CEG 4850 Capstone Geotechnical and Transportation Engineering Design
University of South Florida – City of Palmetto, FL
Community Sustainability Partnership Program, Spring 2017

City of Palmetto Transportation Master Plan

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Executive Summary

The University of South Florida's Capstone Transportation and Geotechnical Engineering Design had the pleasure of working with the City of Palmetto and CSPP to enhance the design of the US 301 and US 41 diamond interchange, as well as US 301 signalized intersections from 8th Avenue to Haben/12th Boulevard, spanning 1.3 miles. With the aid of Professor Qing Lu, Bijan Behzadi, local firms and the Florida Department of Transportation, the capstone team came up with a comprehensive project development and environmental plan that encompasses traffic simulation, traffic calculations, and two alternative roadway designs to support the future of Palmetto City. After a time span of four months, the USF Capstone Transportation and Geotechnical Engineering Design teams present to you this comprehensive report.

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List of Abbreviations

Abbreviation	Definition
AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ARMI	Asphalt Rubber Membrane Interlayer
CSPP	Community Sustainability Partnership Program
DG	Dense Graded
DR	Design Thicknesses
EPIM	Environmental Permit Information Manual
ESAL	Equivalent Single Axle Load
FDOT	Florida Department of Transportation
LBR	Limerock Bearing Ratio
LCCA	Life Cycle Cost Analysis
MReff	Effective Modulus
MSE	Mechanically Stabilized Earthwalls
OG	Open Graded
PSI	Present Serviceability Index
SN	Structural Number
TSIS	Traffic Software Integrated System

Project Development & Environment

1. Introduction

1.1 Project Overview

The goal for this project is to alleviate existing congestion along the US 301 corridor at the intersections of 8th Street, 6th Street, Haben Boulevard/12th Street, as well as the ramp terminals of US 41. Issues occur primarily at the Walmart entrance, because the entrance is located too close to the US 41 northbound ramps influence zone. Utilizing project development and environment (PD&E) technologies such as Traffic Software Integrated System (TSIS) and Excel, it was determined that relocating the Walmart intersection 600 feet east to Palm 2nd and widening the driveway to accommodate the incoming vehicle traffic and truck traffic would raise the level of service. The existing Walmart driveway will be converted to a right-in/right-out driveway. There will be additional left turn lanes added throughout the project limits at the following locations:

- US 301 EB & proposed Walmart entrance
- US 301 WB & US 41 SB on ramp
- US 301 WB & 8th Avenue.

US 301 will be widened from a 4-lane median divided to a 6-lane divided urban arterial. The US 301 corridor has varied lane widths of 11 and 12 feet with continuous curb and gutter, with fully functioning existing 5-foot bike lanes and sidewalks. The US 41 typical section will not change.

Figure 1. Project Location Map

As depicted in Figure 1, the yellow resembles US 301 and the red resembles US 41. As shown, the study begins at 8th Avenue and ends at 12th Avenue/Haben. The scale is set to 500 feet as shown in the right-hand bottom corner.

2. Existing Conditions

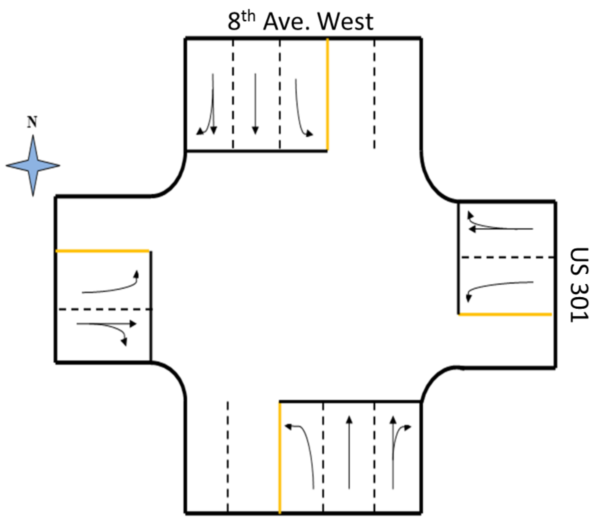

Figure 2. US 301 & 8th Avenue

This intersection is located west of US 41 and the railroad. The street running east and west is 10th Street West, also known as US 301. The north and southbound street, 8th Avenue West is best known as Business 41, which turns into a bridge south of the intersection. This intersection resides in Manatee County, Palmetto. Some issues with the intersection include: poor level of service, minimum right-of-way, heavy traffic south towards the US 41 overpass, and there are only two southbound lanes while the northbound has three.

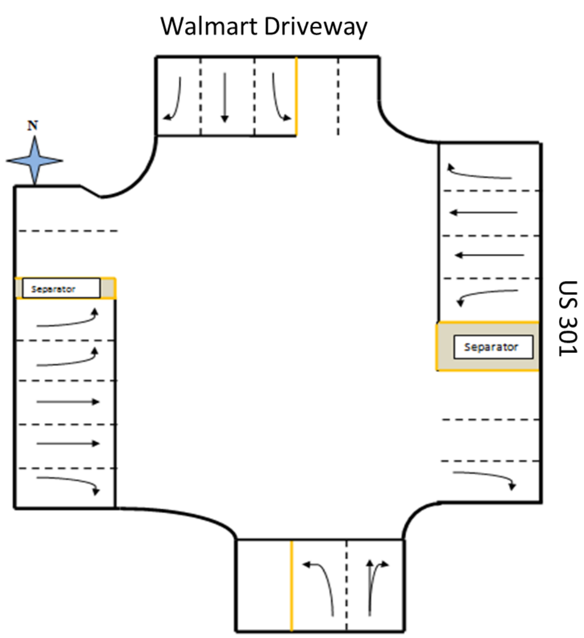

Figure 3. US 301 & Walmart Driveway

This intersection lies just to the east of US 41 Northbound ramps. The street running east and west is 10th Street West, also known as US 301. North of the intersection is Walmart and south of the intersection is a strip mall. This intersection resides in Manatee County, Palmetto. Some issues with the intersection include: poor level of service, and low weaving distance.

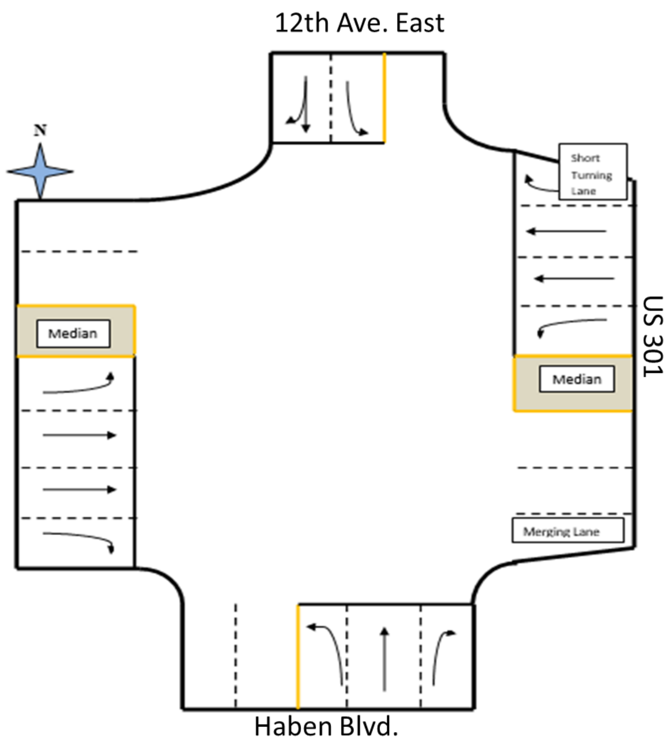

Figure 4. US 301 & Haben Boulevard/12th Avenue

This intersection lies east of US 41. The street running east and west is 10th Street West, also known as US 301. North of the intersection is 12th Avenue East and south of the intersection is Haben Boulevard. This intersection resides in Manatee County, Palmetto. Some issues with the intersection include: poor level of service, minimum right-of-way, heavy traffic east towards US 41 and west from US 41, as well as heavy right hand turn traffic from Haben Blvd.

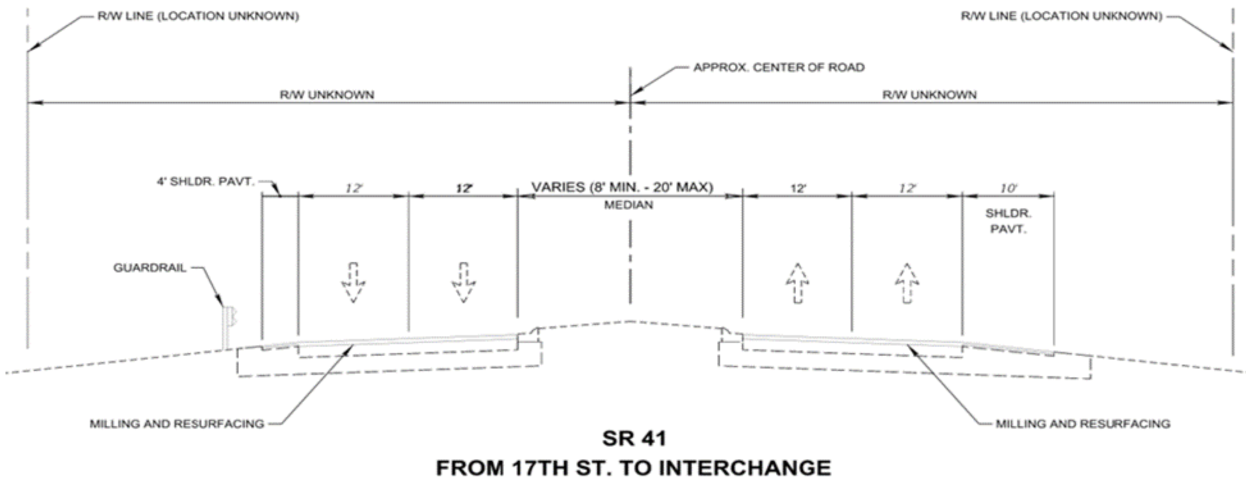

Figure 5. 17th St. to US 41

North of the US 41 and US 301 diamond interchange, US 41 is a four-lane divided highway with 12 foot lanes. The speed limit is 50 mph, and the corridor is classified as a Principle Arterial Highway. The northbound roadway as 10 foot paved shoulders, and the southbound roadway has 4 foot paved shoulders. The southbound roadway has guardrail, and the median is of varying width.

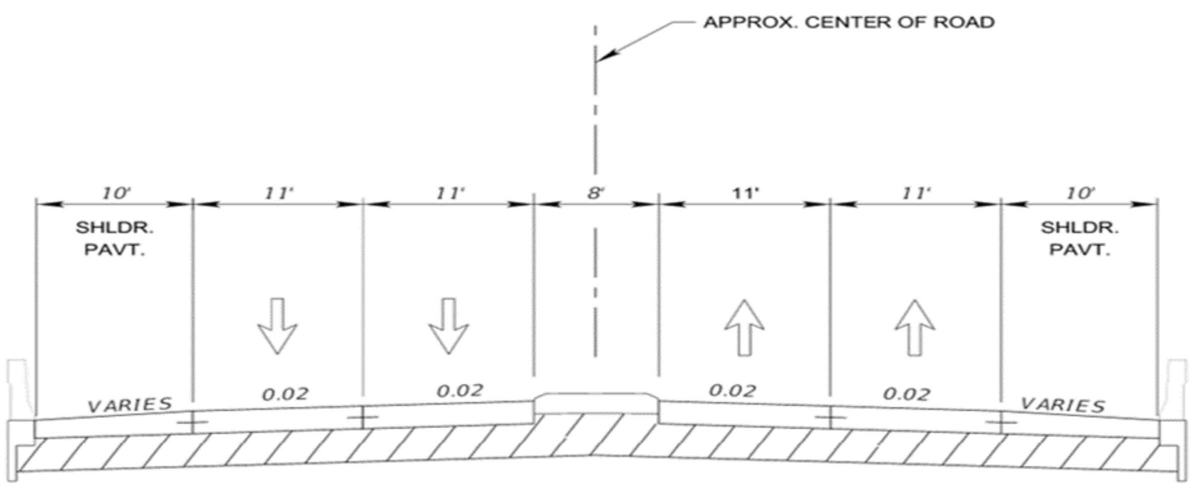

Figure 6. US 41 Bridge over US 301

As US 41 passes over US 301, lane widths are reduced from 12 feet to 11 feet. An 8-foot concrete barrier median is introduced to divide the roadway. Both the northbound and southbound roadways have a 10-foot paved shoulder. The northbound and southbound roadways both have a 2% grade.

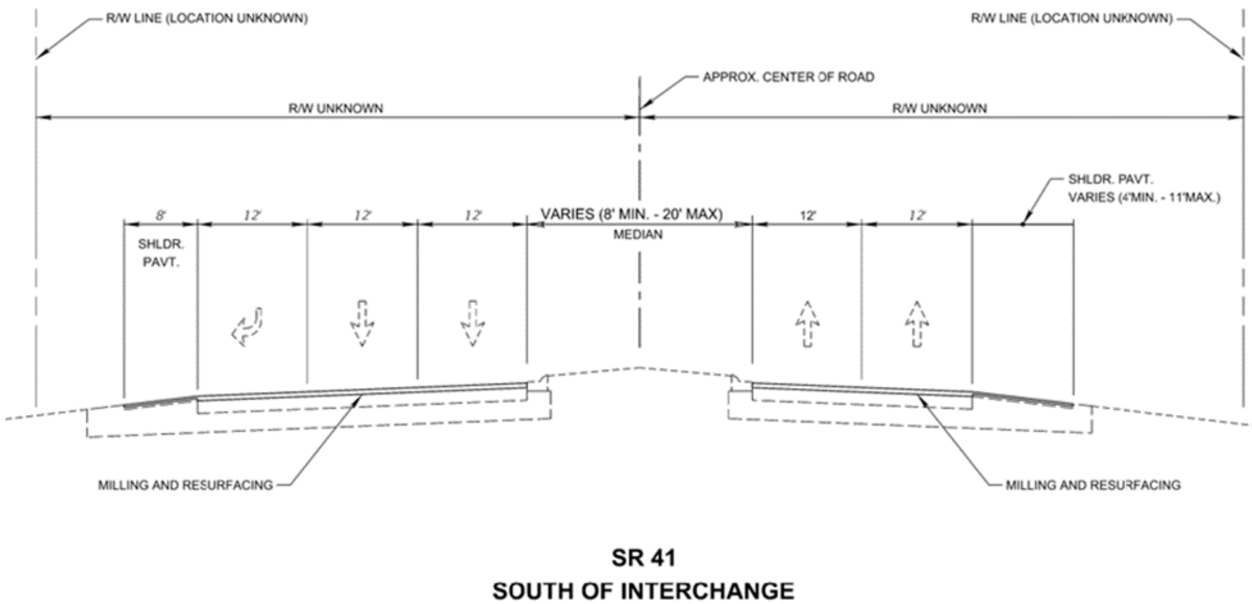

Figure 7. South of US 41 & US 301 Interchange

South of the US 41 and US 301 diamond interchange, following the US 41 overpass, lane widths transition to 12 feet, as the north of the interchange. A right turn lane is introduced to the southbound roadway. The concrete barrier median ends with the overpass, and a varying median is introduced. The southbound roadway has an 8-foot paved shoulder, while the northbound roadway has a paved shoulder of varying width.

2.1 Turning Movement Counts

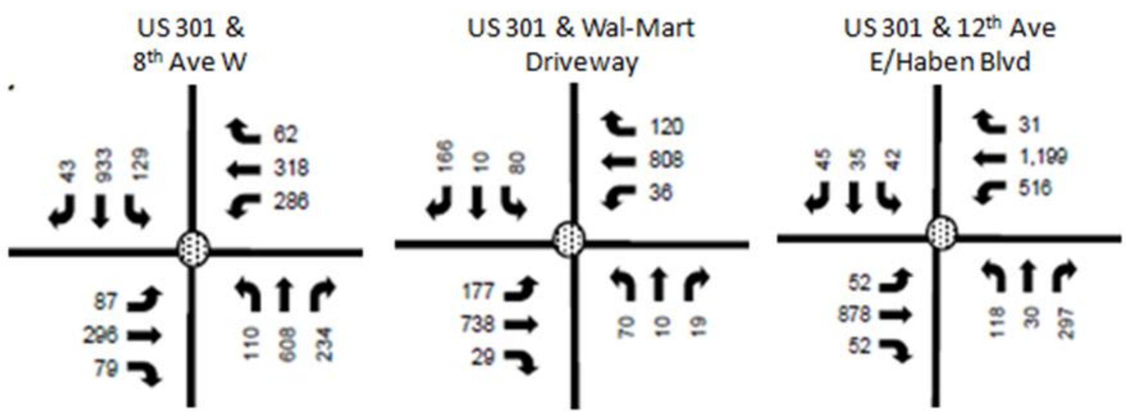

Figure 8. US 301 Existing Turning Movement Counts at A.M. Peak Hour

In the morning, the westbound traffic is still heavier than the traffic eastbound, west of the US 41 because they are avoiding the usage of US 41. It also shows that the traffic is avoiding US 41 all together by the extensive amount of traffic traveling south on 8th avenue. The westbound traffic that is east of US 41 is greater than the eastbound traffic, although not by much. At the entrance of Walmart, the eastbound traffic entering is not significantly higher than the westbound traffic like in the afternoon.

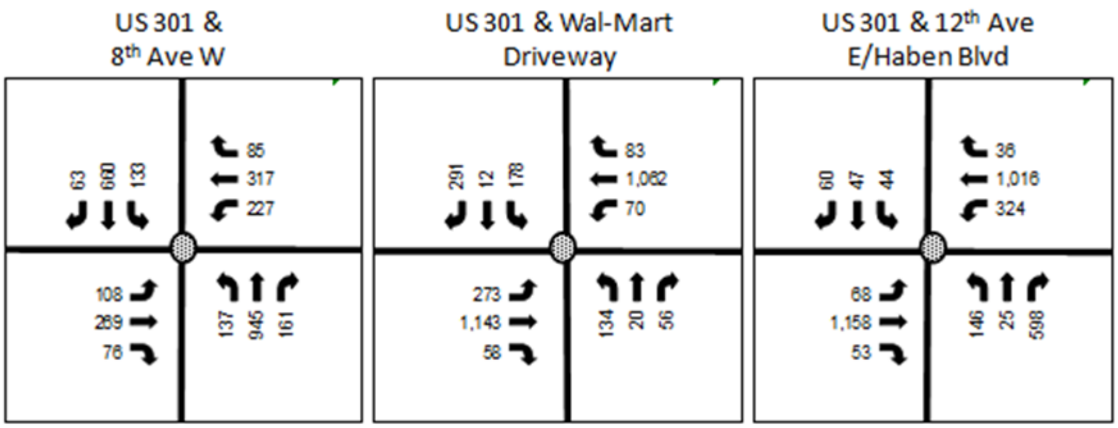

Figure 9. US 301 Existing (2010) Turning Movement Counts at P.M. Peak Hour

The current eastbound traffic, east to US 41, is much heavier than the traffic traveling westbound. However, west of US 41, the traffic is heavier westbound than eastbound. This is most likely because that everyone is getting off US 41 and heading home for the day into their neighborhoods. Another thing to notice is that people are coming off of US 41 and going directly into the Walmart, causing shockwave effects in the traffic flow.

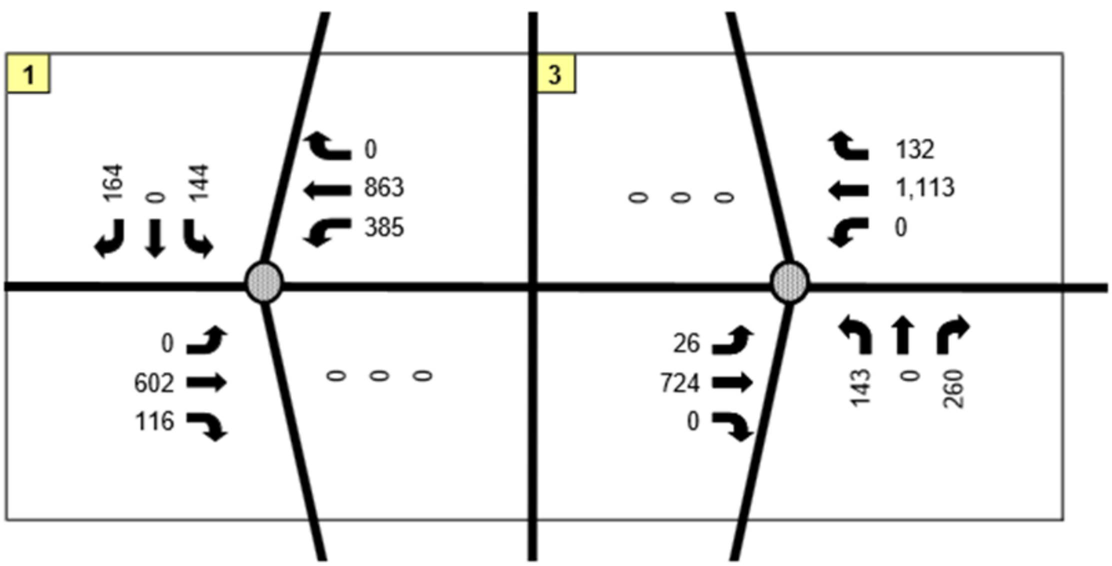

Figure 10. US 41 Existing Turning Movement Counts at A.M. Peak Hour

Only 30% of westbound traffic is using the south US 41 on ramp, and only 10% is using the north US 41 ramp. For the eastbound traffic, 16% are using the US 41 south ramp, while 3% use the north ramp. It goes to show that the traffic is not using the traffic as much in the morning, in fact, more traffic is exiting US 41 in the morning rather than getting on it.

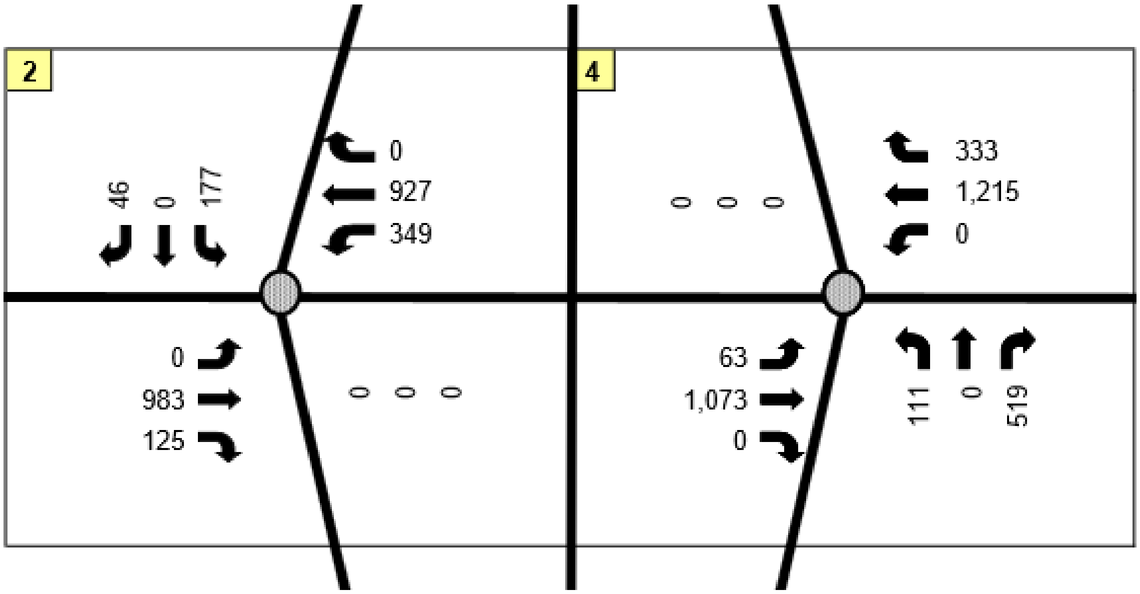

Figure 11. US 41 Existing Turning Movement Counts at P.M. Peak Hour

In the afternoon, there is more traffic going south on US 41 than north, which is strange because this is the same behavior in the morning, usually the opposite would be seen. This is most likely due to an early peak hour. For the traffic coming off of US 41, most of the traffic is headed east towards the Walmart. However, the eastbound and westbound traffic is pretty much 50/50.

2.2 Average Annual Daily Traffic (AADT)

AADT counts were taken from the Florida Department of Transportation (FDOT) Traffic Statistics Website, "Florida Traffic Online". The 2015 version contains the most recent traffic counts for the City of Palmetto. Although new data was available in late March for 2017, it was too late to consider them into this project. The data that is shown will be relevant to 2015, unless stated otherwise.

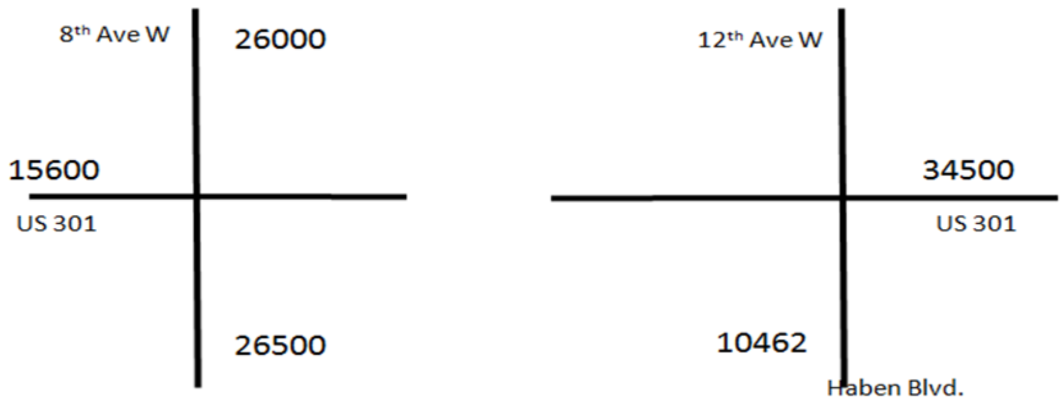

Figure 12. AADT of US 301 & 8th Avenue and US 301 & Haben Boulevard/12th Avenue

Below US 301, on 8th Avenue, traffic is more congested than the traffic north of US 301, so that they can avoid the current US 41 ramp situation and merge onto US 41 more south. The traffic traveling on Haben Boulevard is half that of the traffic traveling on 8th Avenue. However, the traffic east of the US 41 intersection is much greater than the traffic west of the US 41 intersection, probably because of the commercialized area of the Walmart, Taco Bell, etc.

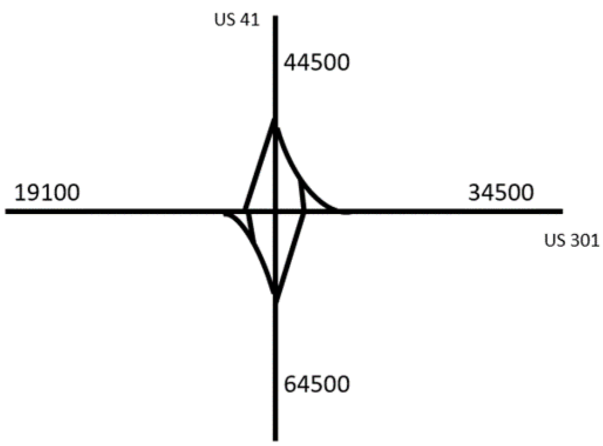

Figure 13. US 41 Ramps & US 301

The high daily volume traveling on US 301 east of the interchange provides data that confirms the congestion along this segment of the roadway, including the traffic traveling to and from the Walmart development.

Based on the existing traffic conditions and noticeable congestion, two problem areas can be identified: the ramp street terminals of US 41 and the location of the Walmart driveway. To solve congestion issues, redesign of the diamond interchange and relocation of the Walmart intersection will be evaluated.

3. Planning Objectives

When predicting future conditions for this project, a growth rate of 2% was used. This is the maximum allowable growth rate and by using 2% it gave us a “worst case” scenario. After determining the growth rate we decided that we wanted an overall level of service C for the network.

We looked at two alternatives for this project, one where the Walmart intersection would remain how it is (Alternative 1) and the other where we suggested moving the signalized intersection east (Alternative 2). After going through the data and simulations it was decided we would choose alternative 2.

4. Forecasting Data

To begin analysis of our alternatives, we projected the traffic volumes to the year 2030. This is considered the buildout year for the project. The following describes our process and results for the future turning movement counts and AADT.

4.1 Turning Movement Counts

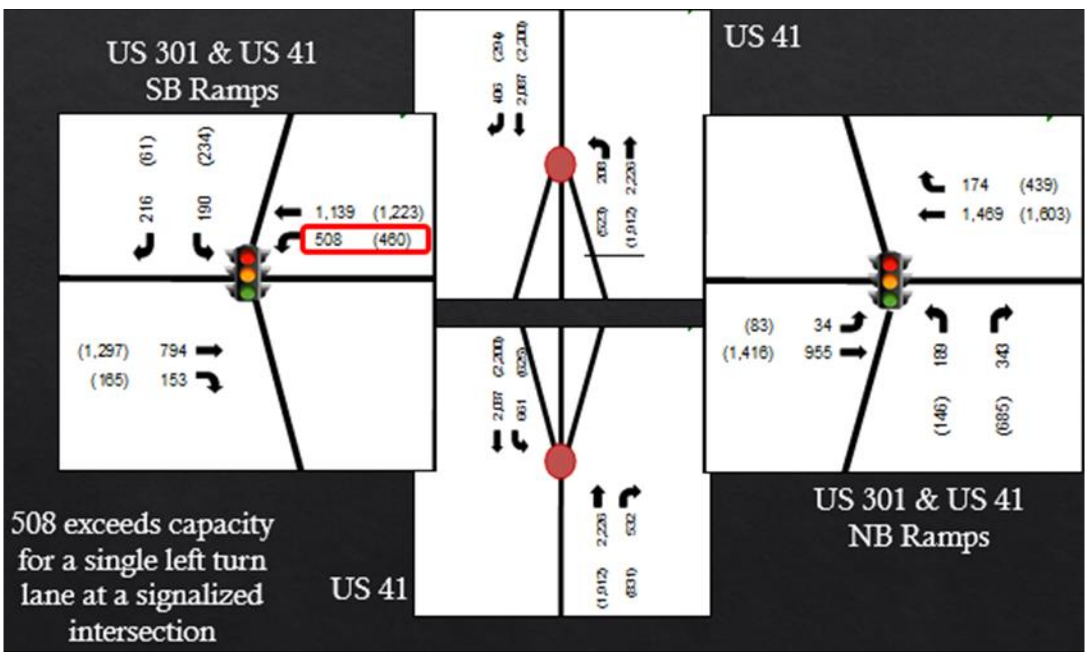

Figure 14. Future (2030) US 41 Turning Movement Counts for Alternative 1

As shown, there is no proposed change to US 41’s continuous typical section. This does show that the 508-volume leading onto the US 41 southbound ramp exceeds capacity for a single left turn lane at a signalized intersection. Because of this, more left turn lanes are needed. This shows high volume is causing queuing delays; i.e. “Stop and Go Traffic.”

4.2 Growth Computational Value

To calculate the growth values we first needed to obtain the historical AADT for US 301 which was provided from the FDOT traffic online website. Using the AADT from 2000 to 2015 we were able to calculate the growth computational value for US 301 which were found to be 2.21% westbound and 0.186% eastbound. Since one of our values is greater than 2%, we decided to use a conservative value of 2% for both directions on US 301.

Table 1. Historical AADT Data from FDOT Traffic Online

10th ST/ US 301		
Year	AADT	
	EB	WB
2015	19700	35000
2014	19800	34000
2013	22000	32000
2012	22000	32000
2011	25500	38000
2010	25500	38000
2009	25000	37500
2008	22500	37500
2007	21000	32000
2006	23500	32500
2005	22000	29500
2004	26500	31000
2003	21000	26000
2002	22000	28000
2001	19700	24000
2000	19600	25500

Table 2. Grow Computation Values

Growth Computational Values			
Direction	slope	slope/avg AADT	% increase
EB	41.6	0.001864	**0.1864**
WB	709.6	0.02215	**2.215**

4.3 Forecasted AADT

To forecast the AADT we need the growth computational values which was calculated but had to use a conservative value of 2% for both directions. Using the historical and the growth computational value we were able to use the formula below:

Equation 1. Future Volume

$$F = P(1+i)^n$$

We plugged in the previous year AADT for P, used 2% for the i value, and each year for the n.

Table 3. Traffic Volume Results

AADT		
Year	East	West
2000	19600	25500
2001	19700	24000
2002	22000	28000
2003	21000	26000
2004	26500	31000
2005	22000	29500
2006	23500	32500
2007	21000	32000
2008	22500	37500
2009	25000	37500
2010	25500	38000
2011	25500	38000
2012	22000	32000
2013	22000	32000
2014	19800	34000
2015	19700	35000
2016	20094	35700
2017	20496	36414
2018	20906	37142
2019	21324	37885
2020	21750	38643
2021	22185	39416
2022	22629	40204
2023	23082	41008
2024	23543	41828
2025	24014	42665
2026	24494	43518
2027	24984	44388
2028	25484	45276
2029	25994	46182
2030	26514	47105

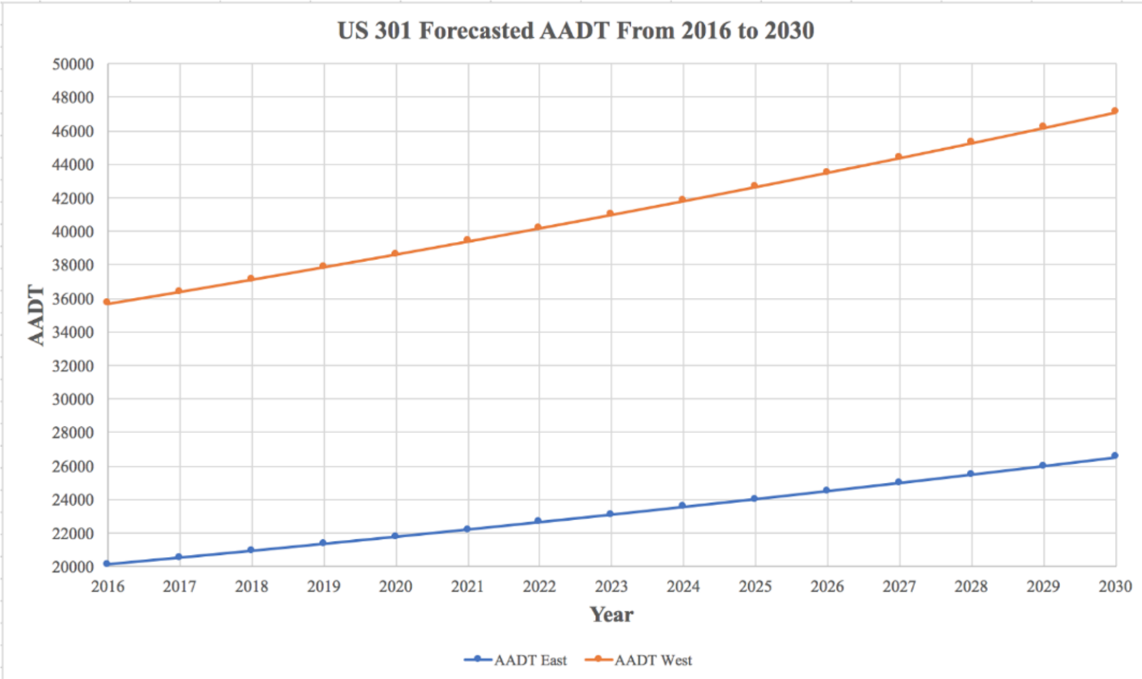

Figure 15. US 301 Forecasted Graph from 2016 to 2030

5. TSIS Analysis

5.1 Access Management for Proposed Walmart Driveway

The build configuration of this signalized intersection involves closing the existing median and relocating the signal approximately 625 feet east on Palm 2nd Street. This configuration would make the existing intersection a right-in/right-out driveway for Walmart.

Work for the new signalized intersection at Palm 2nd Street will include removing the existing directional median opening and relocating the existing mast arm signal poles to this new location. An additional through lane will also be included for both the eastbound and westbound directions to accommodate for future traffic volumes. All through lanes will be 11 feet in width with exclusive right turn lanes going into the Walmart entrance and the residential community living along Palm 2nd Street. Existing signal timings are subject to change under this build configuration in accordance to the forecasted traffic volumes.

5.2 Signal Timing for TSIS

Pre-timed Signal Phase Timing is a prerequisite for any TSIS simulation to be run. Due to TSIS' lack of ability to optimize signal timing, the required phase times were calculated analytically. First, the lights were analyzed to find the optimal signal phases for each individual signalized intersection, and the results were used for the first iteration of TSIS simulations. After the initial results, we found that the intersection with the most problematic traffic was US 301 & US 41 NB Ramp. Therefore, the optimal cycle length for this intersection was used to create a project wide greenway on US 301, starting from Haben Blvd. on the Eastern end, and terminating at 8th Ave. to the West.

The following equations were used to determine the optimal cycle length:

Equation 2. Minimum Cycle Length

$$C_{min} = (L*Xc) / (Xc-\sum(v/s))ci$$

Equation 3. Optimal Cycle Length

$$Copt = (1.5*L+5)/(1.0-\sum (v/s))ci$$

Equation 4. Intersection Effective Capacity

$$Xc = (\sum (v/s)*C)/(C-L)$$

Equation 5. Effective Green Time

$$gi = (v/s)ci*(C/Xi)$$

Equation 6. Yellow Signal Time

$$Y = tr+(V/(2a+2gG))$$

Where:

L = total lost time

Xc = effective capacity

(v/s) = saturation flow rate

tr = driver reaction time

V = velocity

a = acceleration

G = slope (as %/100)

g = gravity

After determining the optimal cycle length for the intersection of US 301 & US 41 NB Ramps, this cycle length was used as the cycle length for all other intersections within the project scope, excluding US 301 & 8th Avenue. Due to the intersection of US 301 & 8th Avenue being dominated by northbound and southbound traffic, it was unable to be integrated into the greenway throughout the rest of US 301 in the project area.

5.3 Intersection Analysis

Table 4. US 301 & 8th Avenue - Signal Timing Analysis

Phase	1		2		3		4	
Movements	WB L	EB L	WB Thru	EB Thru	NB L	SB L	NB Thru	SB Thru
Turns	393	119	437	406	151	177	835	1281
Lanes	2	1	3	3	1	1	3	3
Saturation Rate	3500	1750	5250	5250	1750	1750	5250	5250
Flow Ratios	0.112286	0.068	0.083238	0.077333	0.086286	0.101143	0.159048	0.244
Phase	1		2		3		4	
Movements	WB L	EB L	WB Thru	EB Thru	NB L	SB L	NB Thru	SB Thru
Effective Green	24.1		17.9		21.7		52.4	
Actual Green	20.1		13.9		17.7		48.4	
Yellow	5		5		5		5	
All Red	1		1		1		1	

Table 5. US 301 & US 41 Ramps - Signal Timing Analysis

Phase	1		2		3	
Movements	NB R	EB Left	EB Thru	WB Thru	NB R	NB L
Turns	207.6	63	1073	1215	311.4	111
Lanes	2	1	3	3	2	2
Saturation Rate	3500	1750	5250	5250	3500	3500
Flow Ratios	0.059314	0.036	0.204381	0.231429	0.088971	0.031714
Phase	1		2		3	
Movements	NB R	EB Left	EB Thru	WB Thru	NB R	NB L
Effective Green	11.0		44.0		17.0	
Actual Green	7.0		40.0		13.0	
Yellow	5		5		5	
All Red	1		1		1	

Table 6. US 301 & Proposed Walmart Driveway - Signal Timing Analysis

Phase	1		2		3		4		5	
Movements	WB Thru	WB Left	WB Thru	EB Thru	EB Thru	EB Left	NB Left	SB Left	NB Thru	SB Thru
Turns	200	393	237	200	206	119	151	177	853	1281
Lanes	3	2	3	3	3	1	1	1	2	2
Saturation Rate	5250	3500	5250	5250	5250	1750	1750	1750	3500	3500
Flow Ratios	0.038095	0.112286	0.045143	0.038095	0.039238	0.068	0.086286	0.101143	0.243714	0.366
Yellow times	5		5		5		2.5		2.5	
Phase	1		2		3		4		5	
Movements	WB Thru	WB Left	WB Thru	EB Thru	EB Thru	EB Left	NB Left	SB Left	NB Thru	SB Thru
Effective Green	8.0		20.0		25.0		9.0		3.0	
Actual Green	6.0		18.0		22.0		8.5		2.5	
Yellow	5		5		5		2.5		2.5	
All Red	0		0		1		1		1	

Table 7. US 301 & Haben Boulevard - Signal Timing Analysis

Phase	1		2		3		4		5
Movements	WB thru	WB Left	WB Thru	EB Thru	EB Thru	EB Left	NB Left	NB Thru	SB ALL
Turns	92.8	348	835.3998	835.2	314.6002	61	146	25	115
Lanes	3	1	3	3	3	1	1	1	1
Saturation Rate	5250	1750	5250	5250	5250	1750	1750	1750	1750
Flow Ratios	0.017676	0.198857	0.159124	0.159086	0.059924	0.034857	0.083429	0.014286	0.065714286
Yellow times	5		5		5		2.5		2.5
Phase	1		2		3		4		5
Movements	WB thru	WB Left	WB Thru	EB Thru	EB Thru	EB Left	NB Left	NB Thru	SB ALL
Effective Green	23		20		6		9		7
Actual Green	21.0		18.0		3.0		8.5		6.5
Yellow	5		5		5		2.5		2.5
All Red	0		0		1		1		1

5.4 Queue Lengths

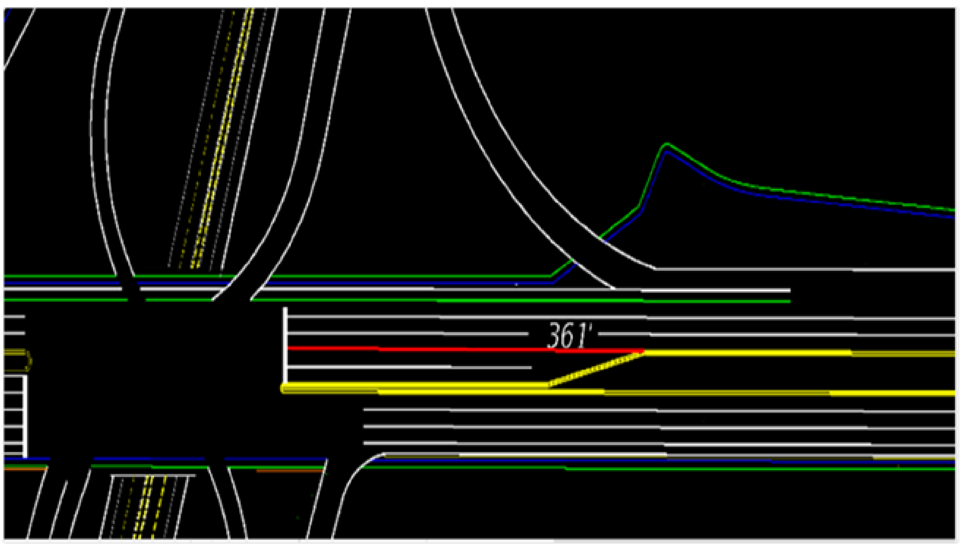

Figure 16 . TSIS figure output data for queue lengths

Queue lengths were determined from the TSIS output data. In order for an intersection to operate at an acceptable LOS, the queue length should be less than or equal to the turn lane pocket length. This design standard prevents the turning traffic from interfering with the through lanes traffic.

5.5 Level of Service

5.5.1 Segmental Analysis

LOS (2030) was calculated for 2 scenarios:

- No Build Peak Hour Scenario - Using existing through lanes with the current Walmart signalized intersection at 6th Ave.

- Build Peak Hour Scenario - Increase number of through lanes and move Walmart signalized intersection to Palm/2nd Ave.

The following equations and charts were used to calculate the LOS:

Equation 7. Analysis Flow Rate

$$Vp = VPHF*N*fHV*fP$$

Equation 8. Heavy-vehicle Adjustment Factor

$$F_{HV}= 11+PT(ET-1)+PR(ER-1)$$

Table 8. Passenger Car Equivalents

Factor	Type of terrain: Level	Rolling	Mountainous
E_T (trucks and buses)	1.5	2.5	4.5
E_R (RVs)	1.2	2.0	4.0

* Assume ET and ER= 1% due to level terrain.

Equation 9. Density

$$D = VpS$$

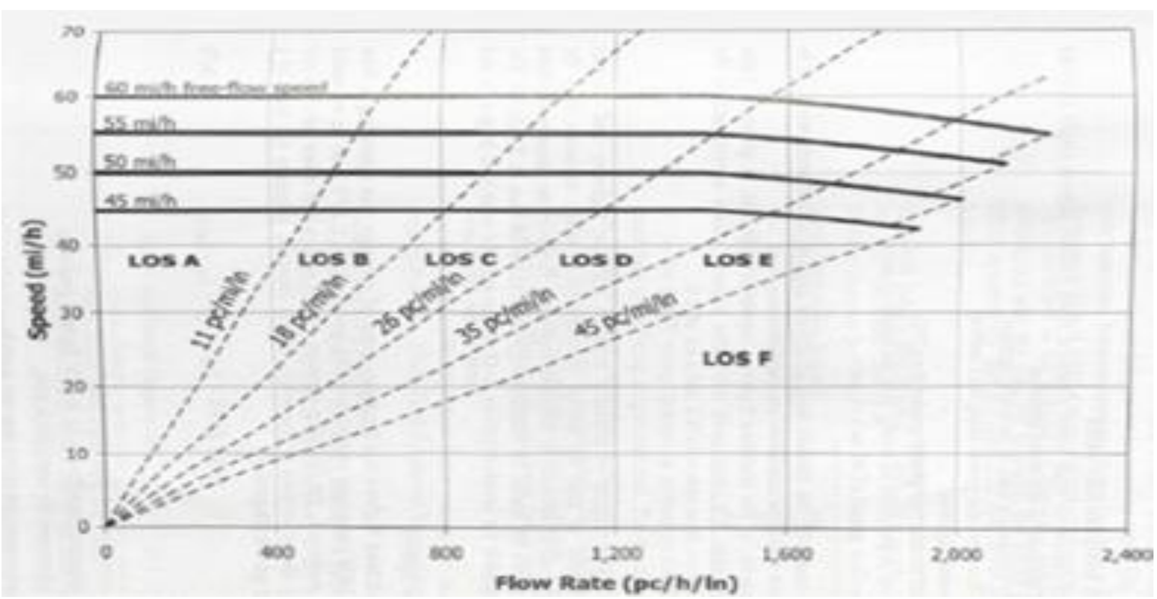

Figure 17. Chart depicting speed flow and LOS (HCM 2010)

* This chart depicting LOS obtained from Speed (mi/h), Density (pc/mi/ln) and Flow Rate (pc/h/ln).

The variables are defined as follows:

- Vp= 15-min passenger car equivalent flow rate (pc/h/ln)
- $V15$ = maximum 15-min flow rate in an hour
- S = average passenger car speed in mi/hr
- D = density in pc/mi/ln
- V = hourly volume (veh/hr)
- PHF = peak-hour factor
- N = number of lanes
- fHV = heavy-vehicle adjustment factor
- fP = driver population factor (assuming 1.0 for familiar-driver traffic streams)
- PT = proportion of trucks and buses (assuming 1%)
- PR = proportion of RV's (assuming 1%)
- ET = passenger car equivalent for trucks and buses
- ER = passenger car equivalent for RV's

Table 9. Level of Service Calculation 1

US 301 AM Peak Hour LOS (No Build)											
Intersection	V	Fp	FHV	N	PHF	Vp	S	D	LOS	D(avg)	LOS (governing)
8th EB	633	1	0.993	1	0.92	693	35	19.8	C	17.35	B
8th WB	915	1	0.993	2	0.88	522	35	14.9	B		
8th NB	1307	1	0.993	2	0.91	726	35	20.7	C	21.9	C
8th SB	1517	1	0.993	2	0.95	807	35	23.1	C		
Walmart/6th EB	1356	1	0.993	2	0.82	833	40	20.8	C	19.21	C
Walmart/6th WB	1272	1	0.993	2	0.91	704	40	17.6	B		
Walmart/6th NB	130	1	0.993	1	0.85	154	40	3.9	A	5.316	A
Walmart/6th SB	229	1	0.993	1	0.85	271	40	6.8	A		
Haben EB	1018	1	0.993	2	0.88	582	45	12.9	B	21.75	C
Haben WB	2595	1	0.993	2	0.95	1375	45	30.6	D		
Haben NB	661	1	0.993	1	0.79	843	35	24.1	C	14.9	B
Haben SB	181	1	0.993	1	0.91	200	35	5.7	A		
US 301 west of US 41 EB	947	1	0.993	2	0.89	536	40	13.4	B	17.72	B
US 301 west of US 41 WB	1647	1	0.993	2	0.94	882	40	22.1	C		
US 41 SB OFF ramp	406	1	0.993	1	0.89	459	30	15.3	B	20.12	C
US 41 SB ON ramp	661	1	0.993	1	0.89	748	30	24.9	C		
US 301 east of US 41 EB	989	1	0.993	2	0.92	541	40	13.5	A	17.88	B
US 301 east of US 41 WB	1643	1	0.993	2	0.93	890	40	22.2	C		
US 41 NB ON ramp	208	1	0.993	1	0.91	230	30	7.7	A	8.742	A
US 41 NB OFF ramp	532	1	0.993	2	0.91	294	30	9.8	A		

Table 10. Level of Service Calculation 2

US 301 PM Peak Hour LOS (No Build)											
Intersection	V	Fp	FHV	N	PHF	Vp	S	D	LOS	D(avg)	LOS (governing)
8th EB	621	1	0.993	1	0.91	687	35	19.6	C	16.5	B
8th WB	864	1	0.993	2	0.93	468	35	13.4	B		
8th NB	1706	1	0.993	2	0.92	934	35	26.7	D	22.63	C
8th SB	1175	1	0.993	2	0.91	650	35	18.6	C		
Walmart/6th EB	1945	1	0.993	2	0.93	1053	40	26.3	D	23.9	C
Walmart/6th WB	1603	1	0.993	2	0.94	859	40	21.5	C		
Walmart/6th NB	277	1	0.993	1	0.72	387	40	9.7	A	13.63	B
Walmart/6th SB	635	1	0.993	1	0.91	703	40	17.6	C		
Haben EB	1325	1	0.993	2	0.92	725	45	16.1	B	20.09	C
Haben WB	2044	1	0.993	2	0.95	1083	45	24.1	C		
Haben NB	1143	1	0.993	1	0.8	1439	35	41.1	E	23.69	C
Haben SB	181	1	0.993	1	0.83	220	35	6.3	A		
US 301 west of US 41 EB	1462	1	0.993	2	0.89	827	40	20.7	C	21.61	C
US 301 west of US 41 WB	1683	1	0.993	2	0.94	901	40	22.5	C		
US 41 SB OFF ramp	295	1	0.993	1	0.91	326	30	10.9	B	16.97	B
US 41 SB ON ramp	625	1	0.993	1	0.91	692	30	23.1	C		
US 301 east of US 41 EB	1499	1	0.993	2	0.92	820	40	20.5	C	24.07	C
US 301 east of US 41 WB	2042	1	0.993	2	0.93	1106	40	27.6	D		
US 41 NB ON ramp	522	1	0.993	1	0.87	604	30	20.1	C	18.09	C
US 41 NB OFF ramp	831	1	0.993	2	0.87	481	30	16.0	B		

Table 11. Level of Service Calculation 3

US 301 AM Peak Hour LOS (Build)											
Intersection	V	Fp	FHV	N	PHF	Vp	S	D	LOS	D(avg)	LOS (governing)
8th EB	633	1	0.993	2	0.92	346	35	9.9	A	9.9	A
8th VB	915	1	0.993	3	0.88	348	35	9.9	A		
8th NB	1307	1	0.993	3	0.91	484	35	13.8	B	14.597	B
8th SB	1517	1	0.993	3	0.95	538	35	15.4	B		
Palm EB	1356	1	0.993	3	0.82	555	40	13.9	B	12.803	B
Palm VB	1272	1	0.993	3	0.91	469	40	11.7	B		
Palm NB	130	1	0.993	1	0.85	154	40	3.9	A	5.3164	A
Palm SB	229	1	0.993	1	0.85	271	40	6.8	A		
Haben EB	1018	1	0.993	2	0.88	582	45	12.9	B	21.753	C
Haben VB	2595	1	0.993	2	0.95	1375	45	30.6	D		
Haben NB	661	1	0.993	2	0.79	421	35	12.0	B	7.449	A
Haben SB	181	1	0.993	2	0.91	100	35	2.9	A		
US 301 west of US 41 EB	947	1	0.993	3	0.89	357	40	8.9	A	11.816	B
US 301 west of US 41 VB	1647	1	0.993	3	0.94	588	40	14.7	B		
US 41 SB OFF ramp	406	1	0.993	1	0.89	459	30	15.3	B	13.889	B
US 41 SB ON ramp	661	1	0.993	2	0.89	374	30	12.5	B		
US 301 east of US 41 EB	989	1	0.993	3	0.92	361	40	9.0	A	11.923	B
US 301 east of US 41 VB	1643	1	0.993	3	0.93	593	40	14.8	B		
US 41 NB ON ramp	208	1	0.993	1	0.91	230	30	7.7	A	8.7421	A
US 41 NB OFF ramp	532	1	0.993	2	0.91	294	30	9.8	A		

Table 12. Level of Service Calculation 4

US 301 PM Peak Hour LOS (Build)											
Intersection	V	Fp	FHV	N	PHF	Vp	S	D	LOS	D(avg)	LOS (governing)
8th EB	621	1	0.993	2	0.91	344	35	9.8	A	9.363	A
8th VB	864	1	0.993	3	0.93	312	35	8.9	A		
8th NB	1706	1	0.993	3	0.92	622	35	17.8	B	15.08	B
8th SB	1175	1	0.993	3	0.91	433	35	12.4	B		
Palm 2nd EB	1945	1	0.993	3	0.93	702	40	17.6	B	15.93	B
Palm 2nd VB	1603	1	0.993	3	0.94	572	40	14.3	B		
Palm 2nd NB	277	1	0.993	1	0.72	387	40	9.7	A	13.63	B
Palm 2nd SB	635	1	0.993	1	0.91	703	40	17.6	B		
Haben EB	1325	1	0.993	2	0.92	725	45	16.1	B	20.09	C
Haben VB	2044	1	0.993	2	0.95	1083	45	24.1	C		
Haben NB	1143	1	0.993	2	0.8	719	35	20.6	C	11.85	B
Haben SB	181	1	0.993	2	0.83	110	35	3.1	A		
US 301 west of US 41 EB	1462	1	0.993	3	0.89	551	40	13.8	B	14.4	B
US 301 west of US 41 VB	1683	1	0.993	3	0.94	601	40	15.0	B		
US 41 SB OFF ramp	295	1	0.993	1	0.91	326	30	10.9	B	11.2	B
US 41 SB ON ramp	625	1	0.993	2	0.91	346	30	11.5	B		
US 301 east of US 41 EB	1499	1	0.993	3	0.92	547	40	13.7	B	16.05	B
US 301 east of US 41 VB	2042	1	0.993	3	0.93	737	40	18.4	C		
US 41 NB ON ramp	522	1	0.993	1	0.87	604	30	20.1	C	18.09	C
US 41 NB OFF ramp	831	1	0.993	2	0.87	481	30	16.0	B		

5.6 Intersection Analysis

The signalized intersection LOS (2030) was determined for two alternative scenarios:

- Alternative 1 - Move current Walmart entrance signalized intersection from 6th Ave. to Palm/2nd Ave.
- Alternative 2 - Leave signalized intersection at 6th Ave.

The equations and charts used from TSIS output were as follows:

Equation 10. Level of Service TSIS Equation

$$\sum \frac{Control\ Delay\ (s) * Flow\ (vehicles\ per\ hour)}{Flow\ (vehicles\ per\ hour)}$$

Table 13. Level of Service for Signalized Intersections (HCM 2010)

EXHIBIT 16-2. LOS CRITERIA FOR SIGNALIZED INTERSECTIONS

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

TSIS simulates traffic modeling by nodal analysis to obtain control delay and vehicle per hour volumes. These values were then used to calculate the LOS.

5.7 TSIS Node Display

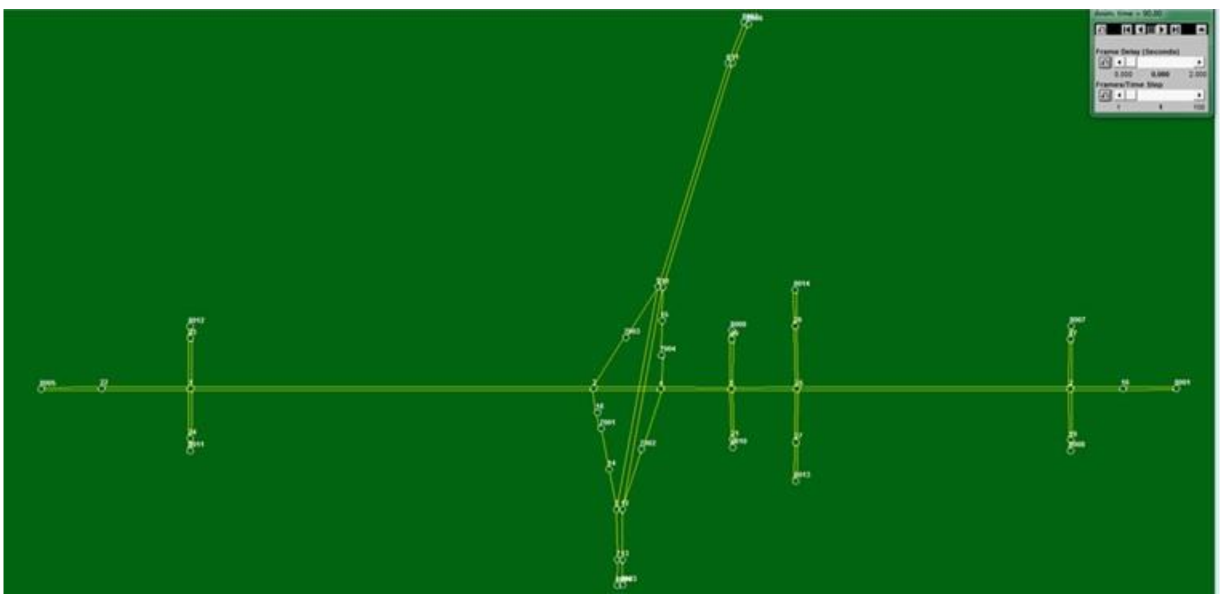

Figure 18. TSIS Simulation Alternative 1

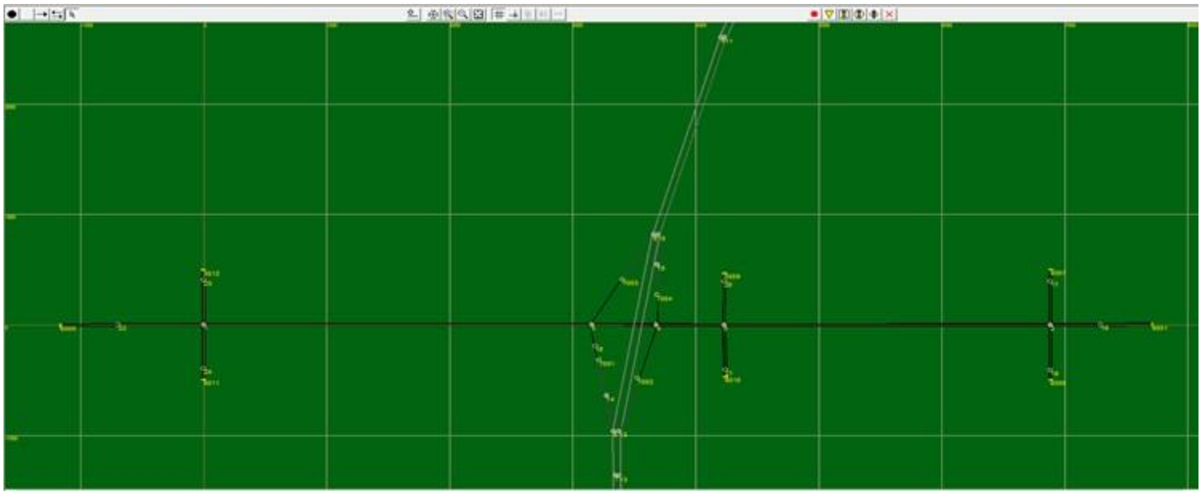

Figure 19. TSIS Simulation Alternative 2

The traffic modeling output from TSIS were as follows:

Table 14. TSIS Simulation Outputs Alternative 1

LINK	VEHICLE MILES	VEHICLE TRIPS	VEHICLE MINUTES MOVE TIME	VEHICLE MINUTES DELAY TIME	VEHICLE MINUTES TOTAL TIME	RATIO MOVE/ TOTAL	MINUTES/MILE TOTAL TIME	MINUTES/MILE DELAY TIME	SECONDS / VEHICLE TOTAL TIME	SECONDS / VEHICLE DELAY TIME	SECONDS / VEHICLE CONTROL DELAY	SECONDS / VEHICLE QUEUE DELAY	SECONDS / VEHICLE STOP* TIME	AVERAGE VALUES STOPS (%)	AVERAGE VALUES VOL VPH	AVERAGE VALUES SPEED MPH
(5, 4)	204.49	1956	305.0	536.6	841.6	0.36	4.12	2.62	25.8	16.4	14.1	11.0	10.4	57	1956	14.6
(2, 19)	68.22	894	101.8	29.2	131.0	0.78	1.92	0.43	8.7	2.0	0.0	0.0	0.0	0	894	31.3
(3, 4)	94.97	957	141.7	169.3	311.0	0.46	3.27	1.78	19.5	10.6	7.2	6.2	6.0	23	957	18.3
(7003, 3)	35.92	396	71.8	119.2	191.0	0.38	5.32	3.32	29.0	18.1	18.8	17.0	16.5	81	396	11.3
(2, 17)	10.93	154	16.3	7.3	23.6	0.69	2.16	0.67	9.2	2.9	0.0	0.2	0.1	0	154	27.8
(5, 21)	2.24	31	4.5	0.5	4.9	0.91	2.21	0.21	9.5	0.9	0.0	0.0	0.0	0	31	27.2
(1, 24)	120.48	1610	179.7	53.9	233.6	0.77	1.94	0.45	8.7	2.0	0.0	0.0	0.0	0	1610	30.9
(8012, 23)		1514													1514	
(25, 5)	191.19	1980	285.2	77.0	362.2	0.79	1.89	0.40	11.0	2.3	0.2	0.1	0.0	0	1980	31.7
(3, 1)	932.47	1562	1390.8	1258.8	2649.6	0.52	2.84	1.35	100.2	47.4	39.1	33.6	32.7	79	1562	21.1
(1, 3)	554.74	935	827.4	245.4	1072.8	0.77	1.93	0.44	68.3	15.5	9.2	7.4	7.0	46	935	31.0
(20, 5)	9.77	130	19.5	5.3	24.8	0.79	2.54	0.54	11.5	2.4	2.0	0.2	0.2	9	130	23.6
(22, 1)	120.05	912	179.1	777.5	956.5	0.19	7.97	6.48	62.6	50.9	48.6	44.6	44.0	81	912	7.5
(8005, 22)		914													914	
(26, 25)	19.59	206	29.2	81.6	110.8	0.26	5.66	4.16	32.2	23.7	22.9	19.3	19.0	90	206	10.6
(25, 27)	7.53	96	11.2	3.9	15.1	0.74	2.01	0.51	9.4	2.4	0.0	0.1	0.1	0	96	29.9
(17, 2)	13.61	181	20.3	92.4	112.7	0.18	8.28	6.79	37.2	30.5	29.9	28.3	28.0	90	181	7.2
(3, 18)	23.11	694	46.2	47.5	93.7	0.49	4.06	2.06	8.1	4.1	1.5	1.4	0.9	32	694	14.8
(8007, 17)		180													180	
(19, 2)	51.23	663	76.4	238.1	314.5	0.24	6.14	4.65	28.4	21.5	20.7	18.1	17.5	93	663	9.8
(4,7004)	12.43	244	24.9	4.8	29.6	0.84	2.39	0.39	7.3	1.2	0.0	0.3	0.3	0	244	25.2
(18,7001)	17.11	695	34.2	14.5	48.7	0.70	2.85	0.85	4.2	1.2	0.0	0.1	0.0	0	695	21.1
(5, 20)	10.70	151	21.4	2.3	23.6	0.90	2.21	0.21	9.4	0.9	0.0	0.0	0.0	0	151	27.1
(5, 25)	121.31	1251	180.9	536.7	717.6	0.25	5.92	4.42	34.3	25.6	23.9	21.5	20.9	65	1251	10.1
(8009, 20)		130													130	
(8010, 21)		14													14	
(7002, 4)	46.20	484	92.4	96.4	188.9	0.49	4.09	2.09	23.4	12.0	13.4	12.2	11.9	73	484	14.7
(16, 2)	201.06	2583	299.9	787.5	1087.4	0.28	5.41	3.92	25.2	18.2	16.3	13.4	12.9	59	2583	11.1
(25, 26)	31.32	351	46.7	14.8	61.5	0.76	1.97	0.47	10.5	2.5	0.0	0.2	0.1	0	351	30.5
(4, 3)	185.88	1873	277.2	1193.3	1470.6	0.19	7.91	6.42	47.5	38.7	34.4	31.8	30.9	59	1873	7.6
(1, 23)	108.62	1471	162.0	51.7	213.7	0.76	1.97	0.48	8.7	2.1	0.0	0.0	0.0	0	1471	30.5
(8011, 24)		1305													1305	
(4, 5)	131.78	1267	196.6	55.9	252.4	0.78	1.92	0.42	11.9	2.6	0.1	0.1	0.1	0	1267	31.3
(2, 16)	113.40	1520	169.1	66.3	235.5	0.72	2.08	0.59	9.3	2.6	0.0	0.2	0.1	0	1520	28.9
(1, 22)	164.52	1255	245.4	48.0	293.4	0.84	1.78	0.29	14.0	2.3	0.0	0.0	0.0	0	1255	33.6
(25, 2)	451.21	1114	673.0	884.1	1557.1	0.43	3.45	1.96	83.4	47.4	39.1	33.9	32.7	91	1114	17.4
(27, 25)	9.24	114	13.8	64.6	78.3	0.18	8.48	6.99	41.2	34.0	33.6	29.7	29.4	88	114	7.1
(2, 25)	799.09	1974	1191.9	698.6	1890.5	0.63	2.37	0.87	57.1	21.1	15.2	12.4	11.8	57	1974	25.4
(23, 1)	114.34	1498	170.5	1620.9	1791.5	0.10	15.67	14.18	71.5	64.8	58.4	54.8	53.6	95	1498	3.8
(24, 1)	98.31	1301	146.6	970.9	1117.6	0.13	11.37	9.88	51.4	44.7	41.0	37.1	36.3	87	1301	5.3
(21, 5)	1.07	14	2.1	0.5	2.7	0.80	2.50	0.50	11.5	2.3	2.3	0.1	0.1	0	14	24.0
(8001, 16)		2594													2594	
(8008, 19)		659													659	
(8013, 27)		113													113	
(8014, 26)		205													205	

Table 15. TSIS Simulation Outputs Alternative 2

	VEHICLE		VEHICLE MINUTES			RATIO	MINUTES/MILE		SECONDS / VEHICLE					- AVERAGE VALUES -		
LINK	MILES	TRIPS	MOVE TIME	DELAY TIME	TOTAL TIME	MOVE/ TOTAL	TOTAL TIME	DELAY TIME	TOTAL TIME	DELAY TIME	CONTROL DELAY	QUEUE DELAY	STOP* TIME	STOPS (%)	VOL VPH	SPEED MPH
(5, 4)	205.46	1979	306.5	544.9	851.4	0.36	4.14	2.65	25.8	16.5	12.6	10.5	10.0	45	1979	14.5
(2, 19)	67.05	876	100.0	28.2	128.2	0.78	1.91	0.42	8.7	1.9	0.0	0.0	0.0	0	876	31.4
(3, 4)	97.16	979	144.9	187.3	332.2	0.44	3.42	1.93	20.4	11.5	7.8	6.7	6.4	26	979	17.5
(7003, 3)	36.92	407	73.8	123.2	197.1	0.37	5.34	3.34	29.0	18.1	18.8	16.9	16.4	81	407	11.2
(2, 17)	10.93	154	16.3	7.0	23.4	0.70	2.14	0.64	9.1	2.7	0.0	0.2	0.1	0	154	28.1
(5, 21)	8.96	127	17.9	3.6	21.5	0.83	2.40	0.40	10.1	1.7	0.0	0.2	0.1	0	127	25.0
(4, 3)	191.04	1925	284.9	1389.5	1674.4	0.17	8.76	7.27	52.2	43.4	38.9	36.0	34.8	65	1925	6.8
(8005, 22)		914													914	
(2, 5)	980.98	1955	1463.2	1097.0	2560.1	0.57	2.61	1.12	77.9	33.3	26.0	20.6	19.7	89	1955	23.0
(3, 1)	956.35	1602	1426.4	1270.2	2696.6	0.53	2.82	1.33	99.5	46.7	38.1	32.7	31.8	80	1602	21.3
(1, 3)	554.74	935	827.4	250.6	1078.0	0.77	1.94	0.45	68.7	15.9	9.6	7.7	7.4	48	935	30.9
(4, 5)	133.02	1279	198.4	347.2	545.6	0.36	4.10	2.61	25.5	16.2	12.4	10.2	9.5	57	1279	14.6
(8009, 20)		336													336	
(16, 2)	200.67	2578	299.3	815.2	1114.5	0.27	5.55	4.06	25.9	18.9	16.8	13.7	13.1	61	2578	10.8
(1, 22)	168.47	1285	251.3	51.4	302.7	0.83	1.80	0.31	14.1	2.4	0.0	0.0	0.0	0	1285	33.4
(1, 23)	109.24	1480	162.9	51.8	214.7	0.76	1.97	0.47	8.7	2.1	0.0	0.0	0.0	0	1480	30.5
(17, 2)	13.53	180	20.2	91.1	111.2	0.18	8.22	6.73	37.0	30.2	29.7	28.1	27.8	91	180	7.3
(3, 18)	23.00	691	46.0	48.0	94.0	0.49	4.09	2.09	8.2	4.2	1.6	1.5	0.9	34	691	14.7
(8008, 19)		659													659	
(19, 2)	51.23	663	76.4	236.9	313.3	0.24	6.11	4.62	28.3	21.4	20.6	17.9	17.3	93	663	9.8
(4,7004)	13.30	261	26.6	3.8	30.4	0.87	2.29	0.29	7.0	0.9	0.0	0.2	0.1	0	261	26.2
(18,7001)	17.04	692	34.1	15.2	49.3	0.69	2.89	0.89	4.3	1.3	0.0	0.1	0.1	0	692	20.7
(21, 5)	9.87	129	19.7	68.1	87.8	0.22	8.90	6.90	40.8	31.7	33.0	29.1	28.9	88	129	6.7
(5, 20)	30.70	461	61.4	10.3	71.7	0.86	2.34	0.34	9.3	1.3	0.0	0.3	0.2	0	461	25.7
(20, 5)	25.41	338	50.8	114.2	165.0	0.31	6.49	4.49	29.2	20.2	21.1	16.9	16.5	91	338	9.2
(7002, 4)	50.40	528	100.8	121.8	222.6	0.45	4.42	2.42	25.3	13.9	15.3	13.8	13.5	74	528	13.6
(8011, 24)		1305													1305	
(2, 16)	115.35	1545	172.0	64.2	236.3	0.73	2.05	0.56	9.2	2.5	0.0	0.2	0.1	0	1545	29.3
(1, 24)	120.56	1611	179.8	53.9	233.7	0.77	1.94	0.45	8.7	2.0	0.0	0.0	0.0	0	1611	30.9
(5, 2)	564.19	1124	841.5	731.2	1572.7	0.54	2.79	1.30	83.1	38.4	31.1	25.1	23.8	97	1124	21.5
(24, 1)	98.39	1302	146.8	972.1	1118.9	0.13	11.37	9.88	51.4	44.7	41.0	37.1	36.3	87	1302	5.3
(22, 1)	120.31	914	179.4	745.5	925.0	0.19	7.69	6.20	60.3	48.6	46.3	42.4	41.8	81	914	7.8
(23, 1)	113.95	1493	170.0	1738.3	1908.2	0.09	16.75	15.25	76.5	69.8	62.6	59.1	57.8	96	1493	3.6
(8001, 16)		2594													2594	
(8010, 21)		128													128	
(8012, 23)		1512													1512	
(8007, 17)		180													180	
0SUBNETWORK=	5088.23	8492	128.31	186.36	314.67	0.41	3.71	2.20	2.16	1.28	1.08	0.94	0.91	174.5		16.2
			-- VEHICLE - HOURS --						--- MINUTES / VEHICLE-TRIP ---					PER TRIP		

5.8 LOS Tables

5.8.1 LOS Tables for Alternative 1 - Signalized Intersections

Table 16. TSIS Simulation Outputs Alternative 1 - LOS 1-6

US-301 & 8th Ave.					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (3,1)	39.1	1562	61074.2	46.69478475	D
EB (22,1)	48.6	912	44323.2		
NB (24,1)	41	1301	53341		
SB (23,1)	58.4	1498	87483.2		

US-301 & Palm/Haskos (New Walmart entrance)					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (2,25)	15.2	1974	30004.8	19.30930889	B
EB (5,25)	23.9	1251	29898.9		
NB (27,25)	33.6	114	3830.4		
SB (26,25)	22.9	206	4717.4		

US-301 & Haben/12th					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (16,2)	16.3	2583	42102.9	23.07780225	C
EB (25,2)	39.1	1114	43557.4		
NB (19,2)	20.7	663	13724.1		
SB (17,2)	29.9	181	5411.9		

US-301 & US-41 NB Ramp					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (5,4)	14.1	1956	27579.6	12.05640271	B
EB (3,4)	7.2	957	6890.4		
NB (7002,4)	13.4	484	6485.6		

US-301 & US-41 SB Ramp					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (4,3)	34.4	1873	64431.2	25.11797753	C
EB (1,3)	9.2	935	8602		
SB (7003,3)	18.8	396	7444.8		

Moving the signalized intersection from 6th Ave to Palm/2nd results in a LOS B for the new Walmart entrance.

5.8.2 LOS Tables for Alternative 2 - Signalized Intersections

Table 17. TSIS Simulation Outputs Alternative 2 - LOS 1-6

US 301(10th Ave) and 8th Ave						
Direction Bound	Direction Node	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB	3, 1	38.1	1602	61036.2	47.10943325	D
EB	22, 1	46.3	914	42318.2		
NB	24,1	41	1302	53382		
SB	23, 1	62.6	1493	93461.8		

US 301 and Walmart						
Direction Bound	Direction Node	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB	2, 5	26	1955	50830	21.0965685	C
EB	4, 5	12.4	1279	15859.6		
NB	21, 5	33	129	4257		
SB	20, 5	21.1	338	7131.8		

US 301 and Haben						
Direction Bound	Direction Node	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB	16, 2	16.8	2578	43310.4	21.40167217	C
EB	5. 2	31.1	1124	34956.4		
NB	19, 2	20.6	663	13657.8		
SB	17, 2	29.7	180	5346		

US 301 and US 41 NB Ramp						
Direction Bound	Direction Node	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB	5, 4	12.6	1979	24935.4	11.66092943	B
EB	3, 4	7.8	979	7636.2		
NB	7002, 4	15.3	528	8078.4		

US 301 and US 41 SB Ramp						
Direction Bound	Direction Node	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB	4, 3	38.9	1925	74882.5	28.01043771	C
EB	1, 3	9.6	935	8976		
SB	7003, 3	18.8	407	7651.6		

Leaving the Walmart signalized intersection at 6th Ave. results in a LOS C for 2030. This shows that that moving the signal to Palm/2nd Ave will alleviate some of the traffic buildup east of US 41.

5.9 SPUI

The diamond interchange that is currently at the intersection of US 301 and US 41 is outdated. We recommend replacing it with a SPUI design. This will decrease the distance in the intersection making it more efficient than the diamond interchange. Unfortunately due to restrictions in TSIS we had to use the diamond interchange in our simulations. This means that the results we received should improve with a SPUI and it is to be expected that the LOS will be at least C, but possibly higher.

Figure 20. Single Point Interchange on US 41

5.10 PD&E Study Based on Calculations

After the necessary calculations had been done to determine the proposed number of lanes, lane widths, and optimal design configuration, a proposed visual of the PD&E design was created. MicroStation, specifically FDOT SS4, was used to create the study. The highlighted area represents the project limits while the linework in each figure represents the proposed number of lanes, existing right of way, and medians. The street names and signalized intersections are also indicated, keeping in mind that north is pointing upwards in each figure.

The PD&E study is mainly characterized by three through lanes along US 301 both eastbound and westbound with 12-foot lane widths. It also considers the build condition of the project (Alternative 2) and indicates the relocation of the current signalized intersection at the Walmart entrance to Palm 2nd Ave.

5.10.1 PD&E Study (US 41/US 301 Interchange)

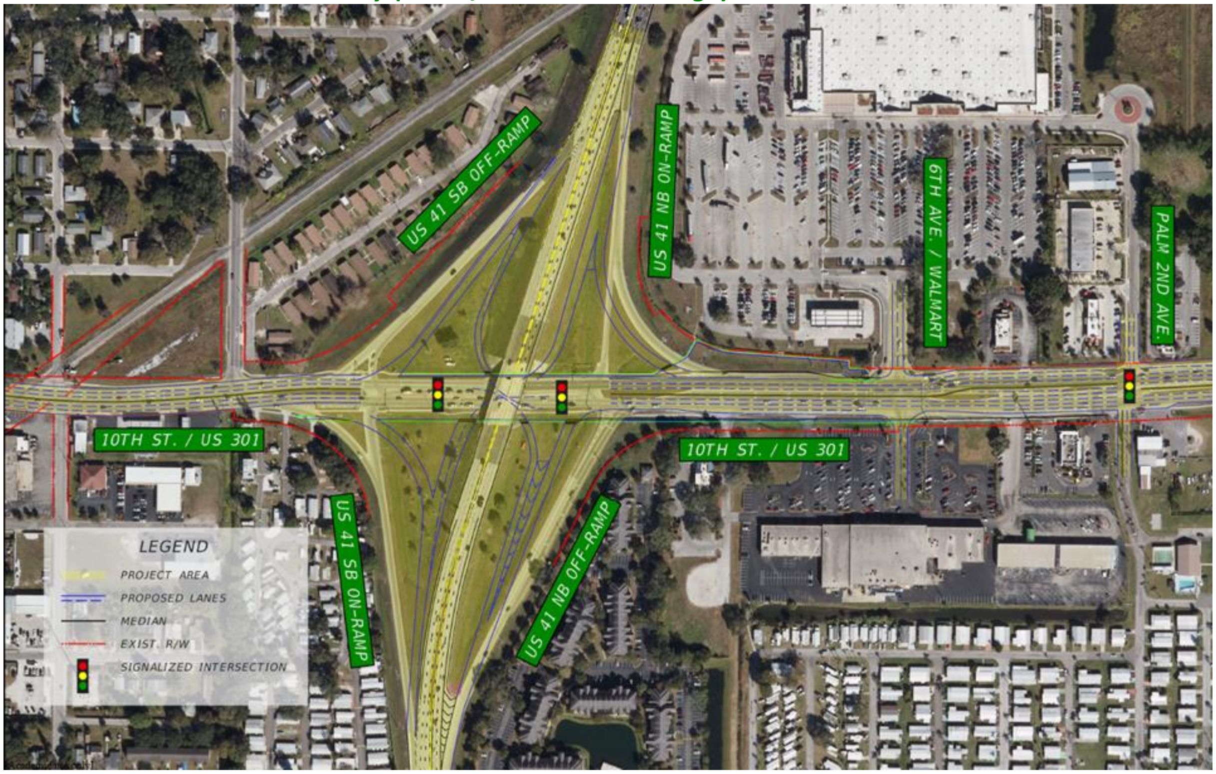

Figure 21. PD&E Study of US 41

This first figure focuses on the proposed single point urban interchange, or SPUI. PD&E has determined that the addition of the SPUI moves the ramps farther from the nearby signalized intersection at Walmart to improve traffic flow and remove traffic delay.

5.10.2 PD&E Study (West of US 41)

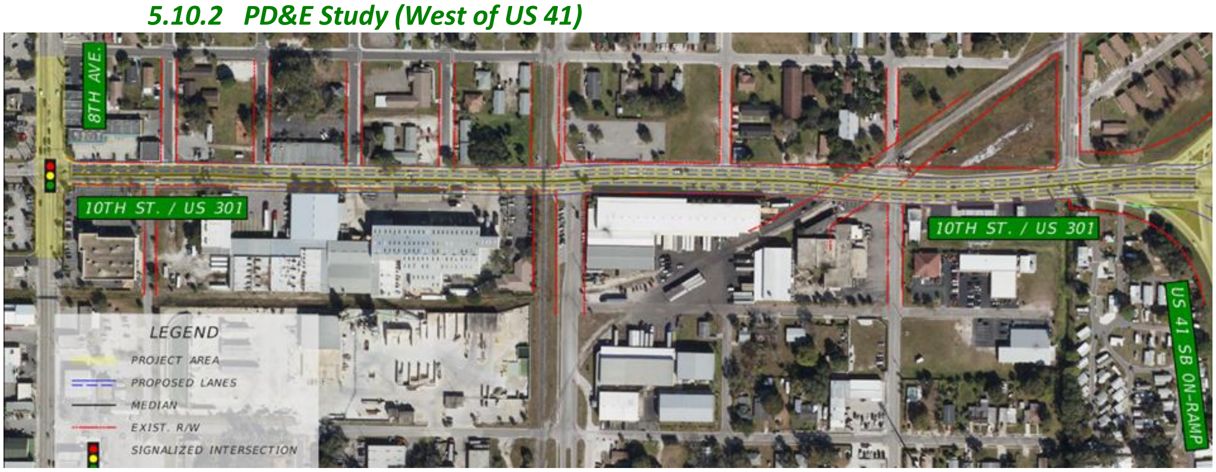

Figure 22. PD&E Study West of US 41 along US 301

The west side of the interchange remains consistent with the number of lanes and lane widths. This area is characterized with existing lane widths of 11 feet and is predominantly inhabited by industrial companies, meaning moderate trucking traffic coming through the area. The proposed lane widths have been increased to 12 feet and additional lane has been added in each direction. This is due to the high traffic volumes that were calculated based on the data above.

5.10.3 PD&E Study (East of US 41)

Figure 23. PD&E Study West of US 41 along US 301

The east side of the interchange is mostly composed of residential areas. Currently, during times where traffic is excessive, local drivers tend to bypass the US 41/US 301 interchange to alternatively travel to other parts of Palmetto. Much of the high traffic volume is due to the proximity of the signalized intersection to the diamond interchange. Therefore, this segment of the project also stay consistent with three through lanes in each direction at 12 feet wide.

Additionally, the relocation of the signalized intersection at Walmart requires expansion of lanes to accommodate traffic coming in and out of the shopping center. This condition closes the existing median and makes the current entrance a right-in, right-out entrance.

5.11 Cost Estimate

The cost for this project can be found in Table 18 below. These estimates are for the build scenario where the Walmart intersection has been moved. The total cost for the project is roughly $84.5 million with the two largest costs coming from the MSC wall and the SPUI design. The estimates take into consideration actions such as adding lanes to US 301, redesigning the bridge, moving the Walmart intersection, geotechnical work, and updating the diamond interchange to a SPUI design.

Table 18. Cost Estimate

Facility	Cost
US 301	$23,835,418.67
US 41	$7,576,473.04
US 41 Ramps	$16,161,136.14
Signalization	$250,000.00
MSE Wall	$24,595,747.00
SPUI	$36,630,584.00
TOTAL	**$84,453,611.85**

5.12 Regulatory and Permitting Government Agencies

The Environmental Permit Information Manual (EPIM) provides information needed by the FDOT for permitting services. The FDOT ensures that the transportation companies follow laws such as NEPA, the National Environmental Policy Act, to ensure that the environment is not in risk of the making of these projects. Other laws protect people’s properties and neighborhoods.

Per the EPIM, there are seven types of permits:

- Dredge and Fill
- Drainage
- Irrigation Water Use
- Bridge
- Tree Removal License
- Coastal Construction Line
- Right of Way Occupancy and Drainage Connection

Geometric Design of US 301

6. Introduction

With the redesign of the interchange it was decided to design upgrades and improvements for the surrounding intersections on US 301. It was determined that the optimal solution would have a scope that would extend as far west as 8th Avenue West, and as far east of the interchange as 16th Avenue East.

The interchange where US 301 meets with US 41 in Palmetto was determined to be in need of a major redesign. This interchange is in need of redesign due to the effect of rapid commercial retail growth within the area. The amount of trips attracted to this area has grown faster than the existing roadway and infrastructure can support. In addition to this, the intersections at Haben Blvd, Walmart Service Road, and 8th Avenue would need upgrading as well. The reasoning behind this decision was based on the proximity of these signalized intersections in relation to the interchange. Even if the interchange were to be upgraded, it would still face issues if the surrounding traffic flow was not corrected to allow for optimal traffic flow within the interchange. This provides an example of how a single project fits within a larger transportation system. As transportation engineers it is our job to provide solutions that not only fit within the context and constraints of our project, but to make sure that it will benefit the local and regional transportation system as a whole.

This chapter focuses on the redesign of US 301 from 8th Avenue West, up to 16th Avenue East. Currently US 301 is a 4 lane undivided urban arterial to the west of the interchange and becomes a 4 lane divided roadway as it approaches and passes east of US 41. All key signalized intersections are currently 4 lane roadways. From the information given by the Planning Teams, the major details of the redesign will include upgrading the interchange, the movement of a signalized intersection, and closing off of a current one, as well as the possible milling and resurfacing of existing lanes while adding new travel lanes, bike lanes, and a shared use path.

7. Roadway Design Criteria

In order to begin the design of the new US 301, roadway design criteria must be established. All the information gathered for this section came from the FDOT Design Manual, the American Association of State Highway and Transportation Officials (AASHTO) Green Book, and from the course instructors, Dr. Qing Lu and Bijan Behzadi. State Road 301 has a current posted speed of 40 mph and the proposed roadway will maintain that same posted speed. Therefore, as Bijan Behzadi addressed in class, the design speed for an urban arterial should be 5 mph higher than the posted speed limit. For the case of State Road 301, the design speed should be 45 mph and the other parameters should be determined based on the design speed. These values were found from the FDOT Design Manual and the AASHTO Green book and are as follows:

Table 19. Roadway Classification (FDOT 2016a; AASHTO 1999)

Roadway Classification		High-Speed Urban Arterial
General Criteria	Design Speed	45 mph
	Design Vehicle	WB-62 FL
Section Features	Median Width	28 feet
	Shoulders	None
	Curb & Gutter	Yes
	Bike Lane	7 feet
Horizontal Clearance	Clear Zone	4 feet from FOC
	Border Width	14 feet
Horizontal Alignment	Max. Super Elevation	5 %
	Max. Grade	6 %
	Min. Grade	0 %
	Min. Length of Curve	400 feet
Vertical Alignment	Base Clearance Above DHW Elevation 3 feet	
	Max. Change in Grade w/o HC	0.6%
	Max. SSD	360 feet
	Min. Length of Crest VC	300 feet
	Min. K Value of Crest VC	136
	Min. Length of Sag VC	200 feet
	Min. K Value of Sag VC	96

State Road 301 is defined as a high-speed urban arterial. The design speed is less than 50 mph, therefore, the AASHTO Green Book confirms that a WB-62FL is an adequate design vehicle (dimensions are shown below). This means that all the parameters of the road must accommodate for a WB-62FL, from the sight stopping distance to a right-hand turn.

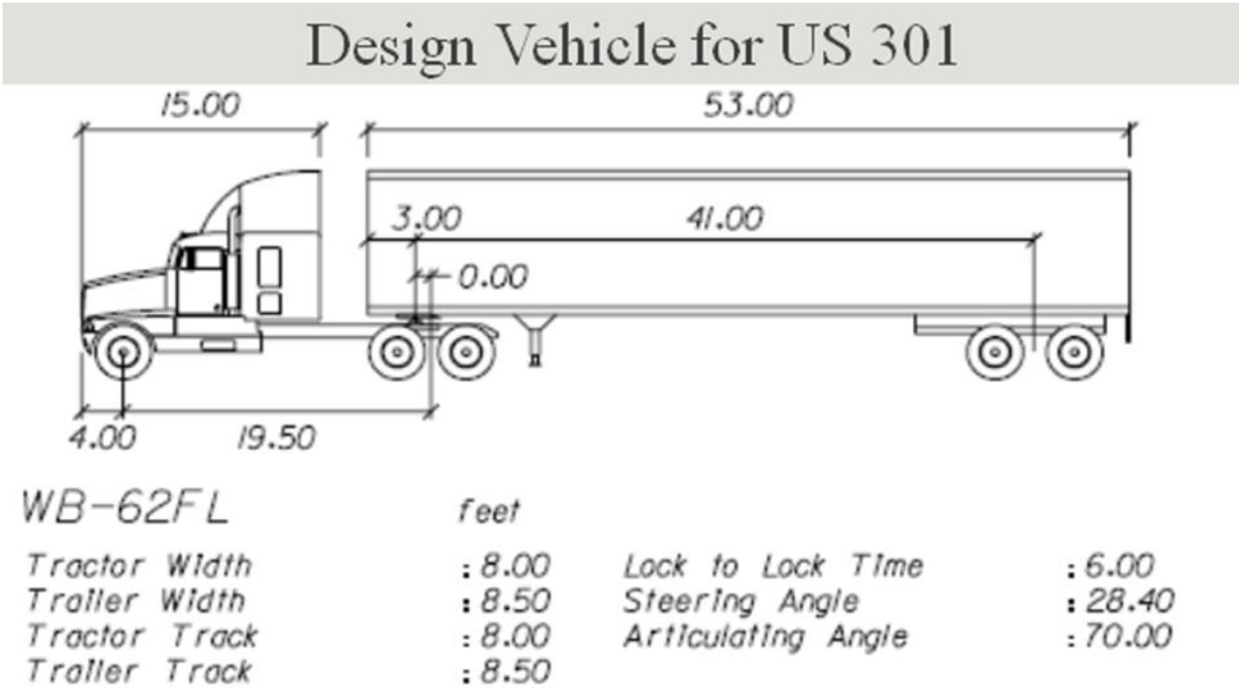

Figure 24. Design Vehicle (FDOT 2016a; AASHTO 1999)

To ensure that State Road 301 can allow a truck the size of a WB-62FL to maneuver, a control radius of 75 feet will be implemented for left turn movements at intersections and any other minimum speed turns a truck will have to make on the roadway. A visual representation of one of these 90° turns is shown in a figure below. Also, Table 20 shows the control radius and other right turning radii.

Table 20. Design Vehicle: WB-62FL (FDOT 2016a; AASHTO 1999)

Turning Radii	50 feet or 3 – centered curve
Control Radius	75 feet
Angle of Turn	90°

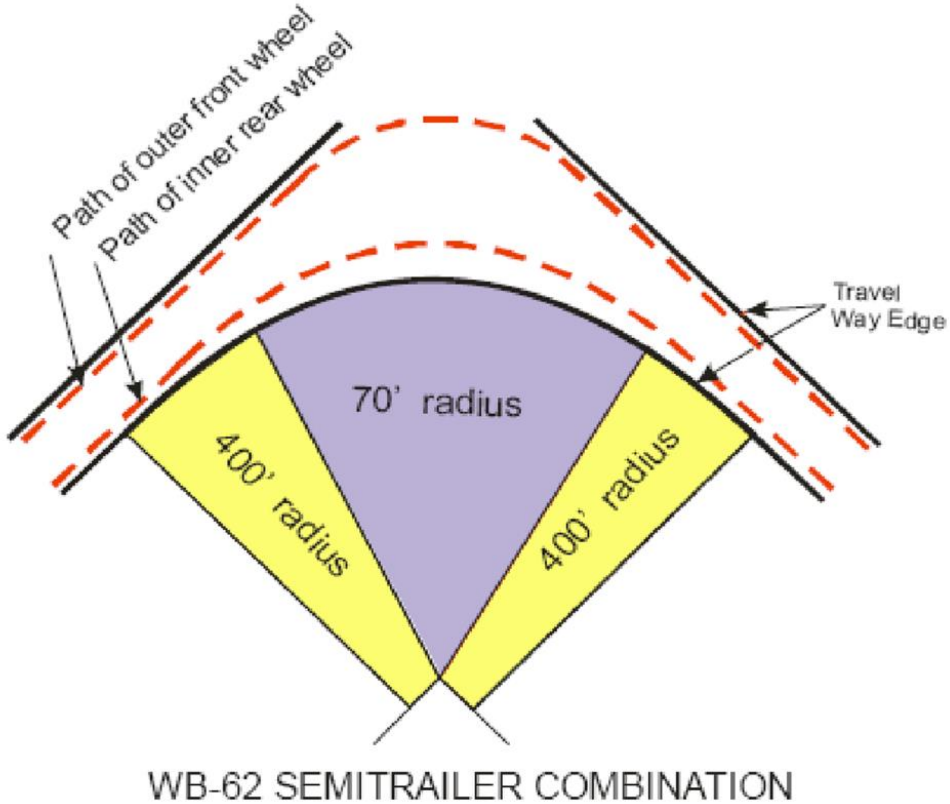

Figure 25 . WB-62 Turning Radius (FDOT 2016a; AASHTO 1999)

The minimum edge of traveled way is shown in Table 21 and Figure 25. The edge of traveled way represents the left turn at a signal and right turns that the design vehicle makes at speeds of less than or equal to 10 mph. As Bijan Behzadi discussed in class, the rear wheels of a vehicle do not follow the same path as the front wheels (also shown in Figure 25). The edge of traveled way is provided as to accommodate a minimum speed turn made by the design vehicle.

Table 21. Edge of Traveled Way Design (FDOT 2016a; AASHTO 1999)

Angle of Turn	Design Vehicle	3 – Centered Compound
90	WB-62 FL	400-70-400

8. Transit Criteria

While designing the proposed US 301 East and West approaches, our goal was to increase vehicle density using US 301 without having any traffic congestions accrued. Traffic congestions can happen due to a variety of factors. For example, it can happen due to the increasing numbers of pedestrian, bus stop stations, and bike lanes. To avoid this possible problem, the new design must be designed accordingly with all traffic needs.

In the new US 301 new road properties have been modified as they will be shown in the following figures. For example, the design of the existing East interchange was having two lanes with 11 feet width. Furthermore, the existing West interchange had also two lanes with 12 feet width. In addition, the existing under ramp which is the core of the traffic problem occurring had just two lanes as well. As noticed from the existing designs all interchanges had just two lanes with no bike lanes as well as the existing under ramp, with relatively high traffic volume. As a result, as shown in the following figures, it was decided to increase the number of lanes for both interchanges from two to three lanes, and adding a 7 feet bike lane in the West interchange. Also 3 lanes have been added to the existing under ramp making the proposed with total 5 lanes. These improvements will help to have high traffic volume avoiding any traffic congestion since it now has the high capacity to serve bike riders and bus stops.

The portion of US 301 that is defined by the project limits was analyzed by the PD&E Team but it was determined that there was no need for any auxiliary lanes. The queuing length is determined based on the Green Book Section 2.2.5. The FDOT requires in an urban/suburban setting that 100 feet of roadway is added to the given deceleration distance. The deceleration distance is based on the Green Book Exhibit 31, which denotes a deceleration distance of 185 feet. This distance is added to the required 100 feet to give a total of 285 feet required for the queuing lane length in the project limits for US 301.

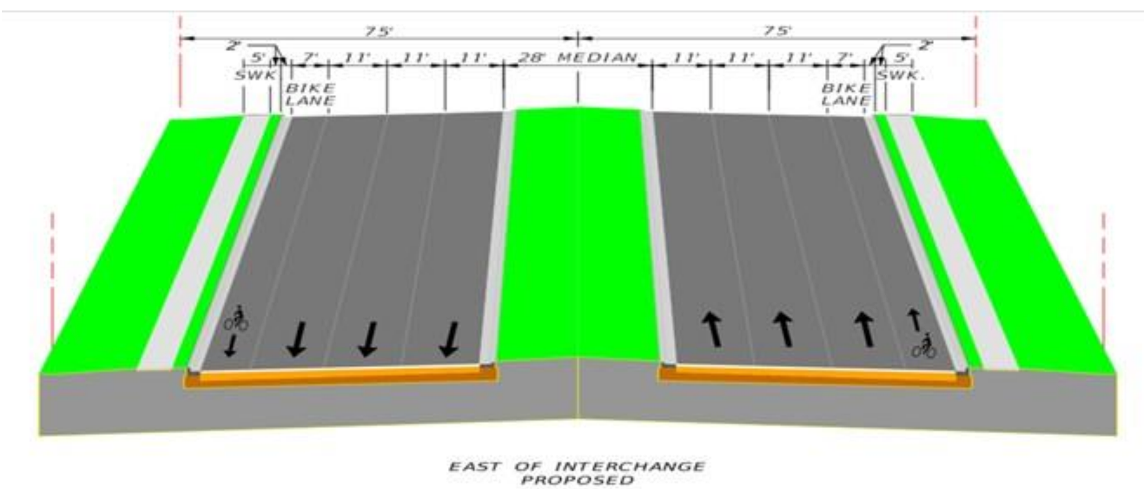

Figure 26. East of Interchange

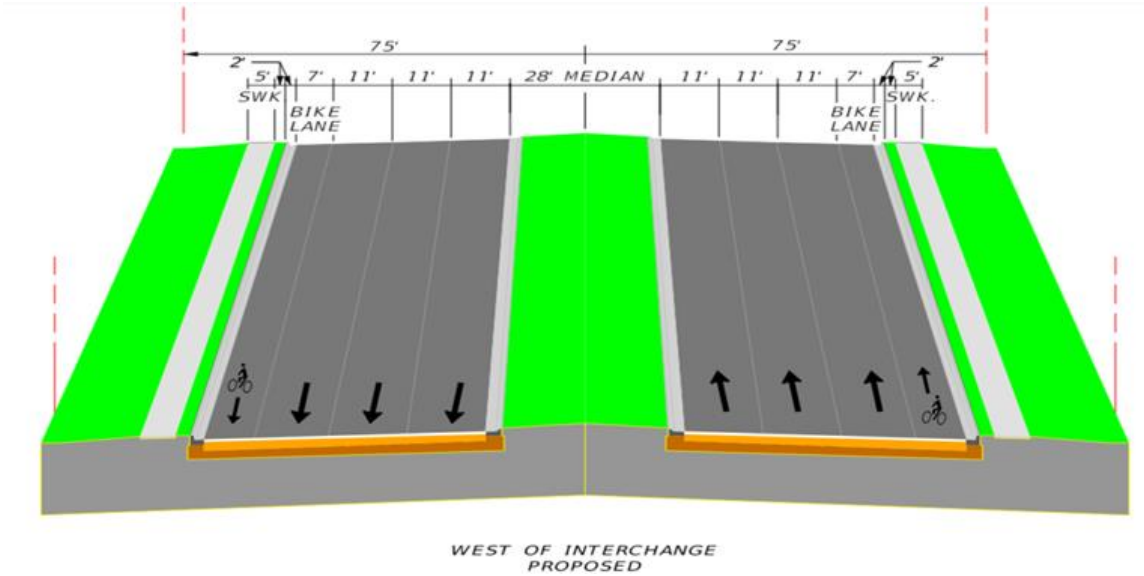

Figure 27. West of Interchange

9. Lane Width/ Cross Slopes

The design criteria for lane width and cross slopes were taken accordingly from AASHTO green book and FDOT standards. According to the following figure, our design speed was less than 45 mph in both west and east interchanges, so as a result we ended up having 3 lanes with 11 feet width that equal to 33 feet in total.

Table 22. Border Width (FDOT 2016a; AASHTO 1999)

BORDER	
TYPE FACILITY	WIDTH (FEET)
FREEWAYS (INCLUDING INTERCHANGE RAMPS)	94 1
ARTERIALS COLLECTORS Design Speed > 45 mph	40
ARTERIALS COLLECTORS Design Speed ≤ 45 mph	33

In the new design of US 301 has a slope of 0.02 applied from 8th AVE to Haben BLV. Having slope will increase the road efficiency in terms of drainage, which will help to maintain high traffic volume even in heavy rain seasons. The super elevation application is a result of vertical and horizontal alignments. The super elevation process has been designed along the US 301 with a simple crown located in midpoint of median as shown in the figure.

10. Key Sheet

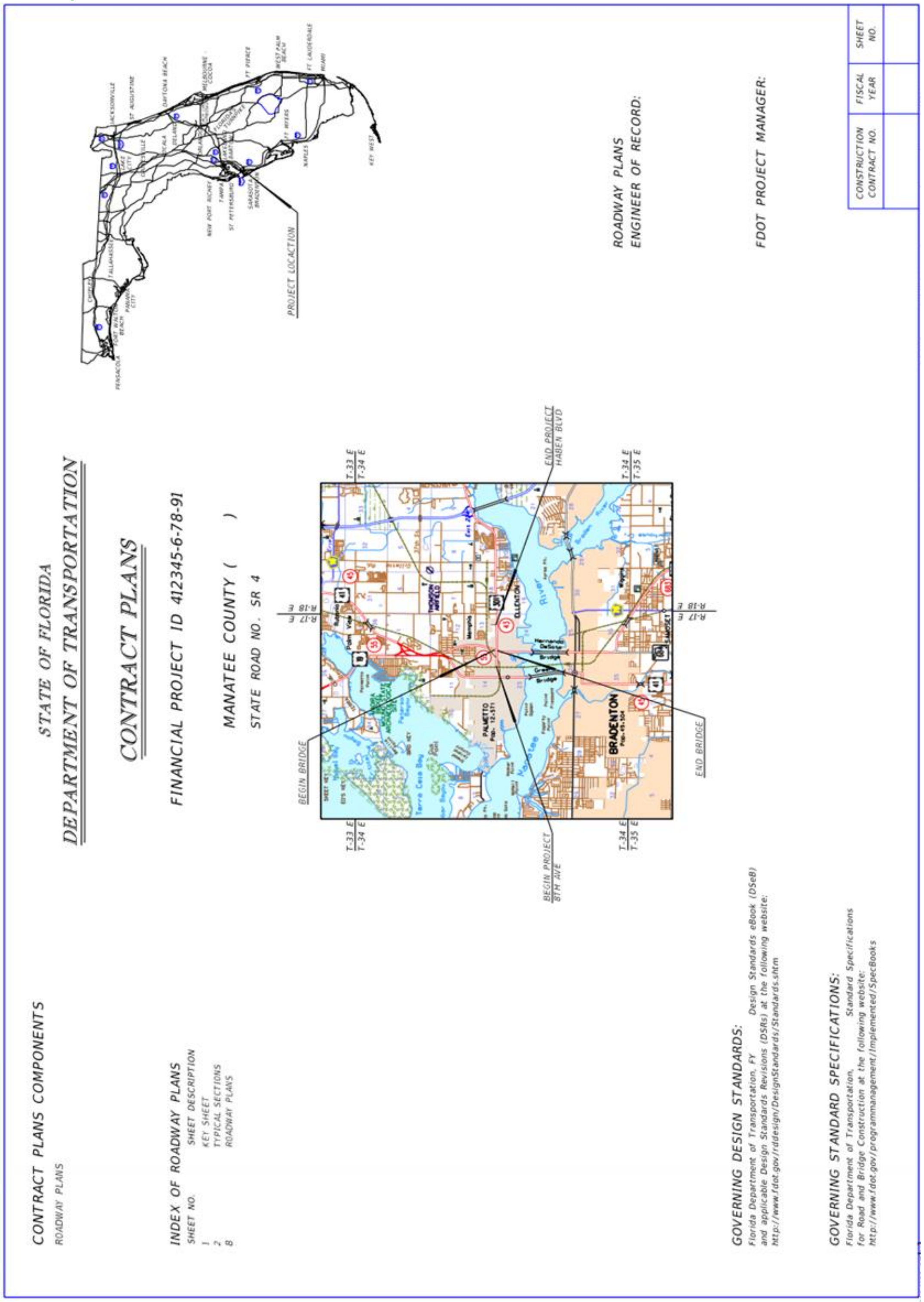

Figure 28. Key Sheet

11. Typical Section

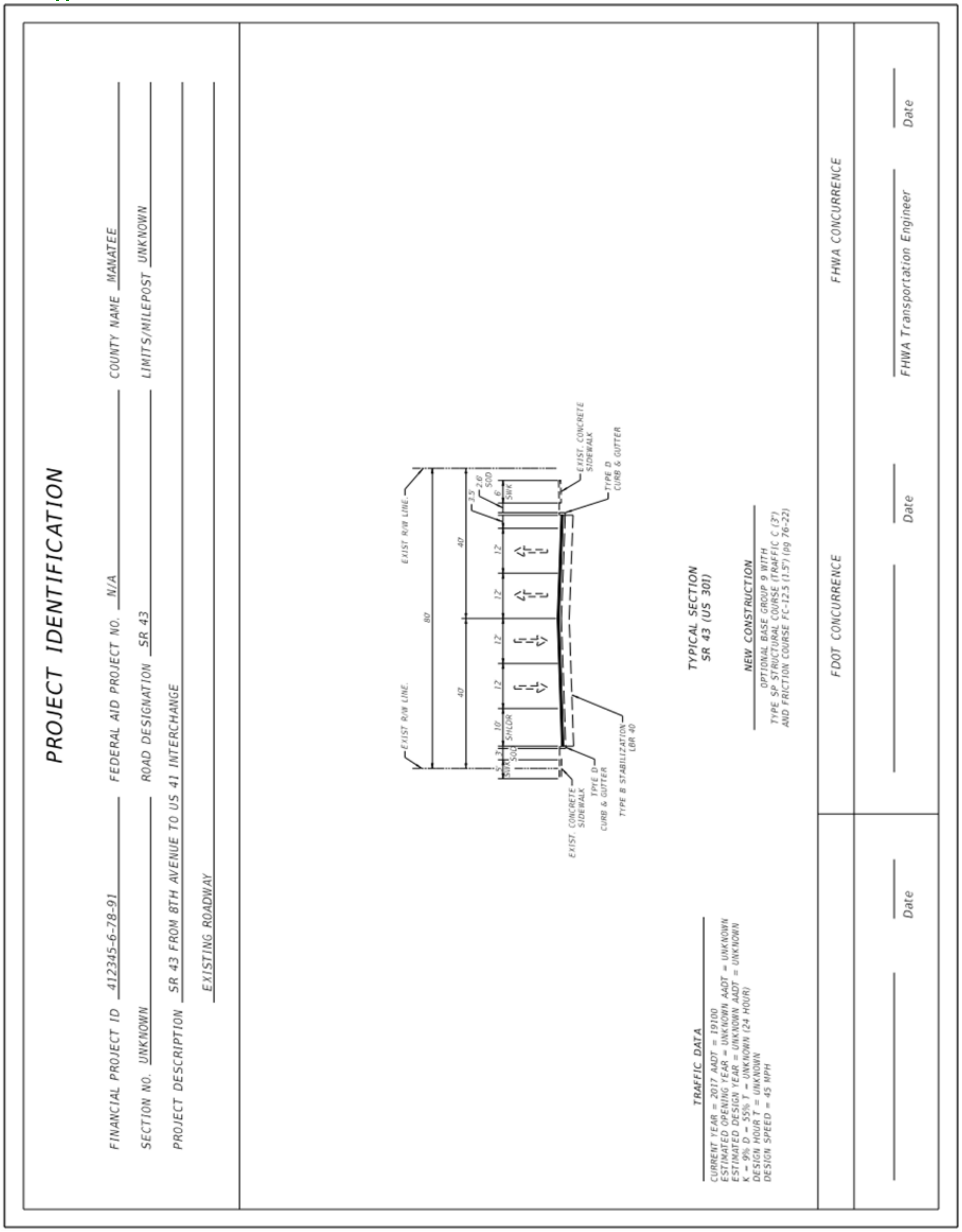

Figure 29. Typical Sections 1

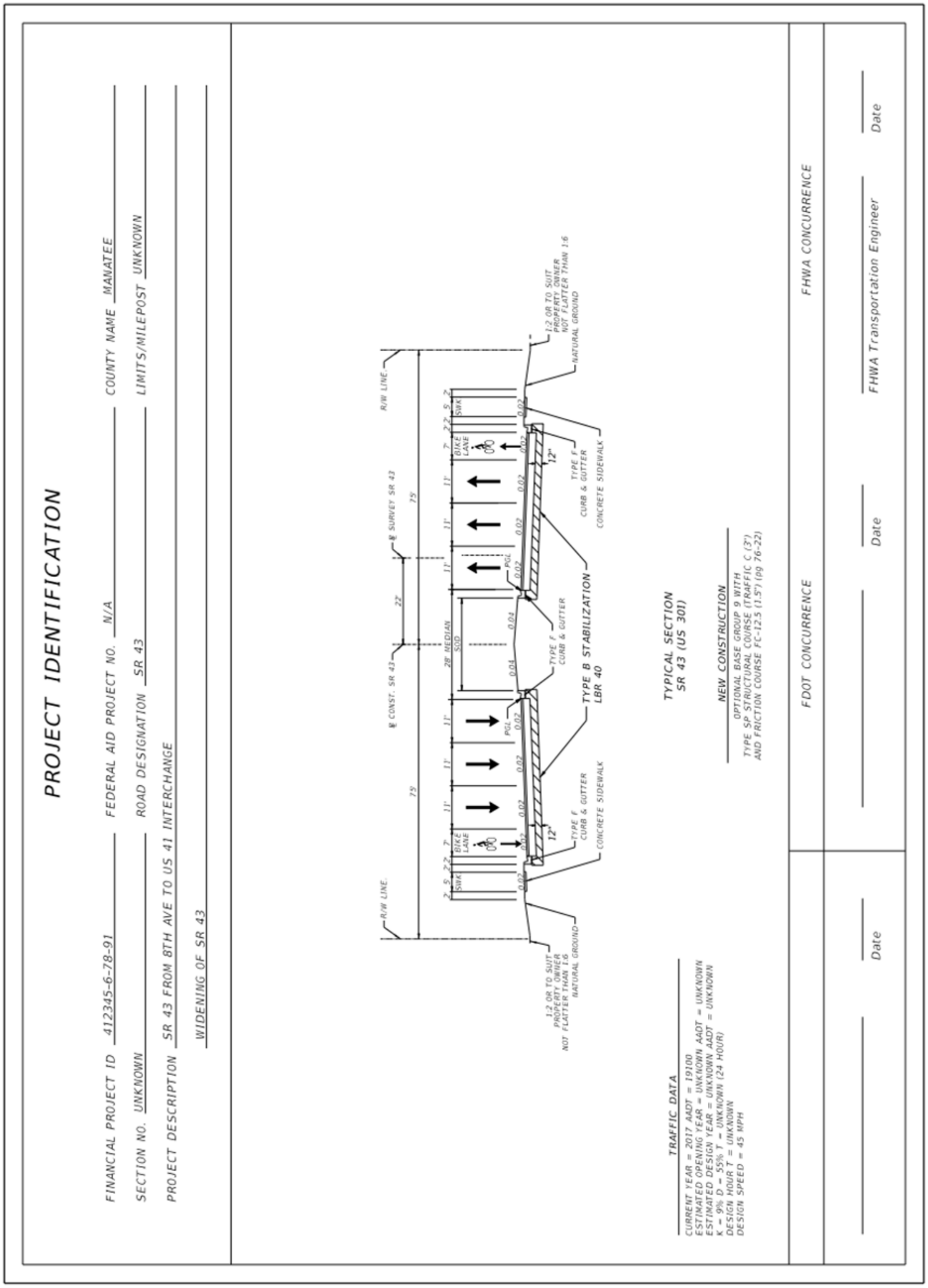

Figure 30. Typical Sections 2

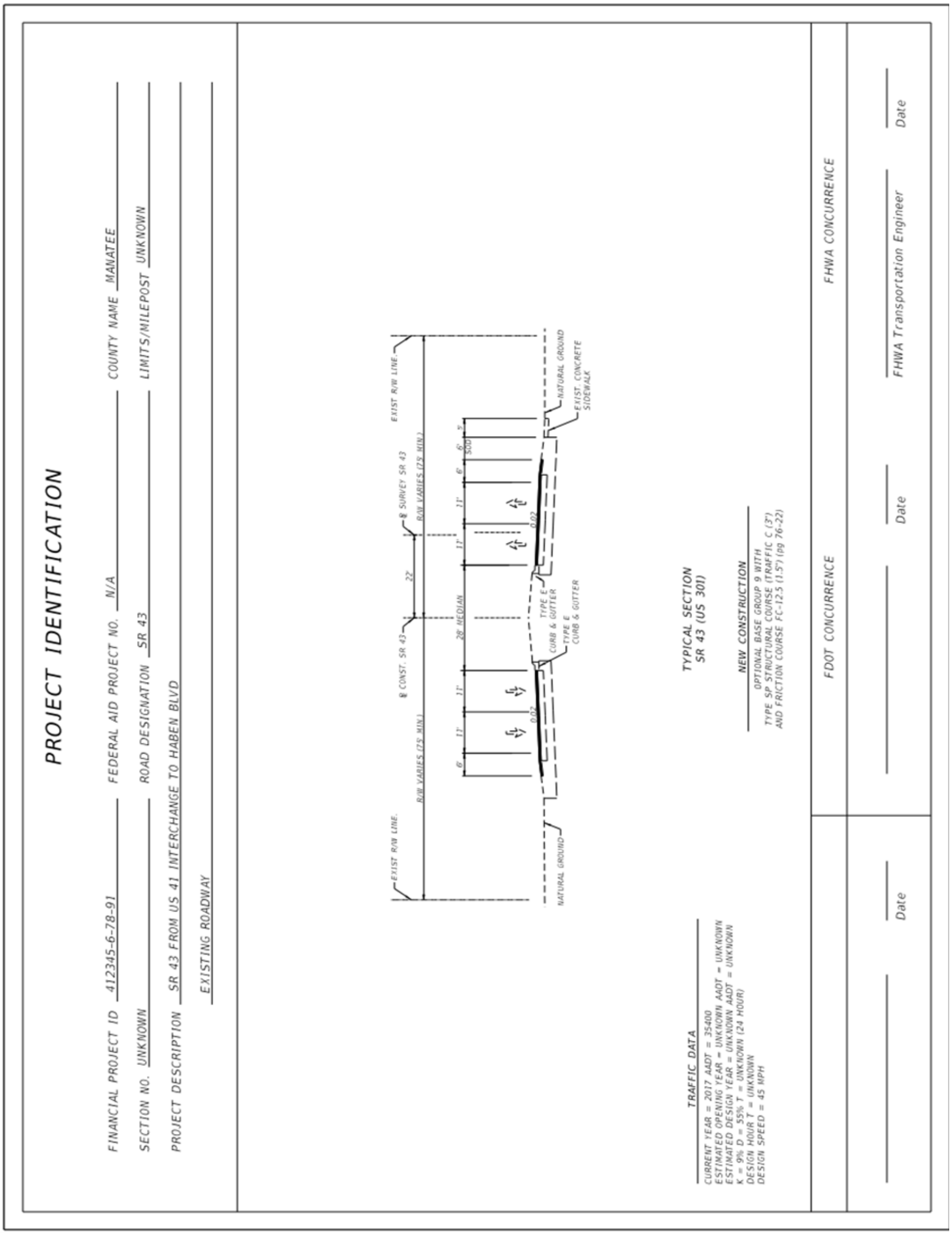

Figure 31. Typical Sections 3

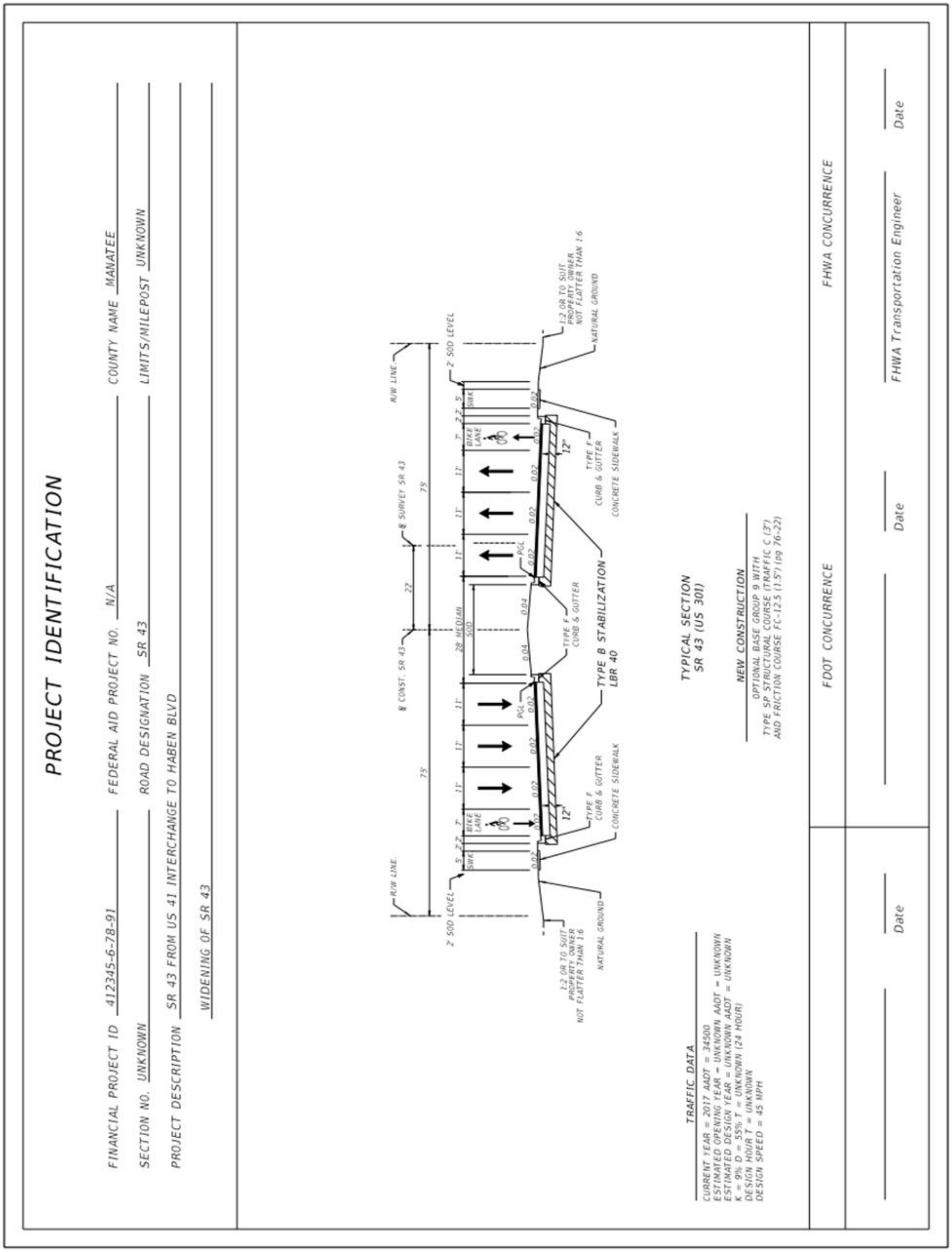

Figure 32. Typical Sections 4

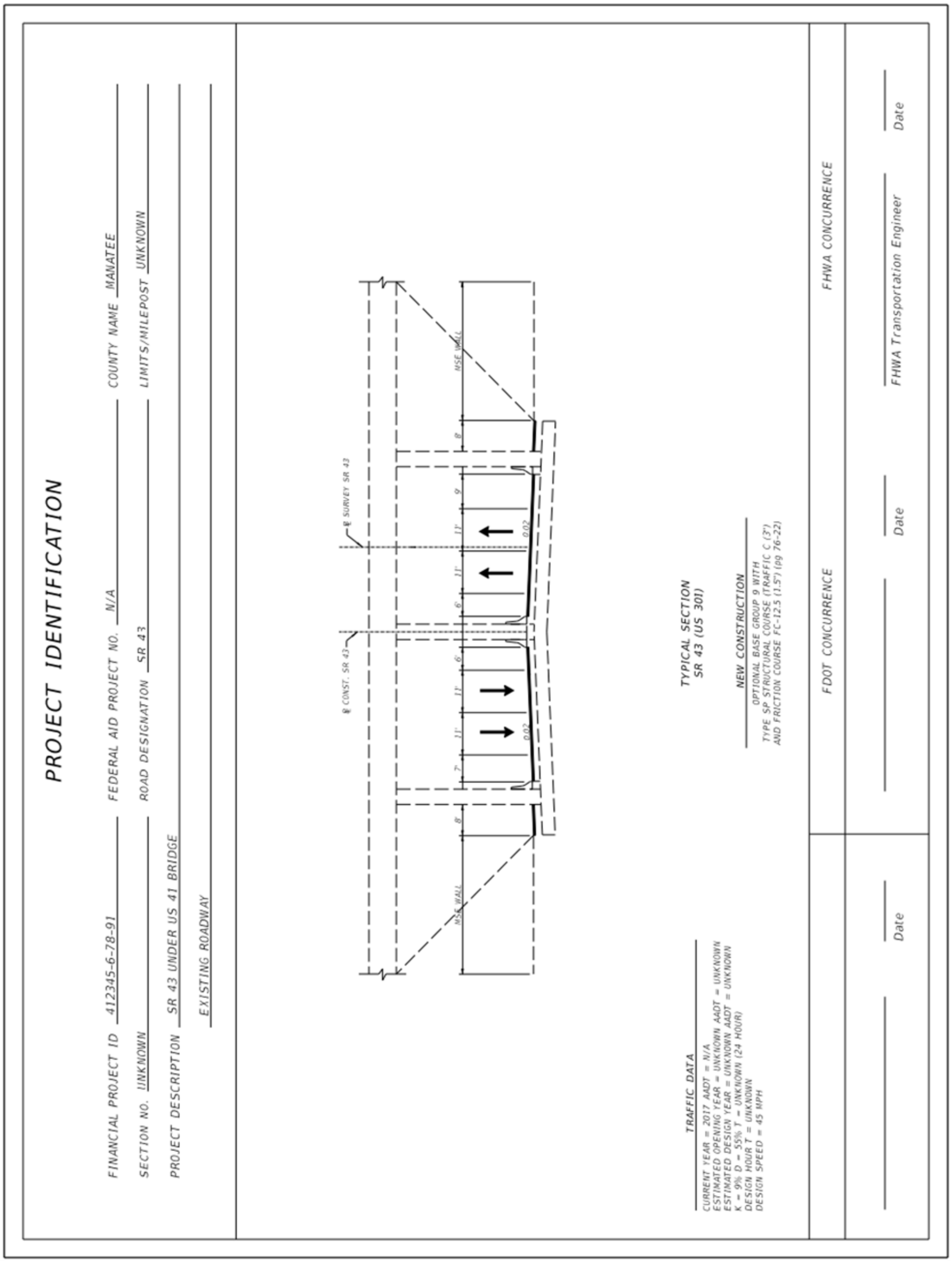

Figure 33. Typical Sections 5

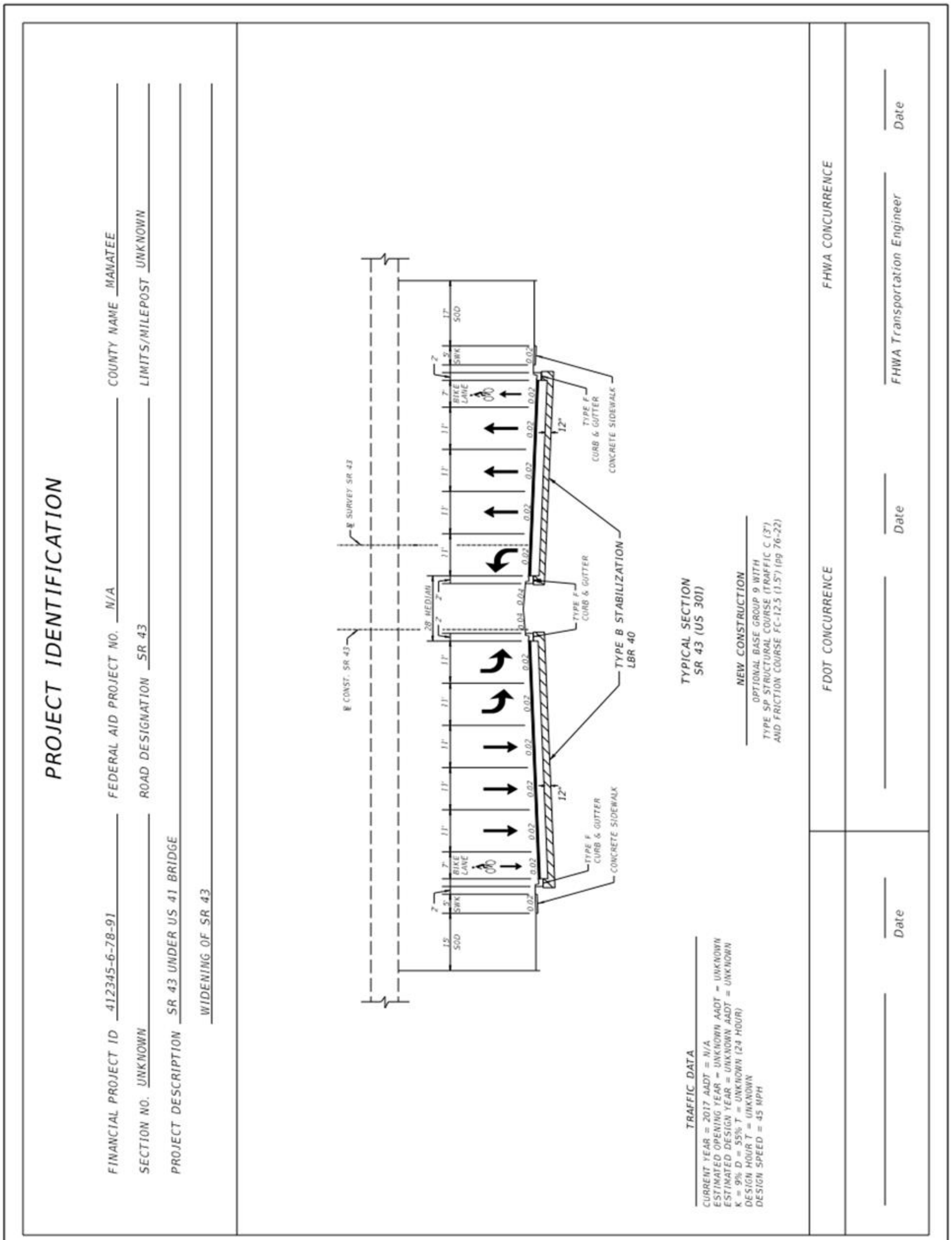

Figure 34. Typical Sections 6

12. Plan Sheets

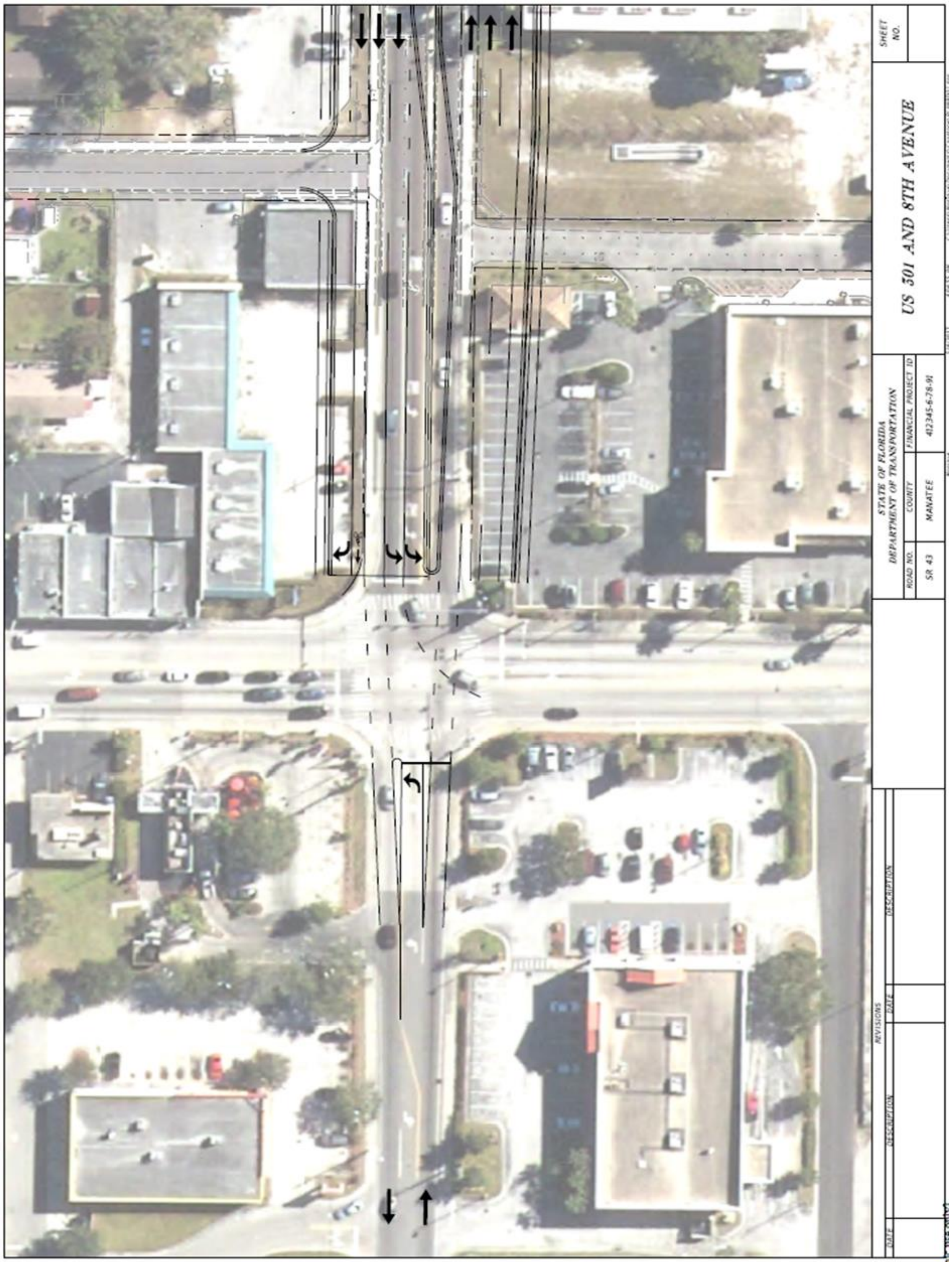

Figure 35. Plan Sheet 1

Figure 36. Plan Sheet 2

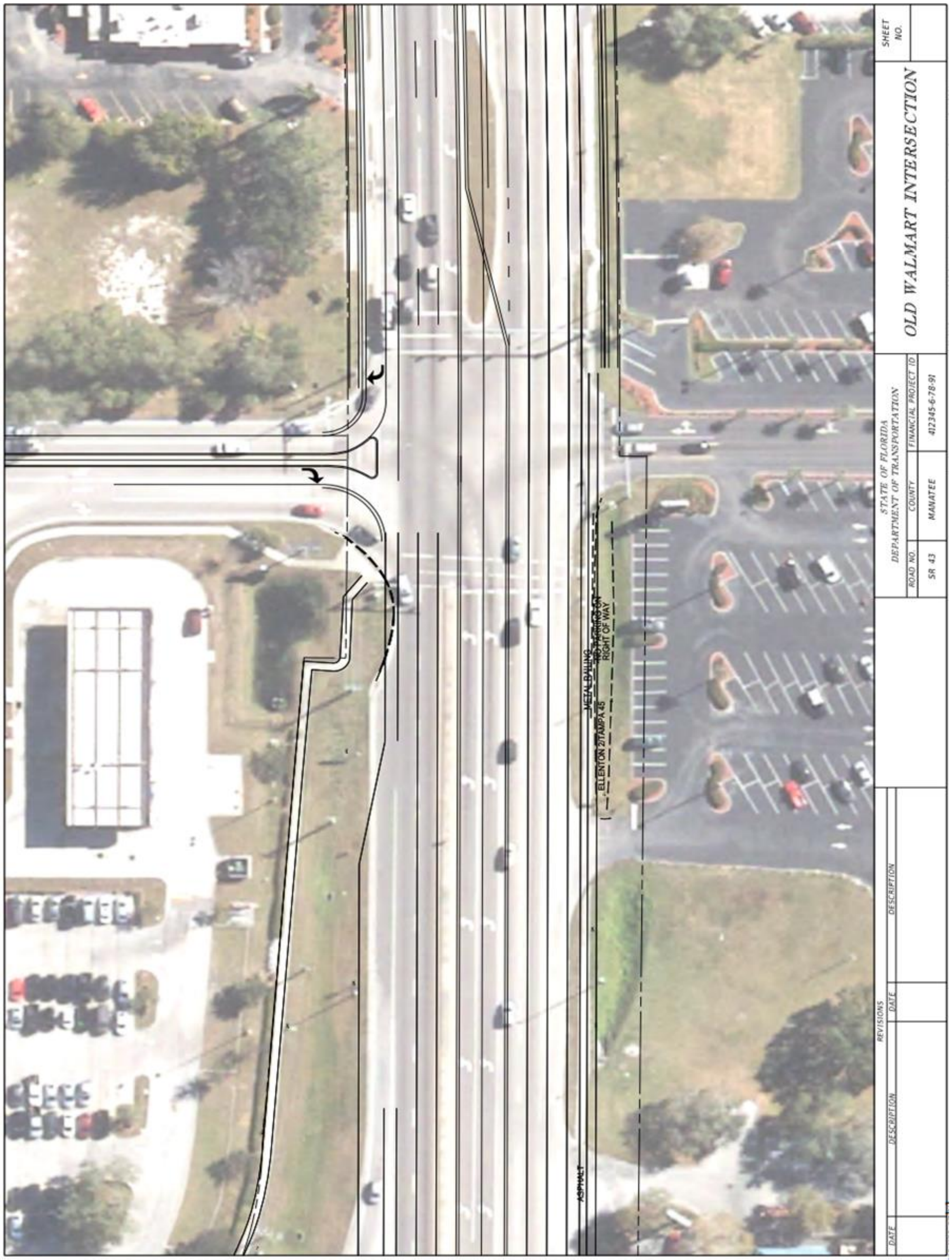

Figure 37. Plan Sheet 3

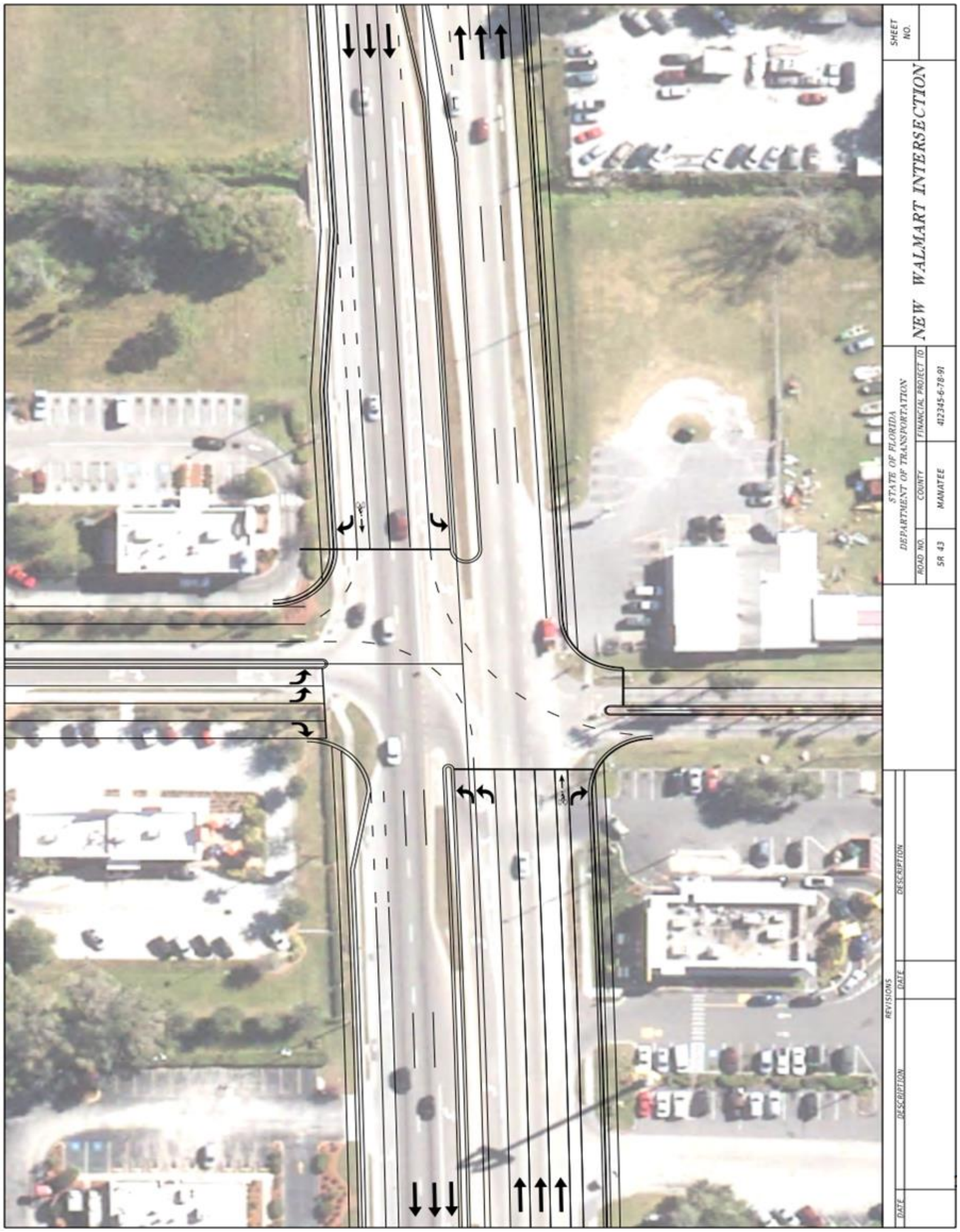

Figure 38. Plan Sheet 4

13. Cost Estimate

Table 23. Pay Items

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST
INLETS, CURB, TYPE P-1, <10'	EA	55	$4,300.00	$236,500.00
PIPE CULVERT,OPTIONAL MATERIAL,ROUND, 24"S/CD	LF	13728	$55.00	$755,040.00
CONCRETE CURB & GUTTER, TYPE F	LF	27600	$16.50	$455,400.00
CONCRETE SIDEWALK AND DRIVEWAYS, 4" THICK	SY	68500	$26.00	$1,781,000.00
PERFORMANCE TURF, SOD	SY	5000	$3.00	$15,000.00
MILLING EXIST ASPH PAVT, 1 1/2" AVG DEPTH	SY	411840	$2.00	$823,680.00
FLEXIBLE PAVEMENT	SY			$2,064,501
CONSTRUCTION SUB-TOTAL				$6,531,121.25
MOBILIZATION			10%	$653,112.13
MAINTENANCE OF TRAFFIC			10%	$653,112.13
LIGHTING			10%	$653,112.13
SIGNING AND PAVEMENT			10%	$653,112.13
PROJECT UNKNOWNS			10%	$653,112.13
GRAND TOTAL				**$9,796,681.90**

In order to determine the unit cost of each item for the suggested construction along U.S 301, the FDOT six month averages were used. The quantity for the individual pay items were determined based on the design files and drawings that were created in MicrosStation. Piping and Inlets are utilized so as to provide drainage along the length of U.S 301 as the suggested design would include curb and gutter. The piping and inlets would allow for water to drain off the roadway and then be collected to the side of the roadway in drainage ditches. Milling and Resurfacing of the existing asphalt on U.S 301 is done to minimize costs and utilize the current roadway as much as possible. The cost of flexible pavement was determined by the pavement design team based on the AADT and Equivalent Single Axle Load (ESAL) values that U.S 301 is expected to undergo, as well as the necessary structural number (SN) of the flexible pavement that will be necessary to ensure the longevity of the roadway. To provide funding for the necessary service that will ensure that the roadway is functional during construction 10% of the Construction Sub-total was designated per additional category that was not specifically roadway related, such as maintenance of traffic and the signing and pavement marking requirements for the roadway. Overall, the projected cost of the roadway is $9,796,681.90.

14. Discussion

Once the PD&E teams were completed, the Geometric Design team was able to develop typical sections of the existing roadways and design proposed typical sections based on results generated by TSIS simulations. Luckily the roadway was relatively straight for the congested areas and considerations for vertical and horizontal curves were avoided. Difficulties arose because the proposed designed called for an additional through lane to be added and the right of way wasn't acquired for all necessary sections of the roadway. High pedestrian volume also causes traffic signalization to be out sync and cause congestion. An additional issue which seemed to be the most troublesome was the Walmart intersection before the on ramp to US 41.

Geometric Design of US 41

15. Introduction

The geometric team for the US 41 mainly focuses on the intersection between 17 street and Haben Blvd. located just under the bridge.

In order to improve the level of service of the intersection and reduce traffic congestion, the US 41 geometric team develops typical sections of the widened US 301 under the interchange based on the information provided by the planning team. The new and upgraded interchange will consist of the elimination of the diamond interchange (by modifying the retaining walls to allow the construction of additional lanes) and the design of a new single point urban interchange, or SPUI. As known, the single point urban interchange is a type of interchange where the arterial and ramp entrances/exists are controlled by a traffic signal. Moreover, the turning movements of the ramp and the road are executed on the underpass which according to the existing literature the SPUIs increase the capacity of the interchange and improve the traffic flow in comparison to the less efficient standard interchange. By developing a SPUI to the intersection in the overpass, the on and off ramps will be closer together which allows for double turns on the north and south.

The new interchange under the ramp, which will be possible with the re-design of the mechanically stabilized earth (MSE) retaining wall, consists specifically of the substitution of the diamond interchange with an SPUI consisting of two through lanes, one left turn auxiliary lane and one bicycle lane with at least 5 ft. of sidewalk at 10th street West and two through lanes, two left turn auxiliary signal lanes, and one bicycle lane with at least of 5 ft. of sidewalk at 10th street East. It should be noted that the SR 41 from 17th street to the interchange and south of the interchange will maintain its existing roadway features and will only be needing milling and resurfacing.

This chapter of the report will address the scope, methods, observations, assessments and recommendations in greater detail for the design of the new typical sections with the new and improved single point urban interchange. Any recommendations offered are of a conceptual nature, and any photos or graphics included were provided for reference only.

15.1 Scope and Objectives

USF was given the responsibility for the redesign of the intersection of 17th St to Haben Blvd. The limits of the project included the redesign of the road from 17th St to Haben Blvd. After the completion of the analysis by the planning team of the available roadways, it was determined that the road would require redesign for it to obtain the minimum level of Service (LOS) C, while it was necessary to attain the minimum level of service D by the year 2045. The proposal of the planning team was to increase the main line by building MSE retaining walls to give more room for additional lanes. Likewise, the barriers were to be removed, and the rebuilding of the bridge was to take place. Similarly, changes to the road involve the addition of helping turn lanes and through lanes at their intersection. The embankment that supports the bridge was also replaced with MSE walls to give room for the lanes added while reducing the length of the bridge. The design began once the scope of the work was understood fully. The team was given the survey of the area to help them in their work and DGN files to help in the design process. The least number of lanes to be added were given to the Geometric Design Teams by the team for planning. Design criteria provided by FDOT and AASHTO were then reviewed by the team to make a design on the details involved in the project. The general sections and plan sheets were formed after the tabulation of the criteria for design. By using the information provided by the PD&E team, calculations were made on the clearance of vertical height for the bridge.

Figure 39. Map of the Project Location

In order to begin the design, roadway design criteria were required (Figure 40). The design criteria information for roadway was gathered from the design standards of AASHTO 2011 and the FDOT standards of design. Similarly, some information was taken from preparation plans manual volume one, 2016. The year 2045 model was provided to the class when the design project was presented.

Roadway Classification		Rural Arterial	High Speed Suburban Arterial	High-Speed Urban Arterial
General Criteria	Design Speed	65 mph	55 mph	50 mph
	Design Vehicle	WB-62 FL	WB-62 FL	WB-62 FL
	Median Widths	40 ft.	30 ft.	30 ft.
Section Features	Inside Shoulder	8 ft.	4 ft.	4 ft.
	Outside Shoulder paved width	5 ft.	5 ft.	6.5 ft.
Horizontal Clearance	Clear Zone	36 ft.	30 ft.	24 ft.
	Border width	40 ft.	40 ft.	29 ft.
	Max Super Elevation	10%	5%	5%
	Min. Length of Curves	400 ft.	400 ft.	400 ft.
Horizontal Alignment	Min. Curve. Radius w/Super	1,348 ft.	2,750 ft.	2,244 ft.
	Min. Curve. Radius w/o Super	13,164 ft.	9,949 ft.	8,337 ft.
	Maximum Grade	3%	5%	6%
	Minimum Grade	0%	0%	0.3%
	Base Clearance above DHW EL	3 ft.	1 ft.	1 ft.
	Max Change in Grade w/o Curve	0.3 %	0.5 %	0.6 %
Vertical Alignment	Minimum SSD	645 ft.	495 ft.	425 ft.
	Minimum Length of Crest Curves	450 ft.	350 ft.	300 ft.
	Minimum K Value of Crest Curves	313	185	136
	Minimum Length of SAG Curves	350 ft.	250 ft.	200 ft.
	Minimum K Value of SAG Curves	157	115	96

Figure 40. Roadway Design Criteria

16. Improvement Plan

The improvement plan involved building MSE retaining wall to give room for more lanes and eliminating the barriers and reconstruction of the bridge as shown in Figure 41.

Figure 41. US 41 Improvement Plan

The On/Off Ramps were brought closer to change the interchange to single point urban interchange.

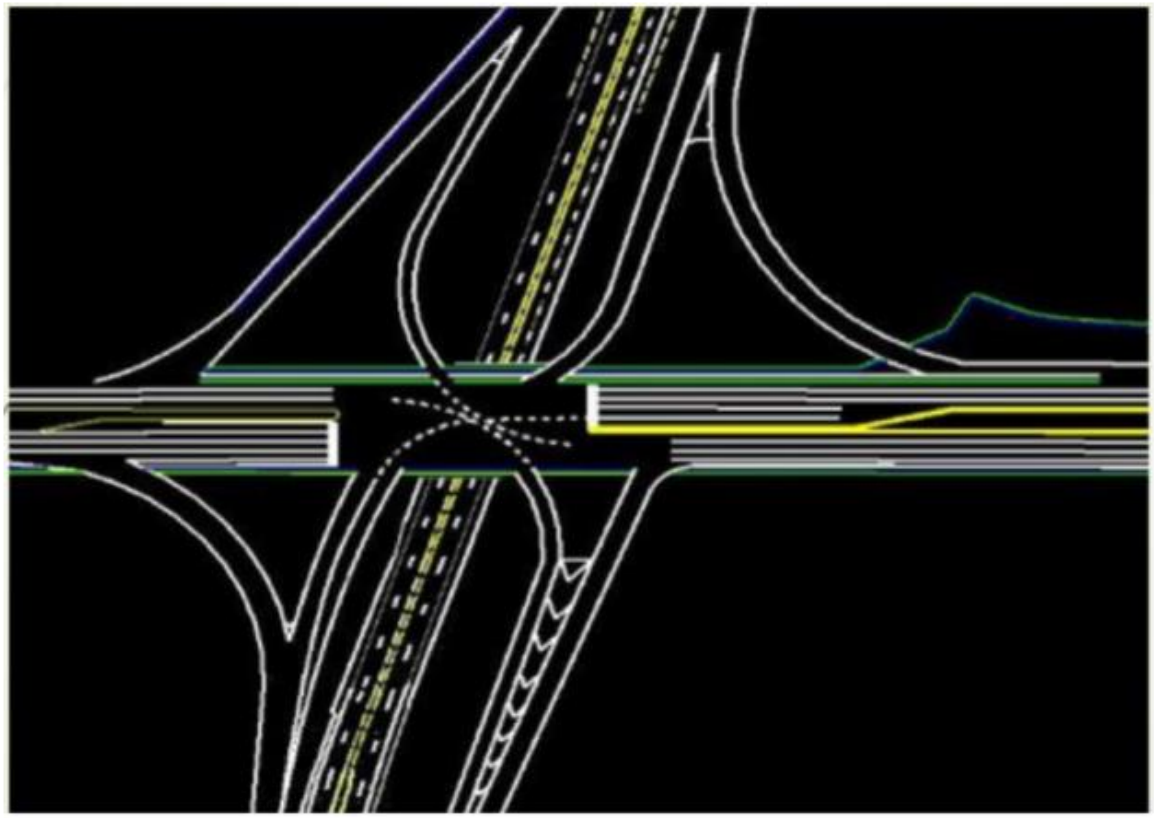

Figure 42. US 41 On and Off Ramps

Table 24. US 41 Lane Widths (HCM 2010)

LANE WIDTHS (FEET)					
FACILITY		TRAVEL LANES	AUXILIARY LANES		
TYPE	AREA		SPEED CHANGE	TURNING (LT/RT/MED)	PASSING
FREEWAY	Rural	12	12	----	----
	Urban	12	12	----	----
ARTERIAL	Rural	12 [6]	12 [6]	12 [6]	12 [6]
	Urban	11 [1]	11 [1]	11 [1,2]	11 [1]
COLLECTOR	Rural	12 [5,6]	11 [2]	11 [2,3]	11 [2,4]
	Urban	11	11	11 [3]	11

- Twelve feet for design speed not greater than 45 mph and all roadways that are not divided
- Twelve feet for two lane roadways
- Twelve feet for when truck volume passes 10 percent

- Eleven feet for low volume AADT
- Eleven feet for roadways that are divided with Design Speeds which is greater or equal to 45 mph and within a mile of an urban area

The section of US 41 north of the interchange continues to 17th St. further on. This section consists of 4 lanes, a median, and two paved shoulders, which stays consistent with its original design. There is excess right of way on the eastern side of the road that allows for a paved shoulder of 10 ft. (much larger than the west side which has a shoulder of only 4 ft.). The four lanes meet the minimum 11.1 ft. width set by FDOT and are a standard 12 ft. The median, which extends the entire section of the roadway, varies from 8 ft. to 20 ft. which causes the total width of the roadway to vary equally with the median.

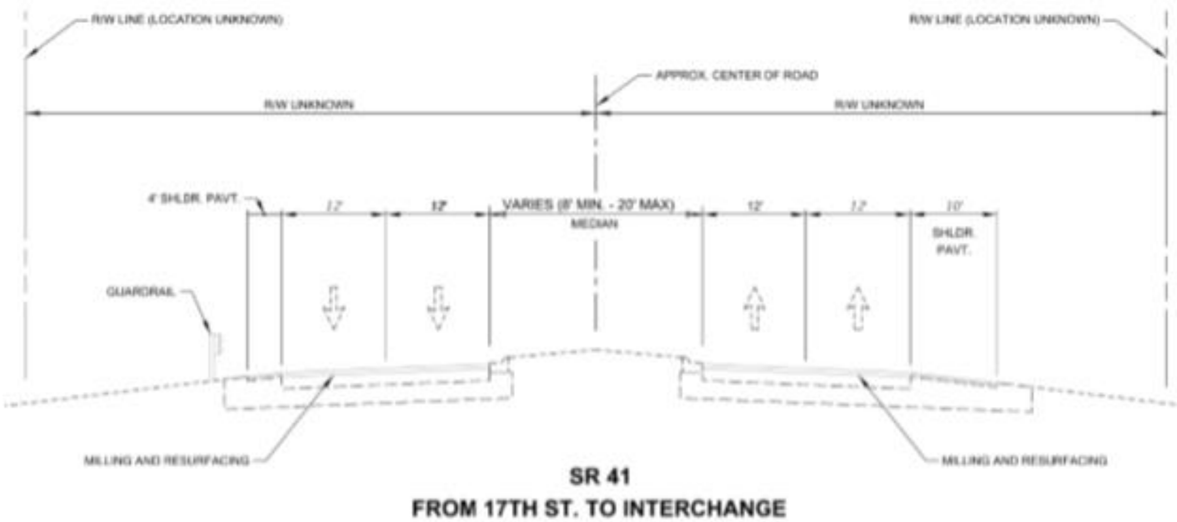

Figure 43. US 41 North Typical Section

The section of US 41 south of the interchange has boundaries of US 301 and Haben Boulevard to the south. This section was kept the same in terms of design consisting of a median, a shoulder on each side of the roadway, and a right turn lane on the southbound portion of the roadway. Keeping with the FDOT's recommendation of 11.1 ft lane width for an urban arterial, each lane (including the turn lane) is 12 ft wide. The median and the western shoulder width vary along the segment of roadway.

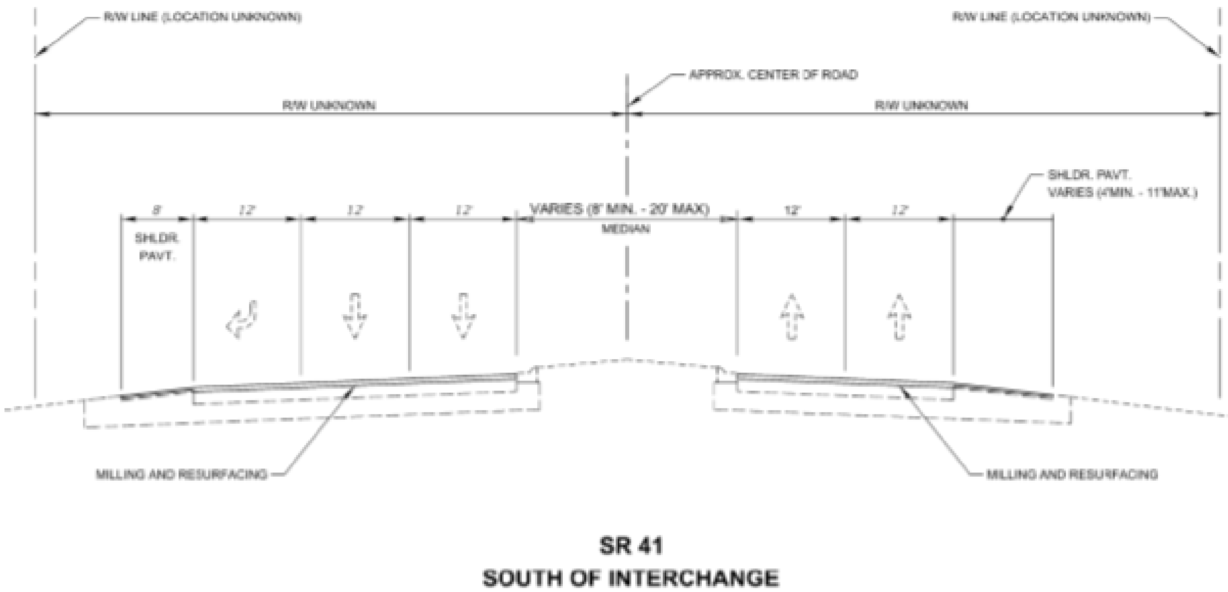

Figure 44. US 41 South Typical Section

The typical section for the section of US 41 that passes over US 301 stays the same in design as it was prior to roadway improvements. The only change to the bridge is the length, because US 301 (the road beneath it) is being widened substantially. The total width of the roadway is 70 ft with a shoulder on each side, an 8 ft median and two lanes and either direction. The width of each lane is shortened to 11 ft (from the 12 ft to the north and south) and each shoulder has a constant length of 10 ft across the length of the bridge.

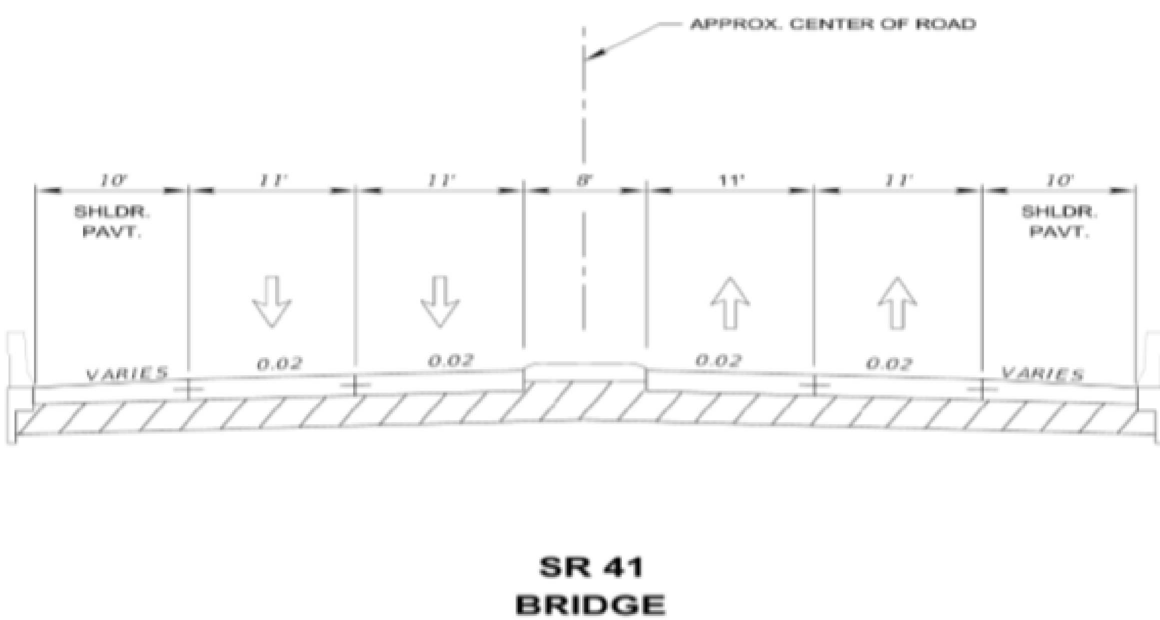

Figure 45. Section of US 41 and US 301

16.1 Design Vehicle

The design vehicle for this project is the WB-62FL. This standard comes from the 2011 edition of "A Policy on Geometric Design of Highways and Streets" published by AASHTO, commonly referred to as the AASHTO Green Book. This vehicle is fairly common and this particular combination vehicle is a sleepercab tractor paired with a 48-foot trailer. While this is a common vehicle, it is more common to use 53-foot trailers instead of 48-foot trailers. The wheelbase is 62 feet. The width of the vehicle is 8 feet 6 inches, and the height is 13 feet 6 inches. The overall length is 68.5 feet, but real world dimensions vary based on the actual dimensions of the tractor, which varies slightly from one manufacturer to another.

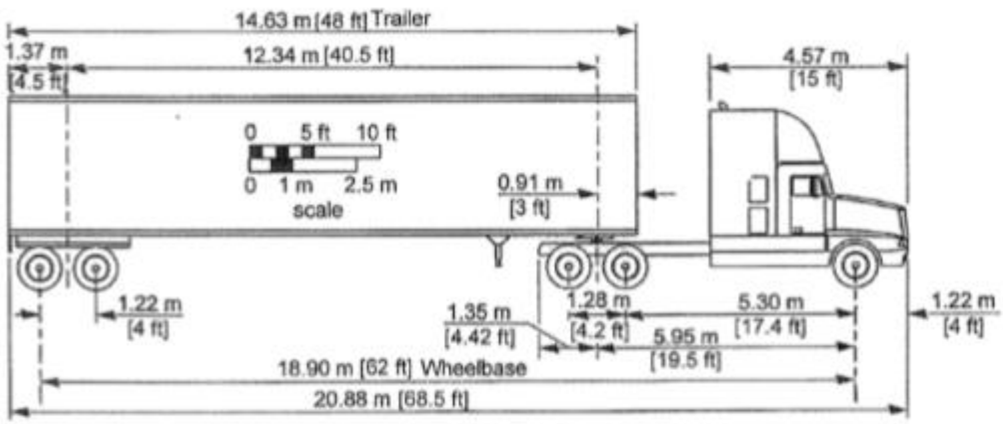

Figure 46. Design Vehicle WB-62FL

The length can also vary based on the position of the fifth wheel. Moving the fifth wheel will change the spacing between the tractor and the trailer. The position of the tandem axle on the trailer can also be adjusted. Moving the fifth wheel and/or the tandem axle is helpful in changing the maneuverability of the vehicle or for weight distribution purposes. It is common to make these adjustments for both purposes. As it relates to the design standard, maneuverability is the primary concern. One key element for the driver of the vehicle to pay attention to is the bridge length. Bridge length is the distance from the kingpin to the center of the tandem axle. The kingpin is the trailer's portion of the hitch or coupling device and combined with the tractor's fifth wheel, this is the combination vehicle's pivot point. Every state has regulations regarding bridge length, so it is common for the driver to make adjustments to the bridge length. The design standard allows for the tandem axle to be in the furthest rearward position, which results in the maximum possible bridge length for this vehicle of 40.5 feet. From a design standpoint, this is key. Essentially, the design standard has been setup to accommodate for this vehicle in its least maneuverable condition. This ensures that these vehicles can be safely operated under any circumstance. Real world concerns for maneuverability will stem from the fact that 53-foot trailers are used much more than 48-foot trailers and the additional length increases the turning radius. Key elements to note in the design standard are the minimum turning radius of 45 feet, as well as the path of the front overhang which is 46.4 feet. The overhang becomes important when looking at the separation between opposing turning motions.

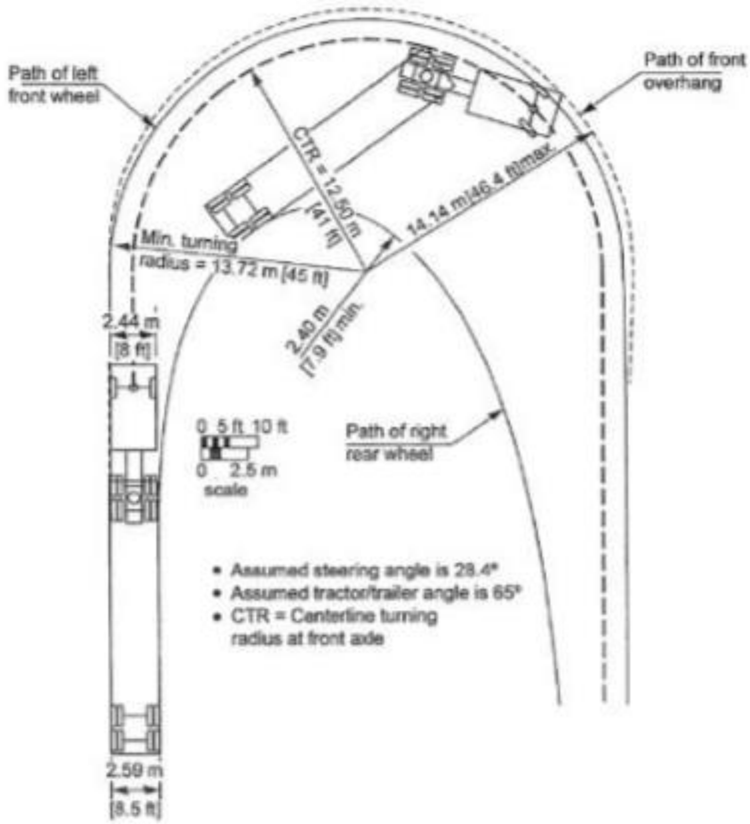

Figure 47. Turning Radii

The radii of curves in the project relate directly to the standard of the selected design vehicle. Right turns from the off-ramps and onto on-ramps have a minimum radius of 45 feet as specified by the WB-62 standard. In addition, the radius of left turns is a minimum of 125 feet for the design. This large radius is due to the geometry of the SPUI. Another key element is the spacing between opposing motions. To allow for opposing turning motions during the same signal phase, there must be a separation of no less than 5 feet. The proposed design has a separation of 6.7 feet, allowing left turns from both the northbound and southbound off-ramps to occur simultaneously. This is a huge positive as it means this interchange can operate in only three signal phases, which further improves its efficiency.

17. US 301 SPUI Accommodations

It was imperative to accommodate the need to match the proposed design of the US 301 Geometric team under the span of the bridge. With that being said, throughout the SPUI there are 5 ft concrete sidewalk as well as bike lanes for pedestrian travel. Stop bars are to be placed in for off ramps at the SPUI. Essentially it was part of the US 41 design to accommodate the transition from high speed suburban to purely urban conditions. Furthermore the left turn motion from US 301 to the southbound on ramp required an additional lane according to the analysis from the PD&E (planning) team. A total length of 360 ft was used to accommodate the queue length requirement.

18. Cost Estimate for Bridge span and State Rural Road

In order to acquire the cost for the units, the description of each beam type and their estimated value was given per feet. The total span length was found to be 180 ft. By using FDOT regulations, a 78-inch FIB was selected and applied. It is important to note that the new bridge construction will have a clearance of 18 ft to accommodate for all vehicle types. The quantity of every item to be used were found by taking the length of the span and the average cost per beam ($260 by 180), which gave a total of $46,800 per beam. In this work a total of six beams were required making the total cost to be $280,800 ($46,800 x 6= $ 280,800).That was to eliminate the columns and give allowance for the addition of lanes. Milling and resurfacing with five-inch paved shoulders cost was $ 515,500 and 5102' is equal to 0.97 miles. The total cost was therefore found by multiplying the miles by the cost of milling and resurfacing with 5 ft paved shoulders. It, therefore, gave a total cost for the road to be $498,121. The project, just like any other project had many variables that were not in the control of the designer. Therefore a 10 percent contingency was applied to meet the unknown costs. The total cost of the project was estimated to be $498,121 in addition to 280,800, which gave $778,920.

19. Discussion

In terms of design work accomplished by the US 41 team, the largest component was the design of the single point urban interchange. Due to the outstanding work of the planning team it was discovered that the bulk of traffic issues were truly being caused by the area adjacent to the Walmart. With that being said the only proposed design work for the length of US 41 (excluding ramps) was standard milling and resurfacing.

US 301 & US 41 Interchange - Pavement Design

20. Introduction

The pavement design project area includes the length of US 301 bounded by 8th Ave and Haben Blvd, the on and off ramps onto US 41, and the bridge passing over US 301. Figure 48 displays an aerial view of the project area. Flexible and rigid pavement designs were performed for each road segment following the criteria and guidelines set by FDOT and AASHTO. The two pavement design types were then compared based on a life cycle cost analysis (LCCA). The final pavement design recommendation is based on which design is most cost effective as well as which design fits the nature of the structure.

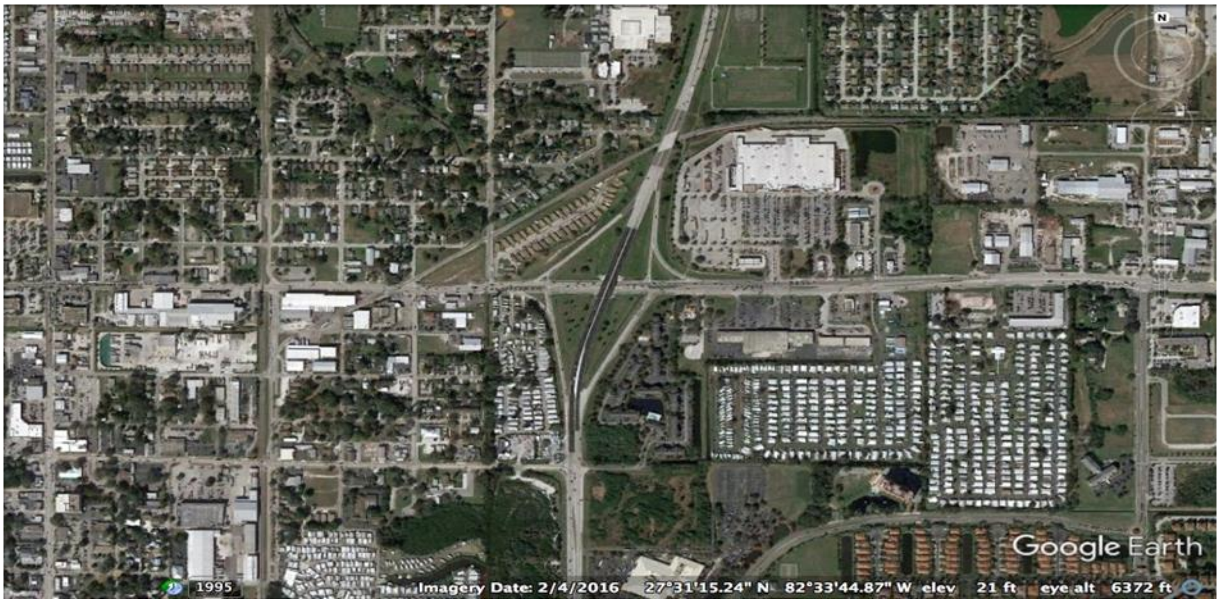

Figure 48. Aerial View of the Project Location

20.1 Pavement Type Selection

Selection of the type of pavement is an important decision in the design of pavement. 1993 AASHTO Guide states, "The selection of pavement type is not an exact science but one in which the highway engineer must make a judgment on many varying factors…" A list of factors to consider is provided in Appendix B of the 1993 AASHTO Guide:

Principle factors:

- Cost Comparison
- Traffic Forecast
- Soil Characteristics
- Weather
- Construction
- Recycling

Secondary factors:

- Area Past Performance
- Existing Pavements
- Scarcity of Materials
- Local Availability
- Traffic Safety
- Environmental features
- Local Competition
- Use of Local Industry

20.2 Economic Analysis

A cost analysis comparing flexible to rigid pavement designs will be performed using the Present Worth Method. This method adjusts future costs to be more appropriate to what investment they would require now. This amount should be less than that of the actual cash flow. This method will be used to for both the capitalized (new construction) and life cycle (rehabilitation) costs of this project.

20.2.1 Present Worth Assumptions

Equation 11. Present Worth Assumptions

$$P = F(1+i)^{-t}$$

Where,

P - Present worth (dollars)

F - Future worth (dollars)

i - Effective periodic interest rate or rate of return (4% used)

t - Number of compound periods; or the expected life of an asset (years).

20.2.2 Life Cycle Cost Analysis

The LCCA is an economic assessment of competing design alternatives. This considers all significant costs of ownership over the economic life of each alternative expressed in equivalent dollars. LCCA contemplates all costs over the lifetime of the facility.

21. Flexible Pavement

Flexible pavement is a multilayer pavement that generally consists of the following layers: friction course, structural course, base course, subbase course, and subgrade. The friction course layer provides traction to vehicles, and drainage. The structural course provides strength and transfers loads to the layers underneath. The base, subbase, and subgrade layers provide additional strength and support the layers above. Most roadways are commonly paved with flexible pavement; traffic lanes, auxiliary lanes, ramps, parking areas, and shoulders are all common applications.

This design has numerous advantages: they adjust to limited differential settlement of soil, are easily repaired, additional layers can be added easily, they provide long term non-skid properties, they feel better to ride on due to reduced noise and increased smoothness, and they can handle greater temperature fluctuations.

However, flexible pavements lose some flexibility and cohesion with time and require resurfacing sooner than cement concrete. Figure 49 shows a typical section for flexible pavements.

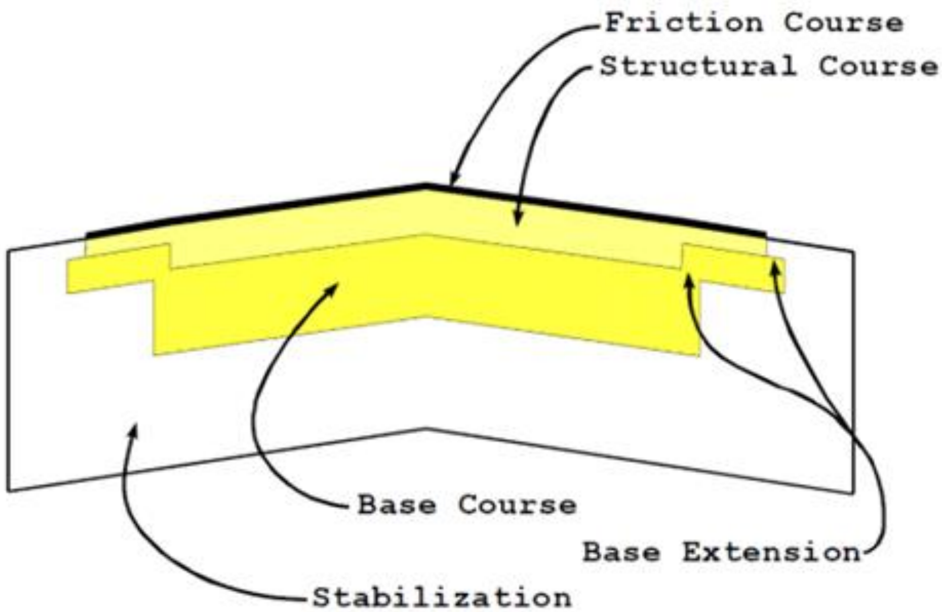

Figure 49. FDOT Typical Flexible Pavement Section (FDOT 2016b)

21.1 Flexible Design Requirements

The AASHTO 1993 Pavement Design Guide provides an empirical flexible pavement design equation that is based on the 1956-1960 AASHO road test in Ottawa, IL. The empirical equation is used based on a set design period and rehabilitation period for the pavement. The design accounts for factors such as: climate, materials used, traffic, response to damage over time. Required inputs of the empirical equation include: traffic quantities in terms of ESALs, required reliability, serviceability, existing resilient modulus, and the SN and layer coefficients that are then used to determine layer thicknesses.

21.2 Design Variables

21.2.1 Time Constraints

Performance Period: the initial time period that the pavement will last before it needs rehabilitation. FDOT initial design life is 20 years.

Analysis Period: the time period for which analysis is to be conducted.

21.2.2 Traffic

18-Kip ESALs: The AASHTO flexible pavement design equation converts AADT into ESALs, 18-kip

ESALs. Cumulative damage to the roadway from vehicles can be approximated from ESAL. The following equation from the FDOT Project Traffic Forecasting Handbook (2014) is used to calculate ESAL:

Equation 12. Equivalent Single Axle Loads

$$\mathbf{ESAL_D} = \sum_{i=1}^{n} \mathbf{AADT_i * L_f * T_{24} * D_f * E_f * 365}$$

Where,

n - design period in years

i - year for which calculation is made

AADTi = average annual daily traffic data in year i, given by the following equation:

T24 = percentage of heavy trucks during a 24-hour period, acquired from FDOT

DF = directional factor, acquired from FDOT

DF = 1.0 if one-way flow

DF ≈ 0.5 if two-way flow

EF = equivalency factor, given below in Table 25

Equation 13. AADT Data in Year i

$$\boldsymbol{AADT_i = AADT_{base\ year} * (1 + GR)^t}$$

Where,

GR = growth rate (1.5%)

Equation 14. Lane Factor, Derived from Copes Equation

$$\boldsymbol{LF_i = (1.567 - 0.0826 * \ln(oneway\ AADT) - 0.12368 * LV}$$

Where,

LV = 0 if number of lanes in one direction is 2 or less

LV = 1 if number of lanes is 3 or more

Table 25. FDOT Flexible Pavement Typical Equivalent Factors (FDOT 2014)

Example of Equivalency Factor E_F (E_{80}) for Different Types Of Facilities		Flexible Pavement	Rigid Pavement
Freeways			
	Rural	1.05	1.60
	Urban	0.90	1.27
Arterials and Collectors			
	Rural	0.96	1.35
	Urban	0.89	1.22

The team used the FDOT Design Spreadsheet to determine the ESALD for each section of the project. The inputs required for the spreadsheet were obtained from online FDOT Traffic Data and verified by the PD&E Team to be the correct values for design.

21.2.3 Reliability

Reliability is the probability that a pavement will perform at a satisfactory level in the duration of the design period. Reliability is reported as a percentage. For this design, which consists of two urban arterial roadways, a reliability of 90% was used.

21.3 Performance Criteria

21.3.1 Serviceability

Serviceability is the measurement of a pavement's ability to serve the traffic demand. In the AASHTO flexible pavement design equation serviceability is measured using the change in the Present Serviceability Index (PSI), or a scale rating from 0 to 5 with 0 being an impossible road. The change in serviceability used for this design was 2.

21.4 Material Properties

21.4.1 Resilient Modulus

The resilient modulus, MR, is an estimate of the modulus of elasticity for various materials. This is generally found by conducting a Limerock Bearing Ratio (LBR) test and relating the LBR results to MR through the following equation:

Equation 15. Resilient Modulus (FDOT 2016b)

$$M_R = 10^{0.7365 * \log(LBR)} * 809$$

In this project the base is designed as crushed aggregate, meaning that the wet resilient modulus is 60% of the dry resilient modulus. The two resilience moduli are then combined by using the follow equation to solve for the effective modulus (MReff) for the entire year:

Equation 16. Effective Modulus

$$\mathbf{MReff} = \mathbf{3005}(\mathbf{1.18} * \mathbf{10^8} * \mathbf{MR}_i{}^{-2.32})^{-0.431}$$

MR provided for the project area is 14,000 psi.

21.4.2 Structural Number and Layer Coefficients

The strength of the pavement, both the total pavement and individual layers, is represented as an index that is referred to as the SN. The following equation relates SN to the layer coefficients and layer thicknesses:

Equation 17. Structural Number (AASHTO 1993)

$$\mathbf{SN} = \mathbf{a_1 D_1} + \mathbf{a_2 D_2 m_2} + \mathbf{a_3 D_3 m_3}$$

Where,

ai = layer i coefficient, the relative ability of layer to function as a pavement structure as shown in Table 26

Di = layer i thickness, minimum thickness by FDOT standards are shown in Table 27

mi = layer i drainage

Table 26. FDOT Flexible Pavement Layer Coefficient by Layer Type (FDOT 2016b)

STRUCTURAL COEFFICIENTS FOR DIFFERENT PAVEMENT LAYERS
(New Construction or Reconstruction)

Layer Type	Layer Coeff. per inch	Spec. Sec.
FC-5	0.00	337
FC-12.5, FC-9.5	0.44	337
Superpave Type SP (SP-9.5, SP-12.5, SP-19.0)	0.44	334
Limerock (LBR 100)	0.18	200
Cemented Coquina (LBR 100)	0.18	911
Shell Rock (LBR 100)	0.18	200
Bank Run Shell (LBR 100)	0.18	200
Graded Aggregate (LBR 100)	0.15	204
Recycled Concrete Aggregate (LBR 150)	0.18	911

Table 27. FDOT Flexible Pavement Required Minimum Thickness (FDOT 2016b)

18-kip ESAL's 20 year period	Minimum Structural Course	Minimum Base Group
Limited Access	4"	9
Greater than 3,500,000	3"	9
Ramp less than 3,500,000	2"	9
300,000 to 3,500,000	2"	6
Less than 300,000	1 1/2"	3
Limited Access Shoulder	1 1/2"	1
Residential Streets, Parking Areas, Shoulder Pavement, Bike Paths	1"	1
Shared Use Paths	1 1/2"	1

21.5 Layer Coefficients

Referring to Figure 49, pavement design is generally separated into five distinct parts: friction course, structural course, base course, stabilized subgrade, and roadbed soil. The thickness and type of material for each layer are shown in Table 28.

Table 28. Pavement Layer Thickness and Type by Segment

Segment	Friction Course	Structural Course	Base	Subgrade
US 301. West of US41	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 301. East of US41	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 301. East of Walmart	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 41	0.75" FC-5	4" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
Ramps	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 301. East of US41	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 301. East of Walmart	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
US 41	0.75" FC-5	4" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)

21.5.1 Friction Course

The uppermost layer of the pavement is the friction course. This is the layer that all traffic comes into direct contact with. The friction course provides a skid-resistant surface for the traffic. A friction course is required in the state of Florida if the road has a design speed greater than 35 mph. For roads with a design speed greater than 45 mph, a non-structural open graded (OG) friction course must be used. OG friction courses are important for roads with higher design speed because the material reduces the potential of hydroplaning. For this project US 41 is designed to have 0.75” FC-5 while all parts of US 301 and the ramps on and off of US 41 are designed to have 1.5” FC-12.5. FC-5 is an OG friction course, so it does not add any structural value to the pavement. The FC-12.5 used on US 301 is a dense graded (DG) friction course and can be considered a structural course having a structural layer coefficient value of 0.44.

21.5.2 Structural Course

The structural course is the main layer of the flexible pavement that transfers the traffic loading to the base course. The structural course resists rutting and is designed to prevent surface water from reaching the layers beneath it. Ride smoothness and noise control are also determined based on the design of this layer. In Florida it is recommended that a Superpave asphalt mix is used for the structural course. The thickness of the structural course is determined by the ESALD for the road, as shown by Table 28. For this project, the FDOT flexible pavement guide recommends US 41 to have 4” of structural course while all other segments of the project and the ramps should have 3” of structural course.

21.5.3 Base Course

The base course is beneath the friction and structural courses and transfers the loading to the stabilized subgrade. The FDOT Flexible Pavement Design Manual recommends using a base that meets a LBR of 100 of materials that can be determined by the contractor, signified by stating Optional Base Group 9. To help reduce pavement failure, it is common practice for the base course to be extended 4” beyond the edge of the structural course, as shown in Figure 49. For this project a standard 10” Base Group 9 with a LBR of 100 is recommended.

21.5.4 Stabilized Subgrade

In the state of Florida it is recommended to use a stabilized subgrade in place of a sub-base layer. The subgrade provides support to the pavement and supports traffic stresses. Similar to the base course, the material is not specified and is up to the discretion of the contractor so long as it meets an LBR of 40. For this project, 12” of Type B Stabilization, meaning unspecified, is recommended.

21.5.5 Roadbed Soil

The bottommost layer is the roadbed soil. This is the existing in-situ or embankment soil layer that the pavement structure is built on. This is the layer which the resilient modulus comes from for the design calculations.

22. Pavement Structural Characteristics

22.1 Drainage

From the above SN equation, the mi component is the drainage coefficient. For this project, all values of m were taken to be 1 to denote good drainage as defined by the 1993 AASHTO Guide. Considerations for adequate drainage are necessary in the roadway design, but that is beyond the scope of this portion of the project.

22.2 Flexible Pavement Rehabilitation

Rehabilitation of the roadway is necessary to keep it from deteriorating to poor condition. Rehabilitation is usually performed by removing the existing asphalt to a depth that is determined by pavement coring data, and replacing that asphalt with a new layer. This process, called milling and resurfacing, fixes issues like cracking and can correct cross slopes. Rehabilitation can be planned as shown in Table 29, but ultimately be performed according to the future pavement conditions.

Table 29. Recommended Rehabilitation Plans from FDOT Flexible Pavement Design Manual (FDOT 2013)

Asphalt Pavement			
Rehab Period	Urban Arterial	Rural Arterial	Limited Access
16 Year	Mill 2 inch Resf. 1 inch Str. AC and DGFC	Mill 2 inch Resf. 3 inch Str. AC and FC	Mill 3 inch Resf. 4 inch Str. AC and OGFC
32 Year	Mill 2 inch Resf. 1 inch Str. AC and DGFC	Mill 2 inch Resf. 3 inch Str. AC and FC	Mill 3 inch Resf. 4 inch Str. AC and OGFC

22.3 Cost Data for Economic Analysis

Table 30. Unit Price for Flexible Pavement Structure Materials and Rehabilitation

Material	Unit Price
FC-5	
FC-12.5	$5.34/SY
$7.85/SY	
Superpave Asphalt (1")(Traffic level C)	$3.39/SY
Superpave Asphalt (2")(Traffic level C)	$6.69/SY
Superpave Asphalt (3")(Traffic level C)	$10.19/SY
Superpave Asphalt (4")(Traffic level C)	$13.58/SY
Superpave Asphalt (4.5")(Traffic level C)	$15.28/SY
Base Group 9	(LBR 100)
Type B Stabilization (LBR 40)	$2.10/SY
Milling (1" avg. depth)	$1.24/SY
Milling (2" avg. depth)	$1.31/SY
Milling (3" avg. depth)	$1.96/SY

*Cost data was obtained from FDOT's "2011 FDOT Item Average Unit Cost"

23. Sample Calculations – Flexible Pavement

Sample calculations will be provided for Segment 1 (US 301-WEST of US 41). The same methodology was applied to each other section to obtain our designs.

23.1 Equivalent Truck Traffic Loads for Segment 1 (US 301 - WEST of US 41)

Segment 1 has 3 east-bound and 3 west-bound lanes

Equation 18. Equivalent Single-Axle Loads (FDOT 2016b)

$$\mathbf{ESAL_D} = \sum_{i=1}^{n} \mathrm{AADT_i} * \mathrm{L_f} * \mathrm{T_{24}} * \mathrm{D_f} * \mathrm{E_f} * 365$$

Formula Inputs:

n = 30 years (project design scope)

AADT1 = 19700

T_{24} = 3.96%

D_F= 0.556

E_f = 0.89

L_f= 0.675

FDOT Traffic Data Online (2017b) was used to obtain the AADT, T_{24}, and D_F. The Flexible Pavement Design Manual provided EF, shown in Table 31. L_F was calculated using the Copes equation.

Table 31. Equivalency factors (FDOT 2014)

Example of Equivalency Factor E_F (E_{80}) for Different Types Of Facilities		Flexible Pavement	Rigid Pavement
Freeways			
	Rural	1.05	1.60
	Urban	0.90	1.27
Arterials and Collectors			
	Rural	0.96	1.35
	Urban	0.89	1.22

23.2 3.2 FDOT Flexible Design Manual Method for Segment 1 (US 301 - WEST of US 41)

Given for Segment 1:

ESALD = 2.975×10^6 W18 equivalent loads in 30 year design period

MR (eff) = 14 ksi

%R = 90% reliability Design

Speed = 45mph

The required SN can be determined from FDOT Design manual table (FDOT 2016b) shown in Figure 50.

TABLE 5.3

REQUIRED STRUCTURAL NUMBER (SN_R)
90% RELIABILITY (%R)
RESILIENT MODULUS (M_R) RANGE 4,000 PSI TO 18,000 PSI

RESILIENT MODULUS (M_R), (PSI x 1000)

$ESAL_D$	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
100 000	3.02	2.77	2.59	2.44	2.31	2.21	2.12	2.04	1.97	1.91	1.86	1.81	1.76	1.72	1.68
150 000	3.23	2.97	2.77	2.61	2.47	2.36	2.27	2.19	2.11	2.05	1.99	1.94	1.89	1.84	1.80
200 000	3.39	3.11	2.90	2.73	2.60	2.48	2.38	2.30	2.22	2.15	2.09	2.03	1.98	1.94	1.89
250 000	3.52	3.23	3.01	2.84	2.69	2.57	2.47	2.38	2.30	2.23	2.17	2.11	2.06	2.01	1.97
300 000	3.62	3.33	3.10	2.92	2.78	2.65	2.55	2.46	2.37	2.30	2.24	2.18	2.12	2.07	2.03
350 000	3.71	3.41	3.18	3.00	2.85	2.72	2.61	2.52	2.44	2.36	2.30	2.23	2.18	2.13	2.08
400 000	3.79	3.49	3.25	3.07	2.91	2.78	2.67	2.58	2.49	2.42	2.35	2.29	2.23	2.18	2.13
450 000	3.87	3.56	3.32	3.13	2.97	2.84	2.73	2.63	2.54	2.46	2.39	2.33	2.27	2.22	2.17
500 000	3.93	3.62	3.38	3.18	3.02	2.89	2.77	2.67	2.59	2.51	2.44	2.37	2.31	2.26	2.21
600 000	4.05	3.73	3.48	3.28	3.12	2.98	2.86	2.76	2.67	2.58	2.51	2.45	2.39	2.33	2.28
700 000	4.14	3.82	3.57	3.36	3.20	3.05	2.93	2.83	2.73	2.65	2.58	2.51	2.45	2.39	2.34
800 000	4.23	3.90	3.64	3.44	3.27	3.12	3.00	2.89	2.80	2.71	2.63	2.57	2.50	2.44	2.39
900 000	4.31	3.97	3.71	3.51	3.33	3.18	3.06	2.95	2.85	2.76	2.69	2.62	2.55	2.49	2.44
1 000 000	4.38	4.04	3.78	3.57	3.39	3.24	3.11	3.00	2.90	2.81	2.73	2.66	2.60	2.54	2.48
1 500 000	4.65	4.30	4.03	3.81	3.62	3.46	3.33	3.21	3.10	3.01	2.92	2.85	2.78	2.71	2.65
2 000 000	4.85	4.50	4.21	3.99	3.79	3.63	3.49	3.36	3.25	3.16	3.07	2.99	2.91	2.85	2.78
2 500 000	5.01	4.65	4.36	4.13	3.93	3.76	3.62	3.49	3.38	3.27	3.18	3.10	3.02	2.95	2.89
3 000 000	5.14	4.77	4.48	4.25	4.05	3.88	3.73	3.60	3.48	3.37	3.28	3.19	3.12	3.04	2.98
3 500 000	5.25	4.88	4.59	4.35	4.14	3.97	3.82	3.69	3.57	3.46	3.36	3.28	3.20	3.12	3.06
4 000 000	5.35	4.98	4.68	4.44	4.23	4.06	3.90	3.77	3.65	3.54	3.44	3.35	3.27	3.19	3.12

Figure 50. Table 5.3 from the Flexible Pavement Design Manual

2500000	3.18	$\frac{x-3.18}{3.28-3.18} = \frac{2975000-2500000}{3000000-2500000}$ => SN_R= 3.27
2975000	X(SN_R)	
3000000	3.28	

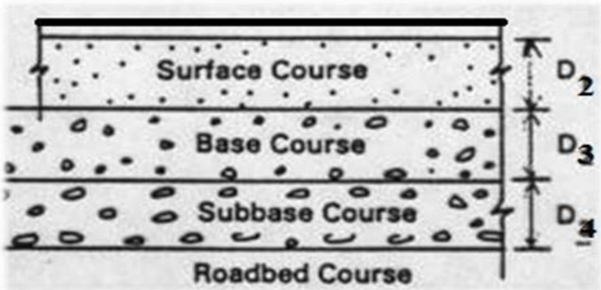

Figure 51. Flexible Pavement Design Layers

A. Friction Course

- FC-12.5
    - 1.5” required thickness (D1)
    - 0.44 structural value per inch (a1)

B. Structural Course

- Superpave design thickness
    - 4” minimum thickness (D2)
    - 0.44 structural value per inch (a2)

C. Base Course

- Base Group 9 (LBR-100)
    - 10” minimum thickness (D3)
    - 0.18 structural value per inch (a3)

D. Subgrade

- Type B Stabilization (LBR-40)
    - 12” assumed thickness (D4)
    - 0.08 structural value per inch (a4)

FDOT design requirements leave the Structural and Base Courses as the remaining design unknowns. The combined SN remaining for the Structural and Base Courses can be calculated using the required SN for the total pavement structure.

From Figure 52:

$\mathbf{SN_R = 3.27''}$

$\mathbf{SN_C = (a_1 * D_1)+(a_2 * D_2)+(a_3 * D_3)+(a_4 * D_4)}$

$\mathbf{3.27''(+/-0.11) = (0 * 0.78'')+(a_2 * D_2)+(a_3 * D_3)+(0.08 * 12'')}$

$\mathbf{2.31''\ (+/-\ 0.11) = (a_2 * D_2) + (a_3 * D_3)}$

The Base and Structural courses must provide a combined SN of 2.31”

TABLE 5.9

COMBINED STRUCTURAL NUMBER (INCHES)

Structural Included. | Stabilization Numbers Not

COMBINED STRUCTURAL NUMBER (INCHES)											
Optional	Structural Course - Inches										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
1	1.12	1.38									
2	1.34	1.56									
3	1.43	1.65	1.87								
4	1.52	1.74	1.96	2.18							
5	1.70	1.92	2.14	2.36	2.58						
6	1.88	2.10	2.32	2.54	2.76	2.98					
7		2.16	2.41	2.63	2.85	3.04					
8		2.37	2.59	2.81	3.03	3.25	3.47	3.69			
9				2.90	3.12	3.34	3.56	3.78			
10					3.30	3.52	3.74	3.96	4.18		
11					3.48	3.70	3.92	4.14	4.36	4.58	
12						3.79	4.01	4.23	4.45	4.67	4.89
13							4.19	4.41	4.63	4.85	5.07
14							4.28	4.50	4.72	4.94	5.16
15							4.46	4.68	4.90	5.12	5.34

Figure 52. Combined Structural Number from the Flexible Pavement Design Manual (FDOT 2016b)

Using the Combined SN from Figure 53, for Base Group 9 and a combined SN of 3.27”, it is determined that the design thickness of the Structural Course is 2.5”.

TABLE 5.5

REQUIRED MINIMUM THICKNESS FOR NEW CONSTRUCTION OR RECONSTRUCTION

In order to avoid the possibility of producing an impractical design, the following minimum thicknesses are required for New Construction. It is assumed that a 12in stabilized subgrade (LBR 40) is to be constructed in order to establish a satisfactory working platform.

18-kip ESAL's 20 year period	Minimum Structural Course	Minimum Base Group
Limited Access	4"	9
Greater than 3,500,000	3"	9
Ramp less than 3,500,000	2"	9
300,000 to 3,500,000	2"	6
Less than 300,000	1 1/2"	3
Limited Access Shoulder	1 1/2"	1
Residential Streets, Parking Areas, Shoulder Pavement, Bike Paths	1"	1
Shared Use Paths	1 1/2"	1

Figure 53. Required Minimum Thickness for New Construction or Reconstruction (FDOT 2016b))

Table 32 from the Flexible Pavement Design Manual requires a minimum thickness of 3” for the Structural Course. FC-12.5 can be considered as part of the structural course, so only 1.5” of Superpave Asphalt is required.

Table 32. Summary of FDOT Flexible Design Manual Results for Segment 1

Layer	Material	SN/in	Thickness (in)		SNc
Friction Course	FC-12.5	0.44	* 1.5	=	0.66
Structural Course	SP	0.44	* 1.5	=	0.66
Base Course	Group 9 LBR-100	0.18	* 10	=	1.80
Stabilization	Type B LBR-40	0.08	* 12	=	0.96
Total SNc				**=**	**4.08**

The SNC is 0.81” greater than the required SN. This over design can be accounted for in the minimum design thickness and the high reliability chosen for the overall design.

Segment 1 recorded on pavement design plans as:

OPTIONAL BASE GROUP 9 AND TYPE SP STRUCTURAL COURSE (TRAFFIC C) 1.5” AND FRICTION

COURSE FC-12.5 (1.5”)

23.3 Detailed Cost Calculation for Segment 1 (US 301 & WEST OF US 41)

23.3.1 Given for Segment 1:

This project segment involves widening US 301 for 3380 feet by adding 1 additional 12’ lane to both directions of travel. There will be a total of 6 travel lanes after construction.

Assuming i=4%

- Total Area = Area of Mainline + Area of Bike Lanes + Area of Turning Lanes
    - Area of Mainline = [3380 (ft) * 3 (lanes) * 11 (ft)]*2= 223080 ft2
    - Area of Bike Lanes = [3380 (ft) * 1 (lane) * 7 (ft)] *2 = 47320 ft2
    - Area of Turning Lands = 180 (ft) * 11 (ft) = 1980 ft2
- Total Area = 272380 ft2 * (1 ft2 / 9 SY) = 30264 SY

Table 33. Segment 1 Initial Costs

Layer	Unit Cost (Per SY)	Total Cost
FC-12.5	$7.85	$237,572
Superpave Asphalt 1.5”	$5.04	$152,530
Base Group 9 (LBR 100)	$12.50	$378,300
Type B (LBR40)	$2.10	$63,554
Total	**$27.49**	**$831,956**

Table 34. Segment 1 Rehabilitation Costs

Pay Item	Unit Cost (Per SY)	Total Cost
Mill 2”	$1.31	$39,642
Resurface 1”	$5.23	$158,281
Total	**$6.54**	**$197,929**

Table 35. Segment 1 Net Present Cost

Pay Item		Total Cost
16-Year Present Worth = $197,929 * $(1+0.04)^{-16}$	=	$105,676
32-Year Present Worth = $197,979 * $(1+0.04)^{-32}$	=	$56,421
Net Present Cost of Rehabilitation	=	$162,098
Segment 1 Net Present Cost	**=**	**$994,067**

23.4 Summary of Flexible Designs and Costs

Table 36. Flexible Designs New Construction Designs

	Segment	Friction Course	Structural Course	Base	Subgrade
1	US 301 - West of US 41	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
2	US 301 - East of US 41	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
3	US 301 - East of Walmart	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
4	US 41	0.75" FC-5	4" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)
5	Ramps	1.5" FC-12.5	1.5" Superpave Asphalt	10" Base Group 9 (LBR 100)	12" Type B Stabilization (LBR 40)

Table 37. Flexible Designs Rehabilitation Plans

	Segment	Milling depth
1	US 301 - West of US 41	2"
2	US 301 - East of US 41	2"
3	US 301 - East of Walmart	2"
4	US 41	3"
5	Ramps	2"

* All plans implement rehabilitation at 16 years and 32 years after the initial construction.

Table 38. Flexible Designs Rehabilitation Plans

	Segment	Construction Cost	Rehabilitation Cost	Total Net Present Cost
1	US 301 - West of US 41	$831,969.58	$162,097.53	$994,067.10
2	US 301 - East of US 41	$593,050.93	$115,547.60	$708,598.54
3	US 301 - East of Walmart	$302,832.89	$59,002.71	$361,835.61
4	US 41	$534,383.29	$273,003.88	$807,387.17
5	Ramps	$412,777.62	$80,423.89	$493,201.51
	Totals	**$2,675,014.32**	**$690,075.62**	**$3,365,089.93**

* If flexible pavement is used across the entire project, the total cost will be approximately $3,365,089.93.

Table 39. Flexible Designs Adjusted Costs

Total Net Present Cost	US 41 Reconstruction	US 41 Rehabilitation	Adjusted Cost	Savings
$3,365,089.93	$534,383.29	$333,351.87	$3,164,058.51	$201,031.42

* Using this recommendation, the cost is reduced to $3,164,058.51 for a savings of $201,031.42.

24. Rigid Pavement

Rigid pavement is a multilayer pavement that consists of a concrete slab, base course, and subgrade course. The concrete slab is designed to carry most of the traffic stress. Typically, rigid pavements are used for roads with high volume traffic, freeway to freeway connections, under overpasses that need clearance, and slow stop-go traffic areas. Rigid pavements are highly durable, have a long service life, and withstand repeated flooding and subsurface water well without deterioration. Disadvantages associated with rigid pavements are as follows: they lose non-skid surface with time, need even sub-grade with uniform setting, and require frequent joint maintenance.

24.1 Rigid Design Requirements

The AASHTO 1993 Pavement Design Guide provides an empirical rigid pavement design equation that is based on the 1958-1960 AASHO road test in Ottawa, IL. The empirical equation is used based on a set design period and rehabilitation period for the pavement. The design accounts for factors such as: climate, materials used, traffic, and response to damage over time. Required inputs of the empirical equation include: traffic quantities in terms of ESALs, required reliability, serviceability, modulus of subgrade reaction, PCC modulus of rupture, layer materials characterization, drainage, load transfer, and loss of support. These are all then used to determine slab thickness.

24.1.1 Design Variables

Time Constraints-

Performance Period: the initial time period that the pavement will last before it needs rehabilitation. FDOT initial design life is 20 years. Concrete rehab is 5 to 10 years.

Analysis Period: the time period for which analysis is to be conducted.

Traffic-

18-Kip ESALs: The AASHTO flexible pavement design equation converts AADT into ESALs, 18-kip ESALs. Cumulative damage to the roadway from vehicles can be approximated from ESAL. The following equation from the FDOT Project Traffic Forecasting Handbook is used to calculate ESAL:

Equation 19. ESAL (FDOT 2016b)

$$\mathbf{ESAL_D} = \sum_{i=1}^{n} \mathbf{AADT_i * L_f * T_{24} * D_f * E_f * 365}$$

Where,

n - design period in years

i - year for which calculation is made

Equation 20. AADT Data in Year I (FDOT 2016b)

$$\boldsymbol{AADT_i = AADT_{base\ year} * (1 + GR)^t}$$

Where,

GR = 1.5%

t = number of years

Lf = lane factor, derived from Copes equation:

Equation 21. Lane Factor (FDOT 2016b)

$$\boldsymbol{LF_i = (1.567 - 0.0826 * \ln(oneway\ AADT) - 0.12368 * LV}$$

Where,

LV = 0 if number of lanes in one direction is 2 or less

LV = 1 if number of lanes is 3 or more

T24 = percentage of heavy trucks during a 24-hour period, acquired from FDOT

DF = directional factor, acquired from FDOT

DF = 1.0 if one-way flow

DF ≈ 0.5 if two-way flow

EF = equivalency factor, given below in Table 25

The team used the FDOT Design Spreadsheet to determine the ESALD for each section of the project. The inputs required for the spreadsheet were obtained from online FDOT Traffic Data and verified by the PD&E Team to be the correct values for design.

Reliability-

Reliability is the probability that a pavement will perform at a satisfactory level in the duration of the design period. Reliability is reported as a percentage. For this design, which consists of two urban arterial roadways, a reliability of 90% was used.

24.1.2 Performance Criteria

Serviceability-

Serviceability is the measurement of a pavement's ability to serve the traffic demand. In the AASHTO flexible pavement design equation serviceability is measured using the change in the PSI, or a scale rating from 0 to 5 with 0 being an impossible road. The change in serviceability used for this design was 1.7.

24.1.3 Material Properties

Modulus of Subgrade-

The modulus of subgrade, k, estimates the support of the layers beneath the PCC slab. The modulus is found through field tests or correlating other tests since there is no direct laboratory procedure for determining it. The slab is modeled to support the roadway as a spring.

PCC Modulus of Rupture-

The PCC modulus of rupture is determined by strength tests on the concrete. The elastic modulus of PCC for this project was given to be 4,000,000 psi.

24.1.4 Layer Materials Characterization

Rigid pavement is separated into four distinct layers: concrete pavement slab, base course, stabilized subgrade, and roadbed soil. These layers are shown in Figure 54.

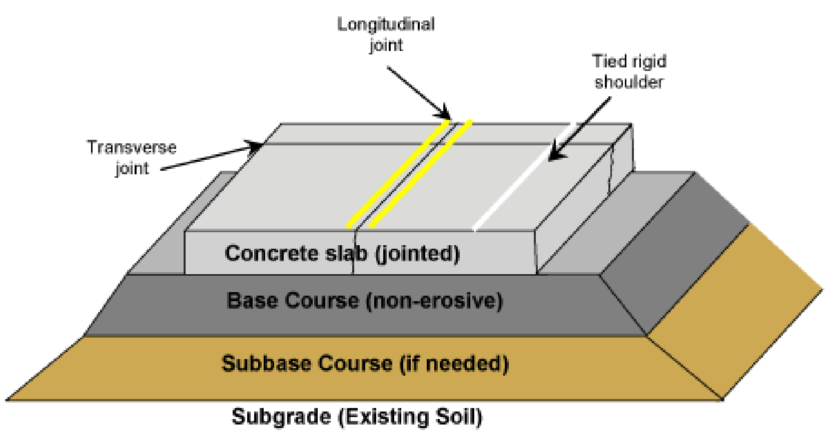

Figure 54. FDOT Typical Rigid Section (FDOT 2009)

Concrete Pavement Slab

The concrete pavement slab is the main component of rigid pavement design. This layer is designed to carry most of the traffic loading and not distribute the load to the base course or subgrade. This project required minimum design thicknesses (DR) for the PCC slab between 9 and 11 inches.

Base Course

The base course provides support to the concrete slab. There are three types of bases to choose from in the state of Florida: asphalt concrete base, treated permeable base of either asphalt or concrete, or special select embankment soil that is Florida sand. Our design uses optional group 9 for the base.

Stabilized Subgrade

In the state of Florida it is recommended to use a stabilized subgrade in place of a sub-base layer. The subgrade provides support to the pavement and supports traffic stresses. Similar to the base course, the material is not specified and is up to the discretion of the contractor so long as it meets an LBR of 40. For this project, 12” of Type B Stabilization, meaning unspecified, is recommended.

Roadbed Soil

The bottommost layer is the roadbed soil. This is the existing in-situ or embankment soil layer that the pavement structure is built on. This is the layer that the modulus of subgrade, k, comes from for the design calculations.

Table 40. Net Present Cost of Project

	Cost
Initial Construction	$3,378,755.19
Rehabilitation	$1,134,569.50
Total	**$4,513,324.69**

25. Sample Calculations – Rigid Pavement

Given for Segment 1:

ESALD = 4.076 x 106 W18 equivalent loads in 30 year design period

k = 200 pci (FDOT recommended value)

%R = 90% reliability

Design Speed > 45mph

The required depth of concrete can be determined from FDOT Rigid Design Manual table shown in Figure 55.

TABLE A.4

REQUIRED DEPTH (D_R) IN inch FOR 90% RELIABILITY (%R)

ESAL$_D$	Modulus Of Subgrade Reaction (K_G), psi/in 40	80	110	150	185	200	260	300	330	370
100 000	to 900 000 ESAL Use 8″ for all K Values									
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10

Figure 55. Table A.4. FDOT Thickness, Dr, of concrete per ESALD for 90% reliability (FDOT 2009)

25.1 FDOT Rigid Pavement Design Manual Method

Rigid pavement layer thickness was determined by using a method provided by FDOT. In order to find DR (depth of the pavement structure), the values below must be determined:

- ESALD , the design lane design period loading
- k ,Modulus of Subgrade Reaction
- %R safety factor

After determining the above values, by using FDOT chart DR can be found. 8'' is the minimum required thickness for concrete slab according to FDOT.

FDOT Ramp Design Information

Since the ramps are located in urban areas and there is no traffic predicted for the ramps, the assumption is to use 50% of the mainline traffic.

Rigid Pavement Rehabilitation

There are two recommended rehabilitation methods that FDOT recommends to improve the serviceability of a poor concrete slab. One method would be CPR (Concrete Pavement Rehabilitation) which involves sealing of random cracks, partially replacing slabs, cleaning and resealing joints. The other method would be CRO (crack, reseat, and overlay). In CRO procedure, the existing cracks in the pavement is cracked up, then reseated, and later overlain with an Asphalt Rubber Membrane Interlayer (ARMI), Asphalt Structural Course, and Friction Course.

Table 41. Sample rigid pavement rehabilitation plan (FDOT 2009)

Concrete Pavements	
Rehab Period	**Limited Access**
23 year	CPR with 3% Slab Replacement
32 year	CPR with 5% Slab Replacement

25.1.1 Cost Data for Economic Analysis:

Table 42. Unit Price for Rigid Pavement Structure Materials and Rehabilitation

Material	Unit Price
PCC Pavement (8.5")	\$59.50/SY
PCC Pavement (9")	\$63.00/SY
PCC Pavement (9.5")	\$67.46/SY
PCC Pavement (10")	\$55.53/SY
PCC Pavement (11")	\$68.28/SY
PCC Pavement (11.5")	\$72.74/SY
PCC Pavement (12")	\$75.32/SY
PCC Pavement (12.5")	\$79.78/SY
Superpave Asphalt (1")(Traffic level C)	\$3.39/SY
Asphalt Treated Permeable Base (ATPB)	\$12.44/SY
Type B Stabilization (LBR 40)	\$2.36/SY
% Slab Replacement	\$35.39/SY
Grinding Concrete Pavement	\$2.81/SY
Clean/Reseal Joints	\$7.50/SY

* Cost data was obtained from FDOT's "2011 Item Averages"

25.2 Sample Calculations - Results

Resulting Design for Segment 1:

Concrete Slab thickness: 9"

Base Course: dependent on drainage requirements

Stabilization Type B: 9"

Appropriate Base selected from:

- Asphalt Base with 9” Type B stabilization
- Treated Permeable Base with 9” Type B stabilization
- Special Select Soil (Florida Sand)

Segment 1 recorded on pavement design plans as:

12” PLAIN CEMENT CONCRETE PAVEMENT

25.3 COST Calculation for Segment 1 (US 301 west of US 41)

Given for Segment 1:

This project segment involves widening US 301 for 3380 feet by adding 1 additional 12’ lane to both directions of travel. There will be a total of 6 travel lanes after construction.

Assuming i=4%

Total Area = Area of Mainline + Area of Bike Lanes + Area of Turning Lanes

- Area of Mainline = [3380 (ft) * 3 (lanes) * 11 (ft)]*2= 223080 ft2
- Area of Bike Lanes = [3380 (ft) * 1 (lane) * 7 (ft)] *2 = 47320 ft2
- Area of Turning Lands = 180 (ft) * 11 (ft) = 1980 ft2

Total Area = 272380 ft2 * (1 ft2 / 9 SY) = 30264 SY

Table 43. US 301 west of US 41 Initial Costs

Layer	Unit Cost (Per SY)	Total Cost
PCC Pavement (9”)	$63.00	$1,906,632
Superpave Asphalt 1”	$3.39	$102,595
ATP Base	$12.50	$378,300
Type B (LBR40)	$2.36	$71,423
Total	$81.25	$2,458,950

Table 44. US 301 west of US 41 Rehabilitation Costs

Pay Item	Unit Cost (Per SY)	Total Cost
3% Slab Replacement	$35.39 (908 SY)	$32,131
5% Slab Replacement	$35.39 (1513 SY)	$53,552
Grind Concrete Cement	$2.81	$85,042
Clean & Reseal Joints	$7.50	$226,042
Total	**$81.09**	**$397,705**

Table 45. Net Present Cost

Pay Item		Total Cost
16-Year Present Worth = $197,929 * $(1+0.04)^{-16}$	=	$105,676
32-Year Present Worth = $197,979 * $(1+0.04)^{-32}$	=	$56,421
Net Present Cost of Rehabilitation	=	$162,098
Segment 1 Net Present Cost	**=**	**$2,620,309**

26. Final Optimal Pavement Design

26.1 Pavement Choice

Flexible pavement is the better choice for the entirety of this project. It is much cheaper to construct, and similar in cost to rehabilitate during its lifetime. This project has no special parameters that require a rigid pavement, so the cheaper option is better.

US 301 and Ramps		
Friction Course	FC-12.5	1.5"
Structural Course	Superpave Asphalt	1.5"
Base	Optional Base Group 9	10"
Subgrade	Type B Stabilization	12"

US 41		
Friction Course	FC-12.5	1.5"
Structural Course	Superpave Asphalt	1.5"
Base	Optional Base Group 9	10"
Subgrade	Type B Stabilization	12"

* Please note that the chosen thicknesses of layers in these designs are based on FDOT minimums. Thicker layers are completely acceptable if required, as they would only serve to increase strength of the roadway.

26.2 Additional Recommendations

We have several recommendations that would be a change from the optimal design. These changes differ from the suggestions of the FDOT Flexible Pavement Design Manual, but will offer improvements in practicality and cost.

26.2.1 Friction Course on US 41

We recommend that FC-12.5 be used on US 41 rather than FC-5.

This section of US 41 is located close to multiple off and on-ramps, so there is frequent deceleration, acceleration, and turning movements of vehicles. These movements will create excess stress and damage on an open graded course like FC-5, so the service life may be drastically reduced, and the safety of the roadway may be compromised.

FC-12.5 offers structural value, and resists damage from deceleration and turning movements. The speed on this section of US 41 is not so high that FC-12.5 would pose a danger or offer less skid resistance.

This design change would reduce cost, and increase the strength of the pavement on US 41

26.2.2 Structural Course Thickness on US 301

We recommend using a 2” thick layer of Superpave asphalt on US 301 rather than 1.5”. It is not practical to measure to the nearest half inch when installing structural course.

This change increases the calculated cost of material.

Construction costs may decrease, as it would be easier to install a more standard thickness layer.

Consistency and reliability of the structural course layer would be easier to ensure with a more commonly used thickness, since workers have more experience installing it, and existing tools would not need to be adjusted or potentially modified.

References

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Appendices

27. Appendix A - Geometric Design of US 301

Geometric Design
US Highway 301

TEAM LEADER: MONIQUE GYANT

TEAM MEMBERS: DANIEL HOEFLICH, ODELMO JOSEPH, PAYDEN CALHOUN, JEREMY ABREU, AHMED AL SHAMISI

INSTRUCTOR: DR. QING LU, P.E.
CO-INSTRUCTOR: MR. BIJAN BEHZADI , P.E., PTOE

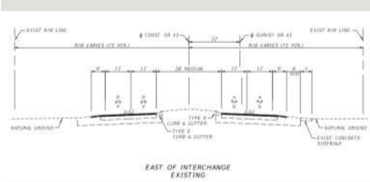
Project Limits

Scope of Work

o Develop Typical Sections of Existing Roadway o Develop New Typical Sections based on Data Simulation o3-D Projections of Proposed Roadway oDevelop Roadway Criteria for Designs o Cost Analysis

Existing US Hwy 301 East of Interchange

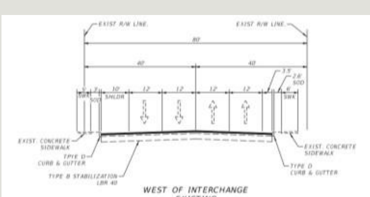
Existing US Hwy 301 East of Interchange Typical



- 2 through lanes
- Signalized interchanges very close to interchange

Existing US Hwy 301 West of Interchange

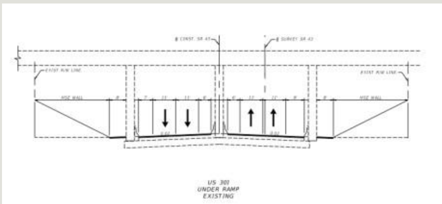
Existing US Hwy 301 West of Interchange Typical



- Two through lanes
- No median
- Tight Right-of-Way

Existing US Hwy 301 Under Ramp

Existing US Hwy301 Under Ramp



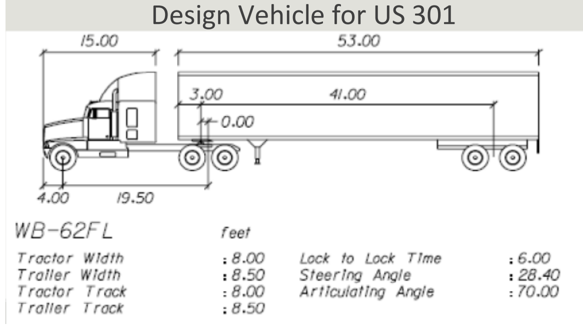
Existing WalMart Intersection

Roadway Design Criteria

Roadway Classification		High Speed Urban Arterial
General Criteria	Design Speed	45 mph
	Design Vehicle	WB-62 FL
Selection Features	Median Width	28 feet
	Shoulders	None
	Curb & Gutter	Yes
	Bike Lane	7 feet
Horizontal Clearance	Clear Zone	4 feet from FOC
	Border Width	14 feet
Horizontal Alignment	Max. Superelevation ()	5%
	Max. Grade	6%
	Min. Grad	0%
	Min. Length of Curve	400 feet

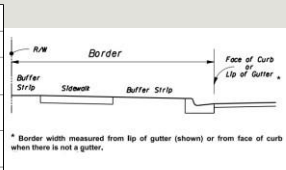
Sources: FDOT Design Manual & AASHTO Green Book

Design Vehicle for US 301



Border Width for US 301

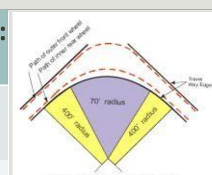
BORDER		
TYPE FACILITY	MINIMUM WIDTH (FEET)	
	TRAVEL LANES AT CURB OR CURB AND GUTTER	BICYCLE LANES OR OTHER AUXILIARY LANES AT CURB OR CURB AND GUTTER
ARTERIALS COLLECTORS Design Speed = 45 mph	14	12
ARTERIALS COLLECTORS Design Speed ≤ 40 mph	12	10
URBAN COLLECTOR STREETS Design Speed ≤ 30 mph	10	8



Sources: FDOT Design Manual & AASHTO Green Book

Roadway Design Criteria

Design Vehicle: WB-62 FL	
Turning Radii	50 feet or 3-centered curve
Control Radius	75 feet
Angle of Turn	90 degrees



Edge of Travel Way Design		
Angle of Turn	Design Vehicle	3-Centered Compound
90	WB-62 FL	400-70-400

Roadway Design Criteria

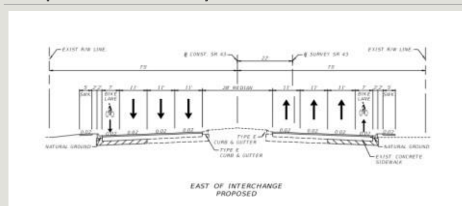
Roadway Classification		High Speed Urban Arterial
Vertical Alignment	Base Clearance Above DHW Elevation	3 feet
	Max Change in Grade w/o HC	0.6%
	Max. SSD	360 feet
	Min. Length of Crest VC	300 feet
	Min. K Value of Crest VC	136
	Min. Length of Sag VC	200 feet
	Min. K Value of Sag VC	96

Sources: FDOT Design Manual & AASHTO Green Book

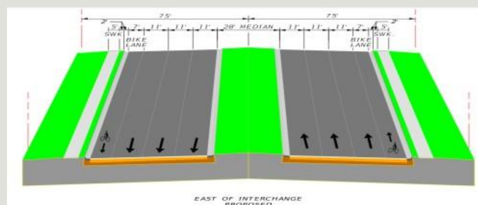
Proposed Changes to Roadway

- Change US301 to 6 lane divided highway from 8th Ave to Haben Blvd
- 7' Bike lanes were added in Eastbound and Westbound directions
- 28' median added to US301 west of US41 interchange
- Moved intersection at Wal-Mart farther east of the interchange with US41
- Kept sidewalk on both sides of US301 and either side of interchange

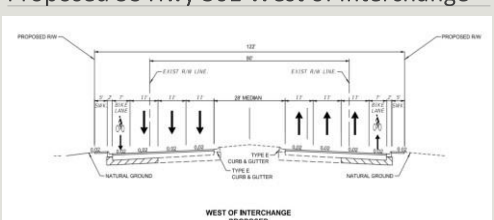
Proposed US Hwy 301 East of Interchange



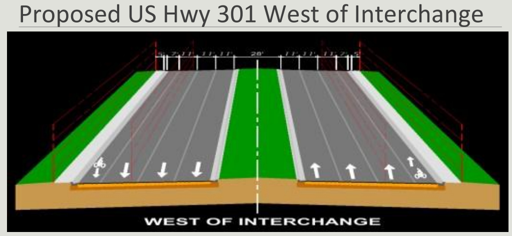
Proposed US Hwy 301 East of Interchange



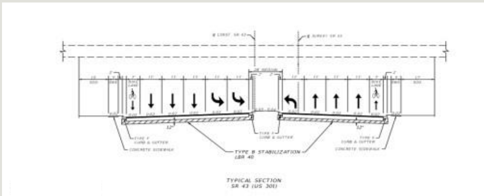
Proposed US Hwy 301 West of Interchange



Proposed US Hwy 301 West of Interchange



Proposed US Hwy 301 Under Ramp

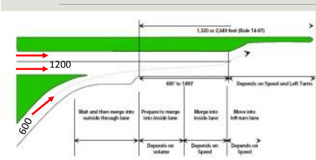


Access Class for US 301

Access Class	Medians "Restrictive" physically prevent vehicle crossing. "Non-Restrictive" allow turns across at any point.	Connection Spacing (feet)		Median Opening Spacing (feet)		Signal Spacing (feet)
		>45 mph	≤45 mph	Directional	Full	
2	Restrictive with Service Roads	1320	660	1320	2640	2640
3	Restrictive	660	440	1320	2640	2640
4	Non-Restrictive	660	440			2640
5	Restrictive	440	245	660	*2640/ 1320	*2640/1320
6	Non-Restrictive	440	245			1320
7	Both Median Types	125		330	660	1320

* 2640 feet for >45 mph; 1320 feet for ≤45 mph

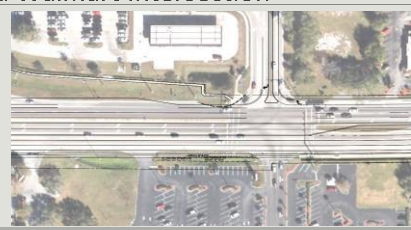
Required Wal-Mart Entrance Location from US 41



The total weaving volume is calculated as: $Vw = V1 + \% LT \times [V1 + V2] / 2$

Where: Vw = total weaving volume
$V1$ = crossroad volume (vph)
$V2$ = ramp volume
$\% LT$ = percentage of vehicles turning left

Old Walmart Intersection



Proposed 8th Ave Intersection

Proposed Wal-Mart Intersection

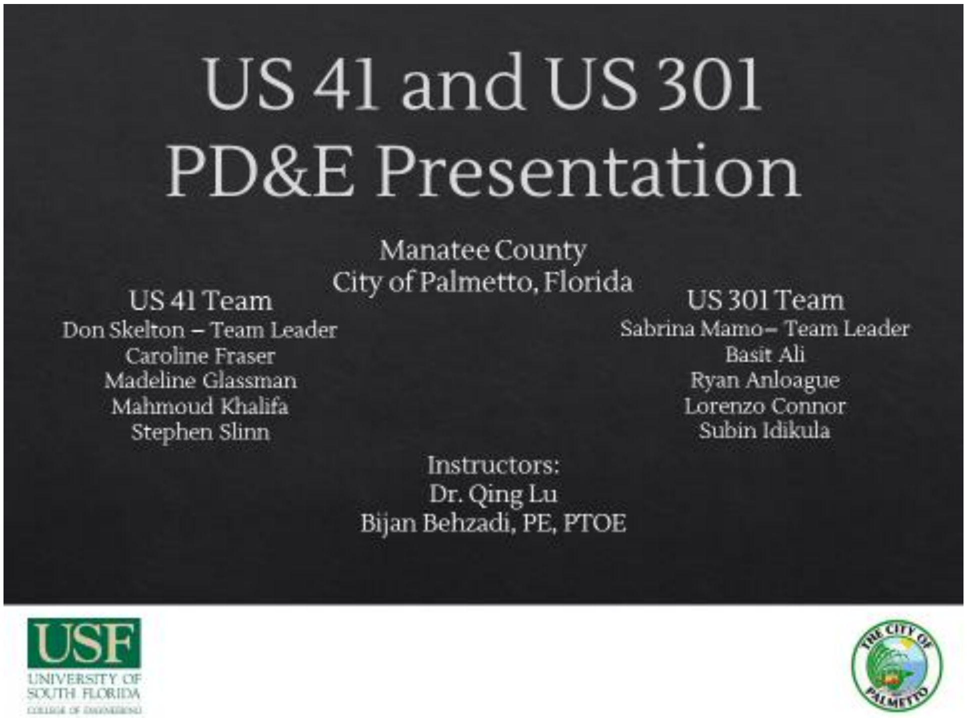
Proposed Haben Blvd Intersection

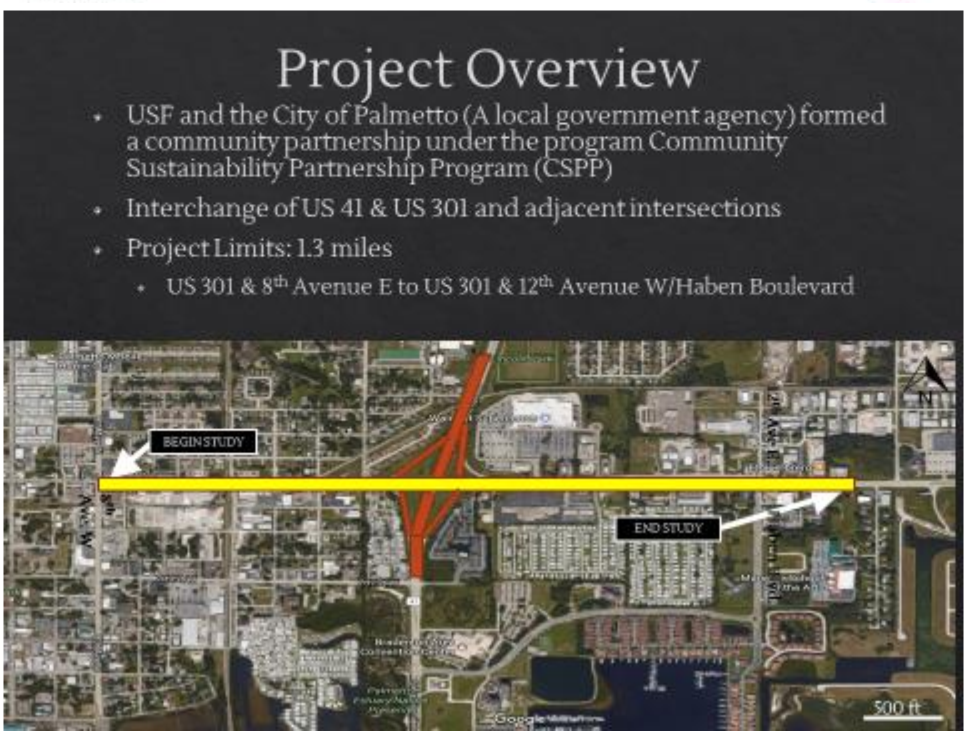
US Hwy 301 Cost Estimate

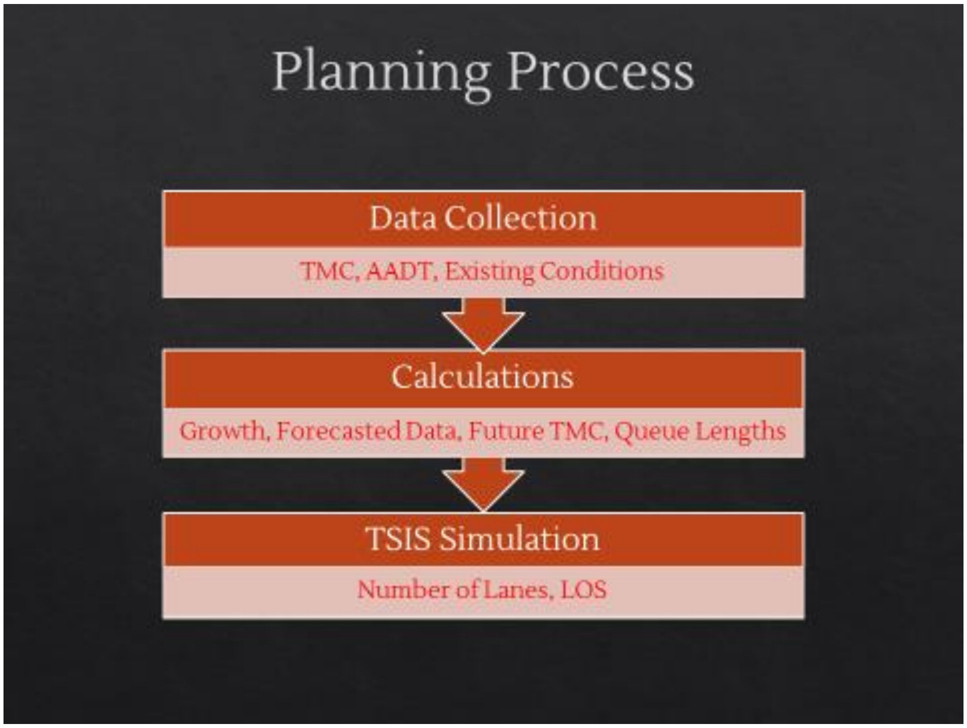
ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	TOTAL COST
INLETS, CURB, TYPE P-1, <10'	EA	55	$4,300.00	$236,500.00
PIPE CULVERT,OPTIONAL MATERIAL,ROUND, 24"S/CD	LF	13728	$55.00	$755,040.00
CONCRETE CURB & GUTTER, TYPE F	LF	27600	$16.50	$455,400.00
CONCRETE SIDEWALK AND DRIVEWAYS, 4" THICK	SY	68500	$26.00	$1,781,000.00
PERFORMANCE TURF, SOD	SY	5000	$3.00	$15,000.00
MILLING EXIST ASPH PAVT, 1 1/2" AVG DEPTH	SY	411840	$2.00	$823,680.00
FLEXIBLE PAVEMENT	SY			$2,064,501
CONSTRUCTION SUB-TOTAL				$6,531,121.25
MOBILIZATION			10%	$653,112.13
MAINTENANCE OF TRAFFIC			10%	$653,112.13
LIGHTING			10%	$653,112.13
SIGNING AND PAVEMENT			10%	$653,112.13
PROJECT UNKNOWNS			10%	$653,112.13
GRAND TOTAL				$9,796,681.90

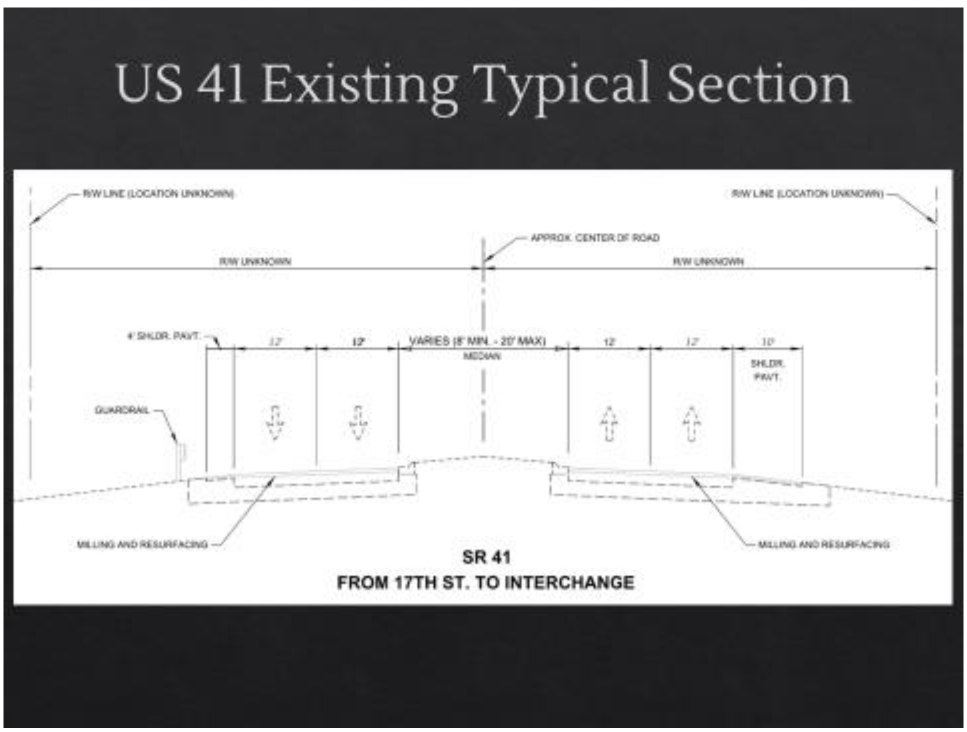
28. Appendix B – PowerPoint Presentations

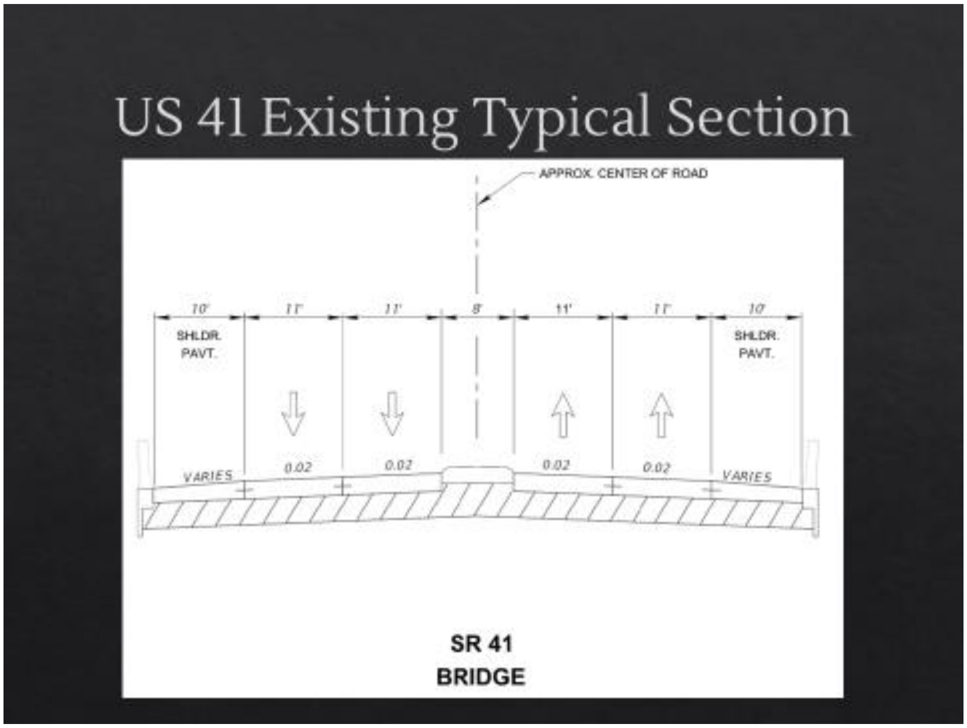
28.1 Project Development & Environment:

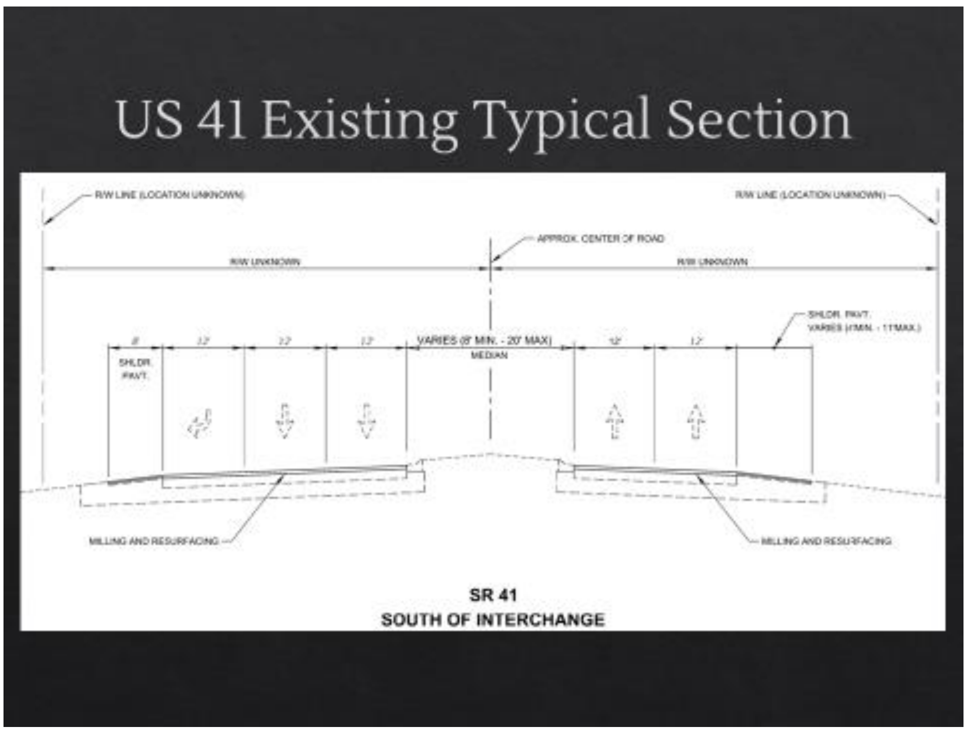


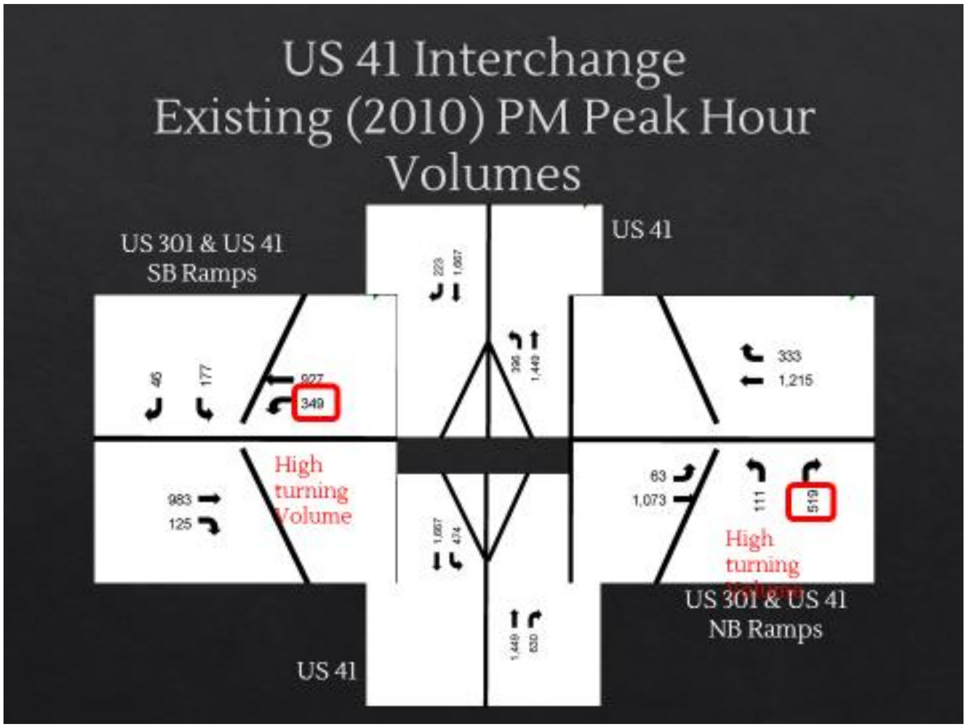



Planning Process
Data Collection
TMC, AADT, Existing Conditions
Calculations
Growth, Forecasted Data, Future TMC, Queue Lengths
TSIS Simulation
Number of Lanes, LOS

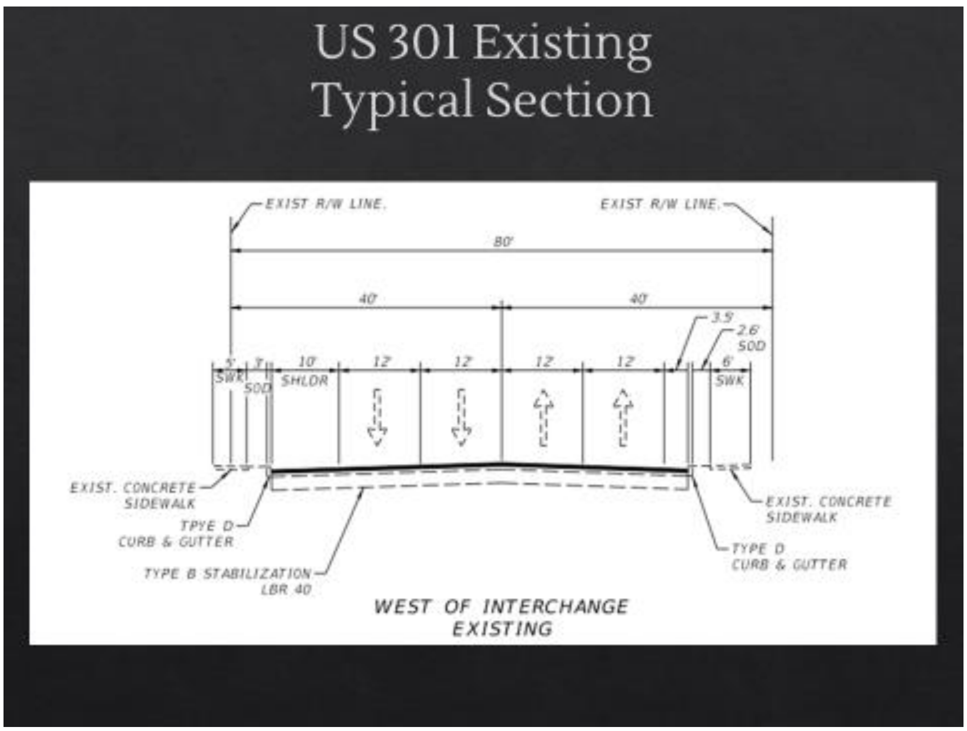

US 41 Existing Typical Section
R/W LINE (LOCATION UNKNOWN)
R/W LINE (LOCATION UNKNOWN)
APPROX. CENTER OF ROAD
R/W UNKNOWN
R/W UNKNOWN
4' SHLDR. PAVT.
12'
12'
VARIES (8' MIN. - 20' MAX)
MEDIAN
12'
12'
10'
SHLDR. PAVT.
GUARDRAIL
MILLING AND RESURFACING
MILLING AND RESURFACING
SR 41
FROM 17TH ST. TO INTERCHANGE


US 41 Existing Typical Section
APPROX. CENTER OF ROAD
10'
11'
11'
8'
11'
11'
10'
SHLDR. PAVT.
SHLDR. PAVT.
VARIES
0.02
0.02
0.02
0.02
VARIES
SR 41
BRIDGE

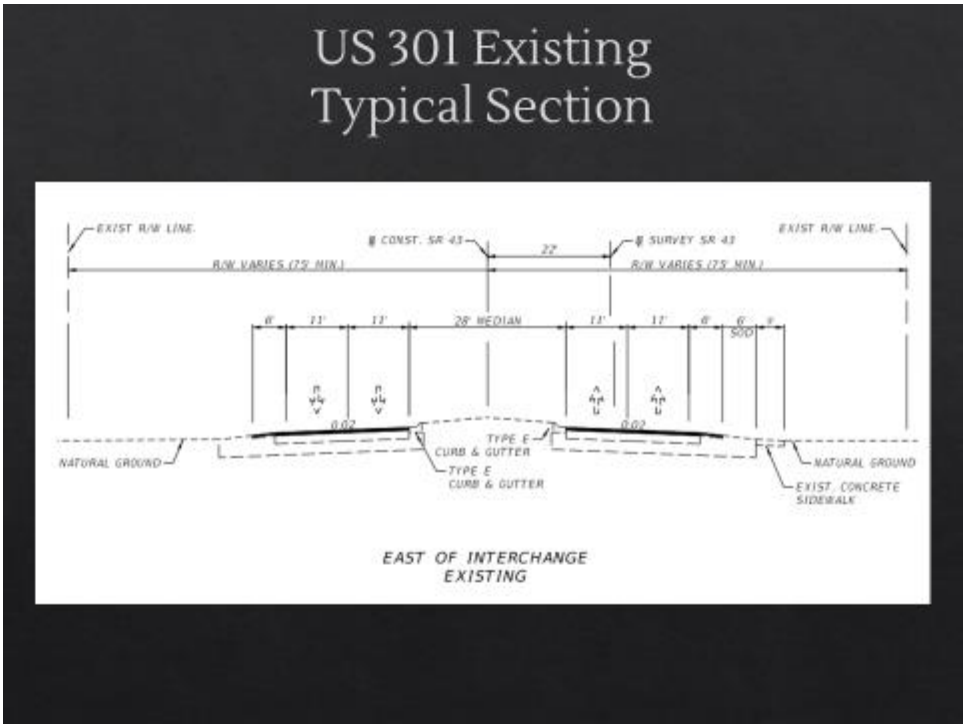

US 41 Existing Typical Section
R/W LINE (LOCATION UNKNOWN)
R/W LINE (LOCATION UNKNOWN)
APPROX. CENTER OF ROAD
R/W UNKNOWN
R/W UNKNOWN
SHLDR. PAVT.
VARIES (8' MIN. - 20' MAX)
MEDIAN
SHLDR. PAVT.
MILLING AND RESURFACING
MILLING AND RESURFACING
SR 41
SOUTH OF INTERCHANGE

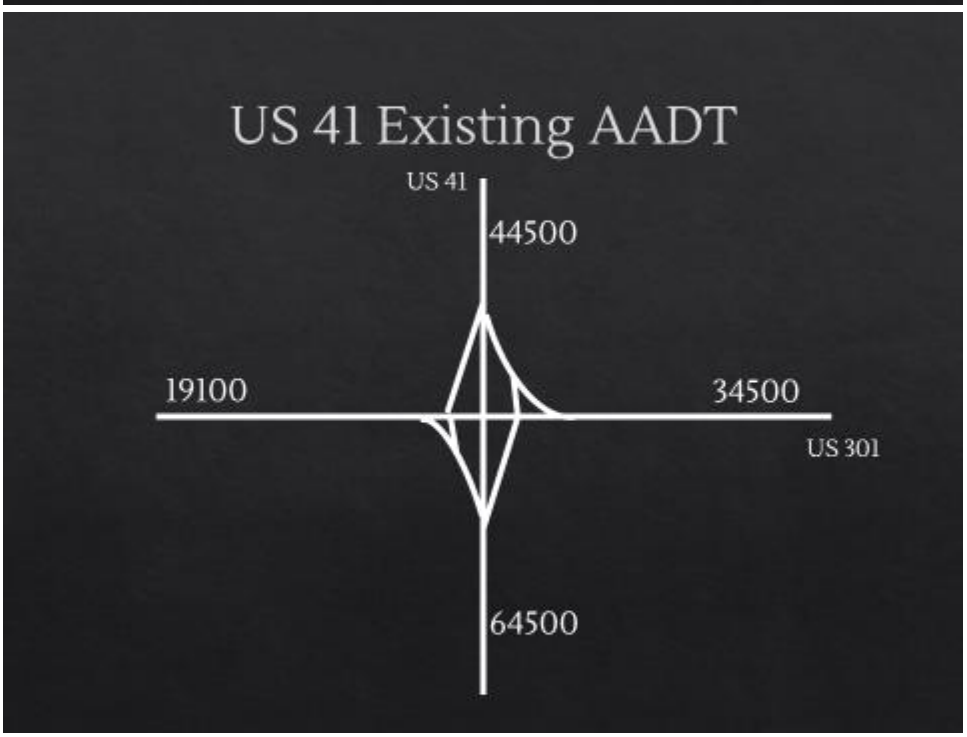


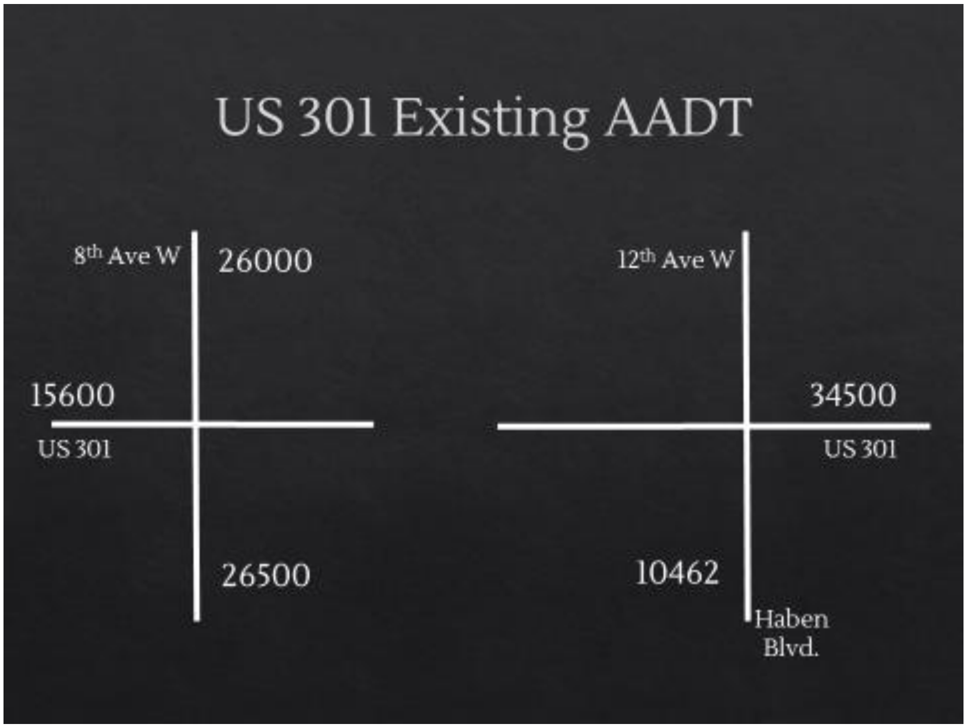
US 41 Interchange
Existing (2010) PM Peak Hour Volumes
US 301 & US 41 SB Ramps
US 41
US 301 & US 41 NB Ramps
US 41
333
1,215
349
983
125
63
1,073
519
High turning Volume
High turning

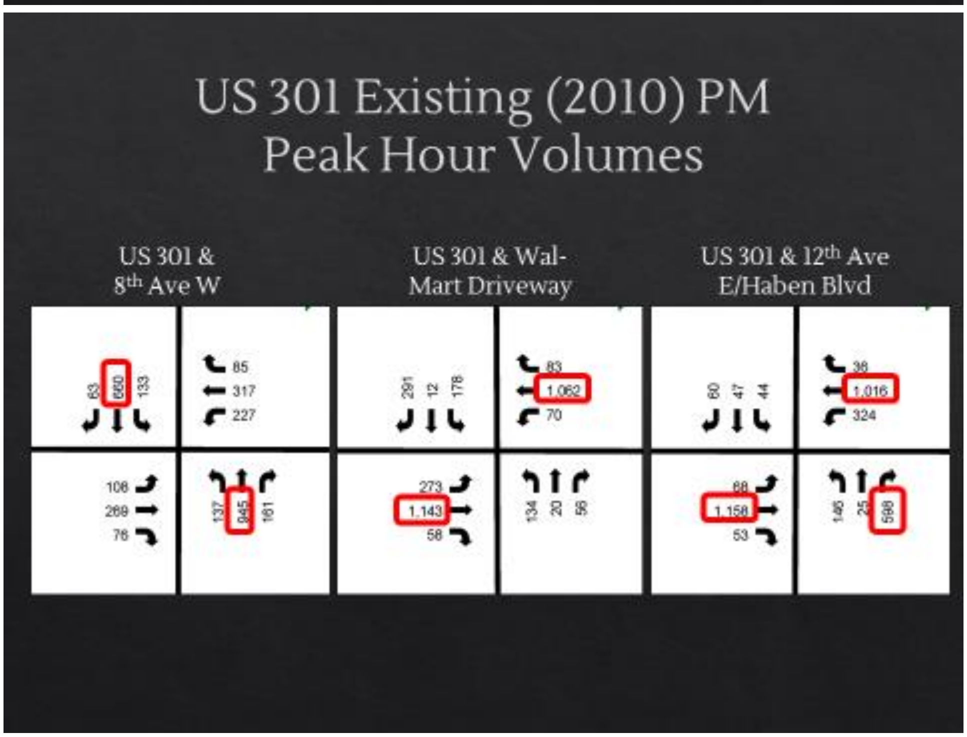


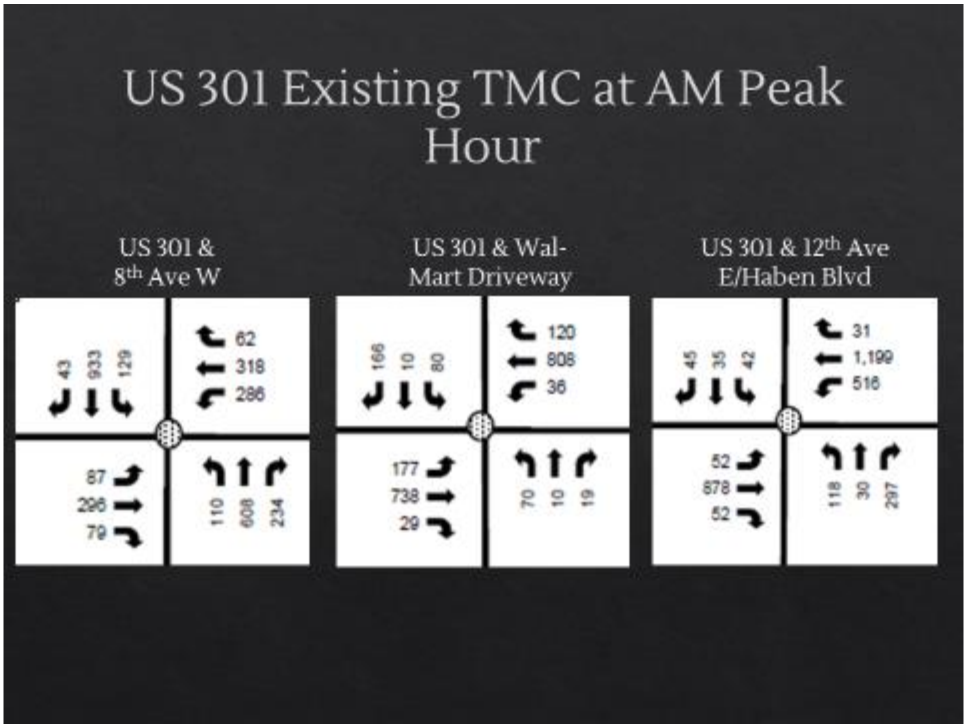
US 301 Existing Typical Section
EXIST R/W LINE.
EXIST R/W LINE.
80'
40'
40'
10' SHLDR
12'
12'
12'
12'
SWK
SOD
SWK
EXIST. CONCRETE SIDEWALK
TPYE D CURB & GUTTER
TYPE B STABILIZATION LBR 40
EXIST. CONCRETE SIDEWALK
TYPE D CURB & GUTTER
WEST OF INTERCHANGE EXISTING


US 301 Existing
Typical Section
EXIST R/W LINE
CONST. SR 43
22'
SURVEY SR 43
EXIST R/W LINE
R/W VARIES (75' MIN.)
R/W VARIES (75' MIN.)
8'
11'
11'
28' MEDIAN
11'
11'
8'
6'
SOD
0.02
0.02
TYPE E
CURB & GUTTER
TYPE E
CURB & GUTTER
NATURAL GROUND
NATURAL GROUND
EXIST. CONCRETE
SIDEWALK
EAST OF INTERCHANGE
EXISTING


US 41 Existing AADT
US 41
44500
19100
34500
US 301
64500


US 301 Existing AADT
8th Ave W
26000
15600
US 301
26500
12th Ave W
34500
US 301
10462
Haben Blvd.


US 301 Existing (2010) PM Peak Hour Volumes
US 301 & 8th Ave W
63
660
133
85
317
227
108
269
76
137
945
161
US 301 & Wal-Mart Driveway
291
12
178
83
1,062
70
273
1,143
58
134
20
56
US 301 & 12th Ave E/Haben Blvd
60
47
44
36
1,016
324
68
1,158
53
146
25
598


US 301 Existing TMC at AM Peak Hour
US 301 & 8th Ave W
43 933 129
62
318
286
87
296
79
110 608 234
US 301 & Wal-Mart Driveway
166 10 80
120
808
36
177
738
29
70 10 19
US 301 & 12th Ave E/Haben Blvd
45 35 42
31
1,199
516
52
878
52
118 30 297


Problem Areas
Wal-Mart Driveway
NB Ramps and US 41
8th Ave. W
N
500 ft
Google

Planning Objectives & Purpose

- Future Volumes were projected by applying 2% growth rate/year
- Target Level of Service for US 41 and US 301 is LOS C
- Two Conditions were analyzed
  - Alternative 1 - moving signalized intersection at Wal-Mart driveway/6th Ave and relocating to Palm 2nd, 4 Lane Divided to 6 Lane Divided Typical Section
  - Alternative 2 - 4 Lane Divided to 6 Lane Divided Typical Section

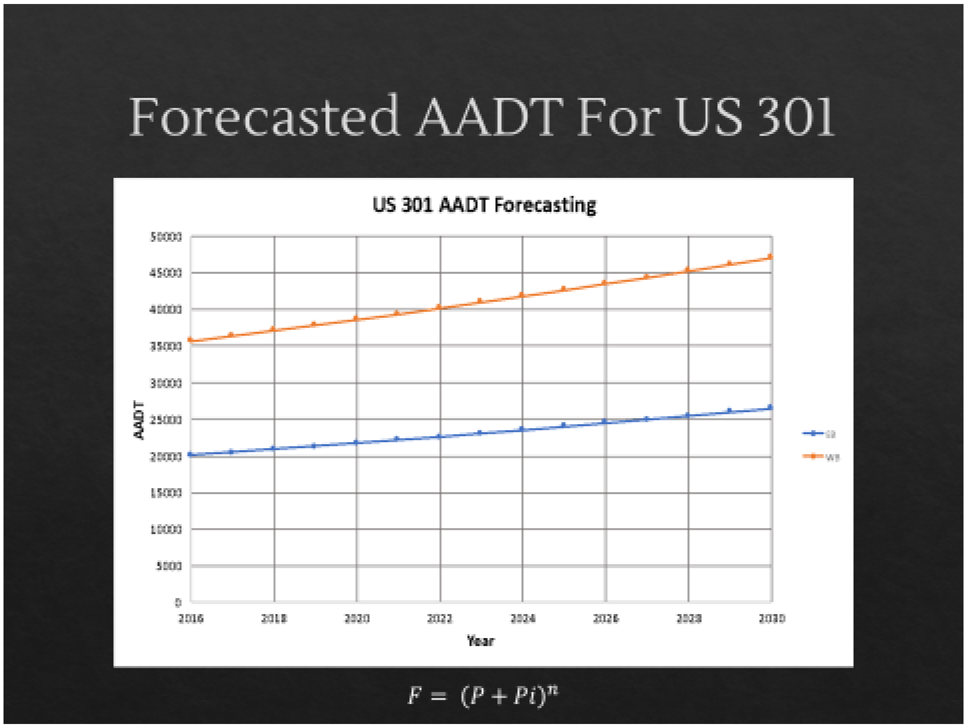
K (%)	D (%)
9	55

Growth Computation Value

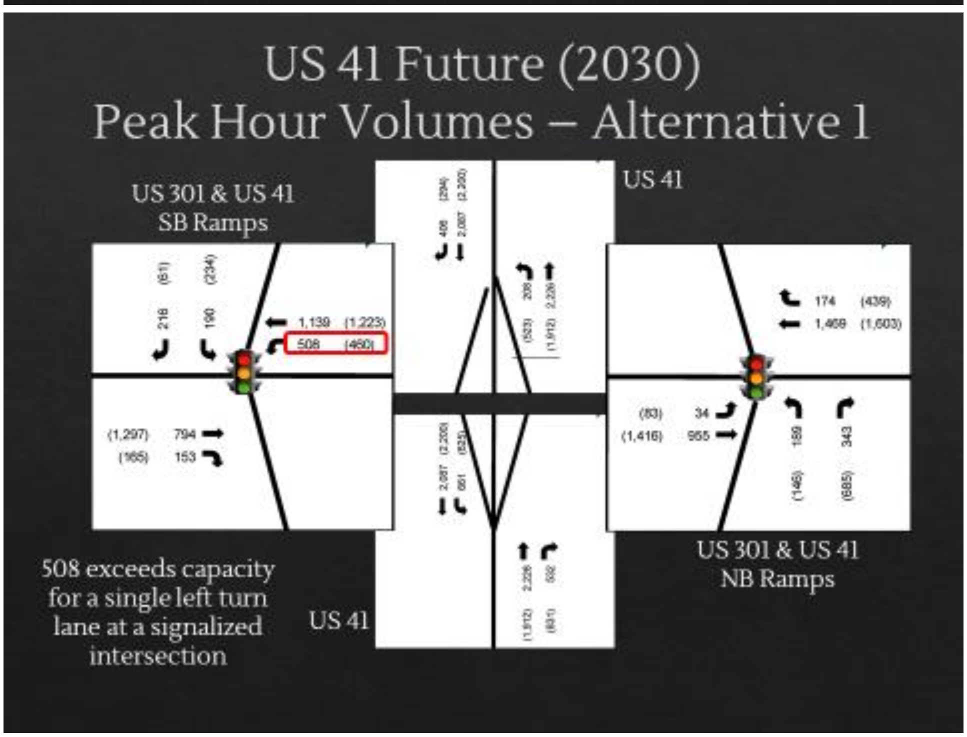
US 301		
Year	AADT	
	EB	WB
2000	19600	25500
2001	19700	24000
2002	22000	28000
2003	21000	26000
2004	26500	31000
2005	22000	29500
2006	23500	32500
2007	21000	32000
2008	22500	37500
2009	25000	37500
2010	25500	38000
2011	25500	38000
2012	22000	32000
2013	22000	32000
2014	19800	34000
2015	19700	35000

- The slope and average AADT was derived using Excel.
- The growth computation was obtained by dividing the slope by the average AADT.

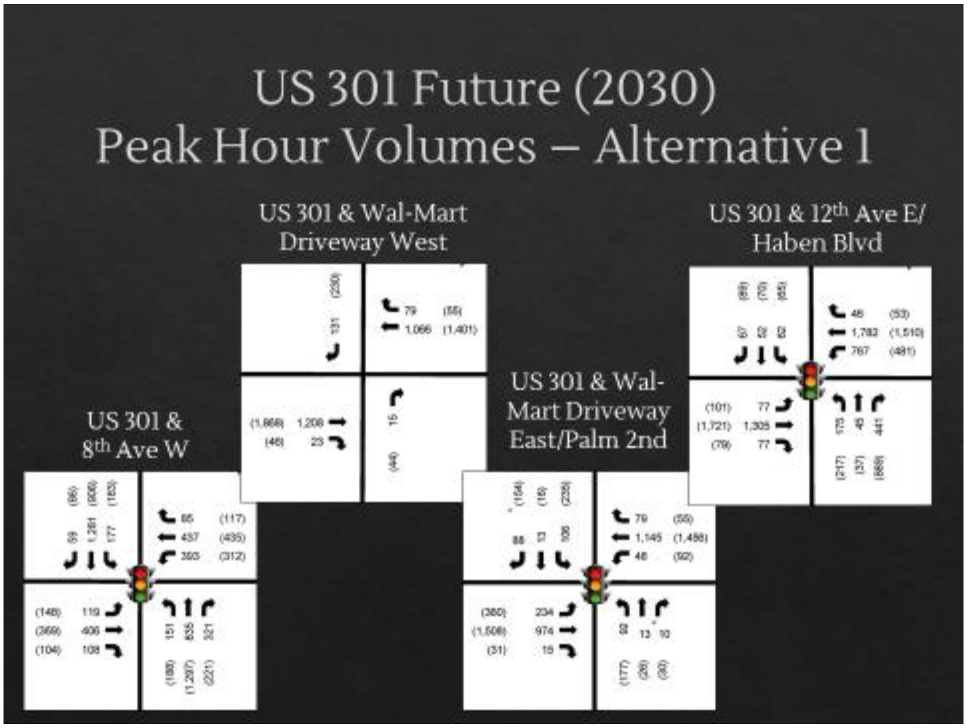
Growth Computational Value			
Direction	slope	slope/avg AADT	% increase
EB	41.6	0.0019	**0.19**
WB	709.6	0.0222	**2.22**



Forecasted AADT For US 301
US 301 AADT Forecasting
AADT
Year
$F = (P + Pi)^n$

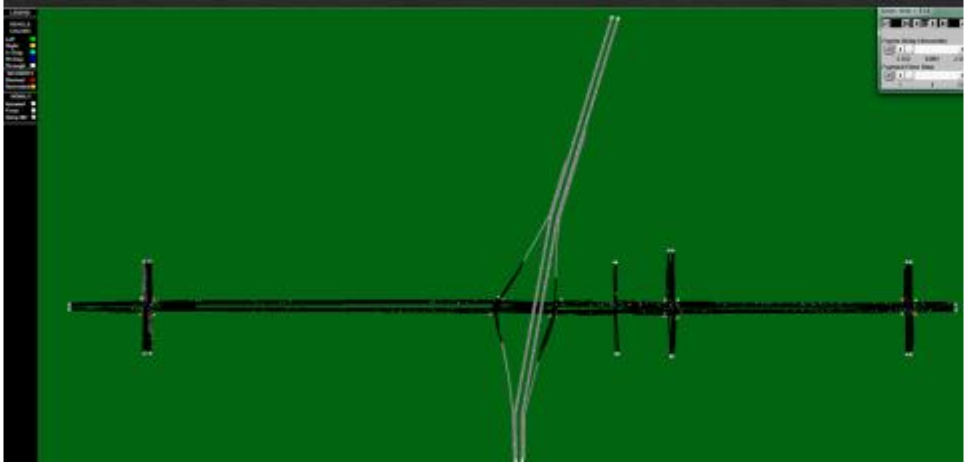


US 41 Future (2030)
Peak Hour Volumes – Alternative 1
US 301 & US 41
SB Ramps
US 41
US 301 & US 41
NB Ramps
US 41
1,139 (1,223)
508 (460)
794 (1,297)
153 (165)
174 (439)
1,469 (1,603)
34 (83)
955 (1,416)
508 exceeds capacity
for a single left turn
lane at a signalized
intersection


US 301 Future (2030)
Peak Hour Volumes – Alternative 1
US 301 & Wal-Mart Driveway West
US 301 & 12th Ave E/ Haben Blvd
US 301 & Wal-Mart Driveway East/Palm 2nd
US 301 & 8th Ave W


Wal-Mart Intersection
Wal-Mart Current Entrance
Proposed Wal-Mart Future Entrance
• Wal-Mart Current Entrance is Too Close to Operational Area of the Interchange
• Less than 400 feet

Peak Hour Traffic Simulation
TSIS Traffic Modeling



Signal Timing

- Calculations were done to optimize the signal timing of all existing and proposed signalized intersections
  - This sequence of signalized intersections was analyzed as a system
- TSIS software does not optimize the signal timing automatically
- East/West bound traffic was the deciding factor for signal priorities.
- A project wide greenway was established to reduce travel time lost due to acceleration and deceleration behaviors.
  - 8th Avenue is dominated by North / South bound traffic, it cannot be included in the green way.
- The Signalized intersection's close proximity to the diamond interchange determined how many auxiliary and through lanes were needed
- After construction is complete and traffic is reopened, new signal timing should be established based on new traffic data collection

Determination of Basic Number of Lanes on US 301

Optimum Cycle Length $C_{opt} = \dfrac{1.5(L)+5}{1-\sum_{i=1}^{n}\left(\dfrac{v}{s}\right)_{ci}}$

C_{opt} = *estimated optimum cycle length (seconds) to minimize vehicle delay*

L = *total lost time per cycle (seconds), 4 seconds per phase is typical*

$(v/s)_{ci}$ = *flow ratio for critical lane group, i (seconds)*

Assumptions and Equations (From *Principles of Highway and Traffic Analysis* by Fred L. Mannering and Scott S. Washburn)

- Saturation Flow Rate (s) = 1750veh/hr/lane
- $C_{min} = \frac{L*Xc}{Xc-\Sigma\left(\frac{v}{s}\right)_{ci}}$
- $X_c = \frac{\Sigma\left(\frac{v}{s}\right)*C}{C-L}$
- $g_i = \left(\frac{v}{s}\right)_{ci} * \frac{C}{X_i}$
- $Y = t_r + \frac{V}{2a+2gG}$
- t_r= driver reaction time (taken to be 2.5 seconds)
- Due to the low number of pedestrians, lights were not designed for pedestrian crossing time

Beginning Equations

- Check Yellow Time
  - Two signalized design times (40mph, 30mph)
  - 40mph:
    - Y = 2.5 Y = 5.4 seconds
    - For the purposes of synchronizing the lights this was often taken to be 5 seconds
  - 30mph:
    - Y = 2.5 Y = 4.5 seconds
    - For the purposes of synchronizing the lights, specifically for short signal phases, this was reduced to 2.5 or 3 seconds as needed. These were generally starting from a stop, so 30mph was assumed to not be indicative of the actual speed.
- Critical Intersection US41 SB Ramps / US301
  - After initial TSIS simulations, the intersection at US301 and US41 SB was determined to be the intersection with the most delay. The optimal time for this intersection was determined, and this cycle length was applied throughout the system.

Light Timing Example (Critical Intersection)

Phase	1		2		3	
Movements	NB R	EB Left	EB Thru	WB Thru	NB R	NB L
Turns	207.6	63	1073	1215	311.4	111
Lanes	2	1	3	3	2	2
Saturation Rate	3500	1750	5250	5250	3500	3500
Flow Ratios	0.059314	0.036	0.204381	0.231429	0.088971	0.031714

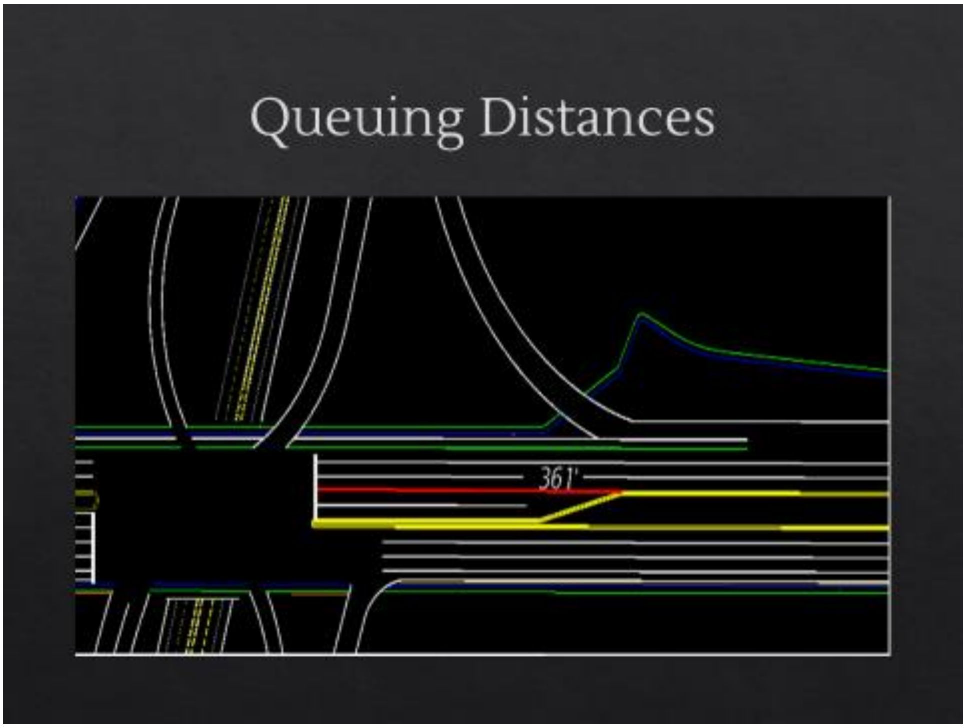
$C_{min} = \frac{L \cdot Xc}{Xc - \Sigma\left(\frac{v}{s}\right)_{ci}} = 34$ seconds

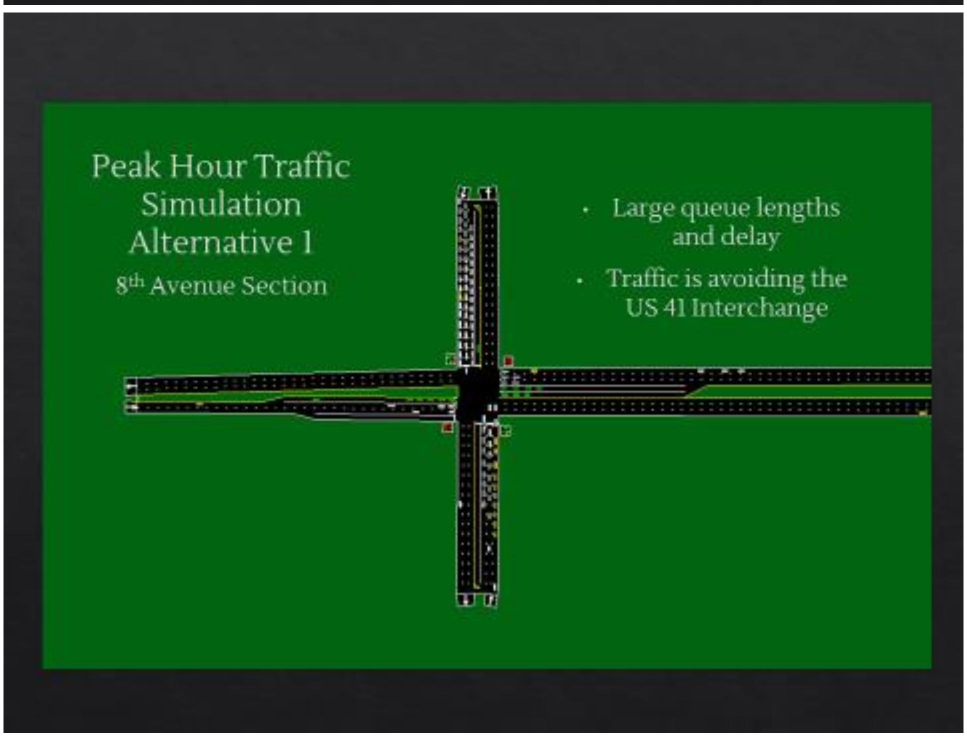
$C_{opt} = \frac{1.5 \cdot L + 5}{1.0 - \Sigma\left(\frac{v}{s}\right)_{ci}} = 76$ seconds (Rounded to 80 seconds)

$X_c = \frac{\Sigma\left(\frac{v}{s}\right) \cdot C}{C - L}$ = effective capacity = 40%

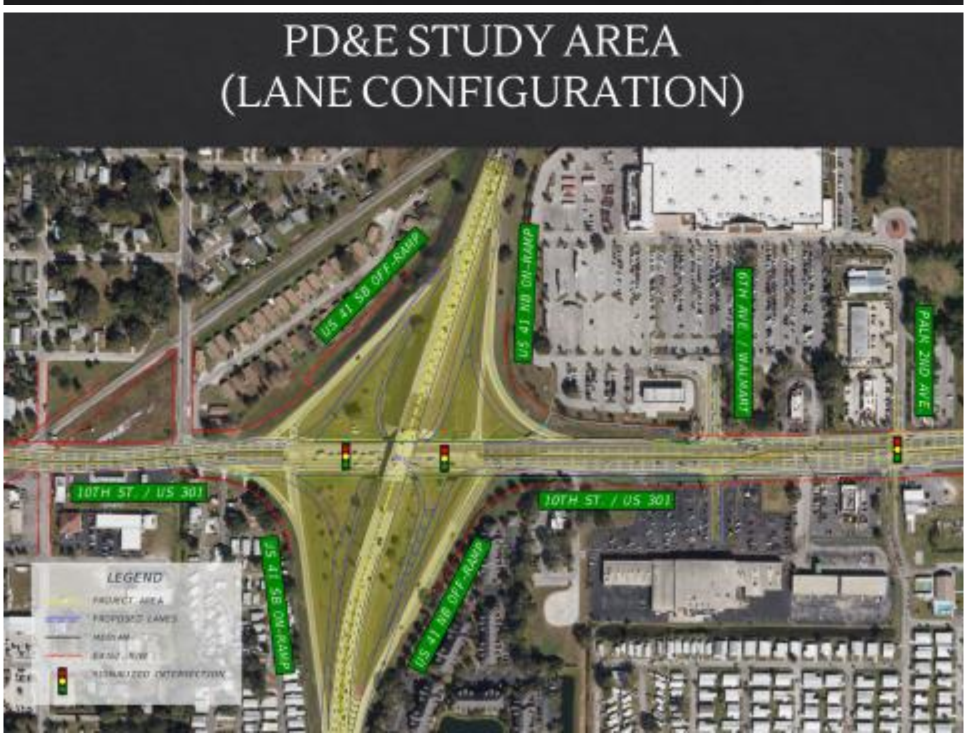
Using the equations for signal phase timing, the following phases were produced.

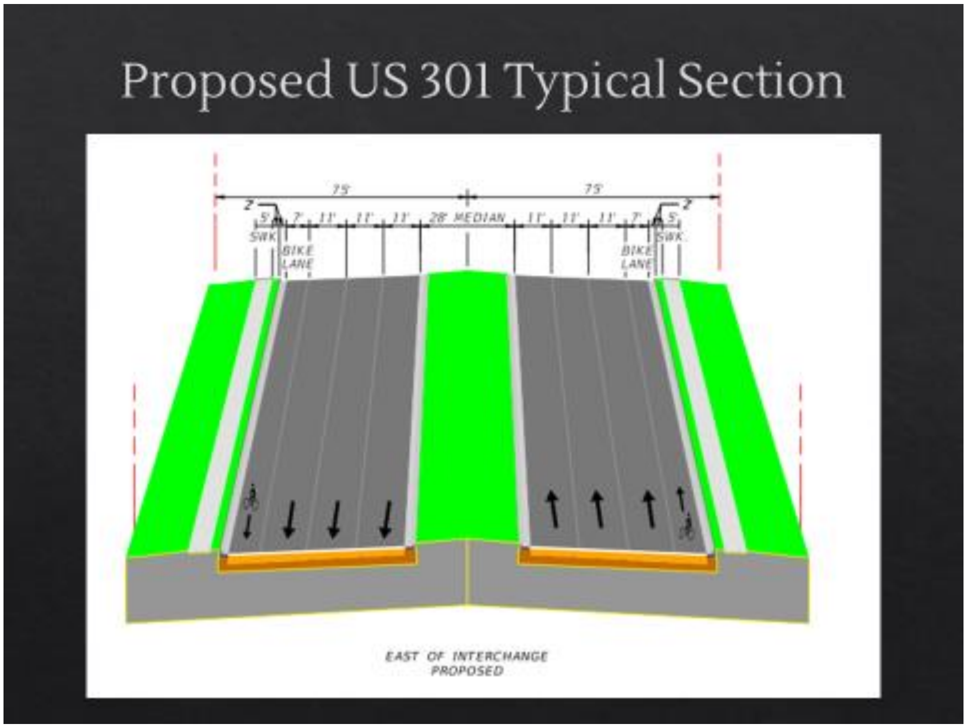
Phase	1		2		3	
Movements	NB R	EB Left	EB Thru	WB Thru	NB R	NB L
Effective Green	11.0		44.0		17.0	
Actual Green	7.0		40.0		13.0	
Yellow	5		5		5	
All Red	1		1		1	

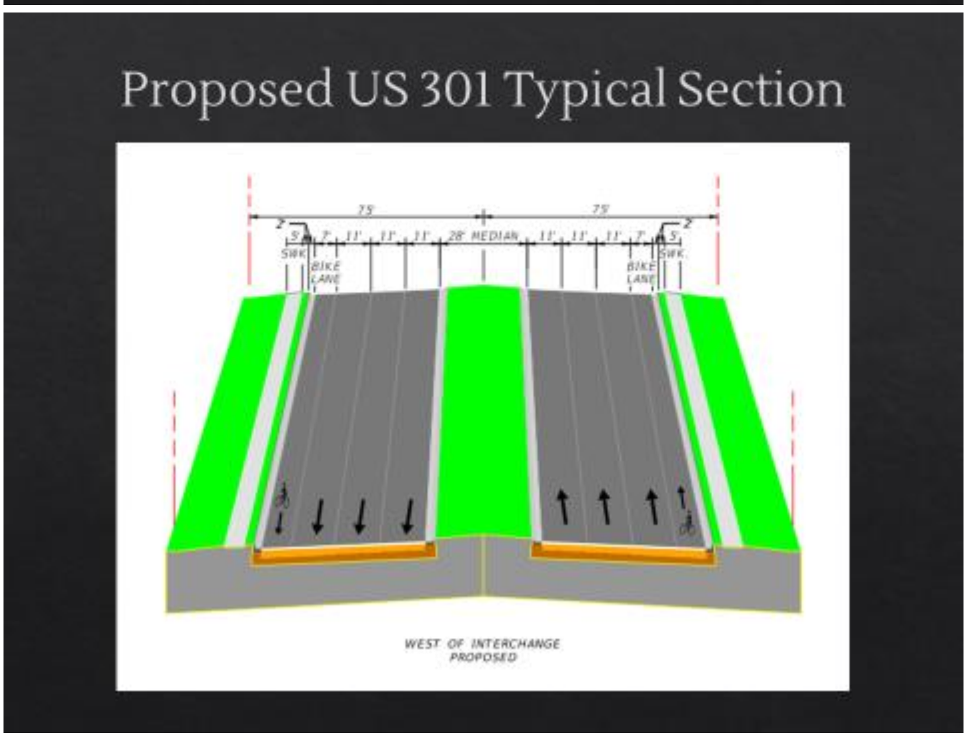

Queuing Distances
361'

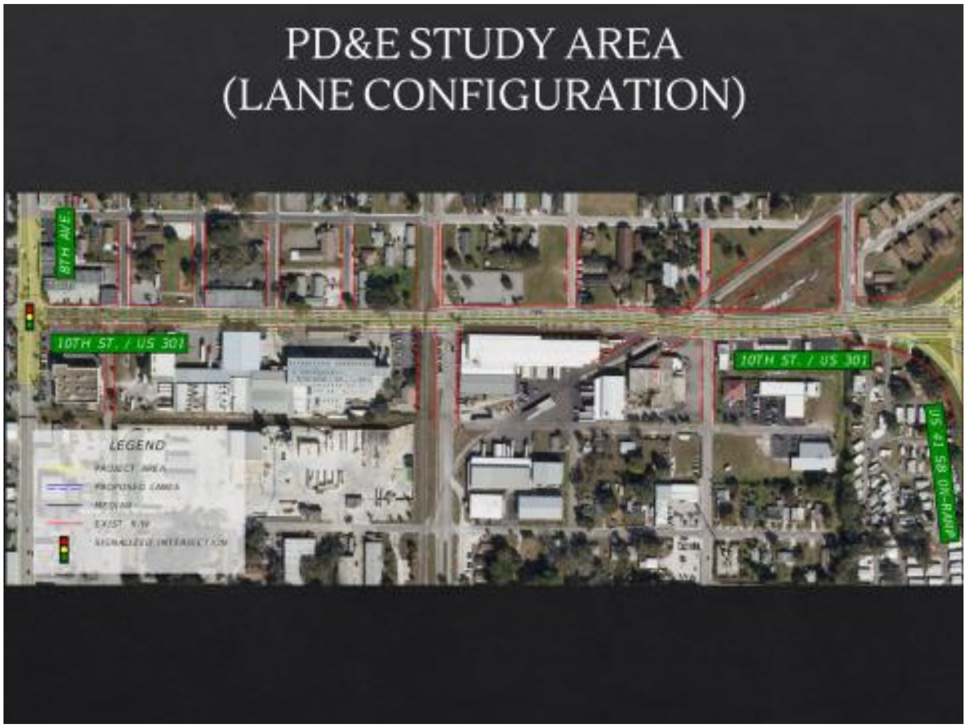

Peak Hour Traffic
Simulation
Alternative 1
8th Avenue Section
Large queue lengths and delay
Traffic is avoiding the US 41 Interchange

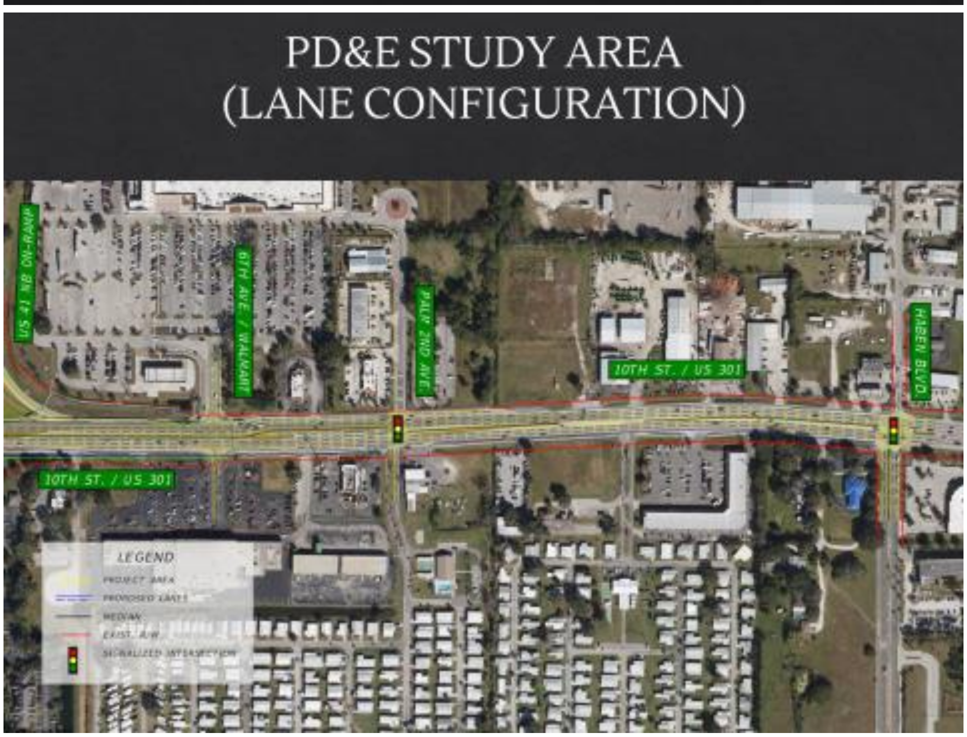

Peak Hour Traffic Simulation Build Condition
6.7'
US 41 – US 301 Ramp Section
• Steady traffic flow with no delay
• Signal Point Interchange is a further solution


PD&E STUDY AREA (LANE CONFIGURATION)
US 41 SB OFF-RAMP
US 41 NB ON-RAMP
10TH ST. / US 301
10TH ST. / US 301
US 41 SB ON-RAMP
US 41 NB OFF-RAMP
LEGEND


Proposed US 301 Typical Section
75'
75'
28' MEDIAN
SWK
BIKE LANE
EAST OF INTERCHANGE
PROPOSED


Proposed US 301 Typical Section
75'
75'
28' MEDIAN
SWK
BIKE LANE
WEST OF INTERCHANGE
PROPOSED


PD&E STUDY AREA
(LANE CONFIGURATION)
8TH AVE
10TH ST. / US 301
10TH ST. / US 301
US 41 SB ON-RAMP
LEGEND


PD&E STUDY AREA
(LANE CONFIGURATION)
US 41 NB ON-RAMP
8TH AVE / WALMART
10TH ST. / US 301
HABEN BLVD.
10TH ST. / US 301
LEGEND

Calculating LOS for Intersections (TSIS)

$$\sum \frac{Control\ Delay\ (s) * Flow(vehicles\ per\ hour)}{Flow(vehicles\ per\ hour)}$$

EXHIBIT 16-2. LOS CRITERIA FOR SIGNALIZED INTERSECTIONS

LOS	Control Delay per Vehicle (s/veh)
A	≤ 10
B	> 10–20
C	> 20–35
D	> 35–55
E	> 55–80
F	> 80

LOS Sample Calculation for US 301/Haben Blvd. (TSIS)

US-301 & Haben/12th - Build					
Direction	Control delay (s)	Flow (vph)	s x vph	Intersection Delay (s)	LOS
WB (16,2)	16.3	2583	42102.9	23.07780225	C
EB (25,2)	39.1	1114	43557.4		
NB (19,2)	20.7	663	13724.1		
SB (17,2)	29.9	181	5411.9		

Alternative 2 Peak Hour Scenario (2030)

Intersection	Time Period	Intersection Delay (s)	LOS	Control
US 301 & 8th Ave	PM	47.10943325	D	Signalized
US 301 & 6th Ave (Current Walmart Entrance)		21.0965685	C	
US 301 & Haben		21.40167217	C	
US 301 & US 41 NB Ramp		11.66092943	B	
US 301 & US 41 SB Ramp		28.01043771	C	

Alternative 1 Peak Hour Scenario (2030)

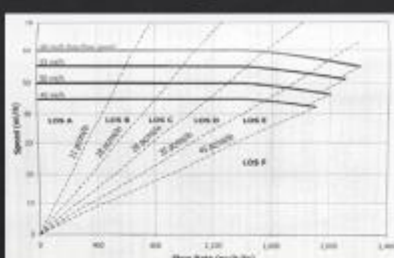
Intersection	Time Period	Intersection Delay (s)	LOS	Control
US 301 & 8th Ave	PM	46.69478475	D	Signalized
US 301 & Palm 2nd (Future Walmart Entrance)		19.30930889	B	
US 301 & Haben		23.07780225	C	
US 301 & US 41 NB Ramp		12.05640271	B	
US 301 & US 41 SB Ramp		25.11797753	C	

Calculating LOS for Roadways using Peak Hour Volumes

- $V_p = \frac{V}{PHF*N*f_{HV}*f_p}$
- $\text{PHF} = \frac{V}{V_{15}*4}$
- $f_{HV} = \frac{1}{1+P_T(E_T-1)+P_R(E_R-1)}$
- $\text{D} = \frac{V_p}{S}$

- V_p = 15-min passenger car equivalent flow rate (pc/h/ln)
- V_{15} = maximum 15-min flow rate in an hour
- S = average passenger car speed in mi/hr
- D = density in pc/mi/ln
- V = hourly volume (veh/hr)
- PHF = peak-hour factor
- N = number of lanes
- f_{HV} = heavy-vehicle adjustment factor
- f_p = driver population factor (assuming 1.0 for familiar-driver traffic streams)
- P_T = proportion of trucks and buses (assuming 1%)
- P_R = proportion of RV's (assuming 1%)
- E_T = passenger car equivalent for trucks and buses
- E_R = passenger car equivalent for RV's

Segmental LOS Calculation



Density (pc/mi/ln)	LOS
11	A
18	B
26	C
35	D
45	E

US 301 AM Peak Hour LOS (No Build)											
Intersection	V	Fp	FHV	N	PHF	Vp	S	D	LOS	D(avg)	LOS (governing)
8th EB	633	1	0.993	1	0.92	693	35	19.8	C	17.34871	B
8th WB	915	1	0.993	2	0.88	522	35	14.9	B		
8th NB	1307	1	0.993	2	0.91	726	35	20.7	C	21.89512	C
8th SB	1517	1	0.993	2	0.95	807	35	23.1	C		

No Build Peak Hour Scenario (2030)

Intersection	Time Period	LOS	Scenario
US 301 and US 41 NB On/Off Ramps	AM	A	Segmental Analysis
	PM	C	
US 301 and US 41 SB On/Off Ramps	AM	C	
	PM	B	
US 301(10th Ave) and 8th Ave-**EB/WB**	AM	B	
	PM	A	
US 301(10th Ave) and 8th Ave-**NB/SB**	AM	C	
	PM	C	
US 301 and Haben Blvd-**EB/WB**	AM	C	
	PM	C	
US 301 and Haben Blvd-**NB/SB**	AM	B	
	PM	C	
US 301 and 6th Ave (Current Walmart Entrance) –**EB/WB**	AM	C	
	PM	C	
US 301 and 6th Ave-**NB/SB**	AM	A	
	PM	B	

Build Peak Hour Scenario (2030)

Intersection	Time Period	LOS	Scenario
US 301 and US 41 NB On/Off Ramp	AM	A	Segmental Analysis
	PM	C	
US 301 and US 41 SB On/Off Ramp	AM	**B**	
	PM	B	
US 301(10th Ave) and 8th Ave-**EB/WB**	AM	**A**	
	PM	A	
US 301(10th Ave) and 8th Ave-**NB/SB**	AM	**B**	
	PM	**B**	
US 301 and Haben Blvd-**EB/WB**	AM	C	
	PM	**C**	
US 301 and Haben Blvd-**NB/SB**	AM	**A**	
	PM	**B**	
US 301 and Palm 2nd (Future Walmart Entrance)-**EB/WB**	AM	**B**	
	PM	**B**	
US 301 and Palm 2nd-**NB/SB**	AM	A	
	PM	**B**	

REGULATORY AGENCIES

- FDOT, Florida Department of Transportation
- Manatee County Public Works Standards
- FHWA, Federal Highway Administration
- DEP, Florida Department of Environmental Protection
- SWFWMD, Southwest Florida Water Management District

Planning Cost Estimate

Facility	Cost
US 301	$23,835,418.67
US 41	$7,576,473.04
US 41 Ramps	$16,161,136.14
Signalization	$250,000.00
MSE Wall	$24,595,747.00
SPUI	$36,630,584.00
TOTAL	**$84,453,611.85**

28.2 Geometric Design of US 301:

Geometric Design US Highway 301

TEAM LEADER: MONIQUE GYANT

TEAM MEMBERS: DANIEL HOEFLICH, ODELMO JOSEPH, PAYDEN CALHOUN, JEREMY ABREU, AHMED AL SHAMISI

INSTRUCTOR: DR. QING LU, P.E.

CO-INSTRUCTOR: MR. BIJAN BEHZADI, P.E., PTOE

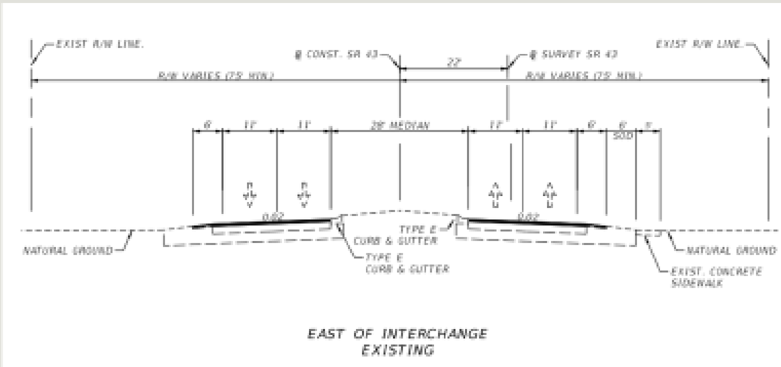
Project Limits

Scope of Work

- Develop Typical Sections of Existing Roadway
- Develop New Typical Sections based on Data Simulation
- 3-D Projections of Proposed Roadway
- Develop Roadway Criteria for Designs
- Cost Analysis

Existing US Hwy 301 East of Interchange

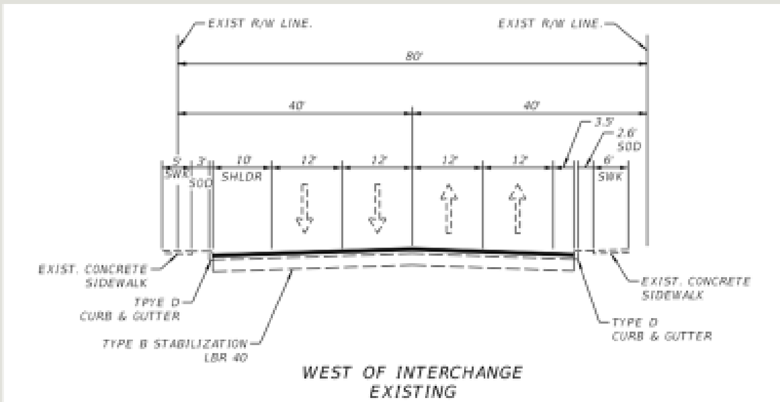
Existing US Hwy 301 East of Interchange Typical



- 2 through lanes
- Signalized interchanges very close to interchange

Existing US Hwy 301 West of Interchange

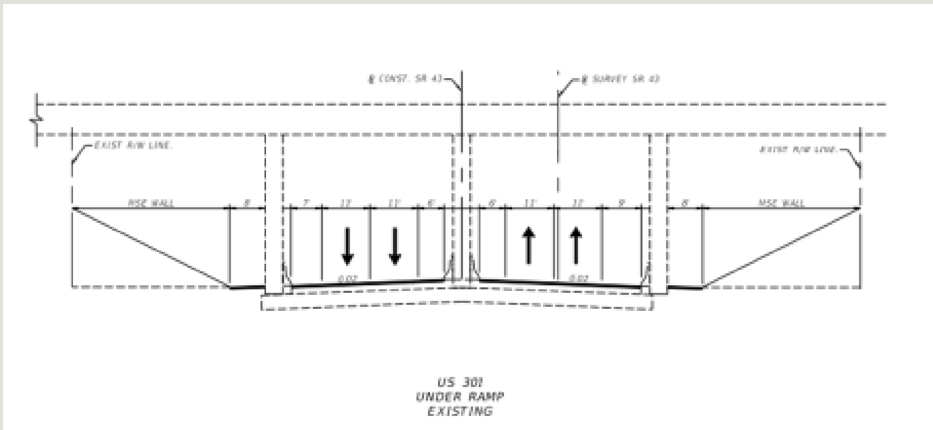
Existing US Hwy 301 West of Interchange Typical



- Two through lanes
- No median
- Tight Right-of-Way

Existing US Hwy 301 Under Ramp

Existing US Hwy 301 Under Ramp



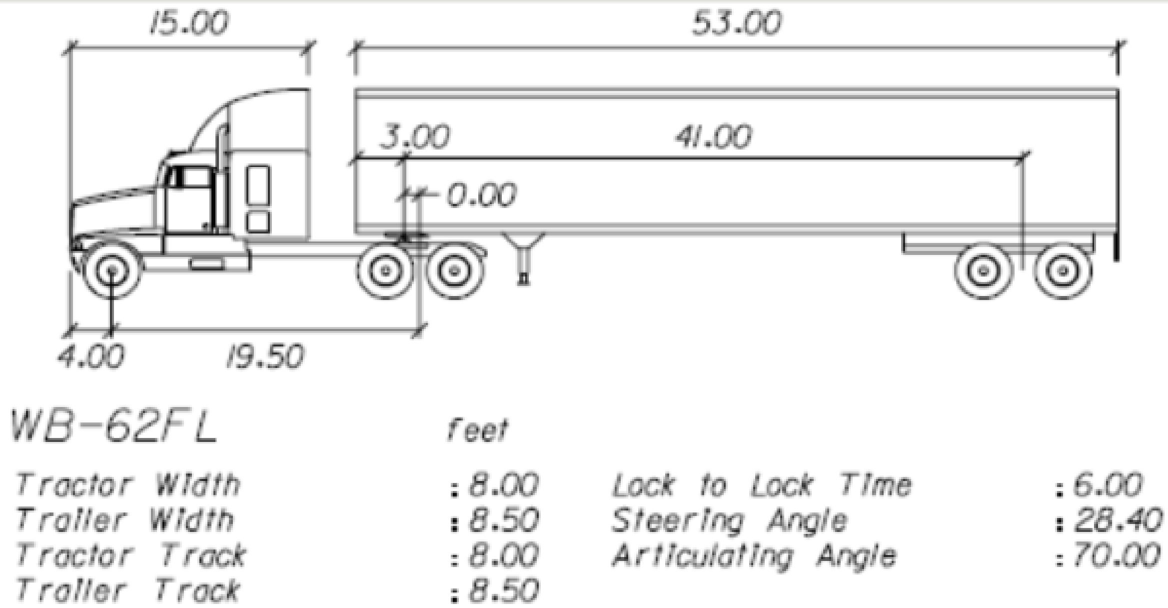
Existing Wal-Mart Intersection

Roadway Design Criteria

Roadway Classification		High Speed Urban Arterial
General Criteria	Design Speed	45 mph
	Design Vehicle	WB-62 FL
Selection Features	Median Width	28 feet
	Shoulders	None
	Curb & Gutter	Yes
	Bike Lane	7 feet
Horizontal Clearance	Clear Zone	4 feet from FOC
	Border Width	14 feet
Horizontal Alignment	Max. Superelevation ()	5%
	Max. Grade	6%
	Min. Grad	0%
	Min. Length of Curve	400 feet

Sources: FDOT Design Manual & AASHTO Green Book

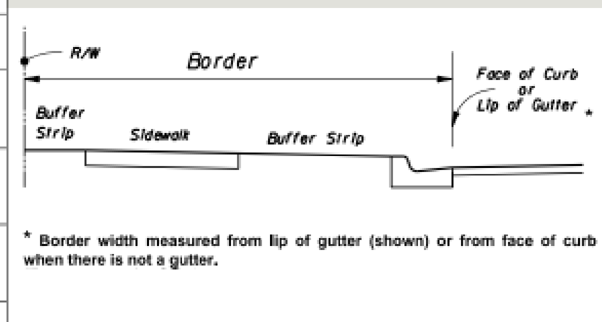
Design Vehicle for US 301



Border Width for US 301

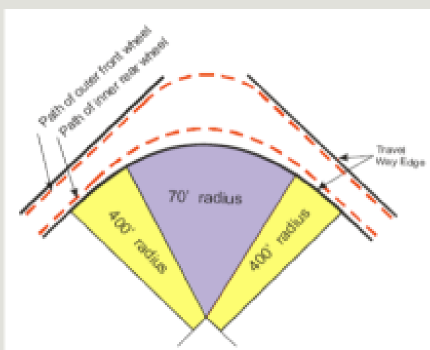
BORDER		
TYPE FACILITY	MINIMUM WIDTH (FEET)	
	TRAVEL LANES AT CURB OR CURB AND GUTTER	BICYCLE LANES OR OTHER AUXILIARY LANES AT CURB OR CURB AND GUTTER
ARTERIALS COLLECTORS Design Speed = 45 mph	14	12
ARTERIALS COLLECTORS Design Speed ≤ 40 mph	12	10
URBAN COLLECTOR STREETS Design Speed ≤ 30 mph	10	8

Sources: FDOT Design Manual & AASHTO Green Book



Roadway Design Criteria

Design Vehicle: WB-62 FL	
Turning Radii	50 feet or
	3- centered curve
Control Radius	75 feet
Angle of Turn	90 degrees



WB-62 SEMITRAILER COMBINATION

Edge of Travel Way Design		
Angle of Turn	Design Vehicle	3- Centered Compound
90	WB-62 FL	400-70-400

Roadway Design Criteria

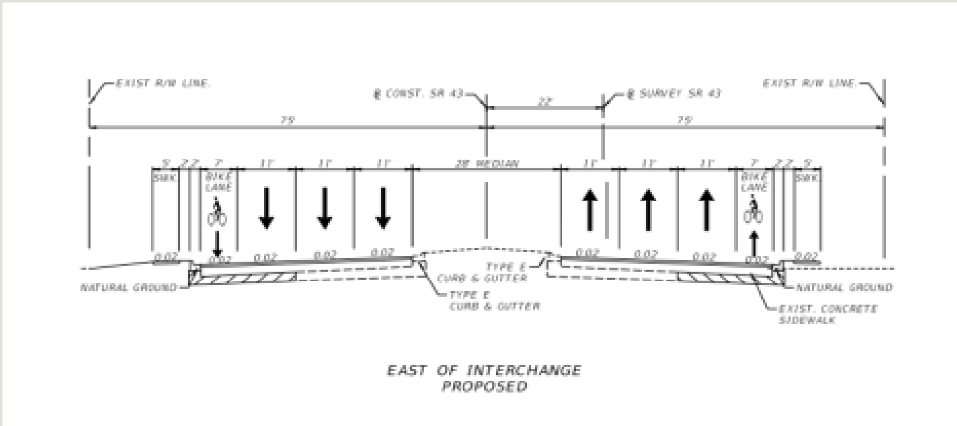
Roadway Classification		High Speed Urban Arterial
Vertical Alignment	Base Clearance Above DHW Elevation	3 feet
	Max Change in Grade w/o HC	0.6%
	Max. SSD	360 feet
	Min. Length of Crest VC	300 feet
	Min. K Value of Crest VC	136
	Min. Length of Sag VC	200 feet
	Min. K Value of Sag VC	96

Sources: FDOT Design Manual & AASHTO Green Book

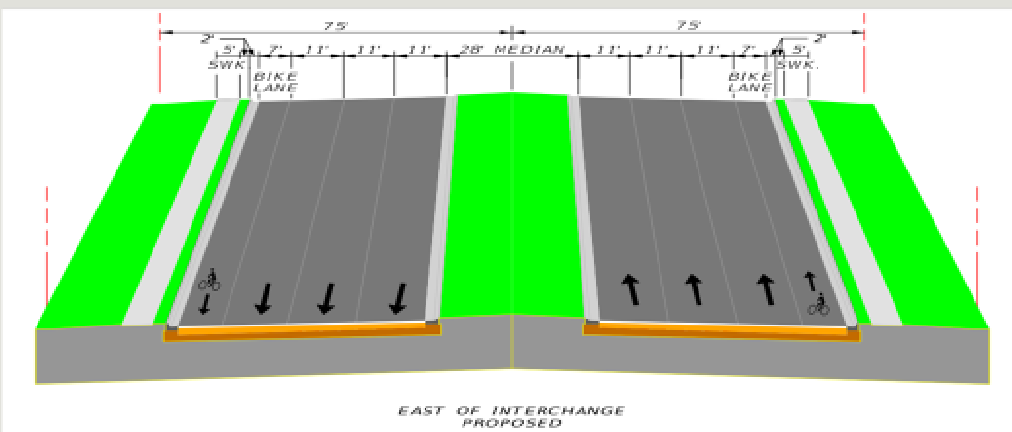
Proposed Changes to Roadway

- Change US301 to 6 lane divided highway from 8th Ave to Haben Blvd
- 7' Bike lanes were added in Eastbound and Westbound directions
- 28' median added to US301 west of US41 interchange
- Moved intersection at Wal-Mart farther east of the interchange with US41
- Kept sidewalk on both sides of US301 and either side of interchange

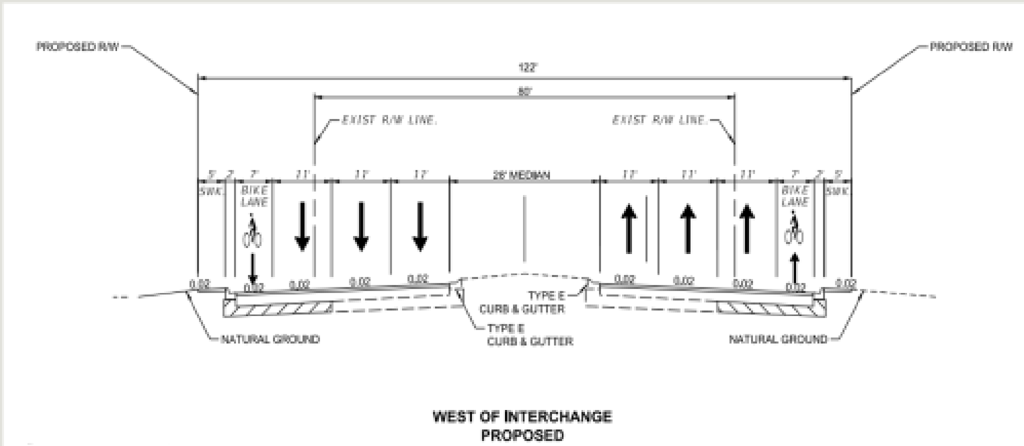
Proposed US Hwy 301 East of Interchange



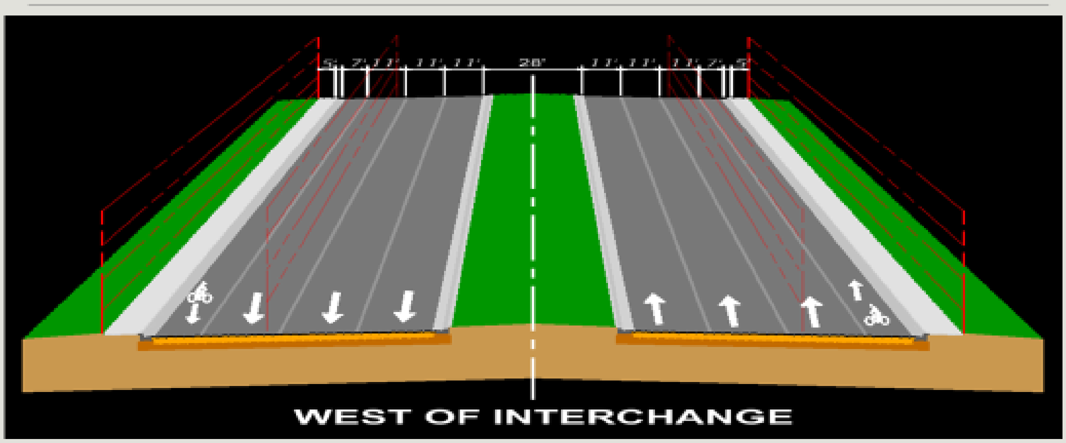
Proposed US Hwy 301 East of Interchange



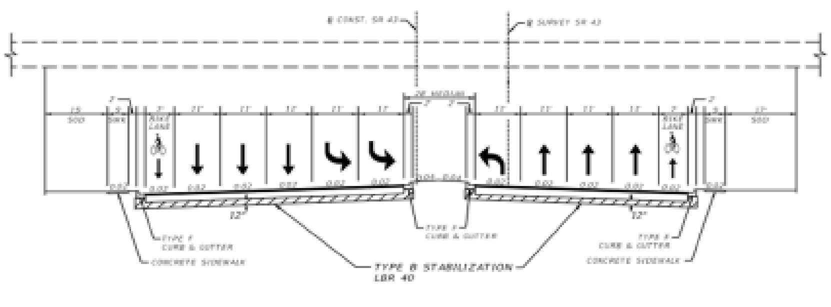
Proposed US Hwy 301 West of Interchange



Proposed US Hwy 301 West of Interchange



Proposed US Hwy 301 Under Ramp



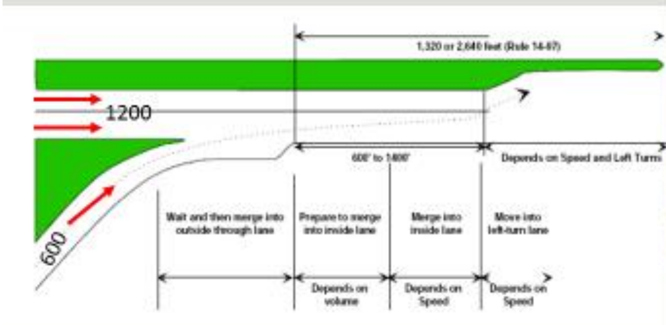
TYPICAL SECTION
SR 43 (US 301)

Access Class for US 301

Access Class	Medians "Restrictive" physically prevent vehicle crossing. "Non-Restrictive" allow turns across at any point.	Connection Spacing (feet)		Median Opening Spacing (feet)		Signal Spacing (feet)
		>45 mph	≤45 mph	Directional	Full	
2	Restrictive with Service Roads	1320	660	1320	2640	2640
3	Restrictive	660	440	1320	2640	2640
4	Non-Restrictive	660	440			2640
5	Restrictive	440	245	660	***2640/ 1320**	***2640/1320**
6	Non-Restrictive	440	245			1320
7	Both Median Types	125		330	660	1320

* 2640 feet for >45 mph; 1320 feet for ≤45 mph

Required Wal-Mart Entrance Location from US 41



The total weaving volume is calculated as: $Vw = V1 + \%LT \times [V1 + V2] / 2$

Where: Vw = *total weaving volume*
$V1$ = *crossroad volume (vph)*
$V2$ = *ramp volume*
$\%LT$ = *percentage of vehicles turning left*

Old Walmart Intersection

Proposed 8th Ave Intersection

Proposed Wal-Mart Intersection

Proposed Haben Blvd Intersection

US Hwy 301 Cost Estimate

ITEM DESCRIPTION	UNIT	UNIT COST	QUANTITY	TOTAL COST
INLETS, CURB, TYPE P-1, <10'	EA	55	$4,300.00	$236,500.00
PIPE CULVERT,OPTIONAL MATERIAL,ROUND, 24"S/CD	LF	13728	$55.00	$755,040.00
CONCRETE CURB & GUTTER, TYPE F	LF	27600	$16.50	$455,400.00
CONCRETE SIDEWALK AND DRIVEWAYS, 4" THICK	SY	68500	$26.00	$1,781,000.00
PERFORMANCE TURF, SOD	SY	5000	$3.00	$15,000.00
MILLING EXIST ASPH PAVT, 1 1/2" AVG DEPTH	SY	411840	$2.00	$823,680.00
FLEXIBLE PAVEMENT	SY			$2,064,501
CONSTRUCTION SUB-TOTAL				$6,531,121.25
MOBILIZATION			10%	$653,112.13
MAINTENANCE OF TRAFFIC			10%	$653,112.13
LIGHTING			10%	$653,112.13
SIGNING AND PAVEMENT			10%	$653,112.13
PROJECT UNKNOWNS			10%	$653,112.13
GRAND TOTAL				$9,796,681.90

28.3 Geometric Design of US 41:

Geometric Design US 41

University of South Florida Spring 2017 Geotechnical/Transportaion Capstone

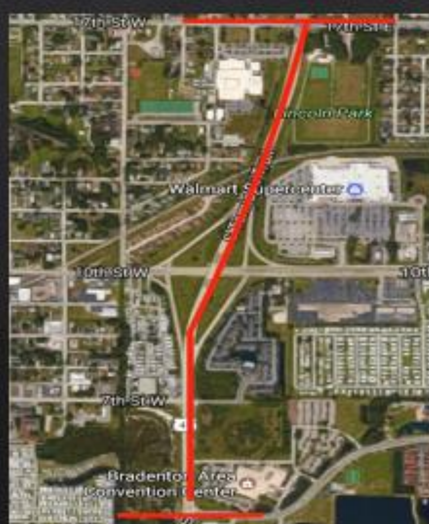
Brandon Mendoza (Team Leader) , Ahmed Alnuaimi

David Gottwik, Ilan Caballero

Ali Buohamad, Jameson Wilson

Project Limits

From 17th St to Haben Blvd



Scope of Work

- Retrieve existing topography file for US301/41
- Digitize remaining topography for US 41
- Develop existing/proposed typical sections
- Widen US 301 under the interchange
- Design a Single Point Urban Interchange

Roadway Design Criteria

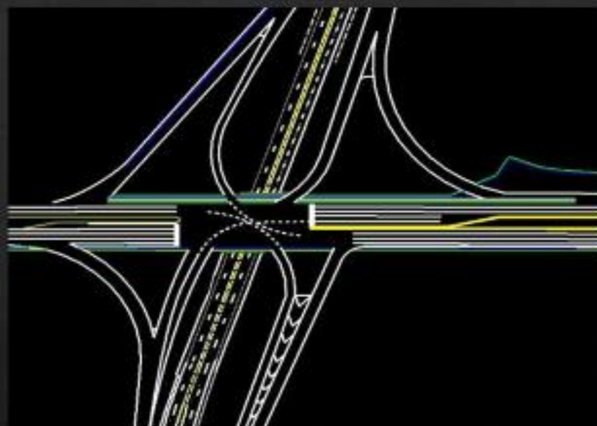
Roadway Classification		Rural Arterial	High Speed Suburban Arterial	High-Speed Urban Arterial
General Criteria	Design Speed	65 mph	55 mph	50 mph
	Design Vehicle	WB-62 FL	WB-62 FL	WB-62 FL
	Median Widths	40 ft.	30 ft.	30 ft.
Section Features	Inside Shoulder	8 ft.	4 ft.	4 ft.
	Outside Shoulder paved width	5 ft.	5 ft.	6.5 ft.
Horizontal Clearance	Clear Zone	36 ft.	30 ft.	24 ft.
	Border width	40 ft.	40 ft.	29 ft.
Horizontal Alignment	Max Super Elevation	10%	5%	5%
	Min. Length of Curves	400 ft.	400 ft.	400 ft.
	Min. Curve, Radius w/Super	1,348 ft.	2,750 ft.	2,244 ft.
	Min. Curve, Radius w/o Super	13,164 ft.	9,949 ft.	8,337 ft.
Vertical Alignment	Maximum Grade	3%	5%	6%
	Minimum Grade	0%	0%	0.3%
	Base Clearance above DHW EL	3 ft.	1 ft.	1 ft.
	Max Change in Grade w/o Curve	0.3 %	0.5 %	0.6 %
	Minimum SSD	645 ft.	495 ft.	425 ft.
	Minimum Length of Crest Curves	450 ft.	350 ft.	300 ft.
	Minimum K Value of Crest Curves	313	185	136
	Minimum Length of SAG Curves	350 ft.	250 ft.	200 ft.
	Minimum K Value of SAG Curves	157	115	96

Improvement Plan

- Building MSE retaining wall to allow additional lanes
- Removing the barriers and rebuilding the bridge

Improvement Plan

Improvement Plan



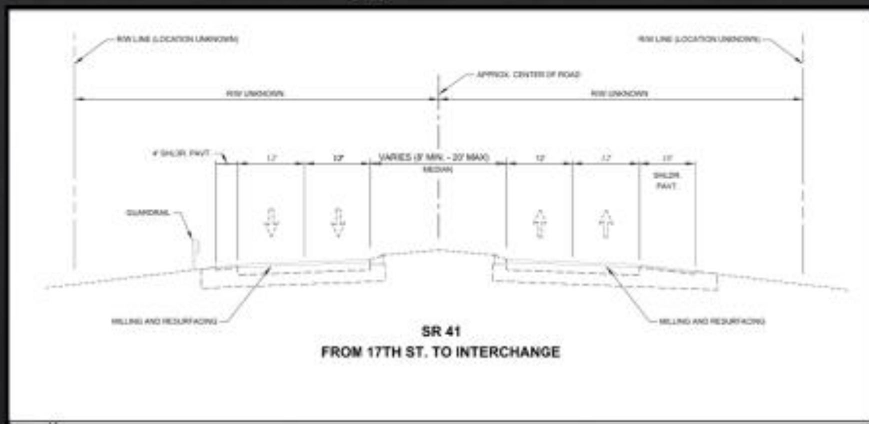
Bring the On/Off Ramps closer to allow
double left turns on North and South

Table 2.1.1 Lane Widths

LANE WIDTHS (FEET)						
FACILITY		TRAVEL LANES	AUXILIARY LANES			
TYPE	AREA		SPEED CHANGE	TURNING (LT/RT/MED)	PASSING
FREEWAY	Rural	12	12	---	---
	Urban	12	12	---	---
ARTERIAL	Rural	12_{6}	12_{6}	12_{6}	12_{6}
	Urban	11_{1}	11_{1}	$11_{1,3}$	11_{1}
COLLECTOR	Rural	$12_{5,6}$	11_{2}	$11_{2,3}$	$11_{2,4}$
	Urban	11	11	11_{3}	11

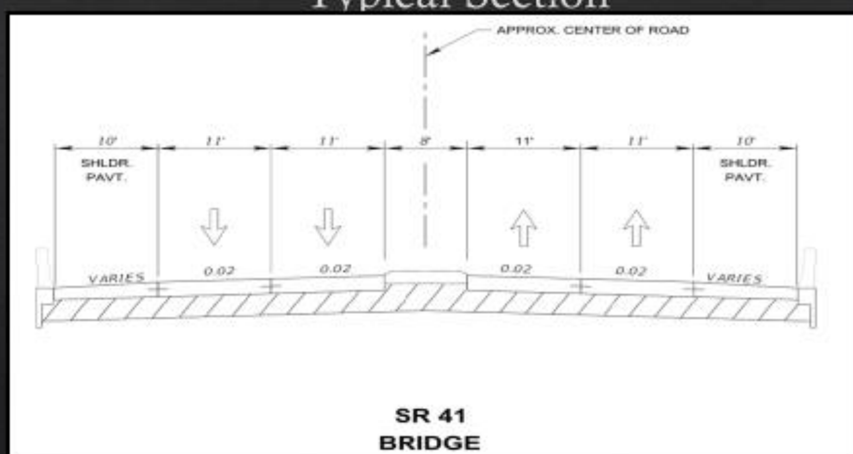
1. 12 ft. for Design Speeds > 45 mph and for all undivided roadways
2. 12 ft. for 2-lane roadways
3. With severe R/W controls, 10 ft. turning lanes may be used where design speeds are 40 mph or less and the intersection is controlled by traffic signals. Median turn lanes must not exceed 15 ft.
4. 12 ft. when truck volume exceeds 10%.
5. 11 ft. for low volume AADT.
6. 11 ft. for divided roadways with Design Speeds ≤ 45 mph and within one mile of an urban area.

Existing/Proposed US 41 Typical Section



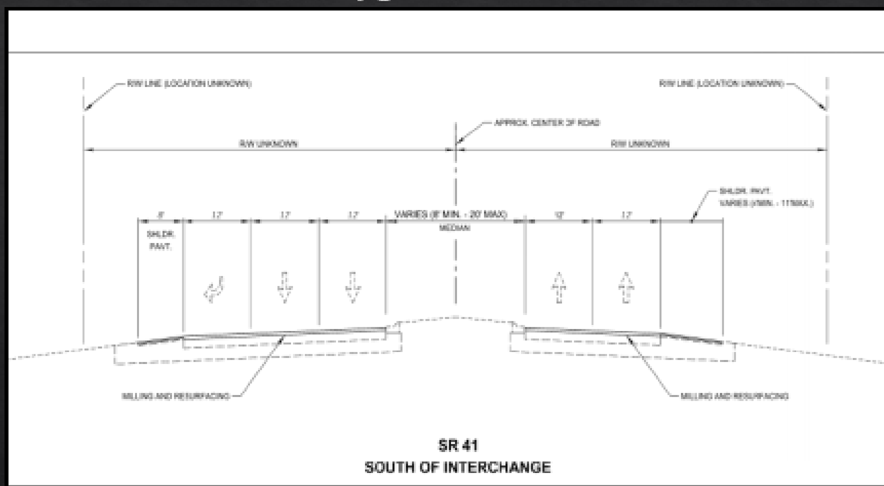
- Milling and resurfacing to be completed
- Maintain existing roadway features

Existing/Proposed US 41 Typical Section



- New Concrete pavement to be installed
- Maintain existing Bridge Conditions

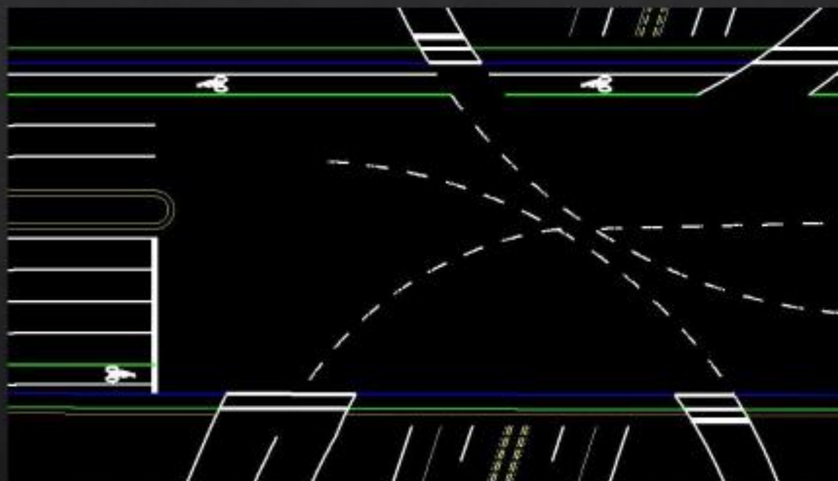
Existing/Proposed US 41 Typical Section



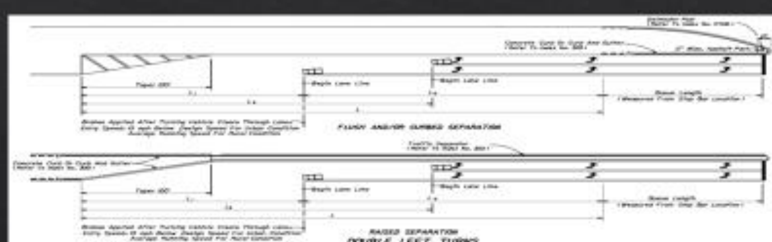
- Milling and resurfacing to be completed
- Maintain existing roadway features

Proposed Typical Section US 301 Under the Bridge

Sidewalks and Bike Lanes



Queuing Distances

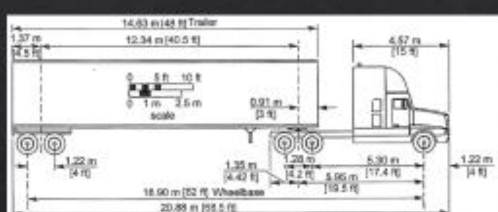


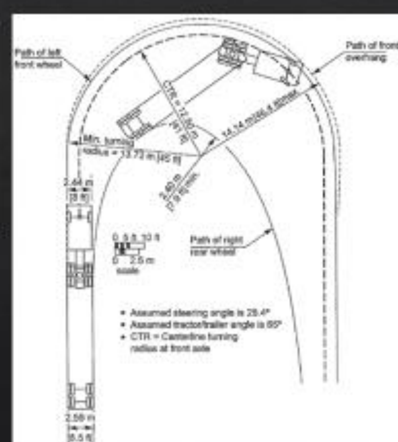
TURN LANES • CURBED AND UNCURBED MEDIANS								
			URBAN CONDITITONS			RURAL CONDITITONS		
Design Speed (mph)	Entry Speed (mph)	Clearance Distance L_1	Brake To Stop Distance L_B	Total Decel. Distance L	Clearance Distance L_q	Brake To Stop Distance L_B	Total Decel. Distance L	Clearance Distance L_q
35	25	70'	75'	145'	110'	— —	— —	— —
40	30	80'	75'	155'	120'	— —	— —	— —
45	35	85'	100'	185'	135'	— —	— —	— —
50	40/44	105'	135'	240'	160'	185'	290'	160'
55	48	125'	— —	— —	— —	225'	350'	195'
60	52	145'	— —	— —	— —	260'	405'	230'
65	55	170'	— —	— —	— —	290'	460'	270'

FDOT

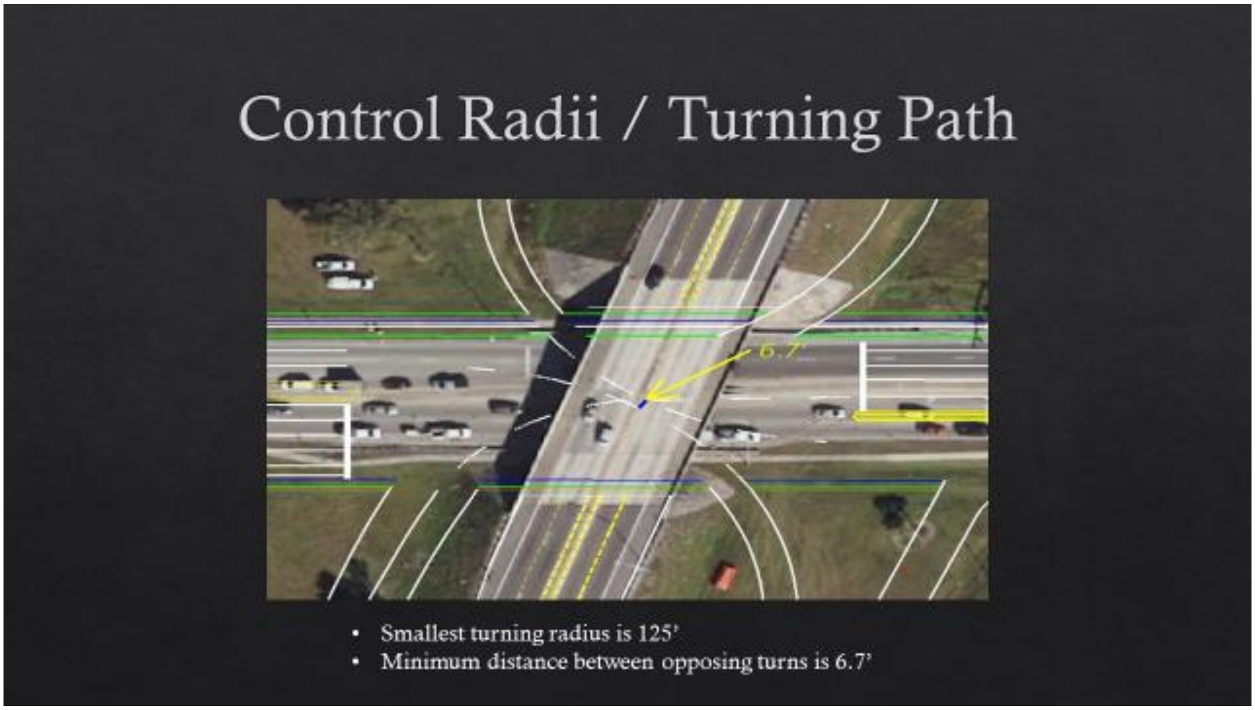
Queuing Distances

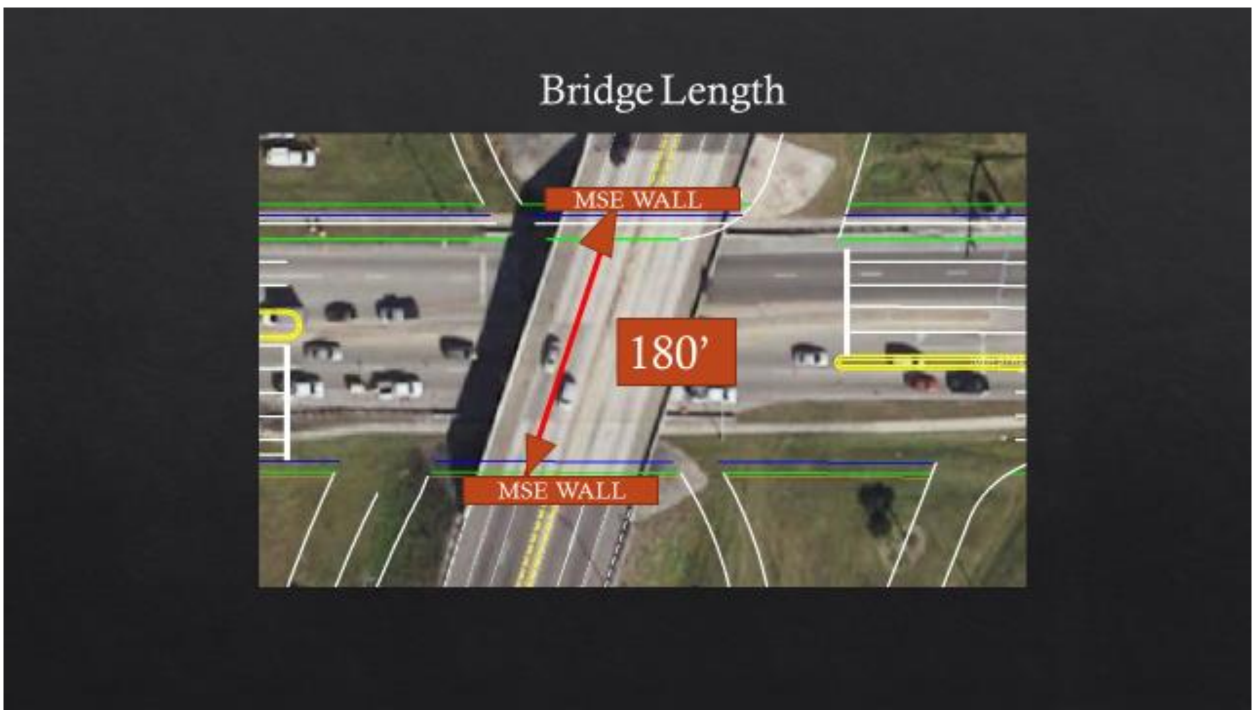
WB-62 [FL62] Design Vehicle



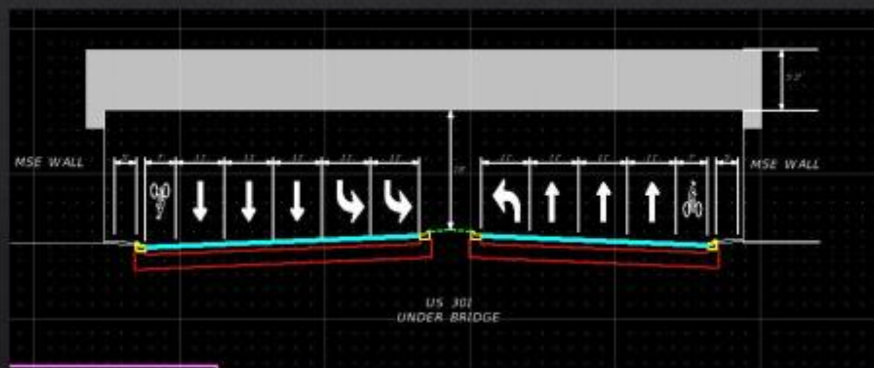


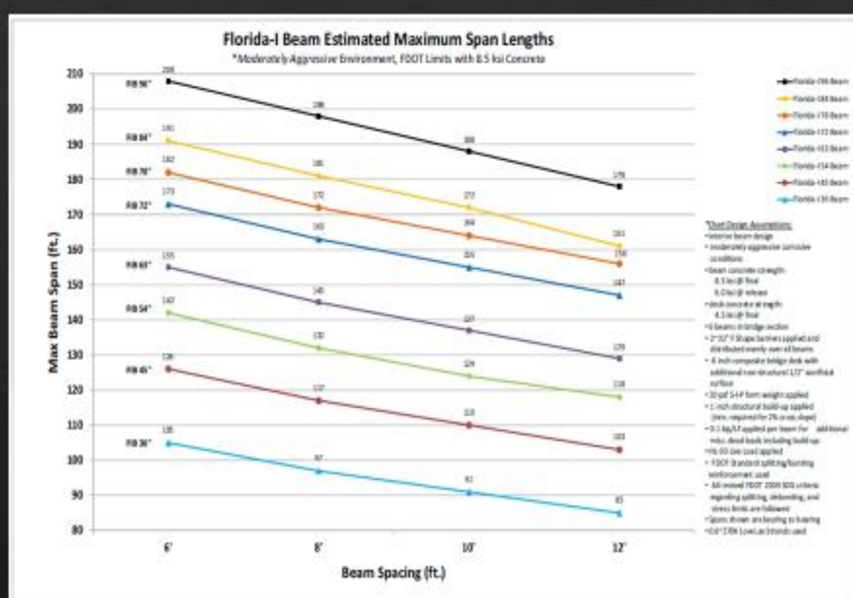
ASSHTO Green Book 2011

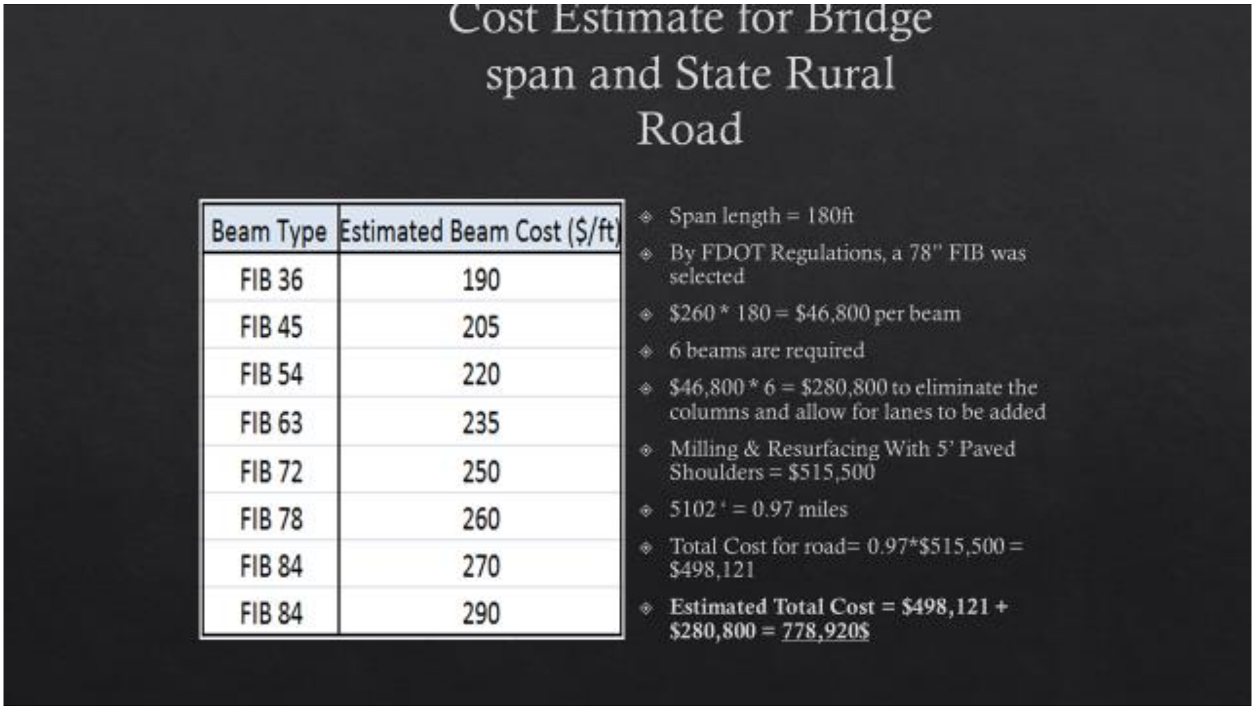

Control Radii / Turning Path
6.7'
• Smallest turning radius is 125'
• Minimum distance between opposing turns is 6.7'


Bridge Length
MSE WALL
180'
MSE WALL

Bridge Typical

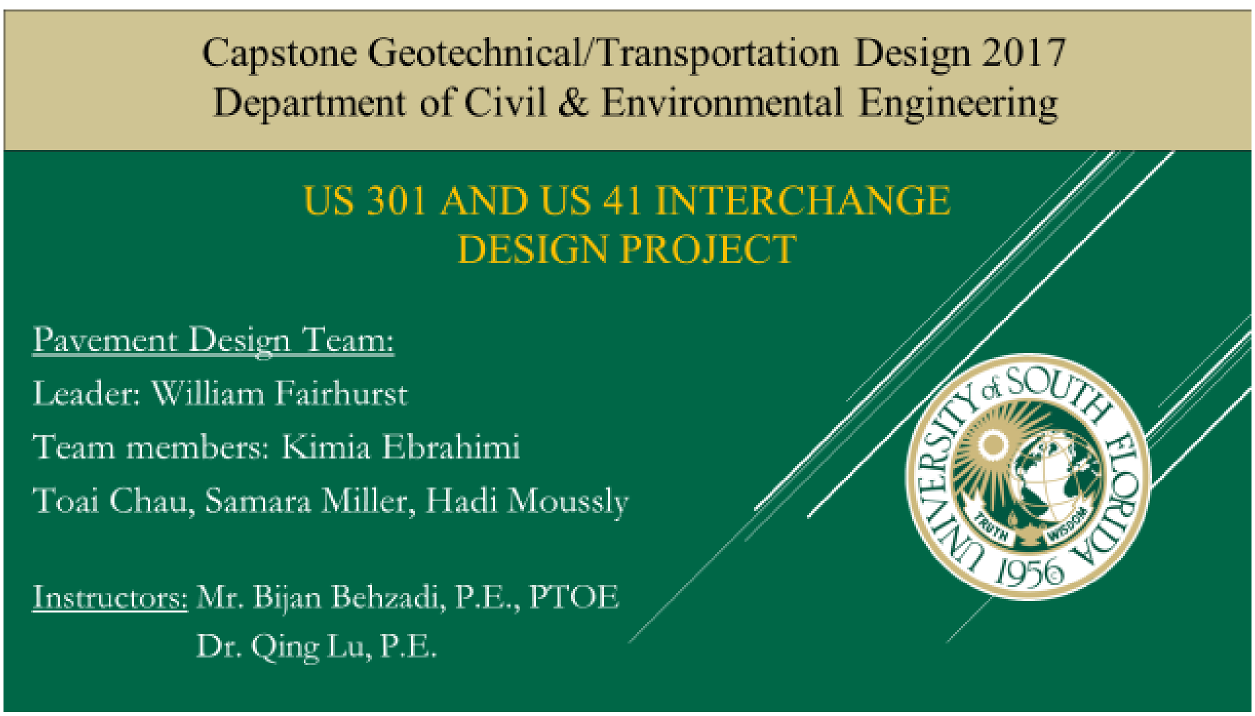






Beam Type	Estimated Beam Cost ($/ft)
FIB 36	190
FIB 45	205
FIB 54	220
FIB 63	235
FIB 72	250
FIB 78	260
FIB 84	270
FIB 84	290

28.4 US 301 & US 41 Interchange - Pavement Design



PROJECT MAP

SCOPE OF WORK

- For the proposed SPUI design and added lanes, use specific inputs to design pavement structures (layer thickness and material) considering two alternatives: flexible and rigid pavements
- Select design structure after comparing the two design alternatives
  - mainly based on life cycle cost analysis

ANALYSIS

- Inputs for Flexible and Rigid
  - AADT, truck percentage, and ESALs per truck
  - Subgrade modulus
    - Flexible: resilient modulus (M_R)
    - Rigid: modulus of subgrade reaction, k
- Outputs for Flexible
  - Structure Number (SN) for each roadway
  - Layer material and layer thickness
- Outputs for Rigid
  - Slab thickness

GIVEN DESIGN INPUTS

- Flexible and Rigid Pavements
  - 20-year initial design life
  - 90% Reliability
  - Base: crush aggregate – Wet resilient modulus is 60% of dry
  - Discount rate of 3.5% and 40 year LCCA
- Flexible Design
  - Change in serviceability = 2
- Rigid Design
  - Change in serviceability =1.7

DETERMINING DESIGN ESAL (W-18)

- By using FDOT design spreadsheet
- Inputs acquired from FDOT Traffic Data Online
  - D – Directional Factor
  - T – Percentage of Heavy Trucks
  - L_F – Lane Factor, derived from Copes equation
  - E_F – Equivalency factor

FDOT Project Traffic Forecasting Handbook

$$ESAL_D = \sum_{i=1}^{n} AADT_i * L_{Fi} * T_{24} * D_F * E_F * 365$$

USING FDOT DESIGN SPREADSHEET WE OBTAINED THE ESAL FOR EACH ROADWAY FOR RIGID AND FLEXIBLE PAVEMENTS.

18 kip EQUIVALENT SINGLE AXLE LOAD ANALYSIS - LOCATION 1

PROJECT TRAFFIC FOR PD&E and DESIGN ANALYSIS INFO / FACTORS

YEARS: *2015 to 2050*

SECTION #: 13020000 **COUNTY:** Manatee **PIN #:**

FLEXIBLE PAVEMENT URBAN HIGHWAY 0.890

SN=5/THICK US 301 & US 41 (Palmetto, Manatee County)

YEAR	AADT	ESAL (1000S)	ACCUM (1000s)	D	T	LF	EF
2015	19700	103	0	0.5	3.96%	0.807	0.890
2016	20000	104	0	0.5	3.96%	0.806	0.890
2017	20400	106	0	0.5	3.96%	0.805	0.890
2018	20900	108	0	0.5	3.96%	0.803	0.890
2019	21300	110	0	0.5	3.96%	0.801	0.890
2020	21700	112	0	0.5	3.96%	0.799	0.890
2021	22100	114	0	0.5	3.96%	0.798	0.890
2022	22600	116	0	0.5	3.96%	0.796	0.890
2023	23000	118	0	0.5	3.96%	0.795	0.890
2024	23500	120	0	0.5	3.96%	0.793	0.890
2025	24000	123	0	0.5	3.96%	0.791	0.890
2026	24400	124	0	0.5	3.96%	0.790	0.890
2027	24900	127	0	0.5	3.96%	0.788	0.890
2028	25400	129	0	0.5	3.96%	0.786	0.890
2029	25900	131	0	0.5	3.96%	0.785	0.890
2030	26500	134	134	0.5	3.96%	0.783	0.890
2031	27000	136	270	0.5	3.96%	0.781	0.890
2032	27500	138	408	0.5	3.96%	0.780	0.890
2033	28100	141	549	0.5	3.96%	0.778	0.890
2034	28600	143	692	0.5	3.96%	0.777	0.890
2035	29200	146	838	0.5	3.96%	0.775	0.890

8 kip EQUIVALENT SINGLE AXLE LOAD ANALYSIS - LOCATION Manat

PROJECT TRAFFIC FOR PD&E and DESIGN ANALYSIS INFO / FACTORS

YEARS: *2015 to 2050*

SECTION #: 13020000 **Location #:** 1 **FIN #:**

RIGID PAVEMENT URBAN HIGHWAY 1.220

SN=12/THICK US 301 & US 41 (Palmetto, Manatee County)

YEAR	AADT	ESAL (1000S)	ACCUM (1000s)	D	T	LF	EF
2015	19700	141	0	0.5	3.96%	0.807	1.220
2016	20000	143	0	0.5	3.96%	0.806	1.220
2017	20400	145	0	0.5	3.96%	0.805	1.220
2018	20900	148	0	0.5	3.96%	0.803	1.220
2019	21300	151	0	0.5	3.96%	0.801	1.220
2020	21700	153	0	0.5	3.96%	0.799	1.220
2021	22100	156	0	0.5	3.96%	0.798	1.220
2022	22600	159	0	0.5	3.96%	0.796	1.220
2023	23000	162	0	0.5	3.96%	0.795	1.220
2024	23500	165	0	0.5	3.96%	0.793	1.220
2025	24000	168	0	0.5	3.96%	0.791	1.220
2026	24400	170	0	0.5	3.96%	0.790	1.220
2027	24900	174	0	0.5	3.96%	0.788	1.220
2028	25400	177	0	0.5	3.96%	0.786	1.220
2029	25900	180	0	0.5	3.96%	0.785	1.220
2030	26500	183	183	0.5	3.96%	0.783	1.220
2031	27000	187	370	0.5	3.96%	0.781	1.220
2032	27500	190	560	0.5	3.96%	0.780	1.220
2033	28100	193	753	0.5	3.96%	0.778	1.220
2034	28600	196	949	0.5	3.96%	0.777	1.220
2035	29200	200	1149	0.5	3.96%	0.775	1.220

W-18's (ESALS)

	Flexible ESALs	Rigid ESALs
US 301. West of US 41	2975000	4076000
US 301. East of US 41	5861000	9729000
US 301. East of Walmart	7102000	8031000
US 41	9239000	12660000
Ramp	4619500	6330000

FLEXIBLE PAVEMENT

FLEXIBLE PAVEMENT DESIGN EQUATION

$$\log_{10}(W_{18}) = Z_R \times S_0 + 9.36 \times \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2-1.5}\right)}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Source: 1993 AASHTO Pavement Design Guide

FLEXIBLE PAVEMENT DESIGN INPUTS

- W-18:

	Flexible ESAL
US 301. West of US41	2975000
US 301. East of US41	5861000
US 301. East of Walmart	7102000
US 41	9239000
Ramp	4619500

- Effective Resilient Modulus (MR): 14,000 psi
- Reliability: 90%
- Standard Normal Deviate (ZR): -1.282
- Standard Deviation (SO): 0.45
- Initial Serviceability (PI): 4.5
- Terminal Serviceability (PT): 2.5
- Change In Serviceability (ΔPSI): 2

TABLE 5.3

REQUIRED STRUCTURAL NUMBER (SN_R)
90% RELIABILITY (%R)
RESILIENT MODULUS (M_R) RANGE 4,000 PSI TO 18,000 PSI

RESILIENT MODULUS (M_R), (PSI x 1000)

$ESAL_D$	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
100 000	3.02	2.77	2.59	2.44	2.31	2.21	2.12	2.04	1.97	1.91	1.86	1.81	1.76	1.72	1.68
150 000	3.23	2.97	2.77	2.61	2.47	2.36	2.27	2.19	2.11	2.05	1.99	1.94	1.89	1.84	1.80
200 000	3.39	3.11	2.90	2.73	2.60	2.48	2.38	2.30	2.22	2.15	2.09	2.03	1.98	1.94	1.89
250 000	3.52	3.23	3.01	2.84	2.69	2.57	2.47	2.38	2.30	2.23	2.17	2.11	2.06	2.01	1.97
300 000	3.62	3.33	3.10	2.92	2.78	2.65	2.55	2.46	2.37	2.30	2.24	2.18	2.12	2.07	2.03
350 000	3.71	3.41	3.18	3.00	2.85	2.72	2.61	2.52	2.44	2.36	2.30	2.23	2.18	2.13	2.08
400 000	3.79	3.49	3.25	3.07	2.91	2.78	2.67	2.58	2.49	2.42	2.35	2.29	2.23	2.18	2.13
450 000	3.87	3.56	3.32	3.13	2.97	2.84	2.73	2.63	2.54	2.46	2.39	2.33	2.27	2.22	2.17
500 000	3.93	3.62	3.38	3.18	3.02	2.89	2.77	2.67	2.59	2.51	2.44	2.37	2.31	2.26	2.21
600 000	4.05	3.73	3.48	3.28	3.12	2.98	2.86	2.76	2.67	2.58	2.51	2.45	2.39	2.33	2.28
700 000	4.14	3.82	3.57	3.36	3.20	3.05	2.93	2.83	2.73	2.65	2.58	2.51	2.45	2.39	2.34
800 000	4.23	3.90	3.64	3.44	3.27	3.12	3.00	2.89	2.80	2.71	2.63	2.57	2.50	2.44	2.39
900 000	4.31	3.97	3.71	3.51	3.33	3.18	3.06	2.95	2.85	2.76	2.69	2.62	2.55	2.49	2.44
1 000 000	4.38	4.04	3.78	3.57	3.39	3.24	3.11	3.00	2.90	2.81	2.73	2.66	2.60	2.54	2.48
1 500 000	4.65	4.30	4.03	3.81	3.62	3.46	3.33	3.21	3.10	3.01	2.92	2.85	2.78	2.71	2.65
2 000 000	4.85	4.50	4.21	3.99	3.79	3.63	3.49	3.36	3.25	3.16	3.07	2.99	2.91	2.85	2.78
2 500 000	5.01	4.65	4.36	4.13	3.93	3.76	3.62	3.49	3.38	3.27	3.18	3.10	3.02	2.95	2.89
3 000 000	5.14	4.77	4.48	4.25	4.05	3.88	3.73	3.60	3.48	3.37	3.28	3.19	3.12	3.04	2.98
3 500 000	5.25	4.88	4.59	4.35	4.14	3.97	3.82	3.69	3.57	3.46	3.36	3.28	3.20	3.12	3.06
4 000 000	5.35	4.98	4.68	4.44	4.23	4.06	3.90	3.77	3.65	3.54	3.44	3.35	3.27	3.19	3.12

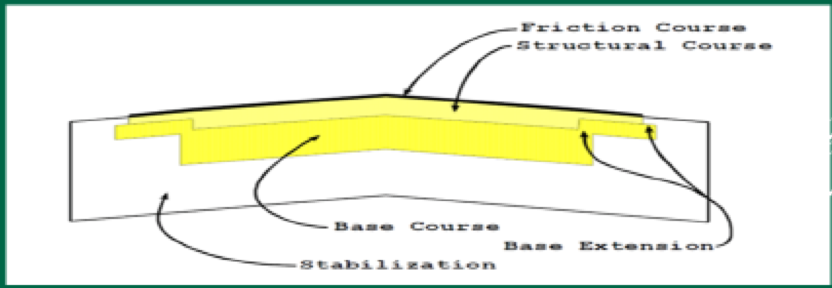
FLEXIBLE PAVEMENT DESIGN EQUATION OUTCOME

Required Structural Number (SNR):

	ESAL	SNR
US 301. West of US41	2975000	3.27
US 301. East of US41	5861000	3.66
US 301. East of Walmart	7102000	3.78
US 41	9239000	3.94
Ramp	4619500	3.52

FLEXIBLE PAVEMENT TYPICAL STRUCTURE

- Friction Course: The top layer of pavement, the layer that traffic comes in direct contact with.

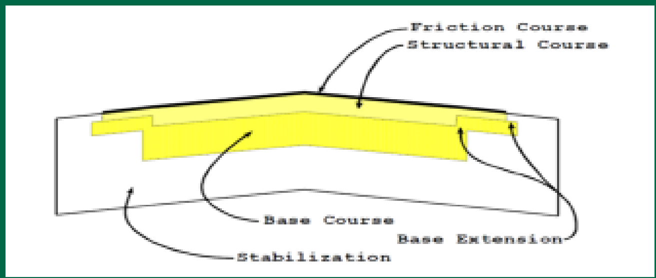


- Structural Course: main asphalt layer designed to transfer the traffic loading down to the base course
  - ride smoothness and noise control are provided
  - resists rutting and prevents surface water from entering into the lower layers.

FLEXIBLE PAVEMENT TYPICAL STRUCTURE

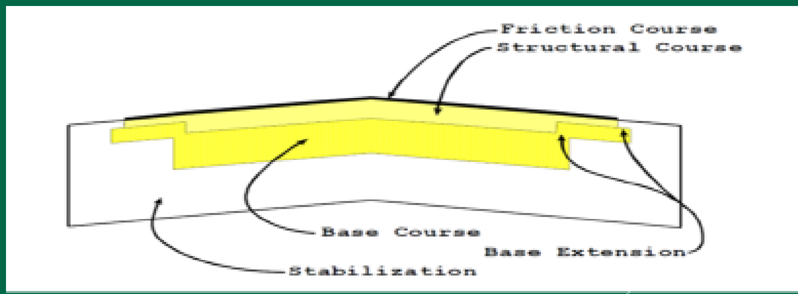
- Base Course:
  - supports the structural course
  - transfers the load received from the structural course to the subbase and subgrade.

- Base Extension: In Florida, to help reduce pavement failure at the edge, it is standard practice to extend the base layer 4 inches beyond the edge of the structural course.



FLEXIBLE PAVEMENT TYPICAL STRUCTURE

- Stabilized Subgrade:
  - recommended in Florida in place of a subbase layer
  - provides support to the pavement structure.



FLEXIBLE PAVEMENT

Advantages

- Adjusts to limited differential settlement
- Easily repaired
- Additional thickness added any time
- Quieter and smoother
- Allow for a greater temperature variations

Disadvantages

- Loses some flexibility and cohesion with time
- Needs resurfacing sooner than PC concrete
- Not normally chosen where water is expected

SELECTION OF SURFACE WEARING COURSE TYPE

- On US 41 the design speed is 50 mph and there are multiple lanes in one direction, an top layer FC-5 is required based on FDOT design manual.
- On US 301 the design speed is lower (40 mph), therefore FC-12.5 can be used.

TABLE 4.1

FRICTION COURSE SELECTION

The Following Friction Courses are Required For Design Speeds of 35 mph or Greater.

All Projects

Design Speed	Two Lane	Multi Lane
35 thru 45 mph	FC-12.5 or FC-9.5	FC-12.5 or FC-9.5
50 mph Or Greater	FC-12.5 or FC-9.5	FC-5

Minimum Structural Course

18-kip ESAL's 20 year period	Minimum Structural Course	Minimum Base Group
Limited Access	4"	9
Greater than 3,500,000	3"	9
Ramp less than 3,500,000	2"	9
300,000 to 3,500,000	2"	6
Less than 300,000	1 1/2"	3
Limited Access Shoulder	1 1/2"	1
Residential Streets, Parking Areas, Shoulder Pavement, Bike Paths	1"	1
Shared Use Paths	1 1/2"	1

FC-12.5 and FC-9.5 can be considered as structural courses and are sufficient for single layer shoulder pavement.

FLEXIBLE PAVEMENT REHABILITATION PROCESS

Asphalt Pavement	
Rehab Period	Urban Arterial
16 Year	Mill 2 inch Resurface. 1 inch Str. AC and DGFC
32 Year	Mill 2 inch Resurface. 1 inch Str. AC and DGFC

Str. AC: Structural Asphaltic Concrete
DGFC: Dense Graded Friction Course
Source: FDOT Pavement Type Selection Manual

SUMMARY OF FLEXIBLE DESIGN

	New Construction:				Rehabilitation	
Segment	Friction Course	Structural Course Superpave Asphalt	Base Base Group 9 (LBR 100)	Subgrade Type B Stabilization (LBR 40)	Milling depth	Resurfacing Depth
US 301. West of US 41	1.5" FC-12.5	1.5"	10"	12"	2"	1" FC 12.5
US 301. East of US 41	1.5" FC-12.5	1.5"	10"	12"	2"	1" FC 12.5
US 301. East of Walmart	1.5" FC-12.5	1.5"	10"	12"	2"	1" FC 12.5
US 41	0.75" FC-5	4"	10"	12"	3"	4" Superpave, 0.75" FC-5
Ramps	1.5" FC-12.5	1.5"	10"	12"	2"	1" FC 12.5

SUGGESTED DESIGN CHANGES

	New Construction:				Rehabilitation	
Segment	Friction Course	Structural Course	Base	Subgrade	Milling depth	Resurfacing Depth
		Superpave Asphalt	Base Group 9 (LBR 100)	Type B Stabilization (LBR 40)		
US 301. West of US 41	1.5" FC-12.5	2"	10"	12"	2"	1" FC 12.5
US 301. East of US 41	1.5" FC-12.5	2"	10"	12"	2"	1" FC 12.5
US 301. East of Walmart	1.5" FC-12.5	2"	10"	12"	2"	1" FC 12.5
US 41	1.5" FC-12.5	3"	10"	12"	3"	2" FC-12.5
Ramps	1.5" FC-12.5	2"	10"	12"	2"	1" FC 12.5

Cost and Area Data

Material	Unit Price
FC-5	$5.34/SY
FC-12.5	$7.85/SY
Superpave Asphalt (1")(Traffic level C)	$3.39/SY
Superpave Asphalt (2")(Traffic level C)	$6.69/SY
Superpave Asphalt (3")(Traffic level C)	$10.19/SY
Superpave Asphalt (4")(Traffic level C)	$13.58/SY
Superpave Asphalt (4.5")(Traffic level C)	$15.28/SY
Base Group 9 (LBR 100)	$12.50/SY
Type B Stabilization (LBR 40)	$2.10/SY
Milling (1" avg. depth)	$1.24/SY
Milling (2" avg. depth)	$1.31/SY
Milling (3" avg. depth)	$1.96/SY

Table 4. Unit Price for Flexible Pavement Structure Materials and Rehabilitation
Cost data was obtained from FDOT's "2011 Item Averages"

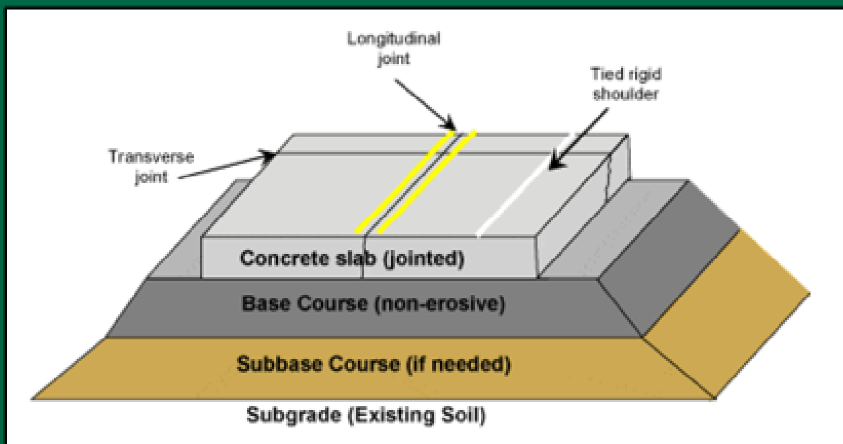
Segment	Area (SY)
US 301. West of US41	30264.4
US 301. East of US41	21573.3
US 301. East of Walmart	11016.1
US 41	15942.2
Ramps	15015.6

TOTAL FLEXIBLE MATERIAL COST

Segment	Construction Cost	Net Present Cost of Rehabilitation	Total Net Present Cost
US 301. West of US 41	$881,905.91	$162,097.53	$1,044,003.44
US 301. East of US 41	$628,646.93	$115,547.60	$744,194.54
US 301. East of Walmart	$321,009.48	$59,002.71	$380,012.19
US 41	$520,354.13	$112,935.70	$633,289.83
Ramps	$437,553.29	$80,423.89	$517,977.18
Total	**$2,789,469.74**	**$530,007.43**	**$3,319,477.70**

RIGID PAVEMENT

RIGID PAVEMENT CROSS SECTION



Source: TheConstructor.org

RIGID PAVEMENT TYPICAL USES

- High stress
  - Port yards
  - Airports
  - Major highways

Source: CEG 4850 Rigid Pavement Design Spring 2017 PPT

RIGID PAVEMENT EXAMPLE

Source: TampaBay.com

RIGID PAVEMENT EXAMPLE

Source: Panoramio.com

RIGID PAVEMENT PROS AND CONS

Advantages

- Good durability
- Long service life
- Withstand repeated flooding and subsurface water without deterioration

Disadvantages

- Cost
- May lose non-skid surface with time
- May fault at transverse joints

RIGID PAVEMENT DESIGN EQUATION

$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.5-1.5}\right)}{1+\frac{1.624\times 10^7}{(D+1)^{8.46}}}$$

$$+(4.22-0.32p_t)\times\log_{10}\left[\frac{(S_c')(C_d)\left(D^{0.75}-1.132\right)}{215.63(J)\left(D^{0.75}-\frac{18.42}{\left(E_c/k\right)^{0.25}}\right)}\right]$$

Source: 1993 AASHTO Pavement Design Guide

RIGID PAVEMENT DESIGN INPUTS

- D = slab thickness trial value
- Reliability = 90%
- Z_R = standard deviation (based on 90%) -1.282
- S_0 = combined std. error of traffic and performance prediction (given) 0.45
- D_PSI = serviceability index (given) 1.7
- W_{18} = predicted number of 18-kip ESALs based on road being analyze

	Rigid ESALs
US 301. West of US41	4076000
US 301. East of US41	9729000
US 301. East of Walmart	8031000
US 41	12660000
Ramp	6330000

RIGID PAVEMENT DESIGN INPUTS

- p_t = terminal serviceability index (given) 2.5
- S_c' =modulus of rupture of PCC (given) 635 psi
- C_d =drainage coeff. (given) 1
- J = load transfer coeff. (table 2.6 in Rigid Lecture notes) 3.2
- E_c =elastic modulus of PCC (given) 4000000 psi
- K =modulus of subgrade reaction 200 psi

FOR US 301 WEST OF US 41

TABLE A.4

REQUIRED DEPTH (D_2) IN inch FOR 90% RELIABILITY (%R)

ESAL$_D$	40	80	110	150	185	200	260	300	330	370
	Modulus Of Subgrade Reaction (K_G), psi/in									
100 000	to 900 000 ESAL Use 8" for all K Values									
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10

FOR US 301 EAST OF US 41

ESAL$_D$	40	80	110	150	185	200	260	300	330	370
	Modulus Of Subgrade Reaction (K_G), psi/in									
100 000	to 900 000 ESAL Use 8" for all K Values									
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10
15 000 000	12	11½	11½	11½	11	11	11	11	11	11
20 000 000	12½	12	12	12	11½	11½	11½	11½	11½	11½

FOR US 301 EAST OF WALMART

Modulus Of Subgrade Reaction (K_G), psi/in

$ESAL_D$	40	80	110	150	185	200	260	300	330	370
100 000 to 900 000 ESAL Use 8" for all K Values										
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10
15 000 000	12	11½	11½	11½	11	11	11	11	11	11
20 000 000	12½	12	12	12	11½	11½	11½	11½	11½	11½

FOR US 41

Modulus Of Subgrade Reaction (K_G), psi/in

$ESAL_D$	40	80	110	150	185	200	260	300	330	370
100 000 to 900 000 ESAL Use 8" for all K Values										
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10
15 000 000	12	11½	11½	11½	11	11	11	11	11	11
20 000 000	12½	12	12	12	11½	11½	11½	11½	11½	11½

FOR RAMP

Modulus Of Subgrade Reaction (K_G),psi/in

$ESAL_D$	40	80	110	150	185	200	260	300	330	370
100 000	to 900 000 ESAL Use 8" for all K Values									
1 000 000	8	8	8	8	8	8	8	8	8	8
1 500 000	8½	8	8	8	8	8	8	8	8	8
2 000 000	9	8½	8½	8	8	8	8	8	8	8
2 500 000	9	9	8½	8½	8½	8½	8	8	8	8
3 000 000	9½	9	9	9	8½	8½	8½	8½	8½	8
3 500 000	9½	9½	9	9	9	9	8½	8½	8½	8½
4 000 000	9½	9½	9½	9	9	9	9	9	9	8½
4 500 000	10	9½	9½	9½	9½	9	9	9	9	9
5 000 000	10	10	9½	9½	9½	9½	9½	9	9	9
6 000 000	10½	10	10	10	9½	9½	9½	9½	9½	9½
7 000 000	10½	10½	10	10	10	10	10	9½	9½	9½
8 000 000	11	10½	10½	10½	10	10	10	10	10	10
9 000 000	11	10½	10½	10½	10½	10½	10	10	10	10
10 000 000	11	11	11	10½	10½	10½	10½	10½	10	10
15 000 000	12	11½	11½	11½	11	11	11	11	11	11
20 000 000	12½	12	12	12	11½	11½	11½	11½	11½	11½

RIGID PAVEMENT DESIGN OUTPUTS: CONCRETE SLAB THICKNESS

Segment	PCC Depth (inches)
US 301. West of US 41	9
US 301. East of US 41	10
US 301. East of Walmart	10.5
US 41	11
Ramp	9.5

RIGID PAVEMENT REHABILITATION PROCESS

Concrete Pavement	
Rehab Period	Urban Arterial
23 Year	CPR (3% slab replacement*)
33 Year	CPR (5% slab replacement*)

** Estimate is based on the percentage of slab are in the truck lane.*

Source: FDOT Pavement Type Selection Manual

TOTAL RIGID PAVEMENT COST

Segment	Cost of New Construction	Cost of Rehabilitation	Total Cost
US 301. West of US41	2,457,170.24	245,661.20	2,702,831.45
US 301. East of US41	1,590,386.13	175,114.10	1,765,500.24
US 301. East of Walmart	882,335.42	89,419.49	971,754.91
US 41	1,378,523.96	129,405.50	1,507,929.45
Ramp	1,286,082.33	121,883.60	1,407,965.93
Total	7,594,498.09	761,483.89	**$8,355,981.98**

PAVEMENT TYPE SELECTION CRITERIA

- Cost
- Traffic Congestion
- Soil Characteristics
- Weather
- Ease of Construction

Source: FDOT Pavement Type Selection Manual

COST COMPARISON OF NEW CONSTRUCTION

Segment	Flexible	Rigid Cost
US 301. West of US 41	$1,044,003.44	$2,702,831.45
US 301. East of US 41	$744,194.54	$1,765,500.24
US 301. East of Walmart	$380,012.19	$971,754.91
US 41	$633,289.83	$1,507,929.45
Ramps	$517,977.18	$1,407,965.93
Totals	$3,319,477.18	$8,355,981.98

Discounted Price

- 3.5%

Flexible pavement	Rigid pavement
$3,203,295.48	$8,063,522.61

RECOMMENDATION

- Use use flexible pavement for US-41 (except bridge deck) and US-301.