CITY OF TUCSON

HOUGHTON ROAD, TANQUE VERDE RD TO SPEEDWAY BLVD

NEEDS ASSESSMENT STUDY – ADDENDUM FINAL



AUGUST 2022

HOUGHTON ROAD, TANQUE VERDE RD TO SPEEDWAY BLVD

NEEDS ASSESSMENT STUDY ADDENDUM - FINAL

CITY OF TUCSON

PROJECT NO.: 11515SP
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EXECUTIVE SUMMARY

The proposed Houghton Road, Tanque Verde Road to Speedway Boulevard project is a part of a series of Houghton Road Corridor projects between I-10 and Tanque Verde Road that the Regional Transportation Authority (RTA) has programmed from Period 1 through Period 3, which span the years FY2007 through FY2021, as part of the RTA plan passed by voters in 2006. In 2019, the City of Tucson Department of Transportation and Mobility (DTM) requested that WSP review the recommendations from the *Houghton Road Improvement Project: Tanque Verde Road to Speedway Boulevard Final Design Concept Report* (2010 DCR) and determine if they were still valid. The *Houghton Road, Tanque Verde Road to Speedway Boulevard Needs Assessment Study* (Needs Study) summarized the findings of that evaluation.

The Needs Study kept 2030 as the design year and used the Pima Association of Governments (PAG) 2045 traffic demand model data to update the 2030 traffic projections from the 2010 DCR and reevaluate the recommended roadway improvements. Based on the revaluation, less extensive improvements were needed than were recommended in the 2010 DCR. The updated project improvements were estimated to cost $12 million, compared to the 2010 DCR recommendations at $28 million (adjusted to 2018 dollars). However, the updated improvements recommended in the Needs Study were not sufficient for acceptable Level of Service (LOS) with 2045 traffic volumes, with the Houghton Road/Tanque Verde Road and Houghton Road/Speedway Boulevard intersections projected to be over capacity at LOS F.

In August 2021, DTM requested that WSP review the Needs Study recommendations to determine what additional improvements would be needed for a minimum LOS D in 2045. DTM requested that WSP use current PAG 2045 model traffic projections for the analysis. The findings of these additional reviews and resulting recommendations are presented in this Needs Study Addendum Report (Study Addendum).

The PAG 2045 model traffic data for the project area was obtained by WSP on September 22, 2021 and compared to the PAG 2045 model data used in the Needs Study which was obtained on May 17, 2019. On most roadway segments, the newer 2045 daily traffic volumes were lower, with some segments seeing a reduction of over 30%.

Annual growth rates were calculated based on 2019 and 2045 daily traffic volumes from the latest PAG model. Growth rates ranged from -1.6% for EB Speedway east of Houghton Road to +1.57% for Houghton Road approaching and departing Speedway Boulevard on the south leg of the intersection. The calculated annual growth rates were also compared with regional estimates of growth from two sources: the University of Arizona MAP (Making Action Possible) for Southern Arizona and the U.S. Census Bureau. The MAP site noted that in 2020 the growth rate for Tucson was 0.7%. U.S. Census Bureau data showed a 0.40% annual growth rate between 2010 and 2020 for Tucson. The calculated annual growth rates of the current PAG 2045 model are near these values, and therefore, the PAG 2045 traffic data was used for the Study Addendum without any adjustment.

Turning movement counts from 2019 were the basis for determining the 2045 AM and PM peak hour traffic volumes for the Houghton Road/Tanque Verde Road and Houghton Road/Speedway Boulevard intersections. The Needs Study traffic count from May 19, 2019 was compared to an October 15, 2019

count conducted by PAG. Both counts showed similar traffic volumes, so the Needs Study count was used in the Study Addendum. The calculated growth rates were applied to the 2019 traffic counts, with the resulting 2045 AM and PM peak hour traffic projections for the Study Addendum less than the 2045 projections from the Needs Study.

Capacity analysis of the Study Addendum 2045 AM and PM peak hour traffic volumes showed that additional improvements are required at the Houghton Road/Tanque Verde Road intersection beyond the NB right turn lane recommended in the Needs Study to achieve LOS D. Adding a SB right turn lane and an additional WB through lane would improve the intersection to LOS D in 2045.

Additionally, a right turn lane warrant evaluation was conducted for the NB and SB right turn lanes proposed for the Houghton Road/Tanque Verde Road intersection using guidelines in the City of Tucson's *2021 Street Design Guide*. 2045 AM and PM peak hour volumes meet criteria for consideration of separate right turn lanes for the speed limit of 45 mph.

The capacity analysis of the Houghton Road roadway segments from Tanque Verde Road to Speedway Boulevard and Speedway Boulevard to Broadway Boulevard did not reveal any differences in the projected Level of Service between the Needs Study and Study Addendum.

Two additional improvements to Houghton Road are recommended apart from intersection improvements. First, a Two-Way Left Turn Lane (TWLTL) on Houghton Road between Corte Vista La Mariposa and Drachman Street is recommended. This location is between the bridges for the Agua Caliente Wash and Tanque Verde Creek. A TWLTL will improve safety for left turns onto Corte Vista La Mariposa and Drachman Street. Second, a continuous multi-use path along the east side of Houghton Road from Broadway Boulevard to Tanque Verde Road is recommended. The Needs Study only evaluated a multi-use path between Speedway Boulevard and Tanque Verde Road, with a sidewalk between Speedway Boulevard and Broadway Boulevard. Through discussion with DTM and a preliminary evaluation of the land use along the east side of Houghton Road, a multi-use path is recommended instead of a sidewalk. This recommendation, however, should be evaluated in more detail during project final design, with consideration of public input and a more detailed review of potential impacts.

The recommended Study Addendum improvements in addition to those from the Needs Study include:

- Constructing a SB Houghton Road right turn lane at Tanque Verde Road
- Constructing a second WB Tanque Verde Road through lane at Houghton Road
- Constructing a TWLTL on Houghton Road between Corte Vista La Mariposa and Drachman Street
- Constructing a multi-use path along the east side of Houghton Road between Speedway Boulevard and Broadway Boulevard instead of a sidewalk

Construction costs were estimated for the additional improvements, and the Needs Study construction cost estimate was adjusted from 2019 dollars to 2021 dollars using a 22% price increase. This price increase was based on the ADOT Construction Cost Index and recent Tucson area construction bid tabs.

The estimated costs are summarized in the table below.

Houghton Road, Tanque Verde Road to Speedway Boulevard Recommended Improvement Costs		
Needs Assessment Study Improvements	**2019**	**2021**
Houghton Road NB Right Turn Lane at Tanque Verde Road	$628,400	$752,400
Houghton Road / Speedway Boulevard Intersection – Multi-Use Path	$9,289,600	$11,695,000
Bridge Repair	$1,143,600	$1,383,600
Multi-Use Path from Speedway Blvd to Tanque Verde Rd	$1,241,040	$1,519,000
Study Addendum Additional Recommendations		
SB Right Turn Lane at Tanque Verde Road		$215,600
WB Through Lane at Tanque Verde Road		$897,500
TWLTL on Houghton Rd, Corte Vista La Mariposa and Drachman Street		$581,300
Multi-Use Path replacing Sidewalk east side of Houghton Road – see above		
Total Project Cost	$12,302,640	$17,044,400
Totals Project Cost (Rounded)	**$12,303,000**	**$17,045,000**

At the time the Needs Study was completed, the project improvements were expected to be constructed in phases. From discussions with DTM during development of the Study Addendum, all improvements are now anticipated to be constructed in a single project due to funding considerations. However, given the existing poor operation of the Houghton Road/Tanque Verde Road intersection, phasing of the project to accelerate construction of the NB Right Turn Lane should be considered.

TABLE OF CONTENTS

EXECUTIVE SUMMARY II

1 PROJECT OVERVIEW 1

1.1 Project Location 1

1.2 Project Description & Project Characteristics 2

2 TRAFFIC 3

2.1 Existing Traffic - 2019 3

2.2 Growth Rate 6

2.3 Existing Capacity Analysis - 2019 9

2.4 Future Traffic - 2045 11

2.5 Future Capacity Analysis - 2045 12

2.6 Crash Data 14

3 PROPOSED RECOMMENDATIONS 15

3.1 Proposed Intersection Configurations 15

3.2 Proposed Roadway Configurations 17

Median Openings 19

3.3 Addendum Recommendation Summary 19

3.4 Proposed Capacity Analysis - 2045 21

Intersections 21

Roadway 22

3.5 Right Turn Warrant Analysis 22

4 POTENTIAL IMPACTS 24

4.1 Existing Utilities 24

Fiber Optic – Cox Communications 24

Natural Gas – Southwest Gas 24

Water – Tucson Water 24

Traffic Signals – City of Tucson 24

4.2 Environmental Study Updates 25

Vegetation 25

Wildlife 25

Special Status Species 25

TABLE OF CONTENTS

Critical Habitat 25
Cultural Resources 25
Air Quality 25
Noise 25
Hazardous Materials 26
Aesthetic Resources 26
Neighborhood Impact 26
Community Resources 26
Recommendation for Further Study 26
Environmental Documentation 26

4.3 Structures 26

4.4 Right of Way 27

5 COST ESTIMATES 29

5.1 Proposed Recommendations Cost 30

Needs Study Recommendations Cost 30
Construction Cost Escalation 31
Study Addendum Additional Recommendation Construction Costs 31

5.2 Project Phasing 32

TABLES

TABLE 1 – GROWTH RATES FOR HOUGHTON ROAD, TANQUE VERDE ROAD TO SPEEDWAY BOULEVARD 7
TABLE 2 – 2019 EXISTING LOS AT HOUGHTON ROAD & TANQUE VERDE ROAD 9
TABLE 3 – 2019 EXISTING LOS AT HOUGHTON ROAD & SPEEDWAY BOULEVARD 10
TABLE 4 – 2019 EXISTING LOS FOR HOUGHTON ROAD ROADWAY SEGMENTS – CLASS I 10
TABLE 5 – 2045 NO BUILD LOS FOR HOUGHTON ROAD & TANQUE VERDE ROAD 13
TABLE 6 – 2045 NO BUILD LOS FOR HOUGHTON ROAD & SPEEDWAY BOULEVARD 13
TABLE 7 – 2045 NO BUILD LOS FOR HOUGHTON ROAD ROADWAY SEGMENTS – CLASS I 14
TABLE 8 – 2045 PROPOSED IMPROVEMENTS LOS FOR HOUGHTON ROAD & TANQUE VERDE ROAD 21
TABLE 9 – 2045 PROPOSED IMPROVEMENTS LOS FOR HOUGHTON ROAD & SPEEDWAY BOULEVARD 22
TABLE 10 – ROADWAY SEGMENT 2045 PROPOSED IMPROVEMENTS LOS 22

TABLE OF CONTENTS

TABLE 11 – 2045 AM / PM RIGHT TURN & APPROACH VOLUMES 23
TABLE 12 – DCR COST ESTIMATE (2009 DOLLARS) 29
TABLE 13 – HOUGHTON ROAD, TANQUE VERDE ROAD TO SPEEDWAY BOULEVARD 32

FIGURES

FIGURE 1 – PROJECT LOCATION 2
FIGURE 2 – PROJECT STUDY AREA 2
FIGURE 3 – 2019 DAILY TRAFFIC – PAG 2045 MODEL, SEPTEMBER 22, 2021 4
FIGURE 4 – 2045 LINK DAILY TRAFFIC VOLUMES – PAG 2045 MODEL, MAY 7, 2019 4
FIGURE 5 – 2045 LINK DAILY TRAFFIC VOLUMES – PAG 2045 MODEL, SEPTEMBER 22, 2021 5
FIGURE 6 – MAY 7, 2019 NEEDS STUDY TURNING MOVEMENT COUNTS 5
FIGURE 7 – OCTOBER 15, 2019 PAG TURNING MOVEMENT COUNTS 6
FIGURE 8 – PAG DATA GROWTH RATE, HOUGHTON ROAD PROJECT AREA BETWEEN 2019 AND 2045 7
FIGURE 9 – 2020 TUCSON GROWTH RATE FROM UNIVERSITY OF ARIZONA MAP 8
FIGURE 10 – 2020 TUCSON GROWTH RATE FROM THE U.S. CENSUS BUREAU 8
FIGURE 11 – 2045 PROJECTED AM AND PM PEAK HOUR TURNING MOVEMENT VOLUMES 11
FIGURE 12 – DCR 2030 PROJECTED AM AND PM PEAK HOUR TRAFFIC VOLUMES 12
FIGURE 13 – HOUGHTON ROAD/TANQUE VERDE RECOMMENDED INTERSECTION IMPROVEMENTS 16
FIGURE 14 – HOUGHTON ROAD/SPEEDWAY BOULEVARD NORTH APPROACH IMPROVEMENTS FROM NEEDS ASSESSMENT STUDY 16
FIGURE 15 – PROPOSED HOUGHTON ROAD ROADWAY ON BRIDGES AT THE AQUA CALIENTE WASH AND TANQUE VERDE CREEK FROM THE NEEDS STUDY 17
FIGURE 16 – PROPOSED HOUGHTON ROAD TWLTL TYPICAL SECTION, CORTE VISTA LA MARIPOSA TO DRACHMAN STREET 18
FIGURE 17 – PROPOSED HOUGHTON ROAD TWLTL PLAN VIEW, CORTE VISTA LA MARIPOSA TO DRACHMAN STREET 18
FIGURE 18 – PROPOSED HOUGHTON ROAD TYPICAL SECTION, SOUTH OF SPEEDWAY BOULEVARD 19
FIGURE 19 – PROPOSED MEDIAN OPENINGS ON HOUGHTON RD BETWEEN SPEEDWAY BLVD AND BROADWAY BLVD 19

TABLE OF CONTENTS

FIGURE 20 – EXISTING CONDITIONS, 2045 RECOMMENDED IMPROVEMENTS, AND 2010 DCR IMPROVEMENTS 20
FIGURE 21 – RIGHT TURN LANE GUIDELINES – RIGHT TURN LANES NB AND SB AT THE HOUGHTON ROAD/TANQUE VERDE ROAD INTERSECTION 23
FIGURE 22 – HOUGHTON ROAD, BROADWAY BLVD TO SPEEDWAY BLVD – NEEDS STUDY IMPROVEMENTS COST 30

APPENDICES

A PAG 2045 MODEL

B TRAFFIC COUNT DATA

C HCM REPORTS

D SYNCHRO REPORTS

E COST ESTIMATE

1 PROJECT OVERVIEW

The Houghton Road, Tanque Verde Road to Speedway Boulevard project is a part of a series of Houghton Road Corridor projects between I-10 and Tanque Verde Road that the Regional Transportation Authority (RTA) project has programmed from Period 1 through Period 3, which span the years FY2007 through FY2021, as part of the RTA plan passed by voters in 2006. The segment between Tanque Verde Road and Speedway Boulevard is the last segment in the implementation plan for Houghton Road. A Design Concept Report was prepared for the segment in 2010 (2010 DCR).

In 2019, the City of Tucson Department of Transportation and Mobility (DTM) requested that WSP review the recommendations from the 2010 DCR and determine if they were still valid. The *Houghton Road, Tanque Verde Road to Speedway Boulevard Needs Assessment Study* (Needs Study) summarized the findings of that evaluation.

Traffic volumes within the region have not increased at the rates that were assumed at the time of the 2010 DCR. The Pima Association of Governments (PAG) regional transportation model has been updated since the 2010 DCR was completed. The Needs Study reviewed the existing traffic operations of this segment of Houghton Road, evaluated projected operations for 2030 traffic, and provided a recommended set of improvements to accommodate the projected traffic and maintain satisfactory level of service (LOS). The Needs Study also included an evaluation of the recommended improvements through 2045, which showed intersection operations beginning to deteriorate in 2035 and reaching LOS E and F in 2045.

In August 2021, DTM requested a review of the Needs Study recommendations to determine what additional improvements would be needed to achieve an acceptable LOS of at least D for 2045 projected traffic volumes. Since PAG periodically updates their regional transportation model, DTM requested that the current PAG 2045 model data be reviewed to see if there had been any updates since the Needs Study was completed. The review of the Needs Study and current PAG 2045 model data are documented in this Needs Study Addendum Report (Study Addendum).

The proposed recommendations from the Needs Study included widening Houghton Road to four lanes south of Speedway Boulevard, adding an additional NB left turn lane at Speedway Boulevard, and adding a NB right turn lane at Tanque Verde Road. The condition of the bridges over the Tanque Verde Creek and Agua Caliente Wash was also reviewed and found to be in good to satisfactory condition with approximately 45 years remaining in their design life. Maintenance work including joint replacement and deck sealing was recommended.

1.1 PROJECT LOCATION

The project is in the northeast corner of the Tucson metro area (Figure 1). The project limits are the same as the 2010 DCR and Needs Study, covering Houghton Road from near 5th Street north to Tanque Verde Road (Figure 2). The total length along Houghton Road is approximately 2 miles. Portions of the project are fully within the City of Tucson limits, and the section north of Speedway Boulevard borders unincorporated Pima County land to the east.

1.2 PROJECT DESCRIPTION & PROJECT CHARACTERISTICS

Detailed project description and project characteristics information is included in the Needs Study. Additional characteristics were not evaluated in the Study Addendum.

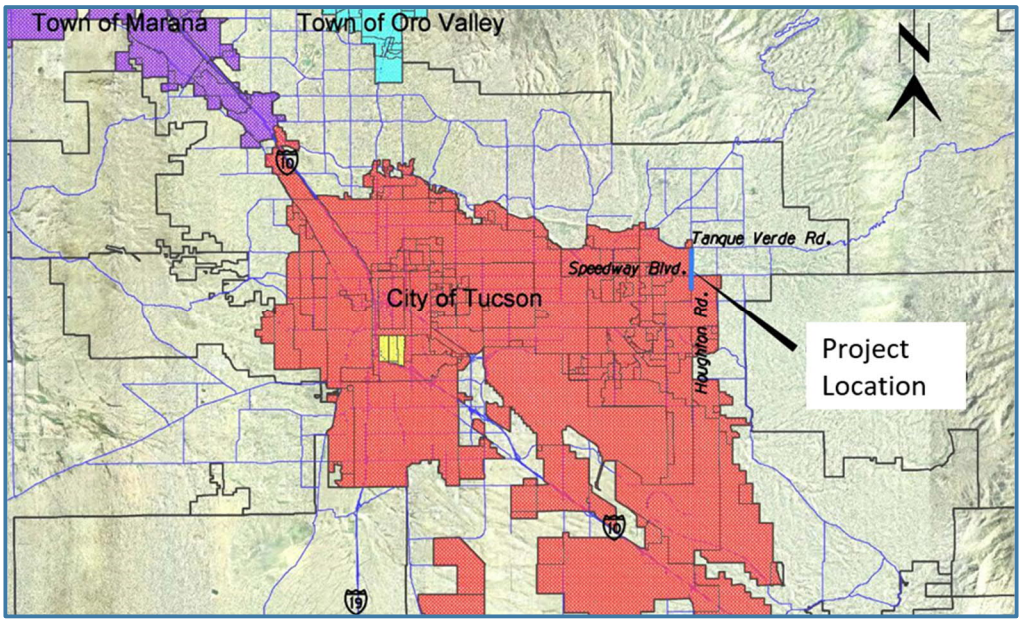


Figure 1 – Project Location

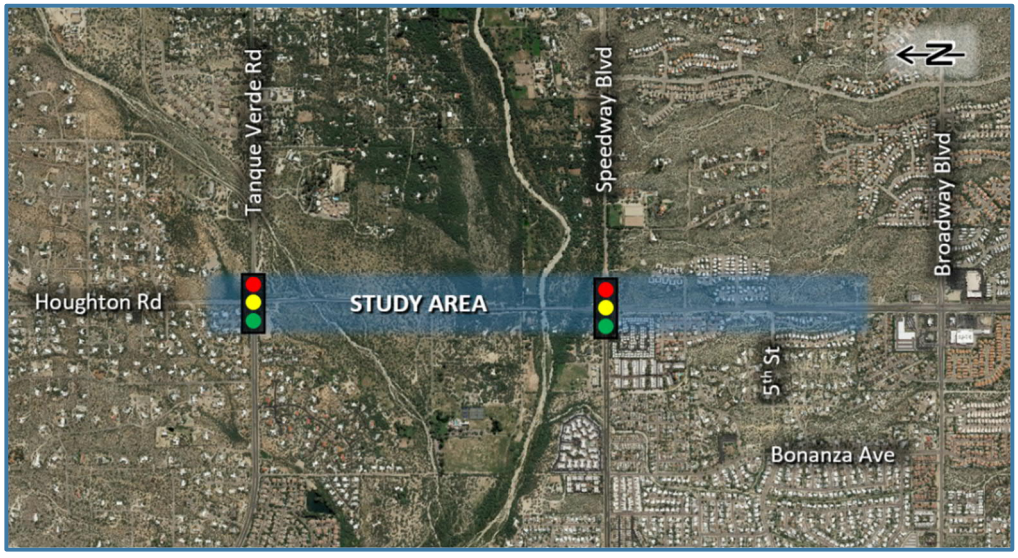


Figure 2 – Project Study Area

2 TRAFFIC

PAG maintains a regional transportation model that currently forecasts traffic to 2045. This model is periodically updated to account for regional changes in population, development, and other factors.

To evaluate the performance of the proposed improvements to Houghton Road from Tanque Verde Road to Speedway Boulevard for a design year of 2045, the following steps were taken to determine 2045 AM and PM peak hour traffic:

- Obtain the current PAG 2045 transportation model data for the project area
- Determine the traffic growth rate between the PAG 2019 and 2045 traffic volume data
- Assess the growth rate against recent growth trends for the project area
- Determine 2045 AM and PM peak hour traffic for the Houghton Road/Speedway Boulevard and Houghton Road/Tanque Verde Road intersections as well as on the approaches to these intersections

Traffic count data is included in Appendix A.

2.1 EXISTING TRAFFIC - 2019

WSP obtained the PAG 2045 transportation model data on September 22, 2021, which included daily traffic volume estimates for roadway links within the project area for both 2019 and 2045. The 2019 data is shown in Figure 3.

The Needs Study used 2045 daily traffic volume estimates based on PAG 2045 data from May 17, 2019, shown in Figure 4. The updated 2045 PAG daily traffic volumes were compared to those used in the Needs Study and were found to be lower for nearly every link, with some links seeing reductions of over 30%. Figure 5 shows the PAG 2045 daily traffic volumes from September 22, 2021, with the percent changes from the 2045 daily traffic used in the Needs Study.

AM and PM peak hour turning movement counts were taken on May 7, 2019 at the Houghton Road/Speedway Boulevard and Houghton Road/Tanque Verde Road intersections for the Needs Study (Figure 6). Later, PAG counts were taken on October 15, 2019 (Figure 7). Traffic volumes for both AM and PM peak hours were consistent between the counts for most movements at both intersections. Since they were consistent, the May 7, 2019 counts were used in the Study Addendum as the basis for the development of the 2045 turning movement volumes. Using the same 2019 turning movement count data as the Needs Study ensured that differences in the projected 2045 traffic volumes would be based solely on differences in the growth rate.

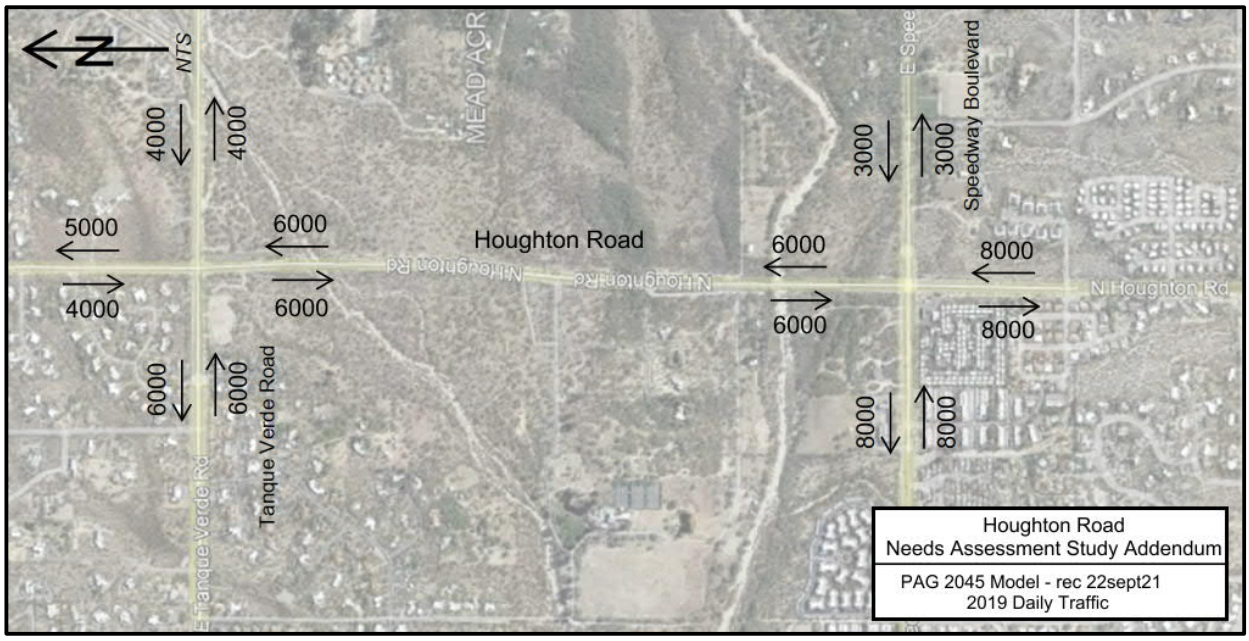


Figure 3 – 2019 Daily Traffic – PAG 2045 Model, September 22, 2021

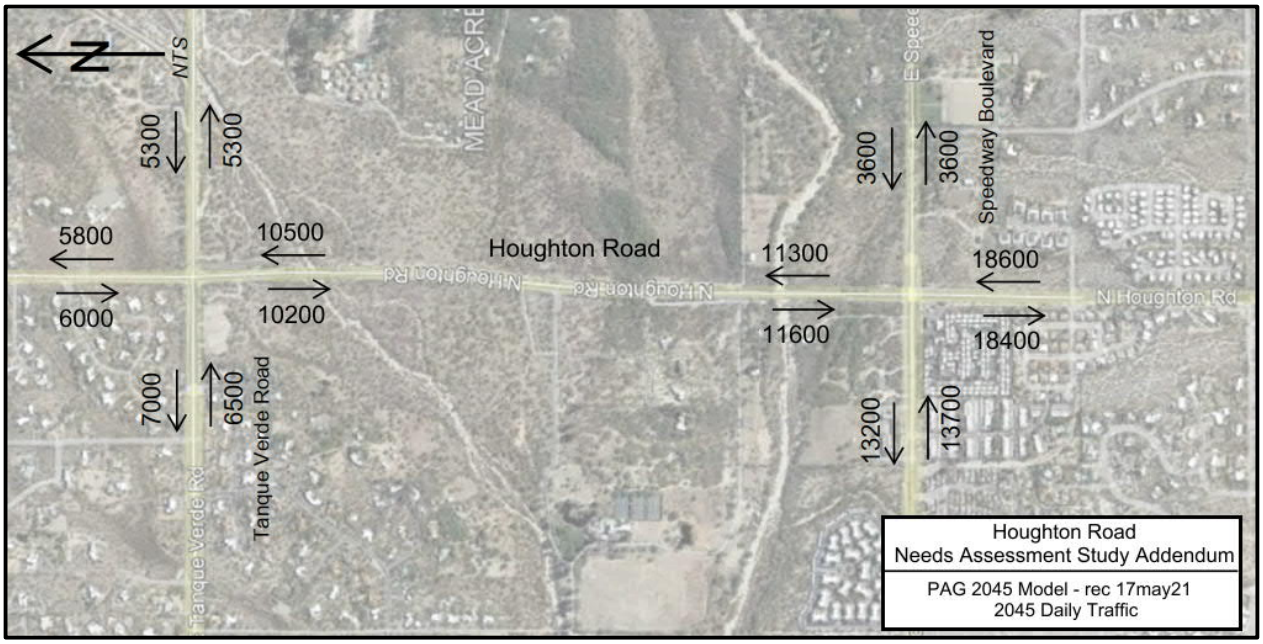


Figure 4 – 2045 Link Daily Traffic Volumes – PAG 2045 Model, May 7, 2019

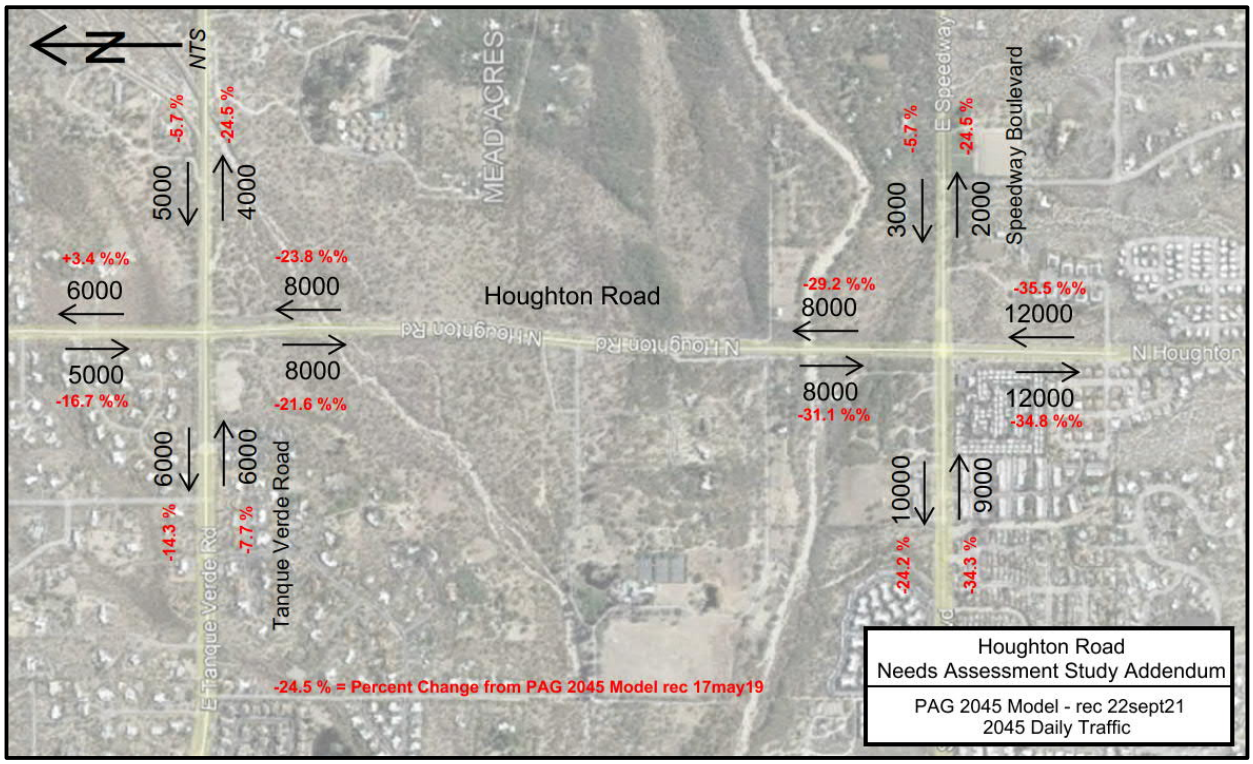


Figure 5 – 2045 Link Daily Traffic Volumes – PAG 2045 Model, September 22, 2021 With Percent Changes from PAG 2045 Model, May 7, 2019

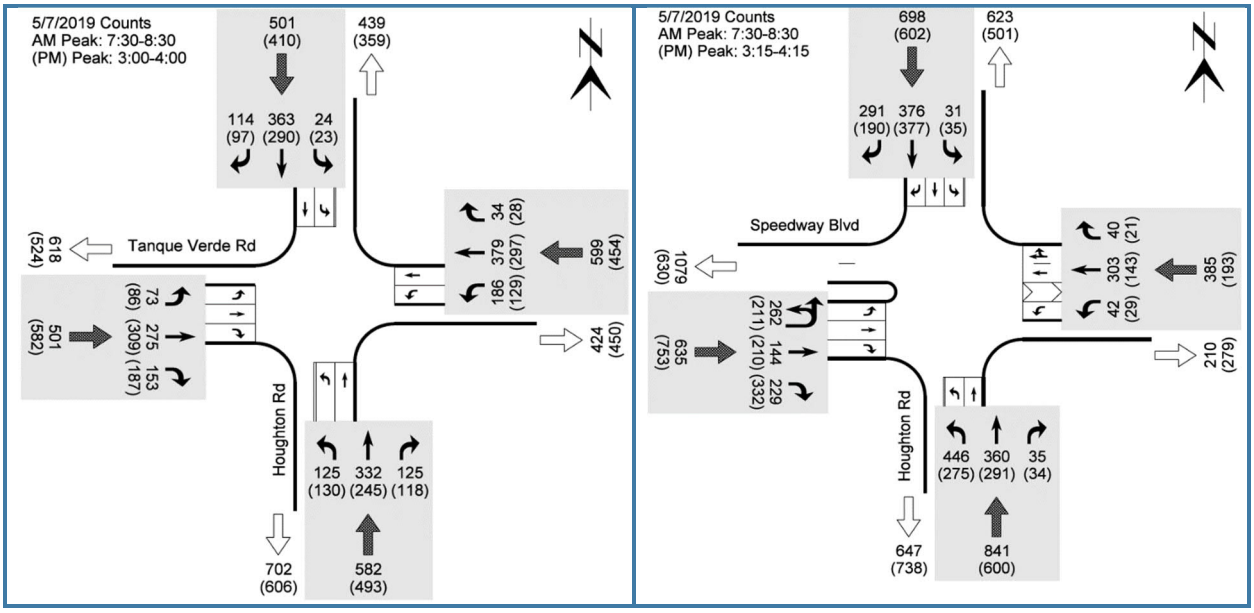


Figure 6 – May 7, 2019 Needs Study Turning Movement Counts

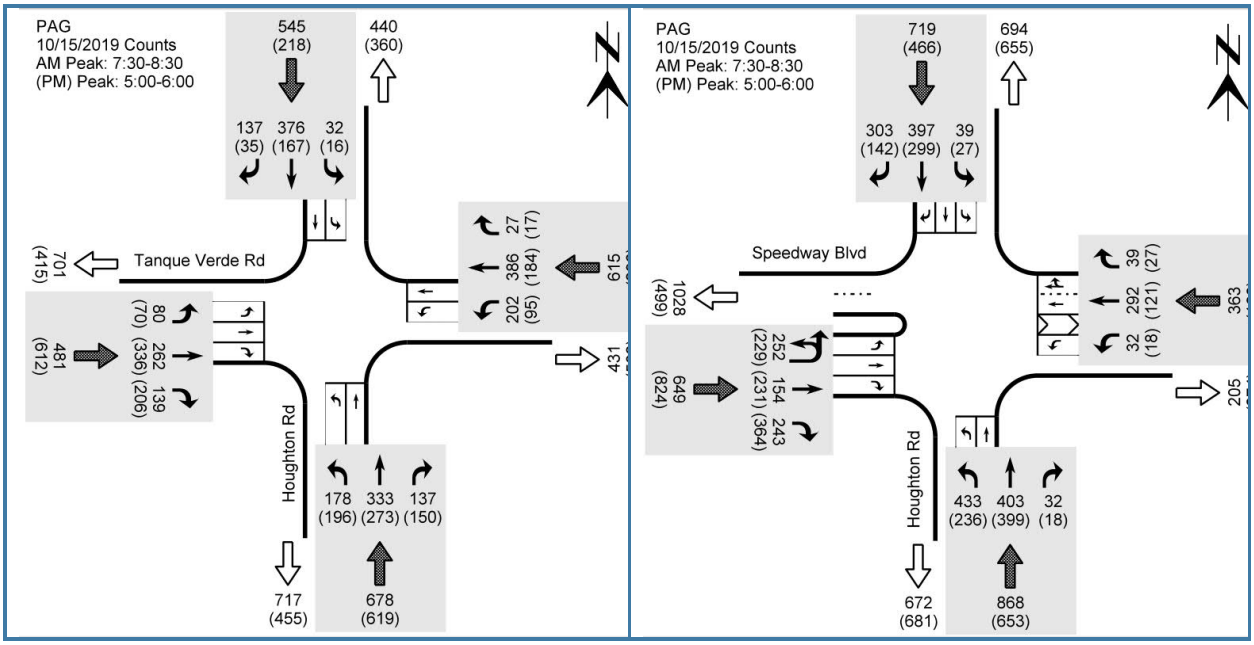


Figure 7 – October 15, 2019 PAG Turning Movement Counts

Pedestrians / Bicycle Volumes

During the six hours that intersection volume data was collected on May 7, 2019, only four pedestrians were observed at the Houghton Road/Speedway Boulevard intersection. Two pedestrians were observed at the Houghton Road/Tanque Verde Road intersection.

Peak hour bicycle movement volumes were less than 8 bicycles per hour, except for the AM EB Tanque Verde Road to SB Houghton Road and AM SB Houghton Road to EB Speedway Boulevard movements. This AM peak likely represents a group ride event and highlights the need for adequate bicycle accommodation through the study corridor despite relatively low overall bicycle volumes.

2.2 GROWTH RATE

The PAG 2045 regional transportation model data, as of September 22, 2021, for the years 2019 and 2045, was analyzed to determine growth rates to apply to the 2019 AM and PM peak hour turning movement counts. The model data is broken down directionally for each roadway link so that different growth rates can be determined for approaches on each link to an intersection. Using a future compound interest rate formula, the growth rate was determined by solving for the rate based on the differences between the 2019 and 2045 volumes. Figure 8 shows the growth rates for the roadway segments within the project area. Growth rates ranged from a decrease in traffic volume of -1.6% for EB Speedway east of the Houghton Road/Speedway Boulevard intersection, to +1.57% for Houghton Road approaching and departing Speedway Boulevard on the south leg of the intersection.

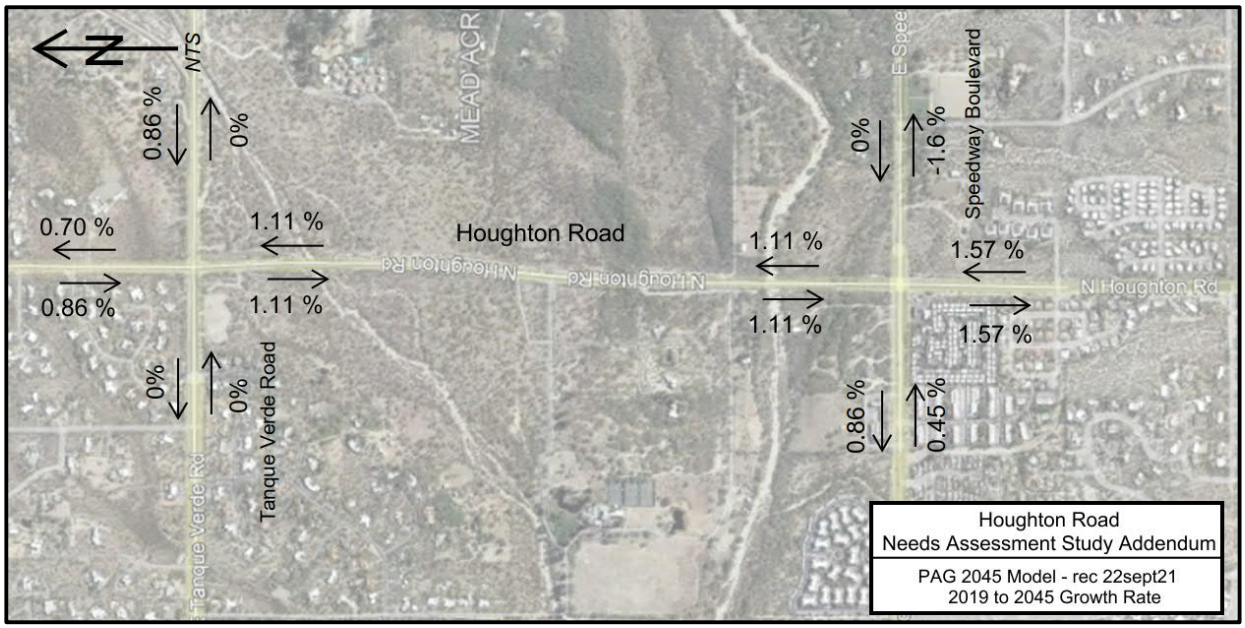


Figure 8 – PAG Data Growth Rate, Houghton Road Project Area between 2019 and 2045

The growth rates are summarized in Table 1 along with the growth rates from the 2010 DCR.

Table 1 – Growth Rates for Houghton Road, Tanque Verde Road to Speedway Boulevard

Roadway	Segment	DCR Growth Rate	Used for this Study
Tanque Verde Rd	West	0.5%	0.00%
	East	0.5%	0.86%
Speedway Boulevard	West	3.4%	0.45%
	East	0.5%	0.00%
Houghton Road	North of Tanque Verde	4.0%	0.86%
	South of Tanque Verde	2.1%	1.11%
	North of Speedway		1.11%
	Speedway to Broadway	5.2%	1.57%

Growth rate trends for the Tucson area were researched to determine if the growth rates calculated from the PAG data were reasonable. Two sources were reviewed: University of Arizona MAP (Making Action Possible) for Southern Arizona and the U.S. Census Bureau. The MAP site provides growth rates for Tucson as well as other cities and shows that in 2020 the growth rate for Tucson was 0.7%. The U.S. Census Bureau has Tucson population data for 2010 and 2020. It shows a population increase of 4.1%, which translates to a 0.40% annual growth rate. Growth rates from each source are shown in Figure 9 and Figure 10.

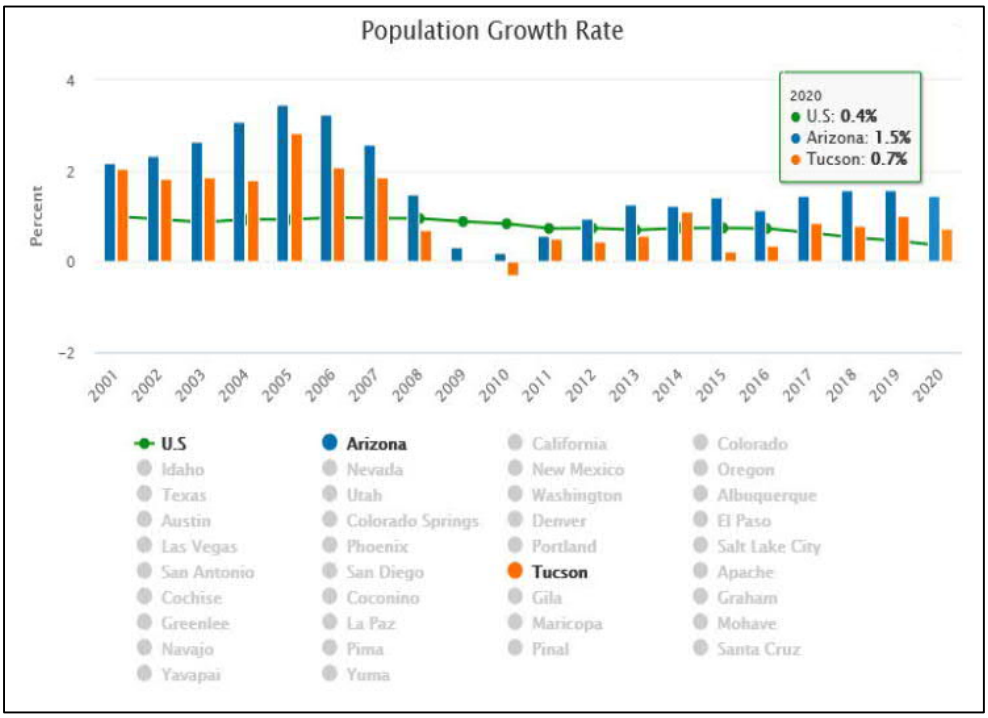
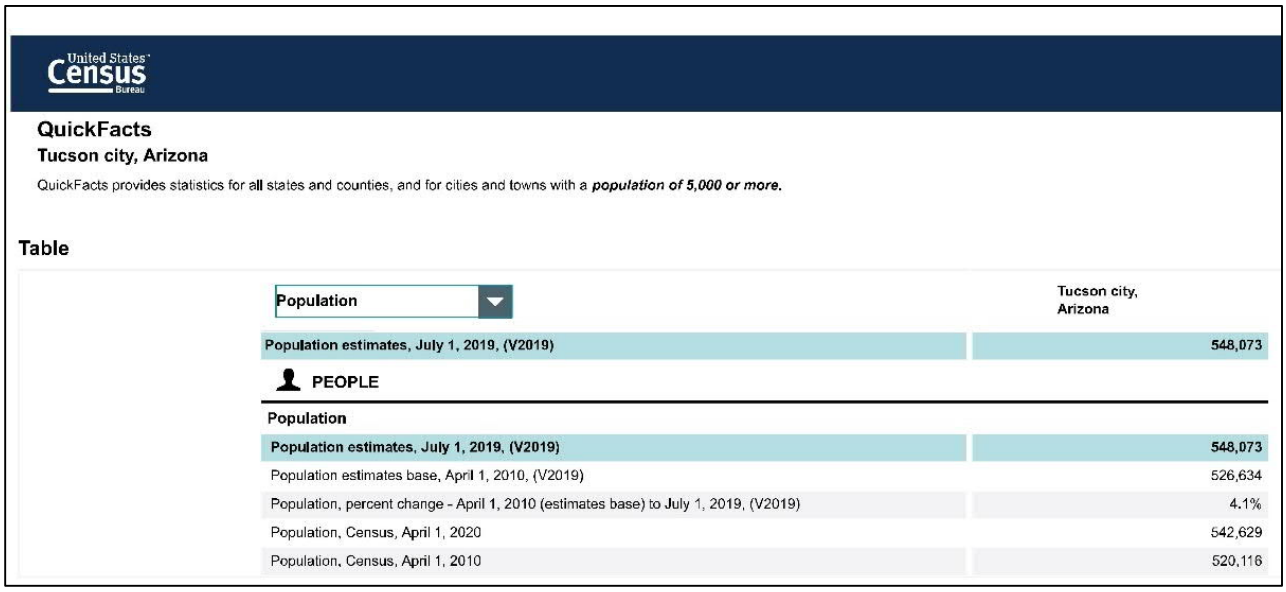


Figure 9 – 2020 Tucson Growth Rate from University of Arizona MAP



United States Census Bureau

QuickFacts

Tucson city, Arizona

QuickFacts provides statistics for all states and counties, and for cities and towns with a ***population of 5,000 or more.***

Table

Population	Tucson city, Arizona
Population estimates, July 1, 2019, (V2019)	548,073
PEOPLE	
Population	
Population estimates, July 1, 2019, (V2019)	548,073
Population estimates base, April 1, 2010, (V2019)	526,634
Population, percent change - April 1, 2010 (estimates base) to July 1, 2019, (V2019)	4.1%
Population, Census, April 1, 2020	542,629
Population, Census, April 1, 2010	520,116

Figure 10 – 2020 Tucson Growth Rate from the U.S. Census Bureau

The growth rates determined for the roadway segments within the project area are comparable to the MAP and U.S. Census Bureau growth rates. Therefore, the growth rates determined from the PAG 2045 model data were used without adjustment to project the 2045 AM and PM peak hour turning movements for the Houghton Road/Speedway Boulevard and Houghton Road/Tanque Verde intersections as well as for the roadway links within the project area.

2.3 EXISTING CAPACITY ANALYSIS - 2019

Synchro traffic software was used to implement Highway Capacity Manual, 6th Edition (HCM) procedures for determining the existing traffic capacity at the two major intersections within the study area. Table 2 and Table 3 show the existing peak hour delay and LOS at the Houghton Road/Tanque Verde Road and Houghton Road/Speedway Boulevard intersections.

The results of the analysis conducted for the Needs Study indicate that the Houghton Road/Tanque Verde Road intersection operates at LOS C in both the AM and PM peak periods with individual turning movements operating at a LOS ranging from B to D. The Houghton Road/Speedway Boulevard intersection operates at LOS D in the AM peak and LOS C in the PM peak. The AM peak hour has both the EB and NB left turns operating at LOS F with the NB approach operating at an overall LOS E, indicating that there are significant delays to traffic at the intersection even though the overall intersection operates within acceptable limits.

The default HCM right turn on red (RTOR) volume of 0 was used for most right turn movements, which is a conservative assumption. At the Houghton Road/Speedway Boulevard intersection, the SB right and EB right RTOR volumes were estimated based on field observations. Without the RTOR estimates, delay estimates were unrealistically high. RTOR percentages of 50% and 75% were used for the two movements, respectively.

Table 2 – 2019 Existing LOS at Houghton Road & Tanque Verde Road

	SB ↓			WB ←			NB ↑			EB →				INT
	L	T/R	APR	L	T/R	APR	L	T/R	APR	L	T	R	APR	TOT
AM Delay	25.6	25.1	25.1	26.1	40.3	35.8	37.1	21.6	24.9	29.8	29.9	24.3	28.2	28.7
AM LOS	C	C	C	C	D	D	D	C	C	C	C	C	C	C
PM Delay	18.8	17.0	17.1	29.0	33.9	32.5	24.9	16.1	19.4	28.8	31.1	24.0	28.5	24.5
PM LOS	B	B	B	C	C	C	C	B	B	C	C	C	C	C

L = Left Lane group T = Through lane group R = Right Lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

	Table 3 – 2019 Existing LOS at Houghton Road & Speedway Boulevard															
	SB ↓				WB ←				NB ↑			EB →				INT
	L	T	R	APR	L	T	R	APR	L	T/R	APR	L	T	R	APR	TOT
AM Delay	29.8	37.1	N/A	33.7	31.8	38.2	38.5	37.7	81.2	21.1	53.0	88.4	39.8	38.7	62.3	47.3
AM LOS	C	D	N/A	C	C	D	D	D	F	C	D	F	D	D	E	D
PM Delay	19.9	39.8	N/A	34.8	35.8	36.6	36.9	36.6	24.8	29.8	27.5	36.8	34.3	33.7	34.9	34.9
PM LOS	B	D	C	C	D	D	D	D	C	C	C	D	C	C	D	C

L = Left Lane group T = Through lane group R = Right lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

Roadway segment LOS was analyzed using HCM methodology for two-lane highways. The existing peak hour roadway segment LOS, Average Travel Speed (ATS), and Percent Time Spent Following (PTSF) are shown in Table 4. The one mile spacing between traffic signals was considered sufficient for application of this HCM methodology.

The HCM two-lane highways capacity evaluation has an option to consider either a Class I or Class II designation. These are defined as follows:

Class I: where motorists expect to travel at relatively high speed. These are major intercity routes and primary connectors of major traffic generators, serving long distance trips.

Class II: where motorists do not necessarily expect to travel at high speed. These are access routes to Class I routes, recreational routes, or routes that pass through rugged terrain, serving relatively short trips.

The HCM states that the primary determinant of a facility's classification is the motorist's expectation, which might not agree with the route's overall functional category. Houghton Road was analyzed as a Class I route but has some characteristics of a Class II route, namely that motorists do not necessarily expect to travel at high speed (speed limit 45 mph). A change in just the class of roadway can change the level of service, with no changes to the performance measures themselves. The existing roadway HCM reports for Houghton Road between Tanque Verde Road and Broadway Boulevard are included in Appendix C.

	Table 4 – 2019 Existing LOS for Houghton Road Roadway Segments – Class I					
	Broadway Blvd to Speedway Blvd			Speedway Blvd to Tanque Verde Rd		
	LOS	ATS (mph)	PTSF	LOS	ATS (mph)	PTSF
AM	E	29.7	86.2%	E	31.6	78.3%
PM	E	31.1	76.2%	E	33.2	72.0%

The HCM two-lane highway capacity evaluation results show that both the Houghton Road Broadway Boulevard to Speedway Boulevard and Speedway Boulevard to Tanque Verde Road segments operate at LOS E with their speeds being significantly less that the 45 mph speed limit.

2.4 FUTURE TRAFFIC - 2045

Future 2045 traffic volumes for both AM and PM peak hours were calculated using growth rates derived from the PAG 2045 regional transportation model. These growth rates (shown in Table 1) were applied to the May 7, 2019 turning movement count data to provide projected turning movement volumes for the 2045 design year. The PAG 2045 model showed approximately 8000 fewer vehicles on Houghton Road at Tanque Verde Road than at Speedway Boulevard. This reduction was considered unrealistic given current and expected land use, so the growth rates on this segment of Houghton Road were adjusted to produce more balanced traffic volumes between the two major intersections. The 2045 AM and PM peak hour projected turning movement volumes are shown in Figure 11.

Compared to the 2030 AM and PM peak hour turning movement from the 2010 DCR, shown in Figure 12, the 2045 AM and PM peak hour traffic projections developed from this Study Addendum are similar and, in some cases, lower. For example, the 2045 AM peak hour NB Houghton Road approach to Speedway Boulevard has 699 vph turning left, 540 vph going straight, and 53 vph turning right. In the 2010 DCR 2030, the AM Peak Hour NB Houghton Road approach to Speedway Boulevard was 770 vph turning left, 660 vph going straight, and 85 vph turning right.

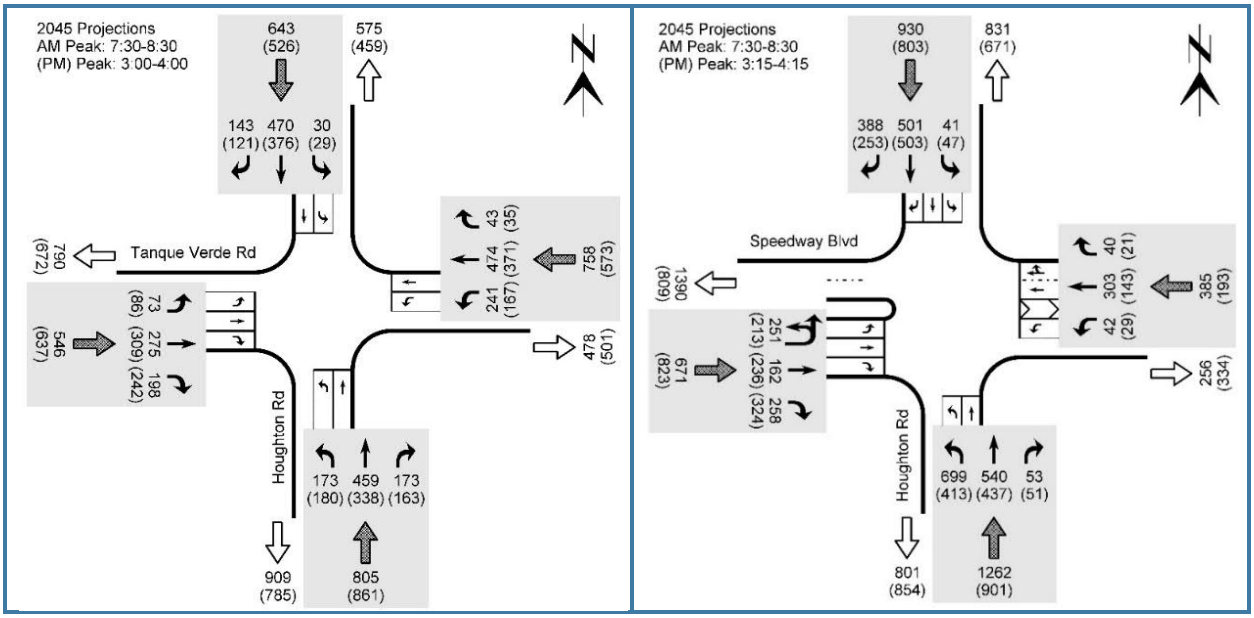


Figure 11 – 2045 Projected AM and PM Peak Hour Turning Movement Volumes

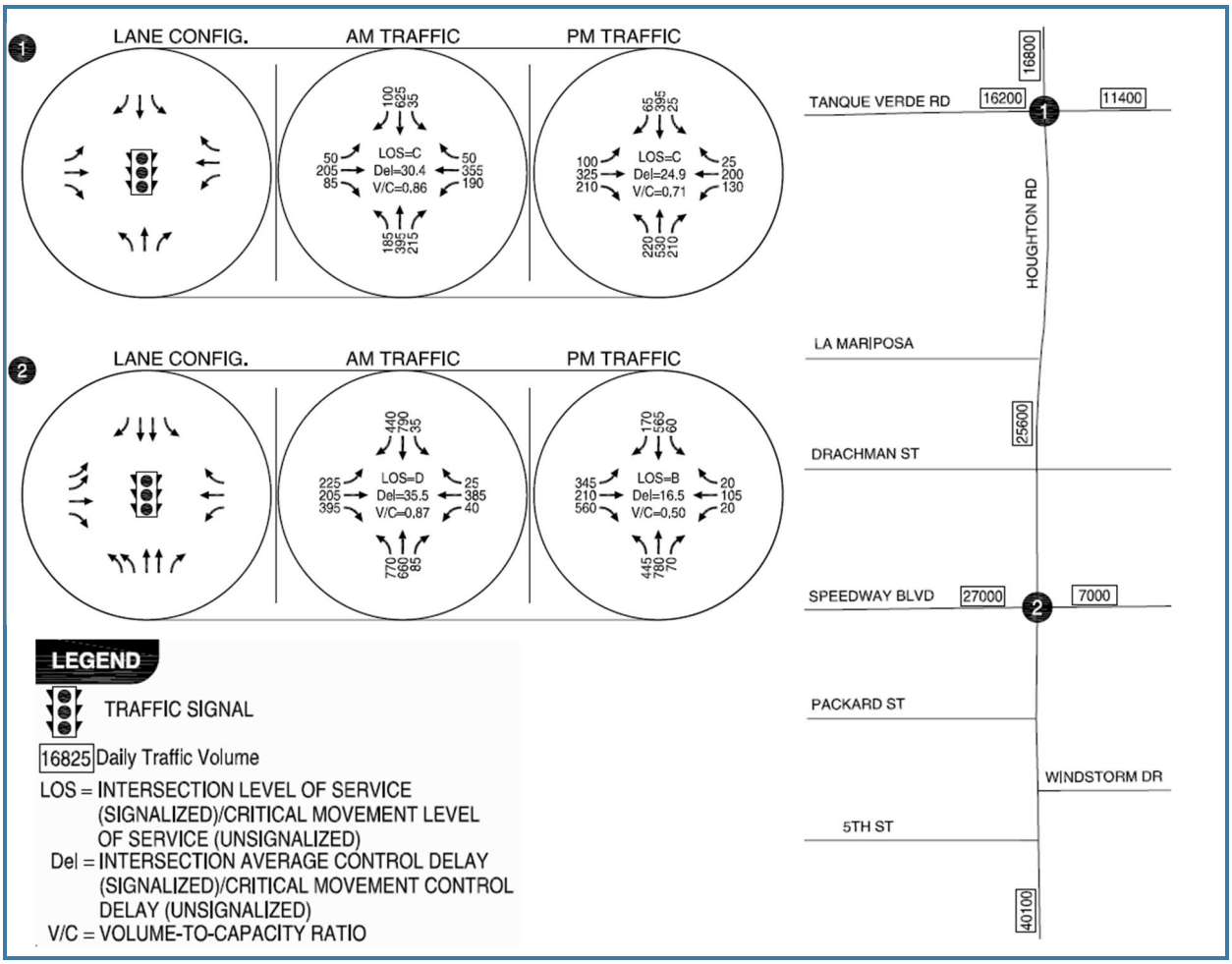


Figure 12 – DCR 2030 Projected AM and PM Peak Hour Traffic Volumes

2.5 FUTURE CAPACITY ANALYSIS - 2045

The projected 2045 AM and PM peak hour turning movement volumes were based on the growth rates determined from the PAG 2045 model data received on September 22, 2021. These traffic volumes were used to determine LOS at the two major intersections for a No-Build scenario with no changes to the existing number of lanes or intersection configurations. Synchro traffic capacity analysis software was used to implement HCM procedures for determining LOS. As with the existing traffic conditions, RTOR volumes were estimated for the SB and EB right movements at the Houghton Road/Speedway Boulevard intersection. Modeled delay and LOS for the two intersections are shown in Table 5 and Table 6.

	Table 5 – 2045 No Build LOS for Houghton Road & Tanque Verde Road													
	SB ↓			WB ←			NB ↑			EB →				INT
	L	T/R	APR	L	T/R	APR	L	T/R	APR	L	T	R	APR	TOT
AM Delay	45.8	31.0	31.7	52.1	74.1	67.2	86.1	29.0	41.3	64.0	58.6	50.1	56.2	49.1
AM LOS	D	C	C	D	E	E	F	C	D	E	E	D	E	D
PM Delay	27.4	21.8	22.1	35.3	50.3	45.9	45.3	21.2	27.5	37.8	41.0	37.3	39.2	33.8
PM LOS	C	C	C	D	D	D	D	C	C	D	D	D	D	C

L = Left Lane group T = Through lane group R = Right Lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

	Table 6 – 2045 No Build LOS for Houghton Road & Speedway Boulevard														
	SB ↓				WB ←				NB ↑			EB →				INT
	L	T	R	APR	L	T	R	APR	L	T/R	APR	L	T	R	APR	TOT
AM Delay	66.4	96.3	N/A	80.1	59.5	93.9	96.2	91.1	136.8	23.3	83.5	184.6	74.5	69.8	125.3	91.0
AM LOS	E	F	N/A	E	E	F	F	F	F	C	F	F	E	E	F	F
PM Delay	33.4	75.2	N/A	60.9	43.2	44.7	45.1	44.6	47.6	28.0	37.0	49.9	48.0	40.4	46.6	47.2
PM LOS	C	F	N/A	E	D	D	D	D	D	C	D	D	D	D	D	D

L = Left Lane group T = Through lane group R = Right Lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

For the 2045 projected volumes, the Houghton Road/Tanque Verde Road intersection will see a decrease in LOS from C to D in the AM peak hour and still have LOS C in the PM peak hour. Although the AM peak hour will operate at an overall acceptable LOS D, several traffic movements will operate at LOS E and the NB left turn at LOS F, representing significantly increased delay for some movements. Therefore, improvements are recommended and discussed in Section 3. The analysis maintained the existing NB and SB permitted only lefts.

The Houghton Road/Speedway Boulevard intersection will begin to experience LOS F for multiple movements in the AM peak, with an overall LOS F in the AM Peak Hour. The AM NB Houghton Road to WB Speedway Boulevard left turns could experience average delays exceeding two minutes and long queues. Based on these expected conditions, improvements are recommended and discussed in Section 3.

Peak hour roadway segment LOS, ATS, and PTSF are shown in Table 7. Roadway segment LOS was analyzed using HCM methodology for two-lane highways. The LOS criteria for Class I highways were used. Based on the analysis, the existing roadway will not see a decrease in LOS with the increased traffic volumes. The roadway segments will operate at LOS E between Tanque Verde Road and Broadway Boulevard during the 2045 AM and PM peak hours. PTSF values are approximately 5-10% higher than with existing traffic volumes. HCM reports are included in Appendix C.

	Table 7 – 2045 No Build LOS for Houghton Road Roadway Segments – Class I					
	Broadway Blvd to Speedway Blvd			Speedway Blvd to Tanque Verde Rd		
	LOS	**ATS** (mph)	**PTSF**	**LOS**	**ATS** (mph)	**PTSF**
AM	E	24.7	94.3%	E	27.9	85.3%
PM	E	27.4	87.7%	E	30.3	79.6%

2.6 CRASH DATA

Crash data for the project area was not reevaluated for this Study Addendum. Analysis of crash data can be found in Section 4.5 of the Needs Study.

3 PROPOSED RECOMMENDATIONS

This section provides an overview of the proposed improvements recommended in the Needs Study and details additional improvements evaluated as part of this Study Addendum. The additional proposed recommendations are based on improving the LOS along the Houghton Road corridor for projected traffic in the 2045 design year. The goal of the proposed improvements is to maintain overall LOS D or better at the intersections during the AM and PM peak hours, minimize the number of movements experiencing LOS E, and have no movements with LOS F. Roadway segment LOS is to be kept at LOS E or better. The proposed improvements feature widening to the south of Speedway Boulevard and capacity improvements at the Tanque Verde Road and Speedway Boulevard intersections.

3.1 PROPOSED INTERSECTION CONFIGURATIONS

The proposed improvements from the Needs Study at the Houghton Road/Tanque Verde Road intersection included:

- Adding a NB right turn lane, which would require a retaining structure (such as gabions or retaining wall) to maintain the existing drainage channel on the east side of Houghton Road. The NB right turn lane will likely require guardrail due to the retaining structure at the bottom of the expanded fill slope.
- Installing curb ramps at all four corners of the intersection to meet ADA standards.
- Constructing a multi-use path on the east side of Houghton Road adjacent to the NB right turn lane.

Projected 2045 AM and PM peak hour traffic volumes at this intersection are expected to be higher than the 2030 volumes used in the Needs Study. Therefore, the following additional improvements are recommended to achieve LOS D or better for most movements:

- Adding a SB right turn lane.
- Adding a second WB through lane.

The benefit of adding a SB right turn lane would be separating turning traffic from the through traffic and allowing for more flexibility in the signal timing. Right turns could more readily make a RTOR movement which would also increase capacity. The second WB through lane adds capacity to the approach and would match the number of WB through lanes along Tanque Verde Road west of the intersection. Figure 13 illustrates the proposed improvements.

At the Houghton Road/Speedway Boulevard intersection, the Needs Study recommendations included:

- Widening Houghton Road south of Speedway Boulevard to a four-lane divided roadway to the existing six-lane section constructed as part of the Houghton Road/Broadway Boulevard intersection improvement project.

- Creating a dual NB left turn lane at Speedway Boulevard, with the left through lane becoming one of the left turn lanes. The right through lane would be a shared through/right at the intersection.
- Adding a multi-use path on the east side of Houghton Road between Tanque Verde Road and Speedway Boulevard.

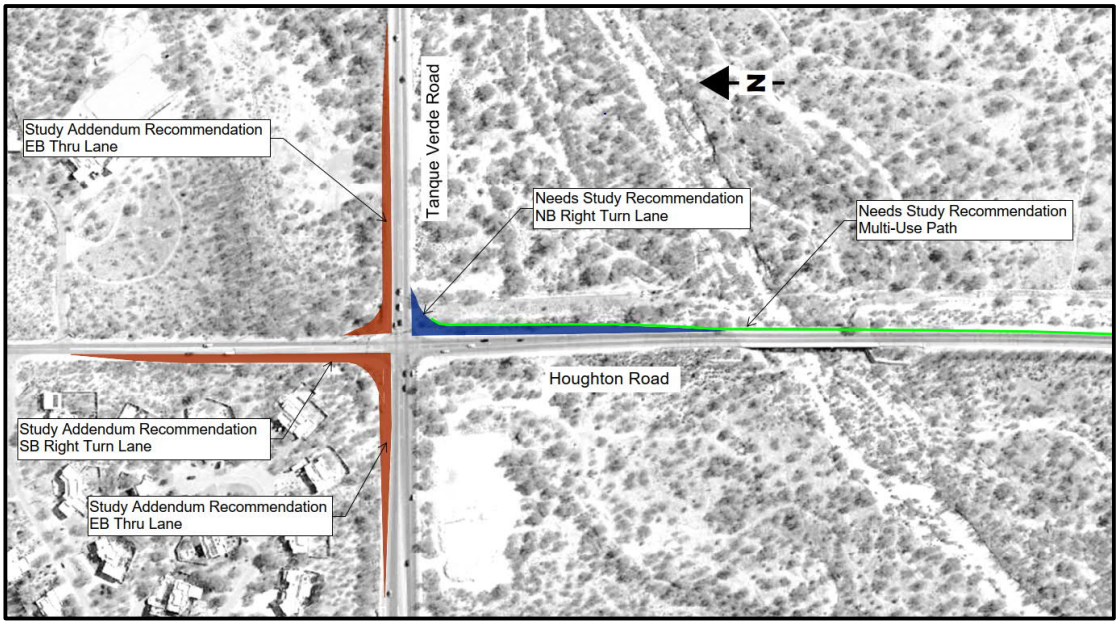


Figure 13 – Houghton Road/Tanque Verde Recommended Intersection Improvements

The Speedway Boulevard approaches were to remain unchanged except where they tie into the intersection.

The SB Houghton Road approach to Speedway Boulevard developed in the Needs Study is shown in Figure 14 with the existing and proposed lane widths. The approach is constrained by the existing Tanque Verde Creek bridge and the analysis and design considerations for the configuration are described in the Needs Study.

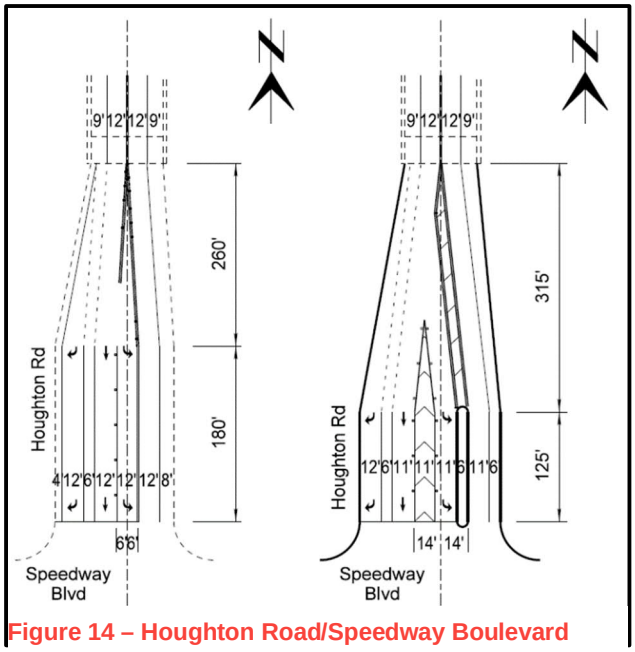


Figure 14 – Houghton Road/Speedway Boulevard North Approach Improvements from Needs Assessment Study

3.2 PROPOSED ROADWAY CONFIGURATIONS

The existing typical section between Tanque Verde Road and the Tanque Verde Creek bridge was to remain unchanged in the Needs Study except for the following recommendation:

- Reconfigure the Houghton Road roadway across the bridges at the Aqua Caliente Wash and Tanque Verde Creek by shifting the barrier between the NB shoulder and sidewalk to accommodate a 10-foot multi-use path.

The resulting Houghton Road typical section would be as shown in Figure 15:

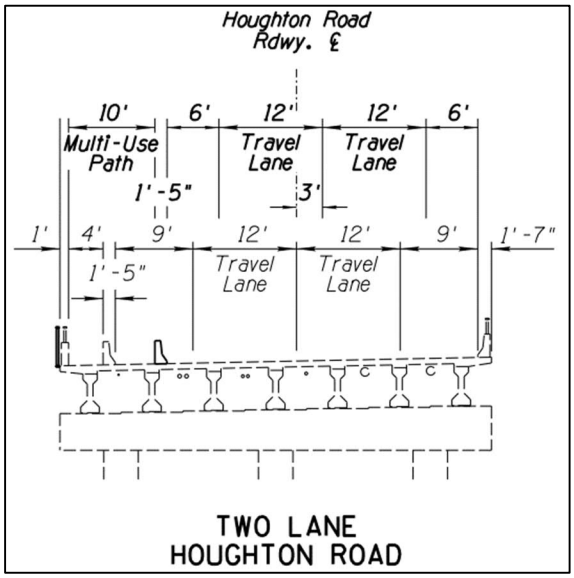


Figure 15 – Proposed Houghton Road roadway on bridges at the Aqua Caliente Wash and Tanque Verde Creek from the Needs Study

No further recommendations are made for the Houghton Road roadway across the Agua Caliente Wash and Tanque Verde Creek bridges for this Study Addendum.

Per discussions with the DTM and the RTA, a new two-way left turn lane (TWLTL) on Houghton Road between the Agua Caliente Wash and Tanque Verde Creek is recommended. The TWLTL would serve two side roads, Corte Vista La Mariposa and Drachman Street. An existing NB left turn lane serves Corte Vista La Mariposa. No SB left turn lanes are present for Drachman Street.

Currently, vehicles turning left onto Drachman Street from Houghton Road use the through lane, which reduces the capacity of Houghton Road and is a potential rear-end crash concern given the 45-mph speed limit. Widening Houghton Road between Corte Vista La Mariposa and Drachman Street and converting the existing NB left turn lane to a TWLTL between Corte Vista La Mariposa and Drachman Street would maintain the capacity of the through lanes and reduce the rear-end crash potential.

Figure 16 and Figure 17 show the roadway typical section for Houghton Road between Corte Vista La Mariposa and Drachman Street with the proposed TWLTL.

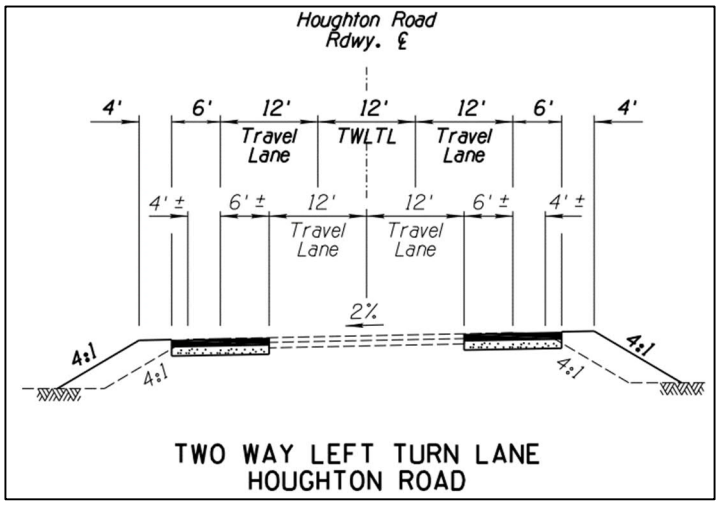


Figure 16 – Proposed Houghton Road TWLTL Typical Section, Corte Vista La Mariposa to Drachman Street

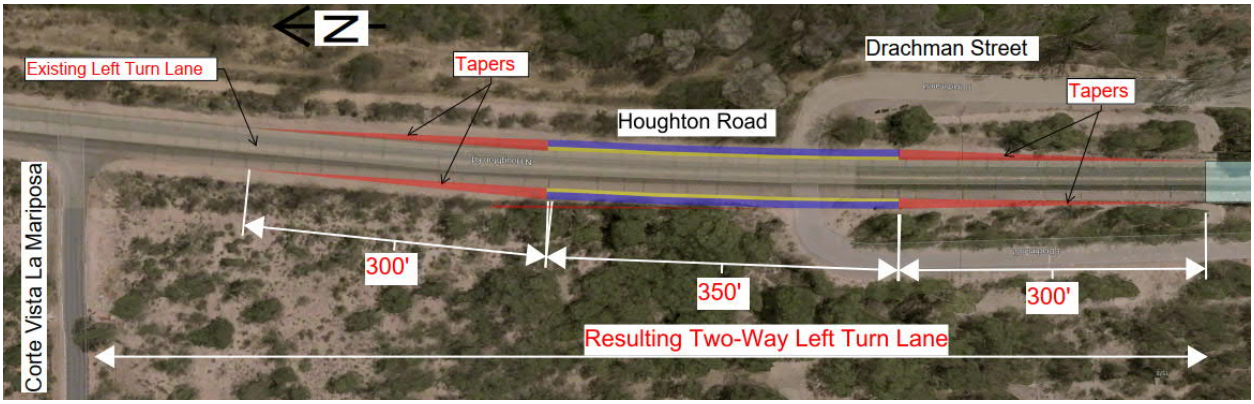


Figure 17 – Proposed Houghton Road TWLTL Plan View, Corte Vista La Mariposa to Drachman Street

South of Speedway Boulevard, the Needs Study proposed widening Houghton Road to a four-lane divided roadway with sidewalks on both sides. Consideration of a multi-use path along the east side of Houghton Road instead of a sidewalk was discussed with DTM. There are several existing driveways on the east side of Houghton Road from Broadway Boulevard to 6th Street with the area to the north mostly developed with the Sierra subdivision. This subdivision has access to Houghton Road at Windstorm Drive. North of the Sierra subdivision, there are nine homes with access to Houghton Road from Whispering Rabbit Place.

Given that a multi-use path is being considered along the east side of Houghton Road north of Speedway Boulevard and there will be a multi-use path along the east side of Houghton Road from Broadway Boulevard south several miles towards I-10, constructing a multi-use path on the east side of Houghton Road instead of a sidewalk is recommended in order to connect the proposed path to the north and existing path to the south near Broadway Boulevard. This recommendation may be reevaluated during final design depending on public input and a more detailed review of potential impacts. The typical roadway section for this section of Houghton Road is shown in Figure 18.

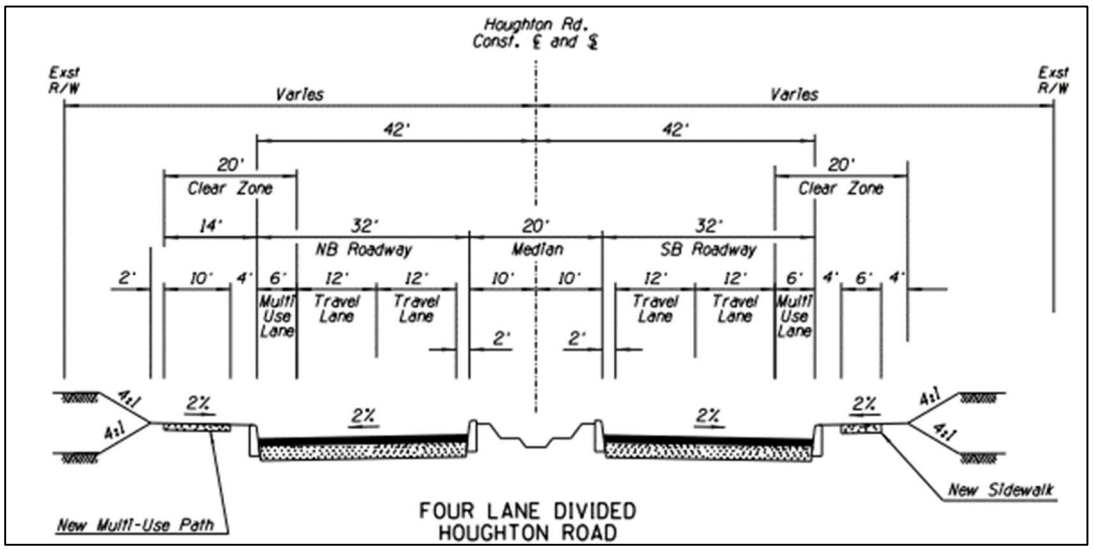


Figure 18 – Proposed Houghton Road Typical Section, South of Speedway Boulevard

Median Openings

Information on the proposed median openings can be found in Section 5.2 of the Needs Study (shown in Figure 19).

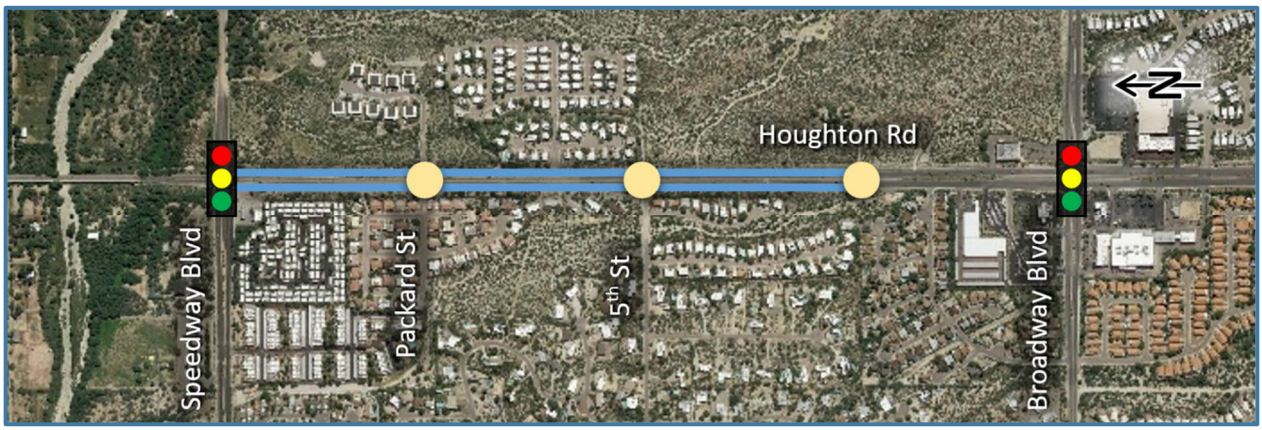


Figure 19 – Proposed Median Openings on Houghton Rd between Speedway Blvd and Broadway Blvd

3.3 ADDENDUM RECOMMENDATION SUMMARY

In addition to the proposed improvements from the Needs Study, the following intersection and roadway improvements are recommended based on the analysis conducted for the Study Addendum:

- Construct a SB right turn lane at the Houghton Road/Tanque Verde Road intersection
- Construct a second WB through lane on Tanque Verde Road at Houghton Road

- Construct a TWLTL on Houghton Road between Corte Vista La Mariposa and Drachman Street
- Construct a multi-use path along the east side of Houghton Road instead of a sidewalk between Speedway Boulevard and Broadway Boulevard

Figure 20 shows recommended improvement for 2045 along with the existing conditions and proposed improvements from the 2010 DCR:

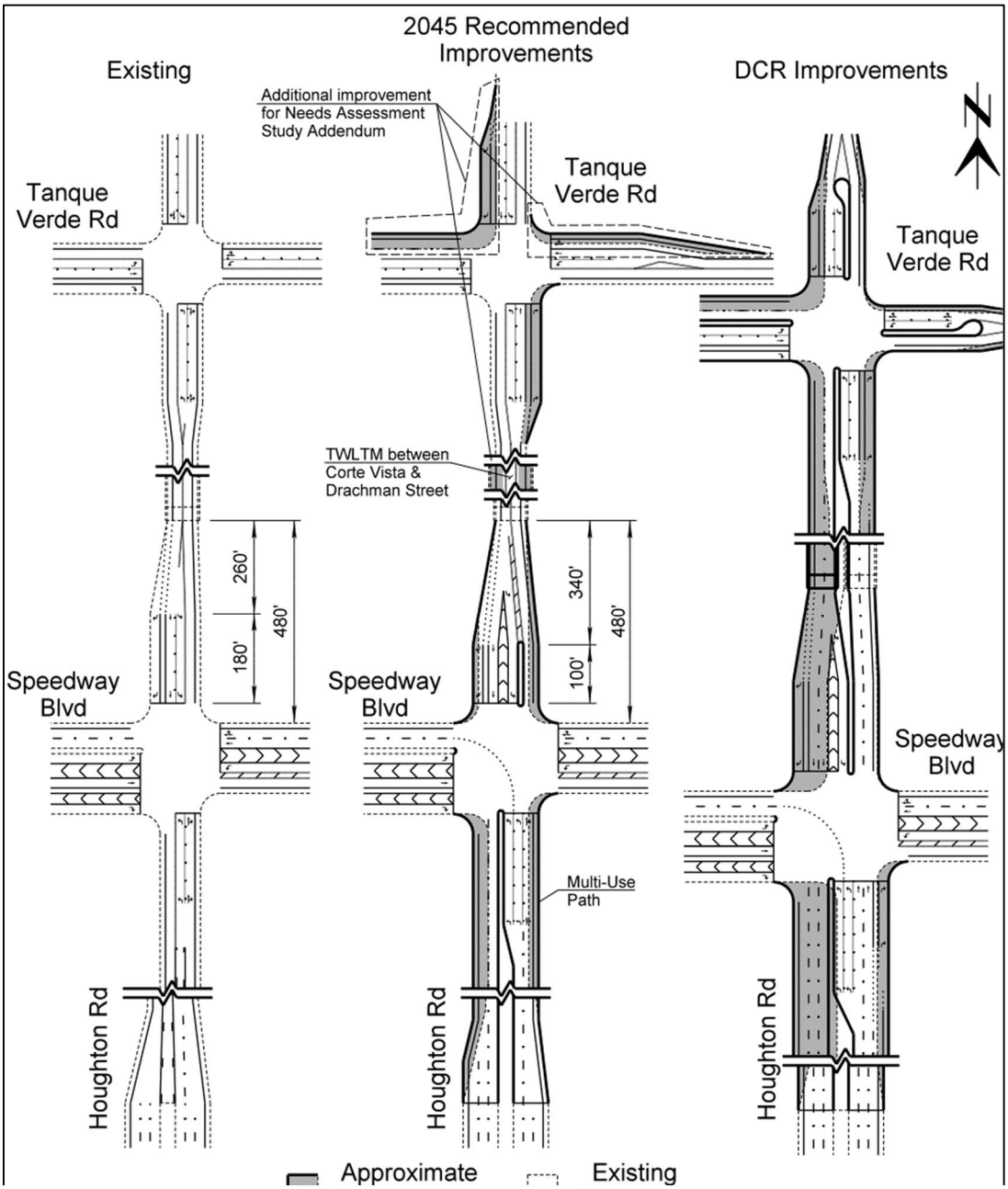


Figure 20 – Existing Conditions, 2045 Recommended Improvements, and 2010 DCR Improvements

3.4 PROPOSED CAPACITY ANALYSIS - 2045

The capacity of the proposed improvements was analyzed for the 2045 design year using the traffic projections described in Section 2.4.

Intersections

Modeled delay and LOS for the Houghton Road/Tanque Verde Road and Houghton Road/Speedway Boulevard intersections are shown in Table 8 and Table 9 for the year 2045 with the proposed improvements. As with the existing traffic conditions, RTOR volumes were estimated for the SB and EB right movements at the Houghton Road/Speedway Boulevard intersection. The addition of the NB right turn lane at Houghton Road/Tanque Verde Road has negligible impact on the overall intersection performance, but the addition of the SB right turn lane and second WB through lane on Tanque Verde Road improved the WB and EB approach from LOS E to D and allowed signal timing optimization to improve the NB left turn movement from LOS F to D.

The proposed improvements from the Needs Study at the Houghton Road/Speedway Boulevard intersection will operate with an overall acceptable intersection LOS D for the 2045 AM and PM Peak Hours. This will be close to existing conditions. For the AM Peak Hour, however, there will not be any movements at LOS F, which is occurring under existing conditions. For the PM Peak Hour, all traffic movements have LOS D or better. This is an overall improvement over the 2045 No Build performance at this intersection, which has several approaches with LOS E or F in the PM Peak.

Table 8 – 2045 Proposed Improvements LOS for Houghton Road & Tanque Verde Road

	SB ↓				WB ←				NB ↑				EB →				INT
	L	T	R	APR	L	T	R	APR	L	T	R	APR	L	T	R	APR	TOT
AM Delay	32.6	54.8	26.4	47.4	53.8	38.3	38.4	43.3	35.6	42.8	26.4	37.7	36.3	49.9	40.5	44.7	42.9
AM LOS	C	D	C	D	D	D	D	D	D	D	C	D	D	D	D	D	D
PM Delay	17.9	15.5	12.2	14.9	54.1	35.4	35.5	40.9	27.1	14.4	12.6	17.3	30.1	41.0	37.3	38.1	27.9
PM LOS	B	B	B	B	D	D	D	D	C	B	B	B	C	D	D	D	C

L = Left Lane group T = Through lane group R = Right Lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

	Table 9 – 2045 Proposed Improvements LOS for Houghton Road & Speedway Boulevard															
	SB ↓				WB ←				NB ↑			EB →				INT
	L	T	R	APR	L	T	R	APR	L	T/R	APR	L	T	R	APR	TOT
AM Delay	27.1	47.1	37.5	48.0	43.0	59.0	59.9	57.7	51.8	52.7	52.2	70.4	57.4	54.8	63.1	53.7
AM LOS	D	D	D	D	D	E	E	E	D	D	D	E	E	D	E	D
PM Delay	27.1	44.7	22.8	38.1	38.2	39.3	39.6	39.3	29.0	40.9	35.5	41.3	39.3	36.9	39.3	37.5
PM LOS	C	D	C	D	D	D	D	D	C	D	D	D	D	D	D	D

L = Left lane group T = Through lane group R = Right lane group T/R = Shared through/right lane group
APR = Approach Delay units: seconds/vehicle

Roadway

Peak hour roadway segment LOS and performance measures for the 2045 design year with proposed improvements are shown in Table 10. Roadway segment LOS between Speedway Boulevard and Tanque Verde Road was analyzed using HCM methodology for two-lane highways. Since there are no changes to the roadway section between Tanque Verde Road and Speedway Boulevard, the LOS remains the same as the 2045 No Build analysis.

The segment between Broadway Boulevard and Speedway Boulevard was analyzed using HCM methodology for multilane highways due to the additional lanes, using Average Speed (AS) and density (Passenger Cars per Mile per Lane, pc/mi/ln) as a performance measure. NB and SB directions were analyzed separately. LOS is expected to improve to LOS B in the AM peak and LOS A in the PM peak. HCM reports are included in Appendix C.

	Table 10 – Roadway Segment 2045 Proposed Improvements LOS					
	NB Broadway Blvd to Speedway Blvd			Speedway Blvd to Tanque Verde Rd		
	LOS	AS	pc/mi/ln	LOS	ATS	PTSF
AM - NB	B	42.1	16.4	E	27.9	85.3
AM - SB	A	42.1	10.5			
PM - NB	B	42.1	11.7	E	30.3	79.6
PM - SB	B	42.1	11.2			

3.5 RIGHT TURN WARRANT ANALYSIS

The City of Tucson requested a warrant analysis for proposed right turn lanes on the Houghton Road project following guidance shown in the City of Tucson's *2021 Street Design Guide*.

Figure 5.5 (Right-Turn Guidelines) of the guide provides graphs for both 2-lane and 4-lane roadways. NB and SB right turn lanes are recommended for the Houghton Road/Tanque Verde Road intersection. At this intersection, Houghton Road is a 2-lane roadway. 2045 AM and PM peak hour approach volumes and right turn volumes were plotted on the 2-Lane Guideline graph for both the NB and SB Houghton Road approaches to Tanque Verde Road (Figure 21). Table 11 shows the data for the evaluation. Since the plotted points fall above the 45-mph curve (used as the reference given the 45-mph speed limit on Houghton Road), the projected 2045 volumes support consideration of right turn lanes on the NB and SB approaches.

Table 11 – 2045 AM / PM Right Turn & Approach Volumes

Houghton Road & Tanque Verde Road				
Direction	**AM Right Turn Volume**	**AM Approach Volume**	**PM Right Turn Volume**	**PM Approach Volume**
NB	173	805	163	681
SB	143	643	121	526

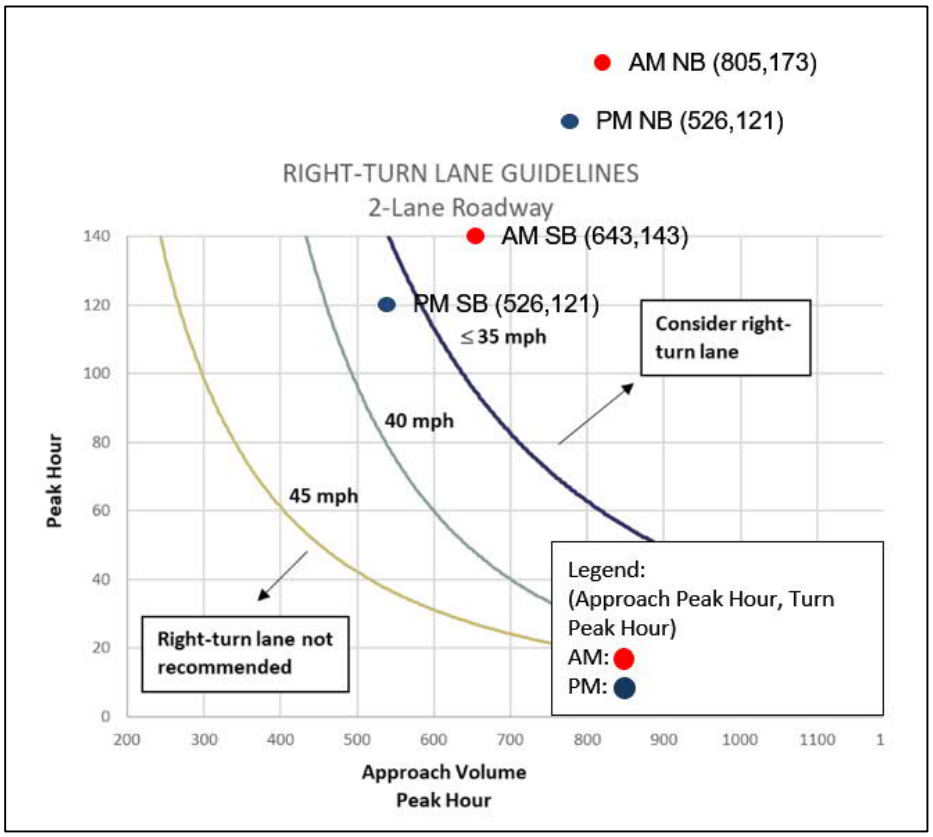


Figure 21 – Right Turn Lane Guidelines – Right Turn Lanes NB and SB at the Houghton Road/Tanque Verde Road Intersection

4 POTENTIAL IMPACTS

The potential utility, environmental, bridge, and ROW impacts of the proposed recommendations are described in Section 6 of the Needs Study. The following sections summarize the added potential impacts from the additional recommendations in this Study Addendum to utilities, the environment, and existing bridges.

4.1 EXISTING UTILITIES

The Needs Study recommendations were evaluated for impacts to the existing utilities and documented in that report. The impact to the existing utilities with the additional recommendations for the Study Addendum were reviewed against the utilities noted in the Needs Study. The following are the known utilities and anticipated impacts for the additional Study Addendum recommendations.

Fiber Optic – Cox Communications

The additions of a TWLTL between the Agua Caliente Wash and Tanque Vere Wash and the multi-use path along the east side of Houghton may have an impact to the fiber optics south of Corte Vista La Mariposa. The other additional recommendations do not impact fiber optic lines.

Natural Gas – Southwest Gas

The addition of WB through lane located on the intersection of Houghton Road and Tanque Verde may impact the gas line running east/west on Tanque Verde Road. The other additional recommendations do not impact the gas line.

Water – Tucson Water

The addition of the SB right turn lane at the Houghton Road and Tanque Verde Road intersection may impact two water lines running North/South on the west side of Houghton Road. The WB through lane at the Houghton Road and Tanque Verde Road may impact a water line located on the east side of the intersection.

The TWLTL along the east side of Houghton Road between the bridges and the multi-use path along the east side of Houghton Road do not have any anticipated impacts to the water utilities.

Traffic Signals – City of Tucson

There are no additional impacts to the traffic signals at the Houghton Road/Tanque Verde Road intersection or at the Houghton Road/Speedway Boulevard intersection from the additional Study Addendum recommendations. The traffic signal at the Houghton Road/Tanque Verde Road intersection was anticipated to be reconstructed based on the recommendations from the Needs Study.

No additional impacts are anticipated for the following utilities:

- Electric – Tucson Electric Power (TEP)
- Telephone – Century Link

- Sanitary Sewer – Pima County Regional Wastewater Reclamation Department
- Cable – Cox Communications

4.2 ENVIRONMENTAL STUDY UPDATES

Information on this topic can be found in Section 6.2 of the Needs Study. Impacts for the additional recommendations from this Study Addendum are as follows:

Vegetation

The areas of impact for the additional recommended improvements will need to be added to the assessment of protected native plants that will be inventoried, salvaged if appropriate, and replanted within the project area.

Wildlife

The additional recommended turn lanes at the Houghton Road / Tanque Verde intersection, the TWLTL on Houghton Road between Corte Vista La Mariposa and Drachman Street, and the multi-use path on the multi-span bridges will not impact the critical wildlife linkages provided by these the bridges over the Agua Caliente Wash and Tanque Verde Creek.

Special Status Species

The additional recommendations will not change the site survey recommended to determine if the Western Yellow-billed Cuckoo and any additional listed species are present in the project area. If any are found, the city should consult with the US Fish and Wildlife Service.

Critical Habitat

The additional recommendations expand the project area but do not extend to critical habitat areas, so no special action is needed.

Cultural Resources

The Needs Study identified two previously recorded prehistoric sites affected by the proposed improvements. The additional recommendations of this Addendum do not impact other recorded prehistoric sites.

Air Quality

As has been discussed in the Needs Study, the additional recommendations of this Addendum are anticipated to reduce congestion and lower air pollutant levels.

Noise

The addition of a SB right turn lane and WB through lane at the Houghton Road / Tanque Verde Road intersection will not be in the vicinity of a significant number of residential properties nor noise-sensitive sites. As noted in the Needs Study, alternative noise abatement measures should be considered to reduce noise during construction and following completion.

Hazardous Materials

No additional property acquisition is anticipated with the additional recommendations of this Addendum. As noted in the Needs Study, a Phase I Environmental Assessment Study will likely need to be conducted for the additional ROW identified in the Needs Study.

Aesthetic Resources

As noted in the Needs Study, Houghton Road is designated as a scenic route and the landscaping recommendations outlined in the Needs Study should be considered for the areas of the additional recommendations of this Addendum.

Neighborhood Impact

Connectivity will be further enhanced along the Houghton Road corridor with the change in the recommendation for a sidewalk to a multi-use path on the east side of Houghton Road between Speedway Boulevard and Broadway Boulevard. As a result, there will be a continuous multi-use path along the Houghton Road corridor from Tanque Verde Road south approximately 13 miles to I-10 with the completion of the RTA projects along Houghton Road.

Community Resources

As noted in the Needs Study, two-way traffic should be maintained as much as possible and emergency access should be preserved during construction of the additional recommendations. The intersection of Houghton Road / Tanque Verde Road will be impacted more from the additional recommendations. Close coordination of construction activities will be needed with the Tanque Verde School District and the City of Tucson Ward 2.

Recommendation for Further Study

No further study is anticipated beyond that mentioned above.

Environmental Documentation

Federal funds are not anticipated to be used for improvements of the Houghton Road, Tanque Verde Road to Speedway Boulevard project, so a scoping document that summarizes the environmental studies likely will not need to be prepared. As noted in the Needs Study, the studies that will need to be updated relate to the Arizona Antiquities Act (cultural resource evaluation), Endangered Species Act (biological evaluation), and Section 404 of the Clean Water Act (preliminary jurisdictional delineation). A review/update of the documents that were prepared at the time of the 2010 DCR will be needed and the updated reports filed with the city.

4.3 STRUCTURES

Information on this topic can be found in Section 6.3 of the Needs Study. There are no further recommendations for the bridges over the Aqua Caliente Wash and Tanque Verde Creek from the reevaluation of the traffic projections to 2045 for this Study Addendum.

4.4 RIGHT OF WAY

Information on this topic can be found in Section 6.3 of the Needs Study Assessment. Each of the additional recommendations for this Study Addendum have potential ROW impacts. The following are the Study Addendum recommendations with the assessment of potential ROW impacts:

- SB Houghton Road right turn lane at Tanque Verde Road:
    - The existing ROW line on Houghton Road north of Tanque Verde Road is approximately 52 feet from the SB roadway edge and 76 feet east of the centerline. The addition of a SB right turn lane will add approximately 11 feet of pavement and include provisions for a 6-foot shoulder. Construction is anticipated to occur without the need for additional ROW or Temporary Construction Easements (TCEs) along the west side of Houghton Road north of Tanque Verde Road.
- Second WB Tanque Verde Road through lane at Houghton Road:
    - The existing ROW on Tanque Verde Road east of Houghton Road is approximately 18 feet from the WB roadway edge and 41 feet north of the centerline. Approximately 312 feet east of the intersection, the existing ROW is 30 feet from the WB roadway edge and 53 feet north of the centerline. The addition of a second WB through lane will add approximately 11 feet of pavement and include provisions for a 6-foot shoulder for use by bikes. This additional pavement will place the roadway edge near the existing ROW line in the vicinity of the intersection. Acquisition of an additional 12 feet within 310 feet of the east approach of the intersection will provide an area for construction activity, maintenance, and potential for future pedestrian facilities on the north side of Tanque Verde Road. This additional ROW is approximately 3745 SF or 0.09 AC. Current property ownership is New Era Tucson LLC.
- TWLTL on Houghton Road between Corte Vista La Mariposa and Drachman Street:
    - The existing ROW on Houghton Road between the Agua Caliente Wash and Tanque Verde Creek bridges is 81 to 130 feet from the existing roadway centerline. The existing roadway is approximately 40 feet wide (2 12-foot lanes plus 2 8-foot shoulders). There is an existing NB Left Turn Lane approaching Corte Vista La Mariposa where the pavement is approximately 44 feet wide (3 12-foot lanes and 2 4-foot shoulders). The addition of a TWLTL is anticipated to widen Houghton Road 10 feet on both the east and west side of the roadway, south of Corte Vista La Mariposa, approximately 950 feet to the bridge over the Tanque Verde Creek and 295 feet north of Corte Vista La Mariposa for a SB right turn lane. The existing side slopes are anticipated to be maintained, so the resulting impact will extend 10 feet beyond the current toes of slope on either side of Houghton Road. This work is anticipated to stay within the existing ROW and will not need TCEs.

- A multi-use path along the east side of Houghton Road instead of a sidewalk between Speedway Boulevard and Broadway Boulevard
    - The multi-use path will be approximately 10 feet wide as opposed to the proposed 6-foot sidewalk. The additional 4 feet of path width will extend work to the east a minimum of 4 feet with additional width required for the side slopes. The existing ROW is approximately 124 feet from the Houghton Road centerline from a point approximately 600 feet south of Speedway Boulevard south to Packard Street and 94 feet from the centerline near Packard Street south to Broadway Boulevard. The Needs Study identified the need for additional ROW within the 600-foot distance south of Speedway Boulevard on the east side. The additional work to construct the multi-use path instead of the sidewalk is anticipated to be contained within the new ROW proposed for the Needs Study and existing ROW south of this acquisition and will not require any additional ROW or TCEs.

5 COST ESTIMATES

The 2010 DCR estimated cost for the project was documented in the Needs Study and is shown in Table 12. The estimate was based on the preliminary design plans included as part of the 2010 DCR. The total estimated project cost was $21.4 million, including construction, right of way, and design fees.

The Federal Highway Administration's (FHWA) National Highway Construction Cost Index (NHCCI) was used to determine the DCR estimated cost in 2018 dollars. The NHCCI index increased 30% between June 2009 and December 2018 (the latest available NHCCI at the time of this study), from 1.4398 to 1.8727. The 2018 adjusted DCR cost was $27,842,000.

Table 12 – DCR Cost Estimate (2009 Dollars)

Item	Cost
Roadway Construction	$5,271,000
Drainage	$2,495,000
Utility Relocations and Modifications	$198,000
Signing	$38,000
Striping	$38,000
Traffic Signals	$580,000
Landscaping	$294,000
Subtotal Roadway Construction Cost	**$8,914,000**
Bridge (Agua Caliente Wash)	$1,690,000
Bridge (Tanque Verde Creek)	$5,246,000
Subtotal Bridge Construction Cost	**$6,936,000**
NPDES (Original)	$158,000
NPDES (Modifications)	$79,000
Mobilization (Est. 10%)	$892,000
Maintenance and Protection of Traffic (Est. 9%)	$803,000
Construction Survey and Layout (1%)	$90,000
Contingencies (20%)	$1,783,000
Miscellaneous Construction Subtotal	**$3,805,000**
Construction Subtotal	**$19,655,000**
Design Fee (6%)	$1,180,000
Right-of-Way (Est. $150,000 / AC)	$528,000
Easements (Est. $40,000 / AC) (not incl. TCE's)	$43,000
Total Project Cost (Rounded)	**$21,406,000**

5.1 PROPOSED RECOMMENDATIONS COST

The cost of the proposed improvements is based on escalating the costs of the recommendations from the Needs Study and providing construction cost estimates for the additional improvements needed to achieve an acceptable LOS for the year 2045.

Needs Study Recommendations Cost

The Needs Study provided cost estimates of the proposed recommendations that included the following improvements:

- Houghton Road NB right turn lane at Tanque Verde Road
- Houghton Road / Speedway Boulevard intersection (with Speedway Boulevard to Broadway Boulevard widening)
- Bridge Repair (to bridges over the Tanque Verde Creek and Agua Caliente Wash)
- Multi-Use Path from Speedway Boulevard to Tanque Verde Road

Those improvements and anticipated construction costs were summarized in a table submitted to the City of Tucson in January 2020 (Figure 22).

	NB Rght	Houghton/ Speedway	Bridge Repair	Multi-Use Path (MUP)	
Description	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Totals**
Roadway Subtotal	$378,000	$5,558,000		$360,000	$6,296,000
Bridge Work for MUP				$345,000	$345,000
Bridge Repair			$775,000		$775,000
Subtotals	**$378,000**	**$5,558,000**	**$775,000**	**$705,000**	**$7,416,000**
Utility Relocation (2.5% of the Roadway Subtotal)	$9,450	$138,950		$9,000	$157,400
NPDES (3% of Roadway Subtotal)	$11,400	$166,800		$21,200	$199,400
Mobilization (10% of Roadway and Bridge Subtotal)	$38,000	$556,000	$78,000	$71,000	$743,000
Maintenance and Protection of Traffic (9% of Roadway and Bridge Subtotal)	$35,000	$501,000	$70,000	$64,000	$670,000
Construction Survey and Layout (1% of Roadway Subtotal)*	$3,780	$55,580		$6,000	$65,360
Miscellaneous Construction Subtotal	**$97,630**	**$1,418,330**	**$148,000**	**$171,200**	**$1,835,160**
* $6,000 min for MUP					
Construction Subtotal	**$475,630**	**$6,976,330**	**$923,000**	**$876,200**	**$9,251,160**
Design Fees (8%-10% of Const Subtotal + Est $30,000 Bridge Repair Design)	$48,000	$559,000	$30,000		$637,000
Design Fees (10% of Const Subtotal + Est $70,000 Bridge MUP Design)				$158,000	$158,000
Right of Way (Est $200,000/AC)		$206,000			$206,000
Subtotals	**$523,630**	**$7,741,330**	**$953,000**	**$1,034,200**	**$10,252,160**
Contingency (20%)	$104,726	$1,548,266	$190,600	$206,840	$2,050,432
Totals	$628,356	$9,289,596	$1,143,600	$1,241,040	$12,302,592
Project Totals (Rounded)	**$628,400**	**$9,289,600**	**$1,143,600**	**$1,241,100**	**$12,303,000.00**

Figure 22 – Houghton Road, Broadway Blvd to Speedway Blvd – Needs Study Improvements Cost

Construction Cost Escalation

In recent years, the cost of roadway construction items has increased significantly. There have been supply shortages and difficulty obtaining materials due to the COVID pandemic as well as general inflation of consumer costs. To account for the cost increases, WSP reviewed the ADOT Construction Cost Index and recent bid tabulations from local construction projects such as the ADOT I-10 Ruthrauff TI project, which was bid in late 2019.

The ADOT Construction Cost Index shows increases in construction costs for roadway projects relative to a given year. Currently this index is based on 2016 costs. There has been an increase in costs each year from 2016 with an overall increase in construction costs from 2016 of 56%. From 2019, when the Needs Study was completed, construction costs have increased approximately 17%.

In the recent bid tabulation for the ADOT I-10 Ruthrauff TI project, items that contributed to a significant portion of a roadway construction cost were reviewed, such as Aggregate Base and Asphalt Concrete. There was an overall average construction cost increase of 22% for these items from the costs used in the Needs Study. Items that have less contribution to the overall construction costs have had more dramatic increases such as nearly 80% for pavement markings and over 60% for concrete items.

Combining the review of the ADOT Construction Cost Index with items from the ADOT I-10 Ruthrauff TI project, a value of 22% was selected for use on escalating costs from the Needs Study. Though higher than the ADOT Construction Cost Index increase of 17%, this percentage takes into consideration concrete items such as curb, sidewalk, curb access ramps, and concrete lined channel for the channel on the southeast corner of Houghton Road and Tanque Verde Road.

Study Addendum Additional Recommendation Construction Costs

The construction costs of the additional recommendations in this Study Addendum were estimated. Construction cost items were estimated at a project assessment level using square foot areas of roadway and relative quantity estimates between the different areas of improvements. An example of this approach would be factoring the estimated construction cost for items for the NB right turn lane on Houghton Road at Tanque Verde Road with the relative areas of the additional SB right turn lane and WB through lane at the Houghton Road / Tanque Verde Road intersection.

The estimate for the roadway improvements at Houghton Road / Speedway Boulevard included a 6-foot sidewalk along the east side of Houghton Road from north of Vicksburg Street to Speedway Boulevard, with a length of approximately 4000 feet. Changing the 6-foot sidewalk to a 10-foot asphalt multi-use path results in a change in unit costs of the materials as well as the added earthwork for the wider facility. The change in the cost is reflected in the 2021 cost estimate for the Houghton Road/Speedway Boulevard Intersection – Multi-Use Path.

Table 13 provides a summary of the overall estimated construction cost for the improvements for the Houghton Road, Tanque Verde Road to Speedway Boulevard project. This includes applying a 22% increase in construction costs to the recommendations for the Needs Study and the additional costs of the recommendations for this Study Addendum.

Table 13 – Houghton Road, Tanque Verde Road to Speedway Boulevard Recommended Improvement Costs		
Needs Assessment Study Improvements	**2019**	**2021**
Houghton Road NB Right Turn Lane at Tanque Verde Road	$628,400	$752,400
Houghton Road / Speedway Boulevard Intersection – Multi-Use Path	$9,289,600	$11,695,000
Bridge Repair	$1,143,600	$1,383,600
Multi-Use Path from Speedway Blvd to Tanque Verde Rd	$1,241,040	$1,519,000
Study Addendum Additional Recommendations		
SB Right Turn Lane at Tanque Verde Road		$215,600
WB Through Lane at Tanque Verde Road		$897,500
TWLTL on Houghton Rd, Corte Vista La Mariposa and Drachman Street		$581,300
Multi-Use Path replacing Sidewalk east side of Houghton Road – see above		
Total Project Cost	$12,302,640	$17,044,400
Totals Project Cost (Rounded)	**$12,303,000**	**$17,045,000**

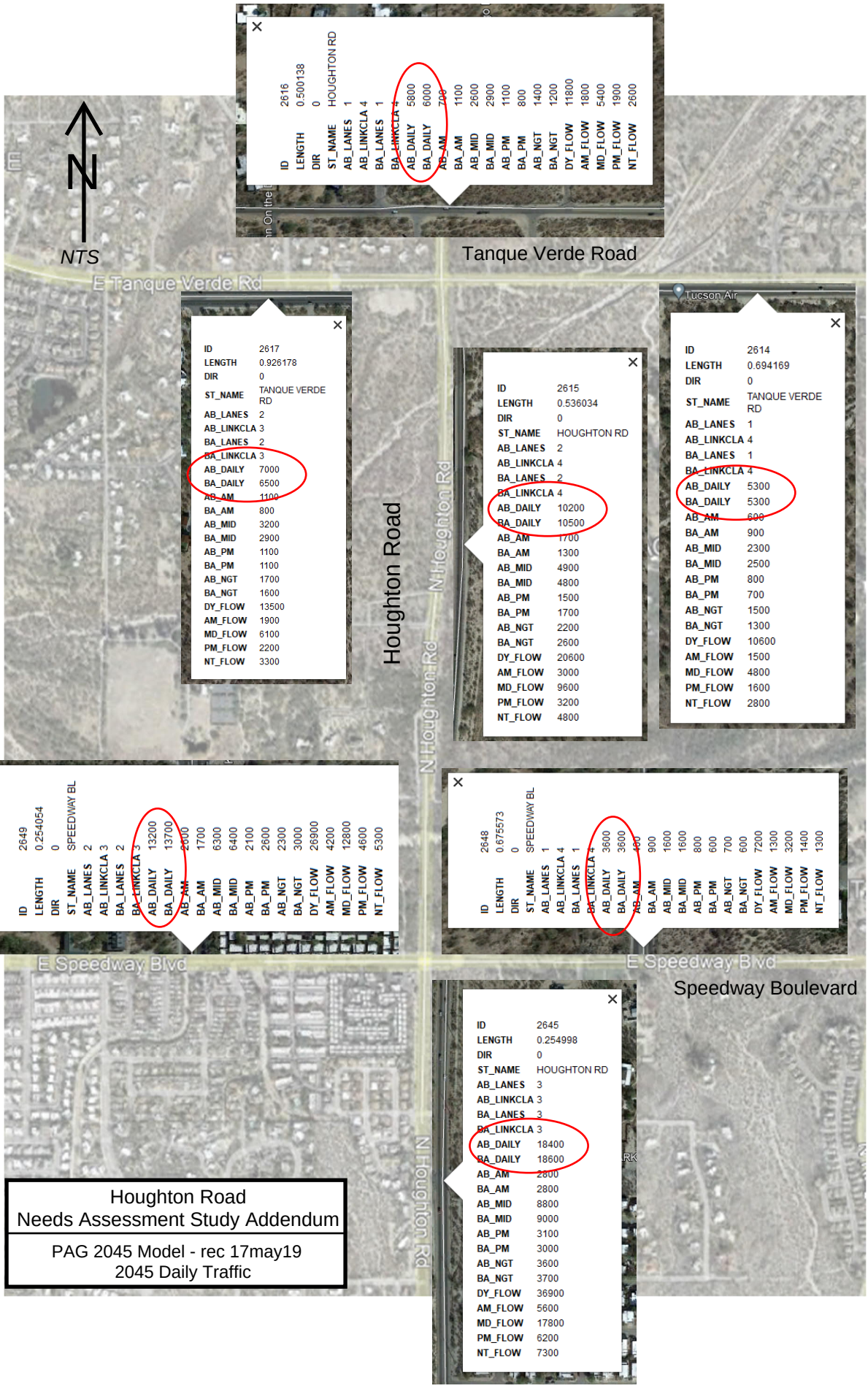
Detailed construction cost breakdowns are included in the appendix.

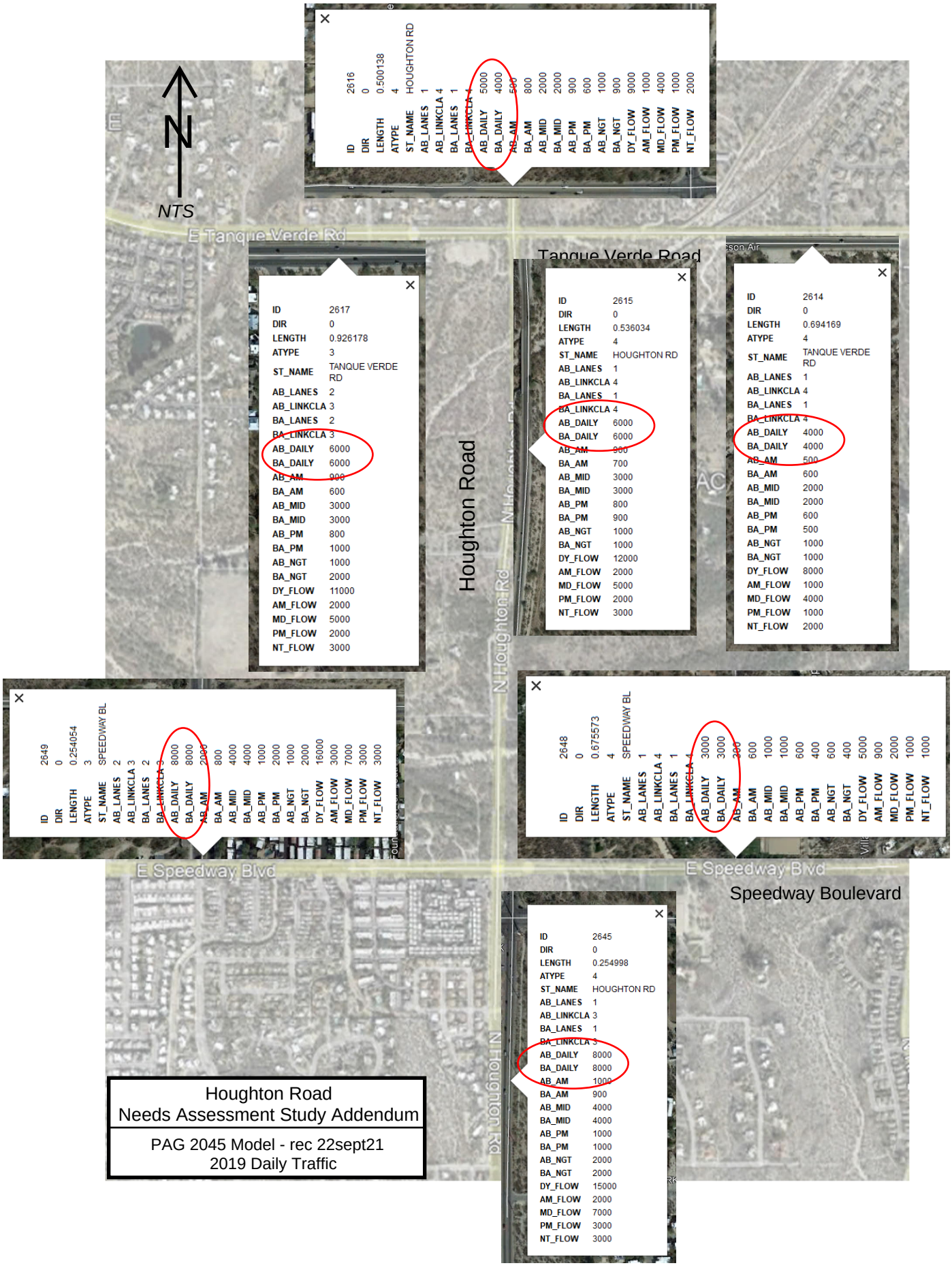
5.2 PROJECT PHASING

In the Needs Study, the project improvements were expected to be constructed in phases. From discussions with DTM during development of the Study Addendum, all improvements are now anticipated to be constructed in a single project due to limited funding from the city outside of the anticipated funding for the project from the RTA. However, phasing of the project should still be considered given the public comment on the existing poor traffic operations at the Houghton Road/Tanque Verde Road intersection during the school year. The NB Right Turn Lane could be constructed as its own project though available funds if the funding and schedule for the remainder of the project are not expected in the near future.

APPENDIX

A PAG 2045 MODEL


NTS
E Tanque Verde Rd
Tanque Verde Road
Houghton Road
N Houghton Rd
E Speedway Blvd
Speedway Boulevard
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PM_FLOW 1900
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PM_FLOW 1600
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Houghton Road
Needs Assessment Study Addendum
PAG 2045 Model - rec 17may19
2045 Daily Traffic



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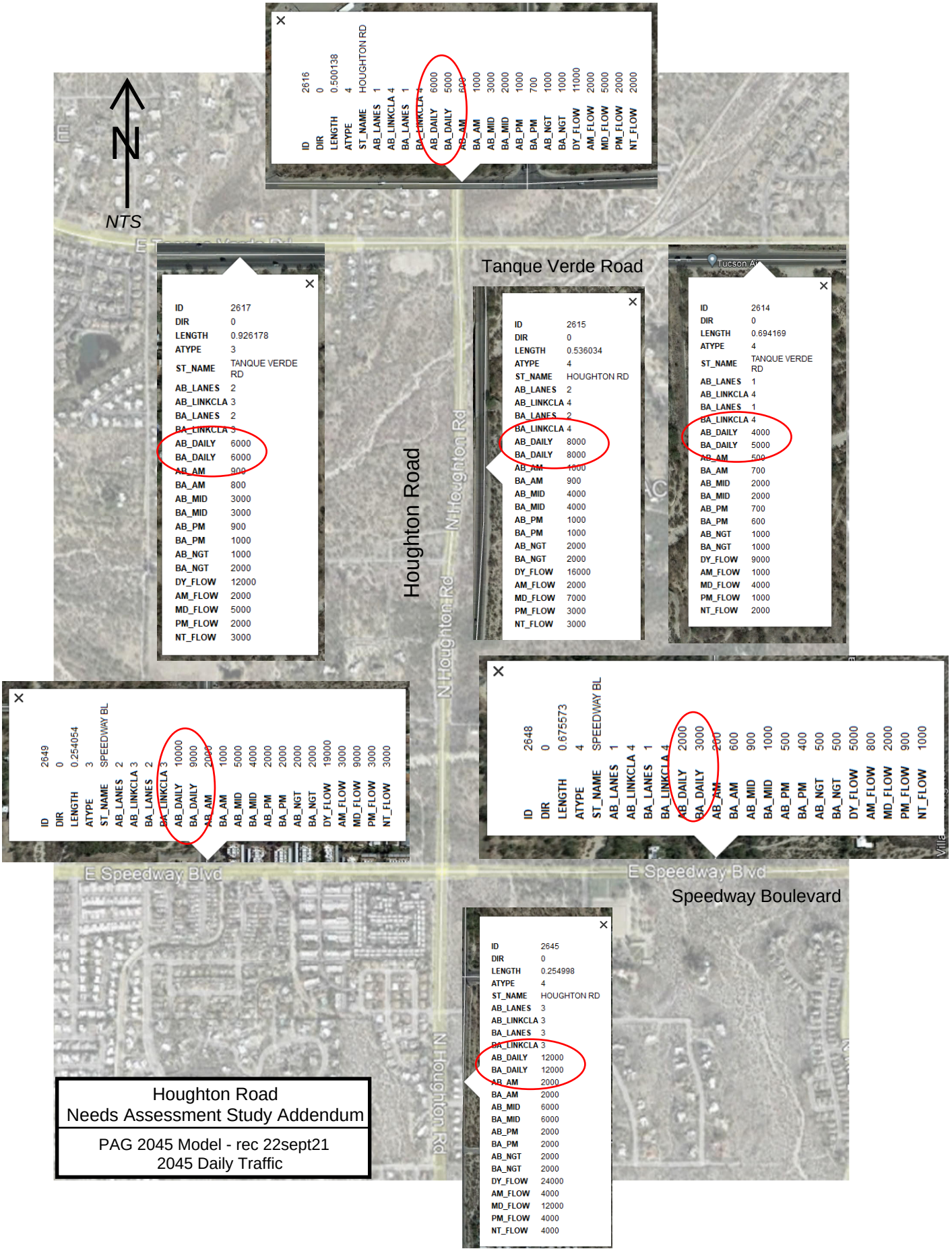
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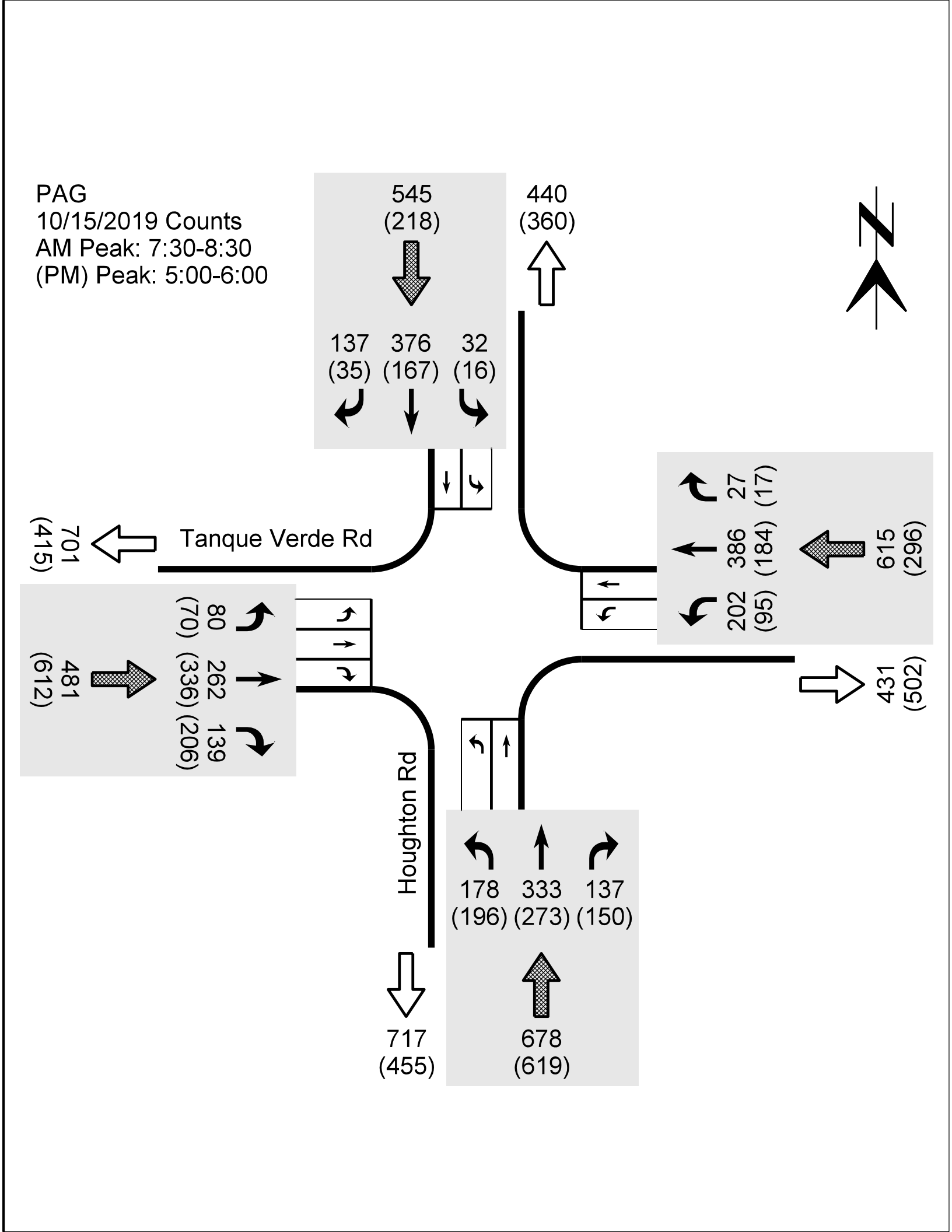
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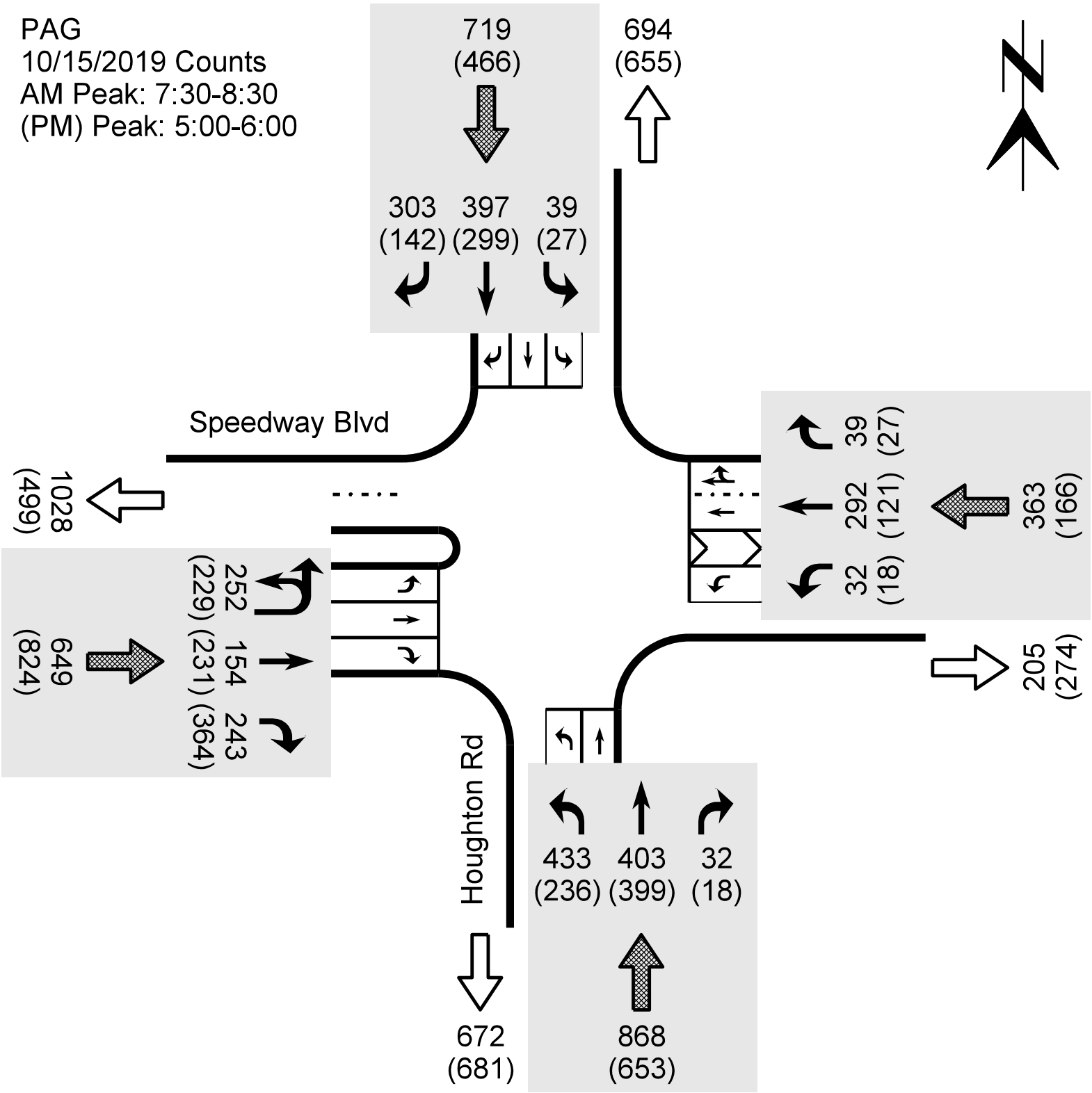
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MD_FLOW	12000
PM_FLOW	4000
NT_FLOW	4000

APPENDIX

B TRAFFIC COUNT DATA

5/7/2019 Counts
AM Peak: 7:30-8:30
(PM) Peak: 3:00-4:00
Tanque Verde Rd
Houghton Rd
501
(582)
73
(86)
275
(309)
153
(187)
618
(524)
702
(606)
501
(410)
114
(97)
363
(290)
24
(23)
439
(359)
125
(130)
332
(245)
125
(118)
582
(493)
186
(129)
379
(297)
34
(28)
599
(454)
424
(450)
5/7/2019 Counts
AM Peak: 7:30-8:30
(PM) Peak: 3:15-4:15
Speedway Blvd
Houghton Rd
635
(753)
262
(211)
144
(210)
229
(332)
1079
(630)
647
(738)
698
(602)
291
(190)
376
(377)
31
(35)
623
(501)
446
(275)
360
(291)
35
(34)
841
(600)
42
(29)
303
(143)
40
(21)
385
(193)
210
(279)


PAG
10/15/2019 Counts
AM Peak: 7:30-8:30
(PM) Peak: 5:00-6:00
545
(218)
440
(360)
137
(35)
376
(167)
32
(16)
701
(415)
Tanque Verde Rd
27
(17)
386
(184)
202
(95)
615
(296)
80
(70)
262
(336)
139
(206)
481
(612)
431
(502)
Houghton Rd
178
(196)
333
(273)
137
(150)
717
(455)
678
(619)


PAG
10/15/2019 Counts
AM Peak: 7:30-8:30
(PM) Peak: 5:00-6:00
719
(466)
694
(655)
303
(142)
397
(299)
39
(27)
Speedway Blvd
1028
(499)
39
(27)
292
(121)
32
(18)
363
(166)
252
(229)
154
(231)
243
(364)
649
(824)
205
(274)
Houghton Rd
433
(236)
403
(399)
32
(18)
672
(681)
868
(653)

APPENDIX

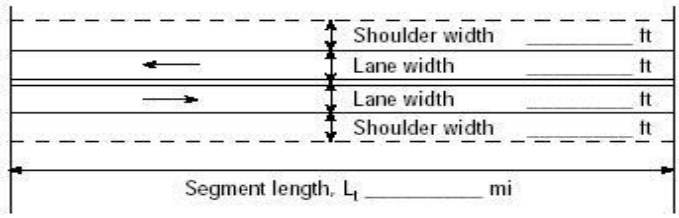
C HCM REPORTS

DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Speedway Blvd to Tanque Verde*
Date Performed	*6/13/2019*	Jurisdiction	*City of Tucson*
Analysis Time Period	*AM Peak*	Analysis Year	*2019 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



Show North Arrow

☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☑ Level ☐ Rolling

Analysis direction vol., V_d	*623*veh/h	Grade Length mi	Up/down
Opposing direction vol., V_o	*698*veh/h	Peak-hour factor, PHF	*0.88*
Shoulder width ft	*8.0*	No-passing zone	*100%*
Lane Width ft	*12.0*	% Trucks and Buses , P_T	*2 %*
Segment Length mi	*1.7*	% Recreational vehicles, P_R	*2%*
		Access points *mi*	*2*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*1.1*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.998*	*0.998*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*709*	*795*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.2 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, ATS_d=FFS-0.00776($v_{d,ATS}$ + $v_{o,ATS}$) - $f_{np,ATS}$	*31.6 mi/h*
		Percent free flow speed, PFFS	*71.0 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*708*	*793*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*65.8*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*26.6*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*78.3*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*
Volume to capacity ratio, *v/c*	*0.42*

Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*71.0*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*708.0*
Effective width, Wv (Eq. 15-29) ft	*28.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*2.24*
Bicycle level of service (Exhibit 15-4)	*B*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

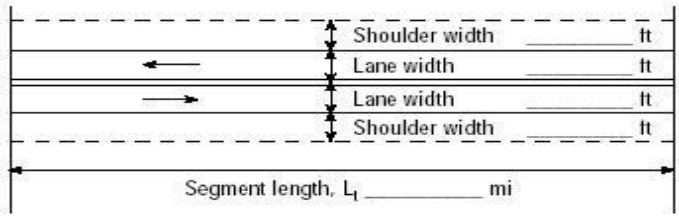
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Speedway Blvd to Tanque Verde*
Date Performed	*6/13/2019*	Jurisdiction	*City of Tucson*
Analysis Time Period	*PM Peak*	Analysis Year	*2030 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



Show North Arrow

☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☑ Level ☐ Rolling

Analysis direction vol., V_d	*501*veh/h	Grade Length mi	Up/down
Opposing direction vol., V_o	*602*veh/h	Peak-hour factor, PHF	*0.88*
Shoulder width ft	*8.0*	No-passing zone	*100%*
Lane Width ft	*12.0*	% Trucks and Buses , P_T	*2 %*
Segment Length mi	*1.7*	% Recreational vehicles, P_R	*2%*
		Access points *mi*	*2*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*1.1*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.998*	*0.998*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*570*	*685*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.5 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, ATS_d=FFS-0.00776($v_{d,ATS}$ + $v_{o,ATS}$) - $f_{np,ATS}$	*33.2 mi/h*
		Percent free flow speed, PFFS	*74.6 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*569*	*684*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*57.5*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*32.0*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*72.0*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*
Volume to capacity ratio, *v/c*	*0.33*

Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*74.6*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*569.3*
Effective width, Wv (Eq. 15-29) ft	*28.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*2.13*
Bicycle level of service (Exhibit 15-4)	*B*
Notes	
1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain. 2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F. 3. For the analysis direction only and for v>200 veh/h. 4. For the analysis direction only 5. Exhibit 15-20 provides coefficients a and b for Equation 15-10. 6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.	

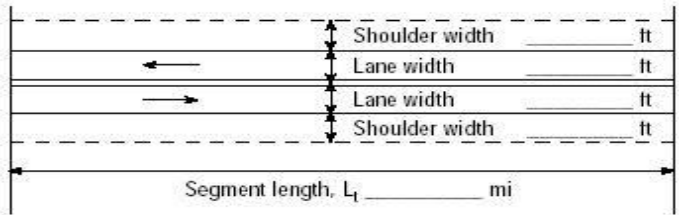
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Speedway Blvd to Tanque Verde*
Date Performed	*10/25/21*	Jurisdiction	*City of Tucson*
Analysis Time Period	*AM Peak*	Analysis Year	*2045 - Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



Show North Arrow

☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☑ Level ☐ Rolling

Analysis direction vol., V_d	*831* veh/h	Grade Length mi	Up/down
Opposing direction vol., V_o	*930* veh/h	Peak-hour factor, PHF	*0.88*
Shoulder width ft	*8.0*	No-passing zone	*100*%
Lane Width ft	*12.0*	% Trucks and Buses , P_T	*2* %
Segment Length mi	*1.7*	% Recreational vehicles, P_R	*2*%
		Access points *mi*	*2*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*944*	*1057*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, FFS=S_{FM}+0.00776(*v*/ $f_{HV,ATS}$)		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.1 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, ATS_d=FFS-0.00776($v_{d,ATS}$ + $v_{o,ATS}$) - $f_{np,ATS}$	*27.9 mi/h*
		Percent free flow speed, PFFS	*62.7* %

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*944*	*1057*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*76.6*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*18.4*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*85.3*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*
Volume to capacity ratio, *v/c*	*0.56*

Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*62.7*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*944.3*
Effective width, Wv (Eq. 15-29) ft	*28.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*2.39*
Bicycle level of service (Exhibit 15-4)	*B*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

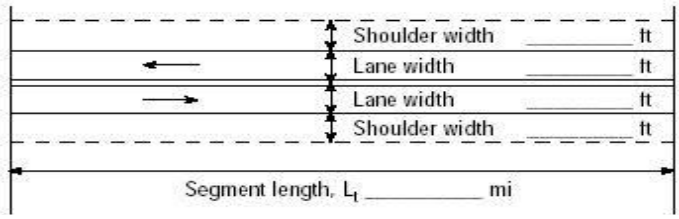
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Speedway Blvd to Tanque Verde*
Date Performed	*10/25/21*	Jurisdiction	*City of Tucson*
Analysis Time Period	*PM Peak*	Analysis Year	*2045 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data





☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☑ Level ☐ Rolling

Grade Length mi Up/down

Peak-hour factor, PHF *0.88*

No-passing zone *100%*

% Trucks and Buses , P_T *2 %*

% Recreational vehicles, P_R *2%*

Access points *mi* *2*/mi

Analysis direction vol., V_d *671*veh/h

Opposing direction vol., V_o *803*veh/h

Shoulder width ft *8.0*

Lane Width ft *12.0*

Segment Length mi *1.7*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.998*	*1.000*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*764*	*913*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.1 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*30.3 mi/h*
		Percent free flow speed, PFFS	*68.2 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*1.00*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*763*	*913*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*68.9*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*23.5*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*79.6*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*
Volume to capacity ratio, *v/c*	*0.45*

Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*68.2*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*762.5*
Effective width, Wv (Eq. 15-29) ft	*28.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*2.28*
Bicycle level of service (Exhibit 15-4)	*B*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

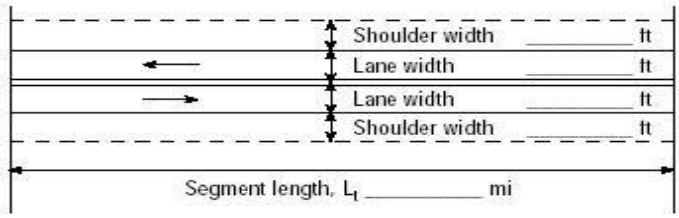
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Broadway Blvd to Speedway Blvd*
Date Performed	*6/28/2019*	Jurisdiction	*City of Tucson*
Analysis Time Period	*AM Peak*	Analysis Year	*2019 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☐ Level ☐ Rolling

Grade Length *1.00* mi Up/down *-3.0*

Peak-hour factor, PHF *0.88*

No-passing zone *100%*

% Trucks and Buses , P_T *2 %*

% Recreational vehicles, P_R *2%*

Access points *mi* *2*/mi

Show North Arrow

Analysis direction vol., V_d *841*veh/h

Opposing direction vol., V_o *647*veh/h

Shoulder width ft *6.0*

Lane Width ft *12.0*

Segment Length mi *0.5*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*4.2*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.940*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*960*	*782*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.3 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*29.7 mi/h*
		Percent free flow speed, PFFS	*66.8 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*0.93*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*956*	*791*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*74.2*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*22.0*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*86.2*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*

Volume to capacity ratio, *v/c*	*0.56*
Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*66.8*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*955.7*
Effective width, Wv (Eq. 15-29) ft	*24.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*3.43*
Bicycle level of service (Exhibit 15-4)	*C*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

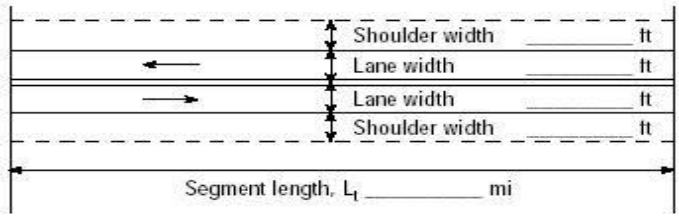
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Broadway Blvd to Speedway Blvd*
Date Performed	*6/28/2019*	Jurisdiction	*City of Tucson*
Analysis Time Period	*PM Peak*	Analysis Year	*2019 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



Analysis direction vol., V_d *600*veh/h

Opposing direction vol., V_o *738*veh/h

Shoulder width ft *6.0*

Lane Width ft *12.0*

Segment Length mi *0.5*



☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☐ Level ☐ Rolling

Grade Length *1.00* mi Up/down *-3.0*

Peak-hour factor, PHF *0.88*

No-passing zone *100%*

% Trucks and Buses , P_T *2 %*

% Recreational vehicles, P_R *2%*

Access points *mi* *2*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*4.2*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.940*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*685*	*892*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.2 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*31.1 mi/h*
		Percent free flow speed, PFFS	*69.9 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*0.93*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*682*	*902*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*65.5*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*24.9*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*76.2*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*

Volume to capacity ratio, *v/c*	*0.40*
Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*69.9*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*681.8*
Effective width, Wv (Eq. 15-29) ft	*24.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*3.26*
Bicycle level of service (Exhibit 15-4)	*C*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

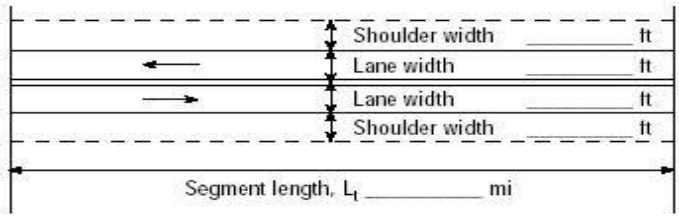
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Broadway Blvd to Speedway Blvd*
Date Performed	*12/21/21*	Jurisdiction	*City of Tucson*
Analysis Time Period	*AM Peak*	Analysis Year	*2045 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data



Analysis direction vol., V_d *1262*veh/h

Opposing direction vol., V_o *801*veh/h

Shoulder width ft *6.0*

Lane Width ft *12.0*

Segment Length mi *0.5*



☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☐ Level ☐ Rolling

Grade Length *1.00* mi Up/down *-3.0*

Peak-hour factor, PHF *0.88*

No-passing zone *100%*

% Trucks and Buses , P_T *2 %*

% Recreational vehicles, P_R *2%*

Access points *mi* *2*/mi

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*4.2*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.940*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*1440*	*968*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, $FFS=S_{FM}+0.00776(v/f_{HV,ATS})$		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.1 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, $ATS_d=FFS-0.00776(v_{d,ATS}+v_{o,ATS})-f_{np,ATS}$	*24.7 mi/h*
		Percent free flow speed, PFFS	*55.5 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*0.93*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*1434*	*979*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*86.8*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*12.7*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*94.3*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*

Volume to capacity ratio, *v/c*	*0.85*
Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*55.5*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*1434.1*
Effective width, Wv (Eq. 15-29) ft	*24.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*3.64*
Bicycle level of service (Exhibit 15-4)	*D*
Notes	
1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain. 2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F. 3. For the analysis direction only and for v>200 veh/h. 4. For the analysis direction only 5. Exhibit 15-20 provides coefficients a and b for Equation 15-10. 6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.	

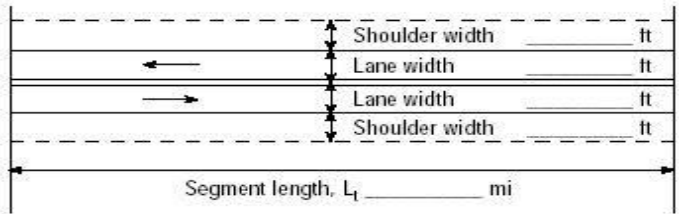
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DIRECTIONAL TWO-LANE HIGHWAY SEGMENT WORKSHEET

General Information		***Site Information***	
Analyst	*Joseph A. Vaskovic*	Highway / Direction of Travel	*Houghton Road*
Agency or Company	*WSP*	From/To	*Broadway Blvd to Speedway Blvd*
Date Performed	*12/21/21*	Jurisdiction	*City of Tucson*
Analysis Time Period	*PM Peak*	Analysis Year	*2045 Existing*

Project Description: *Houghton Road Needs Assessment*

Input Data





☑ Class I highway ☐ Class II highway ☐ Class III highway

Terrain ☐ Level ☐ Rolling

Grade Length *1.00* mi Up/down *-3.0*

Peak-hour factor, PHF *0.88*

No-passing zone *100%*

% Trucks and Buses , P_T *2 %*

% Recreational vehicles, P_R *2%*

Access points *mi* *2*/mi

Analysis direction vol., V_d	*901*veh/h
Opposing direction vol., V_o	*854*veh/h
Shoulder width ft	*6.0*
Lane Width ft	*12.0*
Segment Length mi	*0.5*

Average Travel Speed

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T (Exhibit 15-11 or 15-12)	*1.1*	*4.2*
Passenger-car equivalents for RVs, E_R (Exhibit 15-11 or 15-13)	*1.1*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV,ATS}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*0.996*	*0.940*
Grade adjustment factor[1], $f_{g,ATS}$ (Exhibit 15-9)	*1.00*	*1.00*
Demand flow rate[2], v_i (pc/h) $v_i=V_i/(PHF*f_{g,ATS}*f_{HV,ATS})$	*1028*	*1032*

Free-Flow Speed from Field Measurement		**Estimated Free-Flow Speed**	
Mean speed of sample[3], S_{FM}		Base free-flow speed[4], BFFS	*45.0 mi/h*
Total demand flow rate, both directions, *v*		Adj. for lane and shoulder width,[4] f_{LS}(Exhibit 15-7)	*0.0 mi/h*
Free-flow speed, FFS=S_{FM}+0.00776(*v*/ $f_{HV,ATS}$)		Adj. for access points[4], f_A (Exhibit 15-8)	*0.5 mi/h*
Adj. for no-passing zones, $f_{np,ATS}$ (Exhibit 15-15)	*1.1 mi/h*	Free-flow speed, FFS (FSS=BFFS-f_{LS}-f_A)	*44.5 mi/h*
		Average travel speed, ATS_d=FFS-0.00776($v_{d,ATS}$ + $v_{o,ATS}$) - $f_{np,ATS}$	*27.4 mi/h*
		Percent free flow speed, PFFS	*61.6 %*

Percent Time-Spent-Following

	Analysis Direction (d)	Opposing Direction (o)
Passenger-car equivalents for trucks, E_T(Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Passenger-car equivalents for RVs, E_R (Exhibit 15-18 or 15-19)	*1.0*	*1.0*
Heavy-vehicle adjustment factor, $f_{HV}=1/(1+P_T(E_T-1)+P_R(E_R-1))$	*1.000*	*1.000*
Grade adjustment factor[1], $f_{g,PTSF}$ (Exhibit 15-16 or Ex 15-17)	*1.00*	*0.93*
Directional flow rate[2], v_i(pc/h) $v_i=V_i/(PHF*f_{HV,PTSF}*f_{g,PTSF})$	*1024*	*1043*
Base percent time-spent-following[4], $BPTSF_d(\%)=100(1-e^{av_d^b})$	*78.9*	
Adj. for no-passing zone, $f_{np,PTSF}$ (Exhibit 15-21)	*17.7*	
Percent time-spent-following, $PTSF_d(\%)=BPTSF_d+f_{np,PTSF}*(v_{d,PTSF}/v_{d,PTSF}+v_{o,PTSF})$	*87.7*	

Level of Service and Other Performance Measures

Level of service, LOS (Exhibit 15-3)	*E*

Volume to capacity ratio, *v/c*	*0.60*
Capacity, $C_{d,ATS}$ (Equation 15-12) veh/h	*1700*
Capacity, $C_{d,PTSF}$ (Equation 15-13) veh/h	*1700*
Percent Free-Flow Speed $PFFS_d$(Equation 15-11 - Class III only)	*61.6*
Bicycle Level of Service	
Directional demand flow rate in outside lane, v_{OL} (Eq. 15-24) veh/h	*1023.9*
Effective width, Wv (Eq. 15-29) ft	*24.00*
Effective speed factor, S_t (Eq. 15-30)	*4.42*
Bicycle level of service score, BLOS (Eq. 15-31)	*3.47*
Bicycle level of service (Exhibit 15-4)	*C*
Notes	

1. Note that the adjustment factor for level terrain is 1.00,as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.
2. If v_i(v_d or v_o) >=1,700 pc/h, terminate analysis--the LOS is F.
3. For the analysis direction only and for v>200 veh/h.
4. For the analysis direction only
5. Exhibit 15-20 provides coefficients a and b for Equation 15-10.
6. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

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HCS7 Multilane Highway Report

Project Information

Analyst	Joseph A. Vaskovic	Date	10/25/21
Agency	WSP	Analysis Year	2045 - Proposed
Jurisdiction	City of Tucson	Time Period Analyzed	AM Peak Hour
Project Description	Houghton Road Needs Assessment Study - Addendum		

Direction 1 Geometric Data

Direction 1	Northbound Houghton, south of Speedway		
Number of Lanes (N), ln	2	Terrain Type	Specific Grade
Segment Length (L), ft	-	Percent Grade, %	-3.00
Measured or Base Free-Flow Speed	Base	Grade Length, mi	0.00
Base Free-Flow Speed (BFFS), mi/h	45.0	Total Ramp Density (TRD), ramps/mi	0.00
Lane Width, ft	12	Left-Side Lateral Clearance (LC_R), ft	1
Median Type	Divided	Total Lateral Clearance (TLC), ft	7.00
Access Point Density, pts/mi	2.0	Free-Flow Speed (FFS), mi/h	43.2

Direction 1 Adjustment Factors

Driver Population	Mostly Familiar	Final Speed Adjustment Factor (SAF)	0.975
Driver Population SAF	0.975	Final Capacity Adjustment Factor (CAF)	0.968
Driver Population CAF	0.968		

Direction 1 Demand and Capacity

Volume(V) veh/h	1262	Heavy Vehicle Adjustment Factor (f_{HV})	0.973
Peak Hour Factor	0.94	Flow Rate (V_p), pc/h/ln	690
Total Trucks, %	2.00	Capacity (c), pc/h/ln	1900
Single-Unit Trucks (SUT), %	70	Adjusted Capacity (c_{adj}), pc/h/ln	1839
Tractor-Trailers (TT), %	30	Volume-to-Capacity Ratio (v/c)	0.38

Direction 1 Speed and Density

Lane Width Adjustment (f_{LW})	0.0	Average Speed (S), mi/h	42.1
Total Lateral Clearance Adj. (f_{LLC})	1.3	Density (D), pc/mi/ln	16.4
Median Type Adjustment (f_M)	0.0	Level of Service (LOS)	B
Access Point Density Adjustment (f_A)	0.5		

Direction 1 Bicycle LOS

Flow Rate in Outside Lane (v_{OL}),veh/h	671	Effective Speed Factor (S_t)	4.17
Effective Width of Volume (W_v), ft	18	Bicyle LOS Score (BLOS)	2.84
Average Effective Width (W_e), ft	24	Bicycle Level of Service (LOS)	C

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HCS7 Multilane Highway Report

Project Information

Analyst	Joseph A. Vaskovic	Date	10/25/21
Agency	WSP	Analysis Year	2045 - Proposed
Jurisdiction	City of Tucson	Time Period Analyzed	AM Peak Hour
Project Description	Houghton Road Needs Assessment Study - Addendum		

Direction 2 Geometric Data

Direction 2	Southbound Houghton, south of Speedway		
Number of Lanes (N), ln	2	Terrain Type	Specific Grade
Segment Length (L), ft	-	Percent Grade, %	3.00
Measured or Base Free-Flow Speed	Base	Grade Length, mi	0.00
Base Free-Flow Speed (BFFS), mi/h	45.0	Total Ramp Density (TRD), ramps/mi	0.00
Lane Width, ft	12	Left-Side Lateral Clearance (LC_R), ft	1
Median Type	Divided	Total Lateral Clearance (TLC), ft	7.00
Access Point Density, pts/mi	2.0	Free-Flow Speed (FFS), mi/h	43.2

Direction 2 Adjustment Factors

Driver Population	Mostly Familiar	Final Speed Adjustment Factor (SAF)	0.975
Driver Population SAF	0.975	Final Capacity Adjustment Factor (CAF)	0.968
Driver Population CAF	0.968		

Direction 2 Demand and Capacity

Volume(V) veh/h	801	Heavy Vehicle Adjustment Factor (f_{HV})	0.965
Peak Hour Factor	0.94	Flow Rate (V_p), pc/h/ln	442
Total Trucks, %	2.00	Capacity (c), pc/h/ln	1900
Single-Unit Trucks (SUT), %	70	Adjusted Capacity (c_{adj}), pc/h/ln	1839
Tractor-Trailers (TT), %	30	Volume-to-Capacity Ratio (v/c)	0.24

Direction 2 Speed and Density

Lane Width Adjustment (f_{LW})	0.0	Average Speed (S), mi/h	42.1
Total Lateral Clearance Adj. (f_{LLC})	1.3	Density (D), pc/mi/ln	10.5
Median Type Adjustment (f_M)	0.0	Level of Service (LOS)	A
Access Point Density Adjustment (f_A)	0.5		

Direction 2 Bicycle LOS

Flow Rate in Outside Lane (v_{OL}),veh/h	426	Effective Speed Factor (S_t)	4.17
Effective Width of Volume (W_v), ft	18	Bicyle LOS Score (BLOS)	2.61
Average Effective Width (W_e), ft	24	Bicycle Level of Service (LOS)	C

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HCS7 Multilane Highway Report

Project Information

Analyst	Joseph A. Vaskovic	Date	10/25/2021
Agency	WSP	Analysis Year	2045 - Proposed
Jurisdiction	City of Tucson	Time Period Analyzed	PM Peak Hour
Project Description	Houghton Road Needs Assessment Study		

Direction 1 Geometric Data

Direction 1	Northbound Houghton, south of Speedway		
Number of Lanes (N), ln	2	Terrain Type	Specific Grade
Segment Length (L), ft	-	Percent Grade, %	-3.00
Measured or Base Free-Flow Speed	Base	Grade Length, mi	0.00
Base Free-Flow Speed (BFFS), mi/h	45.0	Total Ramp Density (TRD), ramps/mi	0.00
Lane Width, ft	12	Left-Side Lateral Clearance (LC_R), ft	1
Median Type	Divided	Total Lateral Clearance (TLC), ft	7.00
Access Point Density, pts/mi	2.0	Free-Flow Speed (FFS), mi/h	43.2

Direction 1 Adjustment Factors

Driver Population	Mostly Familiar	Final Speed Adjustment Factor (SAF)	0.975
Driver Population SAF	0.975	Final Capacity Adjustment Factor (CAF)	0.968
Driver Population CAF	0.968		

Direction 1 Demand and Capacity

Volume(V) veh/h	901	Heavy Vehicle Adjustment Factor (f_{HV})	0.973
Peak Hour Factor	0.94	Flow Rate (V_p), pc/h/ln	492
Total Trucks, %	2.00	Capacity (c), pc/h/ln	1900
Single-Unit Trucks (SUT), %	70	Adjusted Capacity (c_{adj}), pc/h/ln	1839
Tractor-Trailers (TT), %	30	Volume-to-Capacity Ratio (v/c)	0.27

Direction 1 Speed and Density

Lane Width Adjustment (f_{LW})	0.0	Average Speed (S), mi/h	42.1
Total Lateral Clearance Adj. (f_{LLC})	1.3	Density (D), pc/mi/ln	11.7
Median Type Adjustment (f_M)	0.0	Level of Service (LOS)	B
Access Point Density Adjustment (f_A)	0.5		

Direction 1 Bicycle LOS

Flow Rate in Outside Lane (v_{OL}),veh/h	479	Effective Speed Factor (S_t)	4.17
Effective Width of Volume (W_v), ft	18	Bicyle LOS Score (BLOS)	2.67
Average Effective Width (W_e), ft	24	Bicycle Level of Service (LOS)	C

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HCS7 Multilane Highway Report

Project Information

Analyst	Joseph A. Vaskovic	Date	10/25/2021
Agency	WSP	Analysis Year	2045 - Proposed
Jurisdiction	City of Tucson	Time Period Analyzed	PM Peak Hour
Project Description	Houghton Road Needs Assessment Study		

Direction 2 Geometric Data

Direction 2	Southbound Houghton, south of Speedway		
Number of Lanes (N), ln	2	Terrain Type	Specific Grade
Segment Length (L), ft	-	Percent Grade, %	3.00
Measured or Base Free-Flow Speed	Base	Grade Length, mi	0.00
Base Free-Flow Speed (BFFS), mi/h	45.0	Total Ramp Density (TRD), ramps/mi	0.00
Lane Width, ft	12	Left-Side Lateral Clearance (LC_R), ft	1
Median Type	Divided	Total Lateral Clearance (TLC), ft	7.00
Access Point Density, pts/mi	2.0	Free-Flow Speed (FFS), mi/h	43.2

Direction 2 Adjustment Factors

Driver Population	Mostly Familiar	Final Speed Adjustment Factor (SAF)	0.975
Driver Population SAF	0.975	Final Capacity Adjustment Factor (CAF)	0.968
Driver Population CAF	0.968		

Direction 2 Demand and Capacity

Volume(V) veh/h	854	Heavy Vehicle Adjustment Factor (f_{HV})	0.965
Peak Hour Factor	0.94	Flow Rate (V_p), pc/h/ln	470
Total Trucks, %	2.00	Capacity (c), pc/h/ln	1900
Single-Unit Trucks (SUT), %	70	Adjusted Capacity (c_{adj}), pc/h/ln	1839
Tractor-Trailers (TT), %	30	Volume-to-Capacity Ratio (v/c)	0.26

Direction 2 Speed and Density

Lane Width Adjustment (f_{LW})	0.0	Average Speed (S), mi/h	42.1
Total Lateral Clearance Adj. (f_{LLC})	1.3	Density (D), pc/mi/ln	11.2
Median Type Adjustment (f_M)	0.0	Level of Service (LOS)	B
Access Point Density Adjustment (f_A)	0.5		

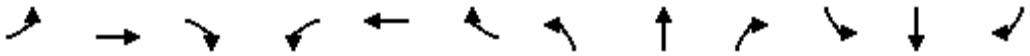
Direction 2 Bicycle LOS

Flow Rate in Outside Lane (v_{OL}),veh/h	454	Effective Speed Factor (S_t)	4.17
Effective Width of Volume (W_v), ft	18	Bicyle LOS Score (BLOS)	2.64
Average Effective Width (W_e), ft	24	Bicycle Level of Service (LOS)	C

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APPENDIX

D SYNCHRO REPORTS



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	73	275	153	186	379	34	125	332	125	24	363	114
Future Volume (veh/h)	73	275	153	186	379	34	125	332	125	24	363	114
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	81	306	170	207	421	38	139	369	139	27	403	127
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	216	384	326	380	468	42	225	502	189	238	528	166
Arrive On Green	0.06	0.21	0.21	0.13	0.28	0.28	0.39	0.39	0.39	0.39	0.39	0.39
Sat Flow, veh/h	1781	1870	1585	1781	1690	153	874	1295	488	891	1363	430
Grp Volume(v), veh/h	81	306	170	207	0	459	139	0	508	27	0	530
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	0	1843	874	0	1783	891	0	1793
Q Serve(g_s), s	0.0	10.1	6.2	1.3	0.0	15.6	8.5	0.0	15.9	1.7	0.0	16.7
Cycle Q Clear(g_c), s	0.0	10.1	6.2	1.3	0.0	15.6	25.2	0.0	15.9	17.6	0.0	16.7
Prop In Lane	1.00		1.00	1.00		0.08	1.00		0.27	1.00		0.24
Lane Grp Cap(c), veh/h	216	384	326	380	0	510	225	0	691	238	0	695
V/C Ratio(X)	0.37	0.80	0.52	0.54	0.00	0.90	0.62	0.00	0.74	0.11	0.00	0.76
Avail Cap(c_a), veh/h	248	547	463	380	0	539	225	0	691	238	0	695
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	0.65	0.00	0.65	1.00	0.00	1.00
Uniform Delay (d), s/veh	28.8	24.5	23.0	24.5	0.0	22.6	29.0	0.0	17.1	24.6	0.0	17.3
Incr Delay (d2), s/veh	1.1	5.3	1.3	1.6	0.0	17.6	8.1	0.0	4.5	1.0	0.0	7.8
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.2	4.5	2.2	2.7	0.0	8.3	2.5	0.0	6.2	0.4	0.0	7.2
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	29.8	29.9	24.3	26.1	0.0	40.3	37.1	0.0	21.6	25.6	0.0	25.1
LnGrp LOS	C	C	C	C	A	D	D	A	C	C	A	C
Approach Vol, veh/h		557			666			647			557	
Approach Delay, s/veh		28.2			35.8			24.9			25.1	
Approach LOS		C			D			C			C	

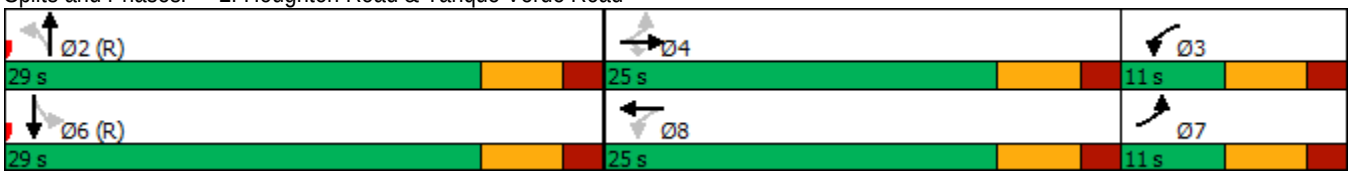
Timer - Assigned Phs		2	3	4		6	7	8				
Phs Duration (G+Y+Rc), s		31.2	14.5	19.4		31.2	9.8	24.0				
Change Period (Y+Rc), s		6.0	6.0	6.0		6.0	6.0	6.0				
Max Green Setting (Gmax), s		23.0	5.0	19.0		23.0	5.0	19.0				
Max Q Clear Time (g_c+I1), s		27.2	3.3	12.1		19.6	2.0	17.6				
Green Ext Time (p_c), s		0.0	0.1	1.3		1.1	0.0	0.4				

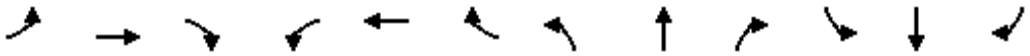
Intersection Summary												
HCM 6th Ctrl Delay			28.7									
HCM 6th LOS			C									

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	73	275	153	186	379	34	125	332	125	24	363	114
Future Volume (vph)	73	275	153	186	379	34	125	332	125	24	363	114
Satd. Flow (prot)	1770	1863	1583	1770	1840	0	1770	1786	0	1770	1796	0
Flt Permitted	0.260			0.451			0.242			0.267		
Satd. Flow (perm)	484	1863	1583	840	1840	0	451	1786	0	497	1796	0
Satd. Flow (RTOR)			170		7			32			27	
Lane Group Flow (vph)	81	306	170	207	459	0	139	508	0	27	530	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Perm	NA		Perm	NA	
Protected Phases	7	4		3	8			2			6	
Permitted Phases	4		4	8			2			6		
Total Split (s)	11.0	25.0	25.0	11.0	25.0		29.0	29.0		29.0	29.0	
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0	
Act Effct Green (s)	20.5	15.4	15.4	25.3	19.5		24.7	24.7		24.7	24.7	
Actuated g/C Ratio	0.32	0.24	0.24	0.39	0.30		0.38	0.38		0.38	0.38	
v/c Ratio	0.32	0.69	0.34	0.49	0.82		0.81	0.73		0.14	0.76	
Control Delay	16.5	30.8	5.4	18.4	36.2		59.5	25.0		16.9	26.8	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	16.5	30.8	5.4	18.4	36.2		59.5	25.0		16.9	26.8	
LOS	B	C	A	B	D		E	C		B	C	
Approach Delay		21.0			30.7			32.4			26.3	
Approach LOS		C			C			C			C	

Intersection Summary	
Cycle Length: 65	
Actuated Cycle Length: 65	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.82	
Intersection Signal Delay: 27.9	Intersection LOS: C
Intersection Capacity Utilization 79.1%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 2: Houghton Road & Tanque Verde Road





Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	86	309	187	129	297	28	130	245	118	23	290	97
Future Volume (veh/h)	86	309	187	129	297	28	130	245	118	23	290	97
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	96	343	208	143	330	31	144	272	131	26	322	108
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	265	421	356	281	389	37	346	509	245	364	572	192
Arrive On Green	0.07	0.22	0.22	0.07	0.23	0.23	0.43	0.43	0.43	0.43	0.43	0.43
Sat Flow, veh/h	1781	1870	1585	1781	1684	158	958	1193	574	982	1340	449
Grp Volume(v), veh/h	96	343	208	143	0	361	144	0	403	26	0	430
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	0	1842	958	0	1767	982	0	1789
Q Serve(g_s), s	0.0	11.3	7.6	0.0	0.0	12.2	8.7	0.0	11.0	1.3	0.0	11.8
Cycle Q Clear(g_c), s	0.0	11.3	7.6	0.0	0.0	12.2	20.5	0.0	11.0	12.3	0.0	11.8
Prop In Lane	1.00		1.00	1.00		0.09	1.00		0.33	1.00		0.25
Lane Grp Cap(c), veh/h	265	421	356	281	0	425	346	0	755	364	0	764
V/C Ratio(X)	0.36	0.82	0.58	0.51	0.00	0.85	0.42	0.00	0.53	0.07	0.00	0.56
Avail Cap(c_a), veh/h	286	547	463	291	0	538	346	0	755	364	0	764
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	0.86	0.00	0.86	1.00	0.00	1.00
Uniform Delay (d), s/veh	27.9	23.9	22.5	27.5	0.0	23.9	21.8	0.0	13.8	18.4	0.0	14.0
Incr Delay (d2), s/veh	0.8	7.2	1.5	1.4	0.0	10.0	3.1	0.0	2.3	0.4	0.0	3.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.3	5.2	2.6	2.0	0.0	5.8	2.0	0.0	4.0	0.3	0.0	4.5
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	28.8	31.1	24.0	29.0	0.0	33.9	24.9	0.0	16.1	18.8	0.0	17.0
LnGrp LOS	C	C	C	C	A	C	C	A	B	B	A	B
Approach Vol, veh/h		647			504			547			456	
Approach Delay, s/veh		28.5			32.5			18.4			17.1	
Approach LOS		C			C			B			B	

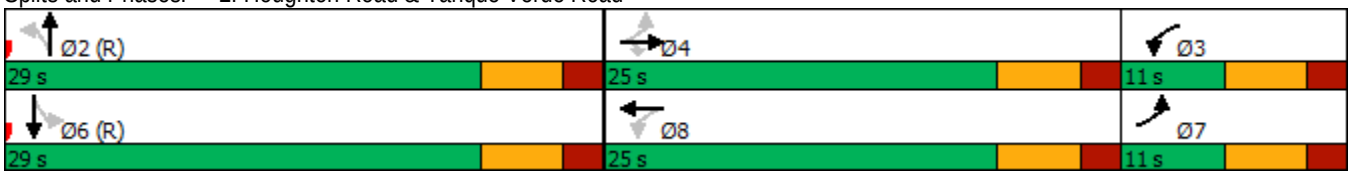
Timer - Assigned Phs		2	3	4		6	7	8				
Phs Duration (G+Y+Rc), s		33.8	10.6	20.6		33.8	10.2	21.0				
Change Period (Y+Rc), s		6.0	6.0	6.0		6.0	6.0	6.0				
Max Green Setting (Gmax), s		23.0	5.0	19.0		23.0	5.0	19.0				
Max Q Clear Time (g_c+I1), s		22.5	2.0	13.3		14.3	2.0	14.2				
Green Ext Time (p_c), s		0.2	0.1	1.3		1.7	0.0	0.8				

Intersection Summary												
HCM 6th Ctrl Delay			24.5									
HCM 6th LOS			C									

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	86	309	187	129	297	28	130	245	118	23	290	97
Future Volume (vph)	86	309	187	129	297	28	130	245	118	23	290	97
Satd. Flow (prot)	1770	1863	1583	1770	1839	0	1770	1771	0	1770	1792	0
Flt Permitted	0.337			0.369			0.392			0.422		
Satd. Flow (perm)	628	1863	1583	687	1839	0	730	1771	0	786	1792	0
Satd. Flow (RTOR)			208		7			41			29	
Lane Group Flow (vph)	96	343	208	143	361	0	144	403	0	26	430	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Perm	NA		Perm	NA	
Protected Phases	7	4		3	8			2			6	
Permitted Phases	4		4	8			2			6		
Total Split (s)	11.0	25.0	25.0	11.0	25.0		29.0	29.0		29.0	29.0	
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0	
Act Effct Green (s)	21.6	16.2	16.2	22.0	16.4		27.5	27.5		27.5	27.5	
Actuated g/C Ratio	0.33	0.25	0.25	0.34	0.25		0.42	0.42		0.42	0.42	
v/c Ratio	0.32	0.74	0.38	0.44	0.77		0.47	0.52		0.08	0.56	
Control Delay	15.6	32.3	5.3	18.3	33.5		22.6	17.3		14.9	18.5	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	15.6	32.3	5.3	18.3	33.5		22.6	17.3		14.9	18.5	
LOS	B	C	A	B	C		C	B		B	B	
Approach Delay		21.2			29.2			18.7			18.3	
Approach LOS		C			C			B			B	

Intersection Summary	
Cycle Length: 65	
Actuated Cycle Length: 65	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.77	
Intersection Signal Delay: 21.8	Intersection LOS: C
Intersection Capacity Utilization 71.8%	ICU Level of Service C
Analysis Period (min) 15	

Splits and Phases: 2: Houghton Road & Tanque Verde Road



HCM 6th Signalized Intersection Summary
1: Houghton Road & Speedway Boulevard

11/02/2021



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	39	223	144	229	42	303	40	446	360	35	31	376
Future Volume (veh/h)	39	223	144	229	42	303	40	446	360	35	31	376
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		248	160	121	47	337	44	496	400	39	34	418
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		252	220	187	321	452	59	480	709	69	298	542
Arrive On Green		0.08	0.12	0.12	0.11	0.14	0.14	0.19	0.42	0.42	0.06	0.29
Sat Flow, veh/h		1781	1870	1585	1781	3164	410	1781	1677	164	1781	1870
Grp Volume(v), veh/h		248	160	121	47	188	193	496	0	439	34	418
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1797	1781	0	1841	1781	1870
Q Serve(g_s), s		6.8	6.8	6.0	0.0	8.4	8.5	16.0	0.0	15.0	0.0	16.9
Cycle Q Clear(g_c), s		6.8	6.8	6.0	0.0	8.4	8.5	16.0	0.0	15.0	0.0	16.9
Prop In Lane		1.00		1.00	1.00		0.23	1.00		0.09	1.00	
Lane Grp Cap(c), veh/h		252	220	187	321	254	257	480	0	778	298	542
V/C Ratio(X)		0.98	0.73	0.65	0.15	0.74	0.75	1.03	0.00	0.56	0.11	0.77
Avail Cap(c_a), veh/h		252	474	402	321	408	412	480	0	778	298	542
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh		36.4	35.3	34.9	31.6	34.0	34.1	30.9	0.0	18.1	29.6	26.9
Incr Delay (d2), s/veh		52.0	4.5	3.8	0.2	4.2	4.4	50.2	0.0	3.0	0.2	10.2
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		8.4	3.2	2.4	0.8	3.7	3.8	15.4	0.0	6.2	0.6	8.4
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		88.4	39.8	38.7	31.8	38.2	38.5	81.2	0.0	21.1	29.8	37.1
LnGrp LOS		F	D	D	C	D	D	F	A	C	C	D
Approach Vol, veh/h			529			428			935			667
Approach Delay, s/veh			62.3			37.7			53.0			33.7
Approach LOS			E			D			D			C

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.0	41.0	15.1	15.8	22.0	30.0	13.0	17.8
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	35.0	5.0	21.0	16.0	24.0	7.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	17.0	2.0	8.8	18.0	18.9	8.8	10.5
Green Ext Time (p_c), s	0.0	2.3	0.0	0.9	0.0	1.4	0.0	1.3

Intersection Summary	
HCM 6th Ctrl Delay	47.3
HCM 6th LOS	D

Notes

User approved pedestrian interval to be less than phase max green.

User approved ignoring U-Turning movement.

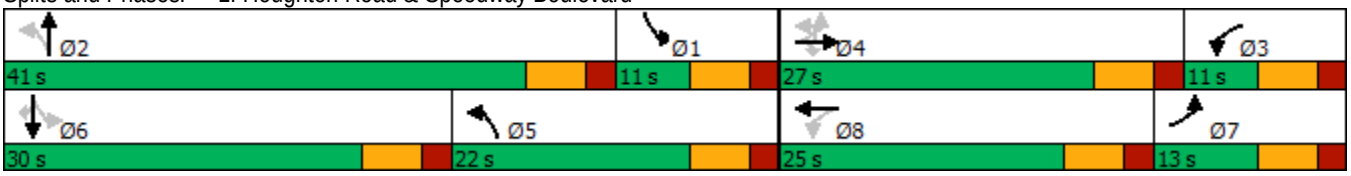


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	291
Future Volume (veh/h)	291
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	215
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	459
Arrive On Green	0.29
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	215
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	9.2
Cycle Q Clear(g_c), s	9.2
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	459
V/C Ratio(X)	0.47
Avail Cap(c_a), veh/h	459
HCM Platoon Ratio	1.00
Upstream Filter(I)	1.00
Uniform Delay (d), s/veh	24.2
Incr Delay (d2), s/veh	3.4
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	3.7
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	27.6
LnGrp LOS	C
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	39	223	144	229	42	303	40	446	360	35	31	376
Future Volume (vph)	39	223	144	229	42	303	40	446	360	35	31	376
Satd. Flow (prot)	0	1770	1801	1583	1770	3479	0	1770	1839	0	1770	1863
Flt Permitted		0.429			0.613			0.275			0.289	
Satd. Flow (perm)	0	799	1801	1583	1142	3479	0	512	1839	0	538	1863
Satd. Flow (RTOR)				255		14			6			
Lane Group Flow (vph)	0	291	160	254	47	381	0	496	439	0	34	418
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	27.0	13.0	27.0	27.0	11.0	25.0		22.0	41.0		11.0	30.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		23.3	19.2	19.2	20.9	14.3		46.1	39.6		29.0	24.0
Actuated g/C Ratio		0.27	0.22	0.22	0.24	0.17		0.54	0.46		0.34	0.28
v/c Ratio		0.98	0.40	0.46	0.14	0.64		0.97	0.51		0.13	0.80
Control Delay		81.6	33.7	7.2	22.0	37.1		61.6	20.6		14.0	42.4
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		81.6	33.7	7.2	22.0	37.1		61.6	20.6		14.0	42.4
LOS		F	C	A	C	D		E	C		B	D
Approach Delay			43.9			35.4			42.3			27.6
Approach LOS			D			D			D			C

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 85.4	
Control Type: Actuated-Uncoordinated	
Maximum v/c Ratio: 0.98	
Intersection Signal Delay: 37.7	Intersection LOS: D
Intersection Capacity Utilization 88.7%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	291
Future Volume (vph)	291
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	255
Lane Group Flow (vph)	323
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	30.0
Total Lost Time (s)	6.0
Act Effct Green (s)	24.0
Actuated g/C Ratio	0.28
v/c Ratio	0.51
Control Delay	9.9
Queue Delay	0.0
Total Delay	9.9
LOS	A
Approach Delay	
Approach LOS	

Intersection Summary



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	22	189	210	332	29	143	21	275	291	34	35	377
Future Volume (veh/h)	22	189	210	332	29	143	21	275	291	34	35	377
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		210	233	185	32	159	23	306	323	38	39	419
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		305	302	256	154	267	38	533	482	57	535	499
Arrive On Green		0.11	0.16	0.16	0.03	0.09	0.09	0.22	0.29	0.29	0.19	0.27
Sat Flow, veh/h		1781	1870	1585	1781	3123	444	1781	1642	193	1781	1870
Grp Volume(v), veh/h		210	233	185	32	89	93	306	0	361	39	419
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1790	1781	0	1836	1781	1870
Q Serve(g_s), s		3.6	8.9	8.3	0.0	3.6	3.7	4.9	0.0	13.0	0.0	15.9
Cycle Q Clear(g_c), s		3.6	8.9	8.3	0.0	3.6	3.7	4.9	0.0	13.0	0.0	15.9
Prop In Lane		1.00		1.00	1.00		0.25	1.00		0.11	1.00	
Lane Grp Cap(c), veh/h		305	302	256	154	152	153	533	0	538	535	499
V/C Ratio(X)		0.69	0.77	0.72	0.21	0.59	0.60	0.57	0.00	0.67	0.07	0.84
Avail Cap(c_a), veh/h		305	474	402	215	450	454	533	0	538	535	499
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.87	0.87
Uniform Delay (d), s/veh		30.4	30.1	29.8	35.1	33.0	33.1	23.3	0.0	23.3	19.9	26.0
Incr Delay (d2), s/veh		6.4	4.2	3.8	0.7	3.6	3.8	1.5	0.0	6.5	0.0	13.8
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		3.9	4.1	3.2	0.6	1.6	1.7	4.3	0.0	6.0	0.5	8.2
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		36.8	34.3	33.7	35.8	36.6	36.9	24.8	0.0	29.8	19.9	39.8
LnGrp LOS		D	C	C	D	D	D	C	A	C	B	D
Approach Vol, veh/h			628			214			667			600
Approach Delay, s/veh			34.9			36.6			27.5			34.8
Approach LOS			C			D			C			C

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	20.4	28.0	8.4	18.1	22.4	26.0	14.1	12.4
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	22.0	5.0	19.0	7.0	20.0	5.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	15.0	2.0	10.9	6.9	17.9	5.6	5.7
Green Ext Time (p_c), s	0.0	1.1	0.0	1.2	0.0	0.6	0.0	0.7

Intersection Summary	
HCM 6th Ctrl Delay	32.7
HCM 6th LOS	C

Notes

User approved ignoring U-Turning movement.

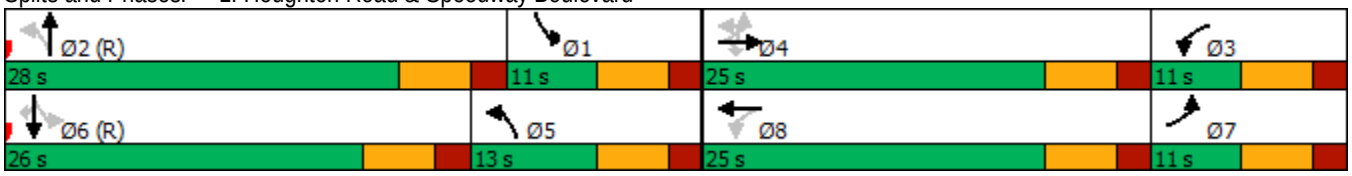


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	190
Future Volume (veh/h)	190
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	142
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	423
Arrive On Green	0.27
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	142
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	5.4
Cycle Q Clear(g_c), s	5.4
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	423
V/C Ratio(X)	0.34
Avail Cap(c_a), veh/h	423
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.87
Uniform Delay (d), s/veh	22.2
Incr Delay (d2), s/veh	1.9
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	2.1
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	24.0
LnGrp LOS	C
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	22	189	210	332	29	143	21	275	291	34	35	377
Future Volume (vph)	22	189	210	332	29	143	21	275	291	34	35	377
Satd. Flow (prot)	0	1770	1801	1583	1770	3472	0	1770	1833	0	1770	1863
Flt Permitted		0.637			0.477			0.310			0.383	
Satd. Flow (perm)	0	1187	1801	1583	889	3472	0	577	1833	0	713	1863
Satd. Flow (RTOR)				369		20			8			
Lane Group Flow (vph)	0	234	233	369	32	182	0	306	361	0	39	419
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	25.0	11.0	25.0	25.0	11.0	25.0		13.0	28.0		11.0	26.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		22.4	19.1	19.1	15.8	10.4		37.0	32.8		31.4	26.4
Actuated g/C Ratio		0.30	0.25	0.25	0.21	0.14		0.49	0.44		0.42	0.35
v/c Ratio		0.57	0.51	0.54	0.13	0.37		0.77	0.45		0.11	0.64
Control Delay		27.1	28.5	6.2	17.0	26.9		36.4	20.0		12.7	28.5
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		27.1	28.5	6.2	17.0	26.9		36.4	20.0		12.7	28.5
LOS		C	C	A	B	C		D	C		B	C
Approach Delay			18.3			25.4			27.5			20.0
Approach LOS			B			C			C			C

Intersection Summary	
Cycle Length: 75	
Actuated Cycle Length: 75	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.77	
Intersection Signal Delay: 22.0	Intersection LOS: C
Intersection Capacity Utilization 71.4%	ICU Level of Service C
Analysis Period (min) 15	

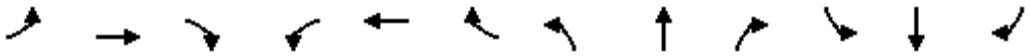
Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	190
Future Volume (vph)	190
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	218
Lane Group Flow (vph)	211
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	26.0
Total Lost Time (s)	6.0
Act Effct Green (s)	26.4
Actuated g/C Ratio	0.35
v/c Ratio	0.30
Control Delay	4.6
Queue Delay	0.0
Total Delay	4.6
LOS	A
Approach Delay	
Approach LOS	

Intersection Summary



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	73	275	198	241	474	43	173	459	173	30	470	143
Future Volume (veh/h)	73	275	198	241	474	43	173	459	173	30	470	143
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	81	306	220	268	527	48	192	510	192	33	522	159
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	129	354	300	368	535	49	201	640	241	184	680	207
Arrive On Green	0.04	0.19	0.19	0.17	0.32	0.32	0.49	0.49	0.49	0.49	0.49	0.49
Sat Flow, veh/h	1781	1870	1585	1781	1689	154	759	1295	488	745	1376	419
Grp Volume(v), veh/h	81	306	220	268	0	575	192	0	702	33	0	681
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	0	1843	759	0	1783	745	0	1795
Q Serve(g_s), s	1.3	19.0	15.7	12.0	0.0	37.2	22.2	0.0	39.4	4.6	0.0	37.1
Cycle Q Clear(g_c), s	1.3	19.0	15.7	12.0	0.0	37.2	59.3	0.0	39.4	44.0	0.0	37.1
Prop In Lane	1.00		1.00	1.00		0.08	1.00		0.27	1.00		0.23
Lane Grp Cap(c), veh/h	129	354	300	368	0	584	201	0	881	184	0	888
V/C Ratio(X)	0.63	0.86	0.73	0.73	0.00	0.99	0.96	0.00	0.80	0.18	0.00	0.77
Avail Cap(c_a), veh/h	134	483	409	368	0	584	201	0	881	184	0	888
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	0.48	0.00	0.48	1.00	0.00	1.00
Uniform Delay (d), s/veh	55.6	47.1	45.8	45.1	0.0	40.7	51.8	0.0	25.3	43.7	0.0	24.7
Incr Delay (d2), s/veh	8.4	11.5	4.3	7.1	0.0	33.4	34.3	0.0	3.7	2.1	0.0	6.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.6	9.7	6.4	7.9	0.0	21.5	7.6	0.0	16.3	0.9	0.0	16.1
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	64.0	58.6	50.1	52.1	0.0	74.1	86.1	0.0	29.0	45.8	0.0	31.0
LnGrp LOS	E	E	D	D	A	E	F	A	C	D	A	C
Approach Vol, veh/h		607			843			894			714	
Approach Delay, s/veh		56.2			67.2			41.3			31.7	
Approach LOS		E			E			D			C	

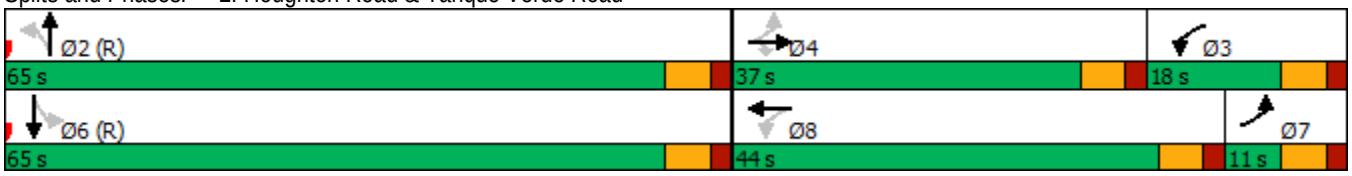
Timer - Assigned Phs		2	3	4		6	7	8				
Phs Duration (G+Y+Rc), s		65.3	25.9	28.7		65.3	10.7	44.0				
Change Period (Y+Rc), s		6.0	6.0	6.0		6.0	6.0	6.0				
Max Green Setting (Gmax), s		59.0	12.0	31.0		59.0	5.0	38.0				
Max Q Clear Time (g_c+I1), s		61.3	14.0	21.0		46.0	3.3	39.2				
Green Ext Time (p_c), s		0.0	0.0	1.7		3.8	0.0	0.0				

Intersection Summary	
HCM 6th Ctrl Delay	49.1
HCM 6th LOS	D

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	73	275	198	241	474	43	173	459	173	30	470	143
Future Volume (vph)	73	275	198	241	474	43	173	459	173	30	470	143
Satd. Flow (prot)	1770	1863	1583	1770	1839	0	1770	1786	0	1770	1798	0
Flt Permitted	0.162			0.321			0.200			0.183		
Satd. Flow (perm)	302	1863	1583	598	1839	0	373	1786	0	341	1798	0
Satd. Flow (RTOR)			220		4			22			18	
Lane Group Flow (vph)	81	306	220	268	575	0	192	702	0	33	681	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Perm	NA		Perm	NA	
Protected Phases	7	4		3	8			2			6	
Permitted Phases	4		4	8			2			6		
Total Split (s)	11.0	37.0	37.0	18.0	44.0		65.0	65.0		65.0	65.0	
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0	
Act Effct Green (s)	29.7	24.7	24.7	46.8	38.0		61.2	61.2		61.2	61.2	
Actuated g/C Ratio	0.25	0.21	0.21	0.39	0.32		0.51	0.51		0.51	0.51	
v/c Ratio	0.60	0.80	0.44	0.69	0.98		1.01	0.76		0.19	0.74	
Control Delay	52.8	60.4	7.6	47.4	74.2		101.2	30.2		20.9	29.1	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	52.8	60.4	7.6	47.4	74.2		101.2	30.2		20.9	29.1	
LOS	D	E	A	D	E		F	C		C	C	
Approach Delay		40.3			65.6			45.5			28.7	
Approach LOS		D			E			D			C	

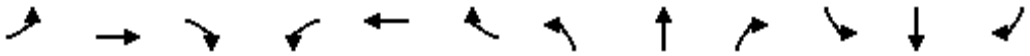
Intersection Summary	
Cycle Length: 120	
Actuated Cycle Length: 120	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.01	
Intersection Signal Delay: 46.1	Intersection LOS: D
Intersection Capacity Utilization 94.7%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 2: Houghton Road & Tanque Verde Road



HCM 6th Signalized Intersection Summary
2: Houghton Road & Tanque Verde Road

11/02/2021



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	86	309	242	167	371	35	180	338	163	29	376	121
Future Volume (veh/h)	86	309	242	167	371	35	180	338	163	29	376	121
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	96	343	269	186	412	39	200	376	181	32	418	134
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	188	406	344	309	448	42	270	541	260	262	616	197
Arrive On Green	0.06	0.22	0.22	0.10	0.27	0.27	0.45	0.45	0.45	0.45	0.45	0.45
Sat Flow, veh/h	1781	1870	1585	1781	1682	159	856	1193	574	852	1357	435
Grp Volume(v), veh/h	96	343	269	186	0	451	200	0	557	32	0	552
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	0	1842	856	0	1767	852	0	1792
Q Serve(g_s), s	0.0	14.1	12.8	2.2	0.0	19.0	16.8	0.0	20.1	2.5	0.0	19.5
Cycle Q Clear(g_c), s	0.0	14.1	12.8	2.2	0.0	19.0	36.3	0.0	20.1	22.6	0.0	19.5
Prop In Lane	1.00		1.00	1.00		0.09	1.00		0.32	1.00		0.24
Lane Grp Cap(c), veh/h	188	406	344	309	0	490	270	0	802	262	0	813
V/C Ratio(X)	0.51	0.85	0.78	0.60	0.00	0.92	0.74	0.00	0.69	0.12	0.00	0.68
Avail Cap(c_a), veh/h	201	491	416	309	0	506	270	0	802	262	0	813
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	0.75	0.00	0.75	1.00	0.00	1.00
Uniform Delay (d), s/veh	35.7	30.0	29.5	32.0	0.0	28.5	32.4	0.0	17.4	26.5	0.0	17.3
Incr Delay (d2), s/veh	2.1	11.0	7.8	3.2	0.0	21.7	12.8	0.0	3.7	1.0	0.0	4.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.8	7.1	5.2	3.4	0.0	10.6	4.6	0.0	7.8	0.5	0.0	7.9
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	37.8	41.0	37.3	35.3	0.0	50.3	45.3	0.0	21.2	27.4	0.0	21.8
LnGrp LOS	D	D	D	D	A	D	D	A	C	C	A	C
Approach Vol, veh/h		708			637			757			584	
Approach Delay, s/veh		39.2			45.9			27.5			22.1	
Approach LOS		D			D			C			C	

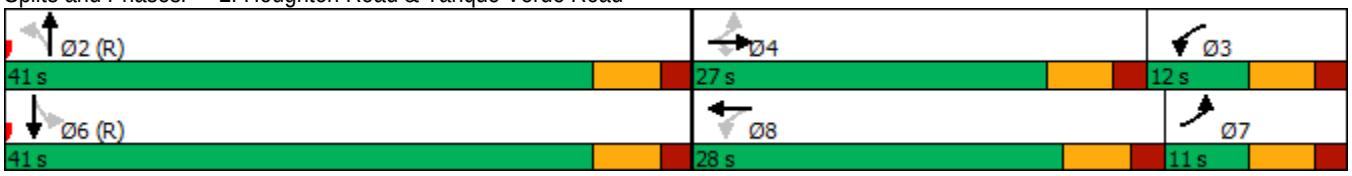
Timer - Assigned Phs		2	3	4		6	7	8				
Phs Duration (G+Y+Rc), s		42.3	14.3	23.4		42.3	10.4	27.3				
Change Period (Y+Rc), s		6.0	6.0	6.0		6.0	6.0	6.0				
Max Green Setting (Gmax), s		35.0	6.0	21.0		35.0	5.0	22.0				
Max Q Clear Time (g_c+I1), s		38.3	4.2	16.1		24.6	2.0	21.0				
Green Ext Time (p_c), s		0.0	0.1	1.3		2.6	0.0	0.3				

Intersection Summary	
HCM 6th Ctrl Delay	33.8
HCM 6th LOS	C

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (vph)	86	309	242	167	371	35	180	338	163	29	376	121
Future Volume (vph)	86	309	242	167	371	35	180	338	163	29	376	121
Satd. Flow (prot)	1770	1863	1583	1770	1839	0	1770	1771	0	1770	1796	0
Flt Permitted	0.215			0.347			0.280			0.276		
Satd. Flow (perm)	400	1863	1583	646	1839	0	522	1771	0	514	1796	0
Satd. Flow (RTOR)			269		6			39			26	
Lane Group Flow (vph)	96	343	269	186	451	0	200	557	0	32	552	0
Turn Type	pm+pt	NA	Perm	pm+pt	NA		Perm	NA		Perm	NA	
Protected Phases	7	4		3	8			2			6	
Permitted Phases	4		4	8			2			6		
Total Split (s)	11.0	27.0	27.0	12.0	28.0		41.0	41.0		41.0	41.0	
Total Lost Time (s)	6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0	
Act Effct Green (s)	23.7	18.6	18.6	28.2	22.6		36.6	36.6		36.6	36.6	
Actuated g/C Ratio	0.30	0.23	0.23	0.35	0.28		0.46	0.46		0.46	0.46	
v/c Ratio	0.47	0.79	0.47	0.58	0.86		0.84	0.67		0.14	0.66	
Control Delay	29.1	42.7	6.3	29.4	46.0		52.9	21.2		15.5	21.4	
Queue Delay	0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0	
Total Delay	29.1	42.7	6.3	29.4	46.0		52.9	21.2		15.5	21.4	
LOS	C	D	A	C	D		D	C		B	C	
Approach Delay		27.0			41.2			29.6			21.0	
Approach LOS		C			D			C			C	

Intersection Summary	
Cycle Length: 80	
Actuated Cycle Length: 80	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.86	
Intersection Signal Delay: 29.8	Intersection LOS: C
Intersection Capacity Utilization 83.5%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 2: Houghton Road & Tanque Verde Road



HCM 6th Signalized Intersection Summary
1: Houghton Road & Speedway Boulevard

11/02/2021



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	44	251	162	258	42	303	40	669	540	53	41	501
Future Volume (veh/h)	44	251	162	258	42	303	40	669	540	53	41	501
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		279	180	133	47	337	44	743	600	59	46	557
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		235	214	182	259	382	49	640	972	96	159	536
Arrive On Green		0.10	0.11	0.11	0.11	0.12	0.12	0.33	0.58	0.58	0.04	0.29
Sat Flow, veh/h		1781	1870	1585	1781	3164	410	1781	1676	165	1781	1870
Grp Volume(v), veh/h		279	180	133	47	188	193	743	0	659	46	557
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1797	1781	0	1841	1781	1870
Q Serve(g_s), s		15.0	14.1	12.2	0.0	15.6	15.9	49.9	0.0	35.1	0.0	43.0
Cycle Q Clear(g_c), s		15.0	14.1	12.2	0.0	15.6	15.9	49.9	0.0	35.1	0.0	43.0
Prop In Lane		1.00		1.00	1.00		0.23	1.00		0.09	1.00	
Lane Grp Cap(c), veh/h		235	214	182	259	215	217	640	0	1068	159	536
V/C Ratio(X)		1.19	0.84	0.73	0.18	0.88	0.89	1.16	0.00	0.62	0.29	1.04
Avail Cap(c_a), veh/h		235	349	296	259	225	228	640	0	1068	159	536
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.69	0.69
Uniform Delay (d), s/veh		65.7	65.1	64.2	59.2	64.8	65.0	48.2	0.0	20.6	65.8	53.5
Incr Delay (d2), s/veh		119.0	9.4	5.6	0.3	29.0	31.2	88.6	0.0	2.7	0.7	42.8
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		16.6	7.2	5.2	1.6	8.7	9.1	38.9	0.0	15.1	1.7	26.0
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		184.6	74.5	69.8	59.5	93.9	96.2	136.8	0.0	23.3	66.4	96.3
LnGrp LOS		F	E	E	E	F	F	F	A	C	E	F
Approach Vol, veh/h			592			428			1402			901
Approach Delay, s/veh			125.3			91.1			83.5			80.1
Approach LOS			F			F			F			F

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.9	93.0	21.9	23.2	55.9	49.0	21.0	24.1
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	87.0	6.0	28.0	49.0	43.0	15.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	37.1	2.0	16.1	51.9	45.0	17.0	17.9
Green Ext Time (p_c), s	0.0	4.7	0.0	1.0	0.0	0.0	0.0	0.2

Intersection Summary	
HCM 6th Ctrl Delay	91.0
HCM 6th LOS	F

Notes

User approved ignoring U-Turning movement.

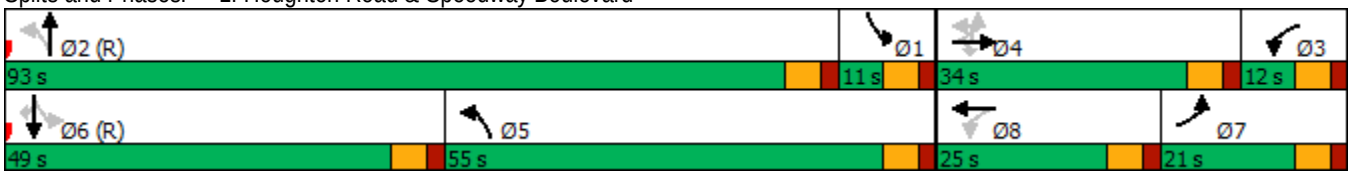


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	388
Future Volume (veh/h)	388
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	298
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	454
Arrive On Green	0.29
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	298
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	24.8
Cycle Q Clear(g_c), s	24.8
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	454
V/C Ratio(X)	0.66
Avail Cap(c_a), veh/h	454
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.69
Uniform Delay (d), s/veh	47.0
Incr Delay (d2), s/veh	5.0
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	10.3
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	52.0
LnGrp LOS	D
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	44	251	162	258	42	303	40	669	540	53	41	501
Future Volume (vph)	44	251	162	258	42	303	40	669	540	53	41	501
Satd. Flow (prot)	0	1770	1801	1583	1770	3479	0	1770	1839	0	1770	1863
Flt Permitted		0.301			0.373			0.086			0.103	
Satd. Flow (perm)	0	561	1801	1583	695	3479	0	160	1839	0	192	1863
Satd. Flow (RTOR)				287		8			6			
Lane Group Flow (vph)	0	328	180	287	47	381	0	743	659	0	46	557
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	34.0	21.0	34.0	34.0	12.0	25.0		55.0	93.0		11.0	49.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		37.3	25.9	25.9	28.9	18.5		98.0	89.2		48.0	43.0
Actuated g/C Ratio		0.25	0.17	0.17	0.19	0.12		0.65	0.59		0.32	0.29
v/c Ratio		1.24	0.58	0.56	0.23	0.87		1.18	0.60		0.40	1.04
Control Delay		185.6	66.4	10.1	47.7	83.7		137.4	22.4		33.2	101.6
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		185.6	66.4	10.1	47.7	83.7		137.4	22.4		33.2	101.6
LOS		F	E	B	D	F		F	C		C	F
Approach Delay			95.3			79.8			83.4			70.2
Approach LOS			F			E			F			E

Intersection Summary	
Cycle Length: 150	
Actuated Cycle Length: 150	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.24	
Intersection Signal Delay: 81.8	Intersection LOS: F
Intersection Capacity Utilization 109.4%	ICU Level of Service H
Analysis Period (min) 15	

Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	388
Future Volume (vph)	388
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	196
Lane Group Flow (vph)	431
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	49.0
Total Lost Time (s)	6.0
Act Effct Green (s)	43.0
Actuated g/C Ratio	0.29
v/c Ratio	0.73
Control Delay	33.5
Queue Delay	0.0
Total Delay	33.5
LOS	C
Approach Delay	
Approach LOS	

Intersection Summary



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Future Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		237	262	189	32	159	23	459	486	57	52	559
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		300	314	266	134	249	35	518	675	79	336	540
Arrive On Green		0.12	0.17	0.17	0.03	0.08	0.08	0.25	0.41	0.41	0.12	0.29
Sat Flow, veh/h		1781	1870	1585	1781	3123	444	1781	1643	193	1781	1870
Grp Volume(v), veh/h		237	262	189	32	89	93	459	0	543	52	559
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1790	1781	0	1836	1781	1870
Q Serve(g_s), s		7.0	12.2	10.1	0.0	4.4	4.5	18.1	0.0	22.3	0.0	26.0
Cycle Q Clear(g_c), s		7.0	12.2	10.1	0.0	4.4	4.5	18.1	0.0	22.3	0.0	26.0
Prop In Lane		1.00		1.00	1.00		0.25	1.00		0.10	1.00	
Lane Grp Cap(c), veh/h		300	314	266	134	142	143	518	0	755	336	540
V/C Ratio(X)		0.79	0.83	0.71	0.24	0.63	0.65	0.89	0.00	0.72	0.15	1.03
Avail Cap(c_a), veh/h		300	395	335	179	375	378	518	0	755	336	540
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.77	0.77
Uniform Delay (d), s/veh		36.7	36.2	35.4	42.3	40.1	40.2	30.8	0.0	22.2	33.3	32.0
Incr Delay (d2), s/veh		13.2	11.8	5.1	0.9	4.6	4.9	16.7	0.0	5.8	0.2	43.2
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		5.9	6.3	4.1	0.7	2.0	2.1	11.2	0.0	9.8	1.0	17.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		49.9	48.0	40.4	43.2	44.7	45.1	47.6	0.0	28.0	33.4	75.2
LnGrp LOS		D	D	D	D	D	D	D	A	C	C	F
Approach Vol, veh/h			688			214			1002			815
Approach Delay, s/veh			46.6			44.6			37.0			60.9
Approach LOS			D			D			D			E

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	17.1	43.0	8.8	21.1	28.1	32.0	16.7	13.2
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	37.0	5.0	19.0	16.0	26.0	5.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	24.3	2.0	14.2	20.1	28.0	9.0	6.5
Green Ext Time (p_c), s	0.0	2.6	0.0	0.9	0.0	0.0	0.0	0.7

Intersection Summary	
HCM 6th Ctrl Delay	47.2
HCM 6th LOS	D

Notes

User approved ignoring U-Turning movement.

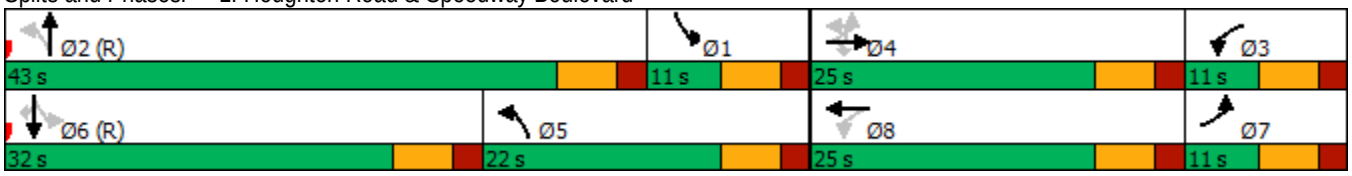


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	253
Future Volume (veh/h)	253
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	204
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	458
Arrive On Green	0.29
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	204
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	9.5
Cycle Q Clear(g_c), s	9.5
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	458
V/C Ratio(X)	0.45
Avail Cap(c_a), veh/h	458
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.77
Uniform Delay (d), s/veh	26.1
Incr Delay (d2), s/veh	2.4
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	3.7
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	28.5
LnGrp LOS	C
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	25	213	236	374	29	143	21	413	437	51	47	503
Future Volume (vph)	25	213	236	374	29	143	21	413	437	51	47	503
Satd. Flow (prot)	0	1770	1801	1583	1770	3472	0	1770	1833	0	1770	1863
Flt Permitted		0.637			0.364			0.129			0.179	
Satd. Flow (perm)	0	1187	1801	1583	678	3472	0	240	1833	0	333	1863
Satd. Flow (RTOR)				416		16			8			
Lane Group Flow (vph)	0	265	262	416	32	182	0	459	543	0	52	559
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	25.0	11.0	25.0	25.0	11.0	25.0		22.0	43.0		11.0	32.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		24.9	19.5	19.5	16.2	11.0		51.9	45.3		34.9	29.9
Actuated g/C Ratio		0.28	0.22	0.22	0.18	0.12		0.58	0.50		0.39	0.33
v/c Ratio		0.69	0.67	0.62	0.17	0.42		1.12	0.59		0.25	0.90
Control Delay		39.4	42.3	7.9	24.7	35.1		112.3	21.5		17.2	50.9
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		39.4	42.3	7.9	24.7	35.1		112.3	21.5		17.2	50.9
LOS		D	D	A	C	D		F	C		B	D
Approach Delay			26.3			33.5			63.1			35.0
Approach LOS			C			C			E			C

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.12	
Intersection Signal Delay: 41.4	Intersection LOS: D
Intersection Capacity Utilization 87.2%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	253
Future Volume (vph)	253
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	255
Lane Group Flow (vph)	281
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	32.0
Total Lost Time (s)	6.0
Act Effct Green (s)	29.9
Actuated g/C Ratio	0.33
v/c Ratio	0.40
Control Delay	6.6
Queue Delay	0.0
Total Delay	6.6
LOS	A
Approach Delay	
Approach LOS	

Intersection Summary



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	44	258	162	251	42	303	40	669	540	53	41	501
Future Volume (veh/h)	44	258	162	251	42	303	40	669	540	53	41	501
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		287	180	132	47	337	44	743	600	59	46	557
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		317	227	193	348	417	54	868	656	65	313	608
Arrive On Green		0.13	0.12	0.12	0.15	0.13	0.13	0.21	0.39	0.39	0.14	0.32
Sat Flow, veh/h		1781	1870	1585	1781	3164	410	3456	1676	165	1781	1870
Grp Volume(v), veh/h		287	180	132	47	188	193	743	0	659	46	557
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1797	1728	0	1841	1781	1870
Q Serve(g_s), s		13.8	11.2	9.6	0.0	12.3	12.5	19.5	0.0	40.7	0.0	34.4
Cycle Q Clear(g_c), s		13.8	11.2	9.6	0.0	12.3	12.5	19.5	0.0	40.7	0.0	34.4
Prop In Lane		1.00		1.00	1.00		0.23	1.00		0.09	1.00	
Lane Grp Cap(c), veh/h		317	227	193	348	234	237	868	0	721	313	608
V/C Ratio(X)		0.91	0.79	0.69	0.13	0.80	0.81	0.86	0.00	0.91	0.15	0.92
Avail Cap(c_a), veh/h		389	608	515	348	341	344	868	0	721	313	608
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.66	0.66
Uniform Delay (d), s/veh		49.0	51.2	50.5	42.8	50.6	50.7	43.3	0.0	34.6	44.2	38.9
Incr Delay (d2), s/veh		21.4	6.1	4.3	0.2	8.5	9.3	8.5	0.0	18.1	0.1	15.2
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		10.1	5.6	4.0	1.2	5.9	6.1	11.2	0.0	20.8	1.2	17.6
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		70.4	57.4	54.8	43.0	59.0	59.9	51.8	0.0	52.7	44.3	54.2
LnGrp LOS		E	E	D	D	E	E	D	A	D	D	D
Approach Vol, veh/h			599			428			1402			916
Approach Delay, s/veh			63.1			57.7			52.2			48.0
Approach LOS			E			E			D			D

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	23.0	53.0	23.4	20.6	31.0	45.0	22.1	21.8
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	47.0	5.0	39.0	13.0	39.0	21.0	23.0
Max Q Clear Time (g_c+I1), s	2.0	42.7	2.0	13.2	21.5	36.4	15.8	14.5
Green Ext Time (p_c), s	0.0	1.6	0.0	1.3	0.0	1.2	0.4	1.3

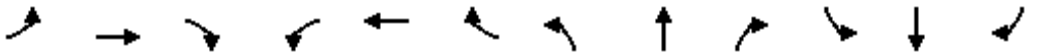
Intersection Summary	
HCM 6th Ctrl Delay	53.7
HCM 6th LOS	D

Notes

User approved pedestrian interval to be less than phase max green.
User approved ignoring U-Turning movement.



Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	388
Future Volume (veh/h)	388
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	313
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	515
Arrive On Green	0.32
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	313
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	19.9
Cycle Q Clear(g_c), s	19.9
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	515
V/C Ratio(X)	0.61
Avail Cap(c_a), veh/h	515
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.66
Uniform Delay (d), s/veh	34.1
Incr Delay (d2), s/veh	3.5
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	8.0
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	37.6
LnGrp LOS	D
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	73	275	198	241	474	43	173	459	173	30	470	143
Future Volume (veh/h)	73	275	198	241	474	43	173	459	173	30	470	143
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	81	306	220	268	527	48	192	510	192	33	522	159
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	289	356	302	306	666	61	336	561	476	342	561	476
Arrive On Green	0.10	0.19	0.19	0.11	0.20	0.20	0.13	0.30	0.30	0.13	0.30	0.30
Sat Flow, veh/h	1781	1870	1585	1781	3294	299	1781	1870	1585	1781	1870	1585
Grp Volume(v), veh/h	81	306	220	268	284	291	192	510	192	33	522	159
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	1777	1816	1781	1870	1585	1781	1870	1585
Q Serve(g_s), s	0.0	14.3	11.7	7.7	13.6	13.7	3.7	23.6	8.7	0.0	24.4	7.0
Cycle Q Clear(g_c), s	0.0	14.3	11.7	7.7	13.6	13.7	3.7	23.6	8.7	0.0	24.4	7.0
Prop In Lane	1.00		1.00	1.00		0.16	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	289	356	302	306	359	367	336	561	476	342	561	476
V/C Ratio(X)	0.28	0.86	0.73	0.87	0.79	0.79	0.57	0.91	0.40	0.10	0.93	0.33
Avail Cap(c_a), veh/h	289	416	352	385	553	565	336	561	476	342	561	476
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	0.51	0.51	0.51	1.00	1.00	1.00
Uniform Delay (d), s/veh	35.8	35.3	34.2	37.3	34.1	34.1	34.4	30.3	25.1	32.5	30.6	24.5
Incr Delay (d2), s/veh	0.5	14.7	6.3	16.5	4.2	4.3	1.2	12.5	1.3	0.1	24.2	1.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.6	7.6	4.8	6.8	6.0	6.1	3.7	11.7	3.2	0.6	13.8	2.7
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	36.3	49.9	40.5	53.8	38.3	38.4	35.6	42.8	26.4	32.6	54.8	26.4
LnGrp LOS	D	D	D	D	D	D	D	D	C	C	D	C
Approach Vol, veh/h		607			843			894			714	
Approach Delay, s/veh		44.7			43.3			37.7			47.4	
Approach LOS		D			D			D			D	

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	17.8	33.0	16.0	23.1	17.8	33.0	15.0	24.2
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	27.0	14.0	20.0	5.0	27.0	6.0	28.0
Max Q Clear Time (g_c+I1), s	2.0	25.6	9.7	16.3	5.7	26.4	2.0	15.7
Green Ext Time (p_c), s	0.0	0.5	0.3	0.9	0.0	0.2	0.0	2.5

Intersection Summary	
HCM 6th Ctrl Delay	42.9
HCM 6th LOS	D

HCM 6th Signalized Intersection Summary
1: Houghton Road & Speedway Boulevard

11/17/2021



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Future Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		237	262	207	32	159	23	459	486	57	52	559
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		318	325	276	147	260	37	816	555	65	410	608
Arrive On Green		0.12	0.17	0.17	0.03	0.08	0.08	0.17	0.34	0.34	0.16	0.32
Sat Flow, veh/h		1781	1870	1585	1781	3123	444	3456	1643	193	1781	1870
Grp Volume(v), veh/h		237	262	207	32	89	93	459	0	543	52	559
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1790	1728	0	1836	1781	1870
Q Serve(g_s), s		5.6	10.8	9.9	0.0	3.9	4.0	4.0	0.0	22.3	0.0	23.0
Cycle Q Clear(g_c), s		5.6	10.8	9.9	0.0	3.9	4.0	4.0	0.0	22.3	0.0	23.0
Prop In Lane		1.00		1.00	1.00		0.25	1.00		0.10	1.00	
Lane Grp Cap(c), veh/h		318	325	276	147	148	149	816	0	620	410	608
V/C Ratio(X)		0.75	0.81	0.75	0.22	0.60	0.62	0.56	0.00	0.88	0.13	0.92
Avail Cap(c_a), veh/h		318	444	376	201	422	425	816	0	620	410	608
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.84	0.84
Uniform Delay (d), s/veh		32.1	31.7	31.4	37.5	35.4	35.4	28.1	0.0	24.9	27.0	26.0
Incr Delay (d2), s/veh		9.2	7.5	5.5	0.7	3.9	4.2	0.9	0.0	16.0	0.1	18.7
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		4.9	5.3	4.0	0.6	1.8	1.8	3.6	0.0	11.3	0.8	12.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		41.3	39.3	36.9	38.2	39.3	39.6	29.0	0.0	40.9	27.1	44.7
LnGrp LOS		D	D	D	D	D	D	C	A	D	C	D
Approach Vol, veh/h			706			214			1002			814
Approach Delay, s/veh			39.3			39.3			35.5			38.1
Approach LOS			D			D			D			D

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.5	33.0	8.5	19.9	19.5	32.0	15.8	12.7
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	27.0	5.0	19.0	6.0	26.0	5.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	24.3	2.0	12.8	6.0	25.0	7.6	6.0
Green Ext Time (p_c), s	0.0	0.9	0.0	1.1	0.0	0.4	0.0	0.7

Intersection Summary	
HCM 6th Ctrl Delay	37.5
HCM 6th LOS	D

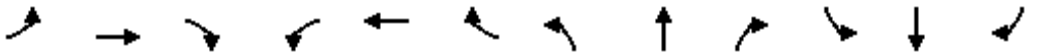
Notes

User approved pedestrian interval to be less than phase max green.

User approved ignoring U-Turning movement.



Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	253
Future Volume (veh/h)	253
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	203
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	515
Arrive On Green	0.32
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	203
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	7.9
Cycle Q Clear(g_c), s	7.9
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	515
V/C Ratio(X)	0.39
Avail Cap(c_a), veh/h	515
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.84
Uniform Delay (d), s/veh	20.9
Incr Delay (d2), s/veh	1.9
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	3.0
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	22.8
LnGrp LOS	C
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	



Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	86	309	242	167	371	35	180	338	163	29	376	121
Future Volume (veh/h)	86	309	242	167	371	35	180	338	163	29	376	121
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach		No			No			No			No	
Adj Sat Flow, veh/h/ln	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h	96	343	269	186	412	39	200	376	181	32	418	134
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	357	406	344	225	550	52	375	902	764	390	902	764
Arrive On Green	0.12	0.22	0.22	0.08	0.17	0.17	0.48	0.48	0.48	0.48	0.48	0.48
Sat Flow, veh/h	1781	1870	1585	1781	3282	309	856	1870	1585	852	1870	1585
Grp Volume(v), veh/h	96	343	269	186	222	229	200	376	181	32	418	134
Grp Sat Flow(s),veh/h/ln	1781	1870	1585	1781	1777	1815	856	1870	1585	852	1870	1585
Q Serve(g_s), s	0.0	14.1	12.8	4.1	9.5	9.6	16.3	10.4	5.3	2.0	11.9	3.8
Cycle Q Clear(g_c), s	0.0	14.1	12.8	4.1	9.5	9.6	28.2	10.4	5.3	12.4	11.9	3.8
Prop In Lane	1.00		1.00	1.00		0.17	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	357	406	344	225	298	304	375	902	764	390	902	764
V/C Ratio(X)	0.27	0.85	0.78	0.83	0.75	0.75	0.53	0.42	0.24	0.08	0.46	0.18
Avail Cap(c_a), veh/h	357	491	416	246	511	522	375	902	764	390	902	764
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	0.72	0.72	0.72	1.00	1.00	1.00
Uniform Delay (d), s/veh	29.7	30.0	29.5	35.1	31.7	31.7	23.2	13.4	12.1	17.4	13.8	11.7
Incr Delay (d2), s/veh	0.4	11.0	7.8	19.1	3.7	3.7	3.9	1.0	0.5	0.4	1.7	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.6	7.1	5.2	4.5	4.1	4.2	3.3	4.0	1.7	0.4	4.7	1.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh	30.1	41.0	37.3	54.1	35.4	35.5	27.1	14.4	12.6	17.9	15.5	12.2
LnGrp LOS	C	D	D	D	D	D	C	B	B	B	B	B
Approach Vol, veh/h		708			637			757			584	
Approach Delay, s/veh		38.1			40.9			17.3			14.9	
Approach LOS		D			D			B			B	

Timer - Assigned Phs		2	3	4		6	7	8				
Phs Duration (G+Y+Rc), s		44.6	12.1	23.4		44.6	16.0	19.4				
Change Period (Y+Rc), s		6.0	6.0	6.0		6.0	6.0	6.0				
Max Green Setting (Gmax), s		34.0	7.0	21.0		34.0	5.0	23.0				
Max Q Clear Time (g_c+I1), s		30.2	6.1	16.1		14.4	2.0	11.6				
Green Ext Time (p_c), s		1.4	0.0	1.3		2.8	0.0	1.8				

Intersection Summary												
HCM 6th Ctrl Delay			27.9									
HCM 6th LOS			C									

HCM 6th Signalized Intersection Summary
1: Houghton Road & Speedway Boulevard

11/02/2021



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	44	258	162	251	42	303	40	669	540	53	41	501
Future Volume (veh/h)	44	258	162	251	42	303	40	669	540	53	41	501
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		287	180	132	47	337	44	743	600	59	46	557
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		317	227	193	348	417	54	868	656	65	313	608
Arrive On Green		0.13	0.12	0.12	0.15	0.13	0.13	0.21	0.39	0.39	0.14	0.32
Sat Flow, veh/h		1781	1870	1585	1781	3164	410	3456	1676	165	1781	1870
Grp Volume(v), veh/h		287	180	132	47	188	193	743	0	659	46	557
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1797	1728	0	1841	1781	1870
Q Serve(g_s), s		13.8	11.2	9.6	0.0	12.3	12.5	19.5	0.0	40.7	0.0	34.4
Cycle Q Clear(g_c), s		13.8	11.2	9.6	0.0	12.3	12.5	19.5	0.0	40.7	0.0	34.4
Prop In Lane		1.00		1.00	1.00		0.23	1.00		0.09	1.00	
Lane Grp Cap(c), veh/h		317	227	193	348	234	237	868	0	721	313	608
V/C Ratio(X)		0.91	0.79	0.69	0.13	0.80	0.81	0.86	0.00	0.91	0.15	0.92
Avail Cap(c_a), veh/h		389	608	515	348	341	344	868	0	721	313	608
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.66	0.66
Uniform Delay (d), s/veh		49.0	51.2	50.5	42.8	50.6	50.7	43.3	0.0	34.6	44.2	38.9
Incr Delay (d2), s/veh		21.4	6.1	4.3	0.2	8.5	9.3	8.5	0.0	18.1	0.1	15.2
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		10.1	5.6	4.0	1.2	5.9	6.1	11.2	0.0	20.8	1.2	17.6
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		70.4	57.4	54.8	43.0	59.0	59.9	51.8	0.0	52.7	44.3	54.2
LnGrp LOS		E	E	D	D	E	E	D	A	D	D	D
Approach Vol, veh/h			599			428			1402			916
Approach Delay, s/veh			63.1			57.7			52.2			48.0
Approach LOS			E			E			D			D

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	23.0	53.0	23.4	20.6	31.0	45.0	22.1	21.8
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	47.0	5.0	39.0	13.0	39.0	21.0	23.0
Max Q Clear Time (g_c+I1), s	2.0	42.7	2.0	13.2	21.5	36.4	15.8	14.5
Green Ext Time (p_c), s	0.0	1.6	0.0	1.3	0.0	1.2	0.4	1.3

Intersection Summary	
HCM 6th Ctrl Delay	53.7
HCM 6th LOS	D

Notes

User approved pedestrian interval to be less than phase max green.

User approved ignoring U-Turning movement.

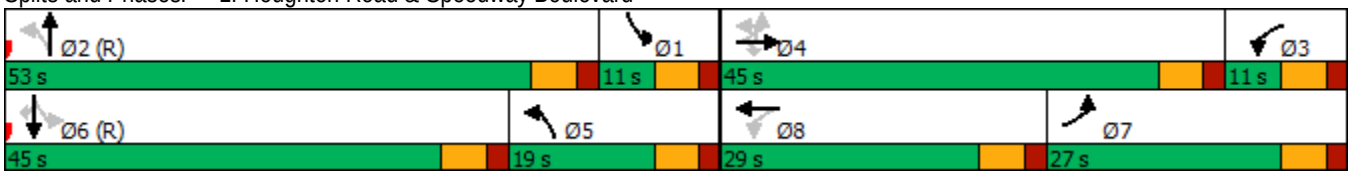


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	388
Future Volume (veh/h)	388
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	313
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	515
Arrive On Green	0.32
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	313
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	19.9
Cycle Q Clear(g_c), s	19.9
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	515
V/C Ratio(X)	0.61
Avail Cap(c_a), veh/h	515
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.66
Uniform Delay (d), s/veh	34.1
Incr Delay (d2), s/veh	3.5
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	8.0
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	37.6
LnGrp LOS	D
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	44	258	162	251	42	303	40	669	540	53	41	501
Future Volume (vph)	44	258	162	251	42	303	40	669	540	53	41	501
Satd. Flow (prot)	0	1770	1801	1583	1770	3479	0	3433	1839	0	1770	1863
Flt Permitted		0.367			0.471			0.189			0.098	
Satd. Flow (perm)	0	684	1801	1583	877	3479	0	683	1839	0	183	1863
Satd. Flow (RTOR)				279		10			5			
Lane Group Flow (vph)	0	336	180	279	47	381	0	743	659	0	46	557
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	45.0	27.0	45.0	45.0	11.0	29.0		19.0	53.0		11.0	45.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		39.2	22.5	22.5	35.6	18.0		64.2	55.4		50.2	45.2
Actuated g/C Ratio		0.33	0.19	0.19	0.30	0.15		0.54	0.46		0.42	0.38
v/c Ratio		0.84	0.53	0.53	0.12	0.72		1.12	0.77		0.32	0.79
Control Delay		59.0	51.5	8.8	24.6	55.0		110.1	36.7		32.2	44.4
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		59.0	51.5	8.8	24.6	55.0		110.1	36.7		32.2	44.4
LOS		E	D	A	C	E		F	D		C	D
Approach Delay			39.7			51.7			75.6			32.3
Approach LOS			D			D			E			C

Intersection Summary	
Cycle Length: 120	
Actuated Cycle Length: 120	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.12	
Intersection Signal Delay: 52.7	Intersection LOS: D
Intersection Capacity Utilization 91.8%	ICU Level of Service F
Analysis Period (min) 15	

Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	388
Future Volume (vph)	388
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	245
Lane Group Flow (vph)	431
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	45.0
Total Lost Time (s)	6.0
Act Effct Green (s)	45.2
Actuated g/C Ratio	0.38
v/c Ratio	0.58
Control Delay	16.6
Queue Delay	0.0
Total Delay	16.6
LOS	B
Approach Delay	
Approach LOS	

Intersection Summary

HCM 6th Signalized Intersection Summary
1: Houghton Road & Speedway Boulevard

11/02/2021



Movement	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Future Volume (veh/h)	25	213	236	374	29	143	21	413	437	51	47	503
Initial Q (Qb), veh		0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)		1.00		1.00	1.00		1.00	1.00		1.00	1.00	
Parking Bus, Adj		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Work Zone On Approach			No			No			No			No
Adj Sat Flow, veh/h/ln		1870	1870	1870	1870	1870	1870	1870	1870	1870	1870	1870
Adj Flow Rate, veh/h		237	262	207	32	159	23	459	486	57	52	559
Peak Hour Factor		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %		2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h		318	325	276	147	260	37	816	555	65	410	608
Arrive On Green		0.12	0.17	0.17	0.03	0.08	0.08	0.17	0.34	0.34	0.16	0.32
Sat Flow, veh/h		1781	1870	1585	1781	3123	444	3456	1643	193	1781	1870
Grp Volume(v), veh/h		237	262	207	32	89	93	459	0	543	52	559
Grp Sat Flow(s),veh/h/ln		1781	1870	1585	1781	1777	1790	1728	0	1836	1781	1870
Q Serve(g_s), s		5.6	10.8	9.9	0.0	3.9	4.0	4.0	0.0	22.3	0.0	23.0
Cycle Q Clear(g_c), s		5.6	10.8	9.9	0.0	3.9	4.0	4.0	0.0	22.3	0.0	23.0
Prop In Lane		1.00		1.00	1.00		0.25	1.00		0.10	1.00	
Lane Grp Cap(c), veh/h		318	325	276	147	148	149	816	0	620	410	608
V/C Ratio(X)		0.75	0.81	0.75	0.22	0.60	0.62	0.56	0.00	0.88	0.13	0.92
Avail Cap(c_a), veh/h		318	444	376	201	422	425	816	0	620	410	608
HCM Platoon Ratio		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.84	0.84
Uniform Delay (d), s/veh		32.1	31.7	31.4	37.5	35.4	35.4	28.1	0.0	24.9	27.0	26.0
Incr Delay (d2), s/veh		9.2	7.5	5.5	0.7	3.9	4.2	0.9	0.0	16.0	0.1	18.7
Initial Q Delay(d3),s/veh		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln		4.9	5.3	4.0	0.6	1.8	1.8	3.6	0.0	11.3	0.8	12.3
Unsig. Movement Delay, s/veh												
LnGrp Delay(d),s/veh		41.3	39.3	36.9	38.2	39.3	39.6	29.0	0.0	40.9	27.1	44.7
LnGrp LOS		D	D	D	D	D	D	C	A	D	C	D
Approach Vol, veh/h			706			214			1002			814
Approach Delay, s/veh			39.3			39.3			35.5			38.1
Approach LOS			D			D			D			D

Timer - Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	18.5	33.0	8.5	19.9	19.5	32.0	15.8	12.7
Change Period (Y+Rc), s	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Max Green Setting (Gmax), s	5.0	27.0	5.0	19.0	6.0	26.0	5.0	19.0
Max Q Clear Time (g_c+I1), s	2.0	24.3	2.0	12.8	6.0	25.0	7.6	6.0
Green Ext Time (p_c), s	0.0	0.9	0.0	1.1	0.0	0.4	0.0	0.7

Intersection Summary	
HCM 6th Ctrl Delay	37.5
HCM 6th LOS	D

Notes

User approved pedestrian interval to be less than phase max green.

User approved ignoring U-Turning movement.

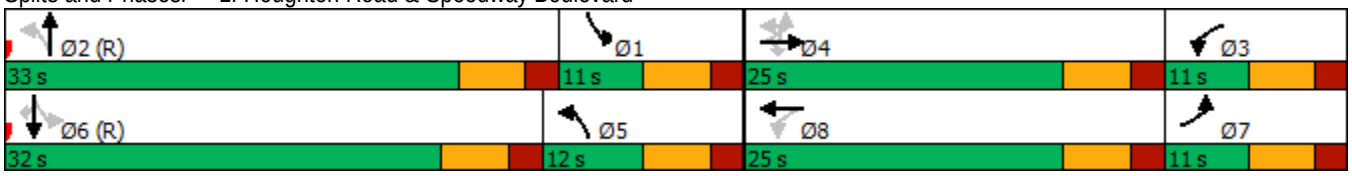


Movement	SBR
Lane Configurations	
Traffic Volume (veh/h)	253
Future Volume (veh/h)	253
Initial Q (Qb), veh	0
Ped-Bike Adj(A_pbT)	1.00
Parking Bus, Adj	1.00
Work Zone On Approach	
Adj Sat Flow, veh/h/ln	1870
Adj Flow Rate, veh/h	203
Peak Hour Factor	0.90
Percent Heavy Veh, %	2
Cap, veh/h	515
Arrive On Green	0.32
Sat Flow, veh/h	1585
Grp Volume(v), veh/h	203
Grp Sat Flow(s),veh/h/ln	1585
Q Serve(g_s), s	7.9
Cycle Q Clear(g_c), s	7.9
Prop In Lane	1.00
Lane Grp Cap(c), veh/h	515
V/C Ratio(X)	0.39
Avail Cap(c_a), veh/h	515
HCM Platoon Ratio	1.00
Upstream Filter(I)	0.84
Uniform Delay (d), s/veh	20.9
Incr Delay (d2), s/veh	1.9
Initial Q Delay(d3),s/veh	0.0
%ile BackOfQ(50%),veh/ln	3.0
Unsig. Movement Delay, s/veh	
LnGrp Delay(d),s/veh	22.8
LnGrp LOS	C
Approach Vol, veh/h	
Approach Delay, s/veh	
Approach LOS	
Timer - Assigned Phs	

Lane Group	EBU	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT
Lane Configurations												
Traffic Volume (vph)	25	213	236	374	29	143	21	413	437	51	47	503
Future Volume (vph)	25	213	236	374	29	143	21	413	437	51	47	503
Satd. Flow (prot)	0	1770	1801	1583	1770	3472	0	3433	1833	0	1770	1863
Flt Permitted		0.637			0.377			0.189			0.195	
Satd. Flow (perm)	0	1187	1801	1583	702	3472	0	683	1833	0	363	1863
Satd. Flow (RTOR)				349		19			8			
Lane Group Flow (vph)	0	265	262	416	32	182	0	459	543	0	52	559
Turn Type	Perm	pm+pt	NA	Perm	pm+pt	NA		pm+pt	NA		pm+pt	NA
Protected Phases		7	4		3	8		5	2		1	6
Permitted Phases	4	4		4	8			2			6	
Total Split (s)	25.0	11.0	25.0	25.0	11.0	25.0		12.0	33.0		11.0	32.0
Total Lost Time (s)		6.0	6.0	6.0	6.0	6.0		6.0	6.0		6.0	6.0
Act Effct Green (s)		22.8	19.6	19.6	15.9	10.6		41.0	37.4		37.0	32.0
Actuated g/C Ratio		0.28	0.24	0.24	0.20	0.13		0.51	0.47		0.46	0.40
v/c Ratio		0.68	0.60	0.64	0.15	0.38		0.83	0.63		0.20	0.75
Control Delay		34.4	33.2	10.6	19.8	29.5		37.4	24.0		11.2	25.0
Queue Delay		0.0	0.0	0.0	0.0	0.0		0.0	0.0		0.0	0.0
Total Delay		34.4	33.2	10.6	19.8	29.5		37.4	24.0		11.2	25.0
LOS		C	C	B	B	C		D	C		B	C
Approach Delay			23.6			28.1			30.1			17.6
Approach LOS			C			C			C			B

Intersection Summary	
Cycle Length: 80	
Actuated Cycle Length: 80	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.83	
Intersection Signal Delay: 24.3	Intersection LOS: C
Intersection Capacity Utilization 76.1%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 1: Houghton Road & Speedway Boulevard





Lane Group	SBR
Lane Configurations	
Traffic Volume (vph)	253
Future Volume (vph)	253
Satd. Flow (prot)	1583
Flt Permitted	
Satd. Flow (perm)	1583
Satd. Flow (RTOR)	205
Lane Group Flow (vph)	281
Turn Type	Perm
Protected Phases	
Permitted Phases	6
Total Split (s)	32.0
Total Lost Time (s)	6.0
Act Effct Green (s)	32.0
Actuated g/C Ratio	0.40
v/c Ratio	0.37
Control Delay	4.1
Queue Delay	0.0
Total Delay	4.1
LOS	A
Approach Delay	
Approach LOS	

Intersection Summary

APPENDIX

E COST ESTIMATE

Preliminary

CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD

Tanque Verde Rd to Speedway Blvd

Houghton Road Needs Study Addendum

December 21, 2021

Description	NB Rght	Houghton/ Speedway	Bridge Repair	Multi-Use Path (MUP)	SB Right @ Tanque Verde	WB Thru @ Tanque Verde	TWLTL Houghton Corte Visa La Mariposa to Drachman	Totals
Roadway Subtotal	$453,000	$6,835,000		$451,000	$125,000	$525,600	$348,000	$8,737,600
Additional cost for **Multi-Use Path South of Speedway**		$61,000						$61,000
Bridge Work for MUP				$421,000				$421,000
Bridge Repair			$947,000					$947,000
Subtotals	**$453,000**	**$6,896,000**	**$947,000**	**$872,000**	**$125,000**	**$525,600**	**$348,000**	**$10,166,600**
Utility Relocation (2.5% of the Roadway Subtotal)	$11,330	$170,880		$11,280	$3,130	$13,140	$8,700	$218,460
NPDES (3% of Roadway Subtotal)	$13,600	$206,900		$26,200	$3,800	$15,800	$10,500	$276,800
Mobilization (10% of Roadway and Bridge Subtotal)	$46,000	$690,000	$95,000	$88,000	$13,000	$53,000	$35,000	$1,020,000
Maintenance and Protection of Traffic (9% of Roadway and Bridge Subtotal)	$41,000	$621,000	$86,000	$79,000	$12,000	$48,000	$32,000	$919,000
Construction Survey and Layout (1% of Roadway Subtotal)*	$4,530	$68,350		$6,000	$6,001	$6,002	$6,003	$96,886
Miscellaneous Construction Subtotal	**$116,460**	**$1,757,130**	**$181,000**	**$210,480**	**$37,931**	**$135,942**	**$92,203**	**$2,531,146**
* $6,000 min for MUP								
Construction Subtotal	**$569,460**	**$8,653,130**	**$1,128,000**	**$1,082,480**	**$162,931**	**$661,542**	**$440,203**	**$12,697,746**
Right of Way (Est $200,000/AC)		$206,000				$18,000		$224,000
Subtotals	$569,460	$8,859,130	$1,128,000	$1,082,480	$162,931	$679,542	$440,203	$12,921,746
Contingency (20%)	$113,892	$1,771,826	$225,600	$216,496	$32,586	$135,908	$88,041	$2,584,349
Subtotals	$683,352	$10,630,956	$1,353,600	$1,298,976	$195,517	$815,450	$528,244	$15,506,095
Design Fees (8%-10% of Const Subtotal)	$69,000	$1,064,000			$20,000	$82,000	$53,000	$1,288,000
Design Fees - Bridge Repair			$30,000					$30,000
Design Fees (10% of Const Subtotal + Est $90,000 Bridge MUP Design)				$220,000				$220,000
Subtotal - Design Fees	$69,000	$1,064,000	$30,000	$220,000	$20,000	$82,000	$53,000	$1,538,000
Totals	$752,352	$11,694,956	$1,383,600	$1,518,976	$215,517	$897,450	$581,244	$17,044,095
Project Totals (Rounded)	**$752,400**	**$11,695,000**	**$1,383,600**	**$1,519,000**	**$215,600**	**$897,500**	**$581,300**	**$17,045,000.00**

* The Design Fee for the Multi-Use Path south of Speedway are included in the Houghton/Speedway Design Fee

Preliminary

CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD

Tanque Verde Rd to Speedway Blvd

Houghton Road Needs Study Addendum

NB Right Turn Lane at Tanque Verde

December 14, 2021

					Addendum	Needs Study
				Unit	Total	Total
Item #	Description	Quantity	Unit	Cost	Cost	Cost
	Borrow	1,300	CY	$30.50	$39,700	$32,500.00
	Aggregate Base	180	CY	$45.00	$8,100	$6,300.00
	Asphalt Concrete	270	TONS	$95.00	$25,700	$23,000.00
	Signing (60% of Striping)	1	L SUM	$1,560.00	$1,600	$2,000.00
	Striping	1,600	LF	$1.60	$2,600	$1,500.00
	Traffic Signals	1	L SUM	$18,300.00	$18,300	$15,000.00
	Type 1 Curb	90	LF	$25.00	$2,300	$1,400.00
	Sidewalk	240	SF	$10.00	$2,400	$1,500.00
	Curb Access Ramp	4	EA	$3,000.00	$12,000	$10,000.00
	Guardrail	675	LF	$27.45	$18,600	$15,200.00
	Concrete Channel Lining (6")	2,070	SY	$96.00	$198,800	$155,300.00
	Reinforced Concrete Cantilever Retaining Wall (H=4')	1,600	SF	$65.00	$104,000	$104,000.00
	Handrail	400	LF	$45.00	$18,000	$10,000.00

Source of Unit Cost are from City of Tucson and Ruthrauff Rd Tabulated Bids

Subtotal	$452,100.00	$377,700.00
Additional Items Not Listed (0%)	$0.00	$0.00
Subtotal	**$452,100.00**	$377,700.00
Project Total	**$453,000.00**	$378,000.00

Preliminary

CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD

Tanque Verde Rd to Speedway Blvd

Houghton Road Needs Study Addendum

Houghton Road/Speedway Boulevard - Including NB Houghton Right Turn Lane at Tanque Verde

December 21, 2021

				Addendum	Needs Study
			Unit	Total	Total
Description	**Quantity**	**Unit**	**Cost**	**Cost**	Cost
Roadway Construction	337,400	SF	$10.66	$3,598,000	$2,949,000.00
Drainage	1	L SUM	$2,769,949.00	$2,770,000	$2,271,000.00
Signing (60% of Striping)	60%	PCT	$107,000.00	$65,000	$37,000.00
Striping	66,700	LF	$1.60	$107,000	$61,000.00
Traffic Signals	1	L SUM	$500,200.00	$501,000	$410,000.00
Landscaping (3.5% of Roadway Subtotal)	3.5%	PCT	$7,041,000.00	$247,000	$208,000.00
Roadway Subtotal*				**$7,288,000**	$5,936,000.00
*** $7,288,00 - $453,00 (NB Rt Turn Lane estimated separately) = $6,835,000**					
Fix Damage to Joint at North End (Tanque Verde Wash)	42	LF	$725.90	$31,000	$25,000.00
Replace Joint Seal at Pier 6 (Tanque Verde Wash)	42	LF	$725.90	$31,000	$25,000.00
Pier Spall Repairs (Tanque Verde Wash)	1	LS	$30,500.00	$31,000	$25,000.00
Deck Sealing (Tanque Verde Wash)	5,500	SY	$122.00	$671,000	$550,000.00
Deck Sealing (Agua Caliente Wash)	1,500	SY	$122.00	$183,000	$150,000.00
Bridge Subtotal				**$947,000**	$775,000.00
Utility Relocations and Modifications (2.5% of Roadway Subtotal)	2.5%	PCT	$7,288,000.00	$183,000	$149,000.00
NPDES (3% of Roadway Subtotal)	3.0%	PCT	$7,288,000.00	$219,000	$179,000.00
Mobilization (10% of Roadway and Bridge Subtotal)	10.0%	PCT	$8,235,000.00	$824,000	$672,000.00
Maintenance and Protection of Traffic (9% of Roadway and Bridge Subtotal)	9.0%	PCT	$8,235,000.00	$742,000	$604,000.00
Construction Survey and Layout (1% of Roadway Subtotal)	1.0%	PCT	$7,288,000.00	$73,000	60000
Miscellaneous Construction Subtotal				**$2,041,000**	1664000
Construction Subtotal				**$10,276,000**	8375000
Design Fees (8%-10% (Construction Subtotal-(NPDES & Const Survey for Bridge) + Est. $30,000 for Bridge Repair))	1	L SUM	$1,288,000.00	$1,288,000	637000
Right of Way (Est $200,000/AC)	1.03	ACRE	$200,000.00	$206,000	206000
			Subtotal	$11,770,000.00	9218000
			Contingency (20%)	$2,354,000.00	1844000
			Subtotal	**$14,124,000.00**	$11,062,000.00
			Project Total	**$14,124,000.00**	$11,062,000.00

Preliminary

CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD

Tanque Verde Rd to Speedway Blvd

Houghton Road Needs Study Addendum

Multi-Use Path South of Speedway Boulevard

December 21, 2021

Item #	Description	Quantity	Unit	Unit Cost	Total Cost
	Multi-Use Path - Asphalt Concrete approx 2" thick				
	10' Wide by 4000' (north of Vicksburg St to Speedway)	40,000	SF	$4.00	$160,000
	Estimate Additional Earthwork				
	4000' x 4' additional width x avg. 1' deep	16000	CF		
		592	CY	$35.00	$20,720
					$180,720
	Concrete Sidewalk				
	6' Wide by 4000' (north of Vicksburg St to Speedway)	24,000	SF	$5.00	$120,000
	Additional cost of Multi-Use Path				$60,720

Subtotal	$60,720.00
Additional Items Not Listed (0%)	$0.00
Subtotal	**$60,720.00**
Total	**$61,000.00**

Preliminary

CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD

Tanque Verde Rd to Speedway Blvd

Houghton Road Needs Study Addendum

Multi-Use Path

December 21, 2021

					Addendum	Needs Study
				Unit	Total	Total
Item #	Description	Quantity	Unit	Cost	Cost	Cost
	Clear and Grubbing	3	AC	$5,750.00	$17,300	$15,000.00
	8" Pre-compaction & scarification of fill areas	7,260	SY	$0.55	$4,000	$3,300.00
	Path Grading	1	LS	$61,000.00	$61,000	$50,000.00
	Fine Grading	1	LS	$24,400.00	$24,400	$20,000.00
	Borrow	1,300	CY	$35.00	$45,500	$24,700.00
	Backfill retaining walls (excludes footing backfill)	250	LF	$12.81	$3,300	$2,700.00
	4" ABC	4,560	SY	$7.50	$34,300	$28,100.00
	2.5" AC	4,560	SY	$20.86	$95,200	$78,000.00
	Curb Access Ramp	2	EA	$5,200.00	$10,400	$10,400.00
	Pavement marking, signage & bumpers	1	LS	$6,344.00	$6,400	$5,200.00
	Scuppers with standard concrete lid	2	EA	$12,688.00	$25,400	$20,800.00
	6" Concrete lined channel	56	SY	$96.00	$5,400	$4,900.00
	3' toe-down	200	LF	$51.24	$10,300	$8,400.00
	Riprap (8" thick grouted)	200	SF	$7.93	$1,600	$1,300.00
	Riprap 8"-12" dumped	500	SF	$4.39	$2,200	$1,800.00
	Riprap (8" - 12" thick non-grouted - hand placed)	500	SF	$5.37	$2,700	$2,200.00
	Retaining walls-(wall backfill above)	250	LF	$146.40	$36,600	$30,000.00
	Barricade railing per PAG SD 105	500	LF	$51.24	$25,700	$21,000.00
	Type A post barricade	10	EA	$805.20	$8,100	$6,600.00
	Landscaping	1	LS	$30,500.00	$30,500	$25,000.00

Subtotal	$450,300.00	359400
Additional Items Not Listed (0%)	$0.00	0
Subtotal	**$450,300.00**	$359,400.00
Project Total	**$451,000.00**	$360,000.00

Preliminary
CONSTRUCTION COST ESTIMATE

HOUGHTON ROAD
Tanque Verde Rd to Speedway Blvd
Houghton Road Needs Study Addendum
Mult-Use Path on Bridges

December 14, 2021

CONSTRUCTION COST

Item #	Description	Quantity	Unit	Unit Cost	Total Cost
	Tanque Verde Wash				
2020027	Removal of Concrete Barrier	1105	LF	$36.60	$40,443.00
6011140	F-Shape Bridge Concrete Barrier and Transition (34")	1105	LF	$158.60	$175,253.00
	Miscellaneous Work (Deck Repair, Deck Drainage, Etc.)	1	L.SUM	$61,000.00	$61,000.00
				SUB-TOTAL	$276,696
	Agua Caliente Wash				
2020027	Removal of Concrete Barrier	300	LF	$36.60	$10,980
6011140	F-Shape Bridge Concrete Barrier and Transition (34")	300	LF	$158.60	$47,580
	Miscellaneous Work (Deck Repair, Deck Drainage, Etc.)	1	L.SUM	$30,500.00	$30,500
				SUB-TOTAL	$89,060
				15% Contingency	$54,863
				TOTAL Cost of Both Bridges=	**$421,000**

DESIGN COST

1 Alternatives Analysis / PA $24,400

2 Final design with 60%/90%/PS&E submittals $58,560

-Two Bridges, Six Sheets per Bridge, At $4000/sheet

1. General Plan & Elevation
2. Typical Section
3. General Notes
4. Deck Plan
5. Deck Details
6. Barrier Details

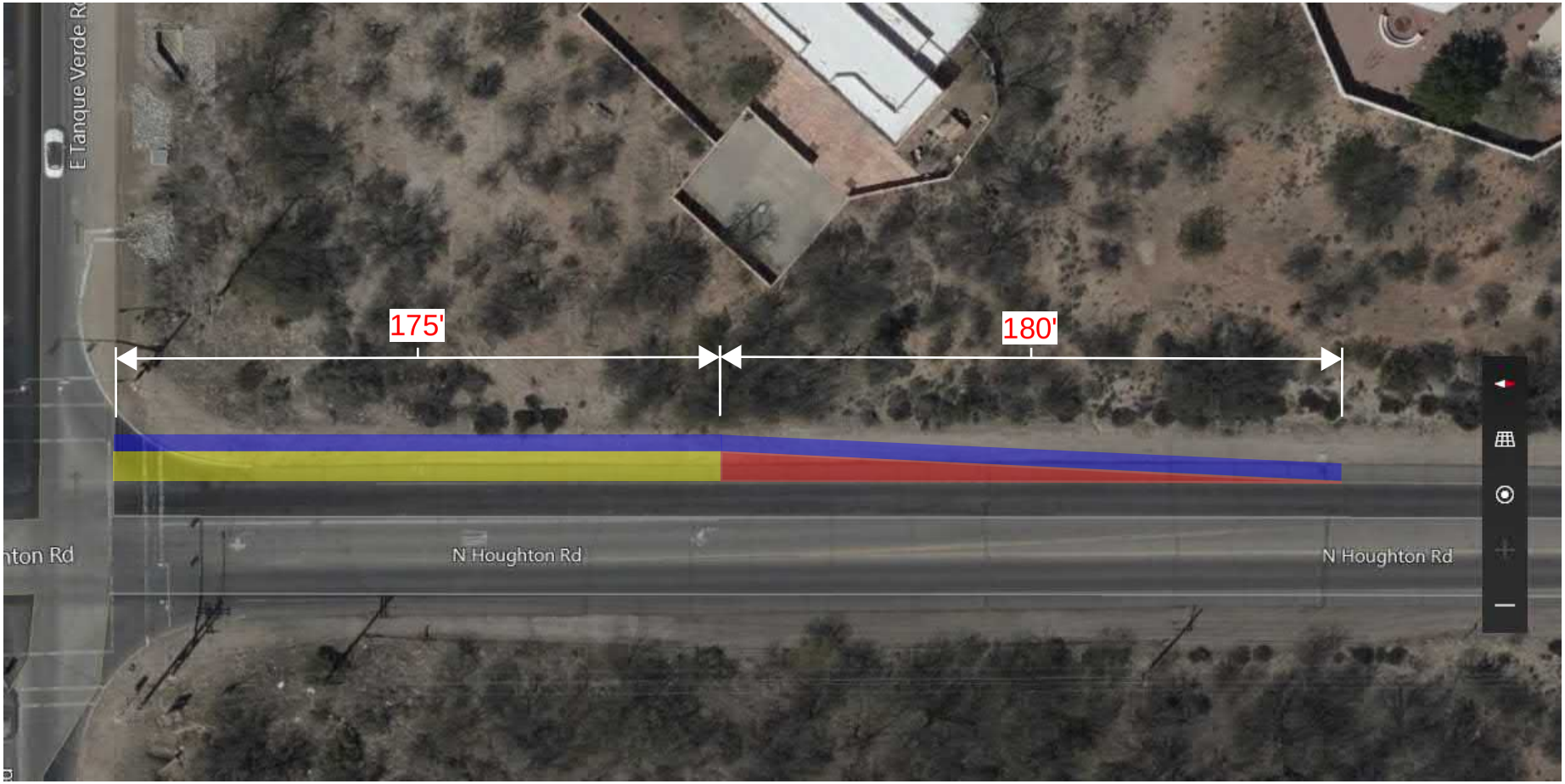
Total Design Cost= **$90,000**

3 Assumptions

a. MASH barrier upgrade not required on barrier to remain place
b. Deck Drains will be allowed drain directly to the waterways similar to existing conditions
c. No Bridge Maintenance repairs are included
d. No adjustment to existing crown location – Crown will not be CL of roadway
e. No sealing or overlay of bridge as part of this work

Chk'd JAV 8dec21

Houghton Road SB Right Turn Lane at Tanque Verde



6' Shoulder	Area = 6 *(175+180) =	2,130 SF
12' Right Turn Lane	Area = 12 *175 =	2,100 SF
12' to 0' Right Turn Taper	Area = (12 *180)/2 =	1,080 SF
	Total =	5,310 SF

Cost per SF based on Phase 1 is $23 per SF

$23 per SF x 5,310 SF = 122,130 vs 125,000 per phase 1 itemized estimate.

KEEP **$125,000**

Notes:
1. Assuming there is no fill due to ground been very level
2. Took the Phase 1 estimate and remove the drainage to apply a quick estimate to this phase.
3. Phase 1 was 380' long this is 355' a reduction ratio of 7%. Reduced the pavement quantities by 7%. (See spreadsheet, tab "Phase 5 Detailed Estimate")

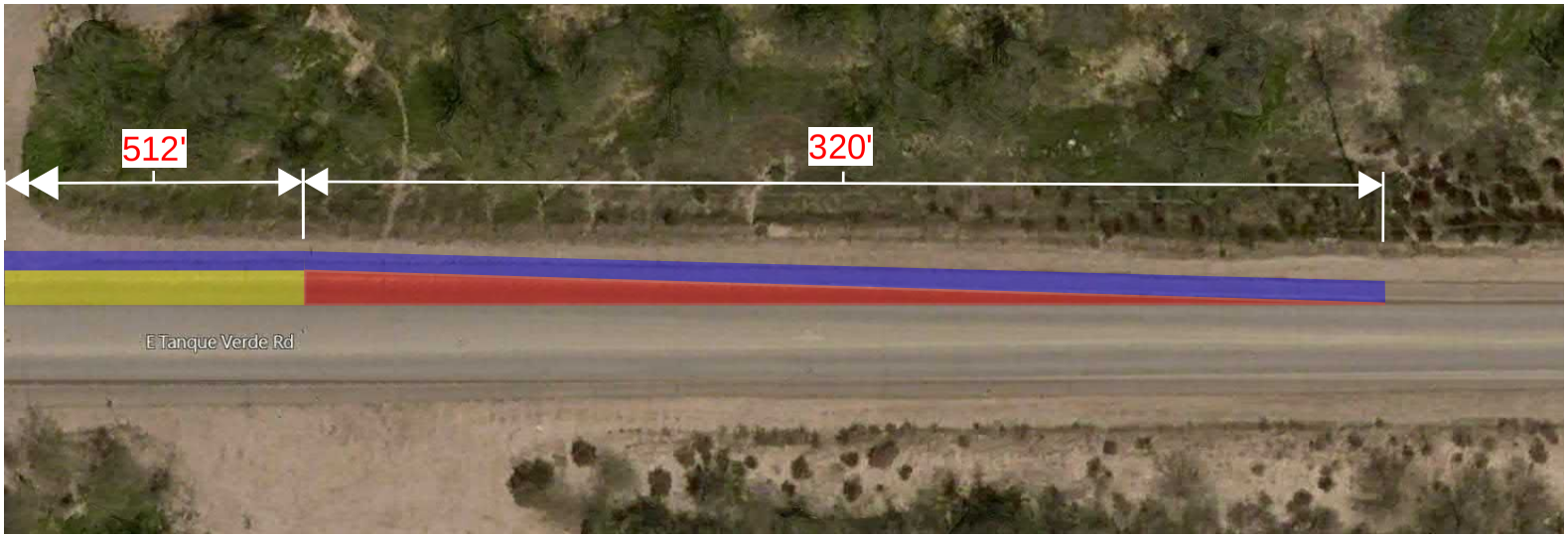
Tanque Verde Through Lane at Houghton Road



6' Shoulder ——— Area = 6 *(512+320) = 4,992 SF
12' Through Lane ——— Area = 12 *512 = 6,144 SF
12' to 0' Through Taper ——— Area = (12 *512)/2 = 3,072 SF
Total = 14,208 SF

Notes:
1. Assuming there is no fill due to ground been very level
2. Took the Phase 1 estimate and remove the drainage to apply a quick estimate to this phase.
3. Phase 1 was 380' long this is 832' an increase ratio of 218.94%. Increase the phase 1 quantities by 218.94% plus the percent increase for the next page. (see next page)

Cost per SF based on Phase 1 is $23 per SF
$23 per SF x 14,208 SF = $326,784 plus the matching existing pavement on the west side of Houghton Rd. (see next page)



Chk'd JAV 8dec21

Tanque Verde Through Lane at Houghton Road -Matching Existing



6' Shoulder ——— Area = 6 *(465+170) = 3,810 SF
12' Through Lane ——— Area = 12 *170 = 2,040 SF
12' to 0' Through Taper ——— Area = (12 *465)/2 = 2,790 SF
Total = 8,640 SF

Notes:
1. Assuming there is no fill due to ground been very level
2. Took the Phase 1 estimate and remove the drainage to apply a quick estimate to this phase.
3. Phase 1 was 380' long this is 635' an increase ratio of 167.11%.
   Increase the phase 1 quantities by 218.94%+167.11% for a total of 220.61%.
   (See spreadsheet, tab "Phase 6 Detailed Estimate)

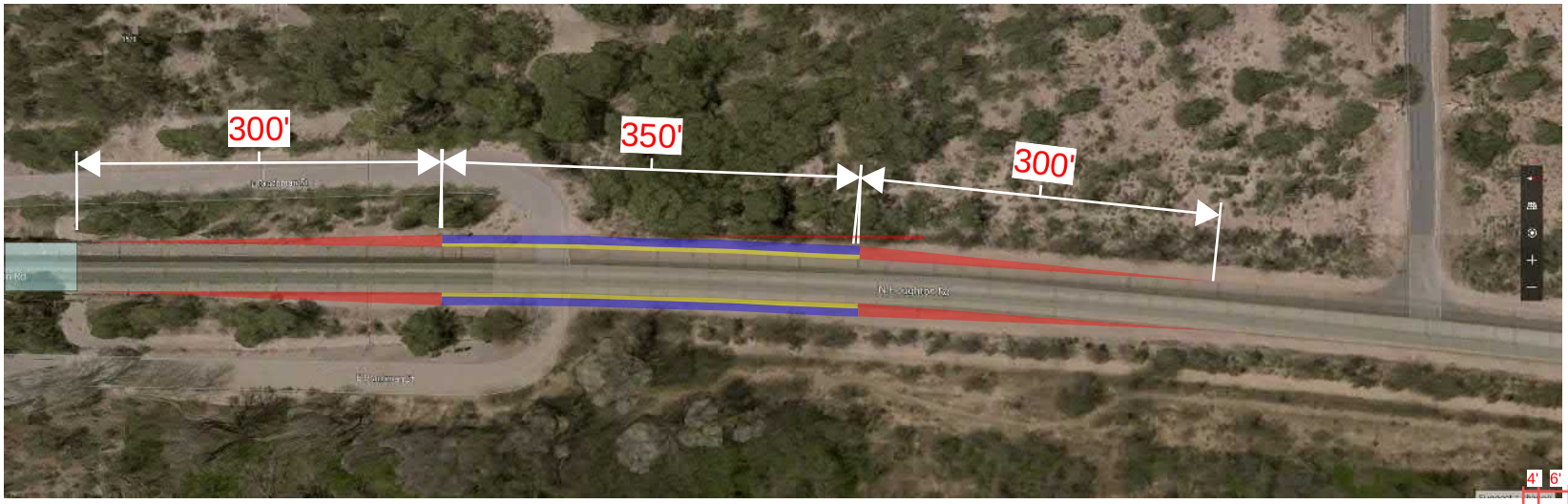
Cost per SF based on Phase 1 is $23 per SF
$23 per SF x 8,640 SF = $198,720

$326,784 +$198,720 = $525,504 vs. $416,000 (shown in Cost Estimate spreadsheet tab "Phase 6 Detailed Estimate")

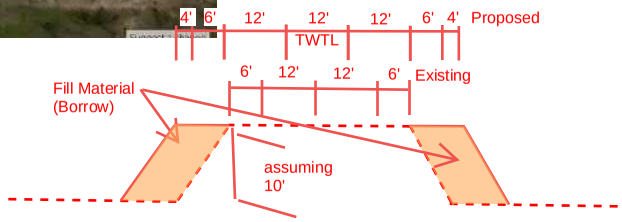
USE $525,504

Chk'd JAV 8dec21

TWLT at Houghton Rd



Exisitng Bridge
6' Taper Wideining — Area = ((6 *600)/2)* 2 sides= 3,600 SF
3' TL + 3' Shld Widening — Area = (6*350)* 2 sides = 4,200 SF
Sub-Total = 7,800 SF



Pavement Area - Check
6'/2x300'x4 tapers=3600 SF
6'x350'x2 sides=4200 SF
4200 + 3600=7800 SF

Fill Quantities for the TWLT Lane - Check
End area= (10'x10')=100 SF
For 300' length,
Volume = (0 SF+100 SF)/2x300'x 4 areas=60,000 CF
For 350' length,
Volume = (100 SF+100 SF)2x350'x2 sides=70,000 CF

Total Volume = 130,000 CF or 130,000/27=4815 CY

Notes:
1. Took the Phase 1 estimate and remove the drainage to apply a quick estimate to this phase.
2. Phase 1 was 380' long; this is 950' an increase of 150%. Increased the pavement quantities by 150%. (See spreadsheet, tab "Phase 7 Detailed Estimate")
3. Took Phase 1 roadway quantities and came up with a dollar per square foot. This amount is $23 per square foot. See spreadsheet tab "Phase 1 Detailed Estimate" for breakdown.

Cost per SF based on Phase 1 is $23 per SF
$23 per SF x 7,800 SF = $179,400
Plus Borrow at $35 per CY = 4815*35 = $168,525 for fill
Grand Total for SF of pavement and fill = $179,400 +$168,525
= $347,925 or $348,000
Cost Estimate spreadsheet tab "Phase 7 Detailed Estimate" = $167,000

Use $348,000