Travel Time Reliability Measure Using Global Positioning System Data

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ABSTRACT

Travel time reliability is a measure of the consistency of a trip duration. Commuter expect to arrive at their work place consistently on time; Unreliability of the journey, where commuters might arrive late, leads to a decrease in ridership satisfaction. The common approach in Auckland is to report travel time reliability using standard deviation. However, standard deviation is based on the normality assumption of observations and is significantly affected by outliers. Furthermore, it is not readily understood by a nontechnical audience and is not easily related to everyday communicating experiences. Hence it is discouraged as a performance measure. In this paper, percentile concepts, Buffer Index are introduced as measures to report traffic congestion and travel time reliability and variability in city of Auckland.

Keywords: Travel time reliability, Travel time percentile concepts, Buffer index, Travel time index

INTRODUCTION

Travel time reliability is defined as a measure of trip consistency during a specific time period in a specific location. It takes into account more than daily congestion and is attributed to route inconsistencies due to unexpected delay (Kimley Horn and Associates, 2011).
Commuter are faced with traffic congestion on a daily basis; they plan their trip based on their experience of the network. However, unexpected congestion may impose a delay and lead to them arriving late at their destination. As a result, travel time reliability has been identified as the most important factor affecting ridership satisfaction (Gaffney, 2006). Provision of accurate, robust and reliable travel time information helps road users to make more informed decisions and also assists road managers in the management and operation of the network.

Standard division and coefficient of variation are the methods typically used to deal with travel time reliability. Standard deviation is based on the normality assumption of the observations and is significantly affected by outliers. Neither method is readily understood by nontechnical audiences, as they are not easily related to every day familiar concepts. More importantly, because of their formulation, the methods give equal weight to late and early observed travel time, while travellers are much more concerned about late arrival time. Therefore, these methods have been discouraged to be applied as a performance measure (Cambridge Systematics, 2008)
In this study, we apply two alternative methods to report travel time reliability including percentile travel time and Buffer Index. These methods are tested and validated using Global Positioning System (GPS) data in Auckland during three time periods.

The reminding of the paper is organized as follows: Methods on travel time reliability measures is covered in next section followed by data collection from selected test routes in Auckland. The

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analysis results are discussed afterward. Finally, the findings of the paper are summarized along with some concluding remarks and suggestions for future research in the last section.

Standard deviation

Standard deviation (SD) measures the spread of the data. The more data there is concentrated around the mean, the smaller the SD will be. As the SD is based on distance from the mean it is affected by outliers and rare events. Sample SD is formulated as:

$$Sample\ SD = \sqrt{\frac{\sum_{i=1}^{N}(X-\bar{X})}{N-1}} \quad (1)$$

Of note, sample SD is different from population SD which is the squared route of variance divided by the number of observations.

Percentile travel time

The simplest alternative method to report travel time reliability is the 90th and 95th percentile travel time. These represent travel time on a specific route in one or two days during the heaviest traffic congestion. Nth percentile travel time is the value that splits the dataset into two parts. The lower part includes the N percent travel time and the upper part includes the rest of the data. The Percentile method is not sensitive to the presence of outliers or rare events as it ranks observations from smallest to largest. Hence it is robust to the presence of any abnormality in the data. Percentiles can be used in the following ways according to the scope of the study:

- 50th percentile (equal to the median)
- Differences between 5th and 95th percentile
- Difference between 50th and 84th percentile (roughly equal to the standard deviation, assuming a one –tailed normal distribution) (List, Williams, & Rouphail, 2014)

Buffer Index

Buffer Index (BI) is the difference between the 95th percentile travel time and the average travel time divided by average travel time. The 95th percentile travel time is used to signify a near-worst case travel time. BI is defined as follows:

$$BI = \frac{TT_{95^{th}} - TT_{Mean}}{TT_{mean}} \quad (2)$$

Where BI is Buffer Index, TT_{95th} is the 95th travel time and TT_{Mean} is average travel time. As the route reliability decreases, the BI increases. Hence it provides a good indication of the uncertainty in travel time for the route.
Buffer Time (BT) is defined as the difference between BI and average travel time in minutes and is expressed as follows:

$$BT = TT_{95^{th}} - TT_{mean} \quad (3)$$

To ensure on-time arrival in 95% of occasions, the traveller should add the BT (in minute or ratio) to the average travel time

The 95th percentile can be explained as follows (Levinson, Liu, & Bell, 2011):

- For normally distributed data, the 95th percentile travel time is 2σ (two times the SD of normally distributed travel time).
- The 95th percentile can be interpreted as 1 in 20 work days delay.

DATA COLLECTION

The web-based GPS data used in this research was provided by New Zealand Transport Agency, and was based on floating car data (FCD). FDC has the following advantages:

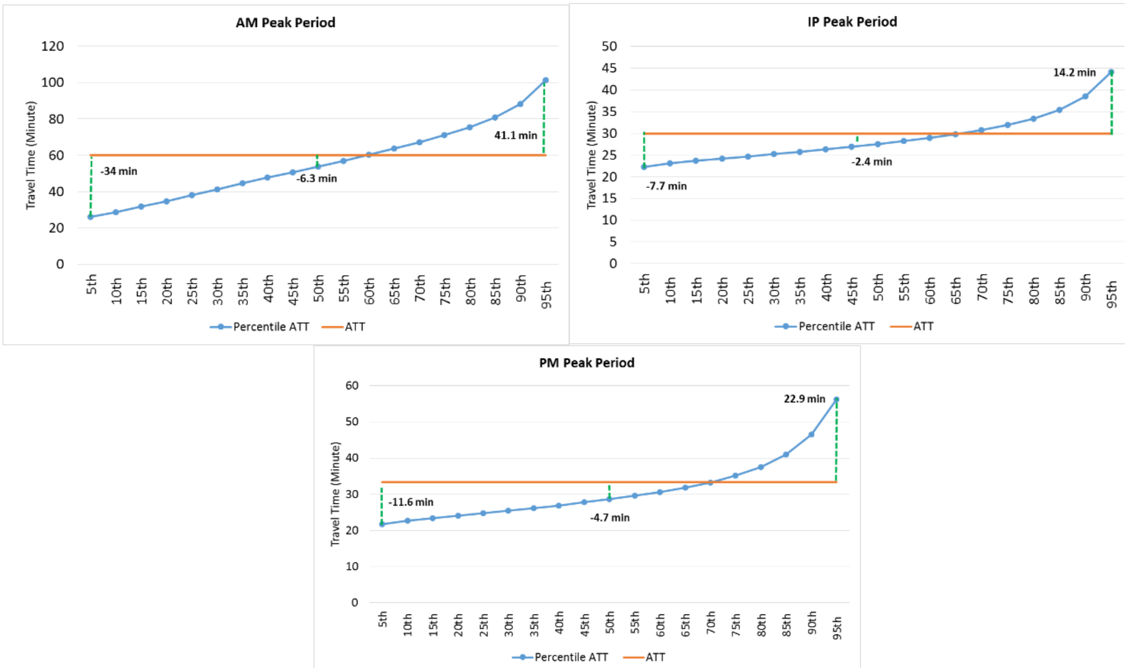
- FCD does not require maintenance or installation, which road side equipment would.
- FCD can provide accurate information even for complex trajectories.
- FCD is not restricted to a specific section and hence provides information on an entire road network.

Five non-holiday working days' GPS data were used for Monday to Friday from March 2008 to March 2015. Morning peak period (AM) (6:30 AM-9:30 AM), inter peak period (IP) (10:00 AM-14:00 PM) and evening peak period (PM) (15:00PM-19: 00 PM) were used for analysis. We selected two test beds for travel time analysis: from the Drury on ramp to the central motorway junction (CMJ) in the inbound direction on State Highway One (SH1) and from the SH18 on ramp to the CMJ on State Highway 16 (SH 16), as shown in Figure (1).

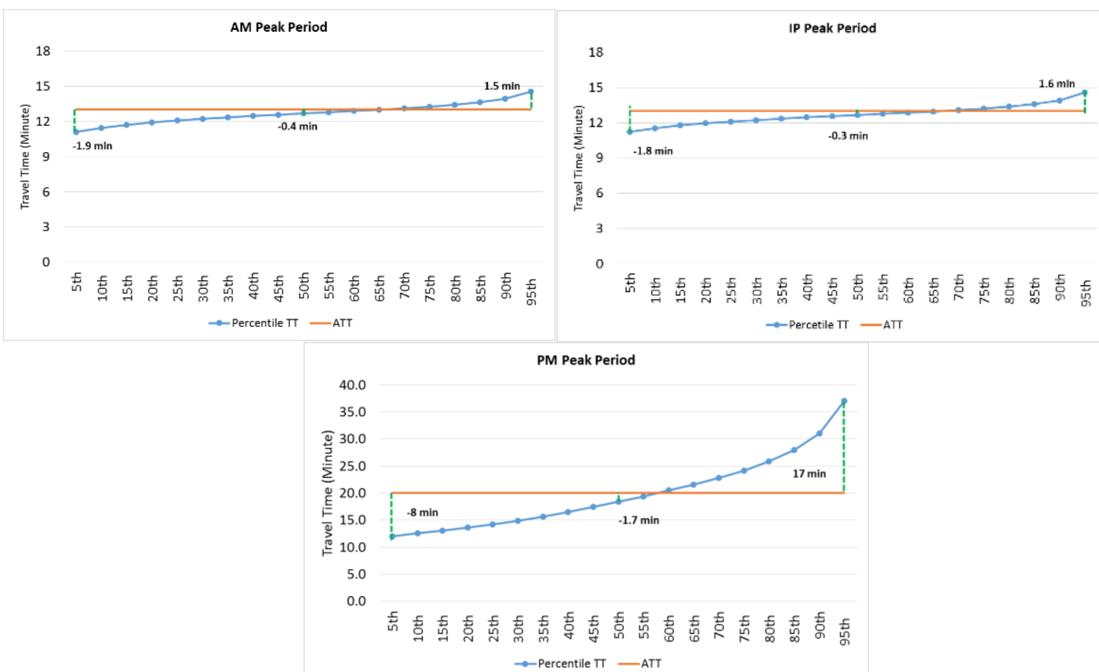
Fig.1. Selected test routes.

RESULTS AND DISCUSSION

BT can be simply calculated using the percentile concept. Figure (2) shows BT for SH 1 and SH 16 using travel time percentile. Figure 2 (A) demonstrates how the BT is calculated as the difference between the average travel time (ATT) and the 95^{th} percentile. As the route gets congested the BT increases, while as congestion decreases, so does the BT.



A) SH1 travel time



B) SH16 travel time

Figure 2 Percentile and average travel time

Therefore, BT directly changes as the traffic status changes. For SH 1 it can be observed that the IP period has the minimum Buffer Time, indicating less congested conditions and more reliable journey time compared to AM and PM peak period. Green dotted lines have been plotted for each graph to identify differences between 5th, 50th and 95th percentile and ATT. The 5th percentile indicates that in five percent of situations traveler may arrive sooner than they expected while the 50th percentile is the median of travel time. The small differences between 50th percentile and ATT may indicate the population average is not significantly affected by skewed observations. Figure 2 (B) appears to show that travel time reliability is higher on SH16 than on SH1. For example, in the PM peak, drivers on SH1 require an additional 22.9 minutes to their average journey time to arrive on time with 95% confidence. Whereas, drivers on SH16 require 17 additional minutes to be 95% confident of arriving on time. However, as discussed below, BT alone does not allow for reliability comparisons between routes; Buffer Index should be used instead.

Table 1 uses a traffic-light system to indicate the relative reliability of the routes examined. It offers a simple tool to quickly identify and compare route reliability. BI can be compared with the same month in previous years, where a change in status (green to red or amber) indicates the route is getting more congested and less reliable compared to the same month in the previous year. As shown in Table 1, travel time reliability is higher in the inter peak than in peak hours on both SH1 and SH16, indicated by the green circles. In the morning peak, travel time reliability is higher on SH16 than on SH1 but in the evening peak, both routes are unreliable.

Buffer time alone ignores the relative typical travel time for different routes. For example, SH1 is likely to have a larger Buffer Time than SH16 purely because it is a longer route. The Buffer Time index takes into account average travel time and allows comparisons to be made between routes of different length. Examining the Buffer Time index (69% for SH1; 85% for SH16) it is clear that, in the PM peak, SH1 travel time reliability is higher than that on SH16, despite the Buffer Time being larger.

AM Peak	SH1		SH 16		IP Peak	SH1		SH 16		PM Peak	SH1		SH 16	
	BI	status	BT	status		BI	status	BI	status		BI	status	BI	status
2008	98%	red	8%	green	2008	34%	green	17%	green	2008	104%	red	85%	red
2009	88%	red	9%	green	2009	46%	green	12%	green	2009	87%	red	80%	red
2010	79%	red	14%	green	2010	54%	amber	13%	green	2010	88%	red	78%	red
2011	76%	red	12%	green	2011	37%	green	13%	green	2011	126%	red	86%	red
2012	84%	red	14%	green	2012	34%	green	13%	green	2012	86%	red	80%	red
2013	76%	red	17%	green	2013	24%	green	15%	green	2013	72%	amber	83%	red
2014	82%	red	20%	green	2014	33%	green	16%	green	2014	80%	red	75%	amber
2015	68%	amber	11%	green	2015	47%	green	12%	green	2015	69%	amber	85%	red

Table 1 Buffer time index

Conclusion

In this study, the percentile concept alongside Buffer Index were used to measure the reliability of travel time in two test beds in Auckland. These measures are easy to understand for non-technical audiences compared to commonly used methods like standard deviation or coefficient of variations.
Results from the Buffer Index and percentile analysis showed that these concepts can be used as more robust and informative methods for reporting both travel time and congestion on the routes tested. It is recommended to use these models instead of standard deviation and coefficient of variation, which are restricted by the assumption of normality and are sensitive to skewed observations.

It was also deduced that Buffer Time alone ignores the relative typical travel time for different routes. The Buffer Index takes into account an average travel time and allows comparisons to be made between routes of different length.

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