TRAVEL TIME RELIABILITY AS A SERVICE MEASURE FOR URBAN FREEWAYS IN FLORIDA

Richard Margiotta, Ph.D.
Cambridge Systematics
4800 Hampden Lane, Suite 800
Bethesda, MD 20814
(865) 670-8516
rmargiotta@camsys.com

Douglas McLeod
Transportation Statistics Office
Florida Department of Transportation
Tallahassee, Florida
(850) 414-4932
douglas.mcleod@dot.state.fl.us

Tyrone Scorsone
Cambridge Systematics
1566 Village Square Boulevard, Suite 2
Tallahassee, Florida 32309
(850) 219 6388
tscorsone@camsys.com

Richard Dowling, Ph.D., P.E.
Kittelson Associates
55 Grand Avenue, Suite 900
Oakland, California 94612
(510) 839-1742
rdowling@kittelson.com

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BACKGROUND

Definitions for Travel Time Reliability

Travel time reliability (TTR) is a relatively new concept in the transportation profession. There are two widely held ways that reliability can be defined. Each is valid and leads to a set of reliability performance measures that capture the nature of travel time reliability. Reliability can be defined as:

1. The ***variability*** in travel times that occur on a facility or for a trip over the course of time; and
2. The number of times (trips) that either "fail" or "succeed" in accordance with a pre-determined performance standard or schedule[1].

In both cases, reliability (more appropriately, unreliability) is caused by the interaction of the factors that influence travel times: fluctuations in demand (which may be due to daily or seasonal variation, or by special events), traffic control devices, traffic incidents, inclement weather, work zones, and physical capacity (based on prevailing geometrics and traffic patterns). These factors will produce travel times that are different from day-to-day for the same trip.

From a measurement perspective, reliability is quantified from the distribution of travel times, for a given facility/trip and time period (e.g., weekday peak period), that occurs over a significant span of time; one year is generally long enough to capture nearly all of the variability caused by disruptions. Figure 1 shows an actual travel time distribution derived from roadway detector data, and how it can be used to define reliability metrics. The shape of the distribution in Figure 1 is typical of what is found on congested freeways – it is skewed toward higher travel times. The skew is reflective of the impacts of disruptions, such as incidents weather, work zones, and high demand, on traffic flow. Therefore, most of the useful metrics for reliability are focused on the right half of the distribution; this is the region of interest for reliability. Note that a number of metrics are expressed relative to the *free-flow travel time*, which becomes the benchmark for any reliability analysis. The degree of (un-)reliability then becomes a relative comparison to the free-flow travel time.

SHRP 2 Project L08 recommended the measures in Table 1 be used for travel time reliability[2]. These measures all relate to the ***distribution of travel times*** for a particular facility or trip for a particular time period (Figure 1). It is often useful to convert the frequency distribution to a cumulative distribution; this is especially useful for comparing two distributions (Figure 2).

[1] Cambridge Systematics et al., *Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies,* SHRP 2 Project L03, Transportation Research Board, April 2013. http://www.trb.org/Main/Blurbs/166935.aspx

[2] Kittelson Associates et al., *Incorporation of Travel Time Reliability into the HCM*, SHRP 2 Project L08, Final Report (in publication), April 2013.

Figure 1. The Travel Time Distribution is the Basis for Defining Reliability Metrics

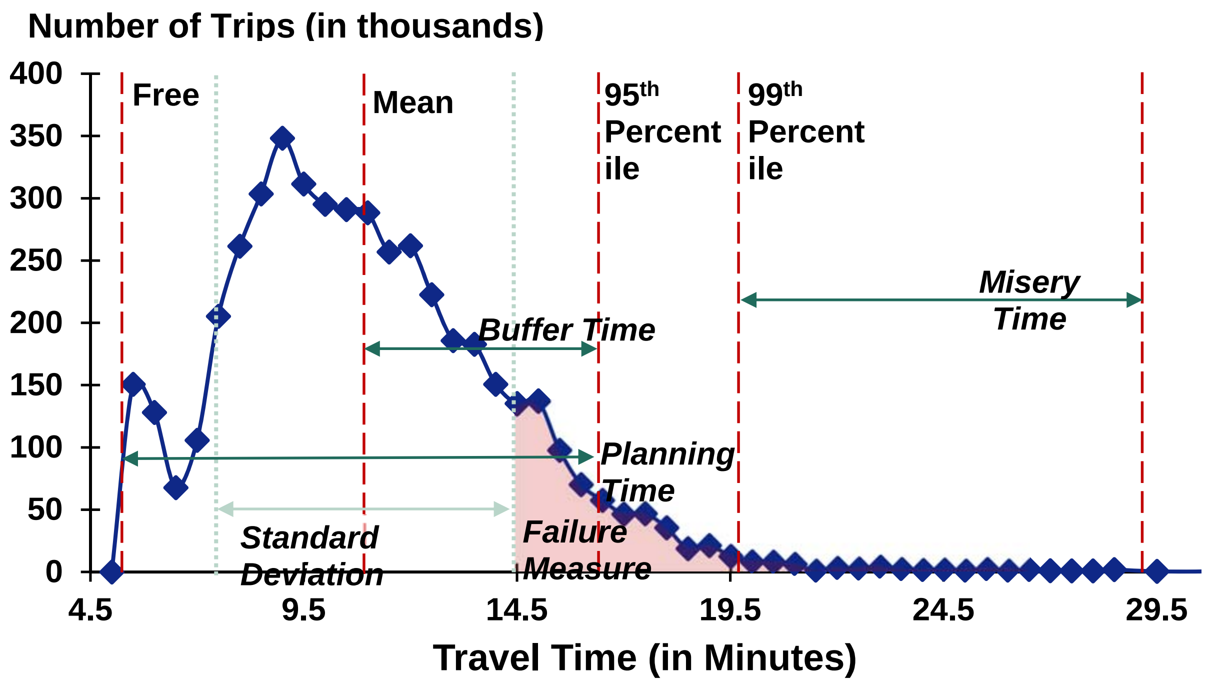

Figure 2. Cumulative Distribution of Travel Time Indices

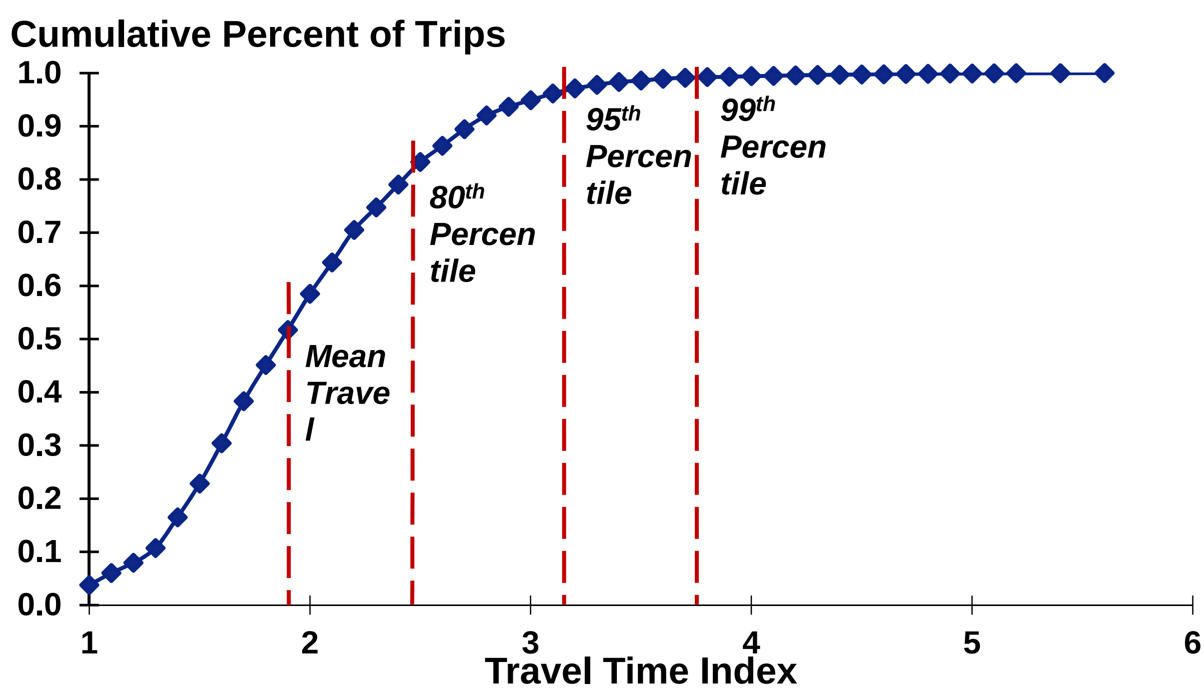

Table 1. Recommended Travel Time Reliability Metrics from SHRP 2 Project L08

Reliability Performance Measure	Definition
Core Measures	
Planning Time Index (PTI)	95th percentile Travel Time Index (TTI) (95th percentile travel time divided by the free flow travel time)
80th Percentile Travel Time Index	80th percentile Travel Time Index (80th percentile travel time divided by the free flow travel time)
Semi-Standard Deviation	The standard deviation of travel time pegged to free flow travel time rather than the mean travel time (variation is measured relative to free flow travel time)
Failure Measure (speed-based)	Percent of trips or VMT with space mean speed less than 50 mph; 45 mph; and 30 mph
Reliability Rating	Reliability Rating: Percent of trips or VMT serviced at or below a threshold travel time index (1.33 for freeways, 2.50 for urban streets)
Supplemental Measures	
Standard Deviation	Usual statistical definition
Misery Index (Modified)	The average of the highest five percent of travel times divided by the free flow travel time

Very little work has been done in terms of creating a service measure for travel time reliability. A service measure defines the **quality** of a service being provided. The *Highway Capacity Manual (HCM)* defines six levels of service for freeways (LOS), based on density of vehicles per mile per lane. LOS is a spatially localized measure. Chen, Skabardonis, and Varaiya made a preliminary investigation into the subject, matching mean and standard deviation of travel times to the current *HCM* levels of service.[3] SHRP 2 Project L08 also addressed the issue of a travel time reliability service measure, recommending that the Reliability Rating (see Table 1) be used as the basis for a service measure but it stopped short of defining actual LOS ranges.

Why Do We Need a TTR Service Measure?

A service measure is a performance measure that has been defined in such a way that a range of conditions indicate different levels of service. In the *HCM*, six levels have been traditionally used, A through F, to indicate various degrees of performance. Defining the ranges takes a great deal of judgment, and ultimately consensus, on the part of knowledgeable professionals.

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[3] Chen, Chao, Skabardonis, Alex, and Varaiya, Pravin, *Travel Time Reliability as a Measures of Service*, presented at 82nd Annual Meeting of the Transportation Research Board, January 2003.

This paper summarizes a project underway at the Florida Department of Transportation (FDOT) to develop TTR service measure. The overall goal of this task is to establish a travel time reliability service measure for use in Florida and as a basis for including a reliability service measure in the *HCM*. Having a TTR service measure will be helpful in communicating performance to nontechnical audiences and for identifying deficiencies. Because TTR is directly related to nonrecurring sources of congestion, a TTR-based service measure provides a way to measure the performance of operations-related improvements.

ISSUES RELATED TO DEVELOPING A TTR SERVICE MEASURE

The first issue is establishing LOS ranges for the TTR measure. The thresholds for the letter grades were defined for each measure being evaluated. After obtaining agreement on the thresholds, the research team applied them a wide variety of potential service measures.. Through testing with data from cities throughout Florida and the U.S., the thresholds were adjusted accordingly.

The second issue is to what type of facilities should a reliability service measure pertain? Operating characteristics of freeways, signalized highways, and rural two-lane highways are radically different, and their current service measures reflect this. From the profession's perspective, many programs to improve travel time reliability (i.e., those that deal with the factors that contribute to unreliable travel) are targeted on congested urban freeways. These programs include incident and work zone management, traveler information and active transportation and demand management strategies (e.g., ramp metering, shoulder use, variable speed limits). They are most effective, and are primarily deployed, in urban conditions where congestion is likely to be a problem. For Florida, the recommendation is to use TTR as a service measure in large urbanized areas (i.e., those with over 1,000,000 population) <u>or</u> urbanized areas with extensive freeway networks.

The third issue is compatibility with current *HCM* definition for freeway LOS, which is based on density, while reliability (by definition) is based on travel time. Further, the current freeway LOS allows for only two categories of what a user would call "congestion" (LOS E) and "severe congestion" (LOS F), yet we know that congestion is a continuum that can be mild, moderate, or severe. Another problem is that the first four density-based LOS categories indicate almost no difference in speeds (or travel times). It is clear that a reliability service measure must radically depart from the current definition, the main reason being to provide more information to users and practitioners about the nature of congestion.

The fourth issue is selection of the performance measure as the service measure. As shown in Table 1, there is a variety of measures that can be used. These fall into two general types: threshold-based and continuous measures. The SHRP 2 L08 recommendation is to use a threshold-based measure (the Reliability Rating). However, as a binary measure (either performance "succeeds" or "fails") it is limited in its ability to describe the severity of congestion.

The fifth issue is: what time period should mobility be reported for? The peak period should be the focus for mobility reporting, but other time slices are possible. For Florida, a two-hour peak period of 5:00 – 7:00 PM is being used. Other time periods have been used as peak periods.

The sixth issue is: how should mobility metrics be derived? We should be striving to measure mobility directly. Models are required for needs analysis and for examining project alternatives (forecasting). Using models to "predict" past performance should only be considered where sufficient data do not exist.

OPTIONS FOR A TRAVEL TIME RELIABILITY SERVICE MEASURE

Four different options for defining reliability LOS for Florida will be discussed in more detail:

1. travel time reliability LOS based on the L08 Reliability Rating;
2. travel time reliability LOS based on the amount of VMT that occurs in travel (space mean) speed ranges;
3. travel time reliability LOS based on a speed statistic from the distribution of travel speeds; and
4. travel time reliability LOS based on a travel time reliability index for the mean, 80^{th}, and 95^{th} percentile TTI.

To test these options, data from freeway surveillance systems in several cities were obtained. These data are from closely spaced (usually less than ½-mile) detectors that measure speeds and volumes simultaneously past a point. The data are archived at 5-minute intervals and are available continuously throughout the year, barring equipment malfunction. These measurements can be converted to travel times over reasonably short distances (less than 5 miles) so that facility travel times can be approximated (reference 1).

We first perform a screening analysis in this section, and then undertake a more detailed analysis of the promising options.

Option 1: Freeway Travel Time Reliability LOS Based on the L08 Reliability Rating

The L08 method uses a single threshold value to determine the cutoff point for unreliable travel on freeways: where TTI is less than or equal to 1.33. This metric is referred to as the ***Reliability Rating***. The percent of VMT or trips occurring below this threshold is the measure of interest. Applying this method to detector data for three facilities in Atlanta, Tampa, and Orlando, we get:

Facility	% VMT[4] where TTI <= 1.33
Atlanta, I-75 NB	13.0%
Orlando, I-4 EB	44.6%
Tampa, I-275 NB	5.9%

[4] Weekdays, 4:30-6:00 PM

Leaving the measure simply as the percent of VMT that are "acceptable" by this criterion does not make it a service measure in the *HCM* sense. To do that, we need to define levels of service around ranges for the percent VMT. For example:

- LOS A = 90-100% of VMT occurs at a TTI of 1.33 or less
- LOS B = 75-89% of VMT occurs at a TTI of 1.33 or less
- LOS C = 50-74% of VMT occurs at a TTI of 1.33 or less

… and so on. The difficult part is determining exactly what these ranges are. Also, the actual metric is the ***percent of VMT***, not a direct measurement of conditions.

A variation on this option is to use space mean speed (SMS) for a facility instead of the TTI. Because the TTI is a function of free flow speed, it can vary from facility to facility. A TTI value of 1.33 is equivalent to 41 mph where free flow speed is 55 mph, and to 53 mph where free flow speed is 70 mph. A reasonable midpoint would be 45 mph.

Regardless of whether the TTI or SMS is used, this option has the appeal of simplicity – it is easy to communicate. The measure is correlated with other reliability metrics, but the correlation is not as strong as between some others (as presented later in this report.) Figures 3 and 4 show the correlation for Florida cities (2012) between the Reliability Rating based on VMT served at 45 mph or higher (RR_{45}) and the 80th and 95th percentiles.

In general, the correlation is reasonably good, but becomes weaker when reliability degrades, especially for the 95th %ile. In Figure 4, if we assume that the 95th perecentile reflects the severity of "unreliability", then we can see that the RR_{45} does not because of the scatter at the upper end of the scale. For example, consider the point in Figure 4 where the 95th percentile TTI is 2.65 and the RR_{45} is 71%. Further analysis indicates that there are very poor travel conditions (TTI > 4.0) on some days; this causes the 95th percentile TTI to be high, while the majority of the days pass the 45 mph test. The opposite is true at the point where the 95th percentile TTI is 2.15 and the RR_{45} is 21%. On this section, the speed test is "failed" the majority of the time, but the size of this failure is not large, keeping the 95th percentile TTI relatively low.

Figure 3. Relationship between the 80th Percentile TTI and the Reliability Rating Based on a 45 mph Threshold (RR_{45})

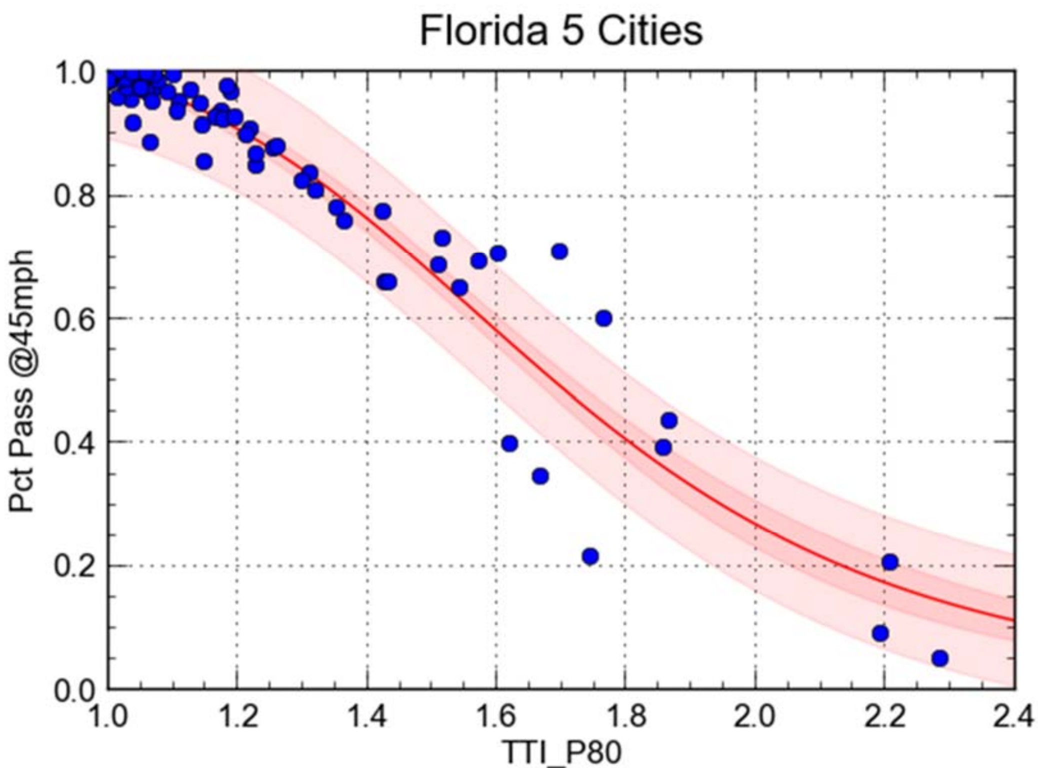
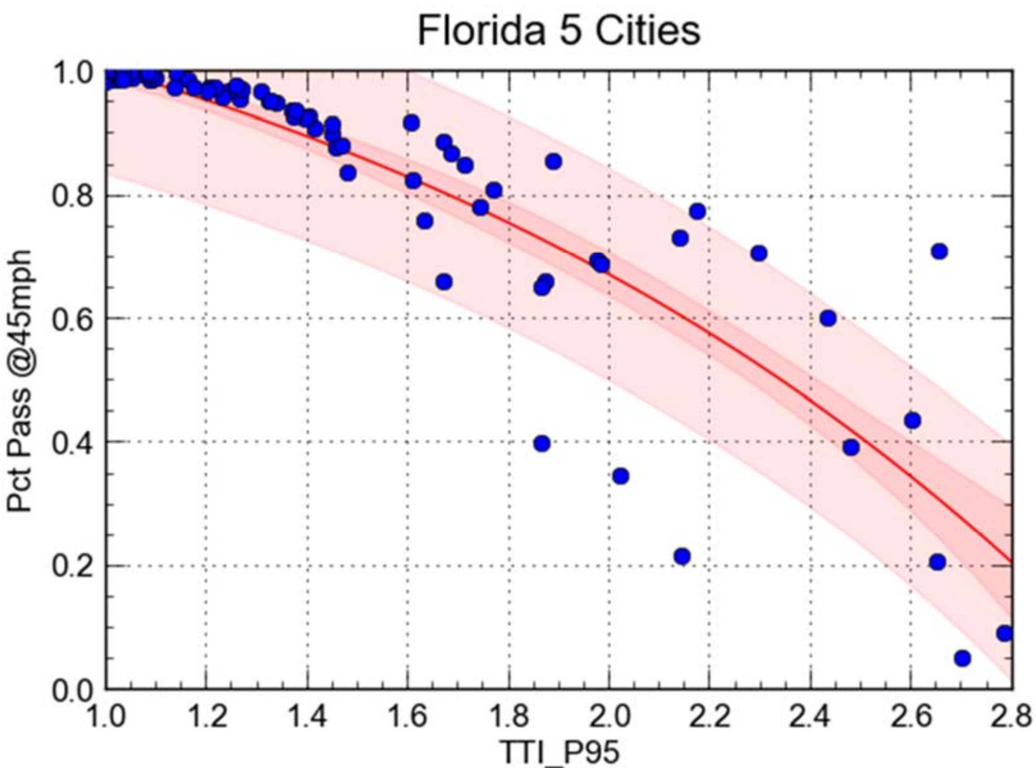


Figure 4. Relationship between the 95th Percentile TTI and the Reliability Rating Based on a 45 mph Threshold (RR_{45})



<u>Option 2: Freeway Travel Time Reliability LOS Based on Travel Speed Ranges (LOS Distribution Approach)</u>

In this approach, travel speed ranges are constructed for freeways in a manner similar to what is done for urban streets. Here, travel speed is analogous to SMS over the entire freeway facility or segment. The LOS ranges may be based on percentages of the free flow speed as is done for urban streets or may be set at fixed SMS values. To calculate LOS using this procedure with archived 5-minute detector data, travel times are computed for each 5-minute time slice for the analysis period (the PM peak in this case). The VMT associated with that travel time is then classified into one of the ranges, and is summed over the course of the entire year.

Because of the insensitivity of travel speeds to a wide range of density and v/c values (current LOS A through D), an option is to extend the number of LOS ranges for oversaturated conditions. An example of how this method would be applied is shown in Table 2, again using detector data from Atlanta, Orlando, and Tampa.

Note that this method doesn't produce a single LOS for how a facility operates – it presents a ***distribution of levels of service***. A distribution like this one is very useful to analysts, but not as useful when trying to communicate reliability to nontechnical audiences who are use to seeing a single value for the LOS of a facility.

Table 2. Potential Freeway Reliability LOS Defined by Travel Speed or Travel Time Index Ranges

		Percent of VMT in Each Range, 4:30 – 6:00 PM Weekdays		
		Atlanta	**Orlando**	**Tampa**
LOS	**Average Travel Speed**	**I-75 NB**	**I-4 EB**	**I-275 NB**
A	>=60 (TTI <= 1.083)	4.0%	5.1%	1.3%
B	50—59 (1.083 < TTI <= 1.300)	7.0%	33.1%	3.2%
C	45—49 (1.300 < TTI <= 1.444)	9.5%	23.9%	13.3%
D	40 – 44 (1.444 < TTI <= 1.625)	20.2%	21.1%	38.6%
E	35 – 39 (1.625 < TTI <= 1.857)	26.7%	10.3%	29.3%
F	< 35 (TTI > 1.857)	32.7%	6.6%	14.4%
	Mean TTI	1.816	1.424	1.669

Notes: (1) LOS ranges are for demonstration purposes only in this table.
(2) TTIs in this table assume an ideal (free flow) speed of 60 mph.

Option 3: Freeway Travel Time Reliability LOS Based on a Travel Speed Statistic

Option 3 is a variation on Option 2, where a statistic from the distribution of space mean speeds for the facility is computed and is compared to LOS ranges used in Option 2. In the above example, if the mean TTI is converted to travel speed (assuming a free flow speed of 60 mph), the levels of service would be E, C, and E for the Atlanta, Orlando, and Seattle sections, respectively. However, using the mean as an indicator of reliability (the variability in travel times) would be unusual; use of a common measure of variability is more appropriate, as discussed in the following sections. Note that if a statistics other than the mean was to be used, the speed ranges would apply to that statistics, not the "Average Travel Speed" as shown in Table 2.

Option 4: Freeway Travel Time Reliability LOS Based on a Travel Time Reliability Index

Through utilizing a travel time index an analyst can account for driver travel speed expectations. Unlike static SMS thresholds, a TTI threshold is dynamic and adjusts to account for free flow speeds. The two most common values used to describe reliability in terms of the travel time distribution are the 80th and 95th percentile TTIs. Historically, the 95th percentile was the first measure put forth as it was postulated that savvy commuters would plan for their trip to take this long, as it would imply that exceeding it they would be late one workday per month; it was subsequently named the Planning Time Index (PTI) for this quality. However, subsequent analysis has shown that the 80th percentile is more sensitive to typical transportation improvements – the travel times in the upper end of the distribution are usually extreme conditions that cannot be reasonably affected by improvements (reference 1).

In this approach, LOS ranges for the selected metric are defined. Then, the value for the metric is computed for the facility being studied and it is assigned a LOS.

A variation on this option is to use the equivalent statistic for space mean speed rather than TTI. The 20th and 5th percentile space mean speeds correspond to the 80th and 95th percentile TTIs. The advantage of this approach is that speeds are more easily communicated.

General Assessment of the Four Options

All of the options have advantages and disadvantages. Option 1 conforms closely to current *HCM* concepts, but also fails to provide detail on what is occurring in the LOS F region, which is the region of greatest interest. It also requires that the LOS be determined based on the range of percent of trips (or VMT) that meet the standard, and this could be confusing to nontechnical audiences. Option 2, while basing LOS on travel speed, does not provide a single LOS value – it provides a distribution of LOS, which is not easily interpreted. Options 3 and 4 are the most direct methods in that they use reliability metrics from the travel time distribution.

Based on this assessment, we have chosen to investigate further the following alternatives:

- Option 2, which produces a LOS distribution based on speed ranges
- Option 3, which uses the same speed ranges as Option 2 but uses a speed-based metric to determine a single LOS; and
- Option 4, including investigating: (1) determining the metric to be used and (2) defining the LOS ranges.

To conduct the analyses of the options, roadway detector data were assembled from several sources. The data were aggregated into trips over individual facilities, defined as 3-6 miles in length, in accordance with the procedures in Reference 1. The data came from several metropolitan areas:

- Five cities in Florida: Orlando, Tampa, Miami, Ft. Lauderdale, and Jacksonville (2012);
- Atlanta, GA (2010);
- Seattle, WA (2008); and
- Knoxville, TN (2011).

A two-hour peak period was chosen: weekdays, 5:00 -- 7:00 PM. Both directions of travel were used, so counterpeak conditions, which are less congested and sometimes uncongested, are included.

Several ways to define the LOS ranges were tried. The ranges that were ultimately used appear in Table 3.

Table 3. LOS Ranges Used in Final Testing

	Options 2 and 3	Option 4	
LOS	Speed Range (mph)	95th %ile TTI	95th %ile TTI
A	> PSL	1.0	1.0
B	B_{LOS} – PSL	>1.0 – 1.25	>1.0 – 1.25
C	50 – B_{LOS}	>1.25 – 1.6	>1.25 – 1.6
D	40 -- < 50	>1.6 – 2.0	>1.6 – 2.5
E	30 -- < 40	>2.0 – 2.5	>2.5 – 3.25
F	< 30	> 2.5	> 3.25

B_{LOS} = 50 + {0.5 * (*PostedSpeedLimit* - 50)}

PSL = Posted Speed Limit

ANALYSIS OF OPTION 2: TTR LOS DISTRIBUTION

Table 4 shows the LOS ranges that were chosen for this option, along with the results for the freeways in the selected metropolitan areas. Table 5 breaks out the five Florida cities individually. The Appendix shows the results for individual Florida facilities.

Table 4. LOS Distributions for TTR on Freeways in Selected Cities, PM Peak Period

		Percent of VMT			
LOS	Speed Range (mph)	5 FL Cities	Atlanta	Seattle	Knoxville
A	> Posted Speed Limit	38.6%	43.3%	38.7%	82.6%
B	B_{LOS} – Posted Speed Limit	29.3%	3.9%	7.9%	5.9%
C	50 -- B_{LOS}	13.8%	3.1%	5.0%	2.9%
D	40 -- < 50	10.2%	14.0%	15.8%	5.5%
E	30 -- < 40	5.9%	18.6%	17.6%	2.2%
F	< 30	2.2%	17.0%	15.0%	0.8%

B_{LOS} = 50 + {0.5 * (*PostedSpeedLimit* – 50)}

Table 5. LOS Distributions for TTR on Freeways in Florida Cities, PM Peak Period

		Percent of VMT				
LOS	**Speed Range (mph)**	**Ft. Lauderdale**	**Jacksonville**	**Miami**	**Orlando**	**Tampa**
A	> Posted Speed Limit	55.0%	63.6%	9.2%	63.5%	4.9%
B	B_{LOS} – Posted Speed Limit	19.3%	18.2%	17.5%	13.1%	62.3%
C	50 – B_{LOS}	15.3%	10.4%	20.8%	7.6%	15.9%
D	40 -- < 50	8.3%	6.1%	26.3%	6.5%	9.8%
E	30 -- < 40	1.9%	1.3%	18.1%	6.1%	5.9%
F	< 30	0.2%	0.4%	8.1%	3.3%	1.3%

$B_{LOS} = 50 + \{0.5 * (PostedSpeedLimit - 50)\}$

The results show a good deal of instability in the LOS A and B ranges between the cities. This is most likely due to the use of speed limits as a boundary point. It should be noted that in the Florida cities, the speed limit ranges from 55 to 70 mph on the studied facilities. In all of the remaining cities, the speed limit is 55 mph on the studied facilities.

ANALYSIS OF OPTION 3: TTR LOS BASED ON A SPEED STATISTIC

Tables 4 and 5 summarize all of the facilities in each city, based on VMT, but the results were built up by analyzing individual facilities. At the facility level, it is possible to compute a single reliability metric and compare it to the same speed ranges as used in Option 2 to see where it falls. We selected the 5th percentile SMS for this purpose. The results are shown in Table 6. Clearly, choice of another SMS percentile would create quite different results, assuming the same speed ranges are used. For example, if the 20th percentile SMS was used (a higher value than the 5th percentile SMS), the LOS distribution would be skewed to left (more observation in the better ranges). In this case, it would be prudent to adjust the speed ranges so that they are better matched to the statistics that is used.

ANALYSIS OF OPTION 4: TTR LOS BASED ON A TRAVEL TIME INDEX METRIC

Previous studies show a high degree of correlation among reliability metrics (references 1, 3). Figures 5 and 6 show the correlation for the 80th and 95th percentile TTIs and for the 95th percentile TTI and the mean for data from urban freeways for five cities in Florida (Tampa, Miami, Fort Lauderdale, Jacksonville, and Orlando). This correlation means that, from a measurement perspective, any of the metrics can be used to describe TTR. The choice of a metric then comes down to which one is most easily understood and communicated.

The correlation also provides a way to gain a sense of scale for the various measures. For example, the mean TTI could be converted to an average travel speed and the same basic relationship would hold (Figure 7).

Table 6. Application of LOS Ranges to Freeways in Selected Cities, PM Peak Period, Based on 5th Percentile SMS

	No. of Facilities					
	LOS A	**LOS B**	**LOS C**	**LOS D**	**LOS E**	**LOS F**
City (Total Facilities)	> PSL	B_{LOS} – PSL	50 -- B_{LOS}	40 -- < 50	30 -- < 40	< 30
Ft. Lauderdale (28)	17	5	5	1	0	0
Jacksonville (10)	2	4	4	0	0	0
Miami (12)	0	3	2	3	1	3
Orlando (33)	11	10	0	7	3	2
Tampa (33)	1	18	7	4	3	0
Atlanta (18)	1	3	1	4	2	7
Seattle (35)	5	0	1	5	5	19
Knoxville (6)	1	1	1	2	1	0

B_{LOS} = 50 + {0.5 * (*PostedSpeedLimit* - 50)}

PSL = Posted Speed Limit

Figure 5. Correlation Between the 80th and 95th Percentile TTIs

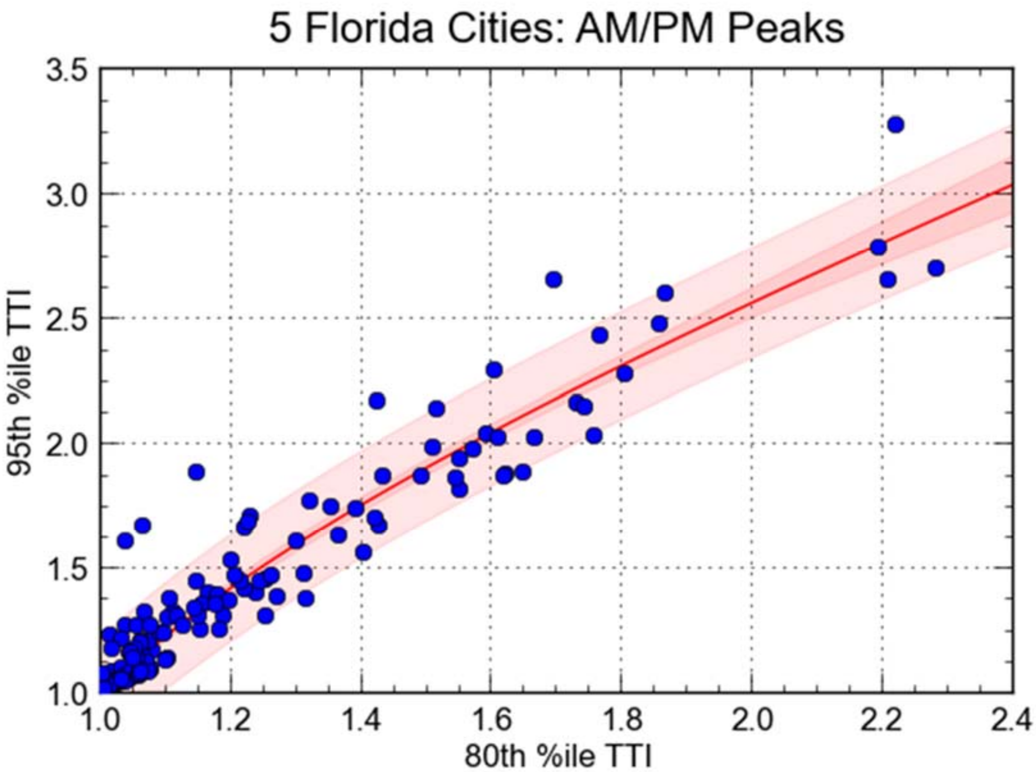


Figure 6. Correlation Between 95th Percentile TTI and Mean TTI

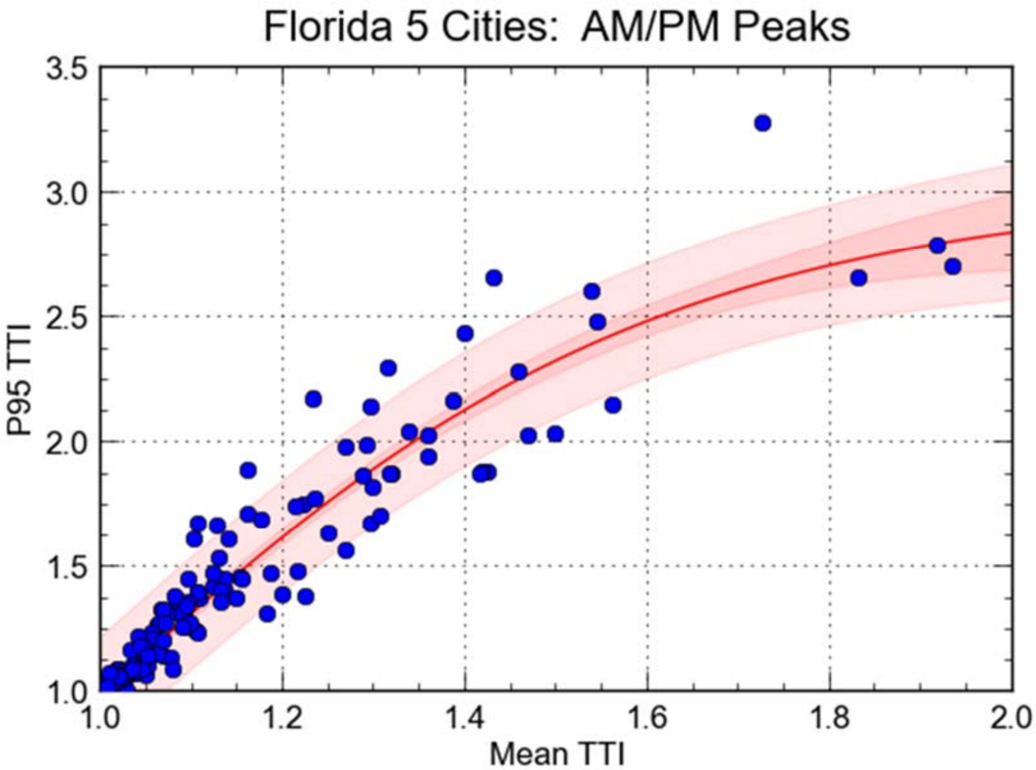
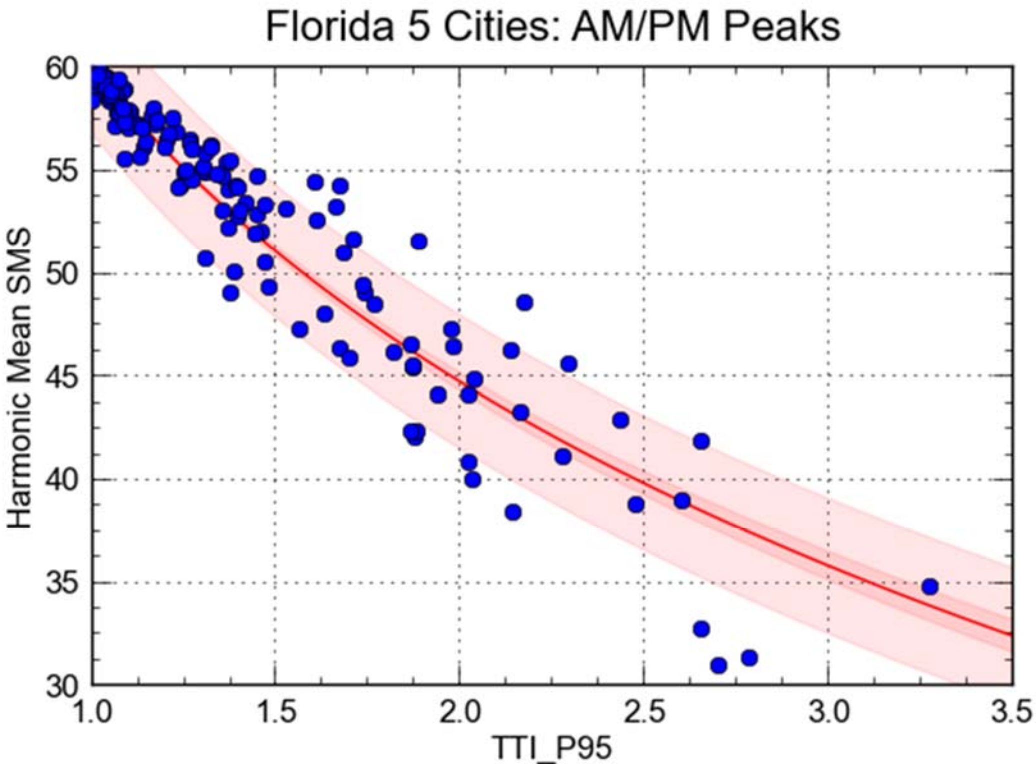


Figure 7. Correlation Between 95th Percentile TTI and Mean Travel Speed



An implication of these relationships is that it is possible to use the mean travel speed as the reliability metric. When a mean comes from a full distribution, especially a skewed one like typical travel time distributions are, it has some variation "built in". However, the mean is never used to describe variability in data, and that is what we're after here. Instead, we turn our attention to the 80th and 95th percentile TTIs as the potential metric, but use these relationships to "roughly equilibrate" their values to more commonly used metrics; this is done as an aid in determining LOS ranges. Using this approach, it is possible to select a primary metric and relate it to other metrics, noting that the correlation is strong but not perfect.

The first step in setting a TTR LOS framework for this option is to select either the 80th or 95th percentile TTI as the metric. As stated before, we want a metric that directly measures the variability in travel times, and these metrics have been used in other work for this purpose. It was noted previously that the 80th percentile is more sensitive to a wide variety of improvements than the 95th percentile (reference 1). The 95th percentile has been applied in more cases to date, such as in congestion monitoring systems, and it is based on the notion that it is the travel time, if planned for by commuters, that would result in being late one day per month (1 day out of 20). Thus, the choice boils down to what perspective to adopt: the agency perspective (80th percentile) or the user perspective (95th percentile). FDOT has already embraced the philosophy that its performance measurement program should be user oriented, so the 95th percentile TTI is the logical choice for the TTR LOS metric. All of these observations are conjecture – we are unaware of any study that identifies the measure that resonates best with users.

A variety of range combinations were tried for the 95th percentile TTI, based on reviewing the spread of the data.

Table 7. Potential TTR Level of Service Ranges for FDOT, Version 1

	Primary Metric	Corresponding Value for 5th %ile Travel Speed		Approximate Value for:	
LOS Level	95th %ile TTI	Where FFS=60	Where FFS=70	80th %ile TTI	Mean Travel Speed[5]
A	1.0	>= 60	>= 70	1.0	>= 60
B	>1.0 – 1.25	48 – <60	56 - <70	>1.0 – 1.1	55 – <60
C	>1.25 – 1.6	37.5 – <48	44 - <56	>1.1 – 1.3	49 – <55
D	>1.6 – 2.0	30 – <37.5	35 - <44	>1.3 – 1.55	45 – <49
E	>2.0 – 2.5	24 – <30	28 - <35	>1.55 – 1.85	40 – <45
F	> 2.5	< 24	< 28	> 1.85	< 40

Table 8. Potential TTR Level of Service Ranges for FDOT, Version 2

	Primary Metric	Corresponding Value for 5th %ile Travel Speed		Approximate Value for:	
LOS Level	95th %ile TTI	Where FFS=60	Where FFS=70	80th %ile TTI	Mean Travel Speed[5]
A	1.0	>= 60	>= 70	1.0	>= 60
B	>1.0 – 1.25	48 – <60	56 - <70	>1.0 – 1.1	55 – <60
C	>1.25 – 1.6	37.5 – <48	44 - <56	>1.1 – 1.3	48 – <55
D	>1.6 – 2.5	24 – <37.5	28 - < 44	>1.3 – 1.9	40 – <48
E	>2.5 – 3.25	18.5 – <24	21.5 - < 28	>1.9 – 2.4	35 – <40
F	> 3.25	< 18.5	< 21.5	> 2.4	< 35

[5] Assuming FFS = 60 mph

LOS values for A, B, and C are the same in these tables. Table 8 offers extended ranges for LOSs D, E, and F.

Note that the corresponding speed values for the ranges vary depending on free flow speed; these are straight mathematical conversions of the 95th percentile TTI values. The approximate values for the 80th percentile and means were taken from the relationships shown in Figures 5 and 7. Note that the mean travel speed is the average of all speeds from the complete distribution. The way to interpret the data in Tables 7 and 8 is as follows.

- A 95th percentile TTI range between 1.8 and 2.2 is approximately equivalent to an 80th percentile range of 1.45 to 1.67, and to a mean travel speed range of 42.5 – 46 mph; and
- The 5th percentile travel speed is the speed at which the 95th percentile TTI occurs. For example, when the 95th percentile TTI for a trip is 2.5, the travel speed is 24 mph.

Application of these two LOS frameworks to 116 urban freeway facilities in the five Florida cities studies for the PM peak period (5:00 – 7:00 PM), resulted in the data in Table 9. Note that Version 2, which has extended ranges for the worst conditions, shows no Florida facilities in LOS F. The high number of facilities in LOSs A and B is due to some facilities that peak in the morning, since these are uni-directional facilities.

Table 9. Application of LOS Ranges to Florida and Atlanta Freeway Data, PM Peak Period

		No. Facilities (Percent)	
	LOS	**LOS Version 1**	**LOS Version 2**
5 Florida Cities	A	31 (26.7%)	31 (26.7%)
	B	40 (34.5%)	40 (34.5%)
	C	18 (15.5%)	18 (15.5%)
	D	15 (12.9%)	22 (19.0%)
	E	7 (6.0%)	5 (4.3%)
	F	5 (4.3%)	0
	LOS	**LOS Version 1**	**LOS Version 2**
Atlanta	A	0	0
	B	6 (33.3%)	6 (33.3%)
	C	4 (22.2%)	4 (22.2%)
	D	2 (11.1%)	4 (22.2%)
	E	2 (11.1%)	3 (16.7%)
	F	4 (22.2%)	1 (5.6%)

Given that the results are dependent on free flow speed, and free flow speed values across facilities, it may be desirable to either fix the free flow speed at a constant value for all facilities or to just use a speed statistic with speed ranges, such as in Option 3.

A comparison was made for the LOS classification of Florida freeway facilities using Option 3 and Option 4 (Table 10). If the two procedures classified facilities at the same LOS, all of the facilities would fall on the diagonal. There is a fairly good match for LOSs A and B, but Option 3 (using the 5th percentile SMS with speed ranges) produces lower (worse) levels of service for categories C, D, and E. LOS F classification is similar. The exact same patterns are evident in Atlanta and Seattle (Tables 11 and 12).

Table 10. Classification Matrix for LOS Methods, 5 Florida Cities

Option 4: 95th %ile TTI (version 1)	Option 3: 5th %ile SMS with Speed Range					
	Level of Service					
Level of Service	**A**	**B**	**C**	**D**	**E**	**F**
A	28	3	0	0	0	0
B	8	20	11	1	0	0
C	0	0	0	18	0	0
D	0	0	0	0	15	0
E	0	0	0	0	1	6
F	0	0	0	0	0	5

Table 11. Classification Matrix for LOS Methods, Atlanta

Option 4: 95th %ile TTI (version 1)	Option 3: 5th %ile SMS with Speed Range					
	Level of Service					
Level of Service	**A**	**B**	**C**	**D**	**E**	**F**
A	0	0	0	0	0	0
B	1	3	1	1	0	0
C	0	0	0	3	1	0
D	0	0	0	0	1	1
E	0	0	0	0	0	2
F	0	0	0	0	0	4

Table 12. Classification Matrix for LOS Methods, Seattle

Option 4: 95th %ile TTI (version 1)	Option 3: 5th %ile SMS with Speed Range					
	Level of Service					
Level of Service	**A**	**B**	**C**	**D**	**E**	**F**
A	2	0	0	0	0	0
B	3	0	1	1	0	0
C	0	0	0	4	1	0
D	0	0	0	0	4	0
E	0	0	0	0	0	8
F	0	0	0	0	0	11

SUMMARY AND NEXT STEPS

The travel time reliability LOS pursued here for urban freeways varies significantly from the current density-based LOS in the *HCM*. Although the study has stopped short of recommending final LOS ranges, the two options are based on the same concept – that urban freeway LOS degrades as a function of travel time, not density. If one considers the speed ranges from Table 2, it is seen that the proposed LOS B is essentially at the current *HCM* LOS E boundary with LOS F. This radical departure from the current *HCM* is done to reflect the fact that users' experience on congested urban freeways is related to travel time. For freeway facilities that are routinely uncongested or for long distance trips, density is still the key factor determining the user experience. Although congestion (characterized by queuing) does occur on these facilities, it almost always is due to rare and severe disruptions such as incidents, inclement weather, and work zones.

However, on the positive side, using travel time for LOS on urban freeways is consistent with the *HCM* approach to urban streets; achieving this consistency for urban conditions in the *HCM* would be useful for both technical and nontechnical audiences.

The next step is to finalize the LOS ranges. Technical analysis can only go so far in this regard – a consensus among practitioners is necessary. This will require applications of the method in a wide variety of circumstances and also deliberations within the Highway Capacity Quality of Service committee.

Finally, the work conducted by FDOT and reported here is for ***facility-based*** analysis. With MAP-21 requirements for performance measurement looming, some consideration should be given to establishing levels of service for ***systemwide*** reporting. The simplest approach is to compute a weighted average 95th percentile TTI for all facilities in a large urbanized area, where each facility is defined in accordance with *HCM* procedures for freeway facilities (currently Chapter 10). The weight could be either highway miles or VMT, but VMT is more user focused and should be preferred. Admittedly, this is an indirect method of assessing systemwide performance; a more direct approach would be to sum the VMT in each LOS range.

APPENDIX

TTR Characteristics of Florida Facilities, 2012

LOS Based on TTI_P95

LOS Level	95th %ile TTI
A	1.0
B	>1.0 – 1.25
C	>1.25 – 1.6
D	>1.6 – 2.0
E	>2.0 – 2.5
F	> 2.5

LOS Based on 5th %ile Speed

LOS	Speed Range (mph)
A	> Posted Speed Limit
B	B_{LOS} – Posted Speed Limit
C	50 -- B_{LOS}
D	40 -- < 50
E	30 -- < 40
F	< 30

CITY	ROUTE	Section	AVG_TTI	TTI_P80	TTI_P95	SMS_P5	SMS_P20	Reliability Rating	LOS Based on TTI_P95	LOS Based on 5th %ile Speed
FT LAUDERDALE	I-75	4NB1	1.009	1.000	1.020	58.8	60.0	0.991	B	B
FT LAUDERDALE	I-75	4NB2	1.009	1.000	1.024	58.6	60.0	0.994	B	B
FT LAUDERDALE	I-75	4SB1	1.013	1.000	1.005	59.7	60.0	0.992	A	B
FT LAUDERDALE	I-75	4SB2	1.004	1.000	1.002	59.9	60.0	0.998	A	B
FT LAUDERDALE	I-75	5NB	1.001	1.002	1.004	59.7	59.9	1.000	A	A
FT LAUDERDALE	I-75	5NB1	1.000	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5NB2	1.001	1.002	1.007	59.6	59.9	1.000	B	A
FT LAUDERDALE	I-75	5NB3	1.000	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5NB4	1.001	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5SB	1.000	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5SB1	1.001	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5SB2	1.003	1.004	1.011	59.3	59.7	1.000	B	B
FT LAUDERDALE	I-75	5SB3	1.001	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-75	5SB4	1.001	1.000	1.000	60.0	60.0	0.999	A	A
FT LAUDERDALE	I-95	10NB	1.000	1.000	1.001	59.9	60.0	1.000	A	A
FT LAUDERDALE	I-95	10SB	1.001	1.000	1.002	59.9	60.0	1.000	A	A
FT LAUDERDALE	I-95	1NB	1.109	1.176	1.370	43.8	51.0	0.933	C	D
FT LAUDERDALE	I-95	1SB	1.223	1.354	1.745	34.4	44.3	0.778	D	E
FT LAUDERDALE	I-95	2NB	1.124	1.220	1.417	42.3	49.2	0.907	C	D
FT LAUDERDALE	I-95	2SB	1.136	1.214	1.450	41.4	49.4	0.896	C	D
FT LAUDERDALE	I-95	6NB	1.068	1.111	1.325	45.3	54.0	0.950	C	D
FT LAUDERDALE	I-95	6SB	1.093	1.189	1.309	45.8	50.5	0.964	C	D
FT LAUDERDALE	I-95	7NB	1.002	1.000	1.005	59.7	60.0	1.000	A	A
FT LAUDERDALE	I-95	7SB	1.009	1.000	1.012	59.3	60.0	0.992	B	A
FT LAUDERDALE	I-95	8NB	1.003	1.000	1.000	60.0	60.0	1.000	A	A

CITY	ROUTE	Section	AVG_TTI	TTI_P80	TTI_P95	SMS_P5	SMS_P20	Reliability Rating	LOS Based on TTI_P95	LOS Based on 5th %ile Speed
FT LAUDERDALE	I-95	8SB	1.000	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-95	9NB	1.001	1.000	1.000	60.0	60.0	1.000	A	A
FT LAUDERDALE	I-95	9SB	1.001	1.000	1.000	60.0	60.0	1.000	A	A
JACKSONVILLE	I-10	4EB	1.069	1.102	1.142	52.5	54.4	0.996	B	B
JACKSONVILLE	I-10	4WB	1.132	1.166	1.404	42.7	51.4	0.925	C	D
JACKSONVILLE	I-295	3NB1	1.063	1.037	1.267	47.3	57.9	0.955	C	D
JACKSONVILLE	I-295	3NB2	1.062	1.072	1.207	49.7	56.0	0.972	B	C
JACKSONVILLE	I-295	3NB3	1.002	1.000	1.001	59.9	60.0	0.998	A	A
JACKSONVILLE	I-295	3SB1	1.006	1.000	1.002	59.9	60.0	0.995	A	A
JACKSONVILLE	I-295	3SB2	1.028	1.015	1.048	57.3	59.1	0.990	B	A
JACKSONVILLE	I-295	3SB3	1.016	1.000	1.044	57.5	60.0	0.987	B	A
JACKSONVILLE	I-95S	2NB	1.153	1.255	1.460	41.1	47.8	0.875	C	D
JACKSONVILLE	I-95S	2SB	1.107	1.179	1.397	42.9	50.9	0.922	C	D
MIAMI	I-195	1EB	1.106	1.092	1.244	48.2	54.9	0.966	B	D
MIAMI	I-195	1WB	1.433	1.697	2.655	22.6	35.4	0.708	F	F
MIAMI	I-75	4NB	1.161	1.229	1.713	35.0	48.8	0.845	D	E
MIAMI	I-75	4SB	1.080	1.077	1.090	55.0	55.7	0.986	B	C
MIAMI	I-95	5NB	1.470	1.668	2.023	29.7	36.0	0.339	E	E
MIAMI	I-95	5SB	1.216	1.311	1.480	40.5	45.8	0.830	C	D
MIAMI	I-95	6NB	1.237	1.321	1.771	33.9	45.4	0.805	D	E
MIAMI	I-95	6SB	1.017	1.016	1.030	58.2	59.1	0.996	B	B
MIAMI	SR-826	2EB	1.149	1.196	1.374	43.7	50.2	0.925	C	D
MIAMI	SR-826	2WB	1.296	1.428	1.673	35.9	42.0	0.652	D	E
MIAMI	SR-826	3NB	1.918	2.195	2.786	21.5	27.3	0.089	F	F
MIAMI	SR-826	3SB	1.935	2.284	2.702	22.2	26.3	0.047	F	F
ORLANDO	I-4	12EB1	1.016	1.000	1.018	59.0	60.0	0.984	B	B
ORLANDO	I-4	12EB2	1.005	1.000	1.008	59.5	60.0	0.996	B	B

CITY	ROUTE	Section	AVG_TTI	TTI_P80	TTI_P95	SMS_P5	SMS_P20	Reliability Rating	LOS Based on TTI_P95	LOS Based on 5th %ile Speed
ORLANDO	I-4	12WB1	1.056	1.015	1.233	48.7	59.1	0.958	B	C
ORLANDO	I-4	12WB2	1.106	1.065	1.674	35.9	56.4	0.885	D	E
ORLANDO	I-4	1EB1	1.316	1.604	2.296	26.1	37.4	0.705	E	F
ORLANDO	I-4	1EB2	1.177	1.228	1.686	35.6	48.9	0.864	D	E
ORLANDO	I-4	1EB3	1.547	1.859	2.480	24.2	32.3	0.389	E	F
ORLANDO	I-4	1WB1	1.270	1.572	1.978	30.3	38.2	0.691	D	E
ORLANDO	I-4	1WB2	1.296	1.517	2.140	28.0	39.6	0.731	E	F
ORLANDO	I-4	1WB3	1.293	1.510	1.984	30.2	39.7	0.685	D	E
ORLANDO	I-4	2EB1	1.832	2.210	2.654	22.6	27.2	0.203	F	F
ORLANDO	I-4	2EB2	1.318	1.435	1.873	32.0	41.8	0.652	D	E
ORLANDO	I-4	2EB3	1.043	1.031	1.220	49.2	58.2	0.972	B	C
ORLANDO	I-4	2WB1	1.539	1.866	2.605	23.0	32.1	0.433	F	F
ORLANDO	I-4	2WB2	1.163	1.148	1.889	31.8	52.3	0.855	D	E
ORLANDO	I-4	2WB3	1.102	1.039	1.609	37.3	57.7	0.917	D	E
ORLANDO	I-4	5EB1	1.021	1.018	1.087	55.2	59.0	0.987	B	B
ORLANDO	I-4	5EB2	1.001	1.000	1.000	60.0	60.0	1.000	A	A
ORLANDO	I-4	5WB1	1.015	1.006	1.011	59.3	59.6	0.991	B	A
ORLANDO	I-4	5WB2	1.003	1.000	1.000	60.0	60.0	0.998	A	A
ORLANDO	I-4	5WB4	1.029	1.000	1.002	59.9	60.0	0.983	A	A
ORLANDO	I-95	13NB	1.002	1.003	1.004	59.7	59.8	1.000	A	A
ORLANDO	I-95	13SB	1.001	1.000	1.001	59.9	60.0	1.000	A	A
ORLANDO	I-95	3NB	1.002	1.001	1.006	59.7	59.9	1.000	B	A
ORLANDO	I-95	3SB	1.004	1.000	1.000	60.0	60.0	0.996	A	A
ORLANDO	I-95	4NB	1.001	1.000	1.000	60.0	60.0	1.000	A	A
ORLANDO	I-95	4SB	1.007	1.000	1.000	60.0	60.0	0.993	A	A
ORLANDO	I-95	6NB	1.002	1.000	1.001	59.9	60.0	1.000	A	A
ORLANDO	I-95	6SB	1.001	1.000	1.000	60.0	60.0	1.000	A	A

CITY	ROUTE	Section	AVG_TTI	TTI_P80	TTI_P95	SMS_P5	SMS_P20	Reliability Rating	LOS Based on TTI_P95	LOS Based on 5th %ile Speed
ORLANDO	I-95	7NB	1.009	1.014	1.028	58.4	59.2	1.000	B	A
ORLANDO	I-95	7SB	1.008	1.011	1.030	58.2	59.4	0.999	B	B
ORLANDO	I-95	8NB	1.000	1.000	1.000	60.0	60.0	1.000	A	A
ORLANDO	I-95	8SB	1.009	1.013	1.021	58.8	59.2	0.999	B	A
TAMPA	I-275	1NB	1.289	1.545	1.866	32.2	38.8	0.647	D	E
TAMPA	I-275	1SB	1.095	1.143	1.341	44.7	52.5	0.946	C	D
TAMPA	I-275	2NB	1.188	1.261	1.471	40.8	47.6	0.879	C	D
TAMPA	I-275	2SB	1.100	1.127	1.273	47.1	53.3	0.968	C	D
TAMPA	I-275	4NB	1.562	1.744	2.145	28.0	34.4	0.213	E	F
TAMPA	I-275	4SB	1.417	1.621	1.868	32.1	37.0	0.393	D	E
TAMPA	I-275	5NB	1.070	1.061	1.201	50.0	56.6	0.967	B	C
TAMPA	I-275	5SB	1.017	1.038	1.064	56.4	57.8	1.000	B	B
TAMPA	I-275	6NB	1.034	1.038	1.073	55.9	57.8	0.995	B	B
TAMPA	I-275	6SB	1.042	1.045	1.165	51.5	57.4	0.984	B	C
TAMPA	I-4	3EB1	1.082	1.107	1.376	43.6	54.2	0.932	C	D
TAMPA	I-4	3EB2	1.234	1.424	2.174	27.6	42.1	0.773	E	F
TAMPA	I-4	3EB3	1.069	1.069	1.328	45.2	56.1	0.950	C	D
TAMPA	I-4	3EB4	1.037	1.053	1.099	54.6	57.0	0.988	B	C
TAMPA	I-4	3WB1	1.142	1.301	1.611	37.3	46.1	0.821	D	E
TAMPA	I-4	3WB2	1.023	1.027	1.055	56.9	58.4	0.987	B	B
TAMPA	I-4	3WB3	1.049	1.051	1.175	51.0	57.1	0.972	B	C
TAMPA	I-4	3WB4	1.014	1.039	1.050	57.1	57.8	0.998	B	B
TAMPA	I-4	7EB1	1.047	1.073	1.090	55.0	55.9	0.996	B	C
TAMPA	I-4	7EB2	1.011	1.007	1.024	58.6	59.6	0.995	B	B
TAMPA	I-4	7EB3	1.005	1.000	1.022	58.7	60.0	0.998	B	B
TAMPA	I-4	7EB4	1.001	1.000	1.000	60.0	60.0	1.000	A	B
TAMPA	I-4	7EB5	1.008	1.012	1.027	58.4	59.3	0.998	B	B

CITY	ROUTE	Section	AVG_TTI	TTI_P80	TTI_P95	SMS_P5	SMS_P20	Reliability Rating	LOS Based on TTI_P95	LOS Based on 5th %ile Speed
TAMPA	I-4	7WB1	1.004	1.003	1.017	59.0	59.8	1.000	B	B
TAMPA	I-4	7WB2	1.007	1.013	1.031	58.2	59.2	1.000	B	B
TAMPA	I-4	7WB3	1.036	1.060	1.085	55.3	56.6	0.999	B	C
TAMPA	I-4	7WB4	1.009	1.015	1.034	58.0	59.1	0.999	B	B
TAMPA	I-75	8NB1	1.015	1.001	1.036	57.9	59.9	0.986	B	B
TAMPA	I-75	8NB2	1.400	1.765	2.435	24.6	34.0	0.598	E	F
TAMPA	I-75	8NB3	1.251	1.365	1.634	36.7	44.0	0.754	D	E
TAMPA	I-75	8SB1	1.091	1.184	1.258	47.7	50.7	0.976	C	D
TAMPA	I-75	8SB2	1.097	1.147	1.450	41.4	52.3	0.914	C	D
TAMPA	I-75	8SB3	1.052	1.051	1.138	52.7	57.1	0.971	B	C