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THE IMPORTANCE OF TRAVEL TIME RELIABILITY WITH SPECIAL REFERENCE TO TRANSPORTATION ENGINEERING

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Abstract— **This paper proposes use of median travel time compared to mean travel time as the measure of central tendency to calculate Buffer Time Index (BTI), one of the most important measures of travel time reliability. Travel time reliability can be defined as the amount of variation in travel times that occur on a day to day basis. Therefore, in this research, relationships between traffic accidents and travel time reliability are examined, and the benefit of traffic accident reduction is calculated based on the scheduling model under travel time uncertainties. The results show the significance of traffic accident reduction for the improvement of travel time reliability.**

Index Terms— **Road network, 2.Traffic Congestion, 3.Travel time reliability, 4. Transportation system**
Area: Civil Engineering [Transportation Engineering]

I. INTRODUCTION

RELIABILITY is defined in system engineering as a probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered

1. In road network, reliability is defined as the network which can guarantee an acceptable level of service for road traffic even if the functions of some links are physically damaged or large amount of travel demand is occasionally generated.
2. Road network problems related to travel time variations are generally caused by uncertainties of traffic conditions of the network. In view of this, travel time reliability analysis has attracted the attention of researchers because of its importance compared with other network reliability measures such as connectivity reliability and capacity reliability
3. The use of travel time reliability measures is growing in recent years in various developed countries like USA and Japan

Alternate Definitions:

1. **Highway Travel Time Reliability:** The Florida Reliability Method defines percent of reliable travel as the percent of travel on a coridor that takes no longer than the acceptable travel time. Acceptable travel time is the amount of additional time beyond the expected time that a commuter would find acceptable. It is represented by a percentage (e.g., 5% above the expected travel time). To calculate the threshold, the median travel time across a corridor for a specific time period and the percentage of the median travel time are added together.
2. **Total Trip On-Time Performance** combines travel times and wait times. According to this measure proposed by Henderson, Adkins, and Kwong, a transit vehicle is late if actual travel time plus actual wait (which is half the headway) exceeds the scheduled travel time plus scheduled wait by more than 5 minutes. Passengers are late if

(Actual Travel Time + Avg Actual Wait) – (Sch'd Travel Time + Avg Sch'd Wait) > 5 minutes

Travel time reliability is an increasing concern of travelers, shippers, and businesses. Recent advances in data collection mean that travel time reliability can now be quantified. This report provides guidance in answering the following questions:

- What is travel time reliability?
- Why is travel time reliability important?
- What measures are used to quantify travel time reliability?
- What are the steps for developing travel time reliability measures?
- Who is using realiability measures?

Travel time is understood as the time elapsed when a traveler displaces between two places in a network. Its duration is related to several factors including but not limited to: characteristics of the driver, and the vehicle; interaction of drivers in the network (e.g. heterogeneity in other drivers and their vehicles); traffic regulations, and traffic management systems; traffic incidents (e.g. traffic signal failure, vehicular crashes); and weather patterns. Thus, travel time is likely to be dissimilar for similar trips (i.e. same spatial trajectories). This underlines the need to think of travel time in terms of frequency, and not just of magnitude. In other words, travel time is defined as a statistical distribution, where the statistics of the (unpredictable or uncertain) variations are thought to exhibit statistical regularity. In this way, travel time reliability can be defined as a measure of the dispersion (or spread) of the travel time distribution. It should be noted that in the transportation research literature Value of Travel Time (un)Reliability is used interchangeably with Value of Travel Time Variability. The basic idea is that low (high) dispersion means high (low) reliability.

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The economic benefits from improved travel time reliability are appearing more commonly in benefit-cost analyses. There are a number of different potential causes of travel time reliability that trace their source at both the demand side (e.g. travelers' heterogeneous behavior), and supply side (e.g. traffic signal failure) of a transportation system.

To incorporate travel time reliability in benefit-cost analysis, the following are needed:

- A measure for travel time reliability
- A value for reliability
- A method for predicting future reliability
- A method for estimating changes in reliability due to a project.

For the former, the study presents a novel approach to characterizing different types of travel time variability reflected in detailed travel time data collected across different vehicles and days. In particular, the study proposes a compound Gamma distribution that captures both vehicle-to-vehicle and day-to-day variability in modeling travel time reliability. The proposed model, termed Gamma-Gamma distribution, is analytically derived in a straightforward manner by using a specific property of observed travel time data, namely, a linear relation between the standard deviation and mean of distance-normalized travel time. The main advantage of the Gamma-Gamma model is its ability to recognize different variability dimensions reflected in travel time data, and clear physical meanings of its parameters in connection with vehicle-to-vehicle and day-to-day variability. As such, the model provides a systematic means of quantifying, comparing and assessing different types of variability, which is important in understanding travel time characteristics and evaluating various transportation interventions that affect reliability.

What is travel time reliability?

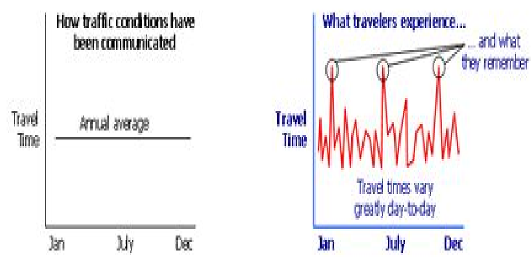
Few people will dispute the fact that traffic congestion is common in many cities in the United States. In these cities, drivers are used to congestion and they expect and plan for some delay, particularly during peak driving times. Many drivers either adjust their schedules or budget extra time to allow for traffic delays. But what happens when traffic delays are much worse than expected? Most travelers are less tolerant of unexpected delays because they cause travelers to be late for work or important meetings, miss appointments, or incur extra childcare fees. Shippers that face unexpected delay may lose money and disrupt just-in-time delivery and manufacturing processes.

In the past, we have communicated traffic congestion only in terms of simple averages (left side of Figure 1). However, most travelers experience and remember something much different than a simple average throughout a year of commutes (right side of Figure 1). Their travel times vary greatly from day to day, and they remember those few bad days they suffered through unexpected delays.

Usage Information

Travel Time Reliability is primarily used by travelers -- more specifically, commuters and others who need to get to their destination at a certain time. In studies it has been shown that transit patrons choose certain modes based on travel time reliability. The measures used by traffic and transportation organizations may not be appropriate for transit. However, their methods for collecting the data may be of value.

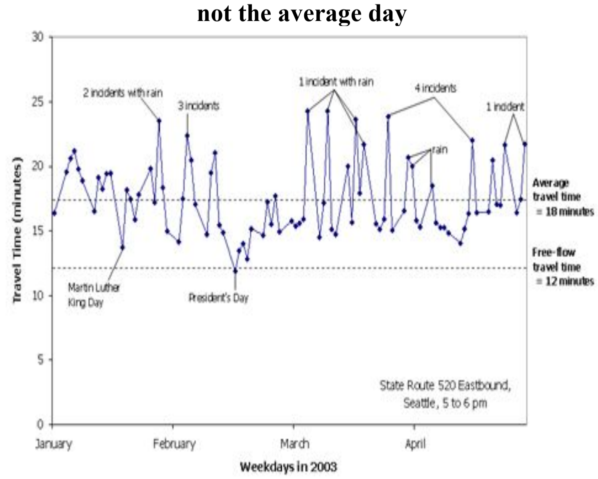
Figure 1: Averages do not tell the full story



In other words, commuters have to build in a time cushion or ***buffer*** to their trip planning to account for the variability. If they build in a buffer, they will arrive early on some days, which is not necessarily a bad thing, but the extra time is still carved out of their day—time they could be using for other pursuits besides commuting..

Figure 2 further illustrates travel time reliability with data from a major commuter route in Seattle, Washington. If there is no congestion on this route, travel times are about 12 minutes (e.g., see President's Day in the figure). On all other weekdays, the average travel time was 18 minutes, or an average speed of 40 miles per hour (mph). But when traffic incidents and weather combine to cause unexpected delay, it could take nearly 25 minutes, or 39 percent longer. Commuters who travel this route must plan for this variability if they want to arrive on time—the average just will not do. If they plan their commute based on the average travel time, they will be late half the time and early the other half of the time.

Figure 2. Commuters plan trips based on the worst days, not the average day



Source: Traffic Congestion and Reliability: Trends and Advanced Strategies for Congestion Mitigation, September 1, 2005, available at http://ops.fhwa.dot.gov/congestion_report/.

MEAN-VARIANCE

It is similar to the risk-return models in finance, and it was originally introduced into travel demand modeling by Jackson and Jucker (1982). It is assumed that a decision-maker's objective is to minimize the sum of two terms (both assumed to be sources of disutility): expected travel time, and the travel time variability. The expected travel time is represented by a measure of centrality (e.g. mean) of the travel time distribution, and the travel time variability as a measure of dispersion of the travel time distribution. The statistical measure of centrality is typically the mean, and the measure of variability is the standard deviation. Hence, the name of the framework. Other measures have been used in the literature for dispersion such as interquartile range, differences of percentiles (e.g. 90th percentile and median). The median have been used for centrality as well.

This approach allows the estimation of the *Value of Travel Time Reliability* (also referred as the *Value of Travel Time Variability*). This value represents the travelers' monetary weight for reducing variability (i.e. improving reliability). In addition, the *Reliability Ratio* is defined as the ratio of the value of travel time reliability, and the value of travel time savings. This ratio permits estimation of the Value of Reliability, especially when only the Value of Travel Time Savings is known.

Several drawbacks exist with this approach. For example, it is assumed that decision-makers desire to avoid similarly all forms of variability; only an estimate is computed for the dispersion measure in the model. In addition, researchers have yet to agree on the appropriate measure of travel time variability. The most common dispersion measure is standard deviation.

Recent research in this framework has focused on the inclusion of risk attitudes, and accounting for heterogeneity in the value of reliability (i.e. the value of reliability is different across the population).

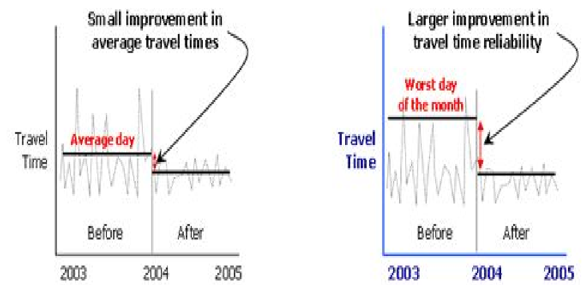
Furthermore, most researchers and practioners agree that the standard deviation (or coefficient of variation) of travel time is the measure of reliability most applicable to benefit-cost analysis. However, there are compounding issues, such as the need for travelers to include a buffer time that may have a lower value of reliability.

Why is travel time reliability important?

Travel time reliability is significant to many transportation system users, whether they are vehicle drivers, transit riders, freight shippers, or even air travelers. Personal and business travelers value reliability because it allows them to make better use of their own time. Shippers and freight carriers require predictable travel times to remain competitive. Reliability is a valuable service that can be provided on privately-financed or privately operated highways. Because reliability is so important for transportation system users, transportation planners and decision-makers should consider travel time reliability a key performance measure.

Traffic professionals recognize the importance of travel time reliability because it better quantifies the benefits of traffic management and operation activities than simple averages. For example, consider a typical before-and-after study that attempts to quantify the benefits of an incident management or ramp metering program. The improvement in average travel time may appear to be modest (left side of Figure 3). However, reliability measures will show a much greater improvement (right side of Figure 3) because they show the effect of improving the worst few days of unexpected delay.

Figure 3. Reliability measures capture the benefits of traffic management



Measures are used to quantify travel time reliability:

The measurement of travel time reliability is an emerging practice; however, a few measures appear to have technical merit and are easily understood by non-technical audiences. Most of these measures compare days with high delay to days with average delay. The four recommended measures: 90th or 95th percentile travel time, buffer index, planning time index, and frequency that congestion exceeds some expected threshold, are explained below.

Perhaps the simplest measure of travel time reliability is ***90th or 95th percentile travel times*** for specific travel routes or trips, which indicates how bad delay will be on the heaviest travel days. The 90th or 95th percentile travel times are reported in minutes and seconds and should be easily understood by commuters familiar with their trips. For this reason, this measure is ideally suited for traveler information. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. It is also difficult to combine route or trip travel times into a subarea or citywide average. Several reliability indices are presented below that enable comparisons or combinations of routes or trips with different lengths.

The ***buffer index*** represents the extra buffer time (or time cushion) that most travelers add to their average travel time when planning trips to ensure on-time arrival. This extra time is added to account for any unexpected delay. The buffer index is expressed as a percentage and its value increases as reliability gets worse. For example, a buffer index of 40 percent means that, for a 20-minute average travel time, a traveler should budget an additional 8 minutes (20 minutes × 40 percent = 8 minutes) to ensure on-time arrival most of the time. In this example, the 8 extra minutes is called the ***buffer time***. The buffer index is computed as the difference between the 95th percentile travel time and average travel time, divided by the average travel time.

This formulation of the buffer index uses a 95th percentile travel time to represent a near-worst case travel time. Whether expressed as a percentage or in minutes, it represents the extra time a traveler should allow to arrive on-time for 95 percent of all trips. A simple analogy is that a commuter or driver who uses a 95 percent reliability indicator would be late only one weekday per month.

The ***planning time index*** represents the total travel time that should be planned when an adequate buffer time is included. The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that, for a 15-minute trip in light traffic, the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is useful because it can be directly compared to the travel time index (a measure of average congestion) on similar numeric scales. The planning time index is computed as the 95th percentile travel time divided by the free-flow travel time.

As with the buffer index, a 95th percentile travel time is used. Other percentiles, such as the 85th, 90th, or even 99th percentile, could be used depending upon the desired level of reliability. For example, a lower percentile may be used in calculating reliability measures for less critical routes or trips.

The last reliability measure presented here is ***frequency that congestion exceeds some expected threshold***. This is typically expressed as the percent of days or time that travel times exceed X minutes or travel speeds fall below Y mph. The frequency of congestion measure is relatively easy to compute if continuous traffic data is available, and it is typically reported for weekdays during peak traffic periods.

Several statistical measures of variability have been suggested to quantify travel time reliability, such as standard deviation and coefficient of variation. These are discouraged as performance measures, as they are not readily understood by non-technical audiences nor easily related to everyday commuting experiences.

What are the steps to develop travel time reliability measures?

Now that you understand the basics of travel time reliability, you may be asking "How can I start producing travel time reliability statistics in my city?" The steps shown in Figure4 serve as an outline, with additional technical details, measure calculation procedures, and case study examples provided in the following sections.

Who is using reliability measures?

Travel time reliability measures are relatively new in transportation analyses, at least for most public agencies who in the past have only been concerned with average conditions. There are a few "early adopters" of reliability measures, and these agencies have primarily used travel time reliability as a performance measure to supplement measures of average congestion. The rest of this section highlights a few examples of how reliability measures are being used.

- National traffic congestion and reliability monitoring
- Measuring travel time and reliability in freight-significant corridors
- State DOT traveler information and performance measures
- Travel time reliability at international border crossings
- Southern California Association of Governments (SCAG) goods movement study
- National Transportation Operations Coalition (NTOC): performance measure initiative

National traffic congestion and reliability monitoring

The Federal Highway Administration (FHWA) Office of Operations supports a national traffic monitoring program that incorporates reliability measures. This program tracks reliability measures like the buffer index and planning time index in more than 30 cities. One of the ways that FHWA communicates current information on national traffic congestion and travel reliability to key decision-makers is a monthly dashboard report. This dashboard report includes trend information on the duration (hours of congested travel per day), magnitude (travel time index), and reliability (planning time index).

Valuation of Reliability: Theoretical Frameworks

In the transportation research literature, several approaches have been formulated for estimating the value of travel time reliability. The three main theoretical frameworks are: Mean-Variance, Scheduling Delays, and Mean-Lateness. Furthermore, these approaches are defined from the viewpoint of the consumer (i.e. traveler in this case) similarly as it is done to estimate the value of travel time savings.

Mean-Variance

It is similar to the risk-return models in finance, and it was originally introduced into travel demand modeling by Jackson and Jucker (1982). It is assumed that a decision-maker's objective is to minimize the sum of two terms (both assumed to be sources of disutility): expected travel time, and the travel time variability. The expected travel time is represented by a measure of centrality (e.g. mean) of the travel time distribution, and the travel time variability as a measure of dispersion of the travel time distribution. The statistical measure of centrality is typically the mean, and the measure of variability is the standard deviation. Hence, the name of the framework. Other measures have been used in the literature for dispersion such as interquartile range, differences of percentiles (e.g. 90th percentile and median). The median have been used for centrality as well.

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CONCLUSION

This study has identified the requirement of travel time reliability measurements for measuring performance of transportation network compared to the traditional measures for Indian roads. Travel time reliability measures such as BTI [Buffer Time Index] are more useful to business-trip users. These results will provide guidance in establishing travel time reliability for Indian road network. r:

- Measure reliability for one peak hour (even if the peak hour changes, comparisons can still be made)
- The time interval for aggregating speed and volume should be less than the travel time under free flow conditions
- The optimum data collection period for the reliability measurement is a six-week peiord using data collected at intervals of five minutes or less
- Data collected over a four-week period at 15-minute intervals is the minimum recommended to provide an adequate sample size

- **on-time performance based on scheduled times and trip frequencies**
  - boarding / alighting times
  - wait times (en-route and at stops)
  - total travel times (from origin to destination including traveling from origin to stop, wait times, in-vehicle travel, traveling from stop to destination)
  - consistent running times from passenger trip origin to destination
- break-downs or missed trips
- accurate prediction of arrival / departure times (via real time information)
- accuracy of pre-trip information
- transfer wait times and misconnections

This information may be derived from the following:

- Actual starter or pullout reports
- Schedule Adherence measures
  - Arrival, departure and dwell times (door open/close) at stops
  - Vehicle waiting times
- Fleet Adherence
  - Headway distribution along routes by direction (by stop)
- Break downs, missed trips and disruption reports

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