Travel Time Reliability as a Performance Measure: Applying Florida's Predictive Model to an Entire Freeway System

By:
Douglas S. McLeod (corresponding author)
Florida Department of Transportation
605 Suwannee Street
Tallahassee, FL 32399-0450
Tel. 850-414-4932
Fax: 850414-4876
douglas.mcleod@dot.state.fl.us

Lily Elefteriadou, Ph.D.
University of Florida
365 Weil Hall, PO Box 116580
Gainesville, FL 32611
Tel. 352-392-9537, Ext. 1452
Fax: 352-992-3394
elefter@ce.ufl.edu

Li Jin, Ph.D.
Kittelson & Associates, Inc.
225 E Robinson Street
Orlando, FL 32801
Tel. 407-540-0555
Fax: 407-540-0550
ljin@kittelson.com

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Abstract
The Florida Department of Transportation (FDOT) developed a travel time reliability model, applied it to all freeways in Florida, and began reporting reliability. This paper introduces the model and development methodology. It then explores potential planning uses for system-wide reporting and project priority, a potential application throughout the U.S.

Keywords
Travel time reliability, system wide reporting, project priority, freight performance measures, traffic management

Introduction

Travel time reliability is recognized as one of the most important quality of service measures to travelers. Total travel time is important, but the variability of travel time often becomes more important. Existing tools such as the 2010 Highway Capacity Manual (HCM)[1] only evaluate system performance for individual time intervals and do not consider its longer-term ability to handle varying demands and capacities as a result of incidents and inclement weather. Agencies are interested in evaluating the performance of their systems in a more comprehensive manner.

Both traffic operations and systems planning analyses are appropriate uses of this important metric. In systems planning, transportation agencies can evaluate the impact of a new incident identification and removal program over a year, then assess benefits and costs when such a program is implemented.

Often the calculation, reporting, and use of expected travel time over a broad range of facilities and time periods is relatively straight forward; however, the calculation and use of travel time reliability on a broad scale has proved elusive. Travelers are primarily interested in the expected travel time for their trip, yet currently that approach is largely limited to the Intelligent Transportation System (ITS) instrumented freeways. Also quality of data is still a major issue.

For statewide reporting and system level prioritization of projects, application of an on-time arrival predictive model is the most appropriate way to address travel time reliability over a broad range of facilities and for presenting trends. Considering the entire spectrum of travel times, on-time arrival is more appropriate for longer-term planning-type applications. Performance measures focusing only on the variability of travel times do not account for the fact that increased congestion may also decrease variability.

The Florida Department of Transportation (FDOT) deems travel time reliability should be one of the primary mobility performance measures to evaluate its ITS program, for statewide reporting, and system level project prioritization. FDOT has funded multiple research projects leading to the development, implementation and refinement of a model for predicting travel time reliability for freeways and signalized arterials[2]. This paper gives an overview of the model and its application, presents results, and provides insights into how FDOT might use the model for its planning and programming processes in the future.

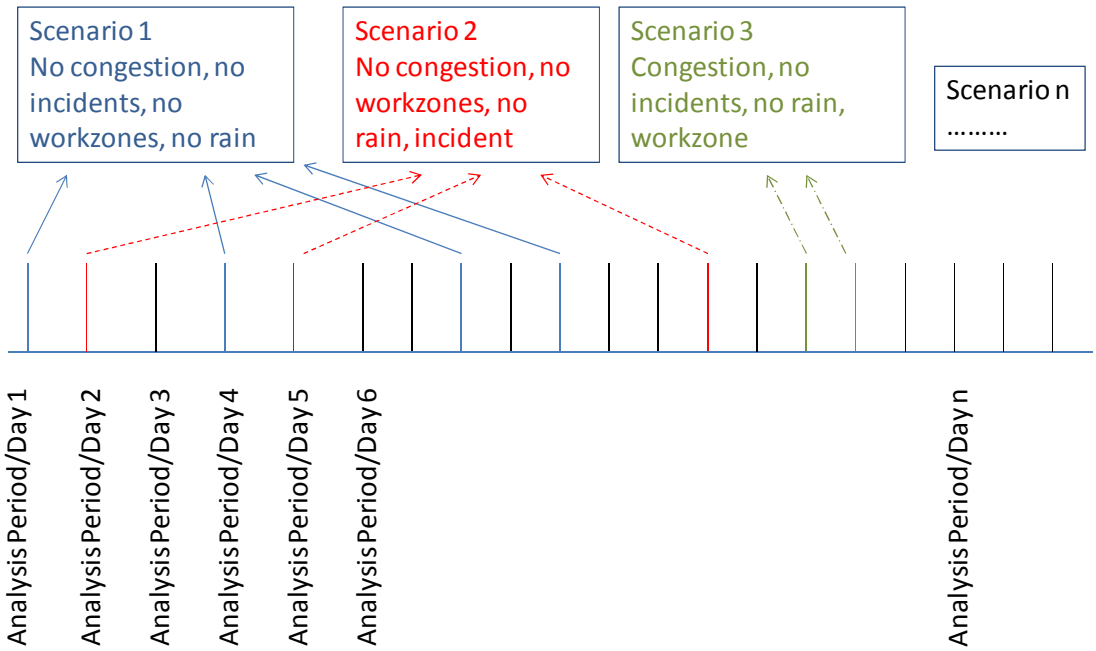
Travel Time Reliability Model Methodology Overview

The methodology developed to estimate travel time reliability considers a series of different scenarios that may occur over a year. Expected travel times are calculated for those scenarios as well as the probability of occurrence of each scenario. Figure 1 illustrates this concept. As shown, each day (or each analysis period during each day) would operate under a particular scenario. A scenario is a set of conditions affecting the travel time of the section.

The following conditions were considered in developing these scenarios: non-congested vs. congested, weather, incidents, and work zones. All days or analysis periods with the same set of conditions are categorized under a given scenario. The percent of analysis periods or days that operate under a particular scenario constitutes the probability of occurrence. The methodology developed estimates expected travel time for each of the scenarios identified, along with expected frequency of occurrence. The method then assembles estimated travel times along with their respective frequencies and obtains travel time distribution for the subject section.

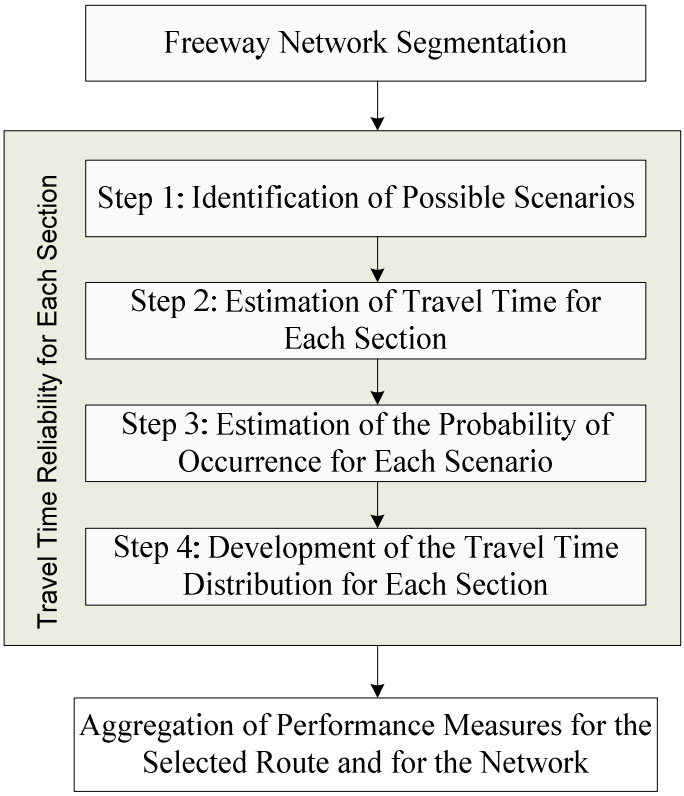
The same method can be applied regardless of the specific number of scenarios selected. Increasing the number of subcategories in each condition increases the number of scenarios and data requirements for analysis. For a planning level analysis, it is more appropriate to group scenarios in broader categories.

Figure 1:
Scenarios Considered throughout the Year
for Travel Time Reliability Estimation



Based on this conceptual framework, the FDOT analysis tool identifies specific sections and scenarios as well as estimates selected travel time reliability measures. An overview of FDOT's travel time reliability methodology appears in Figure 2.

Figure 2:
FDOT's Travel Time Reliability Methodology



Freeway Segmentation

Florida's freeway system is shown in Figure 3. The average lengths of FDOT's freeway segmentation inside urbanized areas and rural areas are about 9 miles and 36 miles, respectively. Approximately one-half of the system is ITS instrumented; primarily in the state's largest urbanized areas.

Figure 3:
Florida's Freeway System

Segmenting the state's freeway system into facility lengths in order to analyze and report travel time reliability is essential. FDOT statewide criteria for facility segmentation are based on the following criteria:

1. Strategic Intermodal System (SIS) freeway to freeway interchanges
    a. Non-SIS freeways are also a major consideration
    b. Logical extensions of SIS freeways if a short gap of freeway is missing. (This scenario occurs if a freeway terminates, and a major arterial provides connection to another freeway)
2. Non-adjacent urbanized area boundaries
    c. Transitioning and rural boundaries are also considered segmentation points
3. SIS intersecting routes
4. Other special considerations
    d. Major downtown core areas
    e. SIS multimodal hubs
    f. State boundaries.
5. Length

Although the basic unit of this segmentation system is a freeway "section" which extends from one interchange to the next, multiple sections are combined in order to analyze and report travel time reliability at a "facility" level. An analyst could alternatively select different termini from FDOT's initial segmentation. Based on the segmentation criteria, beginning and ending milepost numbers for interchanges are obtained from FDOT's Roadway Characteristics Inventory. FDOT's travel time reliability model is then applied.

Travel Time Reliability Model

FDOT's travel time reliability model features four major causes of congestion:

- recurring congestion,
- incidents,
- weather, and
- work zones.

Input data are obtained from the FDOT roadway and level of service databases and typical hourly volume distributions. Hourly and directional distributions of traffic are applied to the freeway's annual average daily traffic (AADT) to determine demand to capacity ratios for each hour. The analysis considers each scenario for each hour in the day. Travel time under recurring traffic congestion conditions is based on planning applications of the HCM and travel time estimation models developed using microscopic simulation. From this information, the travel time for each section by hour and direction is estimated.

With respect to incidents, the travel time reliability model uses probability of blocking incidents and ratio of non-blocking to blocking incidents which is based on the 2007 Sunguide FDOT District 4 Report[3]. Using data from the FDOT Crash Analysis Reporting System (CARS), the probability of a blocking incident per lane-mile per year for each section is determined for four

different scenarios: no rain and no work zone; rain and no work zone; no rain and work zone; and rain and work zone.

The weather component of the model consists of three conditions: clear weather, light rain and heavy rain. Clear weather is considered to be no rain or a trace of rain less than 0.01 inch per hour. Light rain and heavy rain are characterized as 0.01-0.5 and greater than 0.5 inches per hour, respectively. The state is divided into three (with an option for more) regions with a model developed for each region which predicts frequency of rain for different rain intensities. These models were developed based on a five-year period dataset (January, 2006 – December, 2010). To obtain the rainfall distribution for a particular freeway section, the analyst obtains average rainfall for the respective zip code, and uses the corresponding regional model to obtain frequency of no rain, light rain, and heavy rain. The probability of clear weather, light rain and heavy rain is determined for each hour and then applied to the applicable freeway. Speed reductions are 6 percent for light rain and 12 percent for heavy rain.

With respect to work zones, the model assumes impact in terms of capacity reduction would be similar to that of an incident for the applicable portion of the facility. There is currently no data available regarding the probability of having a work zone on each segment for the entire SIS. Thus, the default value used was 3 percent between 10 p.m. and 7 a.m., and 1 percent for the remaining hours. When better models become available regarding the impact of work zones on travel time as well as the probability of a work zone on each section of the SIS, these can be easily inserted into the existing tool.

Probability distributions are developed for each of the possible combinations of recurring congestion, incidents, weather and work zones. For example, the probability of an occurrence during 5-6 p.m. might be 80 percent heavily congested, 1 percent a lane blocking incident would occur, 10 percent rain probability and 100 percent no work zone. This would make the probability of occurrence for this scenario 0.08 percent (0.80*0.01*0.10*1.0). Then the travel times by hour, including spillover effects, by section are aggregated to the facility level for analysis and reporting purposes.

Analysis and System-Wide Reporting

The primary uses of Florida's system level mobility performance measures have been for reporting highway system mobility trends over time and to illustrate additional resource needs. FDOT's preferred reporting travel time reliability statistics are the percentage of trips arriving on-time and the planning time index. For the FDOT analysis tool, on-time is the amount of time it would take a vehicle to traverse the facility length no less than 10 miles per hour below the free flow speed within the relevant time period. Free flow speed is the posted speed limit plus 5 miles per hour. The planning time index is calculated based on the 95^{th} highest travel time for the relevant time period divided by the free flow travel time.

Since the inception of the model, reporting other metrics has been part of the model. The model is also flexible enough to incorporate some of the latest research which may make use of the

combination of the planning time index and an on-time arrival threshold into one overall travel time reliability index[4].

In urbanized areas, FDOT recommends the use of 4:00-7:00 p.m. time period because that is the heaviest travel peak period. However, most of FDOT's mobility measures are based on a peak travel hour. Therefore, for urbanized areas the 5:00-6:00 p.m. peak hour could be used instead of FDOT's primary peak period of 4:00-7:00 p.m. A specific hour may also be desirable for freight haulers.

FDOT began reporting travel time reliability in its 2011 *Highway Data Sourcebook*[5]. 2010 was the most recent year with a complete set of traffic and highway data the travel time model could be applied. FDOT's traffic and highway data inventories were sufficient for the model to calculate travel time reliability results as far back as 2005 to show trend lines.

Figures 4 and 5 appear in the 2012 edition of the Sourcebook. Figure 4 shows the on-time arrival approach for the years 2005 through 2009. The on-time arrival statistics are aggregated using mileage as the weight. Figure 5 presents travel time reliability results in terms of the planning time index approach while keeping the other assumptions in Figure 4 consistent.

Figure 4:
Percent Trips with On-Time Arrival

	2005	2006	2007	2008	2009
Statewide	97.7%	97.2%	97.7%	97.3%	98.1%
7 Largest Counties	94.0%	92.8%	94.5%	92.8%	94.9%
Oth. Urbz. Areas	98.4%	97.7%	97.9%	97.9%	98.8%
Non- Urbz.	99.8%	99.8%	99.8%	99.8%	99.9%
Turnpike	98.9%	98.5%	98.3%	98.8%	99.0%

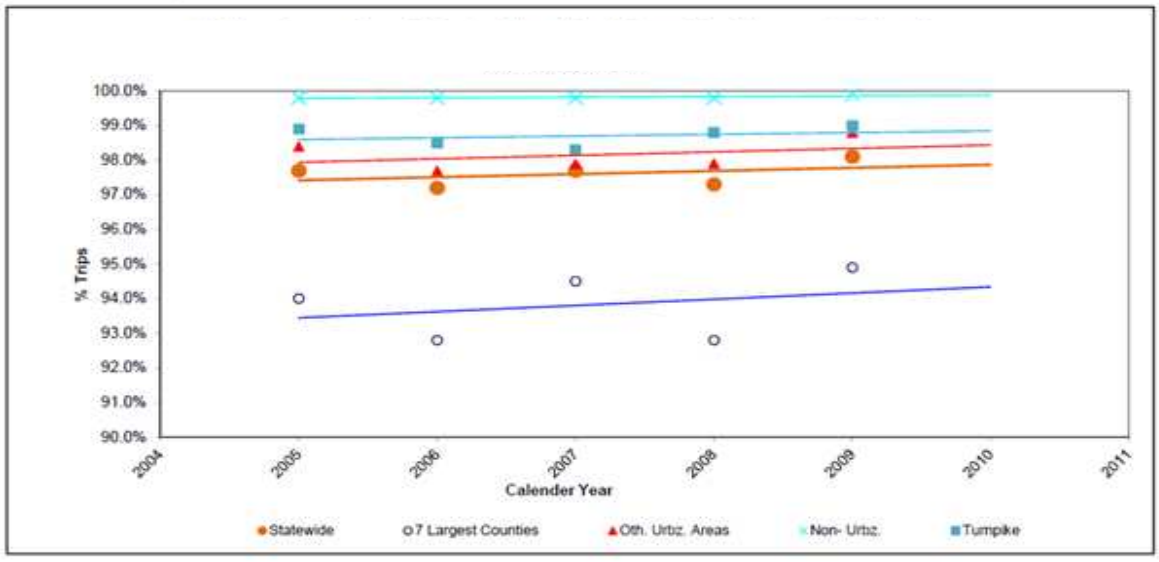
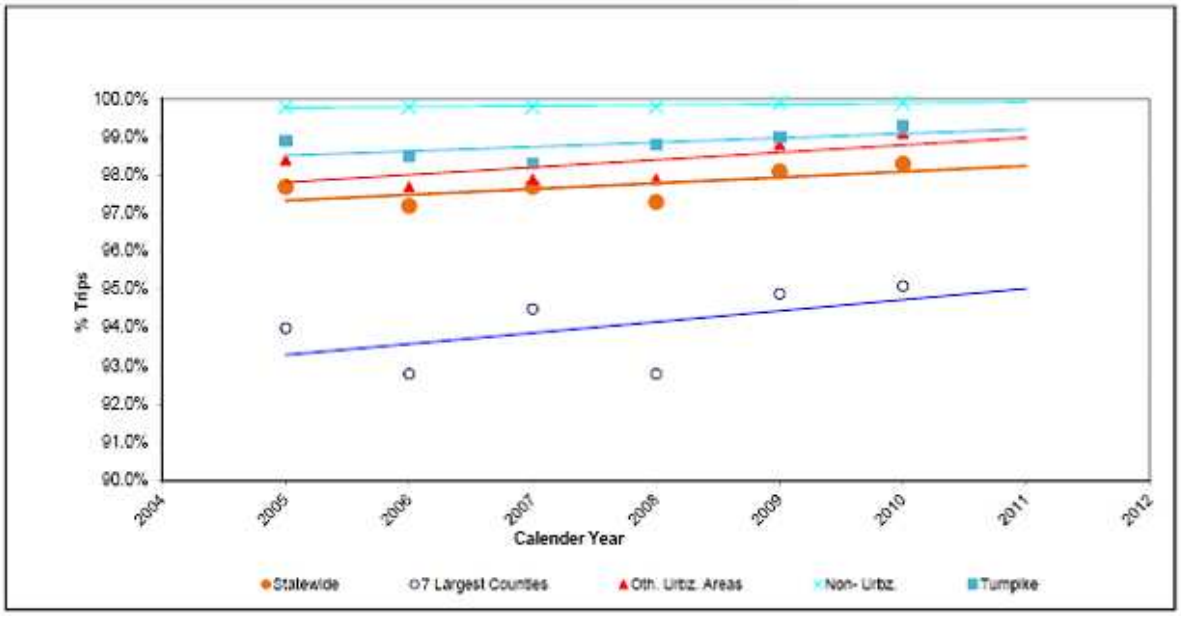


Figure 5:
Planning Time Index

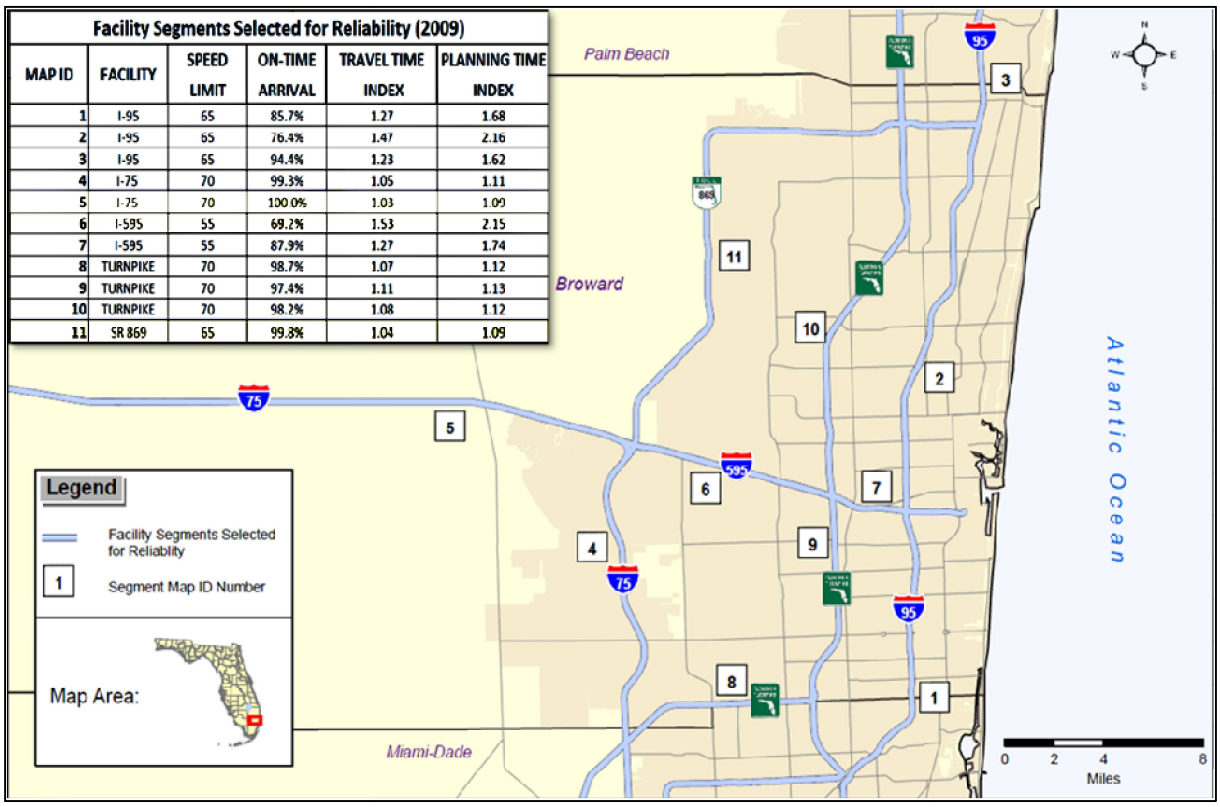
	2005	2006	2007	2008	2009	2010
Statewide	97.7%	97.2%	97.7%	97.3%	98.1%	98.3%
7 Largest Counties	94.0%	92.8%	94.5%	92.8%	94.9%	95.1%
Oth. Urbz. Areas	98.4%	97.7%	97.9%	97.9%	98.8%	99.1%
Non- Urbz.	99.8%	99.8%	99.8%	99.8%	99.9%	99.9%
Turnpike	98.9%	98.5%	98.3%	98.8%	99.0%	99.3%



Looking at the figures, at a statewide level no surprising results occur. Florida's least reliable freeways are in the largest urbanized areas. However, even in these areas travel is quite reliable ranging from 93 to 95 percent.

To depict the capabilities of the model, Figure 6 illustrates travel time reliability on the freeway system of Broward County (Ft. Lauderdale/Hollywood), containing approximately 1,750,000 people.

Figure 6:
Travel Time Reliability in Broward County



Project Priority and Policy Decisions

In addition to system-wide reporting, another potential planning use of the travel time reliability model is in helping set project priorities. FDOT has a Strategic Investment Tool (SIT) to aid in the selection process. It is an interactive tool allowing users to calculate and report performance measures relating to Florida's Strategic Intermodal System (SIS) objectives. The Systems Planning Office at FDOT has already begun the process of proposing methods for incorporating the travel time reliability results into the SIT. The biggest concern has been lack of data on non-freeway facilities, as the SIS is not restricted to just freeways. FDOT and the University of Florida have research projects scheduled through 2014 to expand the travel time reliability model to include arterials. Recognizing FDOT's efforts in the area of project priority, the SHRP 2 L05 project on *Incorporating Reliability Performance Measures in the Planning and Programming Processes*[6] intends to feature FDOT as a best practice example.

Travel time reliability is primarily seen as a mobility performance measure closely connected to operational improvements, linking systems planning and operations. FDOT's travel time reliability model was developed to evaluate the impacts of various ITS applications on travel time reliability. For example, Florida's Road Rangers program is a freeway service patrol designed to assist disabled vehicles along congested freeway segments and relieve peak period non-recurring congestion. The travel time reliability model specifically addresses incident

duration that exceeds one hour, as well as the impact of the Road Rangers program. The impact of other such policies or initiatives to reduce incident times can also be evaluated by incorporating it into the methodology, as additional data is available. Another example is the evaluation of the work zones impacts and the network-wide effects of associated policies. FDOT frequently limits working hours for work zones for freeways in urbanized areas to nighttime hours. In the travel time reliability model, implementation of the policy can be evaluated by making the probability of work zone zero during the day.

Concluding Perspectives

Some advantages of a predictive model include addressing "what if" scenarios, effectiveness of programs and policies, as well as providing projections into the future. It can also be used to evaluate other transportation systems management and operations strategies. Furthermore, the model described in this paper can be used to analyze and track travel time reliability for an entire freeway system, regardless of ITS infrastructure. To address travel time reliability, states and others should make use of real-time travel data and a predictive model.

Although recognized as one of the most important mobility performance measures, there is not a nationally accepted approach for the calculation of travel time reliability. This limits its potential use in the planning, design and operations of U.S. highways. Together with the FDOT model, the SHRP 2 L08 project may go a long way in addressing this problem. Given that the HCM and its analytical methodologies are nationally accepted for highway capacity and quality of service, incorporating travel time reliability into it may significantly elevate it as a mobility performance measure.

Most mobility performance measures are oriented towards the personal auto traveler. Nevertheless, the single most important quality of service measure for freight is probably travel time reliability. On-time arrival is essential for deliveries and to maintain "just in time" inventories, and is widely used as a performance measure for all modes. Development and use of travel time reliability should be viewed as the primary mobility performance measure for freight movement.

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