FINAL REPORT

to

THE FLORIDA DEPARTMENT OF TRANSPORTATION
SYSTEMS PLANNING OFFICE

on Project

Travel Time Reliability Implementation For the Freeway SIS

FDOT Contract BDK77-931-04

December 31, 2010

from

The University of Florida
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METRIC CONVERSION CHART

U.S. UNITS TO METRIC (SI) UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

METRIC (SI) UNITS TO U.S. UNITS

LENGTH

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

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16. Abstract

Four previous FDOT research projects on travel time reliability (FDOT Contracts BD-545-48, BD-545-70, BD-545-75, and BDK-77-977-02) developed tools for predicting travel time reliability for freeways. These tools can provide travel time reliability as a function of various changes in the system, such as incident removal times and work zone occurrences, and were applied to estimate travel time reliability in Broward County, Florida. The objectives of this research were to (a) implement the procedures developed on the entire freeway portion of the SIS, (b) enhance the existing procedures to incorporate additional elements such as the impact of incidents on each freeway segment and the impacts of various ITS strategies, (c) validate the estimates obtained using field data for those portions of the SIS where travel time information is available, and (d) establish procedures for updating the travel time reliability estimates on an annual basis.

A series of recommendations were developed for incorporating the impacts of several ITS strategies into the travel time reliability analysis. However, the literature is sparse relative to the operational impacts of these strategies, thus, the recommendations developed should be used with caution, and they should be updated when additional evaluation studies become available. The methodology was enhanced by considering weather-related impacts on travel time. Weather impacts focus on rain intensity. Visibility impacts were also evaluated, however it was recommended not to include these at this time. The calculation fora non-blocking incident frequencies was re-evaluated and new recommendations were developed and implemented in the database. These revisions provide more reasonable results in the frequencies of non-blocking incidents. Travel time reliability results were provided for the entire portion of the SIS for the year 2007. The results are reasonable, however there are some discrepancies observed between field data and estimated values. It is likely that either the congested travel times are underestimated, or that the frequency of the congested scenarios is underestimated. It is recommended that the results obtained for portions where field data are not available are examined in greater detail to ensure those are reasonable as well. It is also recommended to evaluate the estimation of congested travel times and the frequency of congestion to determine whether the discrepancies identified are related to a specific scenario or series of scenarios. Once discrepancies are identified, appropriate modifications should be implemented.

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EXECUTIVE SUMMARY

The goal of the Strategic Intermodal System (SIS) is to provide a transportation system that efficiently serves Florida's citizens, businesses and visitors: a transportation system that helps Florida become a worldwide economic leader, enhances economic prosperity and competitiveness, enriches quality of life, and reflects responsible environmental stewardship. The SIS consists of transportation facilities and services of statewide and interregional significance, including both freeways and arterials. Much research on the SIS and its users is needed. Travel time reliability is widely recognized as one of, if not the, most important performance measure of highway traveler perceptions. However, determining how to measure, quantify, predict, and report reliability has proved to be elusive.

Four previous FDOT research projects on travel time reliability (FDOT Contracts BD-545-48, BD-545-70, BD-545-75, and BDK-77-977-02) developed and implemented models for predicting travel time reliability for freeways, using data from Philadelphia, Ft. Lauderdale, and Jacksonville. These tools can provide travel time reliability as a function of various changes in the system, such as incident removal times and work zone occurrences, as well as a function of selected ITS programs and initiatives (such as the Road Rangers). These procedures have been applied to estimate travel time reliability in Broward County, Florida. However, there is a need to apply them to the entire freeway portion of the SIS. There is also a need to enhance these procedures to consider the impacts of safety on reliability and to consider a broader range of ITS strategies. Furthermore, the estimates obtained using these models should be validated for those portions of the SIS where travel time data are available. Finally, there is a need to provide the capability to update these travel time reliability estimates on an annual basis, as a function of annual information and data (such as incident frequency and duration) for each freeway segment of the SIS.

The objectives of this research were to (a) implement the procedures developed on the entire freeway portion of the SIS, (b) enhance the existing procedures to incorporate additional elements such as the impact of incidents on each freeway segment and the impacts of various ITS strategies, (c) validate the estimates obtained using field data for those portions of the SIS where travel time information is available, and (d) establish procedures for updating the travel time reliability estimates on an annual basis.

A series of recommendations were developed for incorporating the impacts of several ITS strategies into the travel time reliability analysis. However, the literature is sparse relative to the operational impacts of these strategies. In some cases, there are limited US implementations of these strategies, while in other cases the system evaluations conducted did not focus on operational impacts. Therefore, the recommendations developed should be used with caution, and they should be updated when additional evaluation studies become available.

The methodology was enhanced by considering weather-related impacts on travel time. Weather impacts focus on rain intensity. Visibility impacts were also evaluated, however it was recommended not to include these at this time. The calculation for non-blocking incident frequencies was re-evaluated and new recommendations were developed and implemented in the database. These revisions provide more reasonable results in the frequencies of non-blocking incidents.

Travel time reliability results were provided for the entire portion of the SIS for the year 2007. The results are reasonable, however there are some discrepancies observed between field data and estimated values. It is likely that either the congested travel times are underestimated, or that the frequency of the congested scenarios is underestimated.

It is recommended that the results obtained for portions where field data are not available are examined in greater detail to ensure those are reasonable as well. It is also recommended to evaluate the estimation of congested travel times and the frequency of congestion to determine whether the discrepancies identified are related to a specific scenario or series of scenarios. Once discrepancies are identified, appropriate modifications should be implemented.

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1. INTRODUCTION

1.1. Background

The goal of the Strategic Intermodal System (SIS) is to provide a transportation system that efficiently serves Florida's citizens, businesses and visitors: a transportation system that helps Florida become a worldwide economic leader, enhances economic prosperity and competitiveness, enriches quality of life, and reflects responsible environmental stewardship. The SIS consists of transportation facilities and services of statewide and interregional significance, including both freeways and arterials. Much research on the SIS and its users is needed. Travel time reliability is widely recognized as one of, if not the, most important performance measure of highway traveler perceptions. However, determining how to measure, quantify, predict, and report reliability has proved to be elusive.

Traditionally, state DOTs have concentrated on mitigating recurring congestion by removing bottlenecks and improving poor signal timing. Congestion reduction was often achieved by increasing system capacity to meet demand, but building new roadways or adding additional lane miles requires major financial investments and focuses on the long-term. However, the sources of congestion in the United States are increasingly related to non-recurring events, such as traffic incidents, work zones, adverse weather, and special events. Although non-recurring congestion is a regular phenomenon, it is often inefficient, impractical, or counterproductive to apply standard capacity additions to these types of problems. As a result, new approaches and relationships are necessary to effectively diminish congestion and enhance mobility.

Four previous FDOT research projects on travel time reliability (FDOT Contracts BD-545-48, BD-545-70, BD-545-75, and BDK-77-977-02) developed and implemented models for predicting travel time reliability for freeways, using data from Philadelphia, Ft. Lauderdale, and Jacksonville. These tools can provide travel time reliability as a function of various changes in the system, such as incident removal times and work zone occurrences, as well as a function of selected ITS programs and initiatives (such as the Road Rangers). These procedures have been applied to estimate travel time reliability in Broward County, Florida. However, there is a need to apply these procedures to the entire freeway portion of the SIS. There is also a need to enhance these procedures to consider the impacts of safety on reliability and to consider a broader range of ITS strategies. Furthermore, the estimates obtained using these models should be validated for those portions of the SIS where travel time data are available. Finally, there is a need to provide the capability to update these travel time reliability estimates on an annual basis, as a function of annual information and data (such as incident frequency and duration) for each freeway segment of the SIS.

1.2. Objectives

The objectives of this research are to (a) apply the procedures previously developed onto the entire freeway portion of the SIS, (b) enhance the existing procedures to incorporate additional elements such as the impact of incidents on each freeway segment and the impacts of various ITS strategies, (c) validate the estimates for those portions of the SIS where travel time information is available, and (d) establish procedures for updating the freeway SIS travel time reliability estimates on an annual basis.

1.3. Organization

This report is organized as follows: Chapter 2 discusses specific ITS strategies and their potential impact on travel time reliability, with suggested methods for incorporating them into the existing travel time reliability estimation method. Chapter 3 provides an overview of weather impacts on reliability, while Chapter 4 summarizes the implementation of improvements in calculating the impact of incidents. Chapter 5 summarizes reliability measures for the SIS and compares the model’s estimates of reliability to field data obtained from the STEWARD database. Finally, Chapter 6 provides conclusions and reccomendations.

2. IMPACT OF SELECTED ITS STRATEGIES ON TRAVEL TIME RELIABILITY

This section of the report summarizes the literature findings on the impact of selected ITS strategies on reliability, and provides recommendations for including their impact into reliabiltiy analyses. The strategies discussed here include the use of shoulders during peak hours, ramp metering, High Occupancy Toll (HOT) lanes, and Variable Speed Limits (VSL). For each type of ITS strategy, literature review findings are presented first, followed by recommendations on incorporating the effects of the specific strategy into travel time reliability estimation models. These recommendations consist of suggested increases in capacity, free-flow speed, or both for freeway sections where such strategies are implemented, as well as changes in incident frequency.

2.1. Use of Shoulders

2.1.1. Literature Review

The purpose of the temporary use of the shoulder is to improve the performance of a freeway facility by providing additional capacity during congested times. This strategy has been widely implemented in Europe; only one implementation was identified in the US. There are only a few studies on the impact of using the hard shoulder on traffic operations, and all of them are concerned with implementations in Europe. Furthermore, these European installations operate concurrently with VSL, making it difficult to extract the impact of each strategy separately.

In Germany, the temporary shoulder use strategy was introduced during the 1990s. The first deployment was in December 1996 on the A4 autobahn near Cologne. Shoulder use was permitted only when speed harmonization (VSL) was active and speed limits were reduced (Tignor et al. 1999). A study conducted by the Federal Highway Research Institute (FHRI) indicated that temporary shoulder use provides congested motorways with higher throughput (Mirshahi et al., 2007). Figure 2.1, originally included in Lemke and Irzik (2006), is referenced in the FHRI study as well as in other publications; it indicates that decreasing the speed leads to an increase in traffic volume, and vice versa. The figure also indicates that decreasing the speed to 80 km/h through speed harmonization strategies leads to an increase of traffic throughput to over 5,000 veh/h. According to the figure, two lanes with no speed limit accommodate up to about 1650 veh/h/ln, while allowing shoulder use and lowering the speed limit together accommodate an additional 1900 veh/h, which is more than the original per lane capacity at the site. However, it is not clear how this figure was developed, and whether it is based on field data.

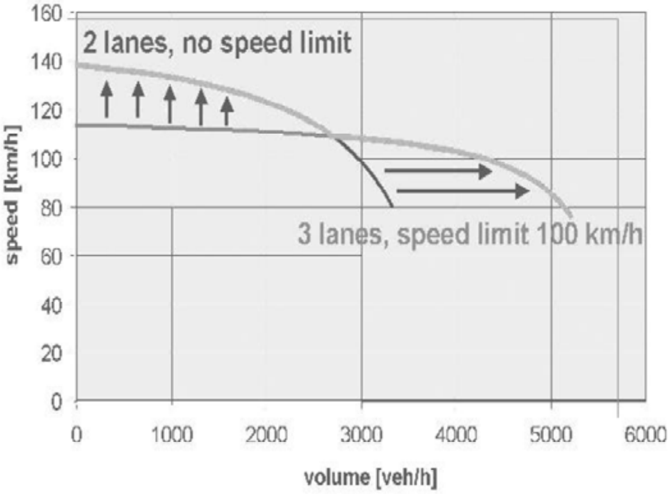


Figure 2.1 Speed-Volume Relationship of Temporary Shoulder Use in Germany

(Source: Mirshahi et al. 2007)

A study conducted by Riegelhuth and Pilz (2007) in Hessen, Germany, concluded that releasing the hard shoulder to traffic increased the capacity of standard three-lane motorway sections by 20%. The authors indicate that it permitted traffic volumes of over 7,000 vehicles per hour without a traffic breakdown. The study site is a three-lane section of the A5 autobahn between the Frankfurt NW intersection and the Friedberg junction. The hard shoulder was used together with speed harmonization. The evaluation showed that neither the total number of incidents nor the number of incidents involving serious injury increased.

A study of the implementation of temporary shoulder use with speed harmonization in the Netherlands (Taale, H., 2006) concluded that across the Netherlands, temporary shoulder use increased overall capacity at individual sites by between 7% and 22% (depending on usage levels). At the same time, travel times decreased by 1 to 3 minutes, and traffic volumes increased up to 7% during congested periods. The study also indicated some reduction in incident levels.

The strategy of temporary shoulder usage was also implemented in England. A 6-month evaluation on the M42 motorway in the West Midlands southeast of Birmingham was conducted by the Highways Agency (2007). The subject segment was 12 miles long and incorporated both temporary shoulder use and VSL. The authors indicate that the variability of weekday travel times decreased by 27% compared to the before case. However, they do not define variability quantitatively. They also indicate that capacity increased by an average of 7% when the hard shoulder was in use, and that there was a drop in the number of incidents from 5.2 a month to 1.5 per month on average. No fatal or serious incidents were attributable to hard shoulder use.

In one of the few U.S. applications of temporary shoulder use, the right shoulder of I-66 through Virginia approaching Washington D.C. is used as an additional lane to accommodate more volume during peak periods. At the same time the left lane was converted to HOV. A study was performed in Virginia (VDOT, 1993) to review the safety of the installation. The study showed that the number of accidents did not increase significantly. It also found that most commuters perceive this eight-mile section to be safe. In comparison with other major highways in the area, about one-fifth felt this section was "more safe" during peak periods, while 48% felt it was "as safe" as other major highways. The study also concluded that most commuters understood shoulder use restrictions. A very high percentage of commuters said the red "X" indicated "the lane is closed to traffic" (93%), and 6% said it indicates "emergency stopping only". The study did not provide any information related to the capacity and operational quality of the facility before and after the system installation.

A study by Lee et al. (2007) analysed the safety of the I-66 section described above, and indicated that there was no evidence that right shoulder use affected the crash frequency. However, the study found a 38% increase in crashes in the merge and diverge areas during adverse visibility conditions.

2.1.2. Recommendations

Most of the studies discussed above are concerned with hard shoulder use together with VSL. Thus it is difficult to extract the impacts of one strategy when it operates separately from the other. The studies of the one documented U.S. location did not provide any information regarding capacity or traffic operational impacts of the strategy.

Generally, installations which include VSL are reported to have a capacity increase that ranges from 7% to 22%. However, only one paper (Riegelhuth and Pilz, 2007) specified the number of lanes in the study freeway segments. According to this paper, hard shoulder use increased the capacity of standard three-lane motorway sections by 20%, which equates to the capacity of the shoulder being 60% that of a regular lane. Until more detailed data from U.S. installations become available, an equivalent capacity rate of 0.6 can be assumed for use of shoulder. For installations with no VSL in place, this number should likely be reduced.

Regarding safety impacts of shoulder use, studies of European installations all indicated a reduction or no significant changes in the number of accidents after implementation. The U.S. studies also did not find any significant changes in the number of accidents. Therefore, it can be conservatively assumed that the probability of incidents does not change when implementing hard shoulder use.

2.2. Ramp Metering

2.2.1. Literature Review

A ramp meter is a traffic signal on a freeway on-ramp that is used to regulate the flow of vehicles onto the freeway. It has been applied since the 1960s in the Chicago, Detroit, and Los Angeles areas, and now is widely implemented in the U.S., including in Miami. Benefits attributed to ramp metering in the literature include increased average speeds and capacity/throughput on the freeway mainline, reduced travel times, and reduced accident rates.

The first ramp metering system in San Diego was initiated in 1968. The system includes over 130 ramp meters along 69 miles of freeway. No detailed evaluations of the ramp metering have been reported, but sustained volumes of 2200 vphpl to 2400 vphpl are common (Piotrowicz and Robinson, 1995).

The Twin Cities metropolitan area first installed ramp meters in 1970 on southbound I-35E. An evaluation of this five-mile section showed that after 14 years of operation, average peak hour speeds increased by 16 percent from 37 to 43.1 mph. At the same time, peak period volumes increased 25% and peak period accident rates decreased 24% (Piotrowicz and Robinson, 1995, Kand and Gillen, 1999). In 1974, a freeway management project was activated along a 17-mile section of I-35W. An evaluation of this project after 10 years of operation showed that average peak period freeway speeds increased by 35% from 34 mph to 46 mph. Over the same 10-year span, peak period volumes increased 32% and the peak period accident rate declined by 27% (MnDOT 1989; Kand and Gillen, 1999). Another evaluation of ramp metering in the Twin City metro area was conducted by Cambridge Systematics, Inc. in 2000. Traffic flow and safety impacts were evaluated while all 430 ramp meters were turned off for six weeks. The “before-and-after” data collection took approximately 12 weeks. The evaluation results showed that after turning off the ramp metering system, freeway volumes were reduced by 9%. Freeway speeds were reduced by 7%, resulting in a 22% increase in travel time. Also, the number of crashes increased by 26% (Cambridge Systematics, Inc., 2001).

Texas first installed ramp meters in the late 1970s along northbound I-35 in Austin. The initial system consisted of three metered ramps set for the AM peak period. Evaluation studies showed that metering increased vehicle throughput by about 7.9% and increased average mainline speed by 60% (Piotrowicz and Robinson, 1995).

In Portland, Oregon, sixteen ramp meters were installed along a 10-km section of I-5. Nine of the metered ramps operated in the northbound direction during the PM peak and seven controlled southbound entrances during the AM peak (Piotrowicz and Robinson, 1995). Fourteen months after installation, the PM peak average speed increased from 16.3 mph to 41.3 mph, and travel time was reduced from 23 minutes to about 9 minutes. Pre-metered conditions in the southbound AM peak were much better, therefore, the improvements were smaller. The average speed increased from 40 to 43 mph after the installation and resulted in only a slight reduction in travel time. Overall accident rates during the peak period were reduced by 43% (Piotrowicz and Robinson, 1995; Kand and Gillen, 1999).

In September 1981, the Washington State Department of Transportation (WSDOT) implemented its first ramp metering system along I-5 north of the Seattle Central Business District. The system initially included 17 southbound ramps that were metered during the AM peak, and 5 northbound ramps that were metered during the PM peak. An evaluation of the initial 22-meter system showed that between 1981 and 1987, mainline volumes during the peak traffic periods increased 86% northbound and 62% southbound. Travel time on a specific 7-mile section dropped from 22 min to 11.5 min after the installation of ramp metering. Over the same six-year time period, the accident rate decreased by 39% (Piotrowicz and Robinson, 1995; Kand and Gillen, 1999; Arnold, 1998).

The Colorado Department of Transportation activated a pilot project to demonstrate the effectiveness of ramp metering on a section of northbound I-25 in Denver in 1981. At that time, the system consisted of 5 metered ramps that operated during the AM peak along a 2.5-mile section of the freeway. The DOT tested the system for about 18 months and the evaluation revealed significant benefits. Average peak period speed increased by 57%, and average travel times decreased by 37%. In addition, accidents declined 5% due to the elimination of stop-and-go conditions (Piotrowicz and Robinson 1995; Kand and Gillen, 1999). The success of the pilot project led to the expansion of the system. In late 1988 and early 1989, a comprehensive evaluation of the metered sections was conducted to compare the changes between 1981 and

1989 (Piotrowicz & Robinson 1995; Kand and Gillen, 1999). The results showed that volumes during the 2-hour AM peak period increased from 2065 vphpl in 1981 to 2450 vphpl in 1989. Speeds measured in late 1988 decreased from the original evaluation, but remained higher than the speeds before metering was implemented (42.9 mph before, 52.8 mph after in 1981, and 49.7 mph in late 1988).

The Michigan Department of Transportation (MDOT) installed its first ramp metering system on I-94 in November 1982. Michigan State University conducted an evaluation of the system and concluded that ramp metering increased speeds by about 8%. At the same time, the typical peak hour volume on the three eastbound lanes increased to 6,400 vph from an average of 5,600 vph before metering. The total number of accidents was reduced nearly 50% and injury accidents declined 71% (Piotrowicz and Robinson, 1995; Kand and Gillen, 1999; Arnold, 1998).

In 1989, Long Island Expressway's ramp meter system was evaluated after two months in operation to determine its effectiveness. The results showed a 20% decrease in mainline travel time (from 26 to 21 minutes) and a 16% increase in average speed (from 29.2 mph to 34.8 mph). Motorists entering at metered ramps also experienced an overall travel time reduction of 13.1% and an increase in average speed from 23 mph to 28 mph. A more extensive evaluation of the system was completed in 1991. It is believed that this study is more representative of the true traffic conditions, since the previous study did not include areas where metering was usually shut off due to heavy ramp volumes, while this study accounted for all ramps. The evaluation showed that throughout only increased about 2%, and the average mainline speeds had only increased about 9% (40 to 44 mph). However, at two separate bottleneck locations, data showed average speed increased 36% and 40% respectively. The accident rate showed a reduction of 15% compared to the control section (Piotrowicz & Robinson 1995; Kand and Gillen, 1999).

The examples described above demonstrate some of the many benefits associated with ramp metering implementation. It should be noted that proper design and placement of ramp meters is important in order to maximize the benefits achieved.

2.2.2. Recommendations

The evaluation studies described above demonstrated significant improvements in traffic flow after installation of ramp metering, which include increased freeway speeds, decreased travel time, increased freeway throughput/capacity and improved safety. Table 2.1 provides a summary of the identified impacts.

As shown, ramp metering has been reported to improve traffic conditions. Speed increases of 2-153% have been reported, depending on the “before” conditions. Throughput has also been shown to increase significantly as well. However, capacity values have not been reported rigorously in all studies discussed above, thus it is not clear if the throughputs reported represent capacity conditions. In any case, throughputs as high as 2,400 vphpl have been reported when ramp metering systems are operational. Crashes have also been shown to be reduced by 5-50%.

Table 2.1 Summary of Changes After Installation of Ramp Metering for Freeway Systems

Location	**Installation/ Evaluation Time**	**Changes After Installation of Ramp Metering**			
		Speed	**Travel Time**	**Throughput/ Capacity**	**Crash Rate**
San Diego	1968			2200 vphpl to 2400 vphpl	
Minneapolis	1974-1984	+35%		+32%	-27%
Twin Cities	1970-1984	+16%		+25%	-24%
	2000	+7%	-22%	+9%	-26%
Austin	1970	+60%		+7.9%	
Portland	1981-1982	+7.5 to 153%	-61%	-	-43%
Seattle	1981-1987		-48%	+86% NB +62% SB	-39%
Denver	1981-1982	+57%	-37%		-5%
	1988-1989	+16%		2450 vphpl +19%	
Detroit	1982	+8%		2130 vphpl +14%	-50%
Long Island	1989	+16%	-20%		
	1991	+2%		+9%	-15%

Regarding ramp metering systems it is proposed to incorporate the impact of ramp metering systems on travel time reliability predictions through increases in capacity and reductions in accident rates. With respect to capacity, it is proposed to assume a very conservative 5% increase in capacity, not to exceed 2,400 vphpl. With respect to incidents, it is proposed to assume a 5% frequency reduction both for lane blocking and non-lane blocking incidents.

2.3. HOT Lanes

2.3.1. Literature Review

HOT lanes are facilities that combine pricing and vehicle eligibility to maintain free-flow conditions, while still providing a travel time savings incentive for high-occupancy vehicles (Obenberger, 2004). This allows excess HOV lane capacity to be used by single-occupancy drivers who pay a fee. Benefits of HOT lanes that have been identified in the literature include speed increase and travel time savings. There are several HOT lane installations now completed around the U.S., and several projects have evaluated their impact on traffic operations.

Recent research conducted in Houston (Burris and Pannu, 2009) collected data related to the use and performance of the HOT lanes on the Katy Freeway (I-10) and the Northwest Freeway (US 290). Speed data for the general purpose lanes (GPLs) were also collected. A comparison of speeds between the GPLs and the HOT lanes showed that the HOT lanes offered a much more reliable trip. Speeds on the US 290 HOT lane were generally between 56 mph and 66 mph, while the GPLs ranged from 12 mph to 64 mph. A travel time reliability analysis was also conducted for the two freeways. As expected, the HOT lane had a highest percentage of observations between 60 mph and 64 mph, while the GPL speeds were more variable. For the US 290 Northwest Freeway, a significant percentage of observations on the GPLs were below 40 mph. The Katy Freeway GPLs operated somewhat better, with a significant percentage of speeds above 40 mph.

The "Guidebook for Converting HOV Lanes to HOT Lanes" prepared by the Federal Highway Administration (2007) discusses the capacity of HOT lanes. It states that HOT lane capacity is a function of the number of access points, the vehicle mix, the roadway slope and configuration, separation treatments, and the number of travel lanes, among other variables. HOT lanes with fewer access points have a higher lane capacity than those with more access points. The Guidebook also indicates that a multilane HOT facility will have a higher managed capacity (vehicles per lane per hour) than a single HOT lane configuration. It also cites two examples:

a) Flows on the Houston I-10 Katy Freeway QuickRide – a one lane, reversible-flow facility – are kept to 1,500 vehicles per hour per lane.

b) The Highway 91 Express Lanes in Southern California – which provide two travel lanes in each direction – operate at acceptable conditions with flow rates of 1,800 vehicles per hour per lane.

2.3.2. Recommendations

As indicated above, HOT lanes are physically separated from the other general purpose lanes. They are only used by high-occupancy vehicles and single drivers who pay a fee, and are managed to maintain free-flow conditions. Therefore, for travel time reliability purposes, HOT lanes will be treated as a separate facility.

One of the papers discussed above concluded that the travel times on HOT lanes are more reliable than those on the general purpose lanes and that average travel speeds are generally higher. However, unlike other ITS strategies, those improvements are not caused by increased capacity or free-flow speed, but as the result of the adjustments in traffic volume caused by pricing and vehicle eligibility requirements. Therefore, for the purposes of this research, for HOT facilities with more than one lane in each direction, the capacity of the HOT lane will be assumed to be the same as that of the general-purpose lanes. If the HOT lane is a separated single lane, the capacity of this lane will be reduced because of constraints in passing slower vehicles. Based on the example of Houston I-10 Katy Freeway QuickRide, a capacity of 1,500 vehicles per hour per lane is recommended for a single HOT lane.

2.4. Variable Speed Limits

2.4.1. Literature Review

Variable speed limit (VSL) systems are a way of recommending safe driving speeds during less-than-ideal conditions. Such systems have also been used to smooth traffic flow and increase throughput along freeway bottlenecks. There are several papers that have assessed traffic operational impacts of VSL both in the U.S. and abroad. The papers most relevant to this project are briefly discussed in the following paragraphs, focusing on U.S. installations.

The first variable speed limit system in the U.S. was implemented in 1960 along the Lodge Freeway (Michigan Highway 10) in Detroit, between the Edsel Ford Freeway (I-94) and the Davison Freeway. The system was installed over a 3.2-mile–long section and included 21

VSL sign locations. An evaluation found that the VSL system did not significantly increase or decrease vehicle speeds (Robinson, 2000).

More recently, a VSL system was implemented along I-40 in Albuquerque in March 1989. The 6-km-long system used three roadside detector stations and a variable message sign to vary the posted speed limit. Evaluation results showed that there was a slight reduction in accidents, but this result was not definitive due to varying road work over the evaluation period. It is possible that the National Maximum Speed Limit (55 mph) in place at the time hindered the effect of the system, as the system might yield a higher speed limit. (Robinson, 2002, CTC and Associates LLC, 2003, Steel et al., 2005).

In Tennessee, a VSL system was implemented along a 19-mile section of I-75 in 1993 to respond to the reduction in visibility during adverse weather conditions (especially fog). The effect of the VSL on actual travel speeds had not been formally evaluated, but the enforcement agency observed a slight (5 to 10 percent) reduction in speed, and there have been no crashes due to fog after the system was implemented. (Robinson, 2002, Road Weather Management, 2003, Steel et al., 2005).

In Colorado, a VSL system was implemented around the Eisenhower Tunnel on I-70 west of Denver in 1995. The purpose of the system was to provide vehicle-specific safe operating speeds for long downgrades. The speed limit was advisory and evaluation results showed that truck-related accidents declined on the steep downhill grade sections on either side of the tunnel after the VSL system was implemented, even though truck volumes increased by an average of 5 percent per year. Also, the mean speed with the system turned off was found to be 12.2 km/h greater than with the system on (Robinson, 2000).

The Washington State Department of Transportation implemented a variable speed limit system on I-90 across Snoqualmie Pass in 1997. An evaluation found that variable speed limits may lose their effectiveness without enforcement by the State Patrol, and that variable speed limits reduced the mean speed, but increased the standard deviation of speeds (CTC and Associates LLC, 2003, TravelAid et al., 2001, Steel et al., 2005).

In Florida, variable message signs were placed along a 9-mile portion of I-4 in Orlando. The system is designed to improve safety along I-4 through more steady flow during congested periods, and to provide advance warning to drivers of slowing traffic ahead. Detectors are used to measure speed, volume, and occupancy for each lane at 30-second intervals. The system uses the SunGuide software to update the sign messages. The software monitors the occupancy level and classifies traffic conditions as either free-flow, light congestion, or heavy congestion. On the basis of these traffic condition classifications, the software recommends speed limits of 30 mph for heavy congestion, 40 mph for light congestion, and the normal speed limit (i.e., 50 or 55 mph) for free flow. The software is developed such that the posted speed limit does not change by more than 10 mph between two adjacent sets of VSL signs (Haas et al., 2009). Evaluation of the system (PBS&J, 2009) indicated that the VSL signs have no significant impact in reducing the speed of motorists. During times of reduced speed limits motorists tended to run at the highest allowable speed, constrained only by congestion or geometric limitations, and not by the posted speed limit. Evaluation of the crash records showed that rear-end crash frequency before and after the installation of the system showed no significant change. The authors indicated that the full benefits of the VSL cannot be evaluated because the motorists are simply not complying with the reduced speed limits.

Kwon et al. (2007) developed and evaluated a variable advisory speed limit system for work zones (VASLS-WZ). The system aimed to lower the speed upstream of the work zone to the same level as the flow downstream of the work zone. The system was implemented in the Twin Cities area for three weeks using three signs at a work zone along I-494. Field data indicated that when the system was implemented, there was a 25% to 35% reduction in the average 1-minute maximum speed difference along the work zone during the 6 to 8 AM peak period. There was an approximate 7% increase in throughput from 6 to 7 AM, but the volume increase between 7 and 8 AM was not significant.

According to Hines (2002), numerous variable speed limit systems have been implemented in real traffic conditions in European countries. Based on the case studies in Europe, he reported that variable speed limits can stabilize traffic flow in congestion and thus decrease the probability of crashes. As indicated earlier in this report, VSL are often installed in conjunction with other treatments, such as temporary shoulder use.

Bertini et al. (2006) investigated the effects of a VSL system in Germany and found that injury accident rates were reduced by 20-29%. The results of an evaluation of a VSL system in the Netherlands showed that drivers reduced their mean speeds by about 8-10 km/h during fog conditions (Robinson, 2000). The evaluation of another VSL system in the Netherlands showed that the severity of shockwaves as well as the average speeds in all lanes were reduced, and there was a 23% decline in the accident rate. (Robinson, 2002; Highways Agency, 2010). For a VSL system in England, results showed a 10-15% decrease in traffic accidents and very high compliance with the VSL system (Robinson, 2000).

Rämä (1999) investigated the effects of weather-controlled speed limits and signs on driver behavior on the E18 highway in Finland, which began in 1998. The analysis was conducted based on speed and headway data collected from loop detectors. The results indicated that the weather-controlled variable speed limits decreased both the mean speed and the standard deviation of speed, which implied a potential safety improvement. There was no remarkable effect on headways.

Variable message signs have been implemented in Sweden at 19 locations. Lind (2006) looked at the impacts of weather-controlled VSLs on the E6 motorway in Halland, and traffic-controlled VSLs on E6 in Mölndal, south of Gothenburg. The results showed an increase in average speed for all driving conditions, and as much as a 40 km/h increase in average speed during potential queue-formation scenarios. The study indicates an improvement in driving behavior for congested conditions and a homogenization of traffic.

Papageorgiou et al. (2008) studied the impact of VSLs on traffic flow behavior on a motorway in Europe. The effect on flow capacity proved inconclusive, however the study showed that capacity was more sensitive to weather changes than without the VSL, with a capacity reduction of approximately 10%.

2.4.2. Recommendations

In summary, VSLs have been implemented in numerous areas throughout the United States, and are widespread throughout Europe. The objectives of each system are different, and the implementation of such systems differs between the U.S. and Europe. Most systems emphasize safety, while others consider mobility.

Nearly every study showed that mean speeds will decrease when a VSL is implemented. However, this speed is typically recorded at the study section, and does not consider the effects on congestion and the potential that overall travel time might actually be reduced because of a reduction in the probability of congestion. There has been no evidence to suggest that implementing VSLs has the potential to increase capacity, but two studies showed the benefits of shockwave dampening. Also, several papers indicated a reduction in accident rate after implementing VSL.

Since there is no conclusive evidence regarding changes in freeway free-flow speed and capacity as a result of VSL implementation, it is recommended that for the purposes of this work that the presence of VSL would result only in a reduction in the probability of incidents. The studies discussed above suggest reductions in incidents of the order of 10-40%. These studies, however, were based on European VSL installations, and there is limited information regarding the effectiveness of such systems in the U.S. Therefore, in this project, it is recommended to assume a 10% reduction in the probability of incidents when a VSL system is present.

2.5. Summary of the Recommendations for ITS Strategies

This section reviewed four ITS strategies to assess their effect on traffic operations and safety. These strategies are: temporary shoulder use, ramp metering, HOT lanes, and VSL. Table 2.2 summarizes the recommendations provided for evaluating the impacts of these strategies on travel time reliability.

Table 2.2 Impacts of Selected ITS Strategies

ITS Strategy	Impacts
Temporary Shoulder Use	Capacity equals 0.6 of the capacity of a regular traffic lane.
Ramp Metering	Freeway capacity is increased by 5% after the implementation of ramp metering; the increased capacity should not exceed 2400 veh/h/ln. A 5% incident frequency reduction is assumed for both lane-blocking and non-lane-blocking incidents.
HOT Lane	If there is more than one HOT lane in each direction, the capacity of the HOT lane is considered to be the same as that of the general-purpose lanes. If the HOT lane is a separated single lane, the capacity of this lane is assumed to be 1500 veh/h/ln.
Variable Speed Limit	The probability of incidents is reduced by 10%.

3. WEATHER IMPACTS

The first part of this chapter discusses the effects of rain on travel time, while the second part summarizes the findings regarding the effects of visibility. The last part provides some additional thoughts and recommendations for considering weather effects in travel time reliability estimation.

3.1. Effects of Rain on Reliability

This section first presents the literature review findings for considering rain effects on travel time, followed by the recommended assumptions for incorporating those effects into travel time reliability estimation models. The next part presents the methodology used for incorporating rain effects in the Florida SIS, while the last part provides an example application.

3.1.1. Literature Review

There are several papers that have studied the impacts of rain on traffic operations. In one of the earliest papers, Lamm et al. (1990) examined 24 curved road sections of rural two-lane highways during both dry and wet conditions. They found no statistical difference in operating speed between those two conditions without the consideration of visibility. Therefore, they concluded that operating speeds are not affected by wet pavement until visibility is also impacted.

Ibrahim and Hall (1994) studied the effect of adverse weather on freeway operations in Canada. The study concluded that light rain and snow resulted in similar reductions in speeds (3%–5%), but heavy rain caused 14%–15% reductions and heavy snow caused 30%–40% reductions in speeds. However, the rain intensity ranges used to differentiate between light and heavy rain were not provided. The authors indicate that their measurements are site-specific and that the speed changes may be different at other locations based on varying driver experience and the design of the highway itself. The Highway Capacity Manual 2000 (HCM 2000) recommendations regarding the evaluation of freeway operations under rainy conditions are primarily based on this research.

Brilon and Ponzlet (1996) investigated 15 sites in Germany to assess the impacts of weather conditions, daylight or darkness, and other factors on speed-flow relationships. The study concluded that wet roadway conditions cause a reduction of 9.5 km/h (6 mph) on four-lane highways and 12 km/h (7.5 mph) on six-lane highways, while freeway capacities were reduced by 350 vehicles per hour (vph) and 500 vph, respectively. However, the study was conducted in Germany, where there are no maximum speed limits on many freeways and drivers' behavior and expectancies may be different from that in the U.S.

The HCM 2000 (Chapter 22) provides some guidance regarding freeway capacity and operating speeds reductions due to light and heavy rain. It suggests that there is no reduction in capacity during light rain. For heavy rain, the recommended reduction in capacity is 14-15 %. It also recommends 2%–14% and 5%–17% reductions in speeds due to light and heavy rains, respectively. However, it does not define the rainfall intensity ranges associated with the categories "Heavy Rain" and "Light Rain".

A more recent study (Smith et al. 2004) of two freeway links emphasized the importance of rainfall intensity values in estimating capacity and average operating speeds. This research classified rainfall intensity into none (less than 0.01 inches/hour), light (0.01–0.25 inches/hour), and heavy (more than 0.25 inches/hour). The study concluded that the light rain and heavy rain decreased freeway capacity by 4-10% and 25-30%, respectively, and that the presence of rain, regardless of intensity, resulted in an approximate 5.0-6.5% average decrease in operating speeds. This research found that rainfall, particularly at high intensities, has a significantly greater impact on capacity than is currently suggested in the HCM 2000. The authors also concluded that the HCM 2000 generally suggests a reasonable impact of rainfall on operating speeds, but the impact of heavy rain may be overestimated.

Similar results were obtained by Agarwal et al. (2005). They quantified the impact of rain, snow, and various pavement surface conditions on freeway traffic flow for freeways in the Twin Cities region and compared the differences between the operating speeds for different snow and rain categories. The study used classifications of rain intensities similar to those used by Smith et al. (2004), but also added a "Trace" category. Speed reductions of 1%–2%, 2%–4%, and 4%–7% were found for trace, light, and heavy rain, respectively. However, differences in speeds for light and heavy rain (0.01–0.25 and more than 0.25 inches/hour) were not statistically significant. Thus, they concluded that reductions in operating speeds due to light rain are comparable with recommended reductions in the HCM 2000. However, they indicated that the heavy rain effects on operating speeds, which are similar to those of light rain, may be overstated in the HCM 2000.

Table 3.1 provides a summary of the literature review findings regarding speed and capacity reductions caused by rain.

3.1.2. Recommended Assumptions on Speed Reductions Caused by Different Rainfall Categories

Only two of the papers discussed above clearly define the rainfall intensity ranges associated with different rainfall categories. They classified the rainfall intensity quantitatively in a similar manner into three groups: less than 0.01 inch/hour, 0.01–0.25 inch/hour, and greater than 0.25 inch/hour. The only difference between the two papers is that the first one considered rainfall less than 0.01 inches/hour to be same as the case with no rain, while the second one renamed that category "Trace" and measured its operational effects. It is important to note that neither of the papers considered extremely heavy rain impacts. The data collected in these papers are from the northern U.S., and did not consider very high precipitations and their respective impacts.

Table 3.1 Summary of Literature on Speed and Capacity Reduction on Freeways Due to Rain

Authors (Year)	Rain Intensity Levels	Speed Reduction	Capacity Reduction
Lamm et al. (1990)	Dry and Wet Conditions	Operating speeds are not affected by wet pavement until visibility is also impacted.	--
Ibrahim; Hall (1994)	Light	3 % - 5 %	--
	Heavy	14 % - 15 %	
Brilon; Ponzlet (1996)	Dry and Wet Conditions	Wet roadway conditions cause speed reduction: 6 mph on four-lane highways; 7.5 mph on six-lane highways	Wet roadway conditions cause speed reduction: 350 vph on four-lane highways; 500 vph on six lane-highways
HCM (2000)	Light	2 % - 14 %	No capacity reduction
	Heavy	5 % - 17%	14 % - 15 %
Smith et al. (2004)	None (<0.01 in/h)	No speed reduction	No capacity reduction
	Light (0.01-0.25 in/h)	5.0 % – 6.5 %	4 % – 10 %
	Heavy (>0.25 in/h)	5.0 % – 6.5 %	25 % – 30 %
Agarwal et al. (2005)	Trace (0-0.01 in/h)	1 % - 2 %	1 % - 3 %
	Light (0.01-0.25 in/h)	2 % - 4 %	5 % - 10 %
	Heavy (>0.25 in/h)	4 % - 7 % Difference in speed reduction for light and heavy rain is not statistically significant.	10 % - 17 %

Based on the literature review, as well as consideration for the specific characteristics of Florida's climate, this research proposes to categorize rainfall intensity into three groups: "None or Trace", "Light Rain", and "Heavy Rain". The first category includes rainfall intensity of less than 0.01 inches/hour (labeled as "Trace"), as well as hours with no precipitation. These conditions are grouped together because there seems to be no discernible impact on free flow speed when there are only traces or rain. According to Lamm et al. (1990), speeds are not affected by very light rain until visibility is also impacted.

The definition of "Light Rain" group and its impact on speed reduction were determined mainly based on the two studies discussed above (Smith et al. 2004; Agarwal et al. 2005). These two papers concluded that speed reductions are similar for both light and heavy rain. As a result, this research combined those two categories of light and heavy rain into a "Light Rain" category with rainfall intensity between 0.01 and 0.5 inches/hour. Smith et al. (2004) concluded that the presence of light and heavy rain decreased operating speed by 5.0-6.5% regardless of intensity. Agarwal et al (2005) indicate that the percentage of this speed reduction was found to be 2-7%. Based on those results and the recommended speed reduction for light rain in HCM 2000, an operating speed reduction percentage of 6% was assumed for the "Light Rain" group in this research.

However, the rain intensities considered in the two papers discussed above (Smith et al. 2004; Agarwal et al. 2005) was not as high as can occur in Florida. To consider the Florida climate, a rainfall category of "Heavy Rain" is defined for precipitation rate exceeding 0.5 inches/hour. A speed reduction of 12% is assumed for this category. No capacity reductions are assumed, because the simultaneous use of both a speed reduction and a capacity reduction might lead to excessive impacts due to rain.

In conclusion, the rainfall intensity categories and their suggested impacts on operating speed reduction are shown in Table 3.2.

Table 3.2 Recommended Rainfall Intensity Classifications and Impacts on Speed Reduction

Rain Category	Rainfall Intensity (inch/hour)	Speed Reduction (%)
None or Trace	< 0.01	0
Light	0.01- 0.5	6
Heavy	>0.5	12

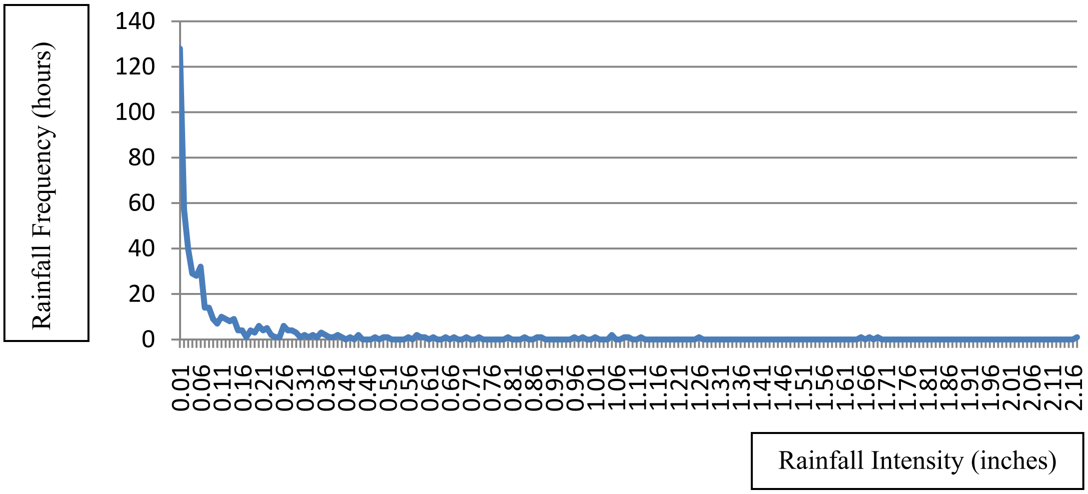
3.1.3. Estimation of the Speed Reduction on Each Freeway Section

Weather data were collected from the Weather Underground website (http://www.wunderground.com) for a one-year period, from January 2007 to December 2007. The website provides weather information by zip code. Therefore, the zip code for each Florida freeway section was identified and the rainfall data associated with each section were then collected. The average rainfall collected through the website was available on an hourly basis. Rainfall data for 72 days out of the year (the 1st, 6th, 11th, 16th, 21th and 26th day of each month) were collected for every zip code. The annual average rainfall intensity and the probability of rain were obtained for each one of the 24 hours in these days. For the purposes of this study, it was assumed that the rainfall intensity was uniform during the entire hour.

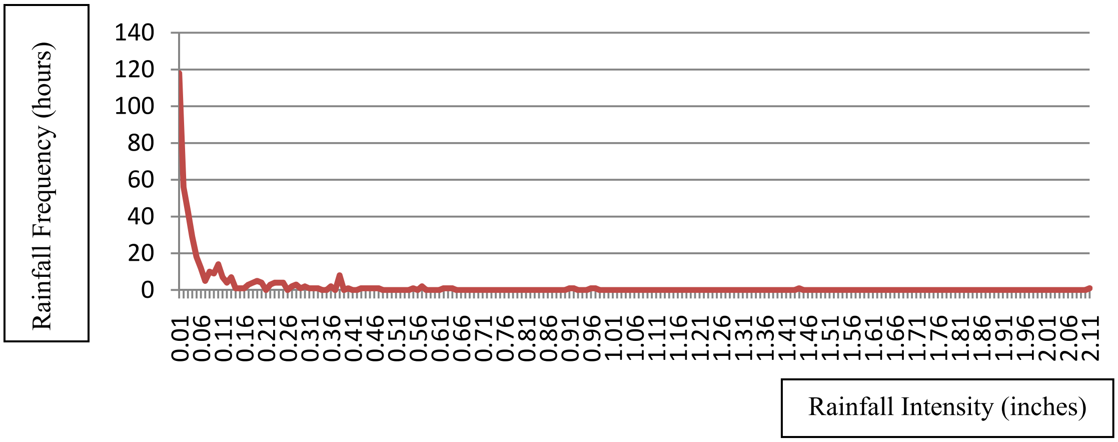
Next, the research team developed a relationship between rain intensity and its corresponding frequency. This was necessary because using just the average rainfall intensity for a particular hour in the day would not take into consideration the varying rain intensity that might occur during that hour throughout the year. This relationship allows us to obtain the probabilities of none or trace, light rain, and heavy rain for each of the 24 hours of analysis.

Several assumptions were made to achieve this goal. Because it is very time consuming to obtain the specific rainfall frequency distribution for each zip code, it was assumed that there are only two rainfall distributions within Florida.

Florida was divided into a northern and southern part to reflect the differences in precipitation patterns, with more frequent heavy rains occurring in the southern part of the state. For each part of the state, one zip code location (33143, in south Miami, and 32204, in Jacksonville) were chosen to represent the frequency characteristics of rainfall intensity of its part of Florida. Figure 3.1 provides the frequency of rainfall intensity for these two representative zip codes. As shown, both the the average rainfall and the variance are higher in Miami.



a) Rainfall Intensity Distribution for Miami 33143
(Mean = 0.1266 inches/hour, Variance = 0.059 inches^2/hour^2)



b) Rainfall Intensity Distribution for Jacksonville 32204
(Mean = 0.0973 inches/hour, Variance = 0.035 inches^2/hour^2)

Figure 3.1 Comparison of Rainfall Intensity Distribution of North and South Florida

Based on a preliminary statistical analysis, it was determined that the frequency of rainfall intensity for every zip code region could be represented by a Gamma distribution. The cumulative Gamma distribution function was obtained for each of the two graphs in Figure 1. This function can be parameterized in terms of a shape parameter k and a scale parameter θ. These two parameters were obtained using regression based on the entire year's hourly rainfall data. Equations 1 and 2 are the cumulative Gamma distribution functions for the two representative zip codes (Equation 1 for south Miami and Equation 2 for Jacksonville).

$$k = 0.1388, \theta = 0.4949$$

$$F_S(x; 0.1388, 0.4949) = \frac{\gamma(0.1388, x/0.4949)}{\Gamma(0.1388)} == \frac{\int_0^{x/0.4949} t^{0.1388-1} e^{-t} dt}{\Gamma(0.1388)} \tag{1}$$

$$k = 0.1447, \theta = 0.3717$$

$$F_N(x; 0.1447, 0.3717) = \frac{\gamma(0.1447, x/0.3717)}{\Gamma(0.1447)} == \frac{\int_0^{x/0.3717} t^{0.1447-1} e^{-t} dt}{\Gamma(0.1447)} \tag{2}$$

Using the specified shape parameter *k* and the mean of the rainfall data for each hour, the specific Gamma distribution for each zip code can then be determined. Based on that it is then easy to obtain the probability for each of the three rainfall scenarios (trace: 0 - 0.01 inches/h, light rain: 0.01- 0.5 inches/h, heavy rain: > 0.5 inches/h) for each freeway section.

Based on the procedure discussed above, a new tab ("Rain") was created in the example application spreadsheet which includes all weather-related calculations. This new tab contains 11 columns (Figure 2). The second and third columns provide the rainfall-related information obtained for the zip code corresponding to a given site. The fourth and fifth columns provide the parameters of the rainfall intensity frequency distribution for the south part of Florida. Based on these parameters, the sixth to eighth columns provide the probability for each of the three rainfall scenarios. Finally, the ninth to eleventh columns provide the probability of rain (light and heavy rain), as well as the split between light rain and heavy rain (i.e., the percent of time light rain occurs and the percent of time heavy rain occurs, as a function of the total frequency of light and heavy rain.) The last three columns are used in the SR9 tab to obtain the free flow speed of a freeway section during a particular hour under the three rain scenarios.

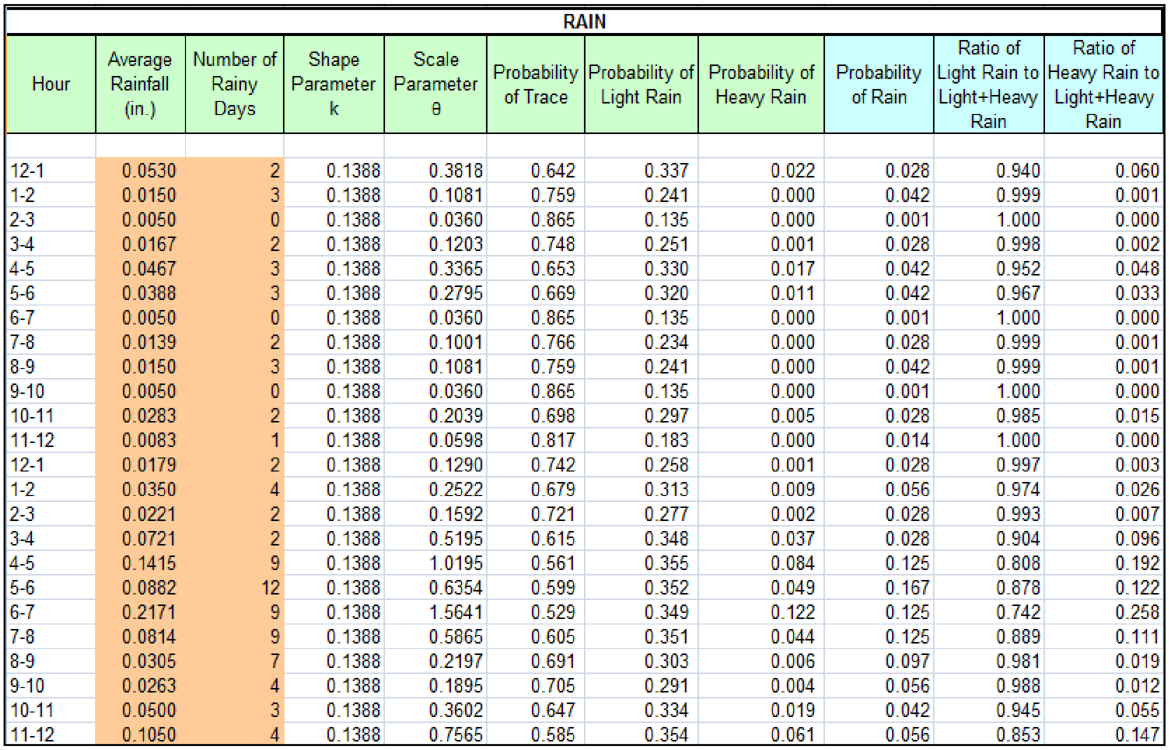
The ratios of light rain and heavy rain are used to adjust the free flow speed and to calculate the corresponding weighted average speed for each rain scenario. The probability of rain is used to calculate the probability of occurrence for each rain-related scenario.

3.1.4. Example

An example is presented below to illustrate the proposed method in more detail. The freeway segment used in this example is a section of I-95/SR 9 between Broward Blvd and Sunrise Blvd. The zip code for this area is 32819.

Step 1. Data Assembly

Rainfall data were obtained for a 72-day sample that included the 1st, 6th, 11th, 16th, 21st and 26th day of each month. The number of rainy days and the average rainfall for each hour were estimated. Figure 3.2 shows the respective calculation table in the “Rain” tab of the worksheet. The orange-highlighted columns indicate the required user inputs in the procedure.



RAIN

Hour	Average Rainfall (in.)	Number of Rainy Days	Shape Parameter k	Scale Parameter θ	Probability of Trace	Probability of Light Rain	Probability of Heavy Rain	Probability of Rain	Ratio of Light Rain to Light+Heavy Rain	Ratio of Heavy Rain to Light+Heavy Rain
12-1	0.0530	2	0.1388	0.3818	0.642	0.337	0.022	0.028	0.940	0.060
1-2	0.0150	3	0.1388	0.1081	0.759	0.241	0.000	0.042	0.999	0.001
2-3	0.0050	0	0.1388	0.0360	0.865	0.135	0.000	0.001	1.000	0.000
3-4	0.0167	2	0.1388	0.1203	0.748	0.251	0.001	0.028	0.998	0.002
4-5	0.0467	3	0.1388	0.3365	0.653	0.330	0.017	0.042	0.952	0.048
5-6	0.0388	3	0.1388	0.2795	0.669	0.320	0.011	0.042	0.967	0.033
6-7	0.0050	0	0.1388	0.0360	0.865	0.135	0.000	0.001	1.000	0.000
7-8	0.0139	2	0.1388	0.1001	0.766	0.234	0.000	0.028	0.999	0.001
8-9	0.0150	3	0.1388	0.1081	0.759	0.241	0.000	0.042	0.999	0.001
9-10	0.0050	0	0.1388	0.0360	0.865	0.135	0.000	0.001	1.000	0.000
10-11	0.0283	2	0.1388	0.2039	0.698	0.297	0.005	0.028	0.985	0.015
11-12	0.0083	1	0.1388	0.0598	0.817	0.183	0.000	0.014	1.000	0.000
12-1	0.0179	2	0.1388	0.1290	0.742	0.258	0.001	0.028	0.997	0.003
1-2	0.0350	4	0.1388	0.2522	0.679	0.313	0.009	0.056	0.974	0.026
2-3	0.0221	2	0.1388	0.1592	0.721	0.277	0.002	0.028	0.993	0.007
3-4	0.0721	2	0.1388	0.5195	0.615	0.348	0.037	0.028	0.904	0.096
4-5	0.1415	9	0.1388	1.0195	0.561	0.355	0.084	0.125	0.808	0.192
5-6	0.0882	12	0.1388	0.6354	0.599	0.352	0.049	0.167	0.878	0.122
6-7	0.2171	9	0.1388	1.5641	0.529	0.349	0.122	0.125	0.742	0.258
7-8	0.0814	9	0.1388	0.5865	0.605	0.351	0.044	0.125	0.889	0.111
8-9	0.0305	7	0.1388	0.2197	0.691	0.303	0.006	0.097	0.981	0.019
9-10	0.0263	4	0.1388	0.1895	0.705	0.291	0.004	0.056	0.988	0.012
10-11	0.0500	3	0.1388	0.3602	0.647	0.334	0.019	0.042	0.945	0.055
11-12	0.1050	4	0.1388	0.7565	0.585	0.354	0.061	0.056	0.853	0.147

Figure 3.2 Calculation Example for the “Rain” Tab

Step 2. Determine Shape Parameter *k* and Scale Parameter *θ*

The location of the freeway segment is used in this step to determine the shape of the rainfall intensity distribution. The subject freeway segment is located in South Florida; therefore, the value used for the shape parameter *k* of the Gamma distribution is 0.1388. The other descriptive parameter for the Gamma distribution, the scale parameter *θ*, can be determined using the average rainfall divided by *k*. For example, for the hour of 4 to 5 PM (or 16:00 to 17:00), the scale parameter *θ* is calculated using the following equation:

$$\theta = \frac{mean}{k} = \frac{0.1415}{0.1388} = 1.0195 \qquad (3)$$

The results of this step are presented in the fourth and fifth columns of Figure 3.2.

Step 3. Probability of Rain

Since the “Trace” category doesn’t have any impact on speed reduction, the probability of rain includes the sum of the probability of light and heavy rain. Based on the results of Step 1, the probability of rain for each hour is calculated by dividing the number of days that rained (precipitation is greater than 0.01 inches/hour) during this particular hour by 72 (the total number of days in the sample). For cases when the number of rainy days in the sample is zero, it is assumed that the probability of rain for this hour is 0.001. The results of this step are presented in the ninth column of Figure 3.2.

Step 4. Estimate the Probability for Three Rainfall Scenarios

Using the cumulative Gamma distribution function developed in step 2, the probability of each of the three rainfall scenarios for the hour of 4 to 5 PM (or 16:00 to 17:00) at this location can be identified.

Based on Equation (1), the probability for the “Trace” condition is as follows:

$$P(Trace) = F_S(0.01; 0.1388, 1.0195) = \frac{\gamma(0.1388, 0.01/0.1.0195)}{\Gamma(0.1388)} = 0.561 \tag{5}$$

The probability for “Light Rain” is calculated as follows

$$\begin{aligned} P(Light\ Rain) &= F_S(0.5; 0.1388, 1.0195) - F_S(0.01; 0.1388, 1.0195) \\ &= \frac{\gamma(0.1388, 0.5/1.0195)}{\Gamma(0.1388)} - \frac{\gamma(0.1388, 0.01/1.0195)}{\Gamma(0.1388)} = 0.355 \end{aligned} \tag{6}$$

The probability for “Heavy Rain” is:

$$P(Heavy\ Rain) = 1 - P(Trace) - P(Light\ Rain) = 0.084 \tag{7}$$

The results of this step are presented in the sixth to eighth columns of Figure 3.2.

Step 5. Estimate the Ratio of Light and Heavy Rain

The ratio of the two rain levels is used to estimate the probability of occurrence for the two levels. The ratio of Light Rain to Light+Heavy Rain is calculated as follows:

$$P(Ratio\ of\ \ Light\ Rain) = \frac{P(Light\ Rain)}{P(Light\ Rain) + P(Heavy\ Rain)} = 0.808 \tag{8}$$

The ratio of Heavy Rain to Light + Heavy Rain is as follows:

$$P(Ratio\ of\ \ Heavy\ Rain) = 1 - 0.808 = 0.192 \tag{9}$$

The results of this step are presented in the last three columns of Figure 3.2.

Step 6. Estimate the Equivalent Free-Flow Travel Time for the Rain Scenario

The three columns with blue headers shown in Figure 3.2 are used in the SR tab of the worksheet to calculate the travel time under rain-related scenarios. The hour of 16:00 to 17:00 is used as an example in the calculations below.

The free flow speed of the subject freeway segment is 65 mph under normal conditions. As discussed above, the free flow speed reduction for light rain and heavy rain are assumed to be 6% and 12% respectively. Therefore, the adjusted free flow speed for light rain is:

$$\begin{aligned} FFS(Light\ Rain) &= FFS \times (1 - FFS\ \ reduction\ for\ \ light\ \ rain) \\ &= 65 \times (1 - 0.06) = 61.1 \end{aligned} \tag{10}$$

Similarly, the adjusted free flow speed for heavy rain is:

$$\begin{aligned} FFS(Heavy\ Rain) &= FFS \times (1 - FFS\ \ reduction\ for\ \ heavy\ \ rain) \\ &= 65 \times (1 - 0.12) = 57.2 \end{aligned} \tag{11}$$

Then, given that the length of this freeway segment is 1.022 miles, the equivalent free-flow travel time for the rain scenario is estimated as the weighted (based on frequency) average of the two rain coonditions:

$$\begin{aligned} & Equivalent\ \ Free\text{-}flow\ \ Travel\ \ Time\ for\ \ Rain \\ & = (((Ratio\ of\ \ Light\ \ Rain \times (3600 / FFS\ for\ \ Light\ \ Rain)) \\ & \quad + ((Ratio\ of\ \ Heavy\ \ Rain \times (3600 / FFS\ for\ \ Heavy\ \ Rain))) \times Length \\ & = (((0.808 \times (3600 / 61.1)) + ((0.192 \times (3600 / 57.2))) \times 1.022 \\ & = 61.00 \end{aligned} \tag{12}$$

The results of the calculation for the equivalent free-flow travel time for the rain scenario are shown in column AI of the “SR” tab in the example worksheet. Using this travel time and the probability of rain obtained in step 3, the hourly adjusted travel time of each segment is obtained for each rain-related scenario.

3.2. Effects of Visibility on Reliability

The first part of this section summarizes the literature review findings, while the second part provides a quantitative assessment and provides recommendations regarding visibility as a consideration in travel time estimation.

3.2.1. Literature Review

A limited amount of research has analyzed the impact of visibility on traffic flow. As stated in a report by FHWA (2009), low visibility has been mostly implied by the presence of heavy rain or snow conditions that reduces the sight distance of the drivers. A brief review of the literature on the impacts of visibility on speed, travel time, and capacity, is provided below.

Brilon and Ponzlet (1996) studied visibility based on data collected on German autobahns. They found darkness caused an average reduction of speed by approximately 5 km/hr. They also found that darkness reduced the capacity on two- and three-lane autobahns by 200-375 vph. That represents a 13% to 47% reduction in capacity in darkness conditions when compared to daylight conditions. However, as Agarwal et al. (2005) pointed out, this study was conducted in Germany, where there are no maximum speed limits on many freeways and where driver behavior and expectancies may differ from U.S.

Liang et al. (1998) evaluated 75 km (45 miles) of a rural section of I-84 in southern Idaho and found that visibility affected speeds according to a logarithmic relationship. Speed at night was about 1.6 km/h less than during daylight hours. The mean speed was reduced by 8 km/h during fog events. However, these findings were based on only two fog events.

Kyte et al. (2000) analyzed weather and traffic data from a section of I-84 and found that limited visibility (0.1-0.23 miles) caused an insignificant decrease (<1 mph) in freeway operating speeds. Following that, Kyte et al. (2001) explicitly defined a critical visibility distance of 0.3 km (0.18 mile), below which the speed was reduced by 0.77 km/hr (0.48 mph) for every 0.01 km (0.0062 mile) reduction in visibility.

Chin et al. (2004) used loop detector data from different regions of the United States to analyze the impacts of weather on operations. They found that the loss of capacity and speed under fog conditions was 6% and 13% for freeways and arterials, respectively.

Agarwal et al. (2005) quantified the impact of rain, snow, and visibility on freeway traffic flow in the Twin Cities region. They classified visibility data due to fog events into four groups : >1 mile (normal weather conditions), 1–0.51, 0.5–0.25, and <0.25 miles. The results showed that there were statistically significant reductions of 10%-12% in freeway capacities for three groups of visibility ranges (1–0.51, 0.5–0.25, and <0.25 miles) when compared with normal weather conditions (visibility >1 mile). However, no statistically significant differences in capacities among the three low visibility groups (1–0.51, 0.5–0.25, and <0.25 mile) were found, when compared in pairs. They also found that there were speed reductions of 6.63%, 7.10%, and 11.78% respectively for three groups of visibility ranges (1–0.51, 0.5–0.25, and <0.25 miles) when compared with visibilities greater than one mile.

Rakha et al. (2007) proposed to represent the impact of inclement weather on traffic parameters by a corresponding weather adjustment factor (WAF). In their study, four different levels of visibility are used: less than 0.8 km (0.5 miles), 0.8 to 1.6 km (0.5 to 1 miles), 1.6 to 4.8 km (1 to 3 miles), and greater than 4.8 km (3 miles). The authors concluded that visibility has a larger impact on traffic stream parameters for snow precipitation when compared to rain. When visibility reduces from 4.8 to 0.0 km (3.0 to 0 miles), reductions in traffic parameters in the range of 10 percent are observed.

In summary, the visibility restrictions that have been studied in the literature relate to darkness, fog, and the presence of rain or snow conditions. No paper was found that discussed reduced visibility due to smoke. The observed speed reductions due to low visibility vary significantly among the papers: speed reductions due to darkness are in the range of 1.6 km/h to 5 km/h, speed reductions due to fog or low visibility are usually 6% to 12%. The observed capacity reductions due to low visibility are in the range of 10% to 47%. Table 3.3 provides a summary of the literature review regarding speed and capacity reductions caused by visibility reductions.

Table 3.3 Summary of Literature on Speed and Capacity Reduction Due to Visibility Reduction

Authors (Year)	Freeway/ arterial	Visibility Levels	Speed Reduction	Capacity Reduction
Brilon and Ponzlet (1996)	freeway (Germany autobahns)	darkness	by 5 km/hr	13% - 47%
Liang et al. (1998)	Freeway	darkness	by 1.6 km/h	--
		fog	by 8 km/h	--
Kyte et al. (2000)	Freeway	0.1-23 mile	insignificant decrease (< 1 mph)	--
Kyte et al. (2001)	Freeway	< 0.3 km (0.18 mile)	reduce by 0.77 km/hr for every 0.01 km (0.0062 mile) reduction in visibility	--
Chin et al. (2004)	freeway and arterial	fog	6%	13%
Agarwal et al. (2005)	Freeway	> 1 mile	0	0
		1–0.51 mile	6.63%	10%-12%
		0.5–0.25 mile	7.10%	10%-12%
		< 0.25 mile	11.78%	10%-12%
Rakha et al. (2007)	Freeway	visibility with rain	sensitive to rain intensity but not impacted by visibility	0
		visibility with snow, reduce from 4.8 to 0.0 km	< 10%	< 10%

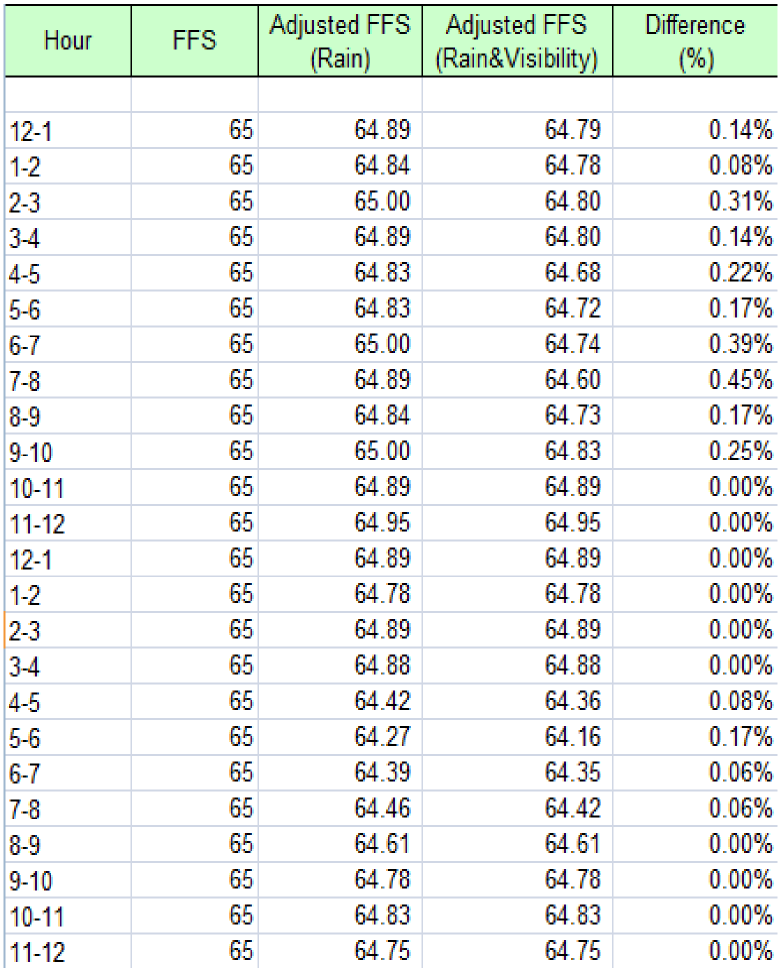
3.2.2. Recommendations and Quantitative Assessment of Visibility Impacts

Considering the interrelationship between rain and visibility, and to avoid duplication of impacts, rain and visibility impacts should be considered jointly. However, only one report (Rakha et al., 2007) studied the effects of visibility under rainy conditions; therefore, the recommendations provided here are based primarily on that report. Table 3.4 summarizes the preliminary recommendations on group categorization and speed reductions for each group based on rain intensity and visibility.

Table 3.4 Visibility and Rain, and Their Impacts on Speed Reduction (%)

Visibility **Rain Category**	Good (> 1 mile)	Limited (1-0.25 mile)	Low (<0.25 mile)
None (<0.01)	0	6	10
Light (0.01-1)	6	6	10
Heavy (>1)	12	12	12

Next, to determine whether the impact of visibility would be significant when estimating travel time reliability, the recommendations shown above were implemented and travel time reliability was estimated for a sample freeway segment (I-95/SR 9 between Broward Blvd and Sunrise Blvd.). Weather data, including visibility and rainfall data, were collected from the Weather Underground website (http://www.wunderground.com) for a one-year period, from January 2007 to December 2007. The calculation results with and without the consideration of visibility is shown in Figure 3.3. The third column provides the adjusted free-flow speed when considering only the effect of rain, while the fourth column provides the adjusted free-flow speed considering the combined impact of rain and visibility. As shown, the difference in the adjusted free-flow speeds with and without consideration of visibility is very small. Even the maximum difference among the 24 hours is only 0.45% between the two adjusted FFS. Therefore, to simplify the calculation algorithm, and given that the research on which the assumptions of Table 3.4 are based is limited, it is recommended that the effects of visibility on travel time reliability not be considered at this time.



Hour	FFS	Adjusted FFS (Rain)	Adjusted FFS (Rain&Visibility)	Difference (%)
12-1	65	64.89	64.79	0.14%
1-2	65	64.84	64.78	0.08%
2-3	65	65.00	64.80	0.31%
3-4	65	64.89	64.80	0.14%
4-5	65	64.83	64.68	0.22%
5-6	65	64.83	64.72	0.17%
6-7	65	65.00	64.74	0.39%
7-8	65	64.89	64.60	0.45%
8-9	65	64.84	64.73	0.17%
9-10	65	65.00	64.83	0.25%
10-11	65	64.89	64.89	0.00%
11-12	65	64.95	64.95	0.00%
12-1	65	64.89	64.89	0.00%
1-2	65	64.78	64.78	0.00%
2-3	65	64.89	64.89	0.00%
3-4	65	64.88	64.88	0.00%
4-5	65	64.42	64.36	0.08%
5-6	65	64.27	64.16	0.17%
6-7	65	64.39	64.35	0.06%
7-8	65	64.46	64.42	0.06%
8-9	65	64.61	64.61	0.00%
9-10	65	64.78	64.78	0.00%
10-11	65	64.83	64.83	0.00%
11-12	65	64.75	64.75	0.00%

Figure 3.3 Calculation Results With And Without The Consideration of Visibility

3.3. Additional Thoughts and Recommendations for Considering Weather Effects

To analyze a variety of demands and conditions throughout the year, the existing method considers demands by hour and for each week throughout the year. Given that weather effects are seasonal, it might be feasible to consider these demands coupled with seasonal weather effects (i.e., rain intensity and frequency). Additional research is needed however to establish whether such a consideration can be accomplished given the data and computational resources available. Also, it is desirable to refine the consideration of weather effects by including data from three regions in Florida rather than two. In doing so, it would be more reasonable to consider data for a 5-year period, rather than only one, so that these can be more representative of each region and time of year. It is recommended that these changes be considered in subsequent research on travel time reliability estimation.

4. IMPROVEMENTS IN THE CONSIDERATION OF INCIDENT OCCURRENCE

This section discusses improvements that relate to the calculation of incident occurrence. The travel time estimation methodology is based on the probability of blocking incidents and the ratio of non-blocking to blocking incidents. The number of blocking incidents and the number of non-blocking incidents are obtained from the Sunguide FDOT District 4 Report (December 2007, http://www.smartsunguide.com/Reports/monthly_Broward-120107-123107_010408-02654.pdf) and the ratio of non-blocking to blocking incidents is calculated from these data. Next, using data from the FDOT Crash Analysis Reporting System (CAR) for January 1 to December 31, 2007, the probability of a blocking incident per lane-mile per year for each segment is determined for four different scenarios: *No Rain, No Work zone*; *Rain, No Work zone*; *No Rain, Work zone*; and *Rain and Work zone*. Since CAR does not provide data related to non-blocking incidents, the probability of non-blocking incidents for each segment is calculated assuming that the proportion of non-blocking to blocking incidents is constant and equal to that in the Sunguide FDOT District 4 Report. In other words, the probability of non-blocking incidents is estimated by multiplying the ratio estimated in the Sunguide FDOT District 4 Report to the probability of blocking incidents.

The ratio of non-blocking to blocking incidents provided directly by the Sunguide FDOT District 4 Report is 20.51. This includes all recorded non-blocking incidents. When using this value to calculate the probability of non-blocking incidents, the results in some cases are unreasonably high. Figure 4.1 provides an example of these results for I-275/SR 93, from milepost 8.802 to milepost 16.021. As shown, the probability for non-blocking incidents exceeds 1.0 during several hours. Therefore, the data used to calculate the ratio of non-blocking to blocking incidents were re-examined to ensure that the final results would be reasonable.

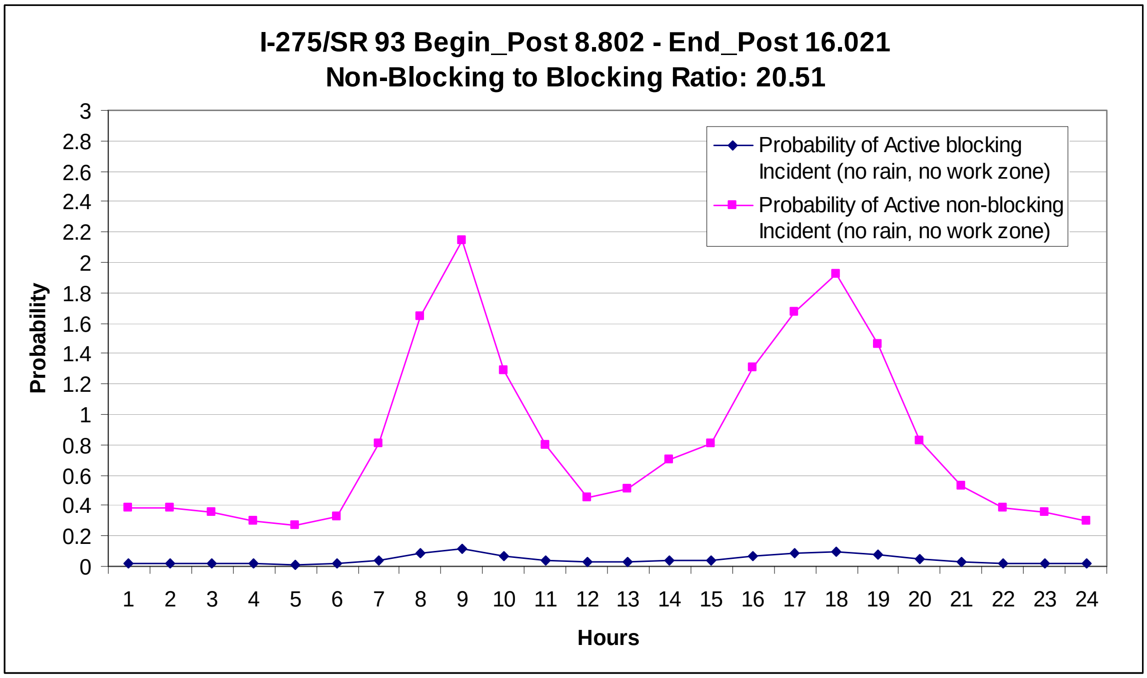


Figure 4.1 Probability for Incident-related Scenarios

The Sunguide FDOT District 4 Report provides the number of blocking and non-blocking incidents by different incident type. All of the incident types that were included in the total number are shown in Table 4.1. Some of these incident types (identified in the table in red) are less likely to have much impact on travel time. If these types of incidents are excluded, the non-blocking to blocking ratio is reduced from 20.51 to 3.26 (Table 4.2.) Using the modified non-blocking to blocking ratio, the probability for all incident-related scenarios can be calculated following the same procedure as before.

Table 4.1 Number of Blocking and Non-blocking Incidents by Event Type

Event Type	Blocking Incidents	Non-blocking Incidents
Abandoned Vehicle	7806	13
Accident	4494	2098
Congestion	10	0
Debris on Roadway	2382	75
Disabled Vehicle	36219	529
Emergency Vehicle	32	23
Off Ramp Backup	6	2
Pedestrian	241	1
Police Activity	144	67
Visibility	7	7
Road Work – Emergency	16	15
Weather	3	0
Other	10607	51
Total	59085	2881
Ratio of non-blocking to blocking incidents	20.51	

Table 4.2 Modified Number of Blocking and Non-blocking Incidents

Event Type	Blocking Incidents	Non-blocking Incidents
Accident	4494	2098
Debris on Roadway	2382	75
Off Ramp Backup	6	2
Pedestrian	241	1
Road Work – Emergency	16	15
Total	7139	2191
Ratio of non-blocking to blocking incidents	3.26	

The results are shown in Figure 4.2. It can be seen that the probabilities for non-blocking incidents are signficantly reduced and the results are now more reasonable.

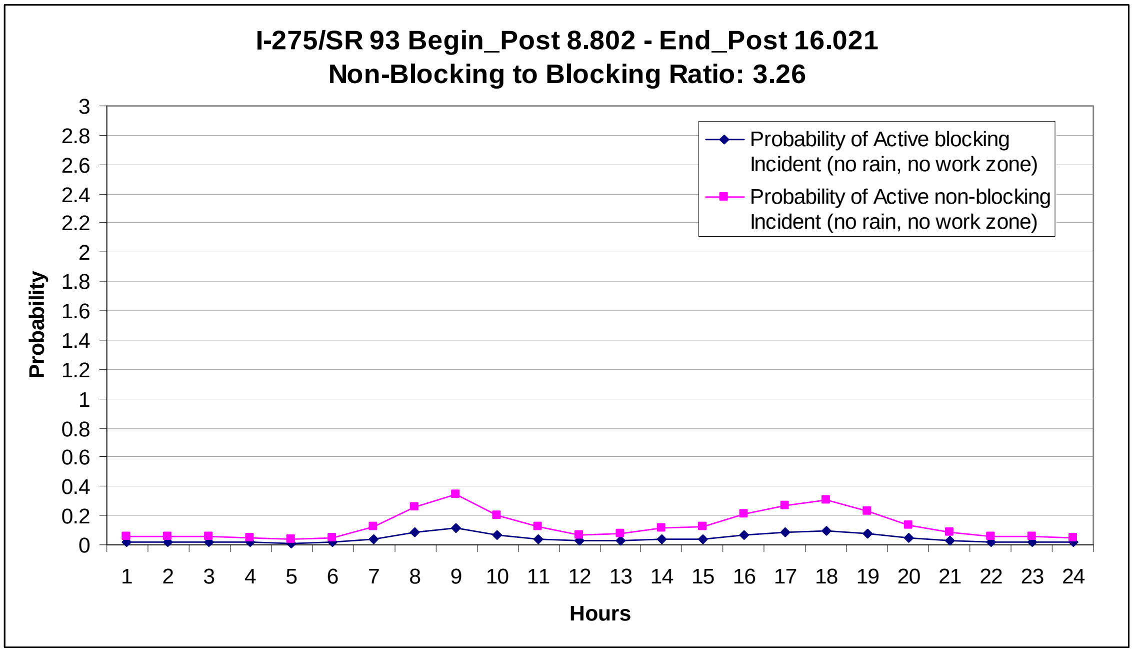


Figure 4.2 Probability for Incident-related Scenarios after Modification

5. TRAVEL TIME ESTIMATION RESULTS AND VALIDATION

This section first provides a summary of the travel time and reliability estimates for the Florida SIS, and then summarizes the results of a comparison of some of these estimates to field data.

Appendix B provides the updated guide to the Example Worksheet developed to implement the methodology for a single freeway section. This guide provides step-by-step information regarding all calculations and assumptions used by the methodology. The calculations were next implemented in a database to estimate travel time reliability for the entire SIS. The database operations have been automated using database queries, allowing the data to be updated on a yearly basis.

The following three items constitute the database implementation.

- Freeway Segmentation
- Input Dataset – FDOT LOS Database
- Reliability Calculations

Each of these is discussed briefly in the following sections.

5.1. Freeway Segmentation

Reliability calculations are performed at the section level (interchange to interchange) and are aggregated (summed) to the facility level. The following definitions are used:

- Sections – A freeway section is defined to be the link between adjacent interchanges; closely spaced interchanges are occassionally grouped together.
- Facilities – A grouping of consecutive freeway sections, with termini for "facility" analysis and reporting ranked in the following order:

  1. FIHS freeway to FIHS freeway interchanges
     - Non-FIHS freeways are also a major consideration; and
     - Logical extensions of FIHS freeways if a short gap of freeway is missing (e.g., Sawgrass to I-95).
  2. Non-adjacent urbanized area boundaries
     - Transitioning and rural boundaries are also a consideration.
  3. FIHS intersecting routes

4. Other special considerations
    - Downtown core areas (e.g., I-4 Orlando north);
    - International hubs (e.g., SR 836/Miami International Airport); and
    - State boundary.
5. Length
    - Consideration given to the area type in which a freeway is located; and
    - Short extensions of freeways leading to the arterial network.
6. However, designated “facilities” may be altered for desired purposes
    - “Extended facilities” composed of multiple facilities (e.g., I-95 from downtown Miami to downtown West Palm Beach); and
    - “Shortened facilities” (e.g., I-95 from Boca Raton to Delray Beach).

5.2. Input Dataset – FDOT LOS Database

On an annual basis, the Systems Planning Office (SPO) of the FDOT Central Office requests each District and the Turnpike to report the LOS for the portion of the State Highway System within their jurisdiction. This information is used to assess the LOS of the highway component of the SIS, to assist in the programming of SIS improvements and future corridors, and to report on statewide mobility performance measures (e.g., delay).

The following is a summary of the steps taken to calculate average hourly speeds and travel time based on the section level data within the District LOS databases:

- Average Annual Daily Traffic (AADT) values are provided for each section.
- Using hourly K-factors, generate peak-direction and off-peak direction hourly volumes as follows:
    - Peak Direction Hourly Volume = AADT x 0.55 x Hourly K-factor
        - Peak Hours = AADT x 0.52 x Hourly K-factor
    - Off-peak Direction Hourly Volume = AADT x 0.45 x Hourly K-factor
        - Off-peak Hours = AADT x 0.48 x Hourly K-factor

- Compare hourly directional volumes with Peak Hour Directional Volumes in the Generalized LOS tables (Tables 4-7 through 4-9 – based on area type) to determine hourly directional LOS values.
- Determine hourly directional travel speeds that are based on LOS assumed urbanized area speeds.

AADT, Hourly K-factors, and D Factors from the FDOT LOS database are used in the reliability database. Peak seasonal factors are obtained from the FDOT traffic information DVD for estimating capacity and demand relationships.

5.3. Reliability Calculations

The first step in the reliability calculations is to import the crash data from the CAR database. The number of incidents with or without rain and with or without workzones are obtained for each section. The following input variables, with a probability of occurrence, are used separately, and in combination with others to the calculated travel speed for each hour:

- Probability of demand over capacity;
- Average rainfall;
- Number of rainy days;
- Average number of closed lanes (incident)- From FDOT BD-545 # 70 Final Report, Table 7 (Assuming Level 1 = 1 lane closed, Level 2 - 2.5 lanes closed, Level 3 = 4.5 lanes closed);
- Probability of work zone – Assumed value;
- Average number of lanes closed per work zone – Assumed value; and
- Equations for estimating TT for each scenario

Using the input variables noted above, a combination of the following scenarios, coupled with either a congested or non-congested condition, is applied to the calculated travel speed for each hour to determine an average travel time/speed for the year:

- Rain

- Lane-blocking Incident
- Non Lane-blocking Incident
- Presence of a Work Zone

Using the result of the combination of scenarios noted above, the reliabilities based on on-time arrival and buffer index are calculated for the selected time intervals (e.g., for the evening peak hour). The following definitions apply:

- Reliability based on on-time arrival
    - Estimated as the percentage of time that the travel speed is no more than 10 miles per hour below the speed limit
    - Estimated as the percentage of trips that take place at 10 miles per hour less than the speed limit
- Reliability based on buffer-time index
    - Computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.
    - It represents the extra time a traveler should allow in order to arrive on-time for 95 percent of all trips.

Based on the process described above, Table 5.1 presents the aggregate all day results for the entire freeway portion of the SIS in 2007. The average weighted speed is calculated as the average speed by hour and for all combinations of scenarios weighted by the hourly traffic volume. Table 5.2 presents the aggregate peak period results for the entire freeway portion of the SIS in 2007. For urban facilities, the peak period is defined as 4:00 p.m.-7:00 p.m. For rural and transitioning facilities, the peak period is defined as 3:00 p.m-6:00 p.m.

Table 5.1. Travel Time Relability All Day Summary Table for 2007

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
1	Don Shula Expwy/SR 874	FLA Turnpike/HEFT	Snapper Creek Expy/SR 878	65.24	64.99	0.99	0.98	0.00
2	Don Shula Expwy/SR 874	Snapper Creek Expwy/SR 878	Palmetto Expy/SR 826	67.26	64.24	1.00	1.00	0.05
3	Snapper Creek Expwy/SR 878	Don Shula Expy/SR 874	SR 5/US 1/South Dixie Hwy	62.72	60.05	1.00	1.00	0.04
4	Dolphin Expwy/SR 836	FLA Turnpike/HEFT	Palmetto Expy/SR 826	58.41	57.82	0.98	0.97	0.01
5	Dolphin Expwy/SR 836	Palmetto Expy/SR 826	SR 953/Lejuene Rd/NW 42nd Ave	40.62	25.06	0.81	0.70	0.62
6	Dolphin Expwy/SR 836	SR 953/Lejuene Rd/NW 42nd Ave	I-95/SR 9	52.22	36.97	0.93	0.89	0.41
7	Dolphin Expwy/SR 836	I-95/SR 9	SR 5/Biscayne Blvd	44.32	28.07	0.87	0.79	0.58
8	Airport Expy/SR 112	NW 21st St	I-95/SR 9A	61.91	59.48	1.00	0.99	0.04
9	Airport Expy/SR 112	I-95/SR 9A	SR 907/Alton Rd	64.06	61.91	0.99	0.98	0.03
10	Gratigny Pkwy/SR 924	Palmetto Expy/SR 826	SR 9/NW 27 Ave	63.49	60.13	1.00	1.00	0.06
11	I-595/SR 862	I-75/SR 93	FLA Turnpike	54.68	56.69	0.96	0.93	0.00
12	I-595/SR 862	FLA Turnpike	I-95/SR 9	52.06	56.06	0.95	0.92	0.00
13	I-595/SR 862	I-95/SR 9	US 1/SR 5	67.32	64.69	1.00	1.00	0.04
14	Lee Roy Selmon Expy/SR 618	US 92/SR 573/S Dale Mabry Hwy	US 41/SR 60/Channelside Dr	64.97	64.69	1.00	1.00	0.00
15	Lee Roy Selmon Expy/SR 618	US 41/SR 60/Channelside Dr	I-75/SR 93A	62.64	62.38	1.00	1.00	0.00
16	I-4/SR 400	I-275/SR 93	I-75/SR 93A	60.88	61.43	0.99	0.99	0.00
17	I-4/SR 400	I-75/SR 93A	Polk Pkwy/SR 570	63.26	62.88	0.99	0.99	0.01
18	I-4/SR 400	Polk Pkwy/SR 570	Polk Pkwy/SR 570	66.96	66.28	1.00	1.00	0.01
19	I-4/SR 400	Polk Pkwy/SR 570	US 27/SR 25	72.12	69.90	1.00	1.00	0.03
20	I-4/SR 400	US 27/SR 25	Daniel Webster Western Beltway/SR 429	69.80	67.93	1.00	1.00	0.03
21	I-4/SR 400	Daniel Webster Western Beltway/SR 429	US 192/SR 530	66.60	64.61	1.00	0.99	0.03
22	I-4/SR 400	US 192/SR 530	Beach Line Exwy/SR 528	59.36	59.45	0.99	0.98	0.00

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
23	I-4/SR 400	Beach Line Exwy/SR 528	FLA Turnpike	57.36	57.87	0.97	0.96	0.00
24	I-4/SR 400	FLA Turnpike	EW Expy/SR 408	58.60	62.41	0.97	0.96	0.00
25	I-4/SR 400	EW Expy/SR 408	SR 436/Altamonde Dr	57.63	60.44	0.97	0.95	0.00
26	I-4/SR 400	SR 436/Altamonde Dr	US 17/SR 15/Seminole Blvd	64.05	64.23	0.99	0.98	0.00
27	I-4/SR 400	US 17/SR 15/Seminole Blvd	SR 44/E New York Ave	65.25	65.55	0.99	0.99	0.00
28	I-4/SR 400	SR 44/E New York Ave	I-95/SR 9	67.43	66.53	1.00	1.00	0.01
29	Polk Pkwy/SR 570	I-4/SR 400	US 98/SR 35/Bartow Rd	73.43	70.21	1.00	1.00	0.05
30	Polk Pkwy/SR 570	US 98/SR 35/Bartow Rd	I-4/SR 400	74.21	70.39	1.00	1.00	0.05
31	Beachline Expy/SR 528	I-4/SR 400	FLA Turnpike	64.40	64.51	0.99	0.99	0.00
32	Beachline Expy/SR 528	FLA Turnpike	SR 436/S Semoran Blvd	64.41	62.95	1.00	0.99	0.02
33	Beachline Expy/SR 528	SR 436/S Semoran Blvd	SR 417/Central Florida Greenway	63.99	64.16	0.99	0.99	0.00
34	Beachline Expy/SR 528	SR 417/Central Florida Greenway	I-95/SR 9	72.65	72.16	1.00	1.00	0.01
35	Beachline Expy/SR 528	I-95/SR 9	SR A1A/Astronaut Blvd	67.79	64.99	1.00	1.00	0.04
36	East-West Expy/SR 408	FLA Turnpike	I-4/SR 400	63.41	63.33	1.00	0.99	0.00
37	East-West Expy/SR 408	I-4/SR 400	SR 417/Central Florida Grnwy	62.43	61.82	0.99	0.99	0.01
38	East-West Expy/SR 408	SR 417/Central Florida Grnwy	SR 50/W Colonial Dr	62.70	62.42	1.00	1.00	0.00
39	SR 202/JT Butler Blvd	I-95/SR 9	Kernan Blvd S	63.83	62.02	1.00	1.00	0.03
40	SR 202/JT Butler Blvd	Kernan Blvd S	SR A1A/3rd St S	62.41	60.46	1.00	1.00	0.03
41	US 90/Arlington Expy/SR 10A	N Liberty St	US 98/SR 113/Southside Blvd	63.23	62.04	0.99	0.99	0.02
42	I-295/SR 9A	I-95/SR 9	I-10/SR 8	64.20	63.06	0.99	0.99	0.02
43	I-295/SR 9A	I-10/SR 8	US 1/SR 15/New Kings Rd	62.77	63.28	0.99	0.98	0.00
44	I-295/SR 9A	US 1/SR 15/New Kings Rd	I-95/SR 9	65.11	63.97	0.99	0.99	0.02
45	I-10/SR 8	State Line	I-110/SR 8A	67.84	65.16	1.00	1.00	0.04
46	I-10/SR 8	I-110/SR 8A	SR 87	68.02	64.48	1.00	1.00	0.06
47	I-10/SR 8	SR 87	SR 85/S Ferdon Blvd	73.27	69.61	1.00	1.00	0.05

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
48	I-10/SR 8	SR 85/S Ferdon Blvd	US 331/SR 83	73.63	69.60	1.00	1.00	0.06
49	I-10/SR 8	US 331/SR 83	US 231/SR 75	73.76	73.67	1.00	1.00	0.00
50	I-10/SR 8	US 231/SR 75	SR 263/Capital Circle NW	73.50	73.34	1.00	1.00	0.00
51	I-10/SR 8	SR 263/Capital Circle NW	US 90/SR 10	66.50	66.94	0.99	0.99	0.00
52	I-10/SR 8	US 90/SR 10	US 19/Florida Georgia Pkwy/SR 57	73.39	73.10	1.00	1.00	0.00
53	I-10/SR 8	US 19/Florida Georgia Pkwy/SR 57	I-75/SR 93	73.60	73.36	1.00	1.00	0.00
54	I-10/SR 8	I-75/SR 93	US 301/SR 200	73.45	73.19	1.00	1.00	0.00
55	I-10/SR 8	US 301/SR 200	I-295/SR 9A	66.19	64.66	0.99	0.99	0.02
56	I-10/SR 8	I-295/SR 9A	I-95/SR 9	60.53	59.98	0.99	0.99	0.01
57	I-110 Spur/SR 8A	SR 30/E Chase St	I-10/SR 8	65.74	64.16	0.99	0.99	0.02
58	I-275/SR 93	I-75/SR 93	SR 682/54th Ave S	67.25	66.79	1.00	1.00	0.01
59	I-275/SR 93	SR 682/54 Ave S	I-175/SR 594	66.44	65.35	1.00	0.99	0.02
60	I-275/SR 93	I-175/SR 594	SR 694/Gandy Blvd	59.90	62.06	0.99	0.98	0.00
61	I-275/SR 93	SR 694/Gandy Blvd	SR 688/Ulmerton Rd	62.17	60.69	1.00	0.99	0.02
62	I-275/SR 93	SR 688/Ulmerton Rd	SR 60/Memorial Hwy	62.45	63.07	0.98	0.97	0.00
63	I-275/SR 93	SR 60/Memorial Hwy	I-4/SR 400	49.79	33.03	0.93	0.89	0.51
64	I-275/SR 93	I-4/SR 400	I-75/SR 93	62.06	62.16	0.98	0.97	0.00
65	I-175/SR 594	I-275/SR 93	SR 687/4th St S	63.46	63.13	1.00	1.00	0.01
66	I-375/SR 592	I-275/SR 93	SR 595/4th Ave N	63.82	63.63	1.00	1.00	0.00
67	Veterans Expy/SR 589	SR 60/Courtney Campbell Cwy	Veterans Spur Exwy/SR 568	66.61	66.71	0.99	0.99	0.00
68	Suncoast Pkwy/SR 589	Veterans Spur Exwy/SR 568	SR 54	68.43	68.11	1.00	1.00	0.00
69	Suncoast Pkwy/SR 589	SR 54	SR 50/Cortez Blvd	73.82	73.71	1.00	1.00	0.00
70	Suncoast Pkwy/SR 589	SR 50/Cortez Blvd	US 98/SR 700/Ponce de leon Blvd	74.50	74.61	1.00	1.00	0.00
71	Veterans Spur Expy/SR 568	Veterans Expy/SR 589	SR 597/Dale Mabry Hwy N	69.22	69.20	1.00	1.00	0.00
72	I-75/SR 93	SR 826/Palmetto Exwy	FLA Turnpike/HEFT	62.23	59.35	1.00	0.99	0.05

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
73	I-75/SR 93	FLA Turnpike/HEFT	I-595/Port Everglades Expy/SR 862	64.28	62.73	1.00	0.99	0.02
74	I-75/SR 93	I-595/Port Everglades Expy/SR 862	US 27/SR 25	63.64	60.79	1.00	1.00	0.05
75	I-75/SR 93/Alligator Alley	US 27/SR 25	CR 951/Collier Blvd	73.49	73.36	1.00	1.00	0.00
76	I-75/SR 93	CR 951/Collier Blvd	SR 80/Palm Beach Blvd	63.22	64.19	0.99	0.98	0.00
77	I-75/SR 93	SR 80/Palm Beach Blvd	US 17/SR 35	71.63	69.56	1.00	1.00	0.03
78	I-75/SR 93	US 17/SR 35	SR 72/Clark Rd	70.22	68.96	0.99	0.99	0.02
79	I-75/SR 93	SR 72/Clark Rd	SR 70/Oneco Myakka City Rd	64.17	64.78	0.99	0.98	0.00
80	I-75/SR 93	SR 70/Oneco Myakka City Rd	I-275/SR 93	65.97	65.49	1.00	0.99	0.01
81	I-75/SR 93A	I-275/SR 93	Lee Roy Selmon Expy/SR 618	68.92	68.45	1.00	1.00	0.01
82	I-75/SR 93A	Lee Roy Selmon Expy/SR 618	I-4/SR 400	59.78	62.25	0.98	0.97	0.00
83	I-75/SR 93A	I-4/SR 400	I-275/E County Line Rd	58.93	45.49	0.95	0.92	0.30
84	I-75/SR 93	I-275/E County Line Rd	CR 54/Wesley Ch Blvd	61.13	62.80	0.98	0.98	0.00
85	I-75/SR 93	CR 54/Wesley Ch Blvd	US 28/SR 50/Cortez Blvd	71.93	71.53	1.00	0.99	0.01
86	I-75/SR 93	US 28/SR 50/Cortez Blvd	FLA Turnpike	72.45	69.15	1.00	1.00	0.05
87	I-75/SR 93	FLA Turnpike	SR 200/SW College Rd	69.66	67.12	1.00	1.00	0.04
88	I-75/SR 93	SR 200/SW College Rd	SR 326/W Hwy 326	67.31	65.12	1.00	1.00	0.03
89	I-75/SR 93	SR 326/W Hwy 326	SR 121/SW Williston Rd	72.51	69.64	1.00	1.00	0.04
90	I-75/SR 93	SR 121/SW Williston Rd	SR 222/NW 39th Ave	66.38	64.38	1.00	1.00	0.03
91	I-75/SR 93	SR 222/NW 39th Ave	I-10/SR 8	73.05	72.68	1.00	1.00	0.01
92	I-75/SR 93	I-10/SR 8	State Line	73.62	73.38	1.00	1.00	0.00
93	Daniel Webster West Beltwy/SR 429	Seidel Rd	US 441/SR 500/W Orange Blossom Trail	68.84	68.62	1.00	1.00	0.00
94	Central Florida Greenway/SR 417	I-4/SR 400	Beachline Expy/SR 528	68.03	65.34	1.00	1.00	0.04
95	Central Florida Greenway/SR 417	Beachline Expy/SR 528	EW Expy/SR 408	67.54	65.30	1.00	1.00	0.03

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
96	Central Florida Greenway/SR 417	EW Expy/SR 408	I-4/SR 400	67.51	67.06	1.00	1.00	0.01
97	FLA Turnpike /HEFT	US1/SR 5/South Dixie Hwy	Don Shula Expy/SR 874	66.64	65.48	0.99	0.99	0.02
98	FLA Turnpike /HEFT	Don Shula Expy/SR 874	Dophin Expy/SR 836	64.83	65.32	0.99	0.99	0.00
99	FLA Turnpike /HEFT	Dophin Expy/SR 836	US 27/SR 25/Okeechobee Rd	58.55	61.05	0.96	0.94	0.00
100	FLA Turnpike /HEFT	US 27/SR 25/Okeechobee Rd	I-75/SR 93	59.53	62.04	0.98	0.97	0.00
101	FLA Turnpike /HEFT	I-75/SR 93	FLA Turnpike /HEFT	66.21	64.73	0.99	0.99	0.02
102	FLA Turnpike /S. Coin	SR 826/Palmetto Expy	FLA Turnpike /HEFT	67.48	64.15	1.00	1.00	0.05
103	FLA Turnpike /S. Coin	FLA Turnpike /HEFT	I-595/SR 862	64.59	63.72	0.99	0.98	0.01
104	FLA Turnpike /S. Coin	I-595/SR 862	SR 869/Sawgrass Expy	65.11	65.23	0.99	0.98	0.00
105	FLA Turnpike /S. Coin	SR 869/Sawgrass Expy	US 98/SR 80/Southern Blvd	65.84	63.43	0.99	0.99	0.04
106	FLA Turnpike/Ticket	US 98/SR 80/Southern Blvd	SR 710/Bee Line Hwy	65.25	63.10	0.99	0.98	0.03
107	FLA Turnpike/Ticket	SR 710/Bee Line Hwy	SR 714/SW Martin Hwy	67.68	64.02	1.00	1.00	0.06
108	FLA Turnpike/Ticket	SR 714/SW Martin Hwy	SR 70/Okeechobee Rd	72.78	69.71	1.00	1.00	0.04
109	FLA Turnpike/Ticket	SR 70/Okeechobee Rd	SR 60/Osceola Blvd	73.24	70.26	1.00	1.00	0.04
110	FLA Turnpike/Ticket	SR 60/Osceola Blvd	CR 525/Kissimmee Park Rd	73.24	69.78	1.00	1.00	0.05
111	FLA Turnpike/N. Coin	CR 525/Kissimmee Park Rd	Central Florida Greenway/SR 417	69.45	66.37	1.00	1.00	0.05
112	FLA Turnpike/N. Coin	Central Florida Greenway/SR 417	Beachline Expy/SR 528	66.73	64.75	1.00	0.99	0.03
113	FLA Turnpike/N. Coin	Beachline Expy/SR 528	I-4/SR 400	61.13	62.43	0.97	0.96	0.00
114	FLA Turnpike/N. Coin	I-4/SR 400	E W Expy/SR 408	64.79	64.02	0.99	0.98	0.01
115	FLA Turnpike/N. Coin	E W Expy/SR 408	Daniel Webster Western Beltway/SR 429	67.10	67.71	0.99	0.99	0.00
116	FLA Turnpike/N. Coin	Daniel Webster Western Beltway/SR 429	SR 50/W Colonial Dr	67.83	67.04	0.99	0.98	0.01
117	FLA Turnpike/N. Coin	SR 50/W Colonial Dr	US 27/SR 25	72.58	69.30	1.00	1.00	0.05
118	FLA Turnpike/N. Coin	US 27/SR 25	I-75/SR 93	72.71	69.36	1.00	1.00	0.05

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
119	Palmetto Expy/SR 826	SR 5/US 1/South Dixie Hwy	Don Shula Expwy/SR 874	61.00	59.00	0.99	0.99	0.03
120	Palmetto Expy/SR 826	Don Shula Expwy/SR 874	Dophin Expy/SR 836	56.89	57.65	0.98	0.97	0.00
121	Palmetto Expy/SR 826	Dophin Expy/SR 836	US 27/SR 25/Okeechobee Rd	59.71	58.40	0.99	0.98	0.02
122	Palmetto Expy/SR 826	US 27/SR 25/Okeechobee Rd	I-75/SR 93	60.65	58.73	0.99	0.99	0.03
123	Palmetto Expy/SR 826	I-75/SR 93	I-95/SR 9	58.80	58.06	0.97	0.96	0.01
124	Sawgrass Expy/SR 869	I-595/SR 84	SR 845/Powerline Rd	66.73	66.66	1.00	0.99	0.00
125	I-95/SR 9	SR 5/US 1/South Dixie Hgwy	Dolphin Expy/SR 836	59.89	58.43	0.99	0.99	0.03
126	I-95/SR 9	Dolphin Expy/SR 836	I-195/Aiport Exwy/SR 112	53.00	33.84	0.90	0.84	0.57
127	I-95/SR 9	I-195/Aiport Exwy/SR 112	SR 924/NW 119th St	58.13	57.42	0.97	0.95	0.01
128	I-95/SR 9	SR 924/NW 119th St	FLA Turnpike	56.34	57.08	0.97	0.95	0.00
129	I-95/SR 9	FLA Turnpike	I-595/SR 862	57.10	57.55	0.98	0.97	0.00
130	I-95/SR 9	I-595/SR 862	SR 869/SW 10th St	54.14	46.84	0.95	0.92	0.16
131	I-95/SR 9	SR 869/SW 10th St	US 98/SR 80/Southern Blvd	58.59	58.98	0.98	0.97	0.00
132	I-95/SR 9	US 98/SR 80/Southern Blvd	SR 708/Blue Heron Blvd	51.01	36.85	0.94	0.91	0.38
133	I-95/SR 9	SR 708/Blue Heron Blvd	SR 76/SW Kanner Hwy	67.63	64.98	0.99	0.99	0.04
134	I-95/SR 9	SR 76/SW Kanner Hwy	SR 70/Okeechobee Rd	68.85	65.91	1.00	1.00	0.04
135	I-95/SR 9	SR 70/Okeechobee Rd	SR 60/20th St	70.14	67.39	1.00	1.00	0.04
136	I-95/SR 9	SR 60/20th St	SR 514/Malabar Rd	72.69	69.50	1.00	1.00	0.05
137	I-95/SR 9	SR 514/Malabar Rd	Beachline Expy/SR 528	65.05	62.80	0.99	0.98	0.04
138	I-95/SR 9	Beachline Expy/SR 528	SR 46/W Main St	67.71	66.97	1.00	1.00	0.01
139	I-95/SR 9	SR 46/W Main St	SR 44/Canal St	73.16	72.82	1.00	1.00	0.00
140	I-95/SR 9	SR 44/Canal St	I-4/SR 400	67.65	65.66	1.00	1.00	0.03
141	I-95/SR 9	I-4/SR 400	SR 40/W Granada Rd	65.75	64.75	1.00	0.99	0.02
142	I-95/SR 9	SR 40/W Granada Rd	SR 207	70.17	69.42	1.00	1.00	0.01
143	I-95/SR 9	SR 207	County Rd 210	72.87	72.25	1.00	1.00	0.01
144	I-95/SR 9	County Rd 210	I-295/SR 9A	67.14	64.88	1.00	1.00	0.03
145	I-95/SR 9	I-295/SR 9A	SR 202/JT Bulter Blvd	62.55	61.63	0.99	0.99	0.01

Group	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
146	I-95/SR 9	SR 202/JT Bulter Blvd	I-10/SR 8	57.85	58.60	0.98	0.97	0.00
147	I-95/SR 9	I-10/SR 8	I-295/SR 9A	60.87	61.01	0.99	0.98	0.00
148	I-95/SR 9	I-295/SR 9A	Pecan Park Rd	65.96	65.57	1.00	1.00	0.01
149	I-95/SR 9	Pecan Park Rd	SR 200/SR A1A	72.67	72.18	1.00	1.00	0.01
150	I-95/SR 9	SR 200/SR A1A	State Border	72.97	72.57	1.00	1.00	0.01
151	US 1/Haines St Expy/SR 115	E Church St	E 1st St	64.56	61.02	1.00	1.00	0.06
152	US 1/20th St Expy (M.L.K. Pkwy)/SR 115	I-95/SR 9	US 90/Arlington Exwy/SR 10A	62.43	60.35	1.00	0.99	0.03
153	US 1/Haines St Expy/SR 115	US 90/Arlington Exwy/SR 10A	US 90/SR 228/Beach Blvd	63.60	60.88	1.00	1.00	0.04
154	US 1/Emerson St Expy/SR 228A	Emerson St	Commadore St Expy/SR 228	63.46	60.66	0.99	0.99	0.05
155	SR 9A	SR 9/I-95	SR 202/JT Bulter Blvd	65.68	63.66	1.00	0.99	0.03
156	SR 9A	SR 202/JT Bulter Blvd	I-95/SR 9	65.20	64.37	0.99	0.99	0.01

Table 5.2. Travel Time Relability Peak Period (Urban 4p.m.-7p.m., Rural and Urban Transitioning: 3p.m.-6p.m.) Summary Table for 2007

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
1	Urbanized	Don Shula Expwy/SR 874	FLA Turnpike/HEFT	Snapper Creek Expy/SR 878	62.11	41.02	0.94	0.93	0.51
2	Urbanized	Don Shula Expwy/SR 874	Snapper Creek Expwy/SR 878	Palmetto Expy/SR 826	66.31	63.17	0.99	0.99	0.05
3	Urbanized	Snapper Creek Expwy/SR 878	Don Shula Expy/SR 874	SR 5/US 1/South Dixie Hwy	62.04	58.90	1.00	0.99	0.05
4	Urbanized	Dolphin Expwy/SR 836	FLA Turnpike/HEFT	Palmetto Expy/SR 826	54.72	37.80	0.92	0.92	0.45
5	Urbanized	Dolphin Expwy/SR 836	Palmetto Expy/SR 826	SR 953/Lejuene Rd/NW 42nd Ave	28.38	15.27	0.41	0.39	0.86
6	Urbanized	Dolphin Expwy/SR 836	SR 953/Lejuene Rd/NW 42nd Ave	I-95/SR 9	43.02	20.68	0.72	0.70	1.08
7	Urbanized	Dolphin Expwy/SR 836	I-95/SR 9	SR 5/Biscayne Blvd	33.03	15.69	0.53	0.50	1.11
8	Urbanized	Airport Expy/SR 112	NW 21st St	I-95/SR 9A	60.82	58.37	0.99	0.99	0.04
9	Urbanized	Airport Expy/SR 112	I-95/SR 9A	SR 907/Alton Rd	61.55	60.20	0.95	0.95	0.02
10	Urbanized	Gratigny Pkwy/SR 924	Palmetto Expy/SR 826	SR 9/NW 27 Ave	63.20	59.65	1.00	1.00	0.06
11	Urbanized	I-595/SR 862	I-75/SR 93	FLA Turnpike	47.62	32.26	0.81	0.79	0.48
12	Urbanized	I-595/SR 862	FLA Turnpike	I-95/SR 9	42.39	23.10	0.76	0.74	0.84
13	Urbanized	I-595/SR 862	I-95/SR 9	US 1/SR 5	66.62	63.14	1.00	1.00	0.06
14	Urbanized	Lee Roy Selmon Expy/SR 618	US 92/SR 573/S Dale Mabry Hwy	US 41/SR 60/Channelside Dr	64.39	60.57	1.00	1.00	0.06
15	Urbanized	Lee Roy Selmon Expy/SR 618	US 41/SR 60/Channelside Dr	I-75/SR 93A	61.75	58.59	0.99	0.99	0.05
16	Urbanized	I-4/SR 400	I-275/SR 93	I-75/SR 93A	58.58	57.83	0.98	0.98	0.01
17	Urbanized	I-4/SR 400	I-75/SR 93A	Polk Pkwy/SR 570	61.16	59.73	0.98	0.98	0.02
18	Urbanized	I-4/SR 400	Polk Pkwy/SR 570	Polk Pkwy/SR 570	66.01	62.29	1.00	1.00	0.06
19	Urban_ Transitioning	I-4/SR 400	Polk Pkwy/SR 570	US 27/SR 25	71.21	67.07	1.00	1.00	0.06
20	Urban_ Transitioning	I-4/SR 400	US 27/SR 25	Daniel Webster Western Beltway/SR 429	68.14	65.03	0.99	0.99	0.05

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
21	Urbanized	I-4/SR 400	Daniel Webster Western Beltway/SR 429	US 192/SR 530	65.28	62.09	0.99	0.99	0.05
22	Urbanized	I-4/SR 400	US 192/SR 530	Beach Line Exwy/SR 528	55.95	56.79	0.96	0.96	0.00
23	Urbanized	I-4/SR 400	Beach Line Exwy/SR 528	FLA Turnpike	50.98	37.03	0.86	0.86	0.38
24	Urbanized	I-4/SR 400	FLA Turnpike	EW Expy/SR 408	49.33	11.40	0.90	0.89	3.33
25	Urbanized	I-4/SR 400	EW Expy/SR 408	SR 436/Altamonde Dr	49.55	31.13	0.85	0.84	0.59
26	Urbanized	I-4/SR 400	SR 436/Altamonde Dr	US 17/SR 15/Seminole Blvd	61.44	61.12	0.96	0.96	0.01
27	Urbanized	I-4/SR 400	US 17/SR 15/Seminole Blvd	SR 44/E New York Ave	62.83	61.85	0.98	0.98	0.02
28	Urbanized	I-4/SR 400	SR 44/E New York Ave	I-95/SR 9	66.65	65.42	1.00	1.00	0.02
29	Urban_ Transitioning	Polk Pkwy/SR 570	I-4/SR 400	US 98/SR 35/Bartow Rd	72.88	68.58	1.00	1.00	0.06
30	Urban_ Transitioning	Polk Pkwy/SR 570	US 98/SR 35/Bartow Rd	I-4/SR 400	73.90	69.50	1.00	1.00	0.06
31	Urbanized	Beachline Expy/SR 528	I-4/SR 400	FLA Turnpike	61.76	61.34	0.98	0.98	0.01
32	Urbanized	Beachline Expy/SR 528	FLA Turnpike	SR 436/S Semoran Blvd	62.32	60.25	0.99	0.99	0.03
33	Urbanized	Beachline Expy/SR 528	SR 436/S Semoran Blvd	SR 417/Central Florida Greenway	62.37	60.40	0.99	0.99	0.03
34	Rural	Beachline Expy/SR 528	SR 417/Central Florida Greenway	I-95/SR 9	71.95	67.99	1.00	1.00	0.06
35	Urbanized	Beachline Expy/SR 528	I-95/SR 9	SR A1A/Astronaut Blvd	66.99	63.52	1.00	1.00	0.05
36	Urbanized	East-West Expy/SR 408	FLA Turnpike	I-4/SR 400	62.21	59.60	0.99	0.99	0.04
37	Urbanized	East-West Expy/SR 408	I-4/SR 400	SR 417/Central Florida Grnwy	60.33	59.42	0.98	0.98	0.02
38	Urbanized	East-West Expy/SR 408	SR 417/Central Florida Grnwy	SR 50/W Colonial Dr	61.74	58.71	0.99	0.99	0.05
39	Urbanized	SR 202/JT Butler Blvd	I-95/SR 9	Kernan Blvd S	62.68	59.87	0.99	0.99	0.05
40	Urbanized	SR 202/JT Butler Blvd	Kernan Blvd S	SR A1A/3rd St S	61.63	58.60	0.99	0.99	0.05
41	Urbanized	US 90/Arlington Expy/SR 10A	N Liberty St	US 98/SR 113/Southside Blvd	61.55	60.04	0.98	0.98	0.03
42	Urbanized	I-295/SR 9A	I-95/SR 9	I-10/SR 8	62.10	60.42	0.98	0.98	0.03

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
43	Urbanized	I-295/SR 9A	I-10/SR 8	US 1/SR 15/New Kings Rd	59.72	60.53	0.98	0.97	0.00
44	Urbanized	I-295/SR 9A	US 1/SR 15/New Kings Rd	I-95/SR 9	63.49	61.52	0.98	0.98	0.03
45	Urbanized	I-10/SR 8	State Line	I-110/SR 8A	66.91	63.75	0.99	0.99	0.05
46	Urbanized	I-10/SR 8	I-110/SR 8A	SR 87	67.58	64.20	1.00	1.00	0.05
47	Rural	I-10/SR 8	SR 87	SR 85/S Ferdon Blvd	72.81	68.70	1.00	1.00	0.06
48	Rural	I-10/SR 8	SR 85/S Ferdon Blvd	US 331/SR 83	73.29	69.30	1.00	1.00	0.06
49	Rural	I-10/SR 8	US 331/SR 83	US 231/SR 75	73.32	69.07	1.00	1.00	0.06
50	Rural	I-10/SR 8	US 231/SR 75	SR 263/Capital Circle NW	72.98	68.78	1.00	1.00	0.06
51	Urbanized	I-10/SR 8	SR 263/Capital Circle NW	US 90/SR 10	64.15	62.33	0.97	0.97	0.03
52	Rural	I-10/SR 8	US 90/SR 10	US 19/Florida Georgia Pkwy/SR 57	72.85	68.66	1.00	1.00	0.06
53	Rural	I-10/SR 8	US 19/Florida Georgia Pkwy/SR 57	I-75/SR 93	73.10	69.07	1.00	1.00	0.06
54	Rural	I-10/SR 8	I-75/SR 93	US 301/SR 200	73.00	73.19	1.00	1.00	0.00
55	Urbanized	I-10/SR 8	US 301/SR 200	I-295/SR 9A	64.41	62.30	0.97	0.97	0.03
56	Urbanized	I-10/SR 8	I-295/SR 9A	I-95/SR 9	58.73	57.47	0.98	0.98	0.02
57	Urbanized	I-110 Spur/SR 8A	SR 30/E Chase St	I-10/SR 8	63.35	62.53	0.98	0.98	0.01
58	Urbanized	I-275/SR 93	I-75/SR 93	SR 682/54th Ave S	66.41	62.47	0.99	0.99	0.06
59	Urbanized	I-275/SR 93	SR 682/54 Ave S	I-175/SR 594	64.82	62.45	0.99	0.99	0.04
60	Urbanized	I-275/SR 93	I-175/SR 594	SR 694/Gandy Blvd	56.30	58.57	0.96	0.95	0.00
61	Urbanized	I-275/SR 93	SR 694/Gandy Blvd	SR 688/Ulmerton Rd	60.97	58.54	0.99	0.99	0.04
62	Urbanized	I-275/SR 93	SR 688/Ulmerton Rd	SR 60/Memorial Hwy	57.42	45.06	0.91	0.91	0.27
63	Urbanized	I-275/SR 93	SR 60/Memorial Hwy	I-4/SR 400	38.60	11.67	0.72	0.71	2.31
64	Urbanized	I-275/SR 93	I-4/SR 400	I-75/SR 93	58.05	43.33	0.90	0.90	0.34
65	Urbanized	I-175/SR 594	I-275/SR 93	SR 687/4th St S	63.04	59.79	1.00	1.00	0.05
66	Urbanized	I-375/SR 592	I-275/SR 93	SR 595/4th Ave N	63.50	60.14	1.00	1.00	0.06
67	Urbanized	Veterans Expy/SR 589	SR 60/Courtney Campbell Cwy	Veterans Spur Exwy/SR 568	65.06	62.82	0.99	0.98	0.04
68	Urbanized	Suncoast Pkwy/SR 589	Veterans Spur Exwy/SR 568	SR 54	67.96	63.93	1.00	1.00	0.06

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
69	Rural	Suncoast Pkwy/SR 589	SR 54	SR 50/Cortez Blvd	73.47	69.38	1.00	1.00	0.06
70	Rural	Suncoast Pkwy/SR 589	SR 50/Cortez Blvd	US 98/SR 700/Ponce de leon Blvd	74.36	70.16	1.00	1.00	0.06
71	Urbanized	Veterans Spur Expy/SR 568	Veterans Expy/SR 589	SR 597/Dale Mabry Hwy N	68.94	64.67	1.00	1.00	0.07
72	Urbanized	I-75/SR 93	SR 826/Palmetto Exwy	FLA Turnpike/HEFT	61.45	58.36	0.99	0.99	0.05
73	Urbanized	I-75/SR 93	FLA Turnpike/HEFT	I-595/Port Everglades Expy/SR 862	62.93	60.41	0.99	0.99	0.04
74	Urbanized	I-75/SR 93	I-595/Port Everglades Expy/SR 862	US 27/SR 25	63.37	60.01	1.00	1.00	0.06
75	Rural	I-75/SR 93/Alligator Alley	US 27/SR 25	CR 951/Collier Blvd	72.90	68.75	1.00	1.00	0.06
76	Urbanized	I-75/SR 93	CR 951/Collier Blvd	SR 80/Palm Beach Blvd	59.08	45.66	0.94	0.93	0.29
77	Urban_ Transitioning	I-75/SR 93	SR 80/Palm Beach Blvd	US 17/SR 35	70.46	66.72	0.99	0.99	0.06
78	Rural	I-75/SR 93	US 17/SR 35	SR 72/Clark Rd	68.29	65.70	0.98	0.98	0.04
79	Urbanized	I-75/SR 93	SR 72/Clark Rd	SR 70/Oneco Myakka City Rd	60.57	60.59	0.96	0.96	0.00
80	Urbanized	I-75/SR 93	SR 70/Oneco Myakka City Rd	I-275/SR 93	63.78	61.35	0.98	0.98	0.04
81	Urban_ Transitioning	I-75/SR 93A	I-275/SR 93	Lee Roy Selmon Expy/SR 618	68.11	64.64	1.00	1.00	0.05
82	Urbanized	I-75/SR 93A	Lee Roy Selmon Expy/SR 618	I-4/SR 400	53.23	24.42	0.92	0.92	1.18
83	Urbanized	I-75/SR 93A	I-4/SR 400	I-275/E County Line Rd	51.56	26.30	0.82	0.81	0.96
84	Urbanized	I-75/SR 93	I-275/E County Line Rd	CR 54/Wesley Ch Blvd	57.18	59.92	0.96	0.96	0.00
85	Urban_ Transitioning	I-75/SR 93	CR 54/Wesley Ch Blvd	US 28/SR 50/Cortez Blvd	70.70	67.48	0.99	0.99	0.05
86	Rural	I-75/SR 93	US 28/SR 50/Cortez Blvd	FLA Turnpike	71.68	67.62	1.00	1.00	0.06
87	Urban_ Transitioning	I-75/SR 93	FLA Turnpike	SR 200/SW College Rd	68.75	64.81	1.00	1.00	0.06
88	Urbanized	I-75/SR 93	SR 200/SW College Rd	SR 326/W Hwy 326	66.29	62.68	0.99	0.99	0.06
89	Rural	I-75/SR 93	SR 326/W Hwy 326	SR 121/SW Williston Rd	71.72	67.92	1.00	1.00	0.06
90	Urbanized	I-75/SR 93	SR 121/SW Williston Rd	SR 222/NW 39th Ave	65.34	62.50	0.99	0.99	0.05

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
91	Rural	I-75/SR 93	SR 222/NW 39th Ave	I-10/SR 8	72.47	68.49	1.00	1.00	0.06
92	Rural	I-75/SR 93	I-10/SR 8	State Line	73.13	69.10	1.00	1.00	0.06
93	Urbanized	Daniel Webster West Beltwy/SR 429	Seidel Rd	US 441/SR 500/W Orange Blossom Trail	68.29	64.34	1.00	1.00	0.06
94	Urbanized	Central Florida Greenway/SR 417	I-4/SR 400	Beachline Expy/SR 528	67.25	63.31	1.00	1.00	0.06
95	Urbanized	Central Florida Greenway/SR 417	Beachline Expy/SR 528	EW Expy/SR 408	66.57	62.88	1.00	1.00	0.06
96	Urbanized	Central Florida Greenway/SR 417	EW Expy/SR 408	I-4/SR 400	66.82	63.18	1.00	1.00	0.06
97	Urbanized	FLA Turnpike /HEFT	US1/SR 5/South Dixie Hwy	Don Shula Expy/SR 874	65.41	62.67	0.99	0.99	0.04
98	Urbanized	FLA Turnpike /HEFT	Don Shula Expy/SR 874	Dophin Expy/SR 836	62.48	61.58	0.98	0.98	0.01
99	Urbanized	FLA Turnpike /HEFT	Dophin Expy/SR 836	US 27/SR 25/Okeechobee Rd	50.92	38.68	0.78	0.77	0.32
100	Urbanized	FLA Turnpike /HEFT	US 27/SR 25/Okeechobee Rd	I-75/SR 93	54.21	27.10	0.94	0.94	1.00
101	Urbanized	FLA Turnpike /HEFT	I-75/SR 93	FLA Turnpike /HEFT	64.64	62.43	0.98	0.98	0.04
102	Urbanized	FLA Turnpike /S. Coin	SR 826/Palmetto Expy	FLA Turnpike /HEFT	66.96	63.18	1.00	1.00	0.06
103	Urbanized	FLA Turnpike /S. Coin	FLA Turnpike /HEFT	I-595/SR 862	61.91	61.64	0.97	0.97	0.00
104	Urbanized	FLA Turnpike /S. Coin	I-595/SR 862	SR 869/Sawgrass Expy	62.28	61.88	0.97	0.97	0.01
105	Urbanized	FLA Turnpike /S. Coin	SR 869/Sawgrass Expy	US 98/SR 80/Southern Blvd	63.44	62.00	0.97	0.97	0.02
106	Urbanized	FLA Turnpike/Ticket	US 98/SR 80/Southern Blvd	SR 710/Bee Line Hwy	62.24	62.04	0.96	0.96	0.00
107	Urbanized	FLA Turnpike/Ticket	SR 710/Bee Line Hwy	SR 714/SW Martin Hwy	67.00	63.44	1.00	1.00	0.06
108	Urban_ Transitioning	FLA Turnpike/Ticket	SR 714/SW Martin Hwy	SR 70/Okeechobee Rd	72.08	68.31	1.00	1.00	0.06
109	Rural	FLA Turnpike/Ticket	SR 70/Okeechobee Rd	SR 60/Osceola Blvd	72.63	68.76	1.00	1.00	0.06
110	Rural	FLA Turnpike/Ticket	SR 60/Osceola Blvd	CR 525/Kissimmee Park Rd	72.58	68.77	1.00	1.00	0.06
111	Urbanized	FLA Turnpike/N. Coin	CR 525/Kissimmee Park Rd	Central Florida Greenway/SR 417	68.83	65.17	1.00	1.00	0.06

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
112	Urbanized	FLA Turnpike/N. Coin	Central Florida Greenway/SR 417	Beachline Expy/SR 528	64.58	62.26	0.97	0.97	0.04
113	Urbanized	FLA Turnpike/N. Coin	Beachline Expy/SR 528	I-4/SR 400	55.86	28.65	0.94	0.94	0.95
114	Urbanized	FLA Turnpike/N. Coin	I-4/SR 400	E W Expy/SR 408	61.32	61.90	0.96	0.96	0.00
115	Urbanized	FLA Turnpike/N. Coin	E W Expy/SR 408	Daniel Webster Western Beltway/SR 429	64.71	63.79	0.99	0.99	0.01
116	Urban_ Transitioning	FLA Turnpike/N. Coin	Daniel Webster Western Beltway/SR 429	SR 50/W Colonial Dr	62.44	65.62	0.96	0.96	0.00
117	Rural	FLA Turnpike/N. Coin	SR 50/W Colonial Dr	US 27/SR 25	71.85	67.82	1.00	1.00	0.06
118	Rural	FLA Turnpike/N. Coin	US 27/SR 25	I-75/SR 93	72.04	67.87	1.00	1.00	0.06
119	Urbanized	Palmetto Expy/SR 826	SR 5/US 1/South Dixie Hwy	Don Shula Expwy/SR 874	59.06	57.33	0.96	0.96	0.03
120	Urbanized	Palmetto Expy/SR 826	Don Shula Expwy/SR 874	Dophin Expy/SR 836	52.80	38.77	0.93	0.92	0.36
121	Urbanized	Palmetto Expy/SR 826	Dophin Expy/SR 836	US 27/SR 25/Okeechobee Rd	56.72	56.65	0.95	0.95	0.00
122	Urbanized	Palmetto Expy/SR 826	US 27/SR 25/Okeechobee Rd	I-75/SR 93	59.03	57.39	0.98	0.98	0.03
123	Urbanized	Palmetto Expy/SR 826	I-75/SR 93	I-95/SR 9	55.45	37.87	0.91	0.90	0.46
124	Urbanized	Sawgrass Expy/SR 869	I-595/SR 84	SR 845/Powerline Rd	65.65	63.45	0.99	0.99	0.03
125	Urbanized	I-95/SR 9	SR 5/US 1/South Dixie Hgwy	Dolphin Expy/SR 836	57.31	56.69	0.96	0.96	0.01
126	Urbanized	I-95/SR 9	Dolphin Expy/SR 836	I-195/Aiport Exwy/SR 112	45.93	30.17	0.71	0.70	0.52
127	Urbanized	I-95/SR 9	I-195/Aiport Exwy/SR 112	SR 924/NW 119th St	54.14	35.42	0.89	0.89	0.53
128	Urbanized	I-95/SR 9	SR 924/NW 119th St	FLA Turnpike	50.99	36.18	0.85	0.84	0.41
129	Urbanized	I-95/SR 9	FLA Turnpike	I-595/SR 862	53.33	39.27	0.94	0.94	0.36
130	Urbanized	I-95/SR 9	I-595/SR 862	SR 869/SW 10th St	45.65	31.32	0.77	0.76	0.46
131	Urbanized	I-95/SR 9	SR 869/SW 10th St	US 98/SR 80/Southern Blvd	53.65	39.93	0.91	0.91	0.34
132	Urbanized	I-95/SR 9	US 98/SR 80/Southern Blvd	SR 708/Blue Heron Blvd	40.86	11.95	0.77	0.76	2.42
133	Urbanized	I-95/SR 9	SR 708/Blue Heron Blvd	SR 76/SW Kanner Hwy	65.93	63.39	0.98	0.98	0.04

Group	Area Type	Facility	From	To	Avg. Weighted Speed	95th% Speed	Percent Time Travel Speed 10 mph Less than Speed Limit	Percent Trips 10 mph Less than Speed Limit	Buffer Index
134	Urbanized	I-95/SR 9	SR 76/SW Kanner Hwy	SR 70/Okeechobee Rd	68.35	64.59	1.00	1.00	0.06
135	Urban_ Transitioning	I-95/SR 9	SR 70/Okeechobee Rd	SR 60/20th St	69.36	65.71	1.00	1.00	0.06
136	Rural	I-95/SR 9	SR 60/20th St	SR 514/Malabar Rd	71.91	68.19	1.00	1.00	0.05
137	Urbanized	I-95/SR 9	SR 514/Malabar Rd	Beachline Expy/SR 528	63.15	61.38	0.96	0.96	0.03
138	Urbanized	I-95/SR 9	Beachline Expy/SR 528	SR 46/W Main St	66.85	63.11	1.00	1.00	0.06
139	Rural	I-95/SR 9	SR 46/W Main St	SR 44/Canal St	72.54	68.63	1.00	1.00	0.06
140	Urbanized	I-95/SR 9	SR 44/Canal St	I-4/SR 400	66.76	63.77	0.99	0.99	0.05
141	Urbanized	I-95/SR 9	I-4/SR 400	SR 40/W Granada Rd	64.29	62.23	0.99	0.98	0.03
142	Urban_ Transitioning	I-95/SR 9	SR 40/W Granada Rd	SR 207	69.32	69.42	0.99	0.99	0.00
143	Urban_ Transitioning	I-95/SR 9	SR 207	County Rd 210	72.22	72.25	1.00	1.00	0.00
144	Urbanized	I-95/SR 9	County Rd 210	I-295/SR 9A	66.06	62.55	0.99	0.99	0.06
145	Urbanized	I-95/SR 9	I-295/SR 9A	SR 202/JT Bulter Blvd	60.73	58.96	0.99	0.99	0.03
146	Urbanized	I-95/SR 9	SR 202/JT Bulter Blvd	I-10/SR 8	53.30	38.65	0.91	0.90	0.38
147	Urbanized	I-95/SR 9	I-10/SR 8	I-295/SR 9A	58.63	58.54	0.98	0.98	0.00
148	Urbanized	I-95/SR 9	I-295/SR 9A	Pecan Park Rd	65.36	61.73	1.00	1.00	0.06
149	Urban_ Transitioning	I-95/SR 9	Pecan Park Rd	SR 200/SR A1A	71.89	68.05	1.00	1.00	0.06
150	Urban_ Transitioning	I-95/SR 9	SR 200/SR A1A	State Border	72.28	68.38	1.00	1.00	0.06
151	Urbanized	US 1/Haines St Expy/SR 115	E Church St	E 1st St	64.32	60.57	1.00	1.00	0.06
152	Urbanized	US 1/20th St Expy (M.L.K. Pkwy)/SR 115	I-95/SR 9	US 90/Arlington Exwy/SR 10A	61.38	58.73	0.99	0.99	0.05
153	Urbanized	US 1/Haines St Expy/SR 115	US 90/Arlington Exwy/SR 10A	US 90/SR 228/Beach Blvd	63.12	59.47	1.00	1.00	0.06
154	Urbanized	US 1/Emerson St Expy/SR 228A	Emerson St	Commadore St Expy/SR 228	63.05	59.53	1.00	1.00	0.06
155	Urbanized	SR 9A	SR 9/I-95	SR 202/JT Bulter Blvd	64.65	61.68	0.99	0.99	0.05
156	Urbanized	SR 9A	SR 202/JT Bulter Blvd	I-95/SR 9	63.20	62.11	0.98	0.98	0.02

These results are next compared to field data obtained for those portions of the freeway SIS where data are available. Field data were obtained through FDOT's Central Data Warehouse (CDW) project, which assembles and reports a variety of traffic-related data from several FDOT districts. Table 5.3 provides a summary of these field data obtained from District 2. Data were obtained for three time periods, starting in 2007. Based on the field data, the 95th percentile speed and Buffer Index were also estimated and are provided in this table.

Table 5.3 Central Data Warehouse (CDW) Field Data from District 2

			CDW (6/28/2007-12/31/2007)			CDW (1/1/2008-12/31/2008)			CDW (1/1/2009-12/16/2009)		
Facility	**From**	**To**	**Average Weighted Speed**	**95th% Speed**	**Buffer Index**	**Average Weighted Speed**	**95th% Speed**	**Buffer Index**	**Average Weighted Speed**	**95th% Speed**	**Buffer Index**
I-95/SR 9	I-295/SR 9A	SR 202/JT Bulter Blvd	66.96	61.33	9.17%	66.86	60.44	10.62%	66.61	59.24	12.44%
I-95/SR 9	SR 202/JT Bulter Blvd	I-10/SR 8	60.00	48.25	24.36%	58.89	50.09	17.58%	60.55	50.30	20.38%
I-95/SR 9	I-10/SR 8	I-295/SR 9A	56.80	48.82	16.34%	56.82	48.67	16.74%	58.21	50.16	16.05%
I-95/SR 9	I-295/SR 9A	Pecan Park Rd	64.76	58.69	10.34%	-	-	-	64.83	55.05	17.78%

The field travel speeds obtained from the CDW are next compared to the estimated measures previously obtained. Table 5.4 presents the estimated performance measures obtained for the freeway sections shown in Table 5.3. The performance measures used in this table are those available from the CDW. The results show that the estimated average weighted speed is within 5 mph of the field data. The estimated 95th-percentile speed is higher than the field 95th-percentile speed data in all cases, with the maximum differences in the range of 10-12 mph. This likely indicates that either the estimation of the congested travel times or the frequency of the occurrence of these travel times is underestimated.

Table 5.4 Estimated travel speed and reliability in 2007

Facility	From	To	Avg Weighted Speed	95th Speed	Buffer Index
I-95/SR 9	I-295/SR 9A	SR 202/JT Bulter Blvd	62.55	61.63	0.01
I-95/SR 9	SR 202/JT Bulter Blvd	I-10/SR 8	57.85	58.60	0.00
I-95/SR 9	I-10/SR 8	I-295/SR 9A	60.87	61.01	0.00
I-95/SR 9	I-295/SR 9A	Pecan Park Rd	65.96	65.57	0.01

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions and Recommendations for Implementation in the SIS

The objectives of this research were to a) implement the procedures developed on the entire freeway portion of the SIS, b) enhance the existing procedures to incorporate additional elements such as the impact of incidents on each freeway segment and the impacts of various ITS strategies, c) validate the estimates obtained using field data for those portions of the SIS where travel time information is available, and d) establish procedures for updating the travel time reliability estimates on an annual basis.

A series of recommendations were developed for incorporating the impacts of several ITS strategies into the travel time reliability analysis. However, the literature is sparse relative to the operational impacts of these strategies. In some cases, there are limited US implementations of these strategies, while in other cases the system evaluations conducted did not focus on operational impacts. Therefore, the recommendations developed should be used with caution, and they should be updated when additional evaluation studies become available.

The methodology was enhanced by considering weather-related impacts on travel time. Weather impacts focus on rain intensity. Visibility impacts were also evaluated, however it was recommended not to include these at this time. The calculation for non-blocking incident frequencies was re-evaluated and new recommendations were developed and implemented in the database. These revisions provide more reasonable results in the frequencies of non-blocking incidents.

Travel time reliability results were provided for the entire freeway portion of the SIS for the year 2007. The results are reasonable, however there are some discrepancies observed between field data and estimated values. It is likely that either the congested travel times are underestimated, or that the frequency of the congested scenarios is underestimated.

It is recommended that the results obtained for portions where field data are not available are examined in greater detail to ensure those are reasonable as well. It is also recommended to evaluate the estimation of congested travel times and the frequency of congestion to determine whether the discrepancies identified are related to a specific scenario or series of scenarios. Once discrepancies are identified, appropriate modifications should be implemented.

It is also recommended that the Travel Time Index (TTI) be used as a performance measure instead of the Buffer Index. Travel time index is the mean time it takes to travel during peak hours compared to free-flow conditions. It is computed as the mean travel time during the hours of interest divided by the free-flow travel time (NCHRP report 618, 2008). The Buffer Index does not correlate well with congestion, as it can decrease both when congestion increases and when it decreases.

6.2. Recommendations on the Application of the Method to Specific Sites and Projects

The method developed and implemented to obtain travel time reliability metrics over the SIS network can also be applied in cases of specific projects and at specific sites. To implement the method to specific area networks or highway segments the following steps are recommended:

Step 1: Select the area, section(s), or segment(s) of interest, based on the scope of the project. The selected highway(s) should encompass all portions of the network potentially affected by the proposed alternative scenarios.

Step 2: Select the hour(s) of analysis. These may include a specific peak hour period, the entire day, or a portion of it. This selection should be made considering the hours potential alternative designs or strategies would be implemented.

Step 3: Select the desired analysis interval. This would typically range from a 15-min period to a one-hour period, depending on the needs of the project.

Step 4: Identify the number of lanes and other geometric elements of the selected highway(s), as well as any ITS programs currently in place (congestion pricing, ramp metering, etc.)

Step 5: For the selected highway(s) obtain incident, weather, and work zone data. These should be obtained from the SIS-related travel time reliability application for each highway section. For example, if the site studied involves two separate sections, incident data should be obtained for each of those sections. Similarly, the weather and work zone information should correspond to the subject sections. In cases when site-specific data are available, these should be used rather than SIS information. The data obtained should include items such as incident frequency, incident duration, rainfall intensity, probability of rain, probability of workzone, etc.

Step 6: Obtain or estimate the demands for each analysis interval of interest (for example, 15-min demands) and for each alternative scenario to be analyzed, including the base-case scenario.

Step 7: Identify any geometric or other changes, or ITS strategies to be evaluated under each alternative scenario.

Step 8: For each analysis scenario (including the base case), compute the desired reliability performance measures (such as on-time performance, travel time index) for the study area and for the selected hour(s) of analysis.

In summary, the methodology is very similar to the method used to estimate travel time reliability for the SIS. Important items to be considered in this application involve a) the selection of the study area, b) the selection of the analysis interval, and c) the use of local incident, weather, and work zone data.

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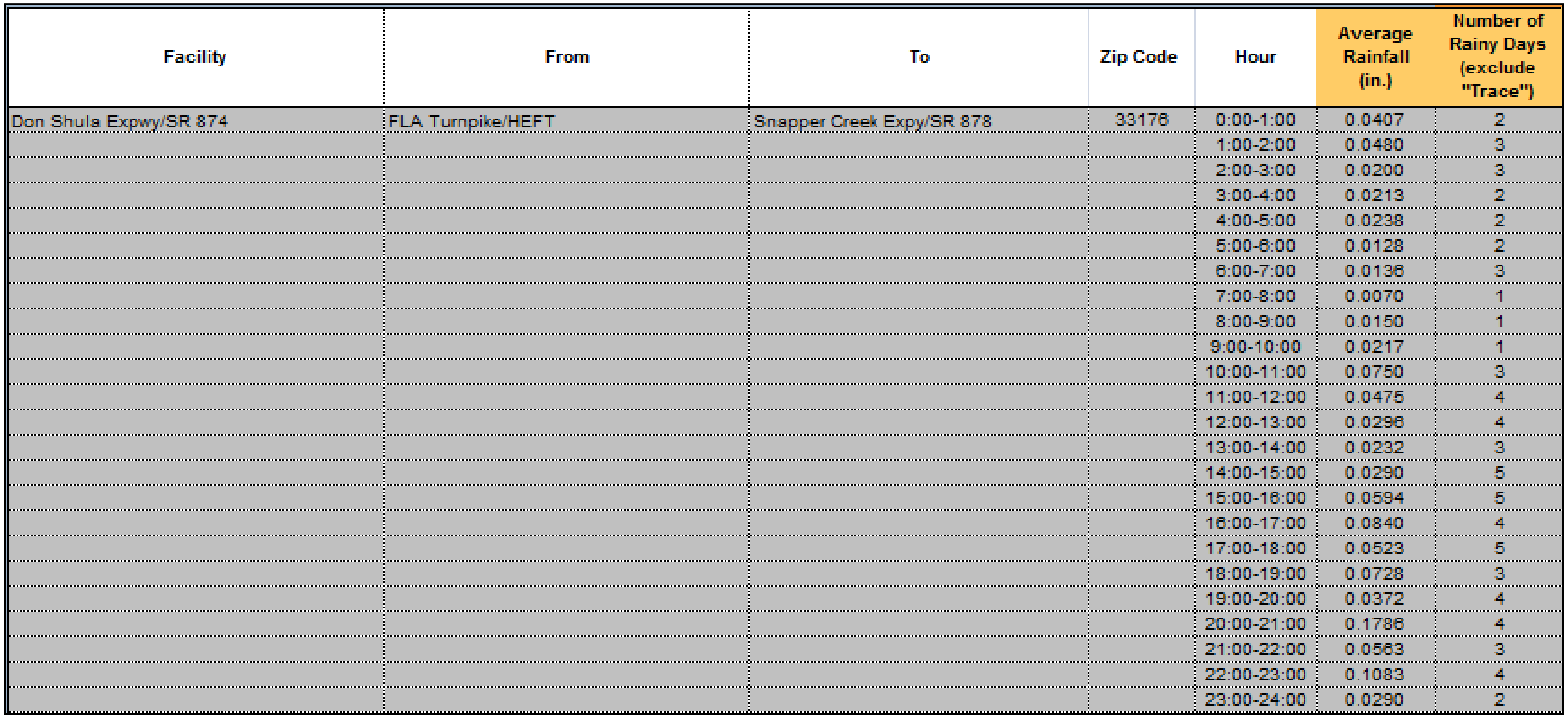
APPENDIX A
Weather Data

Section 3.1 presents the assumptions and methodology used for incorporating rain effects into travel time reliability estimation models. In the proposed calculation procedure, for each freeway segments, the annual average rainfall intensity and the probability of rain for each one of the 24 hours are used as inputs.

To obtain the required inputs, first, rainfall precipitation for each freeway segment was obtained (http://www.wunderground.com) for a one-year period, from January, 2007 to December, 2007. The website provides weather information by zip code. Therefore, the zip code for each freeway section was first identified and rainfall data associated with each section were then obtained. In order to reduce the amount of work required to obtain data for a full year, only a 72-days-sample (1st, 6th, 11th, 16th, 21st and 26th day of each month) was collected.

Figure A-1 presents a sample of the data. The facility is the segment along Don Shula Expwy between the FL Turnpike and Snapper Creek Expy. Weather data for zip code area 33176 were used for this segment. For each hour, average rainfall was calculated by using the total amount of rain through the 72 days for the particular hour divided by the number of rainy days out of those 72 days. Therefore, it is actually the average rainfall of rainy days. The probability of rain was obtained by using the number of rainy days divided by 72. The last two columns of this table with orange headers are the two inputs in the worksheet developed to calculate the rain-related probabilities.



Facility	From	To	Zip Code	Hour	Average Rainfall (in.)	Number of Rainy Days (exclude "Trace")
Don Shula Expwy/SR 874	FLA Turnpike/HEFT	Snapper Creek Expy/SR 878	33176	0:00-1:00	0.0407	2
				1:00-2:00	0.0480	3
				2:00-3:00	0.0200	3
				3:00-4:00	0.0213	2
				4:00-5:00	0.0238	2
				5:00-6:00	0.0128	2
				6:00-7:00	0.0136	3
				7:00-8:00	0.0070	1
				8:00-9:00	0.0150	1
				9:00-10:00	0.0217	1
				10:00-11:00	0.0750	3
				11:00-12:00	0.0475	4
				12:00-13:00	0.0296	4
				13:00-14:00	0.0232	3
				14:00-15:00	0.0290	5
				15:00-16:00	0.0594	5
				16:00-17:00	0.0840	4
				17:00-18:00	0.0523	5
				18:00-19:00	0.0728	3
				19:00-20:00	0.0372	4
				20:00-21:00	0.1786	4
				21:00-22:00	0.0563	3
				22:00-23:00	0.1083	4
				23:00-24:00	0.0290	2

Figure A-1 Weather Data

APPENDIX B
Example Worksheet Guide

Tab 1 – Facility Description

This tab is for information purposes only and it defines the various types of facilities and their corresponding abbreviations that will be used in the rest of the worksheet.

Tab 2 – LOS Criteria

This tab presents the level of service (LOS) volume thresholds (columns C to G) according to facility type (column A), number of lanes (column B) and time period – peak, off-peak and midday (column I).

Tab 3 – Speed Table

This tab presents the speeds corresponding to each level of service (column D) according to facility type (column A) and whether the facility has two lanes or not (column B), as well as the free-flow speed (column E), LOS threshold speed (column F) and delay threshold speed (column G) for each facility type.

Tab 4 – HrlyK with Peak Hours Speed Table

This tab presents the average hourly K factors (column C) according to facility type (column A), hour of the day (column B) and time period (column D).

Tab 5 – Incidents

This tab deals with all incident-related calculations. The orange-highlighted cells indicate user input fields, while the blue-highlighted column headings indicate output that will be used as input in other tabs.

Input

From the 1st page of the December 2007 Sunguide FDOT District 4 Report (http://www.smartsunguide.com/Reports/monthly_Broward-120107-123107_010408-102654.pdf) we obtain the total number of blocking incidents and non-blocking incidents (cells I4 and I5) and the average incident duration for blocking and non-blocking incidents (cells I7 and I8). The average incident durations in this report are with the Road Rangers active 24/7.

From Steven Corbin’s presentation at the 88th Transportation Research Board ("Road Ranger Reduction and its Impact on Incident Management", January 2009) we obtain the average incident duration with the Road Rangers being active and without the Road Rangers (cells I12 and I13).

The user can determine which hours of the day the Road Rangers are active (column E, where 0=inactive and 1=active) as well as how many days a week the Road Rangers are active (column G).

From the FDOT Crash Analysis Reporting System (CAR), using data from January 1^{st} to December 31^{st} 2007, the probability of blocking incident per lane mile per year for this particular segment (segment 702 in the Statewide Segmentation for Reliability) is determined (FDOT Contract BDK77-977-02 “Travel Time Reliability Modeling For Florida” Final Report,January 2010, Appendix A, Segments 693-711) for four different scenarios: *No Rain, No Work zone* (column Q), *Rain, No Work zone* (column Y), *No Rain, Work zone* (column AG), and *Rain and Work zone* (column AO). It is reasonable to have a lot of zero values as some of the scenarios (like incident during rain and work zone) may not have occurred in every hour in that particular segment during that year.

Finally, the Probability of blocking Incident Duration more than 1 hour, depending on Avg. Blocking Incident Duration (% of an hour) can be also modified by the user (cells P4:P11 and S4:S12). The default values used can be found in Table 1-1.

Calculations

Row 6:

Ratio of non-blocking to blocking incidents = (total number of non-blocking incidents/ total number of blocking incidents)

Row 13:

Average increase in incident clearance time = (Average incident clearance time without Road Rangers – Average incident clearance time with Road Rangers)

Row 14:

Percent Incident Duration Increase without RR = (Average increase in incident clearance time/Average incident clearance time with Road Rangers)

Column F:

Percent Duration Increase = 0, if the segment is monitored by RR during that hour, or

Percent Duration Increase= Percent Incident Duration Increase without RR (cell I15) , if the segment is not monitored by RR during that hour.

Column I:

Avg. Blocking Incident Duration Modified for hourly RR coverage = Avg. Blocking Incident Duration*(1+ Percent Duration Increase)

Column J:

Avg. Blocking Incident Duration Modified for daily RR coverage = Avg. Blocking Incident Duration Modified for hourly RR coverage, if the segment is not monitored by RR during that hour.

Avg. Blocking Incident Duration Modified for daily RR coverage = {Avg. Blocking Incident Duration*Number of days per week RR are active] + [Avg. Blocking Incident Duration*(1+ Percent Duration Increase)(7–Number of days per week RR are active)]}/7, if the segment is monitored by RR during that hour.

Column K:

Avg. Blocking Incident Duration (% of an hour) = (Avg. Blocking Incident Duration Modified for daily RR coverage/60)

Column L:

Avg. Non-blocking Incident Duration Modified for hourly RR coverage = Avg. Non-blocking Incident Duration*(1+ Percent Duration Increase)

Column M:

Avg. Non-blocking Incident Duration Modified for daily RR coverage = Avg. Non-blocking Incident Duration Modified for hourly RR coverage, if the segment is not monitored by RR during that hour.

Avg. Non-blocking Incident Duration Modified for daily RR coverage = {Avg. Non-blocking Incident Duration*Number of days per week RR are active] + [Avg. Non-blocking Incident Duration*(1+ Percent Duration Increase)(7–Number of days per week RR are active)]}/7, if the segment is monitored by RR during that hour.

Column N:

Avg. Non-blocking Incident Duration (% of an hour) = (Avg. Non-blocking Incident Duration Modified for daily RR coverage/60)

Columns R, Z, AH, AP:

Probability of blocking Incident Duration more than 1 hour: depending on Avg. Blocking Incident Duration (% of an hour) (see Table B-1)

Avg. Incident Duration (% of an hour)	**Probability of Incident Duration greater than 1 hour**
(200.00%, ∞)	100.00%
(150.00%, 200.00%]	90.00%
(125.00%, 150.00%]	75.00%
(105.00%, 125.00%]	60.00%
(95.00%, 105.00%]	50.00%
(75.00%, 95.00%]	40.00%
(50.00%, 75.00%]	25.00%
(25.00%, 50.00%]	10.00%
[0.00%,25.00%]	0.00%

Table B-1 Probability of Incident Duration greater than 1 hour, based on Average Incident Duration

Columns S, AA, AI, AQ:

Probability of Active blocking Incident per Lane Mile Per Year (during hour **n**) = {Probability of blocking Incident per Lane Mile Per Year (during hour **n**) + [Probability of blocking Incident Duration more than 1 hour (during hour **n-1**)*Probability of blocking Incident per Lane Mile Per Year (during hour **n-1**)]}.

Columns T, AB, AJ, AR:

Probability of Non-blocking Incident per Lane Mile Per Year = Probability of blocking Incident per Lane Mile Per Year* Ratio of non-blocking to blocking incidents (cell I6).

Columns U, AC, AK, AS:

Probability of Non-blocking Incident Duration more than 1 hour: depending on Avg. Non-blocking Incident Duration (% of an hour) (see Table 1-1).

Columns V, AD, AL, AT:

Probability of Active Non-blocking Incident per Lane Mile Per Year (during hour **n**) = {Probability of Non-blocking Incident per Lane Mile Per Year (during hour **n**) + [Probability of Non-blocking Incident Duration more than 1 hour (during hour **n-1**)*Probability of Non-blocking Incident per Lane Mile Per Year (during hour **n-1**)]}.

Output

The average incident durations (% of an hour) for blocking and non-blocking incidents (columns K, N) and the probabilities of active blocking and non-blocking incidents per lane mile per year for the four different scenarios (columns, S,V,AA,AD,AI,AL,AQ,AT) are used as input in the SR9 tab.

Tab 6 – Rain

This tab deals with all weather-related calculations. The orange-highlighted cells indicate user input fields, while the blue-highlighted column and row headings indicate output that will be used as input in other tabs.

Input

From the literature review, we assume the speed reduction for “None or Trace”, “Light Rain” and “Heavy Rain” is 0, 6% (row 3) and 12% (row 4) respectively.

We divided the entire Florida into northern and southern part. North Florida includes Districts 2, 3, 5 and 7, South Florida includes Districts 1.4.6. If the subject freeway segment is located in North Florida, the value of Segment Location (row 6) is 0; if it is located in South Florida, Segment Location is 1. The shape parameter k of the Gamma Distribution was estimated to be 0.1447 for North Florida (cell J7) and 0.1388 for South Florida (cell J8).

From the weather underground website (http://www.wundergroud.com), rainfall data for a 72-days-sample, which includes the 1st, 6th, 11th, 16st, 21th and 26th day of each month, was collected. The number of rainy days is determined based on these data (column C). Average precipitation of the rainy days is also calculated as the input of “Average Rainfall” (column B).

Calculations

Column D:

Shape Parameter k of the Gamma Distribution = 0.1447 if Segment Location = 0; or Shape parameter k of Gamma Distribution = 0.1388, if Segment Location = 1.

Column E:

Scale Parameter θ of the Gamma Distribution = Average Rainfall/Shape Parameter k, if Average Rainfall is not 0; or Scale Parameter θ of the Gamma Distribution = 0.001/Shape Parameter k, if Average Rainfall equals to 0.

Column F:

Probability of Trace= GAMMADIST (0.01, k, θ, TRUE) (Returns the cumulative gamma distribution at 0.01 given values of k and θ). 0.01 is the upper bound of the rainfall intensity range for "Trace". (Trace: 0-0.01 inches/hour; Light Rain: 0.01-0.5 inches/hour; Heavy Rain: >0.5 inches/hour).

Column G:

Probability of Light Rain= GAMMADIST (0.5, k, θ, TRUE) - GAMMADIST (0.01, k, θ, TRUE). 0.01 and 0.5 are the lower and upper bounds of the rainfall intensity range for "Light Rain" respectively.

Column H:

Probability of Heavy Rain= 1- Probability of Light Rain - Probability of Trace

Column I:

Probability of Rain = Number of Rainy Days/72, (72 is the sample size of the rainfall data.) if Number of Rainy Days is not 0; or Probability of Rain = 0.001, if Number of Rainy Days equals to 0.

Column J:

Ratio of Light Rain to Light + Heavy Rain = Probability of Light Rain/(Probability of Light Rain + Probability of Heavy Rain).

Column K:

Ratio of Heavy Rain to Light + Heavy Rain = 1 - Ratio of Light Rain to Light + Heavy Rain.

Output

The Probability of Rain (column I), Ratio of Light Rain to Light plus Heavy Rain (column J) and Ratio of Heavy Rain to Light plus Heavy Rain (column K) are going to be used as input in the SR9 tab.

Tab 7 – Capacity-Demand

This tab deals with all calculations related to capacity and demand. The orange-highlighted cells indicate user input fields, while the blue-highlighted column headings indicate output that will be used as input in other tabs.

Input

From the Number of Events/Severity (YTD) figure on the 4th page of the December 2007 Sunguide FDOT District 4 Report (http://www.smartsunguide.com/Reports/monthly_Broward-120107-123107_010408-102654.pdf), we obtain the ratio of incidents according to severity level (cells B6,C6,D6). The average number of closed lanes for a work zone were not available, thus a number (1 lane) was used for illustrative purposes (cell J8).

From the Highway Capacity Manual 2000, Chapter 22 - Freeway Facilities Methodology, page 22-10, exhibit 22-6, the Capacity Reduction for Incidents was obtained (cells B38:E44), while from page 22-7 the freeway capacity during a work zone (in vphpl) was determined (cell D47).

Finally, the FDOT seasonal factors (for the 52 weeks of a year) are inputted in cells AX33:CW33.

Calculations

Column B, rows 13-36:

The number of lanes per direction is obtained from the SR9 Tab (column J).

Column C, rows 13-36:

Assuming Level 1 incident severity is 1 lane closed, Level 2 is 50% of lanes closed and Level 3 is all lanes closed:

Avg. Number of Closed Lanes (Incident) = 1*$\text{Ratio}_{\text{Level1}}$+(0.5*Number of Lanes per direction)*$\text{Ratio}_{\text{Level2}}$+Number of Lanes per direction*$\text{Ratio}_{\text{Level3.}}$

Column D, rows 13-36:

Avg. Number of Closed Lanes (Work Zone) = Closed lanes_wkzone (cell J8).

Column B, rows 57-80:

LOSE (Capacity without work zone) is obtained from the SR9 Tab (column T).

Column C, rows 57-80:

Capacity/Lane (without work zone) = LOSE (Capacity without work zone)/ Integer(Number of Lanes per direction).

Column D, rows 57-80:

Capacity with work zone = Integer(Number of Lanes per direction- Avg. Number of Closed Lanes (Work Zone))*Capacity/lane of work zones(cell D53), if Capacity/Lane (without work zone) > Capacity/lane of work zones, or

Capacity with work zone = Integer(Number of Lanes per direction- Avg. Number of Closed Lanes (Work Zone))*Capacity/Lane (without work zone).

Column F:

Capacity Reduction for blocking incident (%) is selected from the Incident Capacity Reduction Table (cells B44:E50) using the Integer(Number of Lanes per direction) for the rows (Freeway Lanes/ direction) and the Integer(Avg. Number of Closed Lanes (Incident)) for the columns (Lanes Blocked).

Column G:

Capacity Reduction for non-blocking incident (%) is selected from the Incident Capacity Reduction Table (cells B44:E50) using the Integer(Number of Lanes per direction) for the rows (Freeway Lanes/ direction) and the 0 Lanes Blocked column.

Column H:

Capacity Reduction for work zone (%) = [LOSE (Capacity without work zone) - Capacity with work zone]/ LOSE (Capacity without work zone).

Column I:

Capacity Reduction for blocking incident and work zone (%) is selected from the Incident Capacity Reduction Table (cells B44:E50) using the Integer(Number of Lanes per direction) for the rows (Freeway Lanes/ direction) and the Integer(Avg. Number of Closed Lanes (Incident))+Integer(Avg. Number of Closed Lanes (Work Zone)) for the columns (Lanes Blocked).

Column J:

Capacity Reduction for non-blocking incident and work zone (%) is selected from the Incident Capacity Reduction Table (cells B44:E50) using the Integer(Number of Lanes per direction) for the rows (Freeway Lanes/ direction) and the Integer(Avg. Number of Closed Lanes (Work Zone)) for the columns (Lanes Blocked).

Column L:

Capacity under no incident/no work zone (vphpl) = LOSE (Capacity without work zone)

Column M:

Capacity under blocking incident (vphpl) = Capacity under no incident/no work zone (vphpl)*(1- Capacity Reduction for blocking incident (%))

Column N:

Capacity under non-blocking incident (vphpl) = Capacity under no incident/no work zone (vphpl)*(1- Capacity Reduction for non-blocking incident (%))

Column O:

Capacity under work zone (vphpl) = Capacity under no incident/no work zone (vphpl)*(1- Capacity Reduction for work zone (%))

Column P:

Capacity under blocking incident and work zone (vphpl) = Capacity under no incident/no work zone (vphpl)*(1- Capacity Reduction for blocking incident and work zone (%))

Column Q:

Capacity under non-blocking incident and work zone (vphpl) = Capacity under no incident/no work zone (vphpl)*(1- Capacity Reduction for non-blocking incident and work zone(%)).

Columns T and AV:

Peak Direction Volume (vphpl) = PD HourVol (SR9 Tab, column N)/Integer(Number of Lanes per direction).

Columns U and AW:

Off-Peak Direction Volume (vphpl) = OD HourVol (SR9 Tab, column O)/Integer (Number of Lanes per direction).

Columns AS to EW apply the FDOT seasonal factors (for the 52 weeks of the year) on both the peak and the off-peak direction volumes in order to obtain the average demand as well as the probability of demand over capacity for the different scenarios. In particular:

Cells AX13:CW36:

Peak Direction Volume for each week_i (vphpl) = Peak Direction Volume (vphpl)* FDOT Seasonal Factors_i, where i = the week #.

Cells CX13:EW36:

Off-peak Direction Volume for each week_i (vphpl) = Off-peak Direction Volume (vphpl)* FDOT Seasonal Factors_i, where i = the week #.

Cells AX44:EW67:

$\text{Demand-Capacity}_{\text{no incident/no work zone}} = 0$, if Direction Volume for each week < Capacity under no incident/no work zone (column L).

$\text{Demand-Capacity}_{\text{no incident/no work zone}} = 1$, if Direction Volume for each week > Capacity under no incident/no work zone (column L).

Cells AX72:EW95:

$\text{Demand-Capacity}_{\text{blocking incident}} = 0$, if Direction Volume for each week < Capacity under blocking incident (column M).

$\text{Demand-Capacity}_{\text{blocking incident}} = 1$, if Direction Volume for each week > Capacity under blocking incident (column M).

Cells AX100:EW123:

$\text{Demand-Capacity}_{\text{non-blocking incident}} = 0$, if Direction Volume for each week < Capacity under non-blocking incident (column N).

$\text{Demand-Capacity}_{\text{non-blocking incident}} = 1$, if Direction Volume for each week > Capacity under non-blocking incident (column N).

Cells AX128:EW151:

$\text{Demand-Capacity}_{\text{work zone}} = 0$, if Direction Volume for each week < Capacity under work zone (column O).

$\text{Demand-Capacity}_{\text{work zone}} = 1$, if Direction Volume for each week > Capacity under work zone (column O).

Cells AX156:EW179:

$\text{Demand-Capacity}_{\text{blocking incident and work zone}} = 0$, if Direction Volume for each week < Capacity under blocking incident and work zone (column P).

$\text{Demand-Capacity}_{\text{blocking incident and work zone}} = 1$, if Direction Volume for each week > Capacity under blocking incident and work zone (column P).

Cells AX184:EW207:

Demand-Capacity $_{\text{non-blocking incident and work zone}}$ = 0, if Direction Volume for each week < Capacity under non-blocking incident and work zone (column Q).

Demand-Capacity $_{\text{non-blocking incident and work zone}}$ = 1, if Direction Volume for each week > Capacity under non-blocking incident and work zone (column Q).

Column AT:

weeks Demand > Capacity = SUM of the Demand-Capacity cells.

Column AU:

% of weeks Demand > Capacity = (# weeks Demand > Capacity)/(2*52).

Column AV:

Demand Uncongested = Average of Direction Volumes of the weeks where Demand-Capacity = 0, if (# weeks Demand > Capacity) ≠ 104.

Demand Uncongested = Capacity/Lane (columns L to Q, depending on the scenario), if (# weeks Demand > Capacity) = 104.

Column AW:

Demand Congested = Average of Direction Volumes of the weeks where Demand-Capacity = 1, if (# weeks Demand > Capacity) ≠ 0.

Demand Congested = Capacity/Lane (columns L to Q, depending on the scenario), if (# weeks Demand > Capacity) = 0.

Columns V,W,X,Y,Z,AA:

Probability of demand over capacity = % of weeks Demand > Capacity (column AU), depending on the scenario.

Columns AD,AE,AF,AG,AH,AI:

Demand under uncongested conditions = Demand uncongested (column AV), depending on the scenario.

Columns AL,AM,AN,AO,AP,AQ

Demand under congested conditions = Demand congested (column AW), depending on the scenario.

Output

The capacity reduction (columns F,G,H,I,J), the Probability of Demand over Capacity (columns V,W,X,Y,Z,AA), the Demand under uncongested conditions (columns

AD,AE,AF,AG,AH,AI) and the Demand under congested conditions (columns AL,AM,AN,AO,AP,AQ) are going to be used as input in the SR9 tab.

Tab 8 – SR9

In this tab the main calculations of travel time and probability for each of the 24 scenarios take place. The orange-highlighted cells indicate user input. The grey column headers indicate information related only to the characteristics of the example segment, regardless of conditions. The blue column headers are information pulled from the other calculation tabs, while the green column headers are reserved for the travel times and probabilities of each scenario and the purple column headers and highlighted cells are the results (yearly averages). They yellow column overhead (row 7) indicates that these columns are used directly in the calculations of scenario travel time and probability. Finally, columns with grey font indicate intermediate calculation steps that were given a separate column to simplify the equations within individual cells.

Input

From the FDOT Statewide Segmentation for Reliability document, the characteristics of the example segment are inputted (row 4).

Also, the probability of work zone (column BH) was not available and two numbers (the lowest being during peak hours, to reflect the policy of shifting the work zones to non-peak hours when possible) were selected for illustrative purposes.

Calculations

Columns B,C,D,E,F,G,I,K,L,M:

They obtain their respective values from row 4.

Column H:

Length = END_POST - BEGIN_POST.

Column J:

LANES Adj = LANES/2.

Column N:

PD HourVol = AADT * 0.55 * Avg of HrlyK (from the HrlyK with Peak Hours tab, according to Facility type and hour of the day).

Column O:

OD HourVol = AADT * 0.45 * Avg of HrlyK (from the HrlyK with Peak Hours tab, according to Facility type and hour of the day).

Cells N37, O37:

Sums of their respective columns.

Columns P,Q,R,S,T:

LOSA, LOSB, LOSC, LOSD, LOSE are calculated from the lookup table "LOS Criteria" based on the LOSTABLE field.

Columns U,V:

PD LOS, OD LOS are calculated by comparing the PD HourVol and OD HourVol to the LOSA, LOSB, LOSC, LOSD, LOSE fields and retrieving the appropriate LOS value.

Columns W,X,Y:

Delay Thresh Spd, Peak D Speed, OffPeak D Speed are calculated from the lookup table “Speed Table” based on the LOSTABLE, PD LOS and OD LOS fields respectively.

Column Z:

Peak D Threshold Delay = (Length/Delay Thresh Spd - Length/Peak D Speed)*PD HourVol, if Peak D Speed < Delay Thresh Spd.

Peak D Threshold Delay = 0, if Peak D Speed > Delay Thresh Spd.

Column AA:

OffPeak D Threshold Delay = (Length/Delay Thresh Spd - Length/OffPeak D Speed)*OD HourVol, if OffPeak D Speed < Delay Thresh Spd.

OffPeak D Threshold Delay = 0, if OffPeak D Speed > Delay Thresh Spd.

Column AB:

Two-way Threshold Delay = Peak D Threshold Delay + OffPeak D Threshold Delay.

Column AC:

Two-way Threshold Delay per Mile = Two-way Threshold Delay/Length.

Cells AB35, AC35:

Sums of their respective columns.

Column AD:

Capacity = LOSE/Integer(LANES Adj).

Column AE:

FFS is calculated from the lookup table "Speed Table" (column FFSPD) based on the LOSTABLE field.

Column AF:

FFS adjusted for Light Rain = FFS*(1- Free-flow speed reduction for Light Rain).

Column AG:

FFS adjusted for Heavy Rain = FFS*(1- Free-flow speed reduction for Heavy Rain).

Columns AN,AO:

Light and Heavy rain ratios are obtained from their corresponding columns on the Rain tab.

Column AH:

Free-flow Travel Time for No Rain = (3600/FFS)*Length.

Column AI:

Equivalent Free-flow Travel Time for Rain = ((Ratio of Light Rain to Total Rain*(3600/FFS adjusted for Light Rain)) + (Ratio of Heavy Rain to Total Rain*(3600/FFS adjusted for Heavy Rain)))*Length.

Column AJ,AL:

Average incident durations are obtained from their corresponding columns on the Incidents tab.

Columns AK,AM:

Average incident duration (used for calculations) = 1, if Average incident duration>1

Average incident duration (used for calculations) = Average incident duration, if Average incident duration≤1.

Columns AP,AQ,AR,AS,AT:

Capacity reductions are obtained from their corresponding columns on the Capacity-Demand tab.

Columns AU to BF:

Demand for uncongested and congested conditions are obtained from their corresponding columns on the Capacity-Demand tab.

Columns BP to BW:

Probabilities of active incidents are obtained from their corresponding columns on the Incidents tab.

Column BG:

Probability of Rain is obtained from the Rain tab.

Column BI:

Probability of Incident = The sum of the Probabilities of active incidents (columns BP to BW).

Column BJ:

Probability of non-incident with Rain = (1-Probability of Incident)*Probability of Rain.

Column BK:

Probability of non-incident with no Rain = 1-Probability of Incident)*(1-Probability of Rain).

Column BL:

Probability of non-incident with Rain and Work Zone = Probability of non-incident with Rain* Probability of Work Zone.

Column BM:

Probability of non-incident with Rain and no Work Zone = Probability of non-incident with Rain* (1-Probability of Work Zone).

Column BN:

Probability of non-incident with no Rain and with Work Zone = Probability of non-incident with no Rain* Probability of Work Zone.

Column BO:

Probability of non-incident with no Rain and no Work Zone = Probability of non-incident with no Rain* (1-Probability of Work Zone).

Columns BX to CC:

Probabilities of Congestion (Demand over Capacity) are obtained from their corresponding columns on the Capacity-Demand tab.

Columns CD to EO:

For each of the 24 scenarios, a Probability of Occurrence (columns CE,CG,etc.) and a Travel Time (columns CD,CF,etc.) are calculated. For the scenarios with blocking or non-blocking incident, travel times are further adjusted to take into account the average incident duration (columns CI,CL,etc.).

The Probability of Occurrence for each scenario are shown in Table 1-2.

The Travel Time equations are the following:

Travel Time for Uncongested Conditions (sec/mile) = $(3600/FFS) + 0.00258*d$.

Travel Time for Congested Conditions (sec/mile) = $(3600/FFS) + 0.1238*d - 0.1243*c - 3.46*L + 0.67*T - 15.24*N_{cr} + 0.3964*d*cr - 21.524*L*cr$

where:

FFS = free-flow speed (mph)

d = demand (vphpl)

c = capacity (vphpl)

L = length (miles)

T = time period (min) = always 60 minutes here

N_{cr} = number of lanes, if there is a scenario with capacity reduction (blocking or non-blocking incident and/or work zone), or 0, if there is not a scenario with capacity reduction.

cr = capacity reduction (%)

Travel time per mile needs to be multiplied by length to get the actual segment travel time.

Demand and Capacity Reduction need to be selected for each scenario according to the conditions, and the number of lanes must be omitted for scenarios where there is no capacity reduction.

For scenarios with Rain, the TT is calculated as the weighted (by their respective ratios) average of the travel time under light rain (FFS is replaced by FFS adjusted for Light Rain) and the travel time under heavy rain (FFS is replaced by FFS adjusted for Heavy Rain).

The travel time equations were developed with the use of linear regression from data obtained from simulation. For this reason, it is possible that when the input data takes very low or very high values (such as very low demands, or very high capacity reduction values) that are beyond the range of the data used for the regression, the equation for congested travel time may give “unreasonable” results (less than the minimum, free-flow, travel time). To avoid this rare occasion, for the congested scenarios only, the result of the equation is compared with the equivalent (for rain or no rain) minimum travel time and the maximum of the two values is selected.

The Travel Time equations for each scenario are shown in Table 1-3. In the table the following abbreviations are used:

R_lr = Ratio of light rain to total rain.
R_hr = Ratio of heavy rain to total rain.
FFS = Free-flow speed
FFS_lr = Free-flow speed adjusted for light rain
FFS_hr = Free-flow speed adjusted for heavy rain
d_u_ni,nw = Uncongested Conditions Demand under no incident/no work zone
d_u_bi,nw = Uncongested Conditions Demand under blocking incident
d_u_nbi,nw = Uncongested Conditions Demand under non-blocking incident
d_u_ni,w = Uncongested Conditions Demand under work zone
d_u_bi,w = Uncongested Conditions Demand under blocking incident and work zone
d_u_nbi,w = Uncongested Conditions Demand under non-blocking incident and work zone
d_c_ni,nw = Congested Conditions Demand under no incident/no work zone
d_c_bi,nw = Congested Conditions Demand under blocking incident
d_c_nbi,nw = Congested Conditions Demand under non-blocking incident
d_c_ni,w = Congested Conditions Demand under work zone
d_c_bi,w = Congested Conditions Demand under blocking incident and work zone
d_c_nbi,w = Congested Conditions Demand under non-blocking incident and work zone
c = Capacity
L = Length
N = number of lanes
cr_bi = Capacity Reduction for blocking incident
cr_nbi = Capacity Reduction for non-blocking incident
cr_w = Capacity Reduction for work zone
cr_bi,w = Capacity Reduction for blocking incident and work zone
cr_nbi,w = Capacity Reduction for non-blocking incident and work zone
TT_min = minimum (free-flow) travel time for no rain
TT_min_r = minimum (free-flow) travel time for rain

Finally, Travel Time adjusted for incident duration = Avg. Incident Duration used for calculation*Scenario Travel Time + (1-Avg. Incident Duration used for calculation)*Equivalent non-incident Scenario Travel Time.

Column EP:

Total Probability Check = the sum of all scenario probabilities (must be 100%).

Column EQ:

Annual Expected TT = the sum of all scenario probability*scenario travel time (adjusted for incident duration when applicable).

Column ES:

Annual Average Speed = Length/(Annual Expected TT/3600).

Column EU:

Calculations for TT Weighted By Demand = Annual Expected TT*(PD HourVol + OD HourVol).

Cell EQ37:

Avg. Annual TT = Average of the hourly Annual Expected.

Cell EQ38:

Avg. Weighted by Hourly Demand = (the sum of Calculations for TT Weighted By Demand)/(Total of PD HourVol + Total of OD HourVol).

Cells ES36,ES37:

Avg. Annual Speed = Length/(Avg. Annual TT/3600).

Tabs 9 and 10 – Reliability All Day and Reliability 4-7

In these tabs we use the results of the SR9 tab to estimate reliability performance measures (such as on-time arrival and buffer time index). The procedure followed is essentially the same in the two tabs, thus only tab 9 (Reliability All Day) will be presented in this section.

Input

There is no manual input in this tab, as everything will be obtained from some other tab. In cells AA4,AA5 and AA6 the total days in a year, the total hours in a year and 95% of the total hours in a year are found.

Calculations

Column A:

Travel Time is obtained from all the Travel Time columns (adjusted for incident duration when applicable) of the SR9 Tab.

Column B:

Average Speed = Length/(Travel Time/3600)

Column C:

Frequency (%) is obtained from all the Probability of Occurrence columns of the SR9 Tab.

Column D:

Frequency (hours) = Frequency (%) * Total days in a year.

Column E:

Flow - Both Directions = PD HourVol + OD Hour Vol (from the SR9 Tab).

Column F:

TT*Freq = Travel Time * Frequency (hours).

Column G:

TT*Veh = Travel Time * Flow - Both Directions.

Cells D581,E581,F581,G581:

The sums of Frequency (hours), Flow - Both Directions, TT*Freq and TT*Veh.

Cell F583:

AVERAGE TT (Weighted by Number of Hours) = sum of TT*Freq/sum of Frequency (hours).

Cell F585:

AVERAGE TT (Weighted by Number of Vehicles) = sum of TT*Veh/sum of Flow - Both Directions.

Cell F587:

AVERAGE SPEED (Based on Hours) = Length/ (AVERAGE TT (Weighted by Number of Hours)/3600)

Cell F589:

AVERAGE SPEED (Based on Vehicles) = Length/ (AVERAGE TT (Weighted by Number of Vehicles)/3600)

Columns I,J,K:

These are columns A,B,D sorted by Travel Time.

Column L:

Cumulative hours = the cumulative of the sorted Frequency (hours).

Cell AD11:

Travel time corresponding to free-flow speed – 10 mph = Length*3600/(FFS-10)

Column M:

First, we seek the first travel time value on column I great than the free-flow speed – 10 mph and we highlight that line in yellow.

Cell AB12:

Percent of time travel time is above (FFS-10) mph = Highlighted cell (see above) in the Cumulative Hours column / Total hours in a year.

Column M (again):

Then, we seek the first cumulative hours value on column L that is greater than the 95% of hours and we highlight that line in yellow.

Cell AD18:

Travel Time corresponding to 95% of time = The value of the highlighted cell (see above) on the sorted Travel Time column.

Cell AB18:

The 95% of hours in a year.

Cell AF18: Length/(Travel Time corresponding to 95% of time/3600).

Cell AB 19:

Buffer Index = (Travel Time corresponding to 95% of time - AVERAGE TT (Weighted by Number of Hours))/ AVERAGE TT (Weighted by Number of Hours).

Column P:

Frequency (Hours) by brackets in order to be used in a Chart. Refers to column K.

Columns Q,R:

These are columns A,E sorted by Travel Time.

Column S:

Cumulative Flow = the cumulative of the sorted Flow Both Directions.

Again, we seek the first travel time value on column Q great than the free-flow speed – 10 mph and we highlight that line in yellow.

Cell AB13:

Percent of trips travel time is above (FFS-10) mph = Highlighted cell (see above) in the Cumulative Flows column / Total Flow - Both Directions.

Column V:

Total Vehicles by brackets in order to be used in a Chart. Refers to column R.

	Congestion	Weather	Incident	Work Zone	Probability
Scenario 1	Non-congested	No Rain	No incident	No Work Zone	Probability of non-incident with no Rain and no Work Zone*(1-Probability of Demand over Capacity under no incident/no work zone)
Scenario 2	Non-congested	Rain	No incident	No Work Zone	Probability of non-incident with Rain and no Work Zone*(1-Probability of Demand over Capacity under no incident/no work zone)
Scenario 3	Non-congested	No Rain	Blocking Incident	No Work Zone	Probability of Active blocking Incident (no rain, no work zone)*(1- Probability of Demand over Capacity under blocking incident)
Scenario 3A	Non-congested	No Rain	Non-Blocking Incident	No Work Zone	Probability of Active non-blocking Incident (no rain, no work zone)*(1- Probability of Demand over Capacity under non-blocking incident)
Scenario 4	Non-congested	No Rain	No incident	Work Zone	Probability of non-incident with no Rain and with Work Zone*(1- Probability of Demand over Capacity under work zone)
Scenario 5	Non-congested	Rain	Blocking Incident	No Work Zone	Probability of Active blocking Incident (rain, no work zone)*(1- Probability of Demand over Capacity under blocking incident)
Scenario 5A	Non-congested	Rain	Non-Blocking Incident	No Work Zone	Probability of Active non-blocking Incident (rain, no work zone)*(1- Probability of Demand over Capacity under non-blocking incident)
Scenario 6	Non-congested	Rain	No incident	Work Zone	Probability of non-incident with Rain and Work Zone*(1- Probability of Demand over Capacity under work zone)
Scenario 7	Non-congested	No Rain	Blocking Incident	Work Zone	Probability of Active blocking Incident (no rain, work zone)*(1-Probability of Demand over Capacity under blocking incident and work zone)
Scenario 7A	Non-congested	No Rain	Non-Blocking Incident	Work Zone	Probability of Active non-blocking Incident (no rain, work zone)*(1-Probability of Demand over Capacity under non-blocking incident and work zone)
Scenario 8	Non-congested	Rain	Blocking Incident	Work Zone	Probability of Active blocking Incident (rain, work zone)*(1-Probability of Demand over Capacity under blocking incident and work zone)
Scenario 8A	Non-congested	Rain	Non-Blocking Incident	Work Zone	Probability of Active non-blocking Incident (rain, work zone)*(1-Probability of Demand over Capacity under non-blocking incident and work zone)
Scenario 9	Congested	No Rain	No incident	No Work Zone	Probability of non-incident with no Rain and no Work Zone*Probability of Demand over Capacity under no incident/no work zone
Scenario 10	Congested	Rain	No incident	No Work Zone	Probability of non-incident with Rain and no Work Zone*Probability of Demand over Capacity under no incident/no work zone
Scenario 11	Congested	No Rain	Blocking Incident	No Work Zone	Probability of Active blocking Incident (no rain, no work zone)*Probability of Demand over Capacity under blocking incident
Scenario 11A	Congested	No Rain	Non-Blocking Incident	No Work Zone	Probability of Active non-blocking Incident (no rain, no work zone)* Probability of Demand over Capacity under non-blocking incident
Scenario 12	Congested	No Rain	No incident	Work Zone	Probability of non-incident with no Rain and with Work Zone*Probability of Demand over Capacity under work zone
Scenario 13	Congested	Rain	Blocking Incident	No Work Zone	Probability of Active blocking Incident (rain, no work zone)*Probability of Demand over Capacity under blocking incident
Scenario 13A	Congested	Rain	Non-Blocking Incident	No Work Zone	Probability of Active non-blocking Incident (rain, no work zone)*Probability of Demand over Capacity under non-blocking incident
Scenario 14	Congested	Rain	No incident	Work Zone	Probability of non-incident with Rain and Work Zone*Probability of Demand over Capacity under work zone
Scenario 15	Congested	No Rain	Blocking Incident	Work Zone	Probability of Active blocking Incident (no rain, work zone)*Probability of Demand over Capacity under blocking incident and work zone
Scenario 15A	Congested	No Rain	Non-Blocking Incident	Work Zone	Probability of Active non-blocking Incident (no rain, work zone)*Probability of Demand over Capacity under non-blocking incident and work zone
Scenario 16	Congested	Rain	Blocking Incident	Work Zone	Probability of Active blocking Incident (rain, work zone)*Probability of Demand over Capacity under blocking incident and work zone
Scenario 16A	Congested	Rain	Non-Blocking Incident	Work Zone	Probability of Active non-blocking Incident (rain, work zone)*Probability of Demand over Capacity under non-blocking incident and work zone

Table B-2 Probability of Occurence By Scenario

	Congestion	Weather	Incident	Work Zone	Model
Scenario 1	Non-congested	No Rain	No incident	No Work Zone	{(3600/FFS) + 0.00258*d_u_ni,nw}*L
Scenario 2	Non-congested	Rain	No incident	No Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_ni,nw]+ R_hr*[(3600/FFS_hr) + 0.00258* d_u_ni,nw]}*L
Scenario 3	Non-congested	No Rain	Blocking Incident	No Work Zone	{(3600/FFS) + 0.00258* d_u_bi,nw}*L
Scenario 3A	Non-congested	No Rain	Non-Blocking Incident	No Work Zone	{(3600/FFS) + 0.00258* d_u_nbi,nw}*L
Scenario 4	Non-congested	No Rain	No incident	Work Zone	{(3600/FFS) + 0.00258* d_u_ni,w}*L
Scenario 5	Non-congested	Rain	Blocking Incident	No Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_bi,nw]+R_hr*[(3600/FFS_hr) + 0.00258* d_u_bi,nw]}*L
Scenario 5A	Non-congested	Rain	Non-Blocking Incident	No Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_nbi,nw]+R_hr*[(3600/FFS_hr) + 0.00258* d_u_nbi,nw]}*L
Scenario 6	Non-congested	Rain	No incident	Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_ni,w]+R_hr*[(3600/FFS_hr) + 0.00258* d_u_ni,w]}*L
Scenario 7	Non-congested	No Rain	Blocking Incident	Work Zone	{(3600/FFS) + 0.00258* d_u_bi,w}*L
Scenario 7A	Non-congested	No Rain	Non-Blocking Incident	Work Zone	{(3600/FFS) + 0.00258* d_u_nbi,w}*L
Scenario 8	Non-congested	Rain	Blocking Incident	Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_bi,w]+ R_hr*[(3600/FFS_hr) + 0.00258* d_u_bi,w]}*L
Scenario 8A	Non-congested	Rain	Non-Blocking Incident	Work Zone	{R_lr*[(3600/FFS_lr) + 0.00258* d_u_nbi,w]+ R_hr*[(3600/FFS_hr) + 0.00258* d_u_nbi,w]}*L
Scenario 9	Congested	No Rain	No incident	No Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_ni,nw – 0.1243*c – 3.46*L + 0.67*60}*L)
Scenario 10	Congested	Rain	No incident	No Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_ni,nw – 0.1243*c – 3.46*L + 0.67*60] + R_hr*[(3600/FFS_hr) + 0.1238*d_c_ni,nw – 0.1243*c – 3.46*L + 0.67*60]}*L)
Scenario 11	Congested	No Rain	Blocking Incident	No Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_bi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,nw*cr_bi – 21.524*L* cr_bi}*L)
Scenario 11A	Congested	No Rain	Non-Blocking Incident	No Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_nbi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,nw*cr_bi – 21.524*L* cr_nbi}*L)
Scenario 12	Congested	No Rain	No incident	Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_ni,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_ni,w*cr_bi – 21.524*L* cr_w}*L)
Scenario 13	Congested	Rain	Blocking Incident	No Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_bi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,nw*cr_bi – 21.524*L* cr_bi]+ R_hr*[(3600/FFS_hr) + 0.1238*d_c_bi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,nw*cr_bi – 21.524*L* cr_bi]}*L)
Scenario 13A	Congested	Rain	Non-Blocking Incident	No Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_nbi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,nw*cr_nbi – 21.524*L* cr_nbi]+ R_hr*[(3600/FFS_hr) + 0.1238*d_c_nbi,nw – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,nw*cr_nbi – 21.524*L* cr_nbi]}*L)
Scenario 14	Congested	Rain	No incident	Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_ni,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_ni,w*cr_w – 21.524*L* cr_w]+ R_hr*[(3600/FFS_hr) + 0.1238*d_c_ni,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_ni,w*cr_w – 21.524*L* cr_w]}*L)
Scenario 15	Congested	No Rain	Blocking Incident	Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_bi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,w*cr_bi,w – 21.524*L* cr_bi,w}*L)
Scenario 15A	Congested	No Rain	Non-Blocking Incident	Work Zone	MAX(TT_min,{(3600/FFS) + 0.1238*d_c_nbi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,w*cr_nbi,w – 21.524*L* cr_nbi,w}*L)
Scenario 16	Congested	Rain	Blocking Incident	Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_bi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,w*cr_bi,w – 21.524*L* cr_bi,w]+ R_hr*[(3600/FFS_hr) + 0.1238*d_c_bi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_bi,w*cr_bi,w – 21.524*L* cr_bi,w]}*L)
Scenario 16A	Congested	Rain	Non-Blocking Incident	Work Zone	MAX(TT_min_r,{R_lr*[(3600/FFS_lr) + 0.1238*d_c_nbi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,w*cr_nbi,w – 21.524*L* cr_nbi,w]+ R_hr*[(3600/FFS_hr) + 0.1238*d_c_nbi,w – 0.1243*c – 3.46*L + 0.67*60 – 15.24*N + 0.3964* d_c_nbi,w*cr_nbi,w – 21.524*L* cr_nbi,w]}*L)

Table B-3 Travel Time Estimation Models By Scenario