AN OVERVIEW OF TRAVEL-TIME RELIABILITY: ROADWAY USER NEEDS AND PERFORMANCE MEASURES TOWARDS A MORE RELIABLE NETWORK

Diego Bastos de Franca, M.Sc.
Kittelson and Associates, Inc
John D. Zegeer
Kittelson and Associates, Inc

RESUMO
Este artigo tem como objetivo principal discutir o estado da prática relacionado à pesquisa em variabilidade do tempo de viagem e seus elementos como: relação entre as causas de congestionamento e tempos de viagem; necessidades dos diferentes usuários da malha viária e medidas de desempenho. Aqui é discutido que as principais causas da variabilidade em tempos de viagem é devido ao desequlíbrio de demanda e oferta da malha e aos congestionamentos resultantes desse desequilíbrio. A variabilidade do tempo de viagem pode ser melhorada através do aperfeiçoamento da coleta e disseminação de dados, aliado com o trabalho em conjunto de entidades da área e a adoção de objetivos em comum. Os dados coletados devem ser utilizados com o objetivo de equilibrar e gerenciar a demanda e a capacidade multimodal do sistema de maneira eficaz. Ao mesmo tempo, essa informação deve ser repassada para os usuários afim de que os mesmos possam escolher a melhor forma de viagem dada a percepção dos mesmos dos custos de tempo e confiabilidade.

ABSTRACT
This paper provides a state-of-the practice overview of travel-time reliability research basic elements such as: sources of congestion and their relationship with travel times; different roadway users' needs and performance measures. It is discussed that the basic causes of unreliable travel times are an imbalance between demand and capacity and the congestion that results from too much demand for a given level of capacity. Travel-time reliability will improve through the collection and use of more and better information, together with agency integration and adoption of shared goals. The application of that information must be used to balance and manage demand and transportation system (multi-modal) capacity more effectively. At the same time, information needs to be provided to travelers so that they can make informed choices about their best travel option, given their own values of time and reliability.

1. AN INTRODUCTION TO TRAVEL-TIME RELIABILITY

Travel-time reliability is defined as the variation in travel time for the same trip from day to day ("same trip" implies the same purpose, from the same origin, to the same destination, at the same time of the day, using the same mode, and by the same route). If variability is large, then the travel time is considered unreliable because it is difficult to generate consistent and accurate estimates of travel time. If there is little or no variation in the travel time for the same trip, then the travel time is considered reliable.

Travel time reliability is important because when travel times are variable or unreliable, it is more difficult for travelers and shippers to plan their travel, often forcing them to pay a price of allowing extra time to protect themselves against the uncertainty of arrival times. This may lead to ineffective or even counter-productive travel decisions that waste time and money.

The basic causes of unreliable travel times are an imbalance between demand and capacity and the congestion that results from too much demand for a given level of capacity. Once congestion forms, travel times become more variable (less reliable) and thus less predictable. Moreover, congested facilities do not have the resilience to accommodate unexpected travel interruptions, leading to flow breakdowns and serious degradation of reliability.

Travel times vary from one day to the next because traffic-influencing conditions differ from day to day. There are seven sources of congestion that influence travel-time reliability. They are as follows:

1. Fluctuations in normal traffic
2. Physical bottlenecks
3. Special events
4. Traffic incidents
5. Weather
6. Traffic-control devices
7. Work zones

These seven sources of congestion can be aggregated into a) factors that affect the demand for roadway capacity (including normal traffic demand levels, routine fluctuations in that demand, and special events that cause abnormal levels of demand); and b) factors that affect the functional capacity of any given roadway or set of roadways (bottlenecks, incidents, bad weather, work zones, and traffic controls).

There are two categories of actions we can use to respond to these factors. The first category, aimed at influencing the demand for travel, includes the use of travel information to influence when, where, how, and how much travel (both personal travel and freight movement) occurs. Included in this category is the application of pricing mechanisms to influence travel behavior as well as to generate funds needed for operating, maintaining, and improving the transportation system.

The second category includes actions to increase roadway capacity, such as:

- expansions or additions to highway facilities
- the application of better operational and technical systems to maximize the performance of existing infrastructure
- advances in technology and procedures that more quickly restore capacity that has been lost as a result of disruptions (incidents, bad weather, work zones)
- the optimal use of existing transportation system capacity controlled by other transportation agencies, firms, or individuals (This can be accomplished by providing incentives for mode shifts from single-occupant vehicles to multi-occupant vehicles and more effective use of alternative rights-of-way.)

The types of solutions that can be brought to bear on the demand/capacity imbalance depend on whether congestion can be anticipated or results from unexpected events. Where volume routinely approaches and/or exceeds capacity (recurring congestion), demand management and capacity increases are likely to be effective in improving reliability. In locations where unexpected disruptions cause the majority of congestion, techniques that detect disruptions and facilitate rapid recovery from those events are more likely to be effective.

Next, the key findings of this research effort in terms of characterizing travel-time reliability elements and different roadway user needs are presented.

2. TRAVEL-TIME RELIABILITY BASIC ELEMENTS

The flow diagram in Figure 1 shows the travel-time reliability interactions among roadway users, agencies, and the roadway network. This diagram illustrates the decision-making process used by passenger travelers and freight movers for travel, given information on travel-time reliability. In addition, it illustrates the agency decision-making process given various disruptions and its goals for performance measures.

The elements of this interaction are numbered in Figure 1 and are described in this paragraph. The two roadway user types - (1) passenger travelers and (2) freight movers - have transportation needs. According to these needs, these users make decisions on their trips and estimate an "expected travel time." While both user types undertake their trips on the roadway network (3), the expected travel time is affected by delays from disruptions and from agency operational strategies. The actual travel time is collected through ITS device or traffic counts. The roadway performance data (4) are analyzed and translated to performance measures. The long-term performance measures are reported regularly and compared to the agency goals (5). The near-real-time performance measures are a direct input for the real-time agency decision-making. The disruptions (7) directly affect the roadway network (3) performance. Because the target of agencies (5) is to reach their goals, agency response and monitoring of the roadway network (3) is a process that considers the inputs from the performance measures and from the disruption measures. Another way to minimize the difference between actual and expected travel time is to disseminate information (8) from the agency (5) or from the private sector (6) to passenger travelers (1) and freight movers (2) to assist them in their travel decision-making.

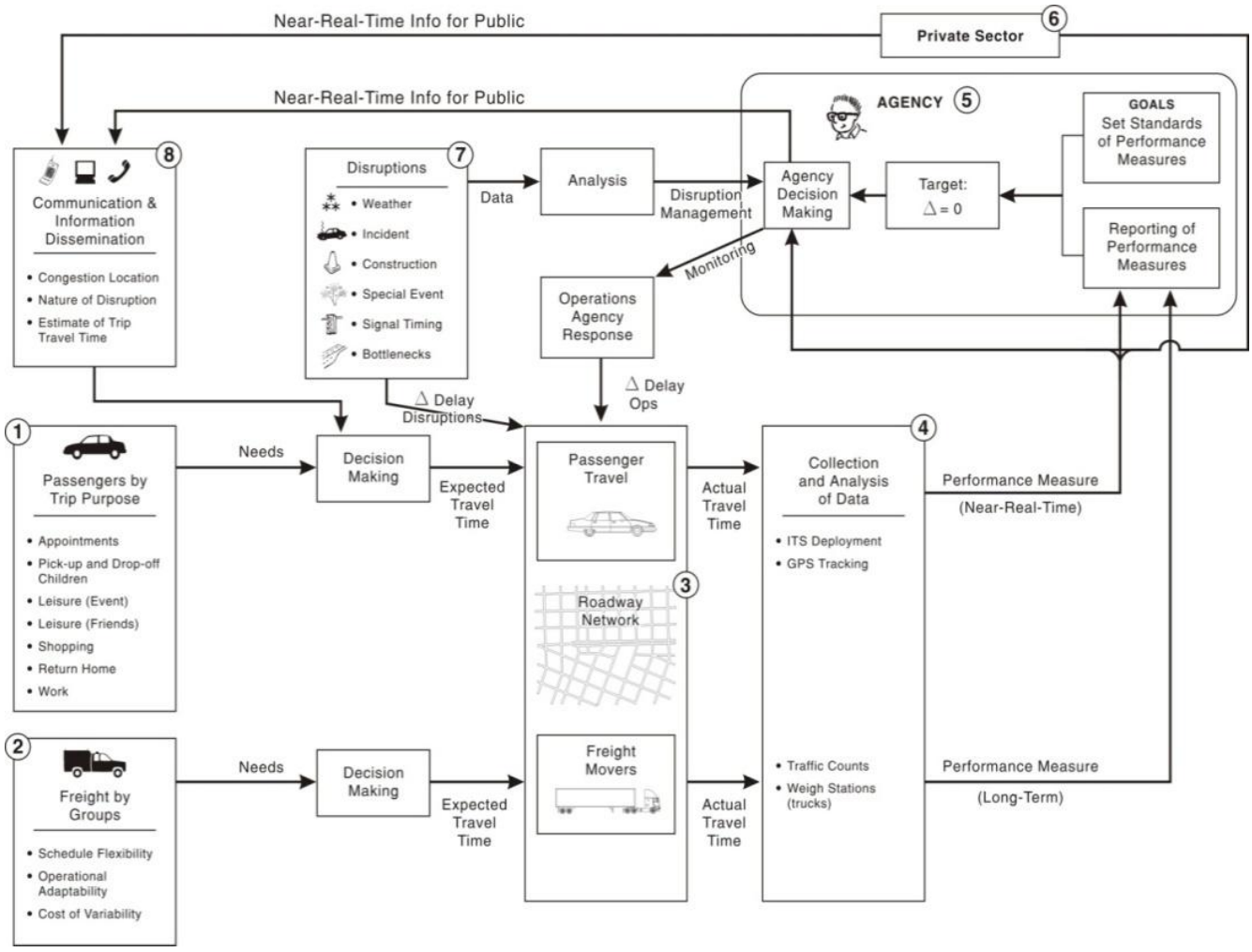

Figure 1: Travel-time Reliability Interactions among Roadway Users, the Agency, and the Roadway Network

2.1. Travel-Time Reliability and Congestion

Travel time varies from one day to the other because the traffic-influencing conditions differ from day to day. While in general, higher congestion leads to higher unreliability in travel times there may be instances where a facility is reliably congested and hence travel time, although high, can be predicted with a high degree of certainty. The results of SHRP2 L03 (2009) indicate that the background traffic volume is the overriding factor affecting reliability. Therefore, strategies and treatments that mitigate congestion or should be helpful in reducing the variability in travel time. A brief summary of the seven sources of congestion and their contribution to congestion follows.

1. **Physical Bottlenecks**: Bottlenecks are sources of congestion that occur on short segments of roadway that exhibit lower capacity than upstream segments of roadway, essentially resulting in unreliable travel. Bottlenecks commonly form either at changes in roadway geometry (e.g., lane drops), or due to crashes, or where significant traffic movements

reduce effective roadway capacity for a given number of roadway lanes (e.g., merge and weave sections).

2. **Traffic Incidents**: Traffic incidents are events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris in travel lanes are the most common incidents.
3. **Weather**: Environmental conditions can lead to changes in driver behavior that affect traffic flow. Weather events such as fog, snow, and heavy rain can negatively impact travel conditions, causing delays and congestion.
4. **Work Zones**: Construction activities on the roadway can result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane "shifts," lane diversions, reduction, or elimination of shoulders, and even temporary roadway closures.
5. **Traffic-control Devices**: Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel-time variability.
6. **Fluctuations in Normal Traffic:** Variation in day-to-day demand leads to some days with higher traffic volumes than others.
7. **Special Events:** Special events are a special case of demand fluctuations whereby traffic flow in the vicinity of the event will be radically different from typical patterns. Special events occasionally cause "surges" in traffic demand that overwhelm the system.

3. CLASSIFICATION OF USER CATEGORIES

Roadway users can broadly be subdivided into passenger travelers and freight movers. Each of these two user groups can be further classified into several categories based on (1) their socio-economic characteristics (in the case of passenger travel) or operational characteristics (in the case of freight) and (2) their context of travel. In the case of passenger travelers, the socio-economic characteristics include attributes such as income, whereas the travel context may be defined using attributes such as trip purpose and mode. In the case of freight movers, the operational characteristics include factors such as size of the fleet and just-in-time delivery, whereas the travel context may be characterized in terms such as international border crossings and long-haul versus local travel. Both groups are further described as follows:

3.1. Passenger Travelers

Research has shown that travel-time reliability is very important to passengers. In fact reliability (or consistency) in travel times appears to be even more important than the *magnitude* of the travel times. ("You expect that it will take 15 minutes and it takes 15 minutes – it does not matter that it was a mile for 15 minutes if you anticipated it.") If it is known in advance that the travel times are going to be long, then the users are able to plan for it. However, if the travel time turns out to be longer than expected, then it could disrupt their plans in different ways depending on the nature of the trip. Finally, it is useful to note that people do not appear to be overly concerned about travel times being *less* than the anticipated values.

This research effort has demonstrated that the **actions** taken by the travelers to deal with unreliability and the **consequences** when the travel time turns out to be greater than the anticipated value were discussed for seven trip purposes. The importance of travel time reliability for the different trip purposes (currently and in the future) can be inferred as shown in Table 1.

3.2. Freight Movers

The consequences of variability are different for various companies as a function of their ability to change their operations, their work environment, and the level of flexibility provided to them by shippers. This research effort has shown that shippers are relatively insensitive to the problem of reliability and provide carriers with little flexibility. Exposure to variability is greater in urban areas, areas with congestion, and for companies that rely primarily on arterial travel and those that need to make many scheduled deliveries in one day. To address travel-time variability, carriers can either change their own operations, or ask their customers to make changes (to delivery windows or to delivery times). A carrier's relative exposure to variability is affected by regional characteristics, for example:

- Quality of Infrastructure
    - This describes (in general terms) the ability of regional infrastructure to accommodate variable conditions such as increased traffic volumes or severe weather.
        - Resilient infrastructure
        - Infrastructure upon which service breaks down quickly with varying conditions
- Environmental Conditions
    - This describes the exposure to variability in travel times. For example, an urban region will typically experience more congestion than a rural environment.
        - Urban
        - Rural.
- Weather Conditions
    - This describes the typical weather patterns in a region, which will affect the exposure to variability in travel times.
        - Frequent weather disruptions
        - Infrequent weather disruptions.

Carriers with greater exposure will exercise a stronger response to variability due to their increased frequency of disruption. However, these are not characteristics of the carrier, rather characteristics of the region in which they operate.

Table 1: Summary of Actions and Consequences of Unreliability for Passenger Travelers

Trip Purpose	Importance of Reliability	Actions to Deal with Unreliability	Consequences of Unreliability
Appointments (medical, personal services, etc.)	High	Schedule appointments in off-peak periods. Allow more time for travel, especially for peak-period appointments and longer distance trips. Organize day around appointment (medical) Change routes if experienced travel time is high.	Missed appointment, and possible missed/late fee. Wait for next available opening – affects travel for rest of day. Several days before next another appointment. Pressure on the travelers.
Pick-up and Drop-off Children	High	Allow more time than ideal for the trip. Ask someone else to escort child. May affect residential-location and school choices.	Child may miss a class. Anxiety keeping child waiting. School / day-care may charge fee for late pick-up or even call police if consistent late.
Leisure (Movies, Sports Events, etc.)	Medium-Low	Schedule during off-peak periods.	Get stressed – not desirable as the trip is for "leisure". Miss event if it is a one-time-only event like sports. Forfeit money paid for tickets. More difficulty in finding parking.
Leisure (Visit Friends, etc.)	Low	Call and reschedule or meet somewhere else. Shorten planned visit in order to meet the start time for the next scheduled event.	Feeling of guilt for wasting someone else's time.
Shopping	Low	None, especially if unplanned or short trip. Choose off-peak times. Abandon trip or go to a different store. Shorten time spent shopping, and possibly limit the number of items shopped for.	None (as long as the groceries are not immediately needed). Affects the subsequent trips planned for the day. May miss the sale.
Return-home	High-Medium	Stop and take a break. Problematic as one may not be able to leave earlier to allow for unreliability in the return-home trip. Choose travel time for the trip *to* the activity so that the travel *from* the activity to home is reliable.	Tired and stressed (especially if kids are travelling). Children needing attention at home. Pets needing attention at home. Ice cream bought at the grocery store can melt!
Work	High	Allow more time than ideal for travel (especially if the work schedule is fixed). Prepare for the day in advance & wake up early. Affects the residential-location choice.	Loss in pay and other types of penalties. Poor reflection. Particular cause of concern in the current economic times.

4. TRAVEL-TIME RELIABILITY PERFORMANCE MEASURES

Performance measures describe the physical performance of a roadway with regard to travel demand and a variety of other factors both within and outside of the transportation agency's control. Within physical roadway performance measures, the primary focus is on the fluctuation of travel time across the year given recurring and non-recurring changes in demand. Demand and travel times should be tracked on a continuous basis to develop a comprehensive picture of the quality of service along a particular facility.

It is important to identify travel-time performance measures that are relevant to travelers and freight carriers. The performance measures presented below are focused on travel time, which is influenced by fluctuations in both demand and supply (i.e., maintenance, utility work, snow and

ice, etc.). The following five reliability measures were found to be most relevant to the user categories and are most widely used by transportation agencies:

- **Planning Time (95th Percentile Travel Time).** This is the length of a particular trip in minutes that a traveler should use in planning to assure arrival as scheduled (required) 95% of the time. It is calculated by computing the 95th percentile travel time for a specific trip measured over a given time period (i.e., six months or one year). This measure estimates how large delay will be during the heaviest traffic days.
- **Buffer Index.** This is the difference between the 95th percentile travel time and the average travel time, divided by the average travel time for specific trips. (The median travel time is often used.) The buffer index represents the extra time (as a multiplier of average time) that travelers must add to their average travel time when planning trips to ensure on-time arrival 95% of the time.
- **Planning-Time Index.** This is the 95th percentile travel time divided by the free-flow travel-time index. The planning-time index can also be understood as the ratio of travel time on the worst workday of the month over the time required to make the same trip at free-flow speeds. Consequently, the planning-time index represents the factor to multiply free-flow travel time to ensure on-time arrival with high probability (19 workdays out of 20 workdays per month would yield a 95th percentile measure).
- **Travel-Time Index.** This is the ratio of the average travel time in the peak period to the travel time at free-flow conditions. It is a measure of average congestion rather than travel-time reliability. Nevertheless, it is an important measure because it can be directly compared to the planning time index.
- **Percent On-time Arrival**. This is the percent of trips that are completed within a given target schedule. It is best suited for tracking the performance of scheduled trips (such as buses and light rail).

While the Buffer Index shows the multiplier of the *average* travel time necessary to achieve high probability of on-time arrival (high reliability), the Planning-Time Index shows the multiplier of free-flow travel time to assure high probability of on-time arrival. The Planning-Time Index is a useful measure during peak travel periods because it can be directly compared to the Travel-Time Index on a similar numerical scale. The Travel-Time Index is a measure of average conditions that indicates how much longer, on average, travel times are during peak periods compared to base periods when traffic is light.

The need for the five measures noted above, rather than just one, is important because travel conditions change (for both freight movers and passenger travel) from trip to trip, depending on the purpose and time of the trip. Roadway users are able to easily understand the meaning of planning time because it gives them specific guidance regarding how to adjust their trip plans to deal with unreliability. Agencies should focus on reporting and evaluating the Planning-Time Index since this measure is better understood by engineers.

All of these performance measures can and should be computed and used with multiple time periods. For example, the 95th percentile travel time can be computed for an entire peak period, or for each specific hour within that peak period. Comparing how these measures change over the

course of a day illustrates how reliability changes during the day. Tracking changes in these measures by time of day describes whether peak spreading is occurring, what benefits travel demand management programs that change when employees come and go to work are likely to provide in terms of travel reliability improvements, and when incident response resources are most needed.

Travel-time reliability performance measures also play a key role in evaluating the effectiveness of ITS strategies used to provide traveler information and reduce congestion. In a funding-restricted environment, it is important that agencies wisely invest their scarce resources on ITS technologies that will improve the system performance and capacity at a minimum cost. With the performance measure indexes, and effective tools to forecast them, agencies will be able to quantify the impact of the deployed ITS technologies and, therefore, prioritize investments in the future.

5. POTENTIAL PERFORMANCE MEASURES FOR AGENCY USE

Within physical roadway performance measures, the primary focus is on the fluctuation of travel time across the year given the demand that occurs. Demand and travel times should be tracked on a continuous basis to develop a comprehensive picture of the quality of service along a particular facility. The following five measures are aimed at characterizing roadway performance:

- The mean travel time along defined segments of the roadway system at specified times of day, days of the week, and times of year;
- The 80thpercentile travel time of defined segments of the roadway system at specified times of day, days of the week, and times of year;
- The 95th-percentile travel time of defined segments of the roadway system at specified times of day, days of the week, and times of year;
- The percentage of time and/or trips that each of those defined segments of the roadway system operate at lower than a reporting standard adopted by the roadway agency; and
- The traffic volume on defined segments of the roadway system at specified time of day, day of the week, and time of year.

For reporting purposes, the 95th percentile travel times can be reported as Buffer Time, Planning Time, Buffer Time Indices, or Planning Time Indices, depending on the specific question being answered. The 80th percentile travel times can also be presented in similar formats. The first three measures characterize the variability of travel occurring on the roadway system. Three different aspects of that travel (mean condition, 80thpercentile, and 95th percentile) are tracked to describe the variability experienced on the roadway segment under study. The need for three statistics rather than one relate to the fact that the importance of travel-time reliability changes (for both freight movers and passenger travel) from trip to trip, depending on the purpose of that trip. For some trips, arriving on time (prior to some deadline) is extremely important, and therefore a traveler might plan with the 95th percentile travel time in mind. For other trips, on-time arrival is less important. A weekend trip to the mall is an example of a trip for which information about the mean travel time is adequate. In many commercial situations where penalties for late delivery must be balanced against the cost of unproductive use of labor and equipment, the 80th percentile

travel time may be a more useful statistic. Of course, for trucking firms that deliver highly time sensitive cargoes, the 95th percentile is more likely the travel time used for planning purposes.

5.1. Travel Difference in Passenger Travelers and Freight Movers

As discussed in previous sections, when considering roadway performance, it is important to note that "freight mover performance" is likely to be different than "passenger traveler performance" on a given roadway at a given time. For example, trucks often avoid certain roads or peak congestion periods, which make point-to-point travel times different because the routes used for those trips may be different. In addition, the pick-up and delivery schedules of trucks determine when they can travel. Similarly, work schedules define when travelers must leave home on the way to work, which provides for different levels of exposure to routinely congested time periods. It is unclear at this time whether freight mover reliability should be reported differently than passenger traveler reliability for the same roads. Table 2 provides example performance measures for roadway users (both passenger travelers and freight movers) as well as for agencies.

Table 2: Example Performance Measures for Roadway Users and Agencies

Stakeholder	Performance related to	Performance Measure	Performance Measure depends mainly on
Roadway Users: Passenger Travelers Freight Movers	Travel Time (point to point)	Mean Travel Time	Demand, capacity
		95th Percentile Travel Time	Disruption occurrence, disruption nature, effectiveness of incident response
		80th Percentile Travel Time	
		Percentage center line miles for which real time travel information is available, and the accuracy of that data	Disruption occurrence, disruption nature, effectiveness of incident response
		Percentage of roadway mile for which disruption data are available	
		Percentage of all disruptions for which a forecast of the effects of that disruption is available	
Agency	Congestion (on a specific roadway segment)	Mean, 80th, 95th Percentile Travel Times for defined roadway segments	Demand, capacity
		Percentages of time and/or trips during which a segment operates lower than an "on-time" standard adopted by the roadway agency	"On-time" standards: Rural: Free-flow speed Urban: "Speed at maximum vehicular throughput" (~45mph) or a slower standard, if heavy congestion.
		Traffic volume operating on a segment at specified times of day, days of the week, and times of year	
		Percentage center line miles for which real time travel information is available, and the accuracy of that data	Travel demand Effectiveness of operational decisions and other management actions and policy decisions
		Percentage of roadway mile for which disruption data are available	
		Percentage of all disruptions for which a forecast of the effects of that disruption is available	

6. EFFECTIVENESS OF AGENCIES

State agencies that are actively looking to report more travel-time reliability performance measures have described a number of concerns about their ability to develop and report reliability-related performance statistics. As part of this research, staffs from several departments of transportation (DOTs) were interviewed about the issues encountered in gathering and using performance-reliability measures. The following are among their concerns:

- They lack consistent, accurate data, especially when considering their entire roadway systems.
- They lack the budgetary resources to significantly expand their current data-collection programs.
- Travel times are affected by a wide variety of factors (e.g., weather) not directly related to the roadway agency's actions, and some agencies are concerned that reporting performance measures can make an agency "look bad" when the factors that cause "bad performance" are beyond the agency's control.
- There is often only a modest link between the actions taken and the travel-time reliability changes that occur. For example, adding one more incident response vehicle to an existing team of ten vehicles may not result in dramatic changes in travel-time reliability, especially if traffic volumes grew during that same time period.
- There is resistance to the adoption of performance measures because of job concerns. As one DOT stated, "Everybody loves performance measures until it affects them."
- The lack of data means that states do not have a current baseline against which to set goals.

It is also important to note that, because specific agencies are rarely responsible for the roadway used throughout a specific trip, there is an organizational disconnect between how a traveler (person or freight shipment) views travel reliability and how any given agency views reliability. By definition, agencies are concerned with the performance of their roadways, while travelers are concerned about the entire trip – which generally uses more than one agency's roads. Until agencies are provided with incentives to work more effectively together to manage disruptions and measure the effects of those disruptions on the combined roadway system, the organizational view of their effectiveness will remain somewhat different than that of the traveler/shipper.

6.1. Developing Performance Measures and Setting Goals

Identifying performance measures is only the first step in setting performance goals. The second and more challenging step involves identifying the points at which roadway performance meets the desired goals of the transportation agencies, stakeholders, and decision makers. The act of developing performance measures and setting goals should be sensitive to the needs of stakeholders identified earlier in this report and should take into account the data limitations in developing statistics describing those characteristics.

Service industries and most government agencies, which are in reality part of the service sector, have a difficult time setting quantitative performance standards. Manufacturers, in contrast, which have control over the supply of raw materials and produce an easily-quantifiable product, can set quantitative performance standards. Transportation agencies, which provide an essential service, may be the industry that has the least control over the inputs and operating parameters. Agencies responsible for transportation management have little or no control over the scheduling of both planned special events and unplanned events like natural disasters. They have no accurate or reliable method to estimate latent demand for transportation facilities. They have no way of controlling what land-use changes will take place. And they have little or no control over the changes in travel demand that those changes will impose on the transportation system. For example, there is no way to know if there is a large family reunion planned for the coming

weekend, if there will be a massive warehouse fire during the next afternoon rush hour, or if someone will run out of gas on a road with no shoulders during the morning commute. As a result, agencies have avoided setting any kind of performance standard, particularly a quantitative one, which they know cannot be met.

As data become available to define the current baseline conditions, agencies set "goals" to improve on those conditions. In terms of travel-time reliability, this means setting goals to decrease the current mean travel times, to reduce the frequency of occurrence of extreme travel times (improve travel-time reliability), while also reducing the size of the travel-time increases when significant disruptions occur, all while accommodating increasing use of the roadway system.

Because travel times differ by time of day (peak versus off-peak) and location (large urban versus small urban versus rural), "improvements" are examined within the context of the current baseline conditions. Similarly, agency operations (e.g., the speed with which incidents are cleared, or the number of center-line miles of roadway for which real-time traveler information is available) are compared against baseline conditions. In addition, once baseline conditions are well understood, more-definitive goals can be set for those measures that describe the performance of agency actions.

Once an event/disruption occurs or is identified as "about to occur" (such as when a construction event is being planned), the ability to restore reliable travel conditions is a function of an agency's ability to quickly implement the appropriate response. This means that the agency needs to:

- Understand the nature of the event/disruption;
- Understand what actions/resources are required to deal with that event/disruption;
- Have access to the necessary resources;
- Be able to take the necessary actions (permission is a big issue here); and
- Possess the appropriate management capabilities to apply the necessary resources/actions in the right places, at the right times, and in the right way.

The quality of execution matters as much as the actual effort expended. Keys to the above tasks are the existence of institutional arrangements that allow:

- Agencies to access and share resources;
- Functional, multi-agency protocols for working together;
- Interagency working arrangements that are region-wide, not simply limited to neighboring jurisdictions;
- Training for staff to ensure that these protocols work effectively (and feedback mechanisms to correct those that are ineffective);
- Surveillance and communications systems identifying problems;
- Decision support systems that help responders take the appropriate corrective actions;
- Control systems that either increase the available functional capacity of roadways/corridors/networks or temporarily dampen travel demand within the affected area until the unreliable condition no longer exists; and

- Support for implementing significant control systems or actions (e.g., closing roadways or ramps) for short periods in response to unusual traffic conditions.

The current SHRP2 L03 (2009), SHRP2 L06 (2009) and SHRP2 L11 (Zegeer, Kittelson, Franca et al, 2011) projects focus on existing processes/techniques used by transportation agencies with respect to incorporating reliability, and were also used as input to this effort.

7. FINAL REMARKS

Since the resources necessary to massively overbuild the transportation system are and will continue to be lacking, improving travel-time reliability requires managing the transportation network at performance levels that are as close to optimum as possible. This management task cannot be accomplished without the ability to monitor the performance of the roadway system. This management task also includes an analysis function which can quantify the on-going effectiveness (in near real-time and as a result of detailed performance analysis) of each of the operational programs adopted to create a more-reliable transportation system. Thus, a key aspect of improving transportation network reliability is having the underlying management support systems that describe:

- The status and performance of the transportation system;
- The causes of unreliable travel times;
- When and where these events/disruptions take place;
- The size of the impacts these events/disruptions have on travel times;
- The effectiveness of each action taken in response to these events/disruptions; and
- Management support to continually improve operational performance.

Reporting is a good way to be aware of the agency's performance in terms of a comparison from year to year or between peers to help evaluate and improve an agency's procedures. Including reliability measures and efficiency is a new trend.

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