TRAVEL TIME STANDARD SCORE AS A NEW MEASURE OF TRAVEL TIME RELIABILITY

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ABSTRACT

In this paper, travel time standard score (TTSS) is proposed as a new measure of travel time reliability. Here each single travel time data from an ETC (Electronic Toll Collection) system is transferred to a TTSS value, based on the average and standard deviation of historical travel times. Distributions of the TTSS at a certain time period are then used to evaluate the travel time reliability performance. The result shows that TTSS distribution is more sensitive to the accident happening situation than the traditional measures of travel time reliability, such like 95percentile travel times. In addition, it has a potential to be used as a tool to better evaluate the influence of travel time reliability experience on individual drivers’ future behavior.
INTRODUCTION

In this paper, we try to propose Travel Time Standard Score (TTSS) as a new measure of travel time reliability, by utilizing data from Electronic Toll Collection (ETC) systems in Tokyo area.

Travel Time Reliability

Travel time reliability is defined as “a consistency or dependability in travel times, as measured from day to day or across different times of day” (1). It is said to be a good measure of service of expressway networks because it focuses more on unexpected delay caused by accidents or other kinds of unexpected incidents (2)(3)(4).

The main purpose of travelers is to be sure to arrive at their destinations on time. Therefore, compared with average travel time, travel time reliability often becomes a more important concern of drivers. On the other hand, for the managing authorities of expressway road networks, the travel time reliabilities of their network reflect their ability of incident management and can give a different perspective in the evaluations of various improving works such as ITS solutions.

Currently the most widely used measures of travel time reliability are: 90th or 95th percentile travel times, buffer index, planning index, and so on (1).

About the ETC Data

After the adoption of an ETC system in 2001, usage of ETC is becoming more and more common among drivers on the Tokyo Metropolitan Expressway Network (MEX). Currently more than 80% of MEX’s 1.16 million daily drivers are using ETC to pay their toll (5). Similar systems are rapidly widespread in the developing world as well, e.g. in Taiwan, Malaysia and China. The entering and exiting records of the ETC using drivers consist of an important data sources for various researches, after clearing the concerns of privacy protection.

In fact, vehicle detector data can also be used to estimate the common travel time reliability measures (3)(4). However, vehicle detectors are usually poorly installed in developing countries. With even poorer maintenance, the data can hardly be used in travel time related estimations (6). Therefore the much more reliable ETC systems (as they must be) should have an important potential in travel time related researches in developing countries as well (7).

Why TTSS is proposed?

Most of the traditional measures of travel time reliability, such like 90th or 95th percentile travel times, buffer index, planning index, are proved to be useful and successfully. They are capable of providing some of the most important information that is related to travel time reliability.

However, these measures are sometimes difficult to be understood by normal drivers who are not familiar with the traffic engineering terminologies. And all of them are aggregated
measures by paying more attention to the total general picture instead of the real experience of
the single drivers.

In Japan, and also in other oriental countries, standard scores (SS) are used for university
entrance tests, which are sure to be one of the most important lifetime events of almost every
people. Ordinary people are familiar with the SS term. When they, especially the parents, try to
evaluate performance a certain class or school, much more attention is paid to how many
students in the class can get extra high standard scores (i.e. enough to elite universities) than the
average scores.

Therefore, we propose the concept of Travel Time Standard Score (TTSS) in this paper. For
a certain road section during a certain time period, the ratios of drivers with some extra high
TTSS (eg. 60) can be used as a measure of its travel time reliability. This measure is much easier
for ordinary people to understand (at least in Japan). More importantly, we can also track the
single drivers’ historical records of TTSS, which are helpful for categorizing drivers and for
evaluating influence of travel time reliability experiences on single drivers’ future behavior.

Contents of the Paper

In this paper, at first ETC data are used to estimate some common day to day travel time and
travel time reliability measures on part of Route No.4, which is a major route that connecting a
major Japanese intercity expressway to the downtown of Tokyo. Then the statistic relationship
between travel time reliability measures and accident happenings is estimated and compared.
Our research is intended to describe and justify the usage of TTSS as a travel time reliability
measure that can be used to evaluate the effects of expressway accident control.

STUDY ROUTE AND TIME PERIOD

A 10.27km long route that connecting Chuo Intercity Expressway and Gaien Exit at downtown
Tokyo is chose for the research. It is a major route used by drivers from west part of Japan to the
downtown Tokyo, as shown in Figure 1. This route consists of 17 sections of lengths varying
from 210m to 1030m (averagely 604.1m).

A one-month data set of July 2006 is chose as the research period. In addition to ETC data,
we also use data from vehicle detectors (double type), and accident happening and endurance
time data (at 5-min time step), on all of the 17 sections.

The route is selected for two reasons. Firstly, it has relatively high accident happening rate
because there is an infamous and dangerous horizontal curve near the end of the route. Secondly,
the traffic volume of the route is high. We can collect adequate amount of ETC data on the route
to carry on this research.
MEASURES USED IN THE PAPER

1. Travel Time Measures
Travel time measures include: median travel times ($mTT$) and average travel times ($aTT$).

\[ aTT = \frac{\sum_{i=1}^{N} TT_i}{N} \]  

(1)

2. Traditional Travel Time Reliability Measures
A wide range of travel time reliability measures have been recommended by earlier researchers (1) (2) (4). The following measures are used in this paper: 95th percentile travel times ($95\text{per} \, TT$), buffer time ($BT$), and average travel time deviations ($aTTD$).

- 95th percentile travel time ($95\text{per} \, TT$)
  The simplest method to measure travel time reliability by estimating the worst delays happened during the research period.

- Buffer Time ($BT$)
  Extra time that travelers have to add to the average travel times so that they can guarantee on-time arrival 95 percent of the time,

\[ BT = 95\text{per} \, TT - aTT \]  

(2)

- Average travel time deviations ($aTTD$)
  This is a measure to show the variation of travel times, the smaller the higher travel time reliability,

\[ aTTD = \frac{\sum_{i=1}^{N} |TT_i - aTT|}{N} \]  

(3)

where $TT_i$ is the travel time of the $i^{th}$ vehicle, and $N$ is the total number of cars in the time period.

3. Travel Time Standard Score ($TTSS_i$) of the $i^{th}$ vehicle
In this paper, we propose to use Travel Time Standard Score as a measure of travel time reliability. Different from average travel times, we want to know more information about the
most extreme situations, such as travel times during congestions caused by accidents. In such
situations, TTSS should be a more convenient measure. We can easily find what a percentage of
travelers may have experienced some unusual (with higher standard deviations) travel times, by
using TTSS.

\[ TTSS_i = \frac{TT_i - aTT}{aTTD} \cdot 10 + 50 \]  \hspace{1cm} (4)

Just like to compare the performance of two classes in a high school, sometimes we have
more interest on the information of how many “excellent” students with outstanding standard
scores in each class. In equation (4), TTSS is adjusted to the same scale as scholastic test scores.
We propose to use the ratio of TTSS above 60 or 70 as a measure of travel time reliability in our
following research. One of the reasons is, in Japan, standard score of 60 is enough to get a
student to a top10 engineering school, and score of 70 would be no problem to even the
University of Tokyo.

Measure of Accident Happenings – NAP

In this paper, we use Number of accident congestion Affected time Periods (NAP) as a measure of
accident happening situations. NAP equals to the total number of 5-min time steps of sections
experiencing congestions caused by accidents. The NAP measure is chose because it shows both
the frequencies of accidents and their seriousness, because the measure gives both temporal and
spatial impacts of the congestions caused by the accidents. For a certain day, NAP is between 0
and the maximum value of 1020 (60 × 17), when all the 17 sections are experiencing accidents
through all the 60 time steps of 5 minutes in a 5-hour morning peak (6:00am ~ 11:00am).

\[ NAP = \sum_{j=1}^{M} \text{Number of Affected Time Steps of Section } j \]  \hspace{1cm} (5)

where \( M \) is the total number of sections on the research route. \( M = 17 \), in this paper.

ESTIMATION RESULTS AND THE ANALYSIS

Here the daily average travel times, and the common travel time reliability measures of the study
route are estimated for all the workdays within the one month study period of July, 2006 at first.
Then analysis is carried on to describe the relationship between travel time reliability and
accident happenings. The data from July 13, 2006 are excluded because some technical errors
happened on that day.
Estimation Results – Common Measures of Travel Time and Travel Time Reliability
From the Table 1, we can see the daily average travel times and travel time reliability measures of the morning peak hours (6:00 ~ 11:00) of all the workdays in July, 2006.

Estimation Results – Travel Time Standard Scores (TTSS)
By Equation (4), the TTSS of all single ETC travel times are calculated. Separated for days with, or without accidents, Table 2 gives a summary of the average TTSS, the ratio of TTSS above 60, and the ratio of TTSS above 70. We can find that although the average TTSS is not very different between days with or without accidents (52.8 to 58.9), the average ratios of TTSS above 60 (26.4% to 40.6%) and 70 are totally different (11.1% to 23.1%). The comparison is more clearly shown in Figure 3.

In Figure 4, we give out the distribution of TTSS scores. Our results show that for days with accidents, the distribution of TTSS is wider, especially at the right part for the most extreme values. Significant differences between the days with/without accidents can be found from the TTSS of 60.

Relationship between Travel Time Reliability Measures and Accident Happenings
As shown in both Table 1 and Figure 2, obviously the measures of travel time reliability show much more significant correlations with NAP, a measure of accident happenings used in this paper. All earlier authors (1)(3)(4) mentioned the practical fact that, unlike average travel times, travel time reliabilities are more dependent on the control of non-recurrent congestions, often caused by accidents and/or other incidents.

- Recurrent Congestions (by over demand) $\rightarrow$ average travel time
- Non-recurrent Congestions (by accidents, etc.) $\rightarrow$ travel time reliability

Our results give out a simple explanation of the above fact. All of the 3 travel time reliability measures, 95per TT, BT, and aTTD show much higher correlations with NAP, if compared with aTT and mTT. Especially for the measure of BT, where the average travel time aTT is subtracted, the highest correlation with the accident happenings is found.

Furthermore, our research shows that we can use percentage of TTSS above 60 as a new measure of travel time reliability. This measure can give out a clear picture of the higher travel time deviations, as the result of non-recurrent congestions. Also it can be more easily understood, at least in the Japanese context.

Comparison of the Major Measures of Travel Time Reliability
All of the major measures of travel time reliability are concerned with the variability of travel
times, but each is measuring a different aspect of the variability. 95 percentile travel times tell the drivers what are the worst situations and can help them to make their travel plans. On the other hand, aTTD is a more general measure of travel time variability as it measures the average variation of travel times directly. However, aTTD is maybe also the most difficult measure for a common driver to understand.

The TTSS measure pays more attention to the personal experience of the single drivers. The drivers can have a very clear idea of what he has experienced: it was a normal situation, bad situation, or extremely bad situation. Mainly in this sense, the TTSS measure is different from all the current measures of travel time reliability. It is a personal experience of a driver, rather than a mere statistic data of a road section.

CONCLUDING REMARKS

In the earlier works and in the practical world as well, travel time reliability measures are widely used to show the effects of accident controls. In this paper, ETC data are used to analyze the relationship between travel time reliability and accident happenings. We find that compared with average travel times, travel time reliability measures show much higher correlations with accident happenings, thus justify the usage of travel time reliability as an LOS measure of road network.

In this paper, we discuss and prove the possibility of using Travel Time Standard Score (TTSS) as a new measure of travel time reliability. TTSS is not only easier for the ordinary people to understand (in Japan at least), the number of extra TTSS in a certain time period is proved to be more sensitive to the accident happenings. Furthermore, more and more researchers are now trying to analyze the influence of travel time reliability on drivers’ future behavior (8). By ETC data, we can obtain long term historical records travel time reliability experience of single drivers, which can be applied in this field. It is one of the authors’ main future directions.
ACKNOWLEDGMENTS

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<table>
<thead>
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<th>Date</th>
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FIGURE 1 Research Route
Comparison of Correlations with NAP

FIGURE 2 Comparison of Correlations with NAP
FIGURE 3 Comparison of TTSS, with or without accidents
FIGURE 4 Distributions of TTSS, with or without accidents