Polk Street and McGowen Street. The southbound entrance ramp would be located at Webster Street which is the same as existing conditions.

Between SH 288 and the I-45 interchange, the I-69/US 59 frontage roads would be reconstructed using the existing Chartres Street for the northbound frontage road and Hamilton Street for the southbound frontage road. Between the I-45 interchange and Buffalo Bayou, St. Emanuel would serve as the northbound frontage road and Hamilton Street would be realigned one block to the east to run adjacent to southbound I-69/US 59 to serve as the southbound frontage road.

I-69/US 59(N) Reversible HOV Lane

The I-69/US 59(N) HOV lane would provide the same access as the existing condition. The reconstructed portion of the reversible lane would connect to the existing HOV lane and would begin/terminate in downtown at Chenevert Street.

SH 288 General Purpose Lanes

The reconstructed SH 288 general purpose lanes would connect to the proposed TxDOT SH 288 Program improvements near Blodgett Street. The SH 288 connection to the Proposed Recommended Alternative is illustrated in **Figure 57**.

The northbound SH 288 general purpose lanes at the connection to the proposed improvements would include five travel lanes with full shoulders. There would be an optional one-lane exit to southbound I-69/US 59 followed by a split to northbound I-69/US 59 and to an exit ramp at Chartres Street. At this split, two lanes would continue on northbound SH 288, two lanes would exit to the northbound I-69/US 59 direct connector and one lane would exit to Chartres Street. Following the split, there would be a two-lane connection from northbound I-69/US 59. The four SH 288 general purpose lanes would be depressed and would parallel the I-69/US 59 main lanes until the terminus of SH 288 at I-45. At the northbound SH 288 terminus, two lanes would split each to the I-45 northbound and I-45 southbound direct connectors.

The southbound SH 288 general purpose lanes would originate near Webster Street at the convergence of a one-lane direct connector from northbound I-45(S) and a two-lane direct connector from southbound I-69/US 59. These three general purpose lanes would parallel I-69/US 59 in a depressed section and would converge with the one-lane direct connector from I-45 northbound which would add a fourth travel lane. Near Alabama Street, SH 288 begins to curve to connect to the proposed SH 288 Program improvements. Also in this vicinity, the inside general purpose lane would split to the southbound SH 288 managed lane.

Following this split are two consecutive entrance ramps, each adding a general purpose lane, the first would be from Hamilton Street/Chenevert Street and the second would be from the northbound I-69/US 59 direct connector. The five general purpose lanes would connect to proposed TxDOT SH 288 Program improvements.

SH 288 Managed Lanes

The TxDOT SH 288 Program proposes to provide single lane managed lanes located between the SH 288 general purpose lanes. The Proposed Recommended Alternative would connect to those proposed managed lanes and would provide access to and from downtown at Chenevert Street. Access between the southbound SH 288 general purpose lanes and the southbound managed lane would occur near Alabama Street.



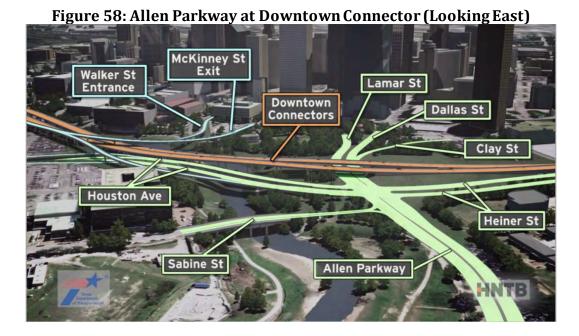
Figure 57: I-69/US 59 at SH 288 Interchange, Looking North

Downtown Connector

The Proposed Recommended Alternative would include the removal of the Pierce Elevated and would provide access to the west side of downtown via the Downtown Connector with three lanes in each direction, as shown on **Figure 58**. For the inbound movement, I-45 southbound and I-10 eastbound would have access to the Downtown Connector. Ramps to McKinney Street and Allen Parkway would be provided and the connector would terminate on Jefferson Street at Brazos Street.

For the outbound movement, the Downtown Connector would connect to eas thound and westbound I-10 and northbound I-45. Southbound I-45 and southbound I-69/US 59 would be accessible via eastbound I-10. The connector would begin on Pease Street at Brazos Street. The connector would still allow traffic on Pease Street to stay on the street network; Pease Street would terminate at W. Dallas Street. Outbound downtown traffic would be able to enter the Downtown Connector from Pease Street and Walker Street.

W. Dallas Street would no longer connect between Heiner Street, traffic traveling to downtown from west of the Downtown Connector would have to use Allen parkway or Brazos Street. The Proposed Recommended Alternative would require the realignment of Heirner Street/Houston Avenue between Memorial Drive and Brazos Street, including the intersection with Allen Parkway.



7.0 Next Steps

The Public Hearings held in May 2017 were heavily attended which in turn generated many public comments on this project. TxDOT and the project team reviewed the public comments received and prepared comment responses for each of the comments.

Direction was given by TxDOT to begin development of design revisions in Summer 2017 to address the public comments that TxDOT committed to addressing. The design revisions affected both Segments 2 and 3.

The design revisions that were incorporated into the latest version of the schematics (July 2018) that addressed the public hearing comments is shown in the list below.

• Segment 2

- o Added a WB elevated ramp from Irvington to I-610 WB that spans the existing light rail crossing at Fulton St.
- o Provide connection from existing pedestrian/bike trail connection to proposed pedestrian features along I-45 SB frontage road.
- Removed u-turns at N Main St and Cottage St.

• Segment 3

- I-10 frontage road
 - I-10 Eastbound frontage road horizontal and profile changes to go under both UPRR and BNSF to allow for unimpeded traffic flow in the northern downtown area.
- o I-69
 - Revised Webster to I-69 SB entrance ramp to one lane.

o SH 288

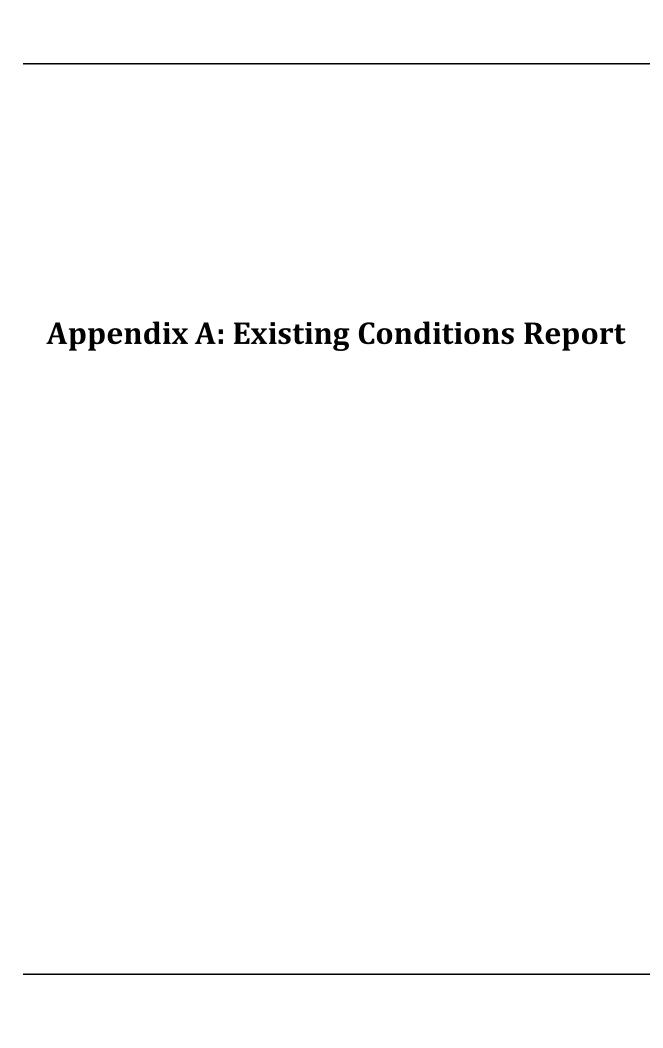
- Relocated NB MaX Lane Connection into Downtown and provided Downtown access via SH 288 NB mainlanes.
- Provided direct access to I-45 NB and I-45 SB from SH 288 NB MaX Lanes.
- Relocated SB MaX Lane Connection from Downtown and provided SB egress via I-69 SB frontage road.
- Revised SH 288 NBFR/Elgin intersection to include a dedicated left turn lane from SH 288 NB entrance ramp.

o St. Emanuel

 Shifted St. Emanuel Street closer to US 59/I-69 to incorporate proposed Navigation/Commerce project.

o Downtown Connectors

- Revised Downtown Connectors profiles from elevated to below grade from just south of Allen Parkway to just south of Andrews St.
- Revised alignment and tie in for Northbound entrance ramp and Northbound Downtown Connector.
- Revised Heiner alignment from Dallas St to St. Joseph Parkway to allow for additional border width that can be used for future pedestrian amenities.
- Added at-grade crossing at Andrews St over Downtown Connectors (for pedestrian use only).
- Revised Northbound Frontage Road alignment from Dallas St to Andrews St.



EVALUATION OF EXISTING CONDITIONS

Updated May 2015

An evaluation of existing infrastructure and traffic conditions along the Interstate Highway 45 and Hardy Toll Road corridors, to be utilized in developing a Universe of Alternatives.

Table of Contents

Report Objectives	2
Study Area	2
Major Facilities of Consideration	2
Interstate Highway 45	2
Hardy Toll Road:	3
Data Collection	4
Analysis of Existing Engineering Elements	6
Roadway Geometry	6
Horizontal Alignment	6
Vertical Alignment	6
Vertical Clearance	6
Typical Sections	7
Cross-street Intersections	11
Condition of Structures	11
Railroad Crossings	12
Hydraulics and Hydrology	12
Terrain	12
Watersheds	12
Floodplains	13
Drainage Crossings	14
Utilities	14
Right-of-Way	14
HOV Facilities	15
Analysis of Existing Traffic Elements	16
Existing Traffic Patterns, Characteristics & Conditions	16
Historical Traffic Growth	17
Existing Traffic Volumes	18
Existing Level of Service	19
Major Traffic Destinations	19
Crash Analysis	20
Planned Improvements	22
Appendix A: Tables	23
Annendix B. Figures	33

Report Objectives

As a precursor to developing a Universe of Alternatives for potential improvements in the I-45 and Hardy Toll Road Corridors, this report summarizes the existing condition of major transportation facilities in the north Houston area.

This report contains two primary analyses – existing engineering elements and existing traffic conditions. Analysis of existing engineering elements was performed by HNTB Corporation, including evaluation of Roadway Geometry, , Right-of-Way, Utilities, and HOV Facilities. Analysis of existing traffic conditions was performed by CDM Smith, as a separate Task Order under this contract. This report presents only an overview of existing traffic conditions, which are fully documented in the *I-45/HardyTrafficStudy Update*, dated August 2011.

Study Area

This report primarily considers the I-45 North Corridor, Hardy Toll Road Corridor, and the constituent freeways comprising the Downtown Loop (I-10, I-69/US 59 and I-45). Other major facilities in the region include I-69/US 59 and SH 249 (primarily north-south facilities) and Sam Houston Tollway/Beltway 8, I-610, and I-10 (primarily east-west facilities). These facilities are considered for those segments within the study area.

For purposes of this report the study area limits are determined as I-45 from downtown to north of Beltway 8; Hardy Toll Road from I-610 to North of Beltway 8 and the Downtown Loop. A graphical depiction of the study area is shown in Appendix B of this report, **Figure 1** and **Figure 2**. It should be noted that the study area limits are different for the analysis of existing traffic conditions and the analysis of existing engineering elements. It should also be noted that the study area limits depicted for the analysis of existing engineering elements extend beyond that described in Work Authorization No. 3. This was done primarily because the information was readily available and inclusion of this information provides a more complete understanding of existing conditions.

Major Facilities of Consideration

As part of the Greater Houston Area highway network, traffic conditions within the I-45 Corridor are significantly impacted by the condition of other major highways in the area. Any analysis of existing conditions or consideration of future improvements to the I-45 Corridor must be made with respect to the other major facilities in the area, which include the Hardy Toll Road, SH249, I-69/I-69/US 59, BW 8, I-610 and I-10.

Interstate Highway 45

I-45 is the only north-south interstate facility within the Houston metropolitan area and is a primary commuter and through facility for regional traffic. The facility is also an official Texas Evacuation Route from Galveston to FM 1314 (north of the Woodlands) in Montgomery County. As a result of the evacuation problems experienced by residents in the region in response to Hurricane Rita in September 2005, plans are currently underway to develop efficient and safe methods for a more systematic and improved evacuation.

Within the study area, I-45 provides between four to eleven travel lanes (10 main lanes and one HOV lane) between north of Sam Houston Tollway/Beltway 8 to the southern terminus at I-69/US 59/SH 288. The posted speed limit is 60 miles per hour. The facility has one-way two-lane frontage roads on both sides for most of its length.

Hardy Toll Road:

Hardy Toll Road, under the auspices of the Harris County Toll Road Authority (HCTRA), is a north-south tolled facility running east of and parallel to the I-45 corridor, providing between four and six travel lanes from its northern terminus at I-45 near The Woodlands to its southern terminus at I-610. Major interchanges exist at both termini and at Beltway 8. The Hardy Toll Road follows right-of-way owned by the Union Pacific Railroad and crosses over the railroad right-of-way at multiple locations. The toll road right-of-way is abutted by overhead transmission lines on the west side between Aldine Mail Route and Berry Road. Most side streets intersecting Hardy Toll Road between Beltway 8 and I-610 cross over the frontage road, mainlanes and railroad, creating elevated intersections throughout the corridor. Clearances for these streets as well as the Hardy Toll Road bridges over the railroad meet vertical clearance requirements for railroads. Hardy Road, a two-lane roadway, runs parallel and west of the Hardy Toll Road within the study area. There are plans to extend the Hardy Toll Road south of I-610 with connectors to Downtown Houston and I-69/US 59 South.

Data Collection

Data of various types was obtained in order to characterize deficiencies of the existing facility and identify constraints which may potentially impact future improvements within the corridor. The sections below briefly describe the types of data collected and the sources from which they were obtained.

As-built Plans

As-built plans were obtained from the TxDOT Houston District. As-built plans were the primary data source for roadway design element information. In some cases, this information was supplemented with field-collected and aerial photography data. In other cases, this information was unavailable.

Topographic Mapping

The mapping information gathered for the screening and evaluation of alternative routes includes digital United States Geological Survey (USGS) Maps, State Roadway Maps, Natural Resources Conservation Service (NRCS) Soil Classification Maps, and Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps.

USGS maps (1:24,000 scale) are being used in combination with digital orthophotos as the base mapping for the engineering element of the study. The USGS maps were utilized to identify topographic relief (terrain), route location, geological features (lakes, rivers, etc.), recreational areas, intermodal facilities (railroads), points of interest, land use conflicts, and regional drainage patterns.

Digital Aerial Photography

Aerial photography (2012) was obtained in the form of 1-foot digital orthophotos from H-GAC. The aerial photography along with USGS maps were used as base mapping.

The NRCS Soil Classification Maps identify approximate locations of various soil associations. The team will use this data to assess constructability issues, which may affect the cost of construction and/or tunnel feasibility.

Design Standards and Criteria

Design manuals and standards were gathered from TxDOT in order to develop the design criteria for the study. The general standards for freeways were obtained and a conceptual typical section was prepared for use in this study.

Bridge Structure Database

The condition of bridge structures will be assessed utilizing data from the TxDOT Bridge Inventory, Inspection and Appraisal (BRINSAP) database and the FHWA's National Bridge Inventory.

Right-of-Way Data

Right-of-Way data was determined from the TxDOT right-of-way plans and available GIS records.

Existing Drainage Studies

The existing drainage study is being conducted by AECOM under a separate TxDOT contract. This information is not provided within this report. Refer to the EIS document for more information concerning the study.

Floodplain Data

The FEMA Flood Insurance Rate Maps (FIRM) identifies existing 100-year and 500-year floodways crossed by the identified alternatives for the study. The FIRM maps were revised June 14, 2006 following the results of the Tropical Storm Allison Recovery Project (TSARP), and became effective in early 2007. Approximate

bridge lengths were determined from the updated FIRM maps during the detailed evaluation phase. Information regarding the watersheds was obtained from "Off the Charts" Tropical Storm Public Report from FEMA & HCFCD

Utilities Data

The locations of existing utilities were obtained using a variety of methods including field investigations, using the City of Houston GIS database, collecting and reviewing TxDOT as-built plan sets, requesting TxDOT permit files, filing requests for utility information with the one-call and dig-test utility location agencies, and sending individual utility request letters to agencies known to have facilities in the Houston area and to those agencies who responded to the one-call and/or dig-test request.

Railroad Data

Railroad data was obtained from the railroad commission records.

Planned Future Improvements

Various TxDOT area offices and the District office were contacted to obtain information on any current or planned transportation or utility improvements that could impact the corridor.

Crash & Traffic Data

Traffic and crash data was obtained primarily from the *IH45/Hardy Traffic Study Update* completed in August 2011 by CDM Smith, and supplemented by additional data obtained from the Department of Public Safety and TxDOT.

Environmental Data

The Environmental Impact Statement is being prepared by AECOM under a separate TxDOT contract. This information is not provided within this report. Refer to the EIS document for the existing environmental conditions, including the environmental constraint map.

Analysis of Existing Engineering Elements

Roadway Geometry

Geometric characteristics of the existing facility were evaluated with respect to design requirements for a proposed facility meeting a 60 mph design speed from BW 8 North to N. Main Street and 50 mph for the remaining Downtown Houston segments. The geometric characteristics considered for this report were horizontal and vertical alignment, vertical clearance, typical sections, condition of structures and railroad crossings. The findings of this analysis are described in the sections below.

Horizontal Alignment

Horizontal alignment data was obtained from available as-built plans. This data provided the radius and cross-slope, which were used to determine the design speed based on current TxDOT design criteria. Where as-built plans were unavailable, radius and length of curve were estimated from aerial photography and planimetric mapping; however, without cross-slope information, design speed of the existing facility could not be determined.

In the downtown area, the horizontal geometry typically meets TxDOT design criteria for 40 to 45 mph. From I-69/US 59 to N. Main, there are 24 curves, at least 8 of which do not meet the desired design speed of 50 mph. From N. Main to I-610 and from Shepherd to BW 8, there are 19 horizontal curves, at least 9 of which do not meet the desired design speed of 60 mph. Between Smith and Preston and between I-610 and Shepherd, as-built plans could not be found; thus, design speed could not be determined.

Horizontal curve data, including approximate location, station, length, radius, cross-slope, maximum design speed and desired design speed are presented in **Table 1** of Appendix A of this report.

Vertical Alignment

The vertical alignment data was obtained from available as-built plans. This data was used to calculate the K-value and corresponding maximum design speed based on current TxDOT design criteria. Where as-built plans were unavailable, design speed of the existing facility could not be determined.

In the downtown area, the vertical geometry typically meets TxDOT design criteria for 40 to 45 mph. From I-69/US 59 to N. Main, there are 14 curves, at least 6 of which do not meet the desired design speed of 50 mph. From N. Main to I-610 and from Shepherd to BW 8, there are 37 vertical curves, at least 16 of which do not meet the desired design speed of 60 mph. Between Smith and Preston, Link and I-610, and Airline and Shepherd, as-built plans could not be found; thus, design speed could not be determined.

Vertical curve data, including approximate location, station, length, back grade, ahead grade, K-value, K-value design speed and type of curve is presented in **Table 2** of Appendix A of this report.

Vertical Clearance

Vertical clearances were obtained from the TxDOT Bridge Inventory, Inspection and Appraisal (BRINSAP) database, posted clearance signs and the National Bridge Inventory database. Clearance data from the BRINSAP database was selected for use over the clearance signs since this data is more likely to be measured and updated during routine inspections, while clearance signs may not always be adjusted after maintenance overlays. The clearance values on signs are not actual clearances, but are generally 3 inches less than actual clearance at time of construction to account for future overlays.

TxDOT design guidelines recommend a vertical clearance of 16.5' for freeways. There are 60 locations along the I-45 corridor where this clearance criterion is not met. Vertical clearance data including station, upper and lower crossing roadways and clearance, for all instances throughout the I-45 corridor can be found in **Table 3** of Appendix A of this report.

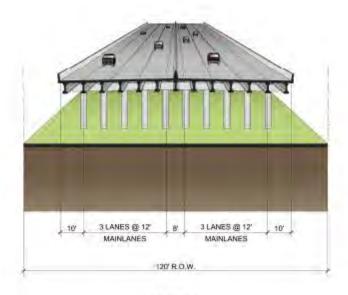
Typical Sections

Existing typical sections were determined using TxDOT as-built drawings and were verified through field visits. **Table 4**, below, summarizes details of interest for each section including width of HOV lane (barrier to barrier), number and width of main lanes and shoulder widths. Following the table, a description and graphical representation is presented for each section.

Table 4: Typical Lane and Shoulder Widths

Location	HOV Facility Width (ft-in)	Main Lane Width (NB/SB)	No. of Mainlanes	Shoulder Width (Outside/Inside)
I-69/US 59 to Allen Pkwy	N/A	12'/12'	3	10'/3'
Allen Pkwy to I-10	N/A	12'/12'	5	10'/10'
I-10 to Patton	18'-8" to 23'-4"	12'/11'	4	6'/0'
Patton to I-610	18'-8"	12'/12'	4	10'/0'
I-610 to Shepherd	19'-0"	11.5'/11.5'	4	10'/1'
Shepherd to BW 8	21'-9"	12'/12'	4	10'/8'

From **I-69/US 59 to Allen Parkway** the existing typical section is within a right-of-way footprint of 120 feet usual with large buildings abutting the freeway. Three 12' lanes run in each direction with a three foot inside and 10' outside shoulder. Much of this section is elevated, except for a depressed section in the vicinity of W. Dallas. Pierce Street runs parallel with I-45 on the east for approximately 4000 feet. This section does not meet desirable design criteria due to the narrow inside shoulder.



IH45 (N)
EXISTING TYPICAL SECTION
US59 TO ALLEN PARKWAY

Figure 3

From **Allen Parkway to I-10** the existing right-of-way varies between 235 and 265 feet. Five 12' lanes in each direction, and full 10' inside and outside shoulders are typical for this section of freeway. An unpaved median of generally 20' separates the northbound and southbound I-45 bridges. Buildings align both sides of the freeway right-of-way. This typical section meets minimum design criteria.



IH45 (N)
EXISTING TYPICAL SECTION
ALLEN PARKWAY TO IH10

Figure 4

From **I-10 to Patton** the existing right-of-way varies between 292 and 320 feet. A six foot outside shoulder and no inside shoulder accompanies the four 11' southbound and four 12' northbound mainlanes. A barrier-separated HOV lane varying in width from 18'-8" to 23'-4" resides in the middle of the freeway. The majority of this freeway section is depressed. Frontage roads exist north of North Main. This section does not meet the minimum and usual lane width criteria of 12', nor does this section meet the minimum design criteria for shoulder widths of 10'.



Figure 5

From **Patton to I-610** the existing right-of-way varies between 290 and 364 feet. This section of freeway has four 12' lanes in each direction, 10' outside shoulders, no inside shoulders and an 18'-8" barrier-separated HOV lane running in the middle of the freeway. Frontage roads exist throughout the section. The freeway is at-grade with overpasses. The section does not meet minimum design criteria due to lack of inside shoulders.



Figure 6

From **I-610 to Shepherd** the existing typical section is within a right-of-way footprint of 256 feet usual with a high density of businesses along the right-of-way. This section of freeway has four 11.5' lanes in both directions, one foot inside shoulders, 10-foot outside shoulders and a 19'-0" barrier-separated HOV lane running in the middle of the freeway. Frontage roads exist along this section except at the railroad crossing

north of Stokes. The freeway is at-grade with overpasses. This section does not meet the minimum and usual lane width criteria of 12′, nor does this section meet the minimum design criteria for shoulder widths of 10′.



IH45 (N) EXISTING TYPICAL SECTION H610 TO SHEPHERD

Figure 7

From **Shepherd to BW 8** the existing right-of-way is 300 feet usual with businesses along the right-of-way. This section of freeway consists of four 12' lanes in each direction, 10' inside shoulders, 8' inside shoulders and a 21'-9" barrier-separated HOV lane running in the middle of the freeway. Frontage roads exist along this section of roadway. The freeway is at-grade with overpasses. This section does not meet minimum design criteria for inside shoulder widths of 10'.



IH45 (N)
EXISTING TYPICAL SECTION
SHEPHERD TO BELTWAY 8

Figure 8

It should be noted that, according to as-built plans, all sections north of I-10 met minimum design criteria for lane and shoulder widths prior to the addition of the HOV lane.

Cross-street Intersections

Currently, there are no at-grade intersections on I-45 from I-69/US 59 to BW 8. Access to cross-streets is generally provided via ramps at diamond interchanges. In some cases, cross-streets do not have direct access to I-45. This is most prevalent in the downtown area, however, these cross-streets connect to other streets which have access to I-45.

There are four fully-directional interchanges located at I-69/US 59, I-10, I-610 and BW 8. The interchange with I-69/US 59 is a five-level, fully-directional interchange with direct-connectors and continuous frontage roads along I-45 and I-69/US 59. The interchange with I-10 is also fully-directional with direct-connectors, but unlike a typical crossing of two facilities, the interchange includes a section where I-45 and I-10 run parallel to each other between direct-connectors before separating. Frontage roads along I-45 and I-10 are not continuous across the interchange. The interchange with I-610 is a four-level, fully-directional interchange with direct-connectors; however, the frontage roads along both I-610 and I-45 are not continuous across the interchange. The interchange with BW 8 is a five-level, fully-directional interchange with direct-connectors and continuous frontage roads along both I-45 and BW 8.

A limited directional interchange exists at Allen Parkway. Four directional ramps provide access from Allen Parkway inbound to I-45 north and south and from I-45 north and south to Allen Parkway outbound.

A list of all cross-streets along I-45, interchange type (if access is provided), and the relative position of I-45 with respect to the cross street (main lanes over or under the cross street), can be found in **Table 5** of Appendix A of this report.

Cross-streets which intersect with frontage roads at extreme skew angles can create design and safety challenges such as limited site distance and difficulty in achieving desirable radii for turning movements. Extreme skew angles at grade-separated intersections also require increased structure lengths. Under ideal circumstances, roadways intersect perpendicularly (at 90 degrees). In the I-45 corridor, there are 7 cross-streets that intersect at skew angles 10 degrees or more from perpendicular. These intersections along with their approximate station and skew angle can be found in **Table 6** of Appendix A of this report.

Condition of Structures

Texas bridges are inspected every two years, and ratings for every element of the bridge are determined based upon the field conditions. These ratings are contained within each bridge's BRINSAP report, as well as the TxDOT BRINSAP database. The BRINSAP database was obtained from TxDOT and key elements on the condition of structures along the I-45 Corridor are presented in **Table 7** of Appendix A of this report.

The TxDOT Bridge Inspection Manual outlines criteria to determine which bridges are eligible for replacement or rehabilitation funding assistance under the National Bridge Program. In order for a bridge to be considered eligible for funding, it must have a Sufficiency Rating (SR) of 80 or less, and be either Structurally Deficient or Functionally Obsolete. These three terms are discussed below.

Sufficiency Rating (SR)

Sufficiency Rating is calculated based upon the bridge inspection ratings (a thorough explanation of the formula may be found in the TxDOT Bridge Inspection Manual). Bridges with an SR less than 30 automatically qualify for replacement. If the SR is below 50, the bridge is eligible for replacement or rehabilitation if the anticipated replacement costs are greater than 120 percent of the rehabilitation costs (determination of these costs is beyond the scope of this report). Bridges are considered rehabilitation eligible if the SR is between 50 and 80. Bridges are not eligible if the SR is greater than 80.

Structurally Deficient

A bridge is considered Structurally Deficient if it is not able to carry the truck loads expected of the bridge, which varies based on the type of roadway (functional classification) being carried.

Functionally Obsolete

A bridge is considered Functionally Obsolete if the width, vertical clearance, waterway adequacy or approach roadway alignments are not adequate for the traffic type, traffic volume, or expected flood waters.

Railroad Crossings

Three rail lines cross the I-45 Corridor. **Table 8**, below, provides the owner, location, approximate station, width of right-of-way and whether I-45 passes over or under the rail line, for all three railroad crossings.

The rail line north of Franklin is currently used by Amtrak for passenger transit, but carries minimal train traffic. METRO is currently planning to move the Amtrak station to an intermodal terminal, which would allow UPRR to use the existing track for local train traffic. The rail lines south of Crocket and north of I-610 both operate with high levels of train traffic.

Right-of-Way **I-45 Mainlanes Owner** Location Station Width (Over/Under) (ft.) UPRR 700' north of Franklin 1136+50 238 0ver UPRR 600' south of Crockett 1166+00 60 Under UPRR 2200' north of I-610 1334+50 100 Over

Table 8: Railroad Crossings

Hydraulics and Hydrology

Terrain

Like the rest of the Houston area, the I-45 Corridor is located within the natural, physiographic region called the Gulf Coastal Plain. Characteristic of the regional terrain the I-45 Corridor is nearly flat, low-lying, and slow draining. As shown in **Table 9**, below, the ground elevation within the Corridor rises gently from south to north.

Table 9: Land Elevation in I-45 Corridor

General Area	Approximate Elevation (ft.)
Near I-69/US 59	40-55 feet
Near I-10	50-60 feet
Near I-610	60-70 feet
Near BW 8	85-100 feet

Source: USGS 1:25,000 topographic data, 1979 and 1982

Watersheds

The I-45 Corridor is drained by several watersheds, which flow towards Galveston Bay and the Gulf of Mexico. These watersheds include Buffalo Bayou, White Oak Bayou, Little White Oak Bayou, and Halls Bayou. A brief description of each follows.

Buffalo Bayou Watershed

The Buffalo Bayou watershed runs through the central portion of the county, starting west and flowing through downtown Houston, ultimately to the Houston Ship Channel. During Tropical Storm Allison, very intense rain fell over the eastern portion of the watershed, while the western portion experienced only minimal rainfall amounts. Between the Houston Ship Channel and Shepherd Drive, 10 to 15 inches of rain fell over the area in a 12-hour period. Over 2,500 residences flooded within the watershed, along with portions of Downtown Houston, and all major roadways going into downtown.

White Oak Bayou & Little White Oak Bayou Watershed

The White Oak Bayou watershed, located in central Harris County, also includes Little White Oak Bayou. During Tropical Storm Allison, areas within this watershed received rainfall amounts of 8 to 15 inches over a 12- hour period, approaching or exceeding 1% chance (100-year) rainfall amounts. Record flood levels were recorded along the full length of Little White Oak Bayou, while flood levels along White Oak Bayou varied from moderate to record, depending on the location. Over 11,000 residences were flooded within the White Oak Bayou watershed.

There are six large regional detention basins along White Oak Bayou, along with numerous smaller detention basins constructed to offset excess storm water runoff from new land developments.

Greens Bayou and Halls Bayou Watershed

Greens Bayou and Halls Bayou are located in the northeast and central parts of Harris County. Although Halls Bayou is often considered an independent watershed, it is a tributary of Greens Bayou and experienced much of the same devastation during Tropical Storm Allison, due to its proximity to that waterway. The Greens Bayou area experienced the most severe rainfall in the county during Tropical Storm Allison. Up to 28 inches of rain was recorded in a 12- hour period – two-and-a-half times the 1% chance (100-year) rainfall and approaching the physical limits of how much rain can fall during that amount of time for this region. As a result, the Greens Bayou and Halls Bayou watersheds experienced some of the most devastating flooding ever recorded in Harris County, far exceeding previous record flood levels.

Floodplains

Certain lands adjacent to the bayous and streams within the Corridor have been designated by FEMA as being within the 100-year and 500-year floodplains. There are 6 major floodplain crossings of I-45 within the study area. The longest floodplain crossing is associated with a drainage which parallels I-45 from northeast of Patton St. to northwest of Lyerly St. for a distance of approximately 1.10 miles. **Table 10**, below, summarizes the major floodplains crossing the I-45 Corridor

Table 10: Floodplain Crossings

Station Range	Floodplain Crossing	100-Year Floodplain Width (ft)	Elevation (ft)
1102+50 - 1113+50	Buffalo Bayou	1100	36.93
1160+50 - 1181+00	White Oak Bayou	2050	37.57
1192+44 - 1198+00	Little White Oak Bayou (crossing SW near North St)	556*	39.03
1253+25 - 1256+50	Little White Oak Bayou (crossing SE near Patton St)	325	43.53
-	Little White Oak Bayou (running parallel to I-45)	5875 **	-
1642+50 - 1670+50	Halls Bayou	2800	80.08

Source: Flood Insurance Rate Map 1"=1000 ft, Revised 2006 and TSARP Final Model

Drainage Crossings

The I-45 Corridor is drained by the Buffalo Bayou, White Oak Bayou, Little White Oak Bayou and Halls Bayou watersheds. Regional drainage in the area is generally to the southeast, toward the Gulf of Mexico. Within these watersheds are multiple natural and man-made drainages. The major drainage crossings through the I-45 Corridor are shown in **Table 11**, below.

100-year Drainage Station **Structure Type Drainage Crossing Elevation** Direction (ft) 37 1103+50 Bridge Buffalo Bayou East 1178+00 37 - 38 Bridge White Oak Bayou East 1195+00 Little White Oak Bayou West 38 - 39 Box Culvert 1240+00 Single Box Culvert Unknown Creek East 44 - 45 1254+00 3 Box Culverts Little White Oak Bayou East 1278+00 Single Pipe Culvert Creek West Jonawski Ditch 1373+00 2 Box Culverts West 1401+00 4 Skew & 2 Box Culverts Ward Gully West -1427+00 5 Box Culverts (Skew) Creek East 1594+00 2 Pipes & 4 Box Culverts Creek East 1617+50 Single Box Culvert Halls Bayou East 1654+00 Bridge Halls Bayou East 79-80 1789+75 2 Box Culverts Tributary to Halls Bayou East 82

Table 11: Drainage Crossings

Utilities

There are numerous petrochemical and utility lines that cross the I-45 corridor. These lines, generally, should not create a significant impediment to potential above-grade improvements. Objects such as overhead utility towers and pipeline valves can create constraints to corridor improvements and should be avoided. The major utility crossings, as determined by TxDOT as-built plans and field collected data, are listed in **Table 12** of Appendix A of this report.

Right-of-Way

Existing right-of-way widths along I-45 were determined from the TxDOT right-of-way plans. Based on field observations, there are numerous office buildings located immediately adjacent to the right-of-way in the downtown area and numerous businesses along the frontage roads north of I-610. **Table 13**, below, attempts to define the locations where the right-of-way is of typical width or varies within a certain range.

Location	Station Range	Width (ft.)		
I-69/US 59 to Allen Pkwy	1022+50 to 1098+50	120' usual		
Allen Pkwy to I-10	1098+50 to 1160+00	Varies 235'-265'		
I-10 to Patton	1160+00 to 1254+00	Varies 292'-320'		
Patton to I-610	1254+00 to 1314+00	Varies 290'-364'		
I-610 to Shepherd	1314+00 to 1568+00	256' usual		

Table 13: Existing Right-of-Way Width

^{*} Data obtained from TSARP's HEC-RAS Model.

^{**} Includes Floodplain widths 100 ft at Cavalcade, 50 ft at Link Rd, 200 ft at Kelly St., 3975 ft between Railroad E107 -02-01 & Burress St, and 1550 ft at Rittenhouse St.

Shepherd to Beltway 8	1568+00 to 1804+00	300' usual
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HOV Facilities

The addition of an HOV facility was primarily accomplished through retrofit of the existing I-45 freeway, utilizing inside shoulders and lane reductions to create a space in the median for a barrier-separated reversible HOV lane. Access to the HOV lane is limited and provided through several large structures. Although there are existing T-ramps and wishbone ramps, there are no park and ride facilities within the study area. **Table 14**, below, summarizes the existing HOV facilities within the study area.

Table 14: HOV Facilities

Location	Station	Туре
2500' north of West Rd	1735+00	Wishbone Entrance/Exit Ramp
Shepherd	1568+00	At-grade Entrance/Exit Ramps
1500' south of Crosstimbers	1355+00	T-Ramp Entrance/Exit
Quitman	1182+50	At-grade Exit
I-10	1184+00	Elevated Exit to DC
Along I-10	N/A	Entrance/Exit to Louisiana/Smith
Along I-10	N/A	Entrance/Exit to Milam/Travis

Analysis of Existing Traffic Elements

Existing Traffic Patterns, Characteristics & Conditions

CDM Smith recently completed the *IH 45/Hardy Traffic Study Update* as part of this contract. The primary purpose of this study was to update the *IH 45/Hardy Traffic Study* completed in 2006 which evaluated existing and future travel patterns and traffic characteristics along the I-45 and Hardy Corridors from north of Sam Houston/Beltway 8 to Downtown Houston, as well as an analysis of I-69/US 59, Beltway 8 and I-10, as traffic conditions along these facilities impact traffic conditions along the I-45 and Hardy Corridors. The traffic analysis from this study will be utilized to develop and evaluate various transportation alternatives along I-45 and Hardy Toll Road from I-610 to Downtown Houston including the Houston Downtown Loop (I-10/I-45/I-69/US 59) and I-69/US 59 from the I-45/I-69/US 59 Interchange to Spur 527, also included as part of this contract.

More detailed findings regarding existing and future traffic conditions can be found in the draft report entitled *IH 45/Hardy Traffic Study Update*, dated August 2011. A few essential metrics which characterize existing traffic conditions are provided below in **Tables 15 to 17**, and summarized in the paragraphs which follow.

Table 15: I-45 North Section (Beltway 8 to I-10)

Tuble 13.1 15 North Section (Bellway 0 to 1 10)		
Traffic Characteristics	Existing Year 2011	
Number of Lanes	8 to 10 lanes (with one reversible HOV lane)	
Historic (2000 to 2010) Traffic Growth (Compounded Annual Growth Rate)	1.9% to 2.9%	
Daily Traffic Volumes*	234,000 to 320,000 vehicles per day	
Percentage of Daily Traffic occurring in Peak Hour (K Factor)	8%	
Percentage of Peak Hour Traffic occurring in Peak Direction (D Factor)	52% to 54%	
Average Travel Speed (AM Peak Hour, Southbound Direction)	30-40 mph	
Average Travel Speed (PM Peak Hour, Northbound Direction)	20-50 mph	
Level of Service (LOS)	E – F	
	Within 610 Loop - 29% to 35%	
Major Destinations	CBD - 12% to 21%	
	Texas Medical Center - 4% to 7%	

^{*}Includes Frontage Road volume

<u>Table 16: I-45 South Section (I-10 to I-69/US 59 S)</u>

Traffic Characteristics	Existing Year 2011
Number of Lanes	6 to 10 lanes
Historic (2000 to 2010) Traffic Growth (Compounded Annual Growth Rate)	1.9%
Daily Traffic Volumes*	220,000 to 265,000 vehicles per day
Percentage of Daily Traffic occurring in Peak Hour (K Factor)	7% to 8%
Percentage of Peak Hour Traffic occurring in Peak Direction (D Factor)	55% to 60%
Average Travel Speed (AM Peak Hour, Southbound Direction)	30-50 mph
Average Travel Speed (PM Peak Hour, Northbound Direction)	Less than 20 to 40 mph
Level of Service (LOS)	F
	Within 610 Loop - 40% to 44%
Major Destinations	CBD - 18%
	Texas Medical Center - 8% to 12%

^{*}Includes Frontage Road volume

Table 17: Hardy Toll Road (Beltway 8 to I-610)

Traffic Characteristics	Existing Year 2011
Number of Lanes	4 to 6 lanes
Historic (2000 to 2010) Traffic Growth (Compounded Annual Growth Rate)	4.9% to 7.3%
Daily Traffic Volumes*	61,000 to 68,000 vehicles per day
Percentage of Daily Traffic occurring in Peak Hour (K Factor)	12%
Percentage of Peak Hour Traffic occurring in Peak Direction (D Factor)	79%
Average Travel Speed (AM Peak Hour, Southbound Direction)	>60 mph
Average Travel Speed (PM Peak Hour, Northbound Direction)	>60 mph
Level of Service (LOS)	A-C
	Within 610 Loop - 31%
Major Destinations	CBD - 21%
	Texas Medical Center - 5%

^{*}Includes Frontage Road volume

Historical Traffic Growth

During the years 2000 to 2010 the Houston metropolitan area has experienced one of the highest population growths in the nation. This has resulted in significant increase in demand for travel on roadways in the region which is directly related to population growth and land use development.

Based on TxDOT Houston District's average annual daily volume maps, compounded annual growth rates (CAGR) were evaluated between the years 2000 and 2010. Historic traffic growth data during this period, including annual traffic growth rate and resultant traffic volumes, measured in vehicles per day (vpd), for study area facilities are summarized below in **Table 18**. This data is also graphically depicted in **Figure 9**, which can be found in Appendix B of this report.

Table 18: Historic Traffic Growth (2000 to 2010)

Facility	Section	2000 Daily Traffic Volumes (vpd)	2010 Daily Traffic Volumes (vpd)	Compounded Annual Growth Rate
	North of BW 8	227,000	313,000	3.3%
I-45	BW 8 to I-610	251,000	314,500	2.3%
1-43	I-610 to I-10	201,000	252,000	2.3%
	I-10 to I-69/US 59 S	220,000	265,000	1.9%
Hardy Toll Road*	BW 8 to I-610	61,000	68,000	5.5%
Beltway 8	Study Area	220,000	265,000	2.4%
I-610	Study Area	160,000	161,000	0.1%
I-69/US 59	Study Area	154,000	313,000	3.0%

*Historic Traffic Growth on Hardy Toll Road was estimated based on last five years of traffic data available from 2006 to 2010.

Some roadways in the study area, particularly near Spur 527/I-69/US 59 and I-10 east of I-45, displayed a reduction in traffic volumes. This trend is not necessarily due to decrease in demand for travel, but mainly a result of changes in travel patterns in the area between 2000 and 2010.

Existing Traffic Volumes

In September 2011, detailed daily traffic volume counts were conducted at key locations along the study corridors. Daily traffic volumes along I-45 range from approximately 320,000 vpd south of Beltway 8 to 163,000 vpd north of I-69/US 59 along Pierce Elevated in Downtown Houston. Hardy Toll Road experienced traffic demand ranging from 68,000 vpd south of BW 8 to 61,000 vpd north of I-610. **Table 19**, below, summarizes existing traffic volumes along corridors within the study area. A more detailed exhibit of existing traffic volumes throughout the study area is graphically depicted in **Figure 10**, which can be found in Appendix B of this report.

Table 19: Existing Traffic Volumes

Facility	Daily Traffic Volume (vpd)
I-45	163000 - 320,000
Hardy Toll Road	61000 - 68,000
I-10	141000 - 215,000
I-69/US 59	210500 - 239,500
SH288	194,500
Spur 527	76,500
Beltway 8	177,000
I-610	161,000

*Note: Historic Traffic Growth on Hardy Toll Road was

Existing Level of Service

Level of Service (LOS) is a qualitative measure of traffic operations, ranging from LOS A through LOS F. LOS A-C represents free flowing driving conditions; LOS D represents unstable traffic conditions with speed restrictions, and LOS E and F representing noticeable to severe congestion.

Although volume to capacity ratio is a standard indicator to measure level of service along a roadway, motorists generally experiences level of service based on the speed at which they are travelling. Some segments of I-45 experience lower travel speeds resulting in poor level of service due to geometric deficiencies and heavy traffic volumes. Using travel speed as a measure, the existing level of service for study area corridors is shown below in **Table 20**. A more inclusive graphical depiction of existing levels of service throughout the study area can be found in **Figure 11**, which can be found in Appendix B of this report.

Table 20: Existing Levels of Service

Facility	Level of Service
I-45	E - F
Hardy Toll Road	A - C
I-10	Е
I-69/US 59	F

Whether for a portion or the entire length, the majority of study area facilities are currently experiencing very high levels of congestion. If no transportation improvements are implemented along the I-45/Hardy corridor, the traffic situation will only continue to exacerbate.

Major Traffic Destinations

Travel patterns are related to the available roadway infrastructure and land use activities in the region. For the purpose of this study, the Houston region was divided into six destination zones to analyze distribution of traffic volumes from selected locations along the study corridors to these major destinations. Select-link modeling technique using the regional travel demand model was utilized to determine the origin and destination of traffic patterns with respect to these major destination areas. The six major destination zones identified within the Houston area are listed below and also illustrated in **Figure 12**, which can be found in Appendix B of this report.

Downtown Houston – within I-45, I-10 and I-69/US 59
I-610 Loop – within I-610 loop (excluding Downtown)
Northeast – outside I-610 loop and between I-45 N and I-10 E
Northwest – outside I-610 loop and between SH 288 and I-10 E
Southwest – outside I-610 loop and between SH 288 and I-10 W

Other destination zones include the Galleria, Texas Medical District and Midtown.

Crash Analysis

The following information on crash history was extracted from the Department of Public Safety records provided by TxDOT. Three-year crash data from 2008 to 2010 was analyzed for the following seven segments within the study area:

- 1. I-45 from Greens Road to Shepherd Drive
- 2. I-45 from Shepherd Drive to I-610
- 3. I-45 from I-610 to I-10
- 4. I-45 from I-10 to I-69/US 59
- 5. I-69/US 59 from Spur 527 to I-45
- 6. I-69/US 59 from I-45 to I-10
- 7. I-10 from San Jacinto Street to I-69/US 59

The crash records were sorted by crash severity including fatality, injury, or property damage only (PDO). This data is summarized in **Table 21**, below.

Table 21: Years 2008-2010 Study Area Crashes

Roadway	Limits	Fatality	Injury	Property Damage Only	Total
	Greens Rd. to Shepherd Dr.	12	543	835	1,390
I-45	Shepherd Drive to I-610	10	510	825	1,345
1-43	I-610 to I-10	12	204	341	557
	I-10 to I-69/US 59	2	119	213	334
I-69/US 59	Spur 527 to I-45	2	143	210	355
1-09/03 39	I-45 to I-10	4	54	98	156
I-10	San Jacinto Street to I-69/US 59	2	184	312	498

Source: Texas Department of Transportation

Figure 13 below illustrates crash data by type from 2008 to 2010 for the study area. The total number of crashes increased from 1,398 crashes in 2008 to 2,143 in 2010.



Figure 13: Crash History for Years 2008 - 2009

The crash rate was calculated based upon the number of crashes per 100 million vehicle miles (100MVM). A review of the results indicate that the section of I-10 East from San Jacinto Street to I-69/US 59 S has the highest three-year average crash rate of 188.4 100MVM, as shown in the **Table 22**, below. The section along I-10 East from I-45 to San Jacinto Street has the lowest three year average crash rate of 61.7 100MVMT.

Table 22: Crash Rates

D J	Y books	Crash Rate (100MVM)				
Roadway	Limits	2008	2009	2010	Average	
	Greens Road to Shepherd Drive	86.48	65.10	82.24	77.94	
I-45	Shepherd Drive to I-610	84.14	66.28	96.8	82.41	
1-45	I-610 to I-10	72.05	46.66	87.67	68.79	
	I-10 to I-69/US 59	18.68	17.78	78.92	38.46	
1.60/115.50	Spur 527 to I-45	42.73	50.55	188.89	94.06	
I-69/US 59	I-45 to I-10	14.65	13.00	78.51	35.39	
I-10	San Jacinto Street to I-69/US 59	71.06	69.68	221.87	120.87	

The statewide average crash rate for interstate facilities in urban areas was 105.21 in Year 2008, 99.08 in Year 2009, and 97.08 in Year 2010. Typically, roadway facilities are considered to have a significant crash problem when the crash rate is at least double the statewide average. The section of I-10 between I-45 and I-69/US 59 had crash rates more than double the statewide average in 2010 posing some significant safety issues. None of the other sections along I-69/US 59 and I-45 are close to double the statewide average.

Planned Improvements

Within the Study Area vicinity, there is a planned rehabilitation project along I-10 from I-45 to I-69/US 59 involving pavement replacement. There will be no changes to ramp configuration, number of lanes or profile adjustments and the major interchanges (I-10/I-45 and I-10/I-69/US 59) will not be affected by this rehabilitation.

An extension to the Hardy Toll Road is currently in the schematic design phase. The project would extend four toll lanes of Hardy Toll Road south of I-610 along the UPRR railroad right-of-way to the I-10/I-69/US 59 interchange. The project is currently on hold.

Table 23, below, summarizes the planned improvements within the study area.

Table 23: Planned Improvements

Туре	Location	Station	Owner
Rehabilitation	I-10 – I-45 to I-69/US 59	1145+00	TxDOT
Reconstruction	I-610 – I-45 (N) to west of I-69/US 59 (N)	1314+00	TxDOT
Rehabilitation	I-610 – East TC Jester to I-45 (N)	1314+00	TxDOT
New Facility	Hardy Toll Road Extension – I-610 to I-69/US 59	N/A	HCTRA

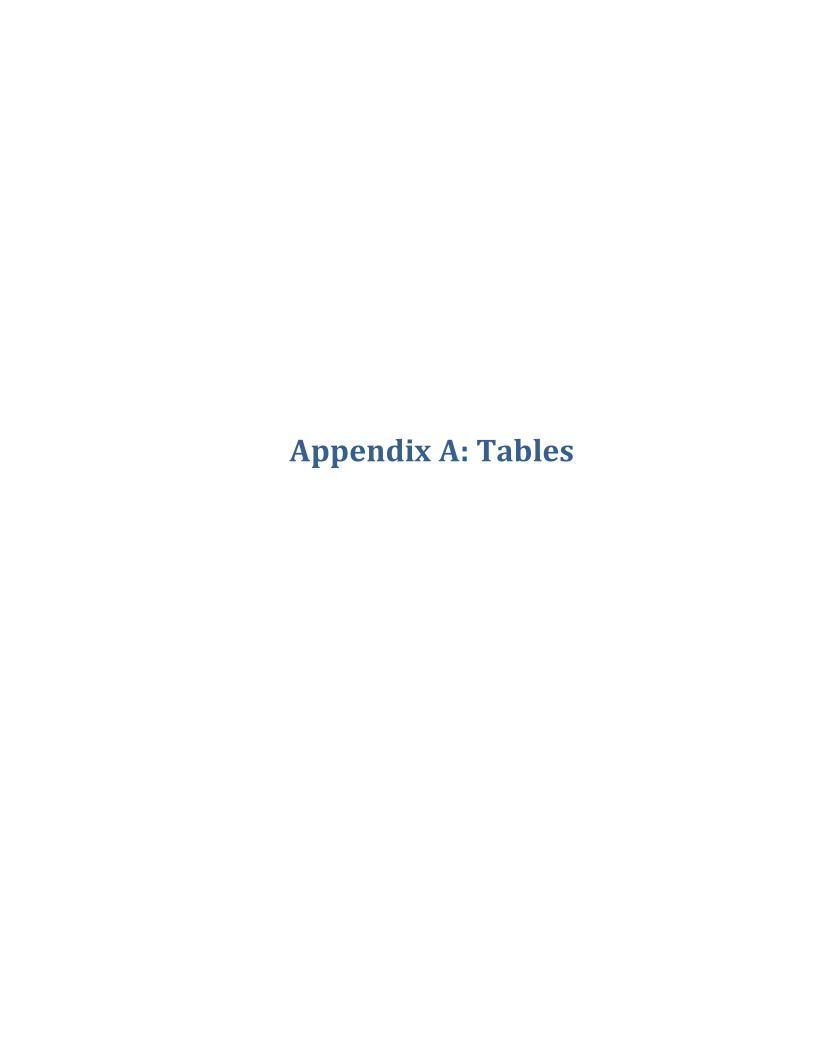


Table 1: Horizontal Alignment Data

				_	_	
		Length	Radius		Max Design	Desired Design
Station	Location	(ft.)	(ft.)	X-slope	Speed	Speed
		(ru)	(Lu)		(mph)	(mph)
1009+50	SB – Entrance from I-69/US 59	677	2865	2%	40	50
1013+00	NB – Exit to SB I-69/US 59	716	3820	2%	40	50
1021+50	SB – Over I-69/US 59	650	2865	2%	40	50
1029+50	NB – Entrance from I-69/US 59	374	2865	2%	40	50
1034+00	NB – Crawford	500	11459	2%	75	50
1066+50	100' south of Smith	1131	1450	N/A	N/A	50
1089+00	SB – 100' south of W Dallas	307	5730	N/A	N/A	50
1090+50	NB – 50' north of W Dallas	99	924	N/A	N/A	50
1102+00	SB – 400' north of Allen Pkwy	681	1164	N/A	N/A	50
1106+00	NB – 700' north of Allen Pkwy	530	1286	N/A	N/A	50
1112+50	SB – 1400' north of Allen Pkwy	43	1765	N/A	N/A	50
1125+00	NB – 200' south of Preston	686	1312	N/A	N/A	50
1126+00	SB – 200' south of Preston	639	1222	N/A	N/A	50
1146+50	SB – 1800' north of Franklin	1022	1432	5%	45	50
1148+00	NB – 1350' south of Crockett	591	955	6%	45	50
1156+50	NB – 550' south of Crockett	303	7639	NC	55	50
1157+00	SB – 450' south of Crockett	371	11459	NC	70	50
1159+50	NB – 250' south of Crockett	303	7639	NC	55	50
1162+00	SB – 100' south of Crockett	371	11459	NC	70	50
1171+00	NB – 400' south of White Oak Bayou	668	1910	5%	55	50
1175+50	SB – 200' south of White Oak Bayou	925	1432	5%	45	50
1189+00	SB – 600' north of Quitman	238	1432	6%	60	50
1200+00	700' south of North St	671	1910	5%	55	50
1220+00	400' south of N Main	513	1432	5%	45	50
1230+00	250' south of Cottage	513	5730	NC	45	60
1235+50	250' north of Cottage	513	5730	NC	45	60
1261+50	Coronado	902	5730	NC	45	60
1294+00	500' north of Link	970	5730	NC	45	60
1325+00	850' south of Stokes	400	5730	2%	50	60
1349+00	1550' north of Stokes	1247	5730	3%	65	60
1371+00	100' north of Crosstimbers	1195	2865	3%	45	60
1400+00	1000' north of Airline	515	5730	N/A	N/A	60
1436+00	550' south of Tidwell	209	5730	N/A	N/A	60
1496+00	400' south of Parker	780	5730	N/A	N/A	60
1537+25	500' south of Little York	50	5730	N/A	N/A	60
1548+00	550' north of Little York	531	5730	N/A	N/A	60
1560+00	NB - 450' south of Canino	755	2865	N/A	N/A	60
1571+00	SB - 600' north of Canino	1531	2865	N/A	N/A	60
1578+00	NB – 1000' south of Mitchell/Dewalt	685	2865	2.10%	40	60
1583+00	SB – 1000' south of Mitchell/Dewalt	277	5730	2.10%	50	60
1719+00	900' north of West Rd	810	11459	NC	70	60
1763+00	750' south of Aldine-Bender	789	11459	2.80%	80	60
1781+00	1050' north of Aldine-Bender	1732	6250	5%	50	60

Table 2: Vertical Alignment Data

Station	Location	Туре	Length (ft.)	Back Grade (%)	Ahead Grade (%)	K- value	Speed (mph) from K-value	Desired Design Speed (mph)
1016+50	SB - 100' south of Hutchins	Crest	1120	4	-3	160	80	50
1018+70	SB - 200' south of St Emanuel	Sag	225	-3	0	75	65	50
1018+75	NB - 200' south of St Emanuel	Crest	800	3.2	-0.2	235	45	50
1029+80	NB - 100' south of Jackson	Crest	640	-0.2	-4	168	65	50
1035+60	NB - 150' north of Crawford	Sag	300	-4	0.2	71	45	50
1078+00	800' north of Brazos	Crest	700	0.1	-5.45	126	55	50
		north of I	Brazos to I-1	0 - no verti	cal alignme	nt data		
1159+00	NB - 300' south of Crockett	Sag	300	0	5	60	40	50
1165+00	SB - 300' north of Crockett	Crest	400	3.75	2.25	267	80	50
1166+00	SB - Union Pacific Railroad	Sag	300	0	3.75	80	45	50
1167+00	NB - 500' north of Crockett	Crest	700	5	-3	88	45	50
1175+00	SB - White Oak Bayou	Crest	1000	2.25	-3	190	80	50
1176+00	NB - 200' N of White Oak Bayou	Sag	200	-3	0	67	45	50
1204+70	900' south of North St	Crest	200	0.35	-0.35	286	80	50
1222+60	150' south of Main	Crest	200	0.35	-0.35	286	80	50
1225+11	100' north of Main	Sag	200	-0.35	0.5	235	65	60
1229+70	300' south of Cottage	Crest	200	0.5	-0.35	235	80	60
1232+70	Cottage	Sag	200	-0.35	0.35	286	70	60
1235+70	300' north of Cottage	Sag	200	0.35	3	75	45	60
1241+70	900' north of Cottage	Crest	300	3	-0.3	91	45	60
1248+20	600' south of Patton	Sag	250	-0.3	4	58	40	60
1254+20	Patton	Crest	650	4	-4	81	45	60
1260+20	600' north of Patton	Sag	250	-4	0.6	54	40	60
1269+60	600' south of Cavalcade	Sag	200	0.6	4	59	40	60
1275+60	Cavalcade	Crest	650	4	-4	81	45	60
1282+10	650' north of Cavalcade	Sag	450	-4	4	56	40	60
1288+85	Link	Crest	650	4	-4	81	45	60
1294+35	550' north of Link	Sag	250	-4	0	63	45	60
		Ū	Link to I-61		cal alignmei			
1314+00	I-610	Crest	800	5	-5	80	45	60
1325+00	750' south of Stokes	Sag	500	-4	5	56	35	60
1335+00	UPRR	Crest	850	5	-5	85	50	60
1343+00	800' north of UPRR	Sag	400	-5	-0.3	85	45	60
1364+50	550' south of Crosstimbers	Sag	300	0	4	75	40	60
1370+00	Crosstimbers	Crest	700	4	-4	88	50	60
1375+50	550' north of Crosstimbers	Sag	300	-4	0	75	40	60
1383+50	650' south of Airline	Sag	300	0	4	75	40	60
1390+00	Airline	Crest	700	4	-4	88	50	60
1397+00	700' north of Airline	Sag	300	-4	0.45	67	40	60
			o south of S					
1561+20	SB - 650' south of Shepherd	Sag	290	0	3	97	50	60
1567+70	SB - Shepherd	Crest	950	3	-3	158	65	60
1573+70	SB - 600' north of Shepherd	Sag	250	-3	0	83	45	60
1607+15	800' south of Gulf Bank	Sag	350	0	3.5	100	50	60
1615+15	Gulf Bank	Crest	1200	3.5	-3.5	171	65	60
1623+15	800' north of Gulf Bank	Sag	400	-3.5	0	114	55	60
1640+80	800' south of SH 249	Sag	350	0	3.85	91	50	60
1648+80	SH 249	Crest	1200	3.85	-3.85	156	60	60
1656+80	800' north of SH 249	Sag	350	-3.85	0	91	50	60
1702+00	800' south of West	Sag	400	0	3.75	107	50	60
1710+00	West	Crest	1200	3.75	-3.75	160	65	60
1718+00	800' north of West	Sag	350	-3.75	0	93	50	60
1763+00	750' south of Aldine-Bender	Sag	300	-0.19	4	72	45	60
1770+50	Aldine-Bender	Crest	1230	4	-4	154	60	60
1770+30	Alume Denuel	GIEST	1230	т	-7	134	00	30

Table 3: Vertical Clearances

		Cleanange	
Station	Lower Roadway	Roadway Crossing Above	Clearance (ft-in)
1016+00	I-69/US 59 NB/Misc Streets	I-45 NB – I-69/US 59 NB DC	14'11"
1019+00	I-69/US 59 NB/Misc Streets	I-69/US 59 NB – I-45 SB DC	24'9"
1020+00	I-69/US 59/DC/Chartres/St Emanuel	I-69/US 59 SB – I-45 SB DC	15'3"
1020+00	I-69/US 59 NB/I-45 SB/Chartres	I-45 NB – I-69/US 59 SB DC	14'9"
1023+00	I-69/US 59/Misc Streets	I-45 NB Pierce Elevated	14'7"
1023+00	I-69/US 59/Misc Streets	I-45 SB Pierce Elevated	14'6"
1024+00	Hamilton/Polk	I-69/US 59 SB – I-45 NB DC	18'1"
1024+00	I-69/US 59 SB/Misc Streets	I-45 SB – I-69/US 59 NB DC	14'10"
1025+00	I-69/US 59 SB/I-45 SB/Misc Streets	I-69/US 59 NB – I-45 NB DC	14'8"
1025+00	I-69/US 59 SB/Hamilton	I-45 SB – I-69/US 59 SB DC	14'7"
1090+00	I-45	W Dallas	14'10"
1090+00	W Dallas	I-45 SB C-D Ramp	14'11"
1090+00	W Dallas	I-45 NB C-D Ramp	15'10"
1100+00	Allen Pkwy	I-45 NB Allen Pkwy Exit	14'10"
1102+00	Allen Pkwy/Buffalo Bayou	I-45 NB Houston Ave Exit	14'5"
1102+00	Buffalo Bayou/Misc Streets	I-45 SB C-D Ramp	14'10"
1102+00	Buffalo Bayou/Allen Pkwy	I-45 NB C-D Ramp	14'4"
1103+00	Buffalo Bayou	I-45 SB Allen Pkwy Exit	15'1"
1105+00	Buffalo Bayou/Allen Pkwy	I-45 NB	14'6"
1106+00	Nothing	I-45 SB Houston Ave Conn	N/A
1108+00	Houston Ave Exit Ramp	I-45 NB	14'7"
1108+00	Buffalo Bayou.Misc Street	I-45 NB Walker Entrance	14'2"
1110+00	I-45 NB/Buffalo Bayou	I-45 SB McKinney Exit	14'4"
1121+00	I-10 EB/Buffalo Bayou/Allen Pkwy	I-45 SB	14'5"
1121+00	I-10/Buffalo Bayou/Allen Pkwy	I-45 NB	15'0"
1139+00	I-10 Exit/Entrance Ramps	I-45 NB – I-10 EB DC	14'7"
1144+00	I-10 EB/I-45	I-10 WB – I-45 SB DC	16'5"
1154+00	White Oak Bayou Floodplain	I-10 WB – I-45 NB DC	N/A
1162+00	I-10/I-45/White Oak Bayou	Crockett	14'4"
1162+00	I-45 SB/I-10 EB/Crockett/UPRR	I-10 HOV	16'9"
1166+00	I-10/I-45/White Oak Bayou	Union Pacific Railroad	14'8"
1175+00	White Oak Bayou	I-45 NB	N/A
1177+00	I-10 WB/White Oak Bayou	I-10 EB – I-45 NB DC	15'4"
1177+00	White Oak Bayou	I-45 SB – I-10 WB DC	15'0"
1178+00	I-10 WB/White Oak Bayou/Quitman	I-45 SB	16'2"
1182+50	I-45 NB	Quitman	14'5"
1206+00	I-45	North	15'0"
1223+00	I-45	N Main	15'3"
1232+50	I-45	I-45 Cottage	
1254+00	Patton	I-45	14'5"
1275+50	Cavalcade	I-45	14'6"
1289+00	Link	I-45	14'3"
1309+50	I-45 NB – I-610 WB DC	I-610 EB	14'8"
1312+00	I-610 EB/Misc Ramps	I-610 WB – I-45 SB DC	17'11"
1314+00	I-610	I-45	16'2"

<u>Table 3 (Continued): Vertical Clearances</u>

Station	Lower Roadway	Roadway Crossing Above	Clearance (ft-in)
1316+00	I-610 WB/Misc Ramps	I-610 EB – I-45 NB DC	18'2"
1316+50	I-45 SB – I-610 EB DC	I-610 WB	14'6"
1334+50	Union Pacific Railroad	I-45 NB	21'11"
1334+50	Union Pacific Railroad	I-45 SB	22'0"
1355+00	I-45 SB/I-45 SB Frtg Rd	I-45 HOV T-Ramp	17'5"
1355+00	Median of I-45	I-45 HOV	N/A
1370+00	Crosstimbers	I-45 NB	16'0"
1370+00	Crosstimbers	I-45 SB	14'5"
1377+00	I-45 SB Crosstimbers Exit Ramp	I-45 SB Airline Entrance Ramp	16'5"
1390+00	Airline	I-45 NB	15'8"
1390+00	Airline	I-45 SB	17'5"
1442+00	Tidwell	I-45	15'1"
1501+00	Parker	I-45	15'2"
1542+00	Little York	I-45	15'4"
1615+00	Gulf Bank	I-45 SB	16'4"
1615+00	Gulf Bank	I-45 NB	16'3"
1648+50	SH 249	I-45 SB	17'6"
1648+50	SH 249	I-45 NB	17'6"
1653+50	Halls Bayou	I-45 NB	N/A
1653+50	Halls Bayou	I-45 NB Frtg Rd	N/A
1653+50	Halls Bayou	I-45 SB Frtg Rd	N/A
1653+50	Halls Bayou	I-45 SB	N/A
1710+00	West	I-45 SB	16'4"
1710+00	West	I-45 NB	16'4"
1725+00	Median of I-45	I-45 HOV	16'10"
1728+50	I-45 NB	I-45 NB HOV Ramp	16'9"
1728+50	I-45 SB	I-45 SB HOV Ramp	16'9"
1770+50	Aldine-Bender	I-45 SB	16'0"
1770+50	Aldine-Bender	I-45 NB	16'1"
1771+00	Aldine-Bender	I-45 NB – BW 8 Frtg Rd Exit	16'0"
1795+00	I-45/I-45 NB Frtg Rd	BW 8 WB – I-45 SB DC	16'4"
1800+00	I-45 NB Frtg Rd/BW 8 EB Frtg Rd	I-45 NB – BW 8 EB DC	15'11"
1801+00	BW 8 WB – I-45 SB DC	BW 8 EB Greenspoint Exit	16'10"
1801+50	BW 8/I-45/Misc Ramps	I-45 NB – BW8 WB DC	16'0"
1802+00	BW 8 EB Frtg Rd/I-45 SB Frtg Rd	BW 8 EB – I-45 SB DC	22'4"
1803+00	BW 8 Frtg Rd	I-45 NB Greens Exit Ramp	16'2"
1803+50	I-45	BW 8 EB	18'1"
1804+00	BW 8 Frtg Rds	I-45	15'5"
1804+00	I-45	BW 8 WB	16'10"
1804+50	I-45 NB Frtg Rd	BW 8 WB Greenspoint Entr	16'9"
1806+00	I-45 SB Frtg Rd/BW 8 WB Frtg Rd	I-45 SB – BW 8 WB DC	16'2"
1806+00	BW 8 WB Frtg Rd/I-45 NB Frtg Rd	BW 8 WB – I-45 NB DC	17'0"
1807+00	BW 8/I-45/Misc Ramps	I-45 SB – BW 8 EB DC	18'1"
1809+50	BW 8/I-45/Misc Ramps	BW 8 EB – I-45 NB DC	16'0"

Table 5: I-45 Intersections

Intersecting Roadway	Approximate Station	Interchange Type	I-45 Mainlanes (Over/Under)
Chartres	1020+50	No Direct Access	Over
I-69/US 59	1022+50	Fully Directional	Over
Hamilton	1024+00	No Direct Access	Over
Jackson	1027+50	No Direct Access	Over
LaBranch	1031+00	No Direct Access	Over
Crawford	1034+00	No Direct Access	Over
Austin	1037+50	No Direct Access	Over
San Jacinto	1041+00	No Direct Access	Over
Caroline	1044+00	No Direct Access	Over
Fannin	1047+50	No Direct Access	Over
Main	1050+50	No Direct Access	Over
Travis	1054+00	No Direct Access	Over
Milam	1057+50	No Direct Access	Over
Louisiana	1064+00	No Direct Access	Over
Pierce	1066+00	Single Ramp	Over
Smith	1068+00	No Direct Access	Over
Howe	1071+50	No Direct Access	Over
Dallas	1090+00	Single Ramp	Under
Allen Pkwy	1098+50	Limited Directional	N/A
Capitol	1116+00	No Direct Access	Over
Memorial	1119+00	No Direct Access	Over
Preston	1127+00	No Direct Access	Over
Franklin	1129+00	No Direct Access	Over
I-10	1160+00	Fully Directional	N/A
Crockett	1162+00	No Direct Access	Under
Quitman	1182+50	Partial Diamond	Over
North	1206+50	No Direct Access	Under
N Main	1223+00	Partial Diamond	Under
Cottage	1232+50	Partial Diamond	Under
Patton	1254+00	Partial Diamond	Over
Cavalcade	1275+00	Full Diamond	Over
Link	1289+00	No Direct Access	Over
I-610	1314+00	Fully Directional	Over
Stokes	1333+50	No Direct Access	Over
Crosstimbers	1370+00	Partial Diamond	Over
Victoria/Airline	1390+00	Full Diamond	Over
Tidwell	1442+00	Full Diamond	Over
Parker	1501+00	Full Diamond	Over
Little York	1542+00	Partial Diamond	Over
Shepherd/Veterans Memorial	1568+00	Full Diamond	Over
Gulf Bank	1615+00	Full Diamond	Over
SH 249	1648+50	Full Diamond	Over
West	1710+00	Full Diamond	0ver
Aldine-Bender	1770+50	Partial Diamond	Over
Beltway 8	1804+00	Fully Directional	Under

Table 6: Skewed Intersections

Cross Street	Approximate Station	Skew Angle (Degrees)
Quitman	1182+50	10
N Main	1223+00	43
Cavalcade	1275+50	15
Crosstimbers	1370+00	21
Airline	1390+00	55
Tidwell	1442+00	30
Little York	1542+00	23

*Note: Skew Angle is defined as the degrees from perpendicular

Table 7: Condition of Structures

1 able 7: Condition of Structures								
Structure	Station	Sufficiency Rating	Structurally Deficient (yes/no)	Functionally Obsolete (yes/no)				
I-45 NB - I-69/US 59 NB DC	1016+00	80	N	N				
I-69/US 59 NB - I-45 SB DC	1019+00	93.8	N	N				
I-69/US 59 SB - I-45 SB DC	1020+00	89.9	N	N				
I-45 NB - I-69/US 59 SB DC	1020+00	78	N	Y				
I-45 NB Pierce Elevated	1023+00	79	N	Y				
I-45 SB Pierce Elevated	1023+00	88	N	Y				
I-69/US 59 SB - I-45 NB DC	1024+00	90.2	N	N				
I-45 SB - I-69/US 59 NB DC	1024+00	77	N	N				
I-69/US 59 NB - I-45 NB DC	1025+00	91.8	N	Y				
I-45 SB - I-69/US 59 SB DC	1025+00	81	N	N				
W Dallas	1090+00	51.4	N	Y				
I-45 SB C-D Ramp	1090+00	79	N	N				
I-45 NB C-D Ramp	1090+00	79	N	N				
I-45 NB Allen Pkwy Exit	1100+00	79	N	N				
I-45 NB Houston Ave Exit	1102+00	52.9	N	N				
IH45 SB C-D Ramp	1102+00	64	N	Y				
I-45 NB C-D Ramp	1102+00	64	N	N				
I-45 SB Allen Pkwy Exit	1103+00	79	N	N				
I-45 NB	1105+00	62	N	N				
I-45 SB Houston Ave Conn	1106+00	66	N	N				
I-45 NB	1108+00	75	N	Y				
I-45 NB Walker Entrance	1108+00	66	N	N				
I-45 SB McKinney Exit	1110+00	64.8	N	Y				
I-45 SB	1121+00	62	N	Y				
I-45 NB	1121+00	76	N	Y				
I-45 NB - I-10 EB DC	1139+00	81	N	Y				
I-10 WB - I-45 SB DC	1144+00	78	N	Y				
I-10 WB - I-45 NB DC	1154+00	75	N	N				
Crockett	1162+00	59.9	N	Y				
I-10 HOV	1162+00	96	N	Y				
Union Pacific Railroad	1166+00	N/A	N	Y				
I-45 NB	1175+00	68	N	N				
I-10 EB - I-45 NB DC	1177+00	82.5	N	Y				
I-45 SB - I-10 WB DC	1177+00	84	N	N				
I-45 SB	1178+00	81	N	Y				
Quitman	1182+50	61.5	N	Y				
North	1206+50	75.7	N	Y				

Table 7 Continued: Condition of Structures

Table / Continued. Condition of Structures							
Structure	Station	Sufficiency Rating	Structurally Deficient (yes/no)	Functionally Obsolete (yes/no)			
N Main	1223+00	84.5	N	Y			
Cottage	1232+50	89.9	N	Y			
I-45	1254+00	97	N	N			
I-45	1275+50	98	N	N			
I-45	1289+00	96	N	N			
I-610 EB	1309+50	83.8	N	Y			
I-610 WB - IH45SB DC	1312+00	77	N	N			
I-45	1314+00	81	N	Y			
I-610 EB - I-45 NB DC	1316+00	76	N	N			
I-610 WB	1316+50	82.8	N	Y			
I-45 NB	1334+50	94	N	N			
I-45 SB	1334+50	94	N	N			
I-45 HOV T-Ramp North of RR	1355+00	94	N	Y			
I-45 HOV	1355+00	98	N	N			
I-45 NB	1370+00	86	N	N			
I-45 SB	1370+00	84	N	N			
I-45 SB Airline Entrance Ramp	1377+00	95	N	N			
I-45 NB	1390+00	96	N	N			
I-45 SB	1390+00	84.5	N	Y			
I-45	1442+00	94	N	Y			
I-45	1501+00	97	N	N			
I-45	1542+00	96	N	N			
I-45 SB	1615+00	96	N	N			
I-45 NB	1615+00	96	N	N			
I-45 SB	1648+50	94	N	N			
I-45 NB	1648+50	95	N	N			
I-45 NB	1653+50	84.1	N	N			
I-45 NB Frtg Rd	1653+50	78	N	Y			
I-45 SB Frtg Rd	1653+50	78	N	Y			
I-45 SB	1653+50	84.1	N	N			
I-45 SB	1710+00	96	N	N			
I-45 NB	1710+00	96	N	N			
I-45 HOV	1725+00	98	N	N			
I-45 NB HOV Ramp	1728+50	96	N	N			
I-45 SB HOV Ramp	1728+50	96	N	Y			
I-45 SB	1770+50	98	N	N			
I-45 NB	1770+50	95	N	N			
I-45 NB Bw 8 Frtg Rd Exit	1771+00	98	N	N			
BW 8 WB - I-45 SB DC	1795+00	97.4	N	Y			
I-45 NB - BW 8 EB DC	1800+00	87.9	N	N			
BW 8 EB Greenspoint Exit	1801+00	93.3	N	N			
I-45 NB - BW 8 WB DC	1801+50	99	N	Y			
BW 8 EB - I-45 SB DC	1802+00	94	N	N			
I-45 NB Greens Exit Ramp	1803+00	94	N	N			
BW 8 EB	1803+50	90.5	N	Y			
I-45	1804+00	94	N	N			
BW 8 WB	1804+00	90	N	Y			
BW 8 WB Greenspoint Entr	1804+50	82.9	N N	N N			
I-45 SB - BW 8 WB DC	1806+00	90	N N	Y			
BW 8 WB - I-45 NB DC	1806+00	94	N N	N			
DVV O VVD = 1-4-3 IVD DU	1000+00	74	IN	IN			
I-45 SB - BW 8 EB DC	1807+00	98	N	N			

Table 12: Utilities in I-45 Corridor

Owner	Location	Station	Crossing/ Parallel	Overhead / Underground	Commodity
Acaia Pipeline	North of West Rd	1714+00	Crossing	Underground	Petrochemical
Amaco	North of West Rd	1714+00	Crossing	Underground	Petrochemical
Amaco	West of I-45 (West Rd)	1714+00 to 1717+00	Parallel	Underground	Petrochemical
AT&T Fiber	Caroline	1040+00	Crossing	Underground	Fiber Optics
AT&T Fiber	West of I-45 (Northpoint)	1711+00 to 1769+00	Parallel	Underground	Fiber Optics
Cell Tower	Cottage	1240+00	N/A	Overhead	Cell Tower
Cell Tower	Patton	1254+00	N/A	Overhead	Cell Tower
Cell Tower	Stokes	1330+00	N/A	Overhead	Cell Tower
Centerpoint Energy	Jackson	1030+00	Crossing	Underground	Natural Gas
Centerpoint Energy	Crawford	1032+00	Crossing	Underground	Natural Gas
Centerpoint Energy	LaBranch	1037+00	Crossing	Underground	Natural Gas
Centerpoint Energy	Fannin	1050+00	Crossing	Underground	Natural Gas
Centerpoint Energy	Main	1054+00	Crossing	Underground	Natural Gas
Centerpoint Energy	Witcher	1465+00	Crossing	Underground	Natural Gas
Centerpoint Energy	East of I-45 (Halls Bayou)	1651+00 to 1655+00	Parallel	Underground	Natural Gas
Centerpoint Energy	East of I-45 (Northpoint)	1782+00 to 1793+00	Parallel	Underground	Natural Gas
Centerpoint Energy	Beltway 8	1798+00	Crossing	Underground	Natural Gas
Centerpoint Energy	East of I-45 (Greens)	1834+00 to 1849+00	Parallel	Underground	Natural Gas
Centerpoint Energy	UPRR	1336+00	Crossing	Overhead	Transmission
Centerpoint Energy	Beltway 8	1798+00	Crossing	Overhead	Transmission
Centerpoint Energy	Jackson	1030+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Crawford	1034+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	LaBranch	1036+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Caroline	1044+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	San Jacinto	1047+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Main	1054+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Travis	1057+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Milam	1060+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Louisiana	1064+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	Franklin	1131+00	Crossing	Underground	Buried Conduit
Centerpoint Energy	West of I-45 (BW8)	1737+00 to 1804+00	Parallel	Underground	Buried Conduit
Centerpoint Energy	East of I-45 (Greens)	1826+00 to 1842+00	Parallel	Underground	Buried Conduit
Centerpoint Energy	Main/Pierce	1050+00	N/A	Underground	Utility Vault
Citgo	Gears	1825+00	Crossing	Underground	Petrochemical
Citgo	West of I-45 (Greens)	1826+00 to 1835+00	Parallel	Overhead	Distribution Sta
Copano Field Services	Gillespie	1754+00	Crossing	Underground	Natural Gas
Exxon Mobil	Gulf Bank	1586+00	Crossing	Underground	Petrochemical
Exxon Mobil	Gulf Bank	1587+50	Crossing	Underground	Petrochemical
Exxon Mobil	Gulf Bank	1588+00	Crossing	Underground	Petrochemical
Exxon Mobil	Gulf Bank	1589+00	Crossing	Underground	Petrochemical
Gulf	Dyna	1737+00	Crossing	Underground	Petrochemical
HL&P	Beltway 8	1798+00	Crossing	Underground	Fiber Optics
Kinder Morgan	Beltway 8	1798+00	Crossing	Underground	Petrochemical
Longhorn Pipeline	Gulf Bank	1587+00	Crossing	Underground	Petrochemical
Mobil	West	1713+00	Crossing	Underground	Petrochemical
Mobil	West	1714+00	Crossing	Underground	Petrochemical

Table 12 Continued: Utilities in I-45 Corridor

Owner	Location	Station	Crossing/ Parallel	Overhead / Underground	Commodity
City of Houston	Milam	1059+00	Crossing	Underground	Sanitary Sewer
City of Houston	Franklin	1137+00	Crossing	Underground	Sanitary Sewer
City of Houston	East of I-45 (Quitman)	1188+00 to 1190+00	Parallel	Underground	Sanitary Sewer
City of Houston	Quitman	1194+00	Crossing	Underground	Sanitary Sewer
City of Houston	North St	1203+00	Crossing	Underground	Sanitary Sewer
City of Houston	Coronado	1260+00	Crossing	Underground	Sanitary Sewer
SBC	La Branch	1040+00	Crossing	Underground	Buried Conduit
SBC	Buffalo Bayou	1124+00	Crossing	Overhead	Conduit
SBC	Victoria	1389+00 to 1392+00	Parallel	Underground	Buried Conduit
SBC	Bluebell	1674+00	Crossing	Underground	Buried Conduit
SBC	Greens	1835+00	Crossing	Underground	Buried Conduit
Seminole Pipeline	Beltway 8	1798+00	Crossing	Underground	Petrochemical
Teppco Crude	Stokes	1337+00	Crossing	Underground	Petrochemical
Teppco Crude	Dyna	1736+00	Crossing	Underground	Petrochemical
Teppco Crude	Aldine-Bender	1764+00	Crossing	Underground	Petrochemical
Teppco Crude	Aldine-Bender	1765+00	Crossing	Underground	Petrochemical
Teppco Products	Beltway 8	1797+00	Crossing	Underground	Petrochemical
Unknown	Gulf Bank	1603+00	Crossing	Underground	N/A
Unknown	Beltway 8	1798+00	Crossing	Underground	N/A
Time Warner Cable	San Jacinto	1047+00	Crossing	Underground	Buried Cable
Time Warner Cable	West	1710+00	Crossing	Underground	Buried Cable
Time Warner Cable	Aldine-Bender	1770+00	Crossing	Underground	Buried Cable
City of Houston	I-69/US 59	1018+00	Crossing	Underground	Water Line
City of Houston	Austin	1040+00	Crossing	Underground	Water Line
City of Houston	San Jacinto	1047+00	Crossing	Underground	Water Line
City of Houston	Capitol	1123+00	Crossing	Underground	Water Line
City of Houston	Allen Pkwy	1125+00	Crossing	Underground	Water Line
City of Houston	Preston	1133+00	Crossing	Underground	Water Line
City of Houston	Franklin	1135+00	Crossing	Underground	Water Line
City of Houston	Hogan	1161+00	Crossing	Underground	Water Line
City of Houston	Hogan	1163+00	Crossing	Underground	Water Line
City of Houston	North St	1207+00	Crossing	Underground	Water Line
City of Houston	N Main	1231+00	Crossing	Underground	Water Line
City of Houston	Jewett/Cavalcade	1260+00 to 1278+00	Parallel	Underground	Water Line
City of Houston	Cavalcade	1278+00	Crossing	Underground	Water Line
City of Houston	Sylvester	1306+00	Crossing	Underground	Water Line
City of Houston	Crosstimbers	1373+00	Crossing	Underground	Water Line
City of Houston	Airline	1382+00	Crossing	Underground	Water Line
City of Houston	Tidwell	1443+00	Crossing	Underground	Water Line
City of Houston	Parker	1501+00	Crossing	Underground	Water Line
City of Houston	Rittenhouse	1521+00	Crossing	Underground	Water Line
City of Houston	Little York	1543+00	Crossing	Underground	Water Line
City of Houston	East of I-45 (Airline/Canino)	1385+00 to 1564+00	Parallel	Underground	Water Line
City of Houston	East of I-45 (Peach/West)	1625+00 to 1710+00	Parallel	Underground	Water Line
City of Houston	East of I-45 (Goodson/Aldine-Bender)	1745+00 to 1771+00	Parallel	Underground	Water Line
City of Houston	Aldine-Bender	1771+00	Crossing	Underground	Water Line
City of Houston	Plaza Verde	1783+00	Crossing	Underground	Water Line
City of Houston	East of I-45 (Aldine-Bender/Beltway 8)	1763+00 to 1800+00	Parallel	Underground	Water Line
City of Houston	West of I-45 (Beltway 8/Gears)	1805+00 to 1820+00	Parallel	Underground	Water Line

Appendix B: Figures

Figure 1: Study Area (Part 1 of 2)

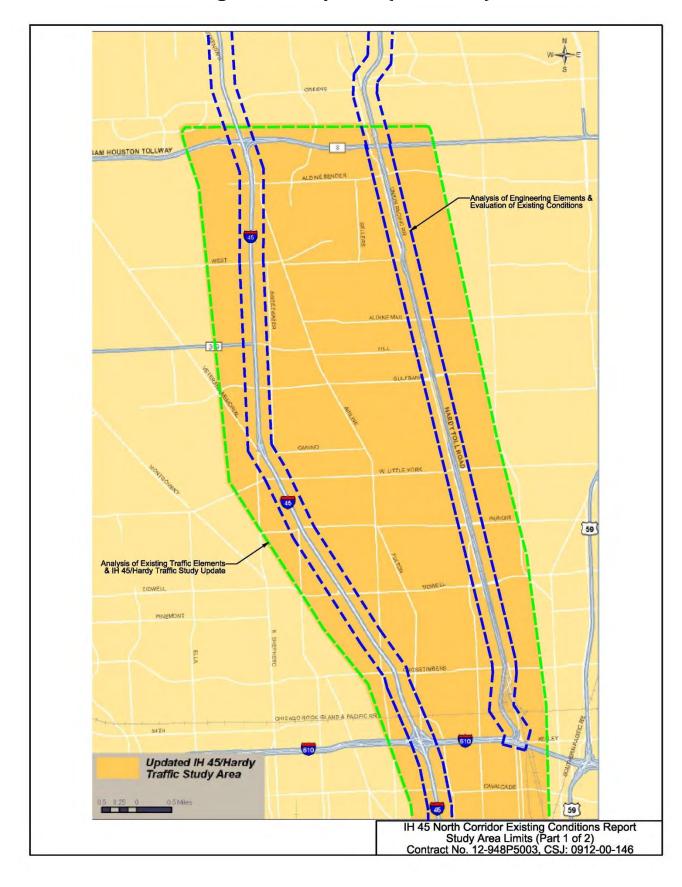
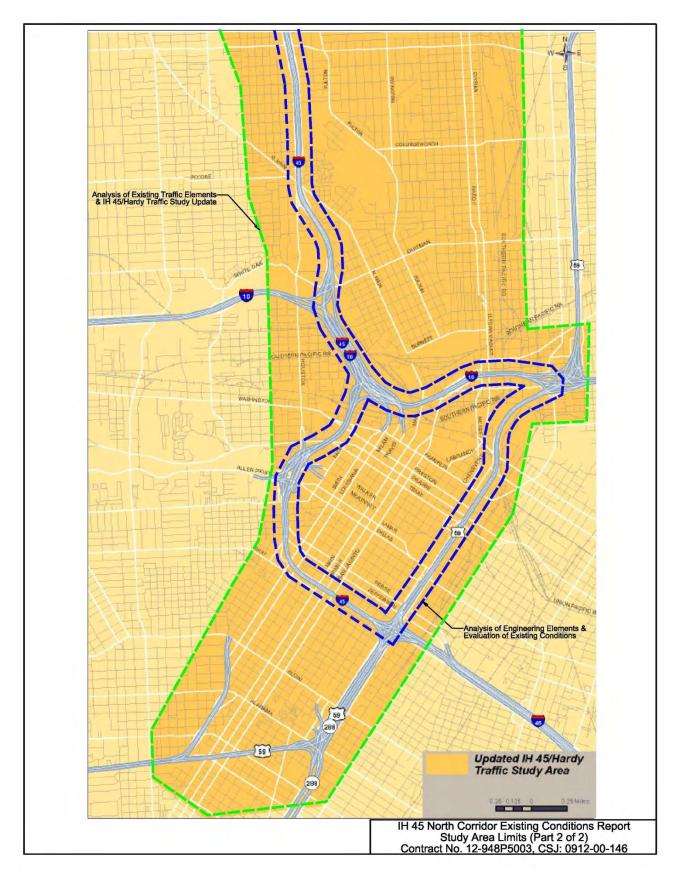
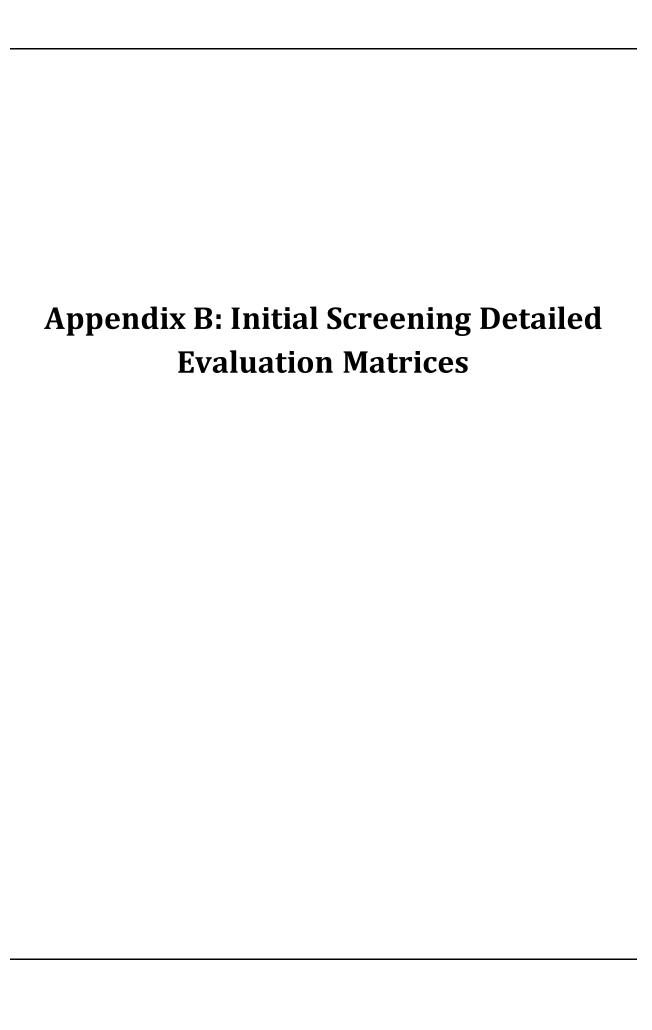


Figure 2: Study Area (Part 2 of 2)





UNIVERSE OF ALTERNATIVES - INITIAL SCREENING SEGMENT 2

			SEGMEN	NT 2										
			EVALUATION CRITERIA											
				l	Initial Scr	eening of L	Universe of Alternatives							
			(o	Engin	eering	Traffic	Environmental							
			es/N		(0)	w)	Lan	ces						
SEGMENT 2	Alternative		Meets Need and Purpose and Project Goals (Yes/No)	Meets Current Design Criteria (Yes/No)	Additional ROW - Cavalcade to Quitman (Yes/No)	Traffic/Mobility Improvements (High/Medium/Low)	Community Parks (Yes/No)	Cemeteries (Yes/No)	National Register Historic Places (Yes/No)	Recorded Archeological Sites (Yes/No)				
IH 610 to IH 10	Type Existing	Description			•	-	ŏ	ŏ	ž	<u> </u>				
Alternative 1	Configuration	NO BUILD SCENARIO TRANSPORTATION SYSTEMS	N/A	No	No	N/A								
Alternative 2	TSM Upgrades	MANAGEMENT (TSM) PROJECTS TWELVE (12) LANE SECTION -	N/A	No	No	N/A								
Alternative 3	Widen Existing	INCLUDES TEN (10) GENERAL PURPOSE LANES AND TWO (2) REVERSIBLE, SPECIAL PURPOSE LANES.	Yes	Yes	No	Medium								
Alternative 4	Widen Existing	TWELVE (12) LANE SECTION - INCLUDES EIGHT (8) GENERAL PURPOSE LANES AND FOUR (4) MANAGED LANES.	Yes	No	No	High								
Alternative 5	Elevated Hot Lanes	TWELVE (12) LANE SECTION - INCLUDES TEN (10) GENERAL PURPOSE LANES AND TWO (2) ELEVATED HOT LANES.	No	Yes	No	Low								
Alternative 6	Widen Existing	TWELVE (12) LANE SECTION - INCLUDES TEN (10) GENERAL PURPOSE LANES AND TWO (2) NON- BARRIER SEPARATED HOT LANES.	No	Yes	No	Low								
Alternative 7	Widen Existing	HOT LANES.	No	No	No	Low								
Alternative 8	Widen Existing	TEN (10) LANE SECTION - INCLUDES EIGHT (8) GENERAL PURPOSE LANES AND TWO (2) NON-BARRIER SEPARATED HOT LANES.	No	Yes	No	Low								
Alternative 9	Widen Existing	REVERSIBLE MANAGED LANES.	No	Yes	No	Low								
Alternative 10	Widen Existing	TWELVE (12) LANE SECTION - INCLUDES EIGHT (8) GENERAL PURPOSE LANES AND FOUR (4) MANAGED LANES.	Yes	Yes	No	High								
Alternative 11	Widen Existing with Elevated Managed Lanes	TWELVE (12) LANE SECTION - INCLUDES EIGHT (8) GENERAL PURPOSE LANES AND FOUR (4) ELEVATED MANAGED LANES ON A SINGLE STRUCTURE AT CENTER.	Yes	Yes	No	High								
Alternative 12	Widen Existing with Elevated Managed Lanes	TWELVE (12) LANE SECTION - INCLUDES EIGHT (8) GENERAL PURPOSE LANES AND FOUR (4) ELEVATED MANAGED LANES ON DOUBLE DECKER STRUCTURE AT CENTER.	Yes	Yes	No	High								
Alternative 13	Widen Existing with Elevated Managed Lanes	PURPOSE LANES AND FOUR (4) ELEVATED MANAGED LANES ON TWO (2) SEPARATE STRUCTURES ON LEFT AND RIGHT SIDES OF CENTERLINE.	No	Yes	No	High								
Alternative 14	Add Tunnel to Existing	TUNNELED ROADWAY UNDERNEATH IH 45. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	No	High								
Alternative 15	Add Direct Connector	ADDITION OF DIRECT CONNECTORS ALONG IH 610 CORRIDOR FROM IH 45 TO HARDY TOLL RD. INCLUDES FOUR (4) MANAGED LANES. THIS ALTERNATIVE ALSO INCLUDES WIDENING OF HARDY TOLL ROAD TO PROVIDE ONE ADDITIONAL LANE INBOUND AND OUTBOUND.		Yes	No	Medium								

Selected as Preliminary Alternative

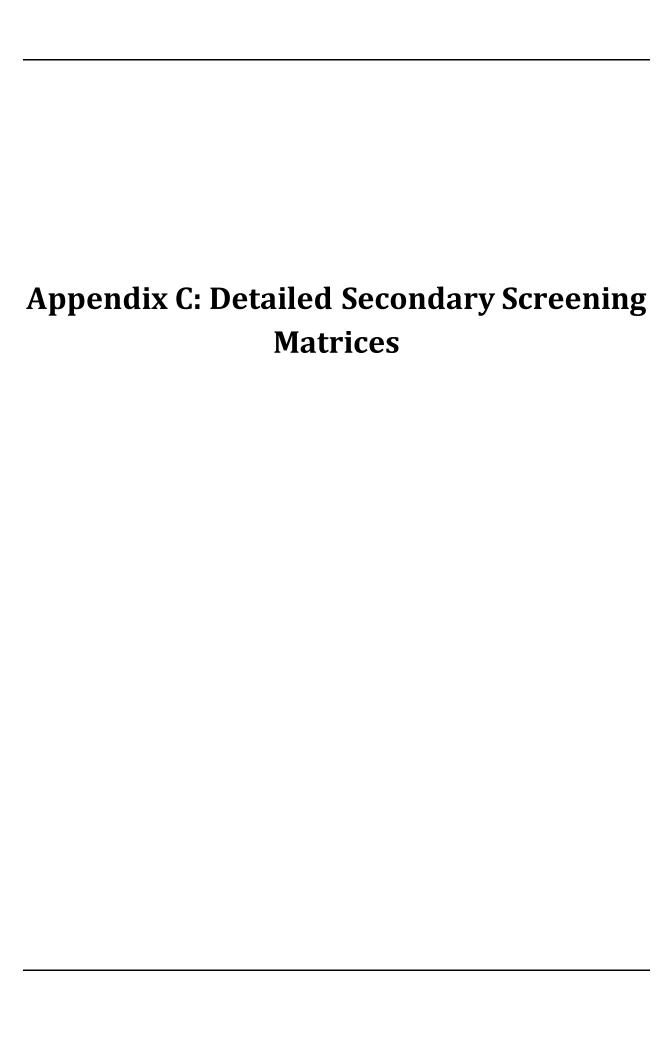
Alternative 1, the "No Build" Alternative, will advance with the Build Alternatives through the process.

UNIVERSE OF ALTERNATIVES - INITIAL SCREENING SEGMENT 2

						EVALUATION	ON CRITEI	RIA		
									00	
			_			eening of U	niverse of			
			(No)	Engin	eering	Traffic	Lon		nmental	roso
SEGMENT 3 Downtown Loop System	Alternative Type	Description	Meets Need and Purpose and Project Goals (Yes/No)	Meets Current Design Criteria (Yes/No)	Additional ROW - Cavalcade to Quitman (Yes/No)	Traffic/Mobility Improvements (High/Medium/Low)	Community Parks (Yes/No)	Cemeteries (Yes/No)	National Register Historic Places (Yes/No)	Recorded Archeological Sites (Yes/No)
Alternative 1	Existing Configuration	NO BUILD SCENARIO	N/A	No	N/A	N/A				
Alternative 2	TSM Upgrades	TRANSPORTATION SYSTEMS MANAGEMENT (TSM) PROJECTS	N/A	No	N/A	N/A				
Alternative 3	Convert Downtown Loop to One Way Loop	CONVERT EXISTING DOWNTOWN LOOP ROADWAY NETWORK TO A ONE-WAY LOOP.	Yes	Yes	N/A	Medium				
Alternative 4	Add Tunnel to Existing	TUNNELED ROADWAY UNDERNEATH LA BRANCH ST AND TERMINATES AT THE US 59/SH 288 INTERCHANGE. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	N/A	Medium				
Alternative 5	Add Tunnel to Existing	TUNNELED ROADWAY UNDERNEATH IH 45, THEN CONTINUES UNDERNEATH BAGBY ST AND TERMINATES AT SPUR 527. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	N/A	Medium				
Alternative 6	Add Tunnel to Existing	TUNNELED ROADWAY UNDERNEATH IH 45, THEN CONTINUES TO JEFFERSON ST AND TERMINATES AT IH 45 SOUTH OF THE IH 45/US 59 INTERCHANGE. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	N/A	Medium				
Alternative 7	Add Tunnel to Existing	TUNNELED ROADWAY UNDERNEATH HOUSTON AVE AND SPLITS TO JEFFERSON ST AND BAGBY ST. TUNNEL TERMINATES AT IH 45 SOUTH OF THE IH 45/US 59 INTERCHANGE AND SPUR 527. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	N/A	High				
Alternative 8	Elevated Managed Lanes	ELEVATED ROADWAY ALONG HOUSTON AVE AND TERMINATES AT IH 45 NEAR ALLEN PARKWAY. INCLUDES FOUR (4) MANAGED LANES.	Yes	Yes	N/A	Low				
Alternative 9	Add Tunnel to Existing	UTILIZES EXISTING IH 10 HOV BRIDGE INTO DOWNTOWN AND THEN BECOMES TUNNELED ROADWAY UNDERNEATH IH 45 AND JEFFERSON ST AND TERMINATES AT IH 45 SOUTH OF THE IH 45/US 59 INTERCHANGE. INCLUDES FOUR (4) MANAGED LANES	Yes	Yes	N/A	Low				
Alternative 10	Widen Existing	EIGHT (8) LANE SECTION FROM IH- 10 TO IH 45/US 59 INTERCHANGE INCLUDES EIGHT (8) GENERAL PURPOSE LANES.	Yes	Yes	N/A	Medium				

Selected as Preliminary Alternative

Alternative 1, the "No Build" Alternative, will advance with the Build Alternatives through the process.



Engineering Evaluation Criteria for Reasonable Alternatives

I-45 Corridor Segment 2 - I-610 to I-10

Engineering Evaluation Criteria: Constructability

	Alternative 3			Alternative 10	Alternative 10 Alternative 11		Alternative 12			Alternative 14	Alternative 15		
		Reversible Managed Lanes		Depressed Managed Lanes		Elevated Managed Lanes		Stacked Managed Lanes	Tunneled Managed Lanes		Elevated Managed Lanes to Hardy Toll Road		
	EBORWOTH JEEP	METORITOR MOTO	19 960 MIDNI- 19 10 OUTSGLAND 19 17 OUTSGLAND 19 17 OUTSGLAND	Let FORT TO R. MOST. A PRINT OF THE PRINT O	19 SON WORTH P	MY SERIES NOW AND	19 SCH WOTH ST.	AND COST NOT MOCH THE STATE OF	1 1	THE COST A DIF MODIN THE COST A DIF MODIN	10° SHLD	SOUTH AND THE PROPERTY OF TH	
Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	
Construction Duration	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years)	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years)	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years)	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years)	U	Only (1) TBM will be used for this project so no overlapping phases will be possible (typical construction duration 5-6 years). Will require reconstruction of I-45.	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years)	
Contractor Availability	D	Involves typical construction practices for the region. Specialty contractors will not be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	U	Does not involve typical construction practices for the region. Specialty contractors will be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	
Construction Risk	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	U	Non-conventional design poses larger risk than other alternatives. Risks include breakdown of TBM, unexpected subsurface conditions, potential damage to buildings, utilities, and unknown infrastructure along alignment due to settlement, Will require reconstruction of I-45.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	
Construction Staging/ Sequencing Complexity	N	Existing number of mainlanes can typically be maintained during construction. Widening to one side allows more to be built at one time and requires fewer traffic shifts. Construction limited to I-45.	N	Existing number of mainlanes can typically be maintained during construction. Widening to one side allows more to be built at one time and requires fewer traffic shifts. Construction limited to I-45.	N	Construction of elevated structure will require additional staging, Number of mainlanes will likely have to be reduced during construction. Construction limited to I-45.	N	Construction of elevated structure will require additional staging, Number of mainlanes will likely have to be reduced during construction. Construction limited to I-45.	U	Construction of tunnel structure will require a large staging area at the portals, This alternative will also require reconstruction of I-45 to bring corridor up to standard.	U	Construction of elevated structure will require additional staging, This alternative will also require construction along Hardy Toll Road, I-610 and reconstruction of I-45 to bring corridor up to standard.	
Permanent ROW Acquisition	N	Managed lanes will be constructed on the existing IH 45 ROW and frontage roads will be constructed as cantilevered structures over the mainlanes so additional ROW will be 9.0 acres.	N	Managed lanes will be constructed on the existing IH 45 ROW and frontage roads will be constructed above the mainlanes so additional ROW will be 9.0 acres.	N	Managed lanes will be constructed as elevated lanes above the existing IH 45 ROW, so additional ROW will be 9.0 acres.	N	Managed lanes will be constructed as elevated lanes above the existing IH 45 ROW, so additional ROW will be 9.1 acres.	N	Tunnel will be constructed underneath existing IH 45 so ROW impact will be 14.2 acres. This additional ROW is needed at portals and for ventilation area.	N	Managed lanes will be constructed as elevated lanes above the existing IH 610 ROW, so additional ROW will be 13.5 acres.	
Utility Relocations	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 72 major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 72 major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 72 major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 72 major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 69 major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require at least 53 major relocations including water, storm, sanitary, and overhead powerlines.	
Long Term Geotechnical Risk	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	N	Presence of fault line will require a special design and reinforcements due to depth of the tunnel. Tunnel will also be affected by the depth of the water table (long term maintenance issue)	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	
Constructability Rating	D	Shorter duration and less construction risk, traffic impact, and ROW impact than the other alternatives.	D	Shorter duration and less construction risk, traffic impact, and ROW impact than the other alternatives.	D	Shorter duration and less construction risk, traffic impact, and ROW impact than the other alternatives.	D	Shorter duration and less construction risk, traffic impact, and ROW impact than the other alternatives.	U	Longest duration due to complex staging, greater risks due to existing fault line than the other at grade alternatives.	N	Longer duration and greater traffic and ROW impacts than the other at grade alternatives.	
	D N U	4 2 1	D N U	4 2 1	D N U	4 2 1	D N U	4 2 1	D N U	0 2 5	D N U	4 1 2	

Engineering Evaluation Criteria for Reasonable Alternatives

I-45 Corridor Segment 2 - I-610 to I-10

Engineering Evaluation Criteria: Functionality Requirements

	Alternative 3		Alternative 10		Alternative 11		Alternative 12			Alternative 14	Alternative 15	
		Reversible Managed Lanes		Depressed Managed Lanes		Elevated Managed Lanes	Stacked Managed Lanes		Tunneled Managed Lanes		Elevated Managed Lanes to Hardy Toll Road	
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Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification
Design Life Expectancy	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	D	Design life for a tunnel is at least 100 years	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)
Design Criteria Limitations	U	Alternative designed per latest TxDOT design standards, however, this alternative is not compatible with any Segment 1 or Segment 3 alternatives.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.	U	Alternative designed per latest FHWA design standards. Design will include limited shoulder widths (2') and limited vertical clearance (14'-6") as these are controlled by the diameter of the tunnel. Tunnels must include additional design features that are not required for nontunnel options.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.
Opportunity for Future Expansion	U	Facility cannot be expanded within existing ROW footprint. Future expansion of facility will require additional ROW.	U	Facility cannot be expanded within existing ROW footprint. Future expansion of facility will require additional ROW.	U	Facility cannot be expanded within existing ROW footprint and would require major reconstruction of cantilevered frontage roads. Future expansion of facility will require additional ROW.	U	Facility cannot be expanded within existing ROW footprint. Future expansion of facility will require additional ROW.	N	Tunnel cannot be expanded, however, I- 45 can be reconstructed to provide additional managed lane capacity. Will not require additional ROW.	N	I-610 and Hardy Toll Road facilities cannot be expanded, however, I-45 can be reconstructed to provide additional managed lane capacity.
Incident Management (Design Factors)	N	Freeway and managed lanes are at grade and do not require special facilities for incident management. Twelve foot shoulders are provided for emergency use.	N	Freeway and managed lanes are at grade and do not require special facilities for incident management. Twelve foot shoulders are provided for emergency use.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives. The lower level will be more challenging and requires additional response time and effort.	U	Tunnel will be enclosed, and have only one entrance and exit. Depending on the nature of the incident, there will be challenges to deal with when incidents involve fire, injuries, or vehicular breakdown. Tunnel alternative will require an addition of a breakdown lane to serve as a emergency staging area.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.
Functionality Requirements Rating	U	Alternative is not compatible with any Segment 1 or Segment 3 alternatives.	N	Alternative meets functionality requirements, however, facility cannot be expanded within existing ROW footprint.	N	Alternative meets functionality requirements, however, facility cannot be expanded within existing ROW footprint.	N	Alternative meets functionality requirements, however, facility cannot be expanded within existing ROW footprint.	U	Tunnel has limited shoulder widths and challenging incident management issues than the other at grade alternatives.	N	Alternative meets functionality requirements and can provide additional managed lane capacity on I-45 within existing ROW footprint.
	D N U	0 2 2	D N U	1 2 1	D N U	1 2 1	D N U	1 2 1	D N U	1 1 2	D N U	1 3 0

Roadway Design Speed: 60 mph Tunnel Design Speed: 45 mph

Engineering Evaluation Criteria for Reasonable Alternatives

I-45 Corridor Segment 2 - I-610 to I-10

Engineering Evaluation Criteria: Operations and Maintenance

	Alternative 3		Alternative 10		Alternative 11		Alternative 12			Alternative 14	Alternative 15	
		Reversible Managed Lanes		Depressed Managed Lanes		Elevated Managed Lanes	Stacked Managed Lanes		Tunneled Managed Lanes		Elevated Managed Lanes to Hardy Toll Road	
	PERCHANDIN MODIN FROM WORTH PERCHANDIN MODIN FROM WORTH PERCHANDIN FROM WORTH PERCHANDIN		THE SERVICE AND MODIFIES AND MO		19 SOL MODITION - MODI		SHE DOMESON, MODIN		246 EXRET R.O.W. WODTH STORM THE ST		aur coccum	MOTI AGE MOTI AGES OF MAN A THE STATE OF THE
Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification
Traffic and Systems Control	U	The directional managed lanes require additional control to accommodate traffic patterns. Also, this alternative is not compatible with any Segment 1 or Segment 3 alternatives.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.	U	Tunnel section would require additional traffic and system control monitoring at portals and throughout tunnel. Tunnels would be new to the region and driver expectancy could cause additional traffic issues.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.
Incident Management (Operations)	N	Facility is mostly at grade with wide shoulders to facilitate incident management.	N	Facility is mostly at grade with wide shoulders to facilitate incident management.	N	Managed lanes are elevated and include full width shoulders, but are less accessible than the at grade alternatives	N	Managed lanes are elevated and include full width shoulders, but are less accessible than the at grade alternatives	U	Tunnel section will have a narrow shoulder (2') so at least one lane will be blocked for each incident that occurs; Incidents will require specialty emergency personnel, training and equipment to clear the incident.	N	Managed lanes are elevated and include full width shoulders, but are less accessible than the at grade alternatives
Maintenance Requirements	D	No special maintenance requirements.	D	No special maintenance requirements.	D	No special maintenance requirements.	D	No special maintenance requirements.	U	TxDOT is not familiar with tunnel maintenance procedures and may have to outsource this work. Maintenance of the tunnel will likely require special equipment and higher level of training for maintenance staff.	D	No special maintenance requirements.
Incident Recovery (Recovery Time)	D	Typical incident recovery time.	N	Depressed structure may increase recovery time due to access where beams are installed over the roadway. Life flight access would be limited.	D	Typical incident recovery time.	N	Double decked structures may increase recovery time due to access on lower level. Life flight access would be limited.	U	Tunnel section will require much more recovery time due to ventilation of smoke and toxic gases (in case of a fire), removal of debris, limited shoulder width, etc.	D	Typical incident recovery time.
Operations and Maintenance Rating	N	Normal maintenance and incident response expected, however, alternative is not compatible with any Segment 1 or Segment 3 alternatives.	N	Normal operations and maintenance. Requires additional recovery time within depressed section.	D	Normal operations, maintenance, and incident response expected.	N	Normal operations and maintenance. Requires additional recovery time within the lower level of the structure.	U	Tunnel is expected to have operations, maintenance and incident response issues when compared to the at grade alternatives.	D	Normal operations, maintenance, and incident response expected.
	D N U	2 1 1	D N U	2 2 0	D N U	3 1 0	D N U	2 2 0	D N U	0 0 4	D N U	3 1 0

Roadway Design Speed: 60 mph Tunnel Design Speed: 45 mph

I-45 Corridor Segment 2 - I-610 to I-10

Summary of Ratings for Segment 2 Alternatives

	Alternative 3	Alternative 10	Alternative 11	Alternative 12	Alternative 14	Alternative 15
	Reversible Managed Lanes	Depressed Managed Lanes	Elevated Managed Lanes	Stacked Managed Lanes	Tunneled Managed Lanes	Elevated Managed Lanes to Hardy Toll Road
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Criteria	Rating	Rating	Rating	Rating	Rating	Rating
Constructability	D	D	D	D	U	N
Functionality	U	N	N	N	U	N
Operations and Maintenance	N	N	D	N	U	D

Roadway Design Speed: 60 mph Tunnel Design Speed: 45 mph

9/24/2013

I-45 Corridor Segment 3 - I-10 to US-59

Engineering Evaluation Criteria: Constructability

		Alternative 3		Alternative 5		Alternative 6		Alternative 10		Alternative 11		Alternative 12
		One-Way Downtown Loop	Tunnel	ed Managed Lanes (North of Downtown)	Tunnelo	ed Managed Lanes (South of Downtown)		I-45 Pierce Widening		I-45 East Shift		I-45 Split
		4,00					<u> </u>					
Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification
Construction Duration	N	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years). This project will likely have a longer than 3 year construction period due to the amount of reconstruction required around the downtown loop.	U	Only (1) TBM will be used for this project so no overlapping phases will be possible (typical construction duration of 5-6 years). Approx. 25% of the tunnel will be Cut & Cover type which requires additional construction time and is more labor intensive. Also requires reconstruction of I-45.	U	Only (1) TBM will be used for this project so no overlapping phases will be possible (typical construction duration 5-6 years). Also requires reconstruction of I-45 and portion of US59.	N	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years). This project will likely have a longer than 3 year construction period due to the amount of reconstruction required around the western portion of the downtown loop.	N	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years). This project will likely have a longer than 3 year construction period due to the amount of reconstruction required along IH10 between IH45 and US59.	D	Project can be broken into multiple phases and phases can be built concurrently by multiple contractors (typical construction duration is 3 years).
Contractor Availability	D	Involves typical construction practices for the region. Specialty contractors will not be required.	U	Does not involve typical construction practices for the region. Specialty contractors will be required.	U	Does not involve typical construction practices for the region. Specialty contractors will be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.	D	Involves typical construction practices for the region. Specialty contractors will not be required.
Construction Risk	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	U	Non-conventional design poses larger risk than other alternatives. Risks include breakdown of TBM, unexpected subsurface conditions, potential damage to buildings, utilities, and unknown infrastructure along alignment due to settlement.	U	Non-conventional design poses larger risk than other alternatives. Risks include breakdown of TBM, unexpected subsurface conditions, potential damage to buildings, utilities, and unknown infrastructure along alignment due to settlement.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.	D	Conventional design poses less risk than other alternatives. ROW acquisition and Utility Relocations are biggest risk factors.
Construction Staging/ Sequencing Complexity	U	Sequencing of traffic control during construction will be challenging due to major reconstruction required for the majority of the project. Temp bridges and roadways may be required to maintain existing traffic flow through the work area to allow access in and out of downtown.	U	Construction of the tunnel will be able to occur with minimal disruption to existing traffic flow. Approaches to the portals will be the only areas where sequencing will likely be required. This alternative requires approx. 25% of the tunnel to be Cut & Cover type which requires additional construction staging area. Also requires reconstruction of I-45.	U	Construction of the tunnel will be able to occur with minimal disruption to existing traffic flow. Approaches to the portals will be the only areas where sequencing will likely be required. This alternative will require reconstruction of I-45 and a portion of US 59 mainlanes and DC's due to proximity of tunnel portal near the I-45 tie in on the south end of the project.	U	Sequencing of traffic control during construction will be challenging due to major reconstruction required for the majority of the project. IH10/IH45 interchange staging will be complex and may require temp bridges and roadways to maintain existing traffic flow through the work area.	U	Sequencing of traffic control during construction will be challenging due to major reconstruction required for the majority of the project. Construction of I-45 lanes along US59 and I-10 will introduce many access challenges for local traffic due to staging areas for new foundations and bents.	U	Sequencing of traffic control during construction will be challenging due to major reconstruction required for the majority of the project. Construction of I-45 lanes along US59 and I-10 will introduce some access challenges for local traffic due to staging areas for new foundations and bents.
Permanent ROW Acquisition	N	Managed lanes and freeway expansion will be constructed mostly above the existing IH 45 ROW, but will require additional ROW of approx. 17.2 acres.	U	Tunnel will be constructed underneath existing IH 45 so ROW impact will be 41.5 acres. This additional ROW is needed at portals and for ventilation area.	N	Tunnel will be constructed underneath existing IH 45 so ROW impact will be 2.8 acres. This additional ROW is needed at portals and for ventilation area.	U	Managed lanes and freeway expansion will be constructed mostly above the existing IH 45 ROW, but will require additional ROW of approx. 36.1 acres.	U	Managed lanes, freeway expansion and new parkway will be constructed mostly above the existing IH 45 ROW, but will require additional ROW of approx. 37.4 acres.	N	Managed lanes and freeway expansion will be constructed mostly above the existing IH 45 ROW, but will require additional ROW of approx. 11.7 acres.
Utility Relocations	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.	U	Utility relocations will be required for the entire project area. Based on Houston GIMS and Google Maps, this alternative will require several major relocations including water, storm, sanitary, and overhead powerlines.
Long Term Geotechnical Risk	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	N	Tunnel will be affected by the depth of the water table (long term maintenance issue).	N	Tunnel will be affected by the depth of the water table (long term maintenance issue). Settlement issues may be encountered when tunneling under Jefferson.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.	D	TxDOT is familiar with impact of fault lines on above grade projects and how to address any issues that arise due to movement.
Constructability Rating	N	Longer duration and greater traffic and ROW impacts than the other at grade alternatives.	U	Longest duration due to complex staging, reconstruction of I-45 and risks due to tunneling near existing bayou.	U	Longest duration due to complex staging, greater risks due to potential settlement issues that may be encountered when tunneling under Jefferson.	N	Longer duration and greater traffic and ROW impacts than the other at grade alternatives.	N	Longer duration and greater traffic and ROW impacts than the other at grade alternatives.	D	Shorter duration and less construction risk, traffic impact, and ROW impact than the other alternatives.
	D N U	2	D N U	0 1 6	D N U	0 2 5	D N U	3 1 3	D N U	3 1 3	D N U	4 1 2

I-45 Corridor Segment 3 - I-10 to US-59

Engineering Evaluation Criteria: Functionality Requirements

		Alternative 3		Alternative 5		Alternative 6		Alternative 10		Alternative 11		Alternative 12
		One-Way Downtown Loop	Tunnele	d Managed Lanes (North of Downtown)	Tunnele	ed Managed Lanes (South of Downtown)		I-45 Pierce Widening		I-45 East Shift		I-45 Split
Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification
Design Life Expectancy	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	D	Design life for a tunnel is at least 100 years	D	Design life for a tunnel is at least 100 years	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)	N	Design life will be similar to recently completed projects (30 years for roadways and 75 years for bridges)
Design Criteria Limitations	U	Alternative contains issues related to signing and weaving due to limited distances between access points and interchanges. Driver expectancy issues are also expected.	U	Alternative designed per latest FHWA design standards. Design will include limited shoulder widths (2') and limited vertical clearance (14'-6") as these are controlled by the diameter of the tunnel. Tunnels must include additional design features that are not required for nontunnel options.	U	Alternative designed per latest FHWA design standards. Design will include limited shoulder widths (2') and limited vertical clearance (14'-6") as these are controlled by the diameter of the tunnel. Tunnels must include additional design features that are not required for nontunnel options.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.	D	Alternative designed per latest TxDOT design standards. Design similar to recently completed projects.
Opportunity for Future Expansion	U	Future expansion is not possible on this alternative due to the lanes being one directional. DC's are designed as 2 lane connectors and cannot expand further without constructing a new structure.	D	Tunnel cannot be expanded, however, I- 45, I-10 and US59 can be reconstructed to provide additional lane capacity. Will not require additional ROW. Portal is located in area away from existing traffic.	N	Tunnel cannot be expanded, however, I- 45, I-10 and US59 can be reconstructed to provide additional lane capacity. Will not require additional ROW.	U	Facility cannot be expanded within existing ROW footprint. Future expansion of facility will require additional ROW.	N	Future expansion is possible utilizing the existing I-45 ROW on the west side of Downtown.	N	Future expansion is possible utilizing the existing I-45 ROW on the west side of Downtown.
Incident Management (Design Factors)	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.	U	Tunnel will be enclosed, and have only one entrance and exit. Depending on the nature of the incident, there will be challenges to deal with when incidents involve fire, injuries, or vehicular breakdown.	U	Tunnel will be enclosed, and have only one entrance and exit. Depending on the nature of the incident, there will be challenges to deal with when incidents involve fire, injuries, or vehicular breakdown.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.	N	Freeway lanes are at grade and do not require additional facilities for incident management. Elevated managed lanes are less accessible than the at grade alternatives.
Functionality Requirements Rating	U	Alternative does not meet functionality requirements and contains signing, weaving and driver expectancy issues along the corridor.	N	Tunnel has limited shoulder widths and challenging incident management issues. Portal would have minimal impacts to existing traffic than the other tunnel alternative.	U	Tunnel has limited shoulder widths and challenging incident management issues than the other at grade alternatives.	N	Alternative meets functionality requirements, however, facility cannot be expanded within existing ROW footprint.	N	Alternative meets functionality requirements and can provide additional managed lane capacity on I-45 within existing ROW footprint.	N	Alternative meets functionality requirements and can provide additional managed lane capacity on I-45 within existing ROW footprint.
	D	0	D	2	D	1	D	1	D	1	D	1
		2	N	0	N	1	N	2	N	3		3
	U	2	Ü	2	Ü	2	Ü	1	Ü	0	U	0
v 1	U D N U	requirements and contains signing, weaving and driver expectancy issues	D N U	Portal would have minimal impacts to existing traffic than the other tunnel alternative.	U D N U	challenging incident management issues than the other at grade alternatives. 1	N D N U	requirements, however, facility cannot be	D N U	requirements and can provide additional managed lane capacity on I-45 within	D N U	requirements and can provide managed lane capacity on I-4:

Roadway Design Speed: 50 mph Tunnel Design Speed: 45 mph

I-45 Corridor Segment 3 - I-10 to US-59

Engineering Evaluation Criteria: Operations and Maintenance

		Alternative 3		Alternative 5		Alternative 6		Alternative 10		Alternative 11		Alternative 12
		One-Way Downtown Loop	Tunne	led Managed Lanes (North of Downtown)	Tunnele	ed Managed Lanes (South of Downtown)		I-45 Pierce Widening		I-45 East Shift		I-45 Split
Sub-Criteria	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification	Rating	Justification
Traffic and Systems Control	U	Alternative contains issues related to signing and weaving due to limited distances between access points and interchanges. Driver expectancy issues are also expected. Different traffic and systems control required beyond what is typical for the region.	U	Tunnel section would require additional traffic and system control monitoring at portals and throughout tunnel.	U	Tunnel section would require additional traffic and system control monitoring at portals and throughout tunnel.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.	D	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region.	N	Managed lanes provided for both directions. No traffic and systems control required beyond what is typical for the region. Guide sign design would be more complex than the other alternatives.
Incident Management (Operations)	N	Facility has wide shoulders to facilitate incident management.	U	Tunnel section will have a narrow shoulder (2') so at least one lane will be blocked for each incident that occurs; Incidents will require specialty emergency personnel / equipment to clear and will take longer time to clear.	U	Tunnel section will have a narrow shoulder (2') so at least one lane will be blocked for each incident that occurs; Incidents will require specialty emergency personnel / equipment to clear and will take longer time to clear.	N	Facility is mostly at grade with wide shoulders to facilitate incident management.	N	Managed lanes are elevated and include full width shoulders, but are less accessible than the at grade alternatives	N	Managed lanes are elevated and include full width shoulders, but are less accessible than the at grade alternatives
Maintenance Requirements	D	No special maintenance requirements.	U	TxDOT is not familiar with tunnel maintenance procedures and may have to outsource this work. Maintenance of the tunnel will likely require special equipment and higher level of training for maintenance staff.	U	TxDOT is not familiar with tunnel maintenance procedures and may have to outsource this work. Maintenance of the tunnel will likely require special equipment and higher level of training for maintenance staff.	D	No special maintenance requirements.	D	No special maintenance requirements.	D	No special maintenance requirements.
Incident Recovery (Recovery Time)	N	Typical incident recovery time.	U	Tunnel section will require much more recovery time due to ventilation of smoke and toxic gases, removal of debris, limited shoulder width, etc.	U	Tunnel section will require much more recovery time due to ventilation of smoke and toxic gases, removal of debris, limited shoulder width, etc.	N	Typical incident recovery time.	N	Typical incident recovery time.	N	Typical incident recovery time.
Operations and Maintenance Rating	N	Normal maintenance and incident response expected, however, alternative will have traffic and systems control issues related to signing, weaving and driver expectancy.	U	Tunnel is expected to have operations, maintenance and incident response issues when compared to the at grade alternatives.	U	Tunnel is expected to have operations, maintenance and incident response issues when compared to the at grade alternatives.	N	Normal operations, maintenance, and incident response expected.	N	Normal operations, maintenance, and incident response expected.	N	Normal operations, maintenance, and incident response expected.
	D N	1 2	D N	0 0	D N	0 0	D N	2 2	D N	2 2	D N	1 3
	U	1	Ú	4	U	4	U	0	U	0	U	0

Roadway Design Speed: 50 mph Tunnel Design Speed: 45 mph

I-45 Corridor Segment 3 - I-10 to US-59

Summary of Ratings for Segment 3 Alternatives

	Alternative 3	Alternative 5	Alternative 6	Alternative 10	Alternative 11	Alternative 12
	One-Way Downtown Loop	Tunneled Managed Lanes (North of Downtown)	Tunneled Managed Lanes (South of Downtown)	I-45 Pierce Widening	I-45 East Shift	I-45 Split
Sub-Criteria	Rating	Rating	Rating	Rating	Rating	Rating
Constructability	N	U	U	N	N	D
Functionality Requirements	U	N	U	N	N	N
Operations and Maintenance	N	U	U	N	N	N

Roadway Design Speed: 50 mph Tunnel Design Speed: 45 mph

9/24/2013

Appendix D: Preliminary Alternatives Traffic Screening Methodology and Results

NHHIP Preliminary Alternatives

Traffic Screening Methodology and Results Memo

Introduction:

This memo documents the impacts that the preliminary alternatives are projected to have on the future traffic and mobility conditions along the IH-45, Hardy Toll Road and Downtown Houston loop study corridors.

Methodology:

The traffic demand along the three corridors is evaluated based upon the Houston Galveston Area Council (HGAC)'s regional travel demand model. The network considers the existing highway system and committed and programmed transportation improvements included in the 2035 Regional Transportation Plan. The no-build scenario is run for the year 2035 to determine the impact of these future projects and projected growth in the region. The model is then modified to include the preliminary alternatives, and the model runs are compared to the 2035 no-build scenario; thus transportation deficiencies along the study corridors are able to be identified.

There are 17 preliminary alternatives presented in this analysis: 6 for Segment 1, defined as the I-45 corridor segment between BW-8 to I-610, 5 for Segment 2, on I-45 between I-610 and I-10, and 6 for Segment 3, which is the Downtown Houston Loop, including portions of US-59, I-10 and I-45.

Each of the three segments has a number of alternatives; however, only certain alternatives on each segment are compatible with others. For travel demand modeling purposes, many of the alternatives are considered identical. For example, in Segment 1, the alternatives 4, 5, and 6 all involve adding 4 lanes, either through acquiring right of way on the west, east or combination of both sides. Alternatives 7 and 8 involve adding these lanes on an elevated structure. However, regardless of the alignment, these 5 alternatives are modeled identically. Similarly, in Segment 2, Alternatives 10, 11, and 12 are identical from a modeling perspective.

For Segment 1, specific segments include the managed lanes along I-45, BW-8, and Hardy Toll Road (depending upon the scenario) as well as the General Purpose Lanes along I-45. Along Segment 2, the specific segments of concern include the managed lanes along I-45, I-610, BW-8 and/or the Hardy Toll Road, and the General Purpose Lanes along I-45. For Segment 3, the specific segments looked at were the downtown street network, I-45, and the downtown freeway loop system, including I-10 and US-59.

Based on compatibility between the various alternatives in each segment, the 17 alternatives across all three segments can be condensed into 9 alternatives for modeling purposes. The engineering alternatives grouped for modeling purposes are presented in Table 1 below. The HGAC's regional travel demand model is run 10 times for this analysis: one for each of the following model alternatives and one no build alternative. The results are used to analyze the traffic and mobility impacts of the preliminary alternatives.

Model	Engi	neering Alterna	tives
Alternatives	Segment 1	Segment 2	Segment 3
No Build	1	-	-
A	3	15	3
В	3	15	12
С	4,5,6,7,8	10,11,12	3
D	4,5,6,7,8	10,11,12	10
Е	4,5,6,7,8	10,11,12	11
F	4,5,6,7,8	10,11,12	12
G	4,5,6,7,8	14	5
Н	4,5,6,7,8	14	6
J	4,5,6,7,8	15	No Build

Table 1: Model vs. Engineering Alternatives

Evaluation criteria

The four primary criteria for evaluation of traffic and mobility impacts are traffic utilization in managed lanes, travel demand reduction, reduction in vehicle hours traveled, and reduction in volume-to-capacity ratio. The criteria vary slightly amongst the three segments, due to the nature of the alternatives and the configuration of the roadways in each segment. The 9 modeling alternatives in each segment are assigned a rating of 1, 2, or 3 based on the relative improvement as compared to the no-build and the range of improvements amongst the alternatives. A ranking of 1 corresponds to undesirable (U), a ranking of 2 corresponds to neutral (N) and a 3 corresponds to desirable (D). The following section will discuss the definition of each criterion, and how each alternative fares in each segment based upon these criteria.

These quantified rankings of 1, 2, and 3 were averaged into an overall ranking for each engineering alternative in each segment. The overall rankings of Undesirable (U), Neutral (N), and Desirable (D) will be presented in the "Overall rankings" section at the end of this document.

Traffic Utilization in Managed Lanes:

Each of the preliminary alternatives requires investment in the current infrastructure in the form of additional capacity. A good investment should provide a return on that investment. Capacity utilization provides a measure of the return on the investment required of each alternative. If the added capacity is underutilized, then capacity exceeds demand. If the added capacity is overutilized, then demand exceeds capacity. Optimal utilization is achieved by balancing capacity and demand.

Utilization on the managed lanes is calculated by assuming 1,800 vehicles per lane per hour as the maximum peak hour capacity. The peak hour factor is assumed to be 10 percent, and there are 4 managed lanes added in each alternative. Thus, the maximum daily capacity for 4 managed lanes is 72,000. The utilization percentages are based upon this figure.

For this analysis, optimal lane utilization is considered to be anything that is less than 100 or 110 percent and would merit a ranking of 3 (desirable). Utilization between 30 and 70 percent is given a 2 (neutral). Utilization of 30 percent or less is considered to be the least ideal, and would thus lead

to a ranking of 1 (undesirable). There are alternatives that consider Managed Lanes on both Segments 1 and 2.

Segment 1:

For Segment 1, Alternatives A and B, which correspond to Engineering Alternative 3, contain managed lanes along Beltway-8, not along I-45 like Modeling Alternatives A-J (Engineering Alternatives 4,5,6,7,8). These managed lanes are underutilized, with average daily traffic volumes of about 16,000-22,000. This is a utilization of less than 30 percent. Both of these score a 1, meaning they are undesirable. The managed lanes along I-45 are extremely well utilized, almost to capacity. All of these score a 3, which is desirable. Adding the additional lanes on I-45 has more of an impact on managed lane utilization than adding the lanes along Beltway 8. The alternatives, ADT, percent utilization and ranking are shown in Table 2 below.

	Table 2: Segment	1	Managed	Lane	Utilization
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Alter	natives	Managed Lanes				
Traffic	Engineering	ADT	Ranking			
No Build						
A	3	15,900	22%	1		
В	3	21,900	30%	1		
С	4,5,6,7,8	71,400	99%	3		
D	4,5,6,7,8	69,800	97%	3		
Е	4,5,6,7,8	71,100	99%	3		
F	4,5,6,7,8	71,400	99%	3		
G	4,5,6,7,8	72,200	100%	3		
Н	4,5,6,7,8	65,000	90%	3		
J	4,5,6,7,8	69,900	97%	3		

^{*}Traffic Alternatives A and B include ML along BW-8, not I-45

Segment 2:

In Segment 2, Traffic Alternatives C, D, E and F all score the highest and earn a 3 (desirable), with utilization of the managed lanes at over 70 percent. These alternatives correspond to Engineering Alternatives 10, 11, and 12, which include 8 general purpose lanes and 4 managed lanes. Traffic Alternative G's utilization percentage is also quite high and merits a ranking of 3 (desirable). Traffic Alternative H is also Engineering Alternative 14, as G is, but the difference in the configuration of the tunnel in Segment 3 affects the utilization of the managed lanes. Thus, they have different rankings. Traffic Alternatives A and B, which correspond to Engineering Alternative 15, lead to poor utilization of the managed lanes and earn a ranking of 1 (undesirable). Traffic Alternative J, which is also Engineering Alternative 15, has a 55 percent utilization of the managed lanes along Beltway-8 and receives a ranking of 2 (neutral). However, Traffic Alternative J involves a no-build alternative for the downtown loop segment and the configuration in Segment 1 adds 4 managed lanes, on I-45. Thus, utilization of the managed lanes for Engineering Alternative 15 in Segment 2

depends greatly on the configuration in the other 2 segments. See Table 2 below for the full matrix of ADT, utilization and rankings.

Table 3: Segment 2 Managed Lane Utilization

Alter	natives	Managed Lanes					
Traffic	Engineering	ADT	Utilization	Ranking			
No Build							
A	15	1,600	2%	1			
В	15	11,100	15%	1			
С	10,11,12	61,100	85%	3			
D	10,11,12	52,600	73%	3			
Е	10,11,12	60,800	84%	3			
F	10,11,12	56,500	78%	3			
G	14	78,400	109%	3			
Н	14	46,900	65%	2			
J	15	39,400	55%	2			

Travel Demand:

The evaluation criteria for Segments 1 and 2 also consider the reduction in the number of vehicles from the general purpose lanes of I-45. A reduction in vehicles on these lanes means that traffic is being diverted to managed lanes or along other routes, alleviating congestion and travel demand on I-45.

The traffic reduction for the preliminary alternatives is compared to the no-build scenarios; the thresholds are developed accordingly. Any alternative which increases traffic volumes as compared to the no-build receives a rating of 1 (undesirable). The alternatives which reduce the traffic by 12,000 vehicles daily or less receive a ranking of 2 (neutral). For Segment 1, those alternatives which reduce traffic by 12,000 to 23,000 receive a rating of 3 (desirable). For Segment 3, the upper threshold of the desirable rating is 33,000.

Segment 1:

Without any change in the configuration of the roads, the no build scenario shows that the ADT on the I-45 general purpose lanes would be 332,000 in 2035. Engineering Alternative 3, which corresponds to Traffic alternatives A and B, reduces traffic considerably less than the other alternatives, with a decrease of between 2,300 and 3,200 vehicles a day. It receives a ranking of 2 (neutral). The reductions in daily traffic for Engineering Alternatives 4, 5, 6, 7 and 8 are much greater, ranging between 16,300 and 22,400, depending on the configurations of the alternatives in Segments 2 and 3. Thus, Traffic Alternatives C, D, E, F, G, H and J receive a 3 (desirable) rating for this segment. The additional lanes on I-45 directly are more effective in reducing travel demand than the direct connector to Hardy Toll Road and additional lane there. The full rankings for the alternatives are presented in Table 4 below

Table 4: Segment 1 Travel Demand Volumes

Alter	natives	I-45 General Purpose Lanes					
Traffic	Engineering	ADT	Ranking				
No	Build	332,000					
A	3	328,800	-3,200	2			
В	3	329,700	-2,300	2			
С	4,5,6,7,8	312,500	-19,500	3			
D	4,5,6,7,8	315,700	-16,300	3			
Е	4,5,6,7,8	310,200	-21,800	3			
F	4,5,6,7,8	314,000	-18,000	3			
G	4,5,6,7,8	309,600	-22,400	3			
Н	4,5,6,7,8	314,400	-17,600	3			
J	4,5,6,7,8	311,900	-20,100	3			

Segment 2:

In the no build scenario, 248,700 vehicles would travel this segment of I-45 daily in 2035. Traffic Alternative A shows an increase in the ADT, with close to 258,000 vehicles. Thus, it is undesirable and gets a ranking of 1. Other alternatives in this segment have modest decreases of about 5,000 to 10,000. These receive a rating of 2 (neutral). Traffic Alternatives E, F, and G show the greatest decrease in traffic volumes and earn ratings of 3 (desirable). These correspond to Engineering Alternatives 10,11, and 12 (E and F) and 14 (G). Table 5 below shows the ADT, difference from the no build, and the rankings for Segment 2.

Table 5: Segment 2 Travel Demand Volumes

Alteri	natives	I-45 (I-45 General Purpose Lanes					
Traffic	Engineering	ADT	Difference	Ranking				
No 1	No Build							
A	15	257,900	9,200	1				
В	15	239,000	-9,700	2				
С	10,11,12	243,100	-5,600	2				
D	10,11,12	239,800	-8,900	2				
Е	10,11,12	216,100	-32,600	3				
F	10,11,12	234,300	-14,400	3				

G	14	215,800	-32,900	3
Н	14	238,300	-10,400	2
J	15	239,600	-9,100	2

Vehicle Hours Traveled:

Total daily vehicle hours of travel (VHT) is a function of traffic volume, travel speed and travel distance. This measure is representative of the total amount of travel time for each alternative and the amount of time motorists spend traveling in their vehicles. The fewer the miles traveled and the less time spent getting to a destination is preferred.

For Segment 1, the analysis focuses on the VHT on I-45's general purpose lanes. System-wide VHT on the highways is also considered to see if the alternative is causing congestion on the other roadways. In Segments 1 and 2, I-45, Hardy Toll Road, and Beltway-8 are all considered. In Segment 3, the system is defined differently: VHT is considered on I-45, as well as the other highways in the downtown loop system, which are I-10 and US-59. The VHT on the downtown street system is important to consider: as some of the alternatives convert the loop system to a parkway, there is a possibility that the traffic would divert to the downtown streets, causing congestion and mobility issues there. Therefore, the analysis considers the downtown street system as well.

The thresholds and rankings are relative to each segment and roadway, based upon the VHT in the no-build scenario.

Segments 1 and 2:

In Segment 1, any alternatives that increase the VHT from the no build scenario scores a 1 (undesirable), for both the general purpose lanes on I-45 and across the entire system. The threshold for a ranking of 2 (neutral) is a decrease of 1,000 hours on the I-45 general purpose lanes, and 1,300 hours for the system. Any alternative with a decrease of 1,000 and 2,100 hours on I-45 is considered desirable for the system-wide VHT the threshold is 1,300 to 2,600.

In Segment 1, Engineering Alternative 3 (Traffic Alternatives A and B) shows the least impact to VHT on the I-45 general purpose lanes and system-wide. The reduction is small, under 2,000 VHT. Traffic Alternatives C through J fare better and show greater VHT reductions. In Segment 2, Engineering Alternatives 10/11/12 and 14 all average out to being desirable in both VHT categories, but Engineering Alternative 15 shows an increase in VHT on I-45 and system wide in one scenario and thus averages out to be neutral.

Table 6: Segment 1 VHT

Alter	natives	I-45 - Gei	neral Purpos	e Lanes	I-45, Hardy & BW-8 VHT		
Traffic	Engineerin g	VHT	Difference	Ranking	Ranking VHT		Ranking
No	Build	77,600			103,500		
A	3	75,700	-1,900	2	101,700	-1,800	2
В	3	76,200	-1,400	2	102,900	-600	2
С	4,5,6,7,8	67,400	-10,200	3	93,800	-9,700	3
D	4,5,6,7,8	69,200	-8,400	3	95,000	-8,500	3
Е	4,5,6,7,8	66,300	-11,300	3	92,800	-10,700	3
F	4,5,6,7,8	68,200	-9,400	3	94,800	-8,700	3
G	4,5,6,7,8	65,900	-11,700	3	92,900	-10,600	3
Н	4,5,6,7,8	68,600	-9,000	3	94,400	-9,100	3
J	4,5,6,7,8	67,500	-10,100	3	93,500	-10,000	3

Table 7: Segment 2 VHT

Alter	natives	I-45 - Ge	neral Purpos	e Lanes	nes I-45, Hardy, & BW-8 VHT		
Traffic	Engineering	VHT	Difference	Ranking	Ranking VHT		Ranking
No Build		11,700			23,800		
A	15	12,400	700	1	22,500	-1,300	3
В	15	11,000	-700	2	23,000	-800	2
С	10,11,12	11,400	-300	2	21,500	-2,300	3
D	10,11,12	11,100	-600	2	22,700	-1,100	2
Е	10,11,12	9,700	-2,000	3	21,200	-2,600	3
F	10,11,12	10,700	-1,000	3	22,700	-1,100	2
G	14	9,600	-2,100	3	22,100	-1,700	3
Н	14	11,000	-700	2	23,000	-800	2
J	15	11,100	-600	2	24,800	1,000	1

Segment 3:

The evaluation of VHT on Segment 3 is based on three sections: the I-45 general purpose lanes, the downtown loop system (including I-10 and US-59), and the downtown streets that are surrounded by I-10, I-45 and US-59. The thresholds are based upon the change from the 2035 no-build scenario. In Segment 3, the criteria for VHT reduction is the same across all three segments. Any alternative that reduces VHT by 1,000 or less receives a 1 (undesirable), an increase of 1,000 to a reduction of 1,000 receives a 2 (neutral) and those that lead to a reduction of greater than 1,000 VHT receive a ranking of 3 (desirable).

The actual VHT numbers are shown in Table 8 below, and the corresponding rankings are shown in Table 9 below. For the downtown street system, Engineering Alternatives 3 and 11 are the least desirable; the conversion of the freeway system to a one way loop or into a parkway results in more users opting to use the downtown streets for travel. VHT increases by over 3,000 for both of these alternatives in the downtown street system. The traffic alternatives with the one way loop and parkway option reduce VHT from the downtown loop highway system greatly, because this traffic diverts itself to the street system.

The one way loop system (Traffic Alternatives A and C) increases VHT on I-45 as well. Traffic Alternatives G and H, which are both tunnels, increase or only slightly decrease VHT on the downtown street system, increase VHT on the I-45 lanes, and decrease the VHT on the downtown loop freeways. Traffic Alternatives B and F (Engineering Alternative 12) show the greatest reduction of VHT on the downtown streets and decrease VHT on the downtown freeway system, but are average on the other two segments. Traffic Alternative E, which corresponds to Engineering Alternative 11, shows the greatest overall reduction in VHT by a significant amount. Although it increases the VHT on the downtown street system, it results in very large reductions of VHT from I-45 and the downtown freeway system.

Table 8: Segment 3 VHT changes

Alte	ernatives		VHT					
Traffic	Engineering	Downtown Streets	Difference	I-45	Difference	Downtown Loop System	Difference	
N	o Build	29,300		17,000		41,200		
A	3	32,600	3,300	20,100	3,100	36,800	-4,400	
В	12	25,400	-3,900	16,800	-200	40,700	-500	
С	3	33,700	4,400	20,000	3,000	36,500	-4,700	
D	10	29,700	400	17,500	500	39,400	-1,800	
Е	11	32,200	2,900	10,000	-7,000	31,400	-9,800	
F	12	26,600	-2,700	18,100	1,100	40,100	-1,100	
G	5	30,200	900	18,500	1,500	41,100	-100	
Н	6	28,500	-800	20,300	3,300	39,600	-1,600	
J	No Build	29,300	0	16,300	-700	41,800	600	

Table 9: Segment 3 VHT changes

Alte	ernatives		Rating	
Traffic	Engineering	VHT Downtown	VHT I-45	VHT DT Loop Freeways
A	3	1	1	3
В	12	3	2	2
С	3	1	1	3
D	10	2	2	3
Е	11	1	3	3

Alte	ernatives	Rating				
Traffic	Engineering	VHT Downtown	VHT I-45	VHT DT Loop Freeways		
F	12	3	1	3		
G	5	2	1	2		
Н	6	2	1	3		
J	No Build	2	2	2		

Volume-to-Capacity Ratio:

Volume-to-capacity (V/C) ratio is a measure of the amount to traffic on given roadway in relationship to the amount of traffic the roadway was designed to handle. It is a way to measure congestion. A volume-to-capacity ratio greater than 1 indicates that the roadway is over capacity. Volume-to-capacity ratios of 0.75 or 0.8 indicate heavy congestion.

In all three segments, the V/C along I-45 only is considered in the evaluation criteria. The evaluation criteria are based upon improvements for the no-build scenario and are segment specific. For all three segments, an increase in V/C would result in a ranking of 1 (undesirable). For Segment 1, alternatives that reduce V/C by less than 3 percent receive a 2 (neutral), and alternatives that reduce V/C by less than 7 percent receive a 3 (desirable). For Segment 2, the thresholds are 5 percent and 14 percent for a ranking of 2 (neutral) or 3 (desirable), respectively. The changes in Segment 3 are more dramatic and have a much wider range. Thus the thresholds are considerably different. Alternatives that result in up to 10% reduction receive a 2 (neutral), and those that result in up to a 70 percent reduction receive a 3 (desirable).

Segment 1:

All alternatives in Segment 1 show a decrease in the V/C ratio as compared to the 2035 no build scenario. Engineering Alternative 3, the direct connector from I-45 to Hardy Toll Road, does the least to ameliorate congestion along I-45. The other alternatives all resultin a similar improvement in V/C ratio of about 5 to 7 percent, but the V/C ratios are still over 1, indicating heavy congestion. Table 10 shows the V/Cs for each alternative, percentage difference from the no-build, and the ranking assigned to each.

Table 10: Segment 1 V/C changes

Alterr	atives	I-45 - General Purpose Lanes			
Traffic	Engineering	V/C % Difference		Ranking	
No l	ouild	1.38			
A	3	1.37	-0.8%	2	
В	3	1.37	-0.7%	2	
С	4,5,6,7,8	1.30	-5.9%	3	
D	4,5,6,7,8	1.31	-4.9%	3	
Е	4,5,6,7,8	1.29	-6.6%	3	

Alterr	atives	I-45 - General Purpose Lanes			
Traffic	Engineering	V/C	% Difference	Ranking	
F	4,5,6,7,8	1.31	-5.4%	3	
G	4,5,6,7,8	1.29	-6.6%	3	
Н	4,5,6,7,8	1.30	-5.5%	3	
J	4,5,6,7,8	1.30	-6.1%	3	

Segment 2:

Traffic Alternative A, which is a direct connector along I-610 to the Hardy Toll Road, shows an increase in V/C ratio from the no-build scenario. The other alternatives show a slight decrease, except for Traffic Alternatives E and G, which show a decrease of over 13 percent to a V/C ratio just above 0.8.

Table 11: Segment 2 V/C changes

Alterr	atives	I-45 - G	eneral Purpo	se Lanes
Traffic	Engineering	V/C % Difference		Ranking
No l	ouild	0.95		
A	15	0.98	3.2%	1
В	15	0.91	-3.9%	2
С	10,11,12	0.93	-2.1%	2
D	10,11,12	0.92	-3.6%	2
Е	10,11,12	0.83	-13.1%	3
F	10,11,12	0.89	-5.8%	3
G	14	0.82	-13.7%	3
Н	14	0.91	-4.2%	2
J	15	0.91	-3.7%	2

Segment 3:

The variation in Segment 3 in the impacts of the V/C ratio on I-45 is greater than the other segments. The tunnel in Engineering Alternative 5 results in an increase in V/C compared to the nobuild situation. Traffic Alternatives B and D show a decrease of V/C of about 7-8 percent, which is substantial but more modest than some of the other alternatives. The tunnel in Engineering

Alternative 6 results in a decrease of V/C of 44 percent, and the parkway in Engineering Alternative E results in a V/C reduction of 67 percent, driving the ratio down to under 0.5.

Table 12: Segment 3 V/C changes

Alt	ernatives	I-45		
Traffic	Engineering	V/C Ratio	V/C Ratio % Difference	
N	lo Build	1.40		
A	3	1.10	-21.3%	3
В	12	1.29	-7.6%	2
С	3	1.09	-21.8%	3
D	10	1.29	-8.0%	2
Е	11	0.46	-67.0%	3
F	12	1.10	-21.4%	3
G	5	1.45	4.0%	1
Н	6	0.78	-44.1%	3
J	No Build	1.37	-1.7%	2

Overall rankings:

The tables below show the overall rankings for each alternative for each segment. In the case of multiple modeling alternatives covering the same engineering alternative, the scores were averaged to obtain an overall Undesirable/Neutral/Desirable (U/N/D) scoring for the alternative.

Segment 1:

Alternatives 4, 5, 6, 7, 8 score the highest with "Desirable" for every evaluation criteria.

Table 13: Overall scores for Segment 1

Criteria	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8
Greena	Rating	Rating	Rating	Rating	Rating	Rating
Managed Lane Utilization (along New ML Facility)	U	D	D	D	D	D
Travel Demand (along I-45)	N	D	D	D	D	D
Vehicle Hours Traveled (along I-45)	N	D	D	D	D	D

Vehicle Hours Traveled (along Study Area Freeway System)	N	D	D	D	D	D
Vehicle Hours Traveled (along Downtown Street System)	NA	NA	NA	NA	NA	NA
Volume-to-Capacity Ratio (along I-45)	N	D	D	D	D	D

Segment 2:

Alternatives 10, 11, 12, 13 and 14 score the highest with "Desirable" for every evaluation criteria. Table 14 below has the overall rankings for all alternatives in Segment 2.

Table 14: Overall scores for Segment 2

Criteria	Alternative 3	Alterative 10	Alternative 11	Alternative 12	Alternative 14	Alternative 15
	Rating	Rating	Rating	Rating	Rating	Rating
Managed Lane Utilization (along New ML Facility)	U	D	D	D	D	U
Travel Demand (along I-45)	U	D	D	D	D	N
Vehicle Hours Traveled (along I-45)	U	D	D	D	D	N
Vehicle Hours Traveled (along Study Area Freeway System)	U	D	D	D	D	N
Vehicle Hours Traveled (along Downtown Street System)	NA	NA	NA	NA	NA	NA
Volume-to-Capacity Ratio (along I-45)	U	D	D	D	D	N

Segment 3:

The scores for Segment 3 are more variable than the other Segments. Alternatives 11 and 12 have 3 Desirables. Alternatives 3 and 6 have 2 Ds, and Alternative 5 does not have any. The rankings can be seen in Table 15 below.

Table 15: Overall scores for Segment 3

Criteria	Alternative 3	Alternative 5	Alternative 6	Alternative 10	Alternative 11	Alternative 12
	Rating	Rating	Rating	Rating	Rating	Rating
Managed Lane Utilization (along New ML Facility)	NA	NA	NA	NA	NA	NA
Travel Demand (along I-45)	NA	NA	NA	NA	NA	NA
Vehicle Hours Traveled (along I-45)	U	U	Ŭ	N	D	N
Vehicle Hours Traveled (along Study Area Freeway System)	D	N	D	D	D	D
Vehicle Hours Traveled (along Downtown Street System)	U	N	N	N	U	D
Volume-to-Capacity Ratio (along I-45)	D	U	D	N	D	D

Appendix E: White Paper: NHHIP Engineering Aspects of Tunnel Alternatives



То	From Samer Sadek, Michael Deutscher, Sean	
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	Subject	
	NHHIP – Engineering Aspects of	
	Tunnel Alternatives	
	Date	
	September 10, 2013	

MEMORANDUM

1. Introduction

This memo presents a discussion of engineering aspects (design, construction, operation) of the tunnel alternatives currently under consideration for the NHHIP. The memo was written to address the Engineering Evaluation and Comparison of Reasonable Alternatives for tunnels. The memo is not intended to address traffic demand or environmental aspects, which will be evaluated by others. Additionally, the memo does not address cost, which will be evaluated at a later stage.

1.1 Codes/Standard/Guidelines

The following national codes/standards/guidelines were considered in the preparation of this memo:

- American Association for State Highway and Transportation Officials (AASHTO), A Policy on the Geometric Design of Highway and Streets, 6th Edition (2011) (also referred to as the AASHTO "Green Book")
- Federal Highway Administration (FHWA), Road Tunnel Design Guidelines, 2004
- Federal Highway Administration (FHWA), Technical Manual for Design and Construction of Road Tunnels – Civil Elements (2009)
- National Fire Protection Association, NFPA 502, Standard for Road Tunnels, Bridges and Other Limited Access Highways (2014)

Additional standards, codes, policies and regulations that would govern design of the tunnel, including the fire protection system, include:

- American National Standards Institute (ANSI)
- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- International Conference of Building Officials and Code Administration (IBCO)
- National Electrical Code (NEC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)
- Underwriters' Laboratory Inc. (UL)
- Uniform Building Code (UBC)
- Uniform Fire Code (UFC)

1.2 Design Life Expectancy

Tunnels for large infrastructure projects are typically designed to have a design life of at least 100 years. It is not uncommon for tunnels to last beyond 100 years, for example, the networks of transit and highway tunnels in New York and Boston. A routine maintenance program and occasional repairs/rehabilitation are required to achieve the design life expectancy, as is the case with any infrastructure element, above ground or below.

2. Description of Tunnel Alternatives

Two combinations of tunnel alternatives are under consideration for the NHHIP:

- Alternative 14 for Segment 2 plus Alternative 5 for Segment 3 (Alt 14+5)
- Alternative 14 for Segment 2 plus Alternative 6 for Segment 3 (Alt 14+6)

Either of the above alternative combinations would add four (4) managed lanes to the existing IH45 roadway in a stacked configuration (i.e., two lanes over two lanes, starting with a cut and cover approach structure leading to a single circular tunnel bore as shown in Figure 1), with unidirectional traffic on each level of the tunnel. In both tunnel alternatives, the managed lanes begin to the north of the northern IH45/IH610 interchange, with the tunnel commencing just south of the interchange. There is no access from IH610. In the first case (Alt 14 +5), the tunnel terminates just east of the IH45/IH10 interchange and provides direct access to/from downtown and IH45. In the second case (Alt 14+6), the tunneled roadway continues to Jefferson Street and terminates at IH45 south of the IH45/US59 interchange. The total lengths of the Alt 14+5 and Alt 14+6 tunnel alternatives are approximately 2.5 miles and 5.1 miles, respectively. The alignments of Alt 14+5 and Alt 14+6 are given in Attachment 1 and Attachment 2, respectively.

3. Conceptual Tunnel Cross Section

The conceptual tunnel cross section considered for the engineering evaluation is presented in **Figure 1**. As mentioned in the previous section, the cross section consists of a stacked configuration (i.e., two lanes over two lanes in a single bore) similar to SR-99 tunnel (Alaska Way Viaduct replacement) project, which is currently under construction in Seattle, WA.

The conceptual tunnel cross section was developed with consideration for several design criteria, including:

- Design Speed
- Vertical Vehicular Clearance
- Width of Shoulders, Sidewalks, Travelled Lanes
- Superelevation
- Sight Shelf
- Ventilation
- Emergency Egress

The design criteria are discussed in the sections that follow.

3.1 Design Speed

As per the AASHTO Green Book (Chapter 8 - Freeways), the design speed should not be less than 50 mph for urban freeways. As per the Green Book (Chapter 10 - Grade Separation and Interchanges), ramp design speeds above 30 mph for loops generally involve large areas and are rarely utilized in urban locations.

<u>Selected Design Speed</u>: Design speeds significantly greater than 50 mph would likely require full-width shoulders, which effectively would increase the required tunnel diameter beyond what is reasonably constructible given the current state of bored tunneling technology. Accordingly, a design speed of 50 mph is assumed for this engineering evaluation and is consistent with designs of other major highway tunnels such as SR-99 in Seattle, WA and Boston, MA's Central Artery.

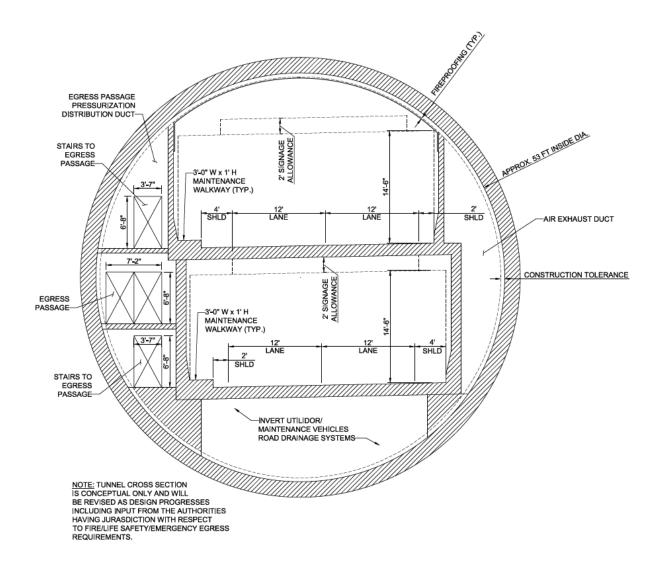


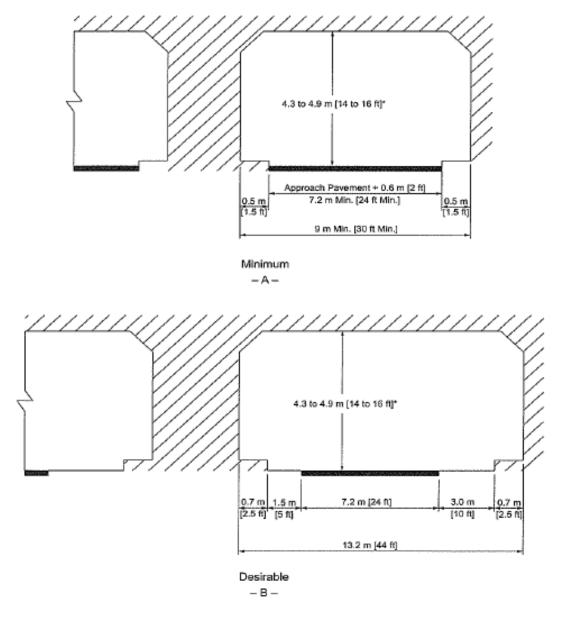
Figure 1. Conceptual tunnel cross section.

3.2 Vertical Vehicular Clearance

As per the AASHTO Green Book (Chapter 4 - Cross Section Elements), the minimum vertical clearance is 14 to 16 feet. However, the minimum clear height should not be less than the maximum height of load that is legal in a particular state, and it is desirable to provide an allowance for the future repaying of roadways. The minimum vertical clearance envelope is shown in Figure 4-14 of the AASHTO Green Book (2011), which is reproduced in Figure 2.

<u>Selected Vertical Vehicular Clearance</u>: A vertical vehicular clearance of 14'-6" is assumed for the engineering evaluation, which is the minimum requirement as per the AASHTO Green Book (2011) with

an additional 6 inches for repaving. In addition to the minimum vertical vehicular clearance, a 2'-0" vertical distance will be provided for signage.



^{*} Note: An allowance should be added to the vertical clearance for future repaying.

Figure 4-14. Typical Two-lane Tunnel Sections

Figure 2. Reproduction of Figure 4-14 from AASHTO Green Book (2011).

3.3 Width of Shoulders, Sidewalks, Travelled Lanes

These topics are combined in Section 4.16.4 of the AASHTO Green Book (2011) and accordingly are addressed together herein.

The FHWA Road Tunnel Design Guidelines (2004) and Technical Manual for Design (2009) recommend 12 foot wide travel lanes as does AASHTO's Green Book. Additionally, the FHWA guidelines and manual both suggest a minimum 4 foot wide shoulder on the right side and a minimum 2 foot shoulder on the left side for unidirectional road tunnels. The manual also suggests that emergency alcoves be provided for broken down vehicles in long tunnels. Finally, AASHTO's Green Book calls for minimum 1.5 foot wide sidewalks on either side, as shown in **Figure 2**.

A literature search of previously constructed long road tunnels with at least two travel lanes in a single direction revealed:

- A travel lane width of 12 feet is typically for most road tunnels, particularly in the United States. However, reduced widths are common for tunnels with restricted access.
- The width of the right, outside shoulder (adjacent to the slower lane) is highly variable, ranging from less than a foot to 12 ft. The width of the left, inside shoulder typically ranges from 1 ft to 4 ft with an average of about 2 ft.

<u>Selected Shoulder, Sidewalk and Lane Widths</u>: Based on an examination of the relevant codes, standards and guidelines and a review of recently completed long road tunnel projects, the preliminary shoulder, sidewalk and lane widths are selected as follows:

- Lane width: 12'-0" travel lanes:
- Shoulder width: 4'-0" inside shoulder, 2'-0" outside shoulder;
- Sidewalk width: a 3'-0" wide maintenance walkway is provided on one side of the tunnel as opposed to a 1.5 foot sidewalk on either side. The maintenance walkway is not an NFPA 502 requirement and is not to be confused with the egress passage, which is discussed in Section 3.8 below.

As per the AASHTO requirements, the reduced shoulder widths will likely require provision for emergency service vehicles that can promptly remove stalled vehicles. Additionally, as per the FHWA design manual, periodic emergency alcoves for broken down vehicles may be desirable given the length of the tunnel alternatives.

3.4 Superelevation

As per the AASHTO Green Book (Chapter 3 – Elements of Design), the minimum rate of cross slope applicable to the travelled way is determined by drainage needs. The usual accepted minimum values for cross slope range from 1.5% to 2.0%. For both tunnel alternatives, a cross slope of 2% is considered.

Given the design speed of 50mph and a cross slope of 2%, the theoretical minimum radius of curvature, R_{min} can be calculated as approximately 1,000 feet. That being said, the determination of R_{min} must also give consideration to tunnel constructability; R_{min} will be controlled by the minimum possible turning radius of the large diameter tunnel boring machines (TBMs) used to construct the tunnel, which is in the order of 2,000 feet. Accordingly, for a TBM of this size the selection of an R_{min} of less than approximately 2,000 feet would require additional investigation and should be avoided if possible.

3.5 Sight Shelf

Horizontal clearance to the sidewalls on curved tunnels may need to be increased to provide adequate sight distances beyond the wall for the given design speed. The width of "sight shelf" required is dependent on design speed and radius. Sight distance is measured to face of high safety walks, if present, as opposed to the face of the wall.

Given the proposed design speed of 50mph and the proposed minimum alignment radius, R_{min} , of 2,000 feet, it is unlikely the bored tunnel cross section will have to be increased in size for the purpose of meeting sight shelf requirements. However, sight shelf width may need further investigation for access ramps associated with Alternate 14+5. Single lane ramps that include a 10ft wide breakdown lane should have sufficient sight shelf width.

3.6 Other Horizontal Space Allocation

Other horizontal space allocation requirements include:

- Fireproofing where the precast segmental liner would otherwise be exposed;
- Construction alignment tolerance associated with tunnel boring machine during excavation of the tunnel.

The conceptual tunnel cross section as presented in **Figure 1** takes into account these requirements.

3.7 Ventilation

Ventilation systems are required to maintain safe normal traffic operating conditions along with mitigation of hazardous smoke and heat environment developed from a fire incident.

Normal Operating Conditions: Federal Highway Administration's (FHWA) memorandum of March 31, 1989 provides guidelines for ventilation requirements to mitigate health hazards developed from high air pollutant concentrations that are developed from traveling cars emissions. These guidelines along with OSHA guidelines provide maximum allowable concentration levels that tunnel air must not exceed. Traffic distribution and fleet emissions conditions combined with the significant length of the tunnel alternatives dictate that a mechanical ventilation system is required. Monitoring of the air is performed with a carbon monoxide monitoring system.

Fire Incident Conditions: System design criteria for mitigation of fire incident conditions are provided in the design standard NFPA 502 which prescribes maximum allowable thresholds for temperature, radiation heat and smoke levels. The standard also provides guidelines for system design including ventilation system selection and equipment configuration. Based upon the lengths of tunnel in our study a mechanical ventilation system is required to be incorporated into the design. Ventilation system designs are generally coordinated with local authority having jurisdiction (such as fire departments or other state/local authorities) who may establish unique component sizing and system configuration requirements beyond that which is outlined in the NFPA 502 design standard.

The conceptual tunnel cross section presented in Figure 1 includes area allocation for the required mechanical ventilation system with consideration to both normal operating conditions and fire incident conditions. Additional information on the envisioned ventilation system is provided below.

Several different mechanical ventilation systems would be appropriate for the tunnel alternatives as follows:

- Extraction exhaust ventilation with portal pressure management
- Push/pull impulse nozzle ventilation

The conceptual cross section presented in Figure 1 is based on the former.

In general the following elements would need to be incorporated into the tunnel ventilation system:

- Intervals between ventilation plants cannot exceed 2 miles
- Minimum ventilation duct size of 150 sq. ft. between ventilation plants for extraction of pollutants and smoke as shown on the conceptual tunnel cross section in **Figure 1**.

The tunnel alternatives introduce a general overall impact to the corridor whereby emissions will be concentrated at portals and ventilation buildings. Air quality dispersion assessment at these discharge locations will be necessary to ensure that levels do not exceed acceptable concentrations.

3.8 Emergency Egress

Tunnel fire and life safety systems codes require provisions for the self-evacuation of motorists within the traffic cell region in case of smoke or fire incidences. The conceptual tunnel cross section presented in Figure 1 was developed with consideration for the emergency egress requirements of NFPA 502 (2014), Section 7.16. The conceptual tunnel cross section includes a common egress passage that serves both traffic cells. The egress passage is separated from the traffic cells by an enclosure, which will be designed to provide a tenable environment in for egress during the evacuation phase in accordance with the emergency response plan developed for specific incidences. Access to the common egress passage will be provided at regular intervals along each roadway cell in accordance with NFPA 502; the motorists will use the roadway surface (including any maintenance sidewalk that may be provided) to reach the access to the egress passage. This egress concept was recently adopted by the Washington State Department of Transportation (WSDOT) for the SR-99 tunnel project.

3.9 Fire and Life Safety Systems

Fire and life safety systems suitable for mitigating fire hazards within tunnel environment require a comprehensive design that incorporates a program whereby the entire facility is actively monitored by trained operating personnel. Systems designed to accommodate heavy cargo will require the installation of overhead deluge fire control spray system (ODFCS) to limit ventilation system size and complexity associated with potential fire incidents. Flammable liquid cargos will not be allowed in the tunnel. National standard design guidelines provide a minimum outline of a coordinated system design that includes the following:

- High performance fire detection system with at least 2 zones.
- Traffic management and control system capable of stopping traffic entering the tunnel

Overhead deluge fire control spray system (ODFCS) is a key in limiting the size of the ventilation system. Designs must take into consideration the following:

- ODFCS zone sizing to anticipated fire incident conditions
- On/off control of ODFCS zones to accommodate active fire safety management operations
- Water supply capacity and duration to accommodate operation of the ODFCS zones. Pumping systems may be required to develop the required water supply capacity and pressures.

Standpipe systems are to be included in the tunnel with hose valves positioned to allow for fire hose access according to the requirements of the authority having jurisdiction.

3.10 Tunnel Drainage Systems

Tunnel drainage systems are designed to:

- Convey ODFCS and fire hose flows developed inside the tunnel during a fire incident
- Convey any seepage flow through the tunnel's liner.

3.11 Breakdown Alcoves/Removal of Disabled Vehicles

As previously discussed in Section 3.3, the absence of full width shoulders will likely require provision of round-the-clock emergency service vehicles that can promptly remove stalled vehicles. Additionally, as per the FHWA design manual, emergency alcoves for broken down vehicles are desirable given the length of the tunnel. The breakdown alcoves would be provided to coincide with ventilation structures, which are constructed in open-cut excavations and accordingly allow for the addition of these alcoves at minimal cost. Breakdown alcoves are envisioned to be approximately 120 feet long with 90 foot long transition zones at either end.

3.12 Traffic Control Systems/Operations and Maintenance Center (OMC)

Traffic control systems/control center must be configured to support fire safety systems operations as described previously. National standard design guidelines provide a minimum outline of a coordinated system design that includes the following:

- Traffic management and control system capable of stopping traffic entering the tunnel and tunnel approaches
- Tunnel facility operations plan that includes coordination with all responding agencies
- Incident detection systems to enable facility to enact precautionary actions
- Operator Interface to allow control and monitoring of all systems in the tunnel facility
- Interface with Regional Traffic operations for smooth transitions between the tunnel facility and adjoining roadways.
- Interface with tunnel communications systems to enable operators to reach emergency responders in the tunnel as well as communicate with drivers through the emergency telephone system
- Surveillance equipment to allow operators to view operating conditions in the tunnel

Central control and monitoring will be performed from an Operations and Maintenance Center (OMC), located at one of the tunnel portals. The building will consist of a one-story 14,000 square foot building with an eight space automobile/pick-up truck parking area. The building will require complete systems design (HVAC, plumbing, fire protection, power, lighting and fire alarm) according to standard commercial building operations requirements with additional provisions for redundancies of key systems. For security, the OMC will have a locking gate/fence at the entrance to the site, high-pressure sodium (HPS) lights, CCTV surveillance cameras and intrusion detection alarms on the doors and windows.

3.13 Other Systems Required in Tunnels: Lighting and Power, Communications, Etc.

Power supply to tunnel ventilation and other safety systems are to be from two different power sources. This can be accomplished in a variety of ways including emergency generators or redundant utility feeds. Critical life safety systems require back up by Uninterruptible Power Supply (UPS) systems.

Tunnel lighting is required to be designed in compliance with ANSI/IES RP-22-05. The light levels at the tunnel portals must be designed to mimic external light levels at that area to provide a safe transition for the driver from one area to the other. This will avoid the effect of momentary blindness that would be caused by the driver moving from a bright area to a dark tunnel area. Lighting design will consider traffic design speeds to space lights appropriately to avoid strobe effects which can lead to seizures. Lighting system would be designed with luminaire placements to facilitate maintenance operations without shutting down all lanes. Design will include emergency light fixtures backed by UPS.

A radio rebroadcast system is required to provide communications inside the tunnel for emergency services including fire, police and emergency medical services. The system will also accommodate

Highway department maintenance personnel and any other agencies required for emergency response in the tunnel.

Emergency telephones in the roadway and egress areas will be provided. A phone will be required at each exit from the tunnel as well as throughout the tunnel with 295 foot spacing.

Surveillance for incident detection and security will be required in the tunnel. In order to confirm the nature of incidents in the tunnel, view progress of emergency response, monitor traffic flow and provide security, a series of video cameras are required throughout the facility. Further security measures include switches to indicate when doors are opened or closed, motion detectors to determine if there are unauthorized personnel on site, and card readers to restrict entrance to non-public areas. Incident detection in the roadway can be provided by video or in-pavement loop detectors. Electronic signage is recommended to provide traffic control through the tunnel. This signage would include variable message signs at the approaches and portals as well as throughout the tunnel to stop traffic in response to emergency conditions. Lane Control signs can be used to facilitate single lane closures or other traffic control measures.

3.14 Durability

Tunnel structures will be designed to prevent tunnel collapse in case of major fire incidences. As any fire would be localized, repairs could be accomplished in a short period of time, given the fact that fire suppression systems will be provided.

As an example of the structural durability of tunnels, areas of New York City's subway system were flooded during the Hurricane Sandy in October of 2012, yet were able to recover and return to service within a couple of weeks.

4. Constructability

4.1 Site Geology

The geological conditions were determined from a desk study as well as boreholes drilled from August 2006 to April 2007. The geological conditions can be summarized as follows:

- Houston is situated on the Texas Coastal Plain, which is underlain by thousands of feet of unconsolidated sediment. Deposition of the near-surface sediments around Houston took place in deltaic and inter-deltaic environments during the Pleistocene Epoch.
- The tunnel will likely be located within the Beaumont Formation, although the northern reaches of the tunnel may encounter the Lissie Formation. The Beaumont Formation is typically in excess of 165ft thick and described as a matrix of stiff, over-consolidated, fissured clay generally classified as CH in the Unified Soil Classification System (USCS). The over-consolidation is the result of desiccation or cyclic raising/lowering of the water table both during and after deposition. The clay matrix is the host of numerous, almost randomly occurring lenses, layers and channels

- of water-charged fine sands and silts. Occasionally, portions of these granular deposits were weakly cemented by precipitation of calcium carbonate. These cemented zones are often less than a meter thick (Merritt et al., 1991).
- Borings drilled along the tunnel alignment to maximum depths of approximately 100ft confirm the soil profile consists mainly of clay with inter-bedded layers of sand with silt lenses/layers. Rock was not encountered.
- In terms of basic tunnel ground classification, the clays of both formations can be characterized as slow to fast raveling owing to the pronounced secondary structure of fissures and joints. Even though most of the clays are potentially expansive, owing to high moisture contents generally found at tunnel depth, these clays are not characterized as swelling. Similarly, owing to their relatively high strength resulting from desiccation, at tunnel depth the clays are seldom characterized as squeezing. The fine sands and silts contained within these formations can be characterized as flowing, and, when dewatered, as potentially running (Merritt et al., 1991).
- The general topography of Houston rises to the west and north at an overall rate of close to lm/km (approximately 0.1 %).
- The groundwater table is typically near the ground surface and seldom more than 10 to 20 feet below the ground surface.
- Two geological hazards are commonly present in Houston, which can impact tunnel design:
 - O Ground subsidence, which results from the pumping of groundwater from deep aquifers (although pumping, and therefore subsidence, is significantly less in the last 30 years due to newer water supply policies intended to address the subsidence problem);
 - O Active geological faults, generally exhibiting a dip of between 55 and 70 degrees from the horizontal. Recorded displacement of active faults in the Houston area has been as much as 1 inch per year or more (Merritt et al., 1991). The movement of the faults is not tectonic but rather the result two geological mechanisms:
 - Massive landslides, which occurred during the deposition of the formations; and
 - Crustal strain as the upward movement of mobile salt masses pierces the formations.

The possibility of active geological faults is of concern to tunnel design. One fault in particular, the Pecore Fault, is known to cross the proposed tunnel alignment west to east from Pecore Street to just north of the Hollywood Cemetery. A site walk of the IH45 in the vicinity of the known location of the Pecore Fault did not reveal evidence of recent or on-going movement.

Additional incremental geotechnical investigations will be required as the project advances through the various design stages.

4.2 Construction Methods for Underground Structures: Tunnels, Portals, Vent Structures

4.2.1 Mainline Tunnel

Given the anticipated geological conditions, the mainline tunnel would most likely be constructed using an earth pressure balance tunnel boring machine (EPB-TBM). The current state-of-the-art in EPB-TBM technology allows for a maximum excavated diameter of nearly 60 feet which allows for an internal diameter (ID) of between 50 and 55 feet for a single bored tunnel (Note: the ID of SR-99 tunnel in Seattle, WA, the largest bored tunnel attempted to date, is approximately 58 feet in excavated diameter and will be bored with an EPB-TBM). An example of an EPB-TBM is shown in **Figure 3**.



Figure 3. Large diameter EPB-TBM prior to launch at SR-99 tunnel project in Seattle, WA (Source: Tunnel Business Magazine, August 2013 ed., p.28).

4.4.2 Portals & Vent Structures

The open-cut excavations for the tunnel portals and ventilation structures will require diaphragm walls (slurry walls or secant piles) given the depth of the excavations (in the range of 100 feet deep at the portals and 150 feet at the vent structures) and the high water table coupled with the presence of numerous cohesionless lenses within the stiff clays of the Beaumont Formation.

4.3 Contractor Availability

The required construction is highly complex and can be performed by only a small number of large highly skilled contractors, many of which are multi-national firms with offices in the US. As a point of reference, only two contracting teams submitted bids for the SR-99 tunnel project in Seattle, WA. The winning team, Seattle Tunnel Partners, was led by Dragados, a Spanish contractor with a US based tunneling firm as its Joint Venture partner. The runner up team, Seattle Tunnel Group, was led by S. A. Healy, which is a wholly-owned subsidiary of Impregilo, an Italian contractor.

4.4 Construction Staging/Sequencing

Construction staging/sequencing, requiring roadway diversions and lane closures, will generally be limited to the approach structure locations at either end of the tunnel. The ventilation building(s) will be located outside of the travelled way and as such should not require extensive construction staging/sequencing.

Where the approach structure locations coincide with local streets, and where long term road closures cannot be obtained, construction staging/sequencing for approach structures will require lane closures for installation of the diaphragm wall. The walls on opposite sides of the excavation will be constructed in series so as to limit the number of lanes closed at any one time. Road decking spanning the opposing walls could then be installed during full street closures on nights and weekends.

A length of the approach structure at the end of the tunnel from which the TBM will be launched will need to be open for a significant portion of the construction phase to: (i) enable assembly of the TBM and its back-up components during start-up, (ii) provide access for removal of muck and supply of materials during tunnel excavation, and (iii) placement of concrete and other operating/functional systems.

4.5 Utility Relocations

Utilities within the limits of the open-cut excavations for portals and ventilation structures will require advance relocation or alternatively will have to be supported in place from decking beams spanning the excavations. Utility relocations will typically not be required within the limits of bored tunneling for the mainline tunnel alignment with the exception of near portal locations where minimum cover above the tunnel's crown may facilitate larger utility settlement than desirable.

Utilities were not investigated as part of this study.

4.6 Construction Easements

Construction easements will be required adjacent to the portals and ventilation structures.

A construction laydown area of approximately 2 acres will be required adjacent to the portal/approach structure from which the TBM will be launched. A construction laydown area of approximately 1 acre will be required adjacent to the portal/approach structure from which the TBM will be received. Some of this area may coincide with the location of the future ventilation structure and O&M facilities, depending upon overall construction schedule requirements.

The construction laydown area required for ventilation structure construction will be approximately 1 acre. This area does not include the ventilation structure footprint.

In all cases, additional off-site construction laydown area may also be required relatively close to the sites for storage of precast tunnel liner segments and other materials.

4.7 Construction Schedule

The construction schedule for a long tunnel depends on the number of tunnel boring machines (TBMs) used. Large diameter tunnel boring machines are expensive. For example, the Hitachi-Zosen 57.5' OD machine used to excavate the SR-99 tunnel in Seattle, WA (52' ID) cost approximately \$85m (2011 dollars); this single TBM will be used to excavate the approximately 2 mile long SR-99 tunnel.

Construction schedule assumptions are as follows:

- Utility relocations: 6 months (concurrent with open-cut excavations)
- Construction of open-cut excavations for portals and vent shafts: 12 months
- Procurement, construction, delivery of TBM(s): concurrent with open-cut excavations
- TBM assembly & testing on site: 3 months
- TBM launch & initial start-up (learning curve): 1 month
- TBM excavation and lining: performed at a rate of ~ 1 mile every 8 months per each TBM utilized.
- Installation of internal tunnel structure (decks, etc.) ~ 3 months lag time as work can occur concurrent with the tunnel construction.
- Installation of tunnel systems & testing ~ 12 months (can be partially concurrent activity with the tunnel construction)
- Completion of portal structures, ventilation structures: concurrent with tunnel fit out

The approximate construction schedule for Alt 14+5, which is approximately 2.5 miles in length, assuming one TBM will be used is 51 months (say 4 and a quarter years).

The approximate construction schedule for Alt 14+6, which is approximately 5 miles in length, assuming one TBM will be used, is 71 months (say 6 years). If two TBMs are used, the construction schedule can be reduced to about 4 and a quarter years also.

It is not anticipated that the construction schedule discussed above will need to be extended, yet should be reanalyzed as more geotechnical information and other technical data becomes available.

5. Risks

This section identifies risks that are more prevalent for the tunnel alternatives than for the at-grade or above-grade alternatives. Risks have been placed into one of three categories: design phase risks, construction phase risks and operational phase risks.

5.1 Design Phase Risks

The main design risks associated with the tunnel alternatives are:

- Discovery of new active faults along tunnel alignment, which could create constructability issues depending on where the fault was found.
- Characterization of ground's behavior on final lining design.
- Time frame required for land acquisition at portal and ventilation structure areas.
- As applicable, time frame required for tunnel ROW land acquisition beneath private property, which will include land usage limitations.

5.2 Construction Phase Risks

The main construction risks associated with the tunnel alternates are:

- Risk of damage to buildings, utilities and other infrastructure along the tunnel alignment due to excessive settlement from bored tunneling and open-cut excavations.
- Encountering hazard gas during construction.
- Encountering mixed face conditions (e.g., softer pockets of clay or loose soils within stiffer clay matrix), which could lead to over-excavation, squeezing conditions, or difficulties maintaining line and grade.
- Potential breakdown of key components of the TBM
- Risk of consolidation settlement caused by drawdown of pore-water pressures in compressible soil layers.
- Potential for encountering ground conditions that were not anticipated or found during the design process, commonly called a Differing Site Condition.

5.3 Operational Phase Risks

The main operational risks associated with the tunnel alternative are:

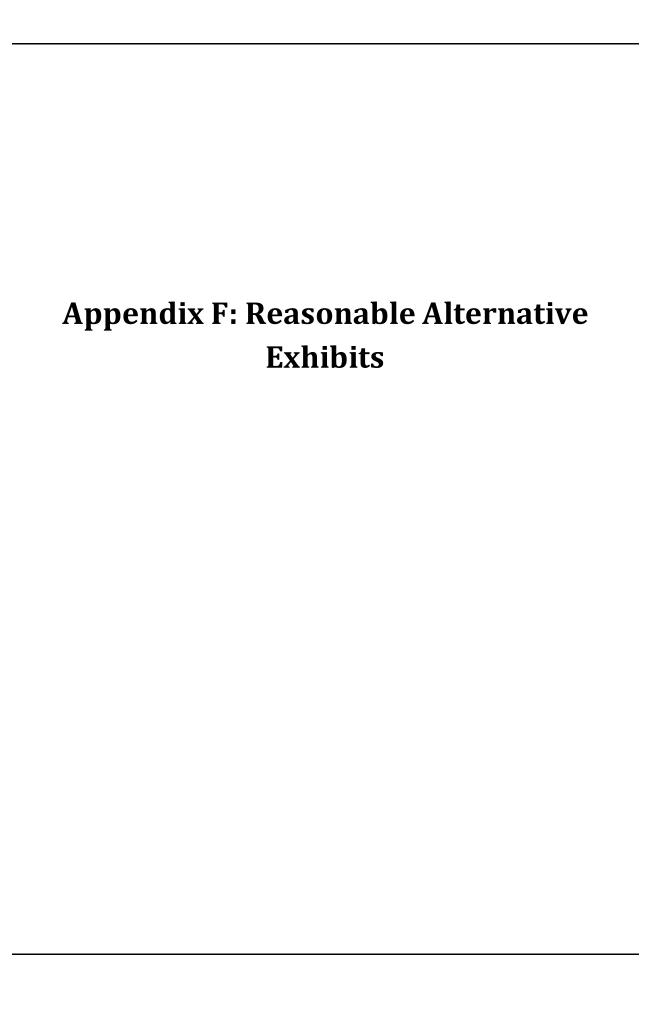
- Fault becomes active during life of tunnel, causing structural damage and/or misalignment requiring costly repair.
- Large scale fire or terrorist attack in tunnel requires complete shutdown of tunnel for extended period of time.
- Little opportunity to expand the tunnel's size other than constructing additional parallel tunnels

6. Conclusions

The preceding information should be considered for the Engineering Evaluation and Comparison of Reasonable Alternatives for the NHHIP.

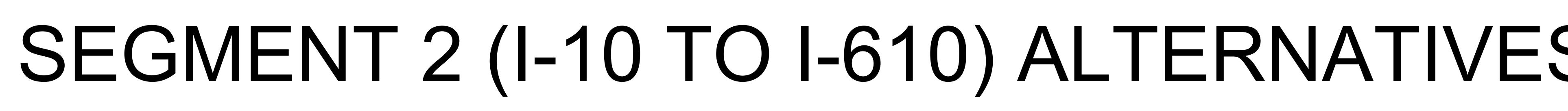
References

Merritt, B.K., Crisci, A. and Klein, G.H. "Houston Pipe Jacking – Large and Small". Proceedings of the Rapid Excavation and Tunneling Conference (RETC) 2013, Chapter 22.



I-45 NORTH - SEGMENT 2 (I-10 TO I-610) PRELIMINARY SUBJECT TO CHANGE ALTERNATIVE 10 - SECTION A-A

SEGMENT 2 (I-10 TO I-610) ALTERNATIVES







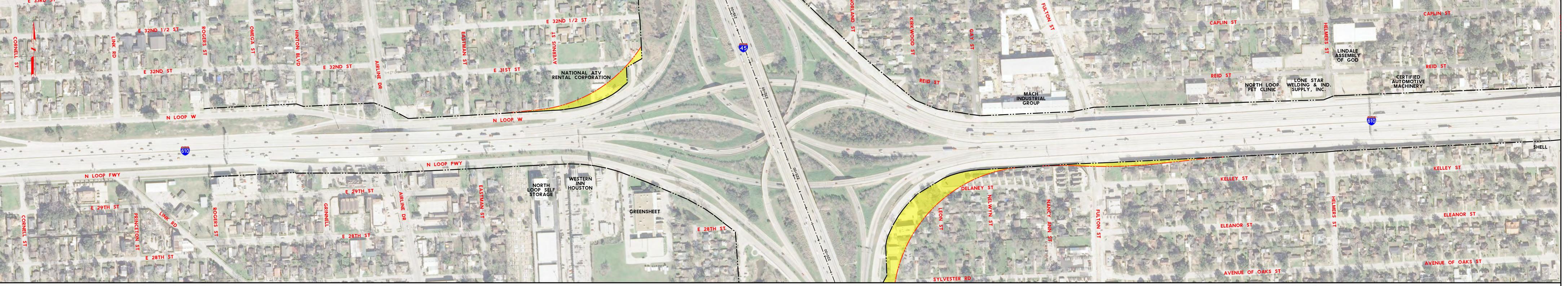
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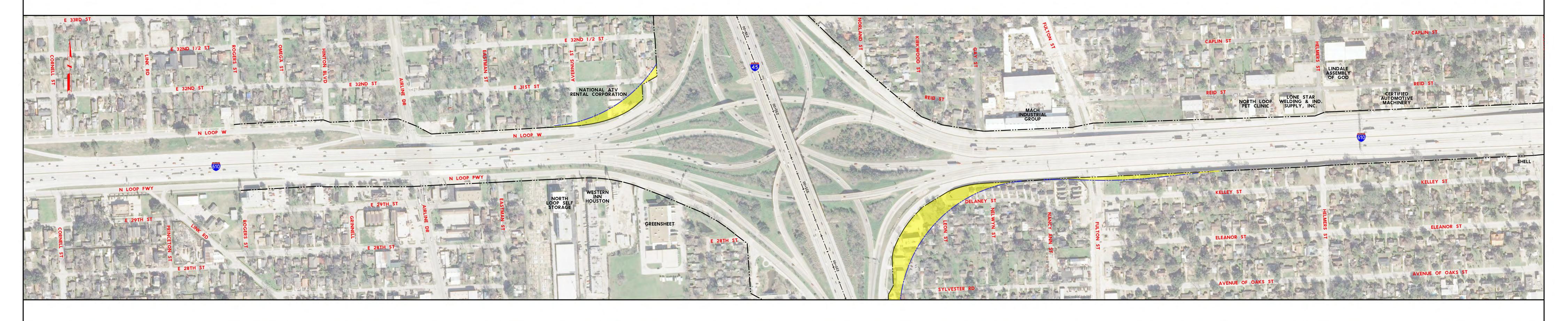


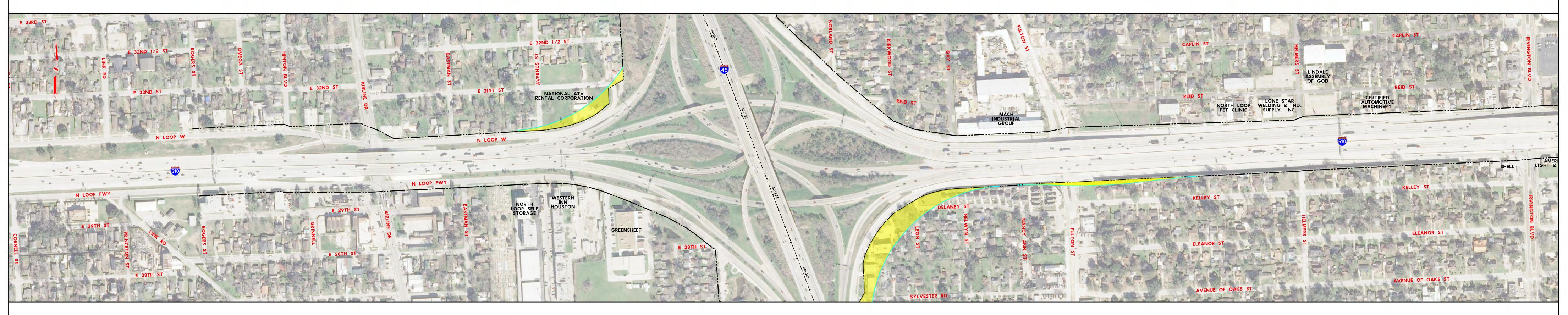
SEGMENT 2 ALTERNATIVES (I-45/I-610 INTERCHANGE)



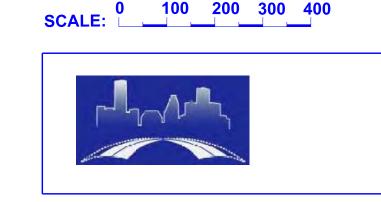
PROPOSED ROW







PRELIMINARY SUBJECT TO CHANGE



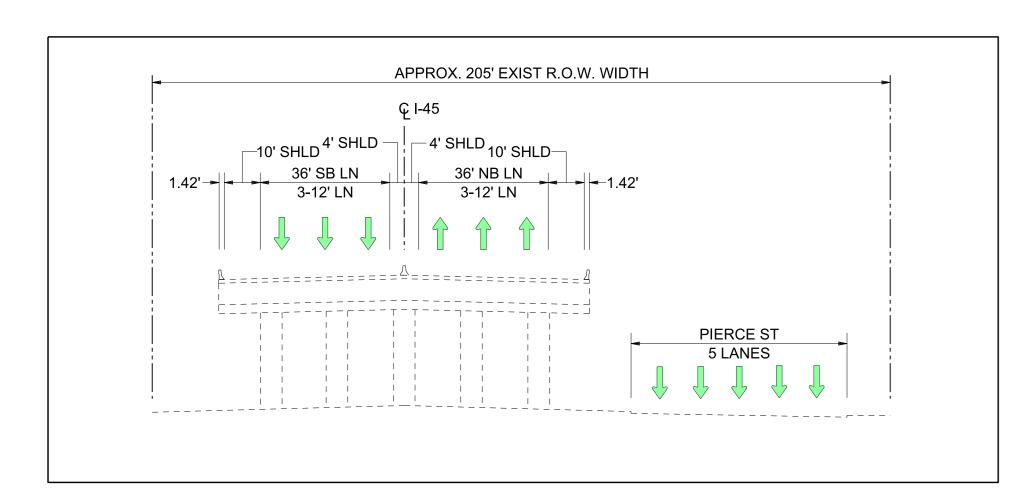
North Houston Highway Improvement Projec



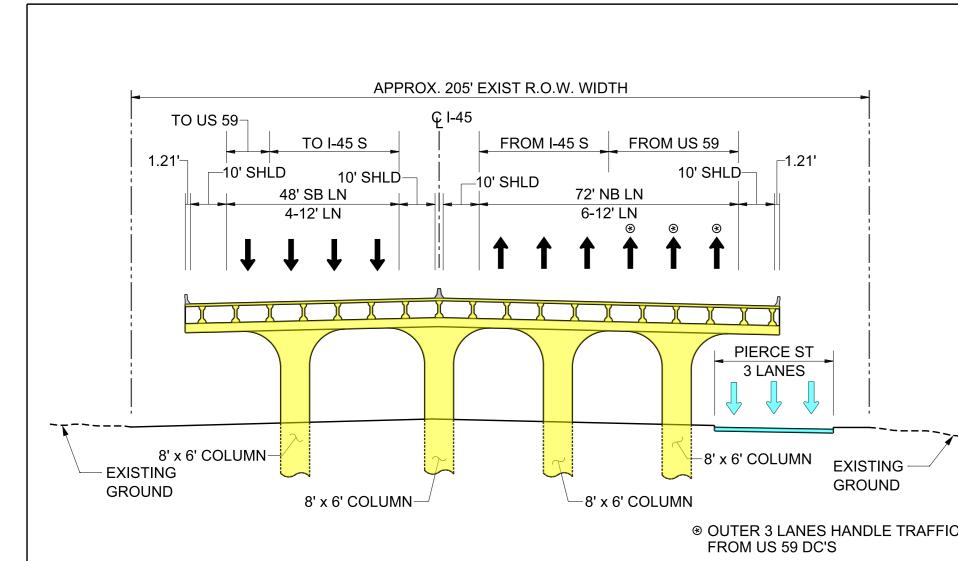




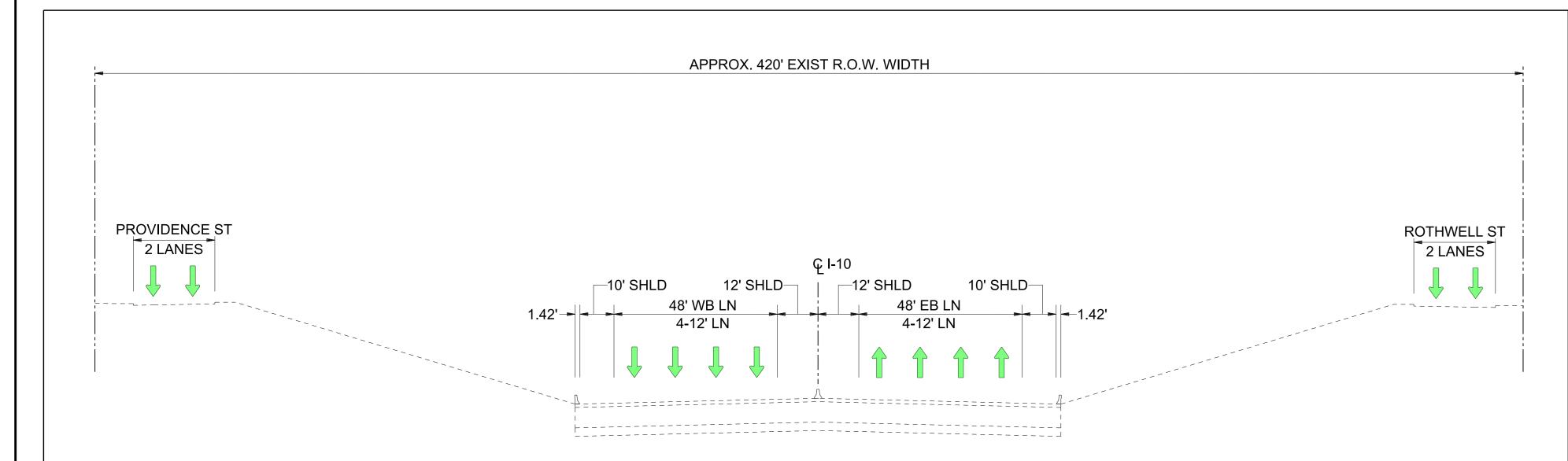
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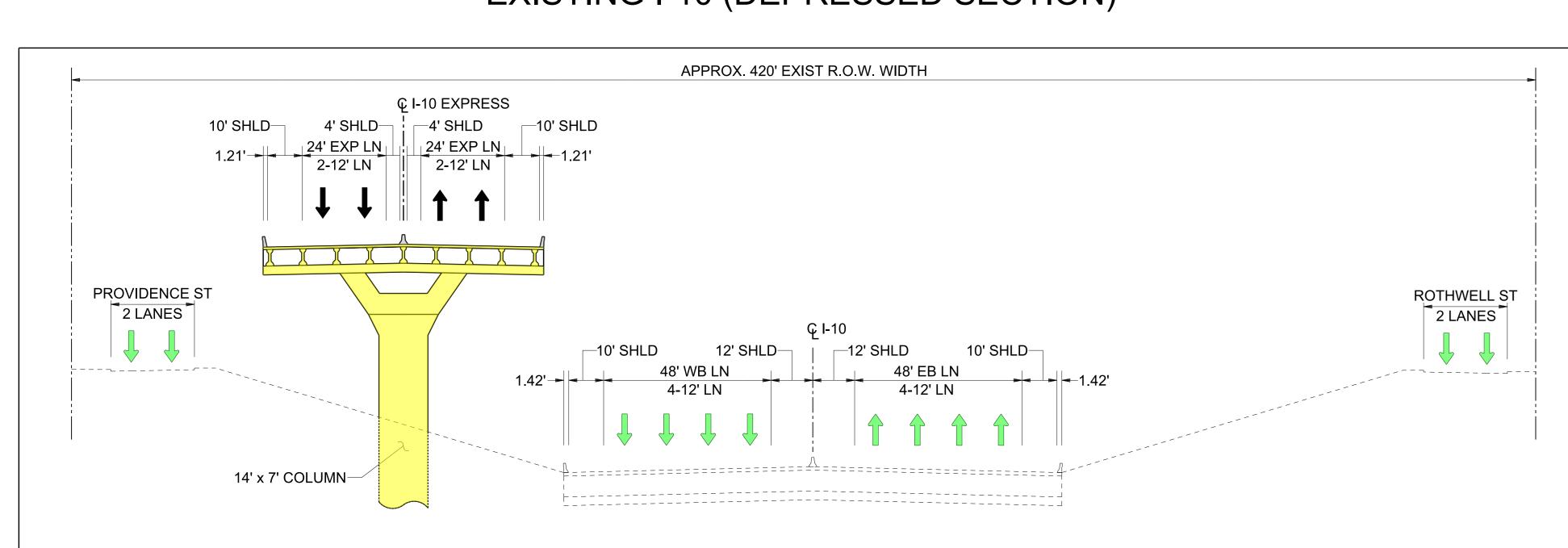
EXISTING I-45 (PIERCE ELEVATED)



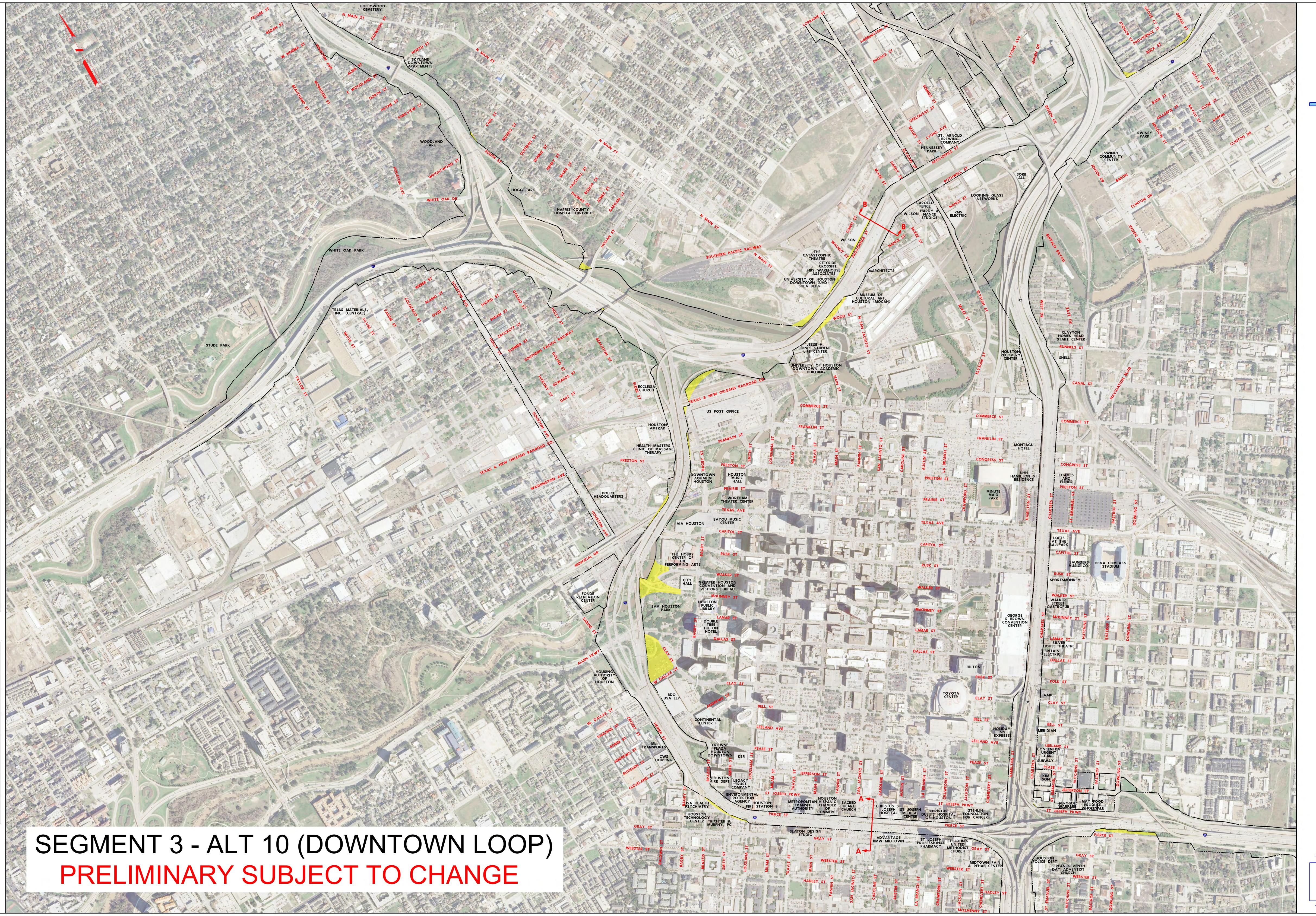
PROPOSED I-45 (PIERCE ELEVATED) SECTION A-A



EXISTING I-10 (DEPRESSED SECTION)



PROPOSED I-10 (DEPRESSED SECTION) SECTION B-B

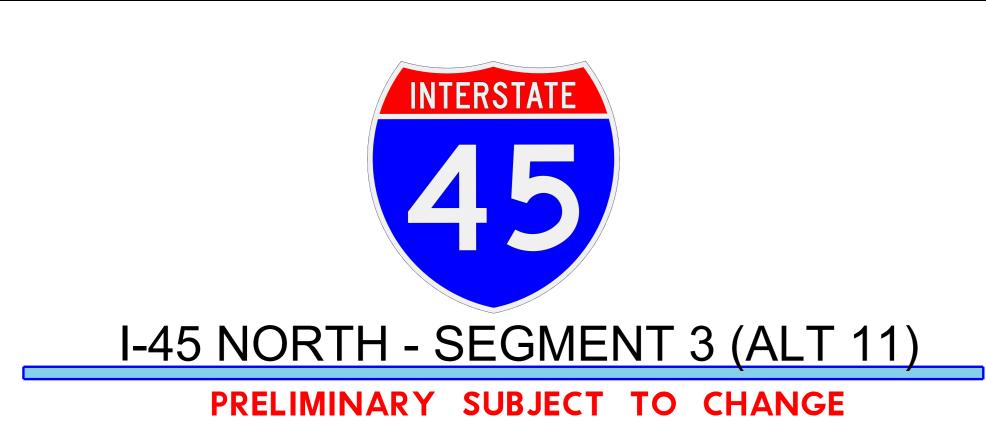


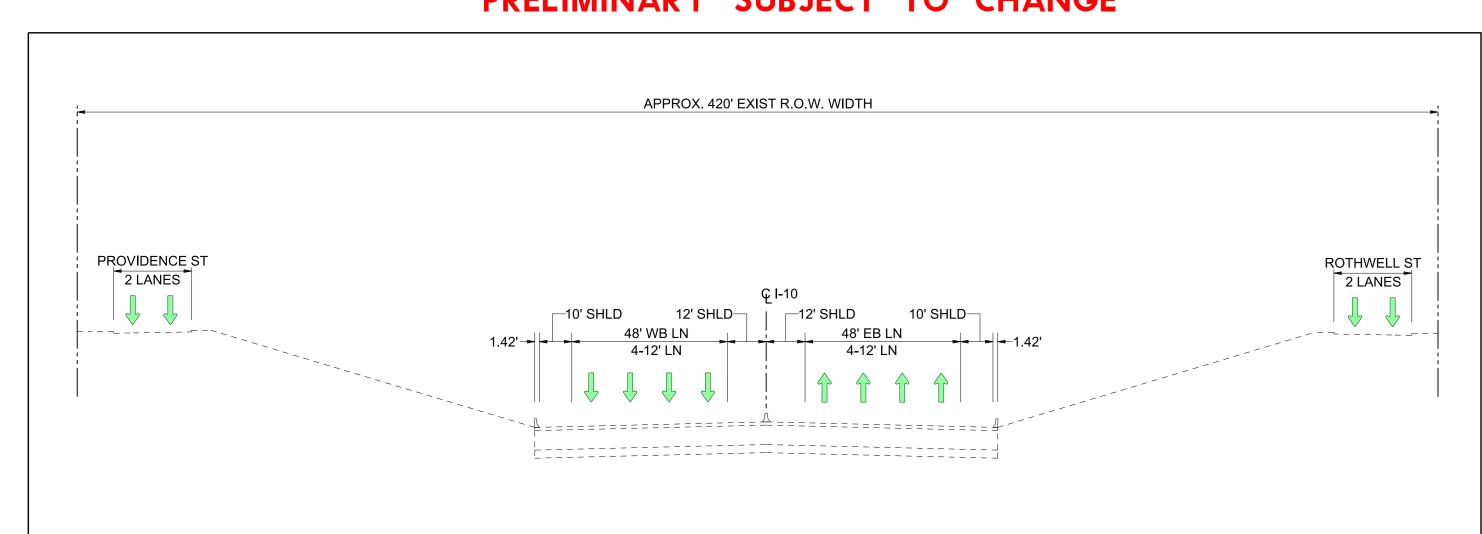




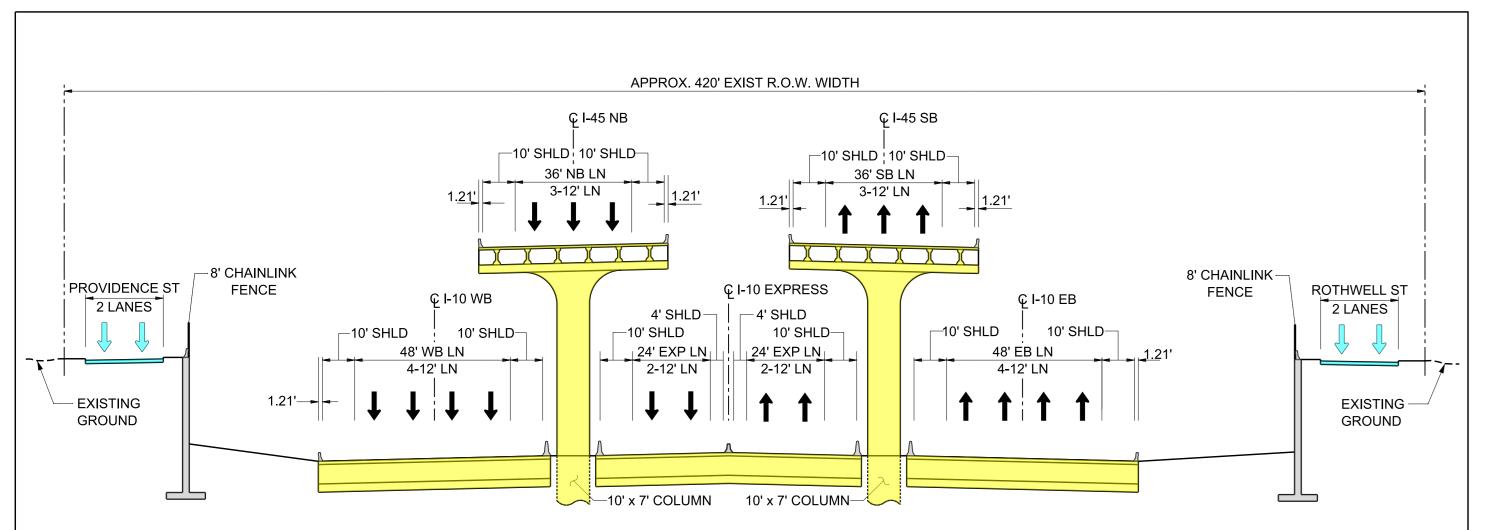




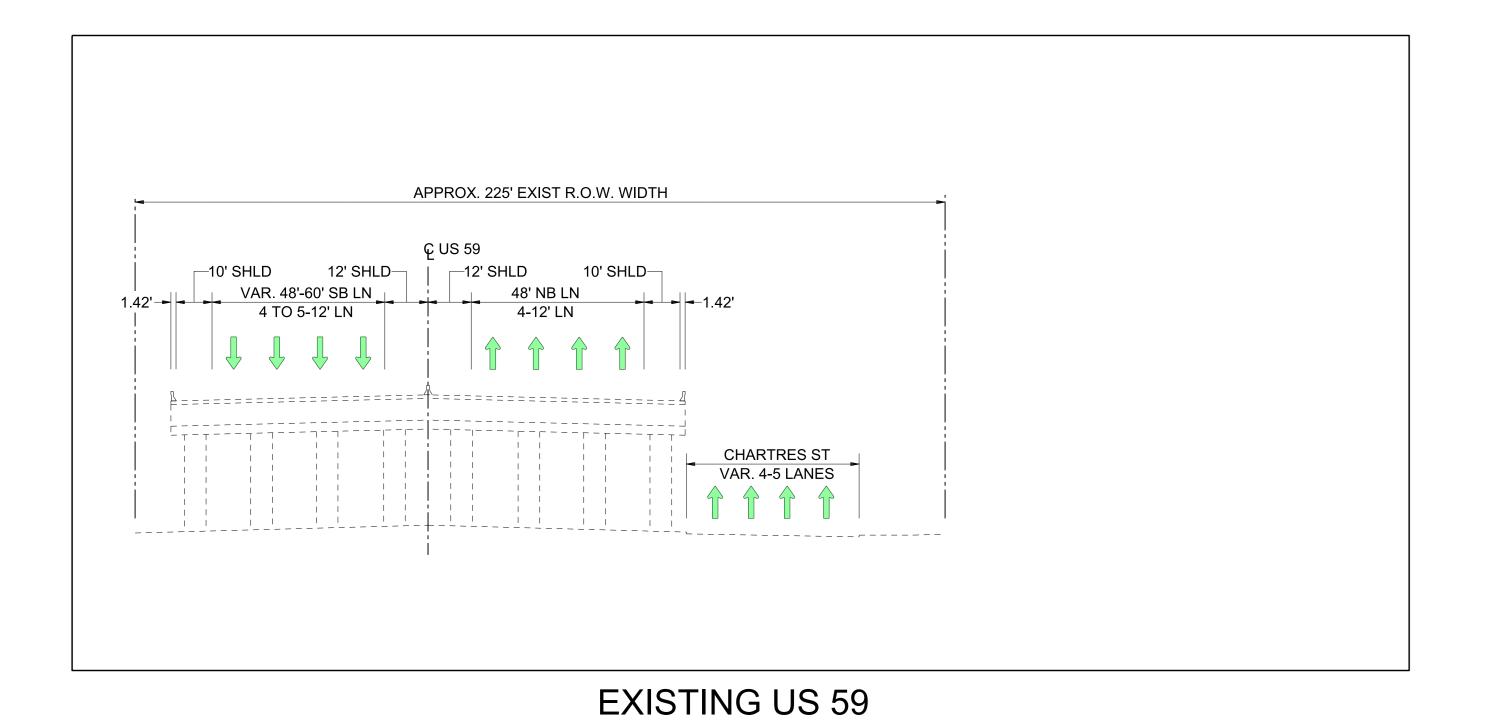


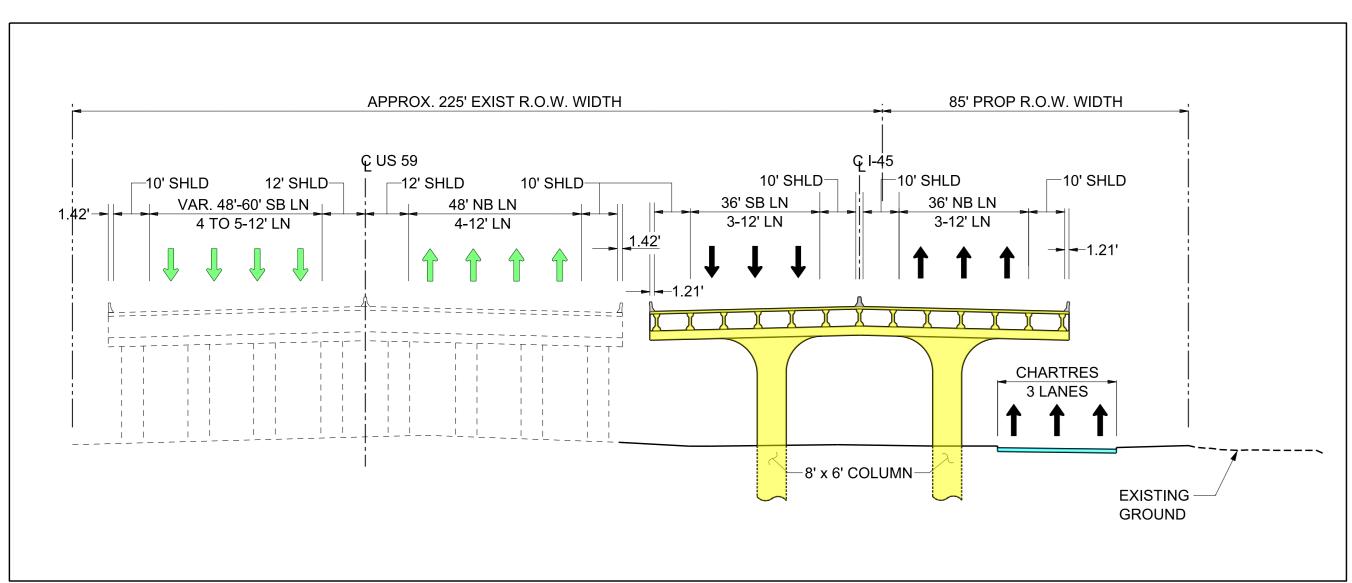


EXISTING I-10 (DEPRESSED SECTION)



PROPOSED I-10 (DEPRESSED SECTION) SECTION A-A



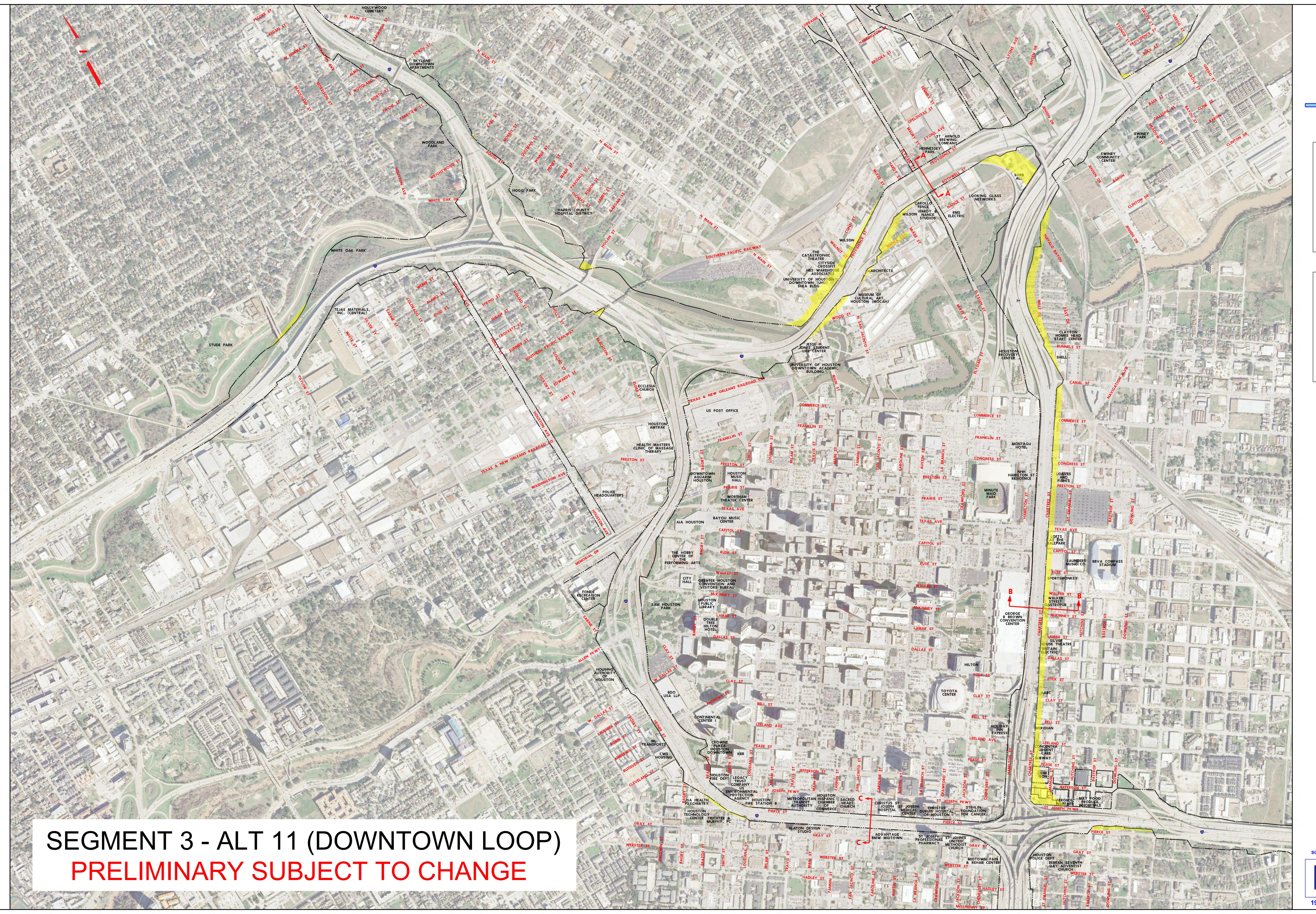


PROPOSED US 5



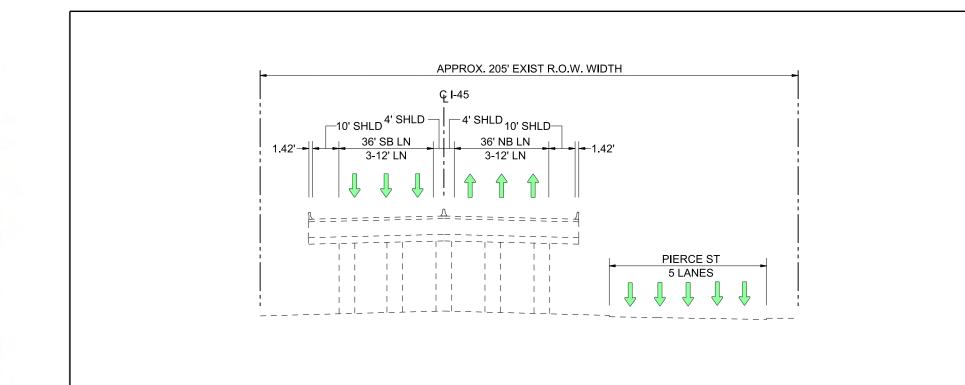
North Houst Highway Improvement P



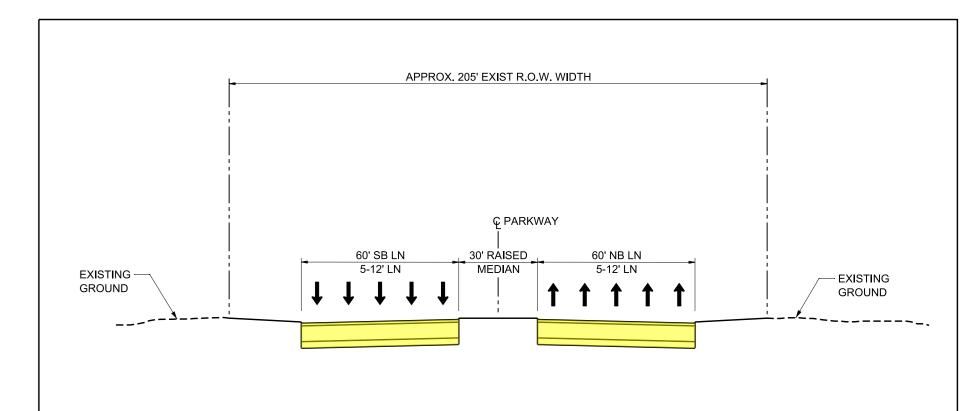




PRELIMINARY SUBJECT TO CHANGE



EXISTING I-45 (PIERCE ELEVATED)



PROPOSED I-45 (PIERCE ELEVATED) SECTION C-C









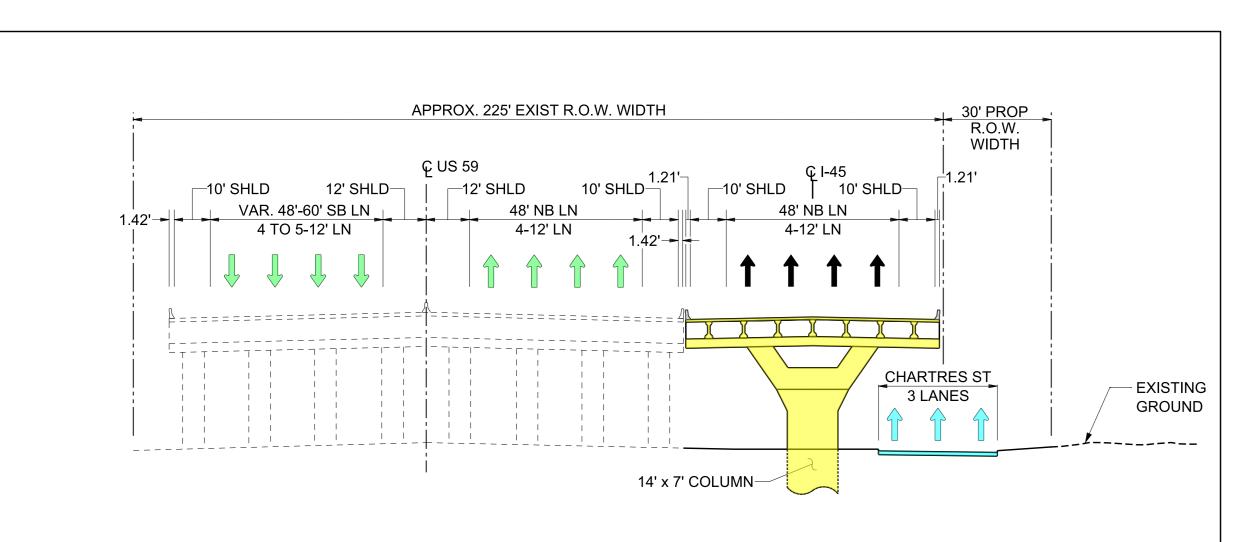


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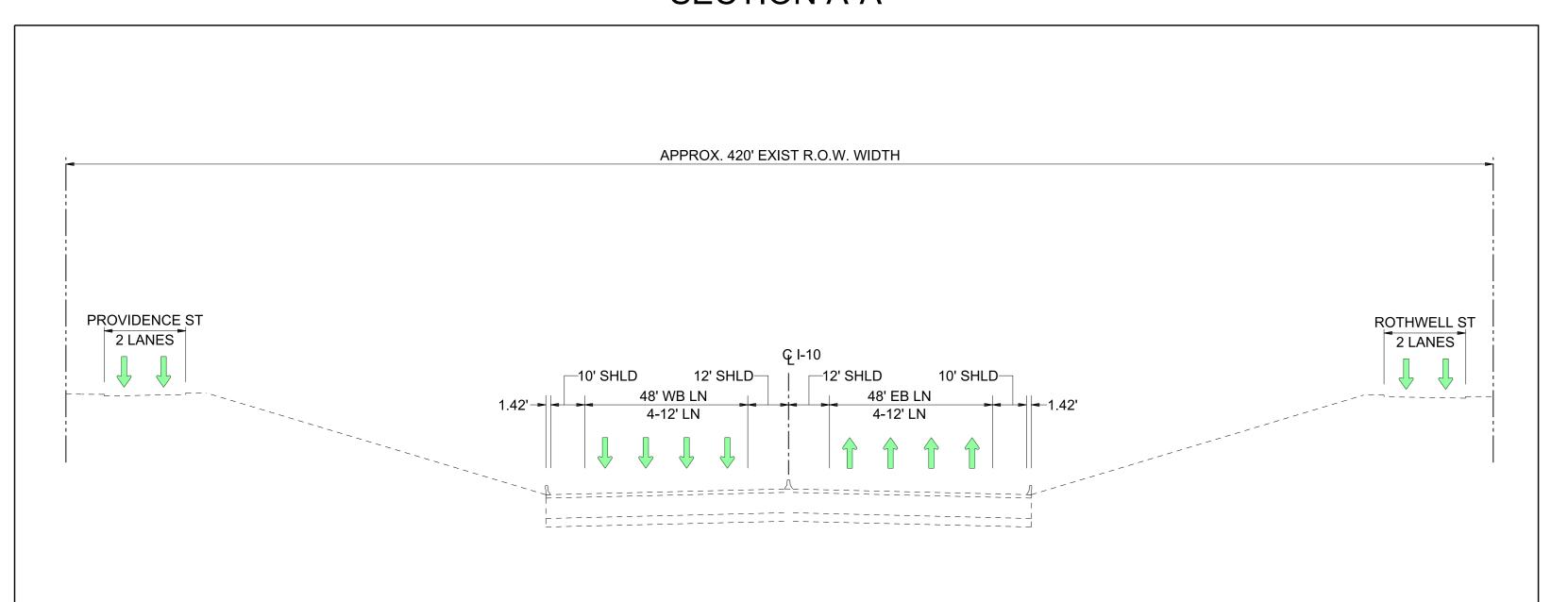
© US 59

10' SHLD
12' SHLD
12' SHLD
48' NB LN
4-12' LN
4-12' LN
CHARTRES ST
VAR. 4-5 LANES

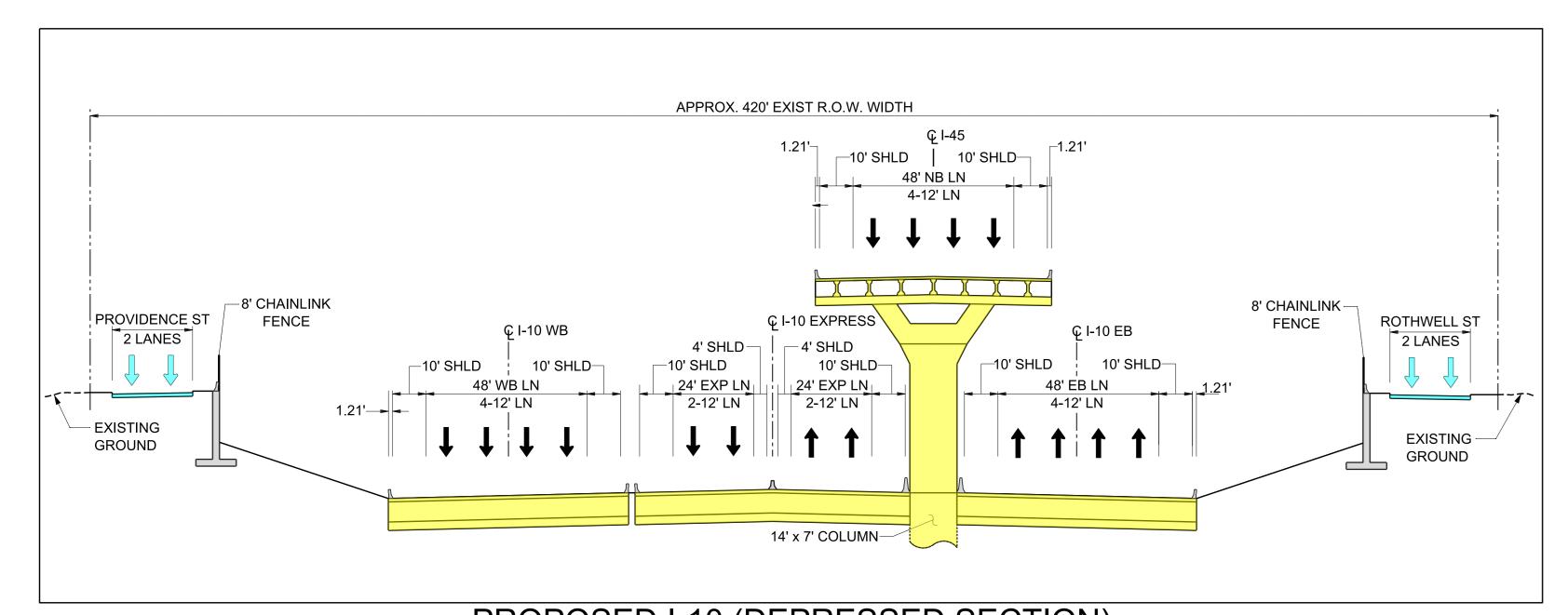
EXISTING US 59



PROPOSED US 59 SECTION A-A



EXISTING I-10 (DEPRESSED SECTION)

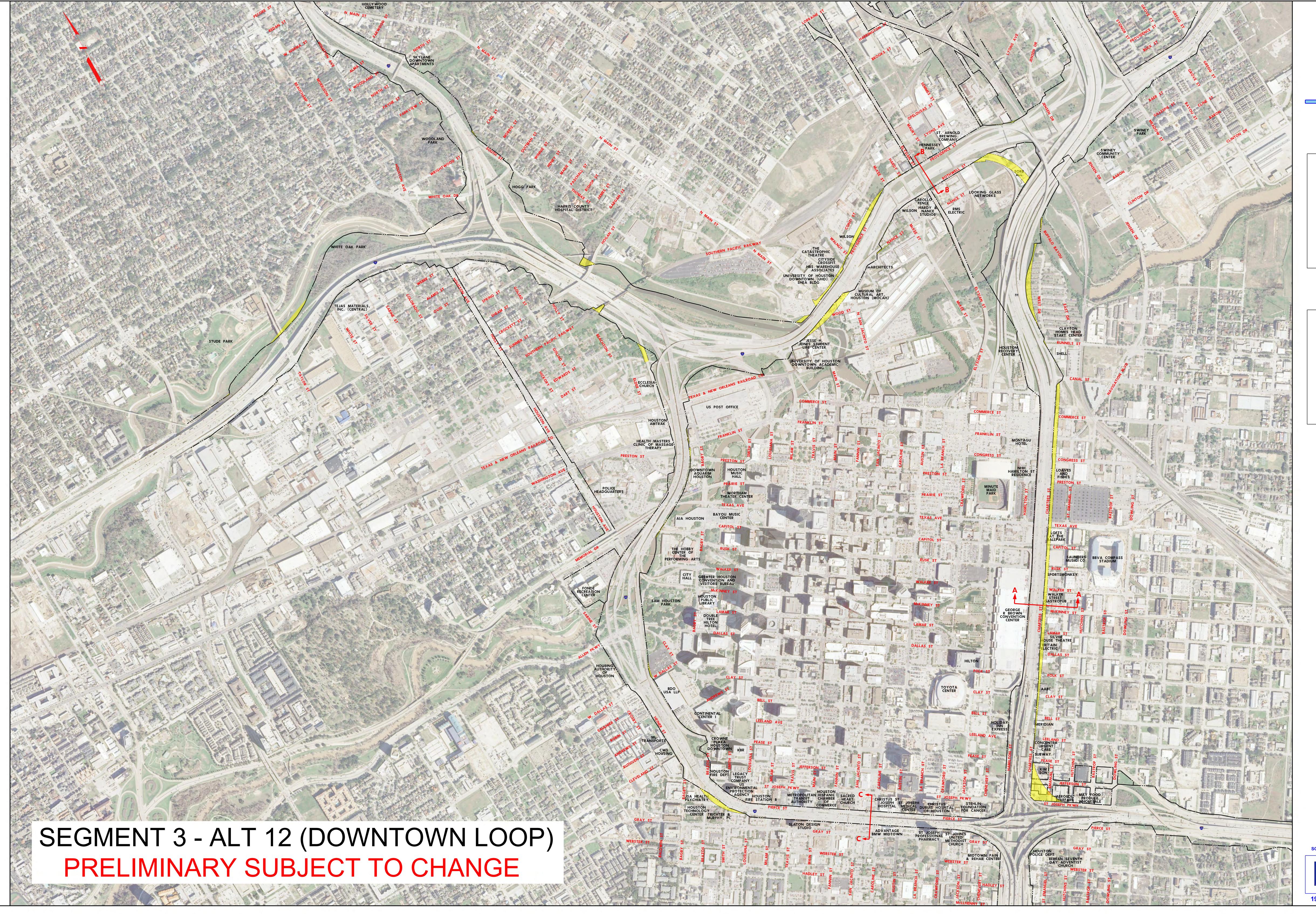


PROPOSED I-10 (DEPRESSED SECTION)

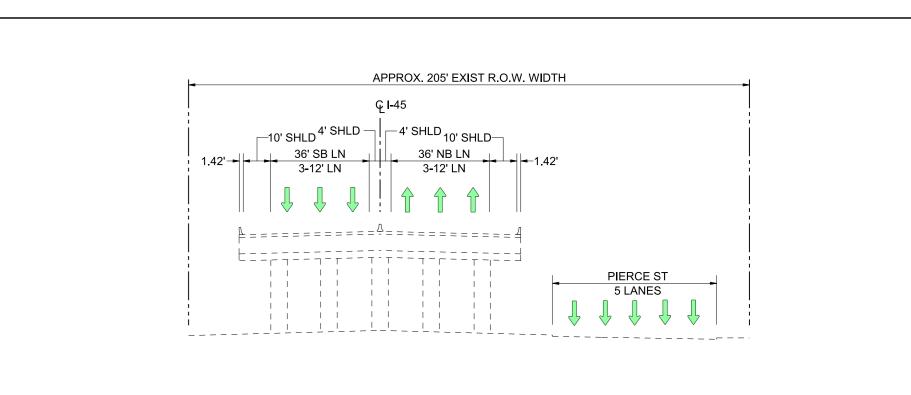
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North Housto Highway Improvement Pr Texas
Department
of Transportation

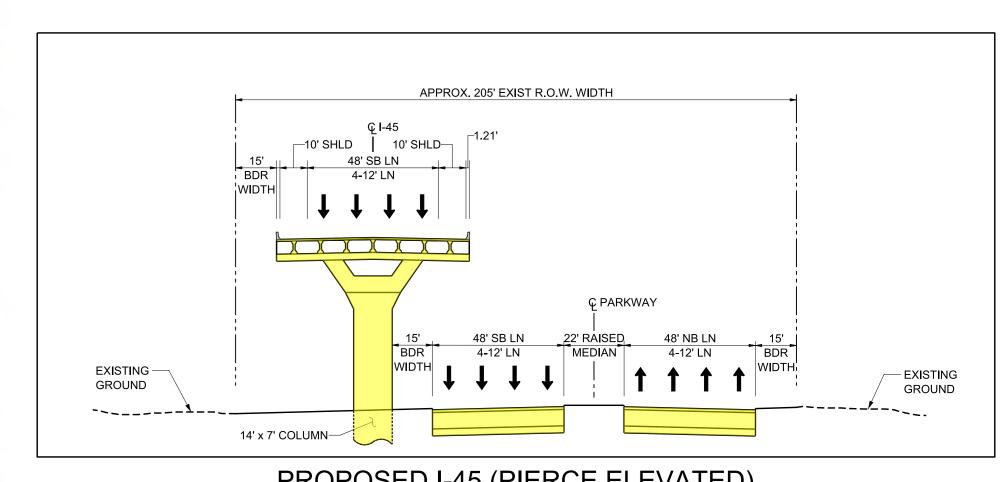
19-NOV-2013







EXISTING I-45 (PIERCE ELEVATED)



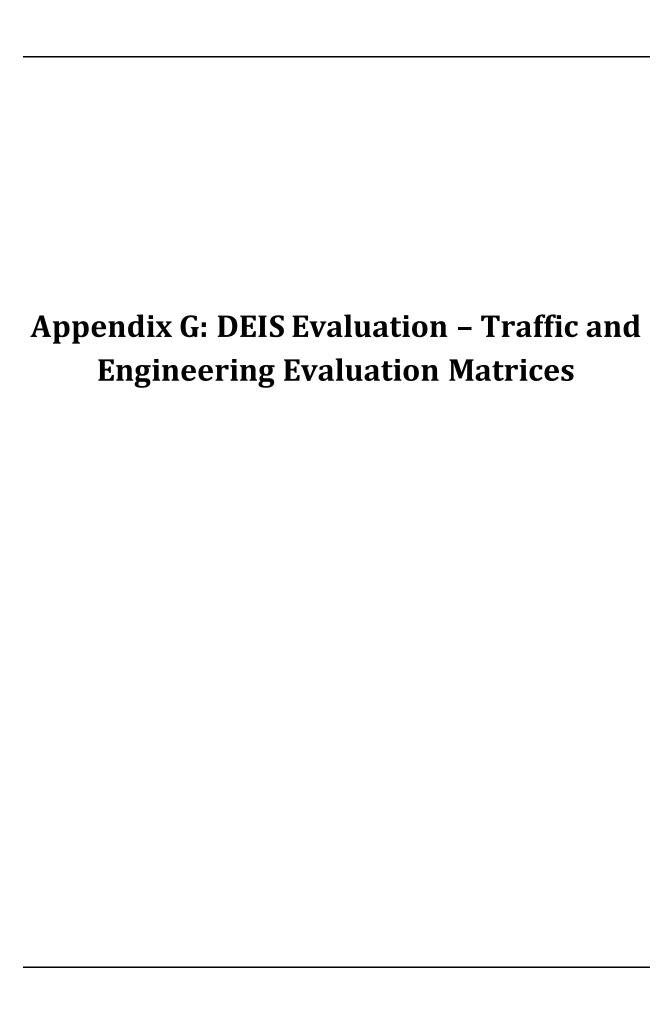
PROPOSED I-45 (PIERCE ELEVATED) SECTION C-C

SCALE: 0 200 400 600 80









Engineering Evaluation Criteria for Recommended Alternatives I-45 Corridor Segment 2 - I-610 to I-10 Engineering Evaluation Criteria: Accessibility

			No Build		Alternative 10		Alternative 11		Alternative 12	
			Baseline		Depressed Managed Lanes		Elevated Managed Lanes		Stacked Managed Lanes	
				se complome	1-4 SOFFREQUED 1-5 SOFFREQUED 1-6 SOFFREQUED 1-6 SOFFREQUED 1-7 SOFFREQUED 1-8 SOFFREQUED 1-8 SOFFREQUED 1-9 SOFFREQUED		H4 30/190/20 H8 NOTIFICADO H4	143 SOTTRECORD FISCH A SOTTRECORD MANAGO LAMS 143 SOTTRECORD MANAGO LAMS 144 SOTTRECORD MANAGO LAMS 144 SOTTRECORD MANAGO LAMS		
Evaluation Sub-Criteria	Description	Rating	Rationale	Rating	Rationale	Rating	Rationale	Rating	Rating Rationale	
Accessibility to Freeway System (Ramping)	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	Desirable	The existing condition includes a fully directional interchange at I-610. 5 northbound ramps and 5 southbound ramps from I-45 to the frontage roads are provided in Segment 2.	Neutral	Alternative 10 includes a fully directional interchange at I-610. Alternative 10 reduces the number of ramps to 3 northbound ramps and 3 southbound ramps from I-45 to the frontage roads. This impacts ease of accessability from the freeway to the frontage roads. Local traffic would utilize the frontage roads while vehicles traveling a longer distance would utilize the frontage roads. This would aid in balancing the traffic volumes between freeway and frontage roads. Managed lanes have no access to frontage for this segment	Neutral	Alternative 11 includes a fully directional interchange at I-610. Alternative 11 includes 4 northbound ramps and 4 southbound ramps from I-45 to the frontage roads. Managed lanes have no access to the frontage roads for this segment	Neutral	Alternative 12 includes a fully directional interchange at I-610. Alternative 12 includes 4 northbound ramps and 4 southbound ramps from I-45 to the frontage roads. Managed lanes have no access to the frontage roads for this segment	
Accessibility to Local Streets	Direct and indirect access to major arterials and minor arterials. This criteria will assess roadway closures, circulation and access to local land use within the corridor.	Neutral	The existing condition include the following 7 roadway crossings of I-45: Stokes St, Link Rd, Cavalcade St, Patton St, Cottage St, N Main St, and North St. The existing condition does not include continuous frontage road through the I-610 interchange, thus limiting the connectivity between the east and west sides of I-45.	Neutral	Alternative 10 includes the same freeway crossings as the existing condition, which include the following 7 roadway crossings of I-45: Stokes St, Link Rd, Cavalcade St, Patton St, Cottage St, N Main St, and North St. Alternative 10 would include continuous I-45 and I-610 frontage roads through the I-45/I-610 interchange. Although the alternative would have a reduced number of the northbound and southbound exit and entrance ramps from I-45, the alternative would balance the traffic using the freeway and frontage roads with the addition of the continuous frontage roads at the I-610 interchange. Local traffic would utilize the frontage roads while vehicles traveling a longer distance would utilize the frontage roads. Manged lanes have no access to local streets	Neutral	Alternative 11 includes the same freeway crossings as the existing condition, which include the following 7 roadway crossings of I-45: Stokes St, Link Rd, Cavalcade St, Patton St, Cottage St, N Main St, and North St. Alternative 11 would include continuous I-45 and I-610 frontage roads through the I-45/I-610 interchange. Alternative 11 reduces the number of ramps by removing the northbound exit ramp and the southbound entrance ramp at Patton St. The slight reduction in ramps could translate into motorists traversing through more signalized intersections to access local streets. Managed lanes have no access to local streets	Neutral	Alternative 12 includes the same freeway crossings as the existing condition, which include the following 7 roadway crossings of I 45: Stokes St, Link Rd, Cavalcade St, Patton St, Cottage St, N Main St, and North St. Alternative 12 would include continuous I-45 and I-610 frontage roads through the I-45/I-610 interchange. Alternative 12 reduces the number of ramps by removing the northbound exit ramp and the southbound entrance ramp at Patton St. The slight reduction in ramps could translate into motorists traversing through more signalized intersections to access local streets. Managed lanes have no access to local streets	
Connectivity to Points of Interest	This criteria will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	Undesirable	With the lack of continuous I-45 and I-610 frontage roads through the interchange, local connectivity is limited and can be considered inconvenient for motorists.	Neutral	With the addition of the continuous frontage roads through the I-45/I-610 interchange connectivity is improved. This alternatives does have slightly limited access from the freeway and no access from managed lanes to the local street network which impedes connectivity to points of interest within Segment 2.	Neutral	With the addition of the continuous frontage roads through the I-45/I-610 interchange connectivity is improved. This alternatives does have slightly reduced access from the freeway to the local street network and no access from managed lanes which impedes connectivity to points of interest within Segment 2.	Neutral	With the addition of the continuous frontage roads through the I-45/I-610 interchange connectivity is improved. This alternatives does have slightly reduced access from the freeway to the local street network and no access from managed lanes which impedes connectivity to points of interest within Segment 2.	
Overa	II Accessibility Rating	Neutral		Neutral		Neutral		Neutral		

5/21/2015 1 of 1

Engineering Evaluation Criteria for Recommended Alternatives I-45 Corridor Segment 3 - I-10 to US-59 Engineering Evaluation Criteria: Accessibility

		N. D. 71							
					No Build Baseline				
			I-45		I-10		US-59		
Evaluation Sub-Criteria	Description	Rating	Rationale	Rating	Rationale	Rating	Rationale		
	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	Undesirable	I-45 currently has fully directional interchange with I-10 and US 59. There are 12 access points along I-45 to and from the downtown area. Access to the managed lane is provided via Travis Street and access to downtown from the managed lane is provided to Milam/Smith. Left exits and exits closely spaced, create weaving and quick decision making on the part of the driver.	Undesirable	I-10 currently has fully directional interchanges with I-45 and US 59. There are 7 access points along I-10 to and from the downtown area. HOV is limited since it goes from near I-10 and I-45 to Franklin St.	Neutral	US 59 currently has fully directional interchanges with I-10, I-45, and SH 288. here are 16 access points along US 59 to and from the downtown area. The US 59 Express currently has access to and from downtown via Jackson St and Chenevert St. There is an HOV Entrance/Exit at Spur 527: Entrance from Milam/W Alabama and Brazos, HOV NB termination at Louisiana/Travis.		
	Direct and indirect access to major arterials and minor arterials. This criteria will assess roadway closures, circulation and access to local land use within the corridor.	Undesirable	Access to western portion of downtown area provided Pierce elevated on I-45 SB. The weaving segments created by the closely spaced exit ramps hinder efficient travel and limit accessibility to local streets.	Neutral	Accessibility between the two sides of I-10, where it runs adajacent and parallel to I-45, is limited due to the 2 freeways and White Oak Bayou. In this area, Crockett/Hogan Street is the only local street that crosses the two freeways. N. Main Street and Houston Avenue are the two adjacent streets that cross I-10. Between I-45 and US 59, I-10 has several crossings due the depressed section in this area.	Neutral	With the existing configuration of US 59 being elevated, connectivity access to local streets under the freeway is provided. Most cross streets connect between the two side of US 59, with the exception of those streets in the vicinity of the George R Brown Convention Center, where streets terminate along the northbound frontage roads.		
Connectivity to Points of Interest	This criteria will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	Neutral	Connectivty between local streets is currenlty provided with the elevated I-45.	Neutral	I-10 currently provides connectivity via ramps and street crossings along the depressed section to points of interest in the northern portion of the downtown vicinity.	Neutral	As motorists exit US 59, the access to the local street system is provided since most of US 59 is elevated in the downtown vicinity. The accessibility to local streets provides connectivity to points of interest in the downtown vicinity.		
C	verall Accessibility Rating	Undesirable		Undesirable		Neutral			

Engineering Evaluation Criteria for Recommended Alternatives I-45 Corridor Segment 3 - I-10 to US-59 Engineering Evaluation Criteria: Accessibility

	T				Alternative 10			
					I-45 Pierce Widening			
			I-45		I-10		US-59	
Evaluation Sub-Criteria	Description	Rating	Rationale	Rating	Rationale	Rating	Rationale	
Accessibility to Freeway System (Ramping)	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	Neutral	I-45 would maintain fully directional interchange with I-10 and US 59. The number of access points to and from the downtown area would increase for northbound. The managed lane access would remain as is. Removal of left exits and improvements on ramp spacing would improve driver's accesibilty to ramps.	Neutral	I-10 would maintain fully directional interchanges with I-45 and US 59. The number of access points to and from the downtown area would increase by point for each direction. There would be a new eastbound exit to Milam and an westbuond entrance from Louisiana from the I-10 managed lanes.	Neutral	US 59 woud maintain fully directional interchanges with I-10, I-45, and SH 288. A new interchange would provide direct access to and from the Hardy extension. The number of access points from NB US 59 would remain the same as existing conditions, while the number of access points for US 59 SB would decrease by two. The managed lane access would remain the same.	
Accessibility to Local Streets	Direct and indirect access to major arterials and minor arterials. This criteria will assess roadway closures, circulation and access to local land use within the corridor.	Neutral	Access to the local streets would be similar to existing conditions. The geometry near Houston Avenue and Allen Parkway would be refined to reduce motorists confusion in that area.	Neutral	Access to the local streets would be similar to existing conditions.	Undesirable	Between San Jacinto and Almeda, five local, existing cross streets (Caroline, Crawford, Cleburne, Eagle, and La Branch) would converted to cul-de-sacs. These road closures may impact motorists traveling to residences and businesses in this vicinity.	
Connectivity to Points of Interest	This criteria will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	Neutral	Only one additional access point along northbound I-45 slightly increases accessibility to the local street system, connectivity to points of interest in the downtown area would increase from the existing conditions.	Neutral	Connectivity and access to points of interest would be similar to existing condistions.	Neutral	Connectivity to George R Brown Convention Center, Toyota Center, Minute Maid Park, and CBD remains similar to existing conditions.	
	Overall Accessibility Rating	Neutral		Neutral		Undesirable		

Engineering Evaluation Criteria for Recommended Alternatives I-45 Corridor Segment 3 - I-10 to US-59

Engineering Evaluation Criteria: Accessibility

		<u> </u>			Alternative 11			
				1	I-45 East Shift			
		1-45			1-10	US-59		
Evaluation Sub-Criteria	Description	Rating	k. ale	Rating	Rationale	Rating	Rationale	
Accessibility to Freeway System (Ramping)	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	Neutral	I-45 would have limited directional interchanges with I-10 and US 59 due to the reconfiguration of I-45. Freeway to freeway direct movements missing from these previously provided movements include: I-45 NB to I-10 EB; I-10 WB to I-45 SB; I-45 SB to US 59 NB I-45 would have freeway to freeway access to and from SH 288 with the following movements: I-45 NB to SH 288 SB; I-45 SB to SH 288 SB; SH 288 NB to I-45 NB; SH 288 NB to I-45 SB. Access to and from the downtown area from I-45 would be reduced from existing conditions. Access to downtown would be provided from elevated connectors from I-45 SB and to I-45 NB. I-45 mainlanes would functions more as a downtown bypass with local access provided by I-10, US 59, and surface streets. The managed lane access would remain as is. Removal of left exits and improvements on ramp spacing would improve driver's accesibility to ramps.	Desirable	I-10 would have a fully directional interchange with US 59 and a limited directional interchange with I-45 due to the reconfiguration of I-45. Freeway to freeway direct movements missing from these previously provided movements include: I-45 NB to I-10 EB: I-10 WB to I-45 SB Access to and from the downtown area from I-10 would increase from existing conditions. There would be five additional access points to and from I-10 EB and three additional access points to and from I-10 WB. There would be a new eastbound exit to Milam and an westbuond entrance from Louisiana from the I-10 managed lanes.	Neutral	US 59 woud have fully directional interchange with I-10 and SH 288. Additionally, US 59 would have direct access to and from the Hardy extension. The direct freeway to freeway between US 59 and I-45 would be slightly limited, the I-45 SB to US 59 NB would not provided and US 59 SB to I-45 NB would be provided via I-10 WB. The movement from I-45 SB to US 59 NB is not provided since I-45 would be shifted to run parallel and adjacent to US-59. The direct freeway to freeway access between US 59 and SH 288 would be limited, the following movements would be provided: US 59 NB to SH 288 NB and SB; US 59 SB to 288 SB; SH 288 NB to US 59 NB and SB. No connectivity between SH 288 SB and US 59 would be provided. Freeway to freeway direct movements to and from US 59 that would not be provided: I-45 SB to US 59 NB, SH 288 SB to US 59 NB and SB. Access to and from the downtown area from US 59 would have two less access point from US 59 SB. The number of access points to and from US 59 NB would remain the same. Access to the area between Main Street and Almeda would have the bigestt change in access with the removal of the SB exit to Fannin. With improvements to SH 288 connectivity to Medical Center , this will be mitigated The US 59 managed lane access would remain as is.	
Accessibility to Local Streets	Direct and indirect access to major arterials and minor arterials. This criteria will assess roadway closures, circulation and access to local land use within the corridor.	Desirable	Accessibility through the downtown local street grid would become critical under Alternative 11 and the realignment of I-45 to the east. Local street access would be similar to existing conditions. W. Dallas Street would no longer connect between the sides of the downtown connector. Overall, removal of the freeway will open up the Downtown area and extends the street system beyond the freeway thus improving overall access and circulation	Desirable	Access to the local streets would be improved in the CBD area with the addition of the connector provided in the vincility of the existing Pierce Elevated. With the realignment of I-TO near Louisiana, some local streets would be closed. Development in this area would be limited due to the freeway's location and constraints due to the bayou and UPRR. Adding managed lanes to downtoen is a plus	Undesirable	In the northern segment of US 59, Runnels/Navigation would not continue under US 59/L45. In this vicinity, Commerce Street would provide connectivty between the east and west sides of US 59. Hamilton, between Ruiz and Bell, would be closed, although the southbound frontage road would provide the same local access as previously provided by Hamilton. Between San Jacinto and Almeda, six local, existing cross streets (Caroline, Crawford, Cleburne, Eagle, Austin, and La Branch) would converted to cul-de-sacs. These road closures may impact motorists traveling to residences and businesses in this vicinity.	
Connectivity to Points of Interest	This criteria will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	Desirable	With the realignment of I-45, the existing connectivity would be significantly different than existing conditions. Connectivity to the northeast portion of downtown would still be provided via the downtown connectors thus accessing multiple downtown streets adn points of interest. Connectivity to the western portion of downtown would be provided via I-10 EB. Connectivity to the southeastern points of interest of downtown would be provided via US 59.	Desirable	Increased access to local street network would improve the connectivity from I-10 to points of interest in the downtown area.	Neutral	Connectivity to George R Brown Convention Center, Toyota Center, Minute Maid Park, and CBD remains similar to existing conditions.	
(Overall Accessibility Rating	Desirable		Desirable	Although two direct freeway to freeway movements would be removed, access would still be available via US 59, which would run parallel to I-45 for a distance. Additional direct access to downtown area would provided from I-10 with Alternative 11 due to the increased number of entrance and exit ramps.	Undesirable		

Engineering Evaluation Criteria for Recommended Alternatives I-45 Corridor Segment 3 - I-10 to US-59 Engineering Evaluation Criteria: Accessibility

			Alternative 12								
					I-45 Split						
			I-45	_	I-10		US-59				
Evaluation Sub-Criteria	Description	Rating	Rationale	Rating	Rationale	Rating	Rationale				
Accessibility to Freeway System (Ramping)	Access provided to local streets and businesses through on and off ramps from the freeway system to the frontage road.	Undesirable	I-10 would have limited directional interchanges with I-45 due to the reconfiguration of I-45. From I-45 NB, a DC would not be provided for I-10 EB. To compensate for this movement, the existing Runnels St ramp would enter I-10 EB. Additionally, direct access to I-10 and I-45 NB is provided in the northeast portion of downtown via Pease and Walker entrance ramps. The direct freeway to freeway access between US 59 and I-45 would be limited by one movement due to the reconfiguration of splitting the I-45 directions. The US 59 SB to I-45 NB movement would not be provided since those two movements would be adjacent and parallel to each other. Access to and from the downtown area would only be provided along I-45 SB, no access points would be provided along I-45 NB. Motorists accessing downtown from I-45 NB, south of the downtown area, would need to take US 59 NB to I-10 EB to have access to local streets. The configuration of split freeway is against driver expectation Access for the managed lanes would remain as is. Removal of left exits and improvements on ramp spacing would improve driver's accessibilty to ramps.	Neutral	I-10 would have a fully directional interchange with US 59. I-10 would have limited directional interchanges with I-45 due to the reconfiguration of I-45. This movement is compensated for with the addition of new entrance ramps. The freeway to freeway movement missing would be I-45 NB to I-10 WB. Access to and from the downtown ara would remain similiar to existing, with the addition of one WB exit ramp.	Neutral	US 59 would have fully directional interchanges with I-10 and SH 288. US 59 would have direct access to and from the Hardy extension. The direct freeway to freeway access between US 59 and I-45 would be limited by one movement due to the reconfiguration of splitting the I-45 directions. The US 59 SB to I-45 NB movement would not be provided since those two movements would be adjacent and parallel to each other. Access to and from the downtown area would remain the same for US 59 NB and would decrease by two access points on US 59 SB.				
Accessibility to Local Streets	Direct and indirect access to major arterials and minor arterials. This criteria will assess roadway closures, circulation and access to local land use within the corridor.	Undesirable	Accessibility to the local street grid would not be directly provided from I-45 NB. Motorists accessing downtown from I-45 NB, south of the downtown area, would need to take US 59 NB to I-10 EB to have access to local streets. Access to the western portion of the downtown area would be provided via I-45 SB. W. Dallas Street would no longer connect between the sides of the downtown connector.	Neutral	Access to the local streets would be similar to existing conditions.	Undesirable	Between San Jacinto and Almeda, five local, existing cross streets (Caroline, Crawford, Cleburne, Eagle, and La Branch) would converted to cul-de-sacs. These road closures may impact motorists traveling to residences and businesses in this vicinity.				
Connectivity to Points of Interest	This criteria will look into the relative degree of connectivity within the corridor to major traffic generators including the level of ease of dispersing of traffic to the various points of interest once the traffic is off the Freeway. High connectivity translates to high accessibility, on the other hand low connectivity translates to low accessibility.	Undesirable	With the realignment of I-45, the existing connectivity would be significantly different than existing conditions. Connectivity to the northeast portion of downtown would still be provided via the downtown connectors. Connectivity to the western portion of downtown would be provided via I-10 EB. Connectivity to the southeastern portion of downtown would be provided via US 59.	Neutral	Connectivity between local streets and ramps would be similar to existing condistions.	Neutral	Connectivity to George R Brown Convention Center, Toyota Center, Minute Maid Park, and CBD remains similar to existing conditions.				
C	Overall Accessibility Rating	Undesirable		Neutral		Undesirable					

Appendix H: Reasonable Alternatives Traffic Screening Methodology and Results

NHHIP Reasonable Alternatives - Traffic Screening Methodology and Results Memo

Traffic and Mobility Impacts

Traffic volume is steadily increasing in the Houston region, as significant development growth continues in the region. Travel demand modeling is a necessary component in evaluating the need for and usage of any transportation improvements, such as widening existing roadways or constructing new freeways.

The North Houston Highway Improvement Project (NHHIP) proposes improvements along I-45 from Beltway 8 into the downtown loop area, including the highways of US 59/I-69 and I-10. Segment 1 in the study area is from Beltway 8 to I-610, Segment 2 is demarcated from I-610 to the interchange of I-10, and Segment 3 is considered the downtown freeway loop system, including I-45, US 59, I-10, with Spur 527 as the southern limit.

The Reasonable Alternatives are evaluated with regards to the potential for each of them to ameliorate traffic conditions in the area. The evaluation criteria used for traffic and mobility impacts are Vehicle Miles Traveled (VMT) in Congestion, Vehicle Hours Traveled (VHT), Average Travel Speed and Managed Lane Utilization. To evaluate the effectiveness of each alternative in improving traffic and mobility conditions, they are compared to the 2035 no build scenario.

For this study, the Houston-Galveston Area Council's 2035 Travel Demand Model (H-GAC TDM) in *Cube Voyager* was utilized. The regional travel demand models are developed and maintained by H-GAC, TxDOT and METRO. The base year (2014) and future year (2035) networks were obtained from H-GAC. The existing and future year networks were both refined to better reflect the existing access and connectivity in the downtown. The regional model was also coded for each of the 2035 alternatives, and the Quarter 3 2014 demographics were used as the socioeconomic inputs for each network.

In addition to a regional level travel demand model analysis which was used to conduct daily model runs for existing and future years to evaluate future travel patterns and demand on various sections of the study corridors, a detailed micro-simulation analysis was also done for Segment 3 of the project.

The speeds in Segment 3, the downtown loop area, are based upon a VISSIM analysis. VISSIM is a time step and behavior based simulation tool to model urban traffic conditions. The VISSIM model was developed for both AM and PM peak period conditions and was utilized to evaluate the operational impacts associated with the transportation improvements in the downtown loop system. Inputs to the VISSIM model included detailed traffic counts conducted by C.J. Hensch and Associates and traffic signal timing plans, obtained from Houston TranStar. The study area for VISSIM incorporates the freeways, access points in the downtown loop area, as well as the interchanges of I-10 and I-45, I-45 and US 59, US 59 and I-10, Spur 527/US 59 and US 59 and US 288.

Evaluation Criteria

Vehicle Miles Traveled (VMT) in Congestion

Vehicle Miles Traveled (VMT) describes the level of travel demand on a highway system and measures the collective distance that all drivers travel. It is calculated by multiplying the number of vehicles on a roadway segment by the length of that segment. When the number of vehicles on a segment begins to reach capacity of that particular segment, congestion occurs and travel time increases. This metric measures the VMT that travel in congested conditions, where the volume of traffic on a roadway exceeds its capacity. Congested segments are those where the volume to capacity ratio is greater than 0.8.

Vehicle Miles Traveled in Congestion (V/C Ratio >0.8): Segments 1 and 2									
SEGMENT 1	Limit 1	Limit 2	No Build VMT	Alternative VMT	% change from No Build				
I-45 (Mainlanes only)	Beltway 8	I-610	2,571,436	2,535,257	-1%				
I-45, BW 8, Hardy, I-45 HOV/ML	Syster	mwide	3,102,627	2,939,315	-5%				
SEGMENT 2	Limit 1	Limit 2							
I-45 (Mainlanes only)	I-610	I-10	510,978	226,225	-56%				
I-45, I-610, Hardy Ext, I-45 HOV/ML	Syster	mwide	599,558	328,146	-45%				

Results of the analysis for Vehicle Miles Traveled only on the congested segments are compared. In Segment 1, Alternatives 4, 5 and 7 show the VMT decreasing from the 2035 no build scenario, both on the mainlanes of I-45 itself as well as on a system-wide level, including the roadways of Beltway 8, Hardy Toll Road and the new managed lanes on I-45. Based on the model output, the VMT in congestion is approximately 3,000,000, a decrease of 3 percent from the 2035 no build scenario.

For Segment 2, the Vehicle Miles Traveled in congestion on the segments significantly decreased in all three Alternatives, 10, 11 and 12, as compared to the no build 2035 scenario. The VMT miles in congestion decreases by 56 percent on I-45 and 45 percent on the segments of I-45, the I-45 HOV lane, I-610 and the Hardy Extension, as compared to the no build.

In Segment 3, all three alternatives show a system-wide increase in the VMT traveled in congested segments. This includes the highways of I-45, I-10, and US 59/I-69. However, when looking at just I-45, Alternative 11 shows a decrease of nearly 20 percent from the No Build condition on I-45.

Vehicle i	Vehicle Miles Traveled in Congestion (V/C Ratio >0.8): Segment 3									
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12				
1-45	I-10	US 59/I-69	773,440	840,034	622,635	826,618				
I-10	I-45	US 59/I-69	119,958	223,243	279,896	183,653				
US 59/I-69	I-10	Spur 527	1,066,153	1,102,657	1,096,270	1,122,768				
I-45, I-10, US 59/I-69	Sy	stemwide	1,959,550	2,165,935	1,998,801	2,133,039				
Percent Change:										
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12				
1-45	I-10	US 59/I-69		9%	-19%	7%				

Vehicle Miles Traveled in Congestion (V/C Ratio >0.8): Segment 3									
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12			
I-10	I-45	US 59/I-69		86%	133%	53%			
US 59/I-69	I-10	Spur 527		3%	3%	5%			
I-45, I-10, US 59/I-69	Sy:	stemwide		11%	2%	9%			

Vehicle Hours Traveled (VHT)

Total daily vehicle hours of travel (VHT) is a function of traffic volume, travel speed and travel distance. This measure is representative of the total amount of travel time in hours that motorists spend traveling in their vehicles. The lower the VHT, the less time drivers are spending getting to their destinations. The percentage decrease from the 2035 no build scenario is used to compare how each alternative improves mobility conditions.

Vehic	le Hours Trave	eled: Segme	nts 1 and 2		
SEGMENT 1	Limit 1	Limit 2	No Build VHT	Alternative VHT	% change from No Build
I-45 (Mainlanes only)	Beltway 8	I-610	57,354	55,351	-3%
I-45, BW 8, Hardy, I-45 HOV/ML	System	nwide	79,341	83,335	5%
SEGMENT 2					
I-45 (Mainlanes only)	I-610	I-10	11,700	10,735	-8%
I-45, I-610, Hardy Ext, I-45 HOV/ML	System	nwide	19,341	20,750	7%

In Segment 1, the alternatives show a decrease in VHT on the I-45 mainlanes of about 3 percent. System-wide, however, the alternatives show a slight increase of 5 percent, when combining the VHT for I-45 mainlanes, Beltway 8, Hardy Toll Road and the I-45 managed lanes. Segment 2 shows a similar pattern, with the VHT on I-45 decreasing by 8 percent as compared to the no build, but increasing system-wide by 7 percent.

	Vehicle Hours Traveled: Segment 3										
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12					
I-45	I-10	US 59/I-69	21,208	21,146	16,995	20,564					
I-10	I-45	US 59/I-69	12,276	12,705	13,591	12,617					
US 59/I-69	I-10	Spur 527	28,510	30,433	29,400	29,866					
I-45, I-10, US 59/I-69	Syst	emwide	61,994	64,283	59,986	63,048					
Percent Change:											
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12					
I-45	I-10	US 59/I-69		0%	-20%	-3%					
I-10	I-45	US 59/I-69		3%	11%	3%					
US 59/I-69	I-10	Spur 527		7%	3%	5%					
I-45, I-10, US 59/I-69	Syst	emwide		4%	-3%	2%					

In Segment 3, Alternative 11 fares the best out of the three alternatives. Overall, it shows a system-wide decrease of 3 percent as compared to the no build. While I-10, US 59/I-69 show a slight increase in VHT for Segment 3 in Alternative 11, the I-45 shows a decrease of -20 percent. The other alternatives both show an increase system-wide.

Average Travel Speed

Speed is a function of the vehicle miles traveled divided by the vehicle hours of travel. Reducing travel demands or increasing capacity on roadways can affect the average travel speeds. This measure is an indicator of the delay on the system – higher speeds reflect better system performance. The less congestion, the faster the average travel speeds.

	Model	Speeds			
SEGMENT 1	Limit 1	Limit 2	No Build Speed (mph)	Alternative Speed (mph)	% change from No Build
I-45 (Mainlanes only)	Beltway 8	I-610	45	46	2%
I-45, BW 8, Hardy, I-45 HOV/ML	Systen	nwide	47	48	3%
SEGMENT 2					
I-45 (Mainlanes only)	I-610	I-10	48	49	1%
I-45, I-610, Hardy Ext, I-45 HOV/ML	Systen	nwide	51	52	2%

In Segments 1 and 2, speed is evaluated through using the metrics found in the H-GAC TDM; for Segment 3, the results are from the VISSIM analysis. VISSIM is a software program that allows for a finer level of analysis on each of the highway segments and ramps/access points in the study area for Segment 3. The VISSIM analysis is an operational study and gives more detailed information about delay.

In Segments 1 and 2, the alternatives show a slight improvement over the 2035 No Build condition. The average travel speeds in segments 1 and 2 for the alternatives only change marginally, about 1 or 2 miles per hour on both I-45 and systemwide, as compared to the no build.

	VISSIM Model Speeds: Segment 3											
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12						
I-45	I-10	US 59/I-69	42	38	52	50						
I-10	I-45	US 59/I-69	27	32	44	24						
US 59/I-69	I-10	Spur 527	21	32	50	24						
I-45, I-10, US 59/I-69	Sys	stemwide	26	34	49	25						
Percent Change:												
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12						
I-45	I-10	US 59/I-69		-10%	24%	19%						
I-10	I-45	US 59/I-69		19%	63%	-11%						
US 59/I-69	I-10	Spur 527		52%	138%	12%						
I-45, I-10, US 59/I-69	Sys	stemwide		31%	88%	-4%						

The speeds in Segment 3 are evaluated based upon the VISSIM analysis. To develop the speeds, count data and growth rates from the travel demand model were used. The base year 2011 count data collected by CJ Hensch were used as a base and then extrapolated to the future year using the growth rates between the 2014/2035 NB/2035 Alternatives in the H-GAC travel demand model to estimate volumes. The volumes were fed into the VISSIM model, which then calculated the speeds.

The biggest change in speeds is visible mostly in Segment 3. In Alternative 10, the speed decreases slightly on I-45, and in Alternative 12, speeds decrease on I-10. However, all other highways show an improvement in speed across the other alternatives. The biggest change can be seen on US 59/I-69 in Alternative 11, where speeds increase from 21 mph in the 2035 No Build to a projected 50 mph. Other notable improvements are along I-10, where speeds are projected to increase from 27 mph to 44 mph in Alternative 11, and an increase from 21 to 50 mph on US 59/I-69 in Alternative 10.

Alternative 11 shows the greatest improvement in speeds for a number of reasons. Firstly, the capacity increases, which ameliorates congestion. The separation of I-45 into local and through traffic helps with the distribution of traffic; this split of traffic also eliminates merges and vehicles switching lanes while entering and exiting the roadway. In particular, the congestion at the Allen Parkway ramp is eliminated with Alternative 11, as the merge is eliminated. The reconfiguration of the direct connectors between I-10 and I-45 also increases systemwide speeds; the direct connector to I-45 southbound (from I-10 westbound) is eliminated, and I-10 WB three lanes east of the I-45 connection, thus there is little congestion on that segment, as compared to the no build scenario. The roadway which sees the greatest improvement in the system is US 59, showing an almost 140 percent increase in speeds. The main reason for this is the elimination of the "chicken merge" where the traffic bottlenecks on US 59 between SH 288 and I-45. In addition, the added capacity also helps with the speeds along US 59.

Alternative 11 fares better than the other two alternatives when evaluating systemwide speeds on Segment 3 because it fundamentally changes traffic patterns such that key bottleneck points are eliminated, thus reducing delay.

Managed Lane Utilization

This measure determines the utilization of managed lanes based on travel demand and capacity. If the added capacity is underutilized, then capacity exceeds demand. If the added capacity is over-utilized, then demand exceeds capacity. Optimal utilization is desirable, which is achieved by balancing capacity and demand. Utilization under 60 percent is considered undesirable, ideal utilization is between 60 percent and 80 percent; this shows that the managed lanes are being utilized without being overburdened.

Managed Lane Utilization										
Managed Lane Roadway	Segment 1	Segment 2	Seg 3: Alt. 10	Seg 3: Alt. 11	Seg 3: Alt. 12					
I-45 Managed Lanes	67%	65%	N/A	N/A	N/A					
I-10 Express Lanes	N/A	N/A	29%	32%	31%					

Segment 1 and Segment 2 show the I-45 managed lanes in each alternative to be between 60 and 70 percent. This is adequate; however, the I-10 Express lanes in Segment 3 show poor utilization in all alternatives. At below 40 percent, these managed lanes are not being utilized to their capacity,

indicating that they are potentially a poor investment. The express lanes for Segment 3 only divert traffic traveling through downtown Houston; from a regional perspective, they would be more effective and heavily utilized if they were connected to I-610.

Segment 2 Traffic Evaluation

				•	
V/C Ratio >0.	.8)				
Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-610	I-10	510,978	168,468	315,119	241,793
Systemwide		599,558	291,601	436,852	364,227
Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-610	I-10		-67%	-38%	-53%
Syst	temwide		-51%	-27%	-39%
	Limit 1 I-610 Syst Limit 1 I-610	I-610 I-10 Systemwide Limit 1 Limit 2	Limit 1 Limit 2 2035 NB I-610 I-10 510,978 Systemwide 599,558 Limit 1 Limit 2 2035 NB I-610 I-10	Limit 1 Limit 2 2035 NB Alt. 10 I-610 I-10 510,978 168,468 Systemwide 599,558 291,601 Limit 1 Limit 2 2035 NB Alt. 10 I-610 I-10 -67%	Limit 1 Limit 2 2035 NB Alt. 10 Alt. 11 I-610 I-10 510,978 168,468 315,119 Systemwide 599,558 291,601 436,852 Limit 1 Limit 2 2035 NB Alt. 10 Alt. 11 I-610 I-10 -67% -38%

Vehicle Hours Traveled						
SEGMENT 2	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-610	I-10	11,700	10,946	10,831	10,889
I-45, I-610, Hardy Ext, I-45 HOV/ML	Syst	temwide	19,341	20,762	20,970	20,866
Percent Change:						
SEGMENT 2	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-610	I-10		-6%	-7%	-7%
I-45, I-610, Hardy Ext, I-45 HOV/ML	Syst	temwide		7%	8%	8%

Model Speeds						
SEGMENT 2	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-610	I-10	48	49	49	49
I-45, I-610, Hardy Ext, I-45 HOV/ML	Syst	temwide	51	52	52	52
Percent Change:						
SEGMENT 2	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-610	I-10		2%	1%	1%
I-45, I-610, Hardy Ext, I-45 HOV/ML	Syst	temwide		2%	2%	2%

Managed Lane Utilization						
SEGMENT 2	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45 ML	I-610	I-10		67%	61%	64%

	Vehicle Miles Traveled in Congestion							
SEGMENT 2	Alt. 10	Alt. 11	Alt. 12					
I-45	D	D	D					
Systemwide	D	D	D					
	3	3	3					
	3	3	3					
	3	3	3					

	Vehicle Hours Traveled								
SEGMENT 2	Alt. 10	Alt. 11	Alt. 12						
I-45	D	D	D						
Systemwide	U	U	U						
	3	3	3						
	1	1	1						
	2	2	2						

	Model Speeds		
SEGMENT 2	Alt. 10	Alt. 11	Alt. 12
I-45	N	N	N
Systemwide	N	N	N
	2	2	2
	2	2	2
	2	2	2
	Managed Lane l	Jtilization	
SEGMENT 2	Alt. 10	Alt. 11	Alt. 12
I-45 ML	D	D	D

Segment 3 Traffic Evaluation

Vehicle Miles Traveled in Co	ongestion (V/	C Ratio >0.8)				
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-10	US 59/I-69	773,440	840,034	622,635	913,041
I-10	I-45	US 59/I-69	119,958	223,243	279,896	420,542
US 59/I-69	I-10	Spur 527	1,066,153	1,102,657	1,096,270	1,265,234
I-45, I-10, US 59/I-69	Sys	Systemwide		2,165,935	1,998,801	2,598,817
Percent Change:						
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-10	US 59/I-69		9%	-19%	18%
I-10	I-45	US 59/I-69		86%	133%	251%
US 59/I-69	I-10	Spur 527		3%	3%	19%
I-45, I-10, US 59/I-69	Sys	temwide		11%	2%	33%

Vehicle Hours Traveled						
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-10	US 59/I-69	21,208	21,146	16,995	22,239
I-10	I-45	US 59/I-69	12,276	12,705	13,591	13,753
US 59/I-69	I-10	Spur 527	28,510	30,433	29,400	35,685
I-45, I-10, US 59/I-69	Sys	temwide	61,994	64,283	59,986	71,677
Percent Change:						
Percent Change: SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
•	Limit 1	Limit 2 US 59/I-69	2035 NB	Alt. 10	Alt. 11 -20%	Alt. 12 5%
SEGMENT 3	-		2035 NB			-
SEGMENT 3 1-45	I-10	US 59/I-69	2035 NB	0%	-20%	5%

Model Speeds						
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-10	US 59/I-69	42	38	52	50
I-10	I-45	US 59/I-69	27	32	44	24
US 59/I-69	I-10	Spur 527	21	32	50	24
I-45, I-10, US 59/I-69	Sys	Systemwide		34	49	25
Percent Change:			-			
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-45	I-10	US 59/I-69		-10%	24%	19%
I-10	I-45	US 59/I-69		19%	63%	-11%
US 59/I-69	I-10	Spur 527		52%	138%	12%
I-45, I-10, US 59/I-69	Sys	temwide		31%	88%	-4%

Managed Lane Utilization						
SEGMENT 3	Limit 1	Limit 2	2035 NB	Alt. 10	Alt. 11	Alt. 12
I-10 ML	I-45	US 59/I-69		29%	32%	38%

	Vehicle Miles Traveled in Congestion		
SEGMENT 3	Alt. 10	Alt. 11	Alt. 12
I-45	U	D	U
I-10	U	U	U
US 59/I-69	N	N	N
Systemwide	U	N	U
	1	3	1
	1	1	1
	2	2	2
	1	2	1
	5	8	5
	1.25	2	1.25

	Vehicle Hours Traveled		
SEGMENT 3	Alt. 10	Alt. 11	Alt. 12
I-45	N	D	N
I-10	N	U	N
US 59/I-69	U	N	U
Systemwide	N	D	N
	2	3	2
	2	1	2
	1	2	1
	2	3	2
	7	9	7
	1.75	2.25	1.75

	Model Speeds			
SEGMENT 3	Alt. 10	Alt. 11	Alt. 12	
I-45	U	D	D	
I-10	D	D	U	
US 59/I-69	D	D	N	
Systemwide	D	D	U	
	1	3	3	
	3	3	1	
	3	3	2	
	3	3	1	
	10	12	7	
	2.5	3	1.75	
	Managed Lane U	Itilization		
SEGMENT 3	Alt. 10	Alt. 11	Alt. 12	
I-10 ML	U	U	U	
	1	1	1	

EGMENT 3	Alt. 10	Alt. 11	Alt. 12
I-10 ML	U	U	U
	1	1	1
	23	30	20
	1.8	2.3	1.5