Travel Time Variability and Reliability

Mozhgan Pourmoradnasseri, PhD
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How and when should I go home if I want to be home at 6 pm?

I want to spend maximum possible time with family.

I want to go to cinema with family and want to be on time with probability of 90%
Averages don’t tell the full story

How traffic conditions have been communicated

Annual average

What travelers experience...

Travel times vary greatly day-to-day

...and what they remember
minimal and maximal travel time on 11.3 km of Frederikssundsvej towards Copenhagen, observed over a period of about three months (only weekdays). Where the minimum travel time, the free flow travel time, is around 10 minutes, the maximum varies up to about 40 minutes in the morning peak.
Travel Time

Definition
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- can be explained by observed characteristics of the trip
- cannot be foreseen and taken into account
Travel Time is Important

- Increasing traffic demand and limited road capacities, resulting in congestion.
- Congestion not only increases travel times, but travel times also become more variable and unpredictable as congestion increases.
- Changes in travel times are routinely handled in economic evaluations of transport policy through the application of values of time.
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Understanding travel time is essential for reliable route choices and traffic management and control.
Travel Time is Important
Reliability is more important :)

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Computing reliable travel time is difficult.
Determinants of Travel Time Distribution

Travel time = free flow time + systematic delay + unexplained delay

(Systematic delay is also known as recurrent delay, and unexplained delay is also known as non-recurrent delay.)

Systematic Delay Actors:

- the general (average) demand level
- the physical road characteristics, i.e. the general capacity level
- the speed-flow relationship

Higher demand → Higher traffic density → Higher travel time → Higher variability
Travel Time Variability

Definition
Travel time variability is an indicator of the variability of travel time from an origin to destination in the transportation network (including any model transfer or en-route stops). It can be defined as the random variation in travel time, i.e. the variation in unexplained delay.

Variability Actors:
- Demand variation through the day
- Traffic control signals
- Unforeseen incident
- Weather conditions
- Random perturbations to traffic flow
Travel Time Reliability

Definition

Travel time reliability is a measure of the consistency or dependability in the travel time of a trip, or time to traverse a road segment, as experienced at different hours of the day and days of the week. It is measured in terms of the additional time (i.e., time cushion or buffer) that drivers need to allocate to compensate for unexpected delays.

The U.S. Department of Transportation (USDOT): the degree of certainty and predictability in travel times on the transportation system.
Travel Time Reliability (TTR) Measures

- Average Travel Time
- Standard Deviation of Travel Time (SDTT)
- Travel Time Index (TTI)
- 95th Percentile Travel Time
- Buffer Index (BI)
- Planning Time Index (PTI)
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Travel Time Reliability (TTR) measures help in **quantifying** unexpected delays and describe the **distribution of travel times** that occur over a substantial period of time.
Average Travel Time

$T_l$ is equal to the sum of the travel times ($t_{il}$) collected by $n$ number of floating cars, traveling on the link $l$.

$$T_l = \frac{1}{n} \sum_{i=1}^{n} t_{il}$$
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Standard Deviation of Travel Time

The measure of the dispersion of travel times formulated as follows.

\[
\sigma_l = \sqrt{\frac{\sum_{i=1}^{n} (t_{il} - T_l)^2}{n}}
\]
Travel Time Index (TTI)

The ratio of Average Travel Time in peak hours to Free-Flow Travel Time. In other words, the Travel Time Index represents the average additional time required for a trip during peak times in comparison with that trip duration in no-traffic condition.

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How to compute Free-Flow Travel Time?

[50 \div 100 = 0.5h = 30 min]
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TTI = \frac{45}{30} = 1.5
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This method, the 95th percentile travel times, is perhaps the simplest method to measure travel time reliability. It estimates how bad the delay will be on specific routes during the heaviest traffic days.

This means that users may experience issues resulting in travel time delays in 1 out of 20 travels. Other percentiles can also be used depending on the needs, e.g., 90th or 85th percentile.
Buffer Index (BI)

The buffer index represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival.

$$BI = \frac{T_{95i} - T_i}{T_i} \times 100\%$$
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For example, a BI of 40 percent means that for a trip that usually takes 20 minutes a traveler should budget an additional 8 minutes to ensure on-time arrival most of the time.

The 8 extra minutes is called the buffer time. Therefore, the traveler should allow 28 minutes for the trip in order to ensure on-time arrival 95 percent of the time.
Planning Time Index (PTI)

Planning Time Index is the ratio of the 95th percentile to the free-flow travel time and shows the total time which is needed for on-time arrival in 95 percent of all trips.

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\]

For example, a planning time index of 1.60 means that for a trip that takes 15 minutes in light traffic a traveler should budget a total of 24 minutes to ensure on-time arrival 95 percent of the time.

Free-flow travel time = 15 minutes
Planning time index = 1.60
Planning time = 15 minutes \times 1.60 = 24 minutes
Free-Flow Travel Time: 2:04 min

Average Travel Time: 5:45 min

95th Percentile Travel Time: 8:00 min

Buffer Time: 2:15 min

Reliability Measures:

1- Planning Time: 8:00 min

2- Planning Index:

8.0 / 2.04 = 3.87

3- Buffer Index:

(8.0 - 5.45) / 5.45 = 39.13%

Source: SMATS iNode
<table>
<thead>
<tr>
<th>Agency</th>
<th>Reliability Metrics Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Georgia Regional Transportation Authority</td>
<td>Buffer index and planning time index</td>
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<tr>
<td>and Georgia Department of Transportation</td>
<td></td>
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<tr>
<td>(GDOT)</td>
<td></td>
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<tr>
<td>Florida Department of Transportation</td>
<td>Buffer index and on-time arrival</td>
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<td>(FDOT)</td>
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<tr>
<td>Southern California Association of</td>
<td>Buffer index</td>
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<td>Governments (SCAG)</td>
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<tr>
<td>Washington State Department of Transportation (WSDOT)</td>
<td>95th percentile travel time</td>
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<td>Maryland State Highway Administration (MDSHA)</td>
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</table>
Unit distance travel time for different types of road through the day

Travel time reliability studies require **quality travel time data**. It can also be measured by dividing the distance between the two points of interest by an **average speed**.

Methods for measuring travel time include
- vehicles equipped with Global Positioning System (GPS) and cellular devices,
- license plate matching,
- aerial photogrammetry,
- vehicle-detecting devices, and
- road-user experience surveys.

Travel time over longer periods of time is required to
- capture daily and seasonal variations and adequately calculate travel time reliability measures.
Case Study:
Impact of Data Source on Travel Time Reliability Assessment

This project investigated the effects of data sources on travel time reliability performance measurements by comparing travel time reliability assessments based on travel time data obtained from permanently deployed Bluetooth sensors with INRX data. The studied area covers the freeway segment in Maryland: from Interstate 95 (I-95) southbound between Route 100 and I-495.

Field Data and Observations

- Weekday scatter plots and boxplots of every 15-minute Bluetooth and INRIX travel time for the entire year on both segments.
- Figures (a) and (b) show that both Bluetooth and INRIX illustrate morning and afternoon peak hours for the I-95 segment with similar patterns.

- Box-and-whisker plots based on both Bluetooth and INRIX data are presented in Figures (c, d) for the segment.
- On the vertical axis, the bottom and top of the blue box are the first and third quartiles of the travel time data for any given time of the day, and the black band inside the box is the median travel time.
- During nonpeak hours, the first and third quartiles are close to the median with relatively smaller variations of travel time.
Plot of INRIX and Bluetooth Data for Peak Hours of May 16, 2012
The plot of INRIX and Bluetooth Hourly Based Travel Time Index (a), and Planning Time Index (b) for the Entire Year.
It seems that the reliability measures of Width, BI, Planning Time Index (PTI), and 90th, 85th, and 80th Percentile Travel Rate are highly correlated with each other, while Skewness is significantly different from other measures.
In general, correlation coefficients based on Bluetooth and INRIX are similar, with Skewness relatively more sensitive to the data source.
## Difference Between Correlations Coefficients of INRIX and Bluetooth (I-95)

In general, correlation coefficients based on Bluetooth and INRIX are similar, with Skewness relatively more sensitive to the data source.

The test results indicate that there is no significant evidence that reliability performance measures derived from the Bluetooth and INRIX data are different from each other on the I-95 segment.

<table>
<thead>
<tr>
<th>Difference</th>
<th>Mean</th>
<th>STD</th>
<th>PV</th>
<th>SKEW</th>
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<tbody>
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<td>Mean</td>
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<tr>
<td>WIDTH</td>
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<tr>
<td>BI</td>
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<td>0.03</td>
<td>0.04</td>
<td>0.16</td>
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<tr>
<td>PTI</td>
<td>0</td>
<td>0.02</td>
<td>0.04</td>
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<td>90th%</td>
<td>0</td>
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<td>0.03</td>
<td>0.18</td>
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<tr>
<td>85th%</td>
<td>0</td>
<td>0.02</td>
<td>0.04</td>
<td>0.2</td>
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<tr>
<td>80th%</td>
<td>0</td>
<td>0.01</td>
<td>0.02</td>
<td>0.2</td>
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<tr>
<td>MI</td>
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<td>0.02</td>
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<tr>
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