TRAVEL TIME RELIABILITY ANALYSIS BY ETC DATA

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1. Introduction

In this paper, utilizing data from Electronic Toll Collection (ETC) system, we try to analyze the explicit statistic relationship between travel time reliability measures and accident happenings.

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" (Federal Highway Administration (FHWA), 2006). 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 (Chen C., *et al*., 2003; Maruyama et al, 2007; Mehran, 2009). The main purpose of travelers is to be sure to arrive at their destinations on time. Therefore, compared with average travel time, travel 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.

Travel time reliability is important and often come out with the mention of accidents. However, the explicit relationship between travel time reliability and accident happening is still absent from our literature review so far.

After the adoption of ETC system in 2001, usage of ETC is becoming more and more common among the MEX drivers. Currently more than 80% of MEX's 1.16 million daily drivers are using ETC to pay their toll (MEX, 2008). Similar systems are rapidly widespread in the developing world as well, e.g. Taiwan, Malaysia and China. The entering and exiting records of the ETC using drivers consist of an important data sources for various researches, if with careful considerations of privacy protection.

In fact, vehicle detector data can also be used to estimate common travel time reliability measures (Maruyama et al, 2007; Mehran, 2009). 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 (Wang and Nakamura, 2003). Therefore the much more reliable (it must be) ETC data should have an important potentials in travel time related researches in developing countries.

In this research, at first ETC data from the MEX network are used to estimate some common day to day travel time reliability measures of a part of Route No.4, a major route of MEX which linking a major intercity expressway from west part of Japan to the downtown Tokyo. Then the statistic relationship between travel time reliability and accident happening is stated. Our research is intended to describe and justify the usage of travel time reliability as a Level of Service (LOS) measure of expressway accident control.

*Keywords: travel time reliability, ETC data, urban expressway

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2. Study Route and Period

A route connecting Chuo Expressway Tokyo Exit and Gaien is selected for the research. This is a major route used by drivers from west part of Japan to enter the downtown Tokyo, as shown in Figure 1. The total length of the route is 10.27 km. This route consists of 17 sections of lengths from 210m to 1030, with an average value of 604.1m.

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

This route is selected because there are relatively more accidents happening on it with a sudden curb near the end of it. Also the traffic volume of this route is high, thus enable enough data for our research.

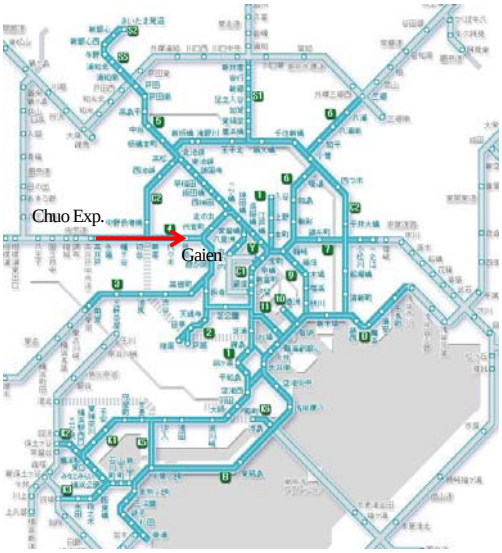

Figure 1: The Research Route

3. Average Travel Time and Travel Time Reliability Measures Used in the Research

(1) Travel Time Measures

Travel time measures include: median travel times (*mTT*) and average travel times (*aTT*).

$$aTT = \frac{\sum_{i=1}^{N} TT_i}{N} \qquad (1)$$

(2) Travel Time Reliability Measures

A wide range of travel time reliability measures have been recommended by earlier researchers (Chen C., *et al.*; FHWA, 2006; Mehran, 2009). The following measures are used in this paper: 95th percentile travel times (*95per TT*), buffer time (*BT*), and average travel time deviations (*aTTD*).

- 95th percentile travel time (*95per 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 to guarantee on-time arrival 95 percent of the time,

$$BT = 95per\ TT - aTT \qquad (2)$$

- Average travel time deviations (*aTTD*)

This is a measure to show the variation of travel times, the smaller the higher travel time reliability,

$$aTTD = \frac{\sum_{i=1}^{N} |TT_i - aTT|}{N} \qquad (3)$$

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

4. Measure of Accident Happenings – *NAP*

In this paper, we use number of accident affected time periods (*NAP*) as a measure of accident happenings on the research route. *NAP* equals the total number of 5-min time steps affected by accident aroused congestions during the research period. It represents both the frequency of accidents and their seriousness and impact ranges, thus a suitable measure. *NAP* is between 0 and the maximum value 288×17 = 4896 when all the 17 sections are affected by accidents through all the 288 times steps of 5 minutes within a day.

$$NAP = \sum_{j=1}^{M} Number\ of\ \ Affected\ Time\ Steps\ of\ \ Section\ \ j \qquad (4)$$

where *M* is the total number of sections on the research route, which equals to 17 for the research route of this paper.

5. Estimation Results and the Analysis

Here the daily average travel times and travel time reliability measures of the study route are estimated for the 1-month study period of July, 2006, before the analysis of the relationship between travel time reliability and accident happenings.

(1) Estimation results

From the following table, we can see the daily average travel times and travel time reliability measures.

Table 1: Estimation Results – Chuo Expressway to Gaien Exit, MEX (July, 2006)

	Average Travel Times		Travel Time Reliability Measures			*NAP*
	aTT	*mTT*	*95per TT*	*BT*	*aTTD*	
Jul. 1(Sat.)	14.3	14.3	29.2	14.9	7.0	82
Jul. 2(Sun.)	9.3	8.1	16.7	7.4	3.3	46
Jul. 3(Mon.)	8.6	7.0	13.6	5.0	3.0	3
Jul. 4(Tue)	12.9	11.2	26.5	13.6	6.0	95
Jul. 5(Wed)	13.5	9.8	30.5	17.0	7.0	89
Jul. 6(Thu)	9.9	7.2	18.1	8.2	4.5	0
Jul. 7(Fri)	13.0	11.6	23.8	10.8	5.9	62
Jul. 8(Sat)	15.0	16.1	22.8	7.8	6.0	33
Jul. 9(Sun)	7.9	6.5	14.6	6.7	2.5	52
Jul. 10(Mon)	9.1	7.2	14.1	5.0	3.4	0
Jul. 11(Tue)	12.9	9.3	24.8	11.9	6.5	53
Jul. 12(Wed)	14.6	13.9	24.6	10.0	6.8	24
Jul. 13(Thu)	6.7	6.2	8.2	1.5	1.1	49
Jul. 14(Fri)	19.8	21.6	38.8	19.0	9.9	126
Jul. 15(Sat)	18.9	12.3	46.9	27.9	13.4	424
Jul. 16(Sun)	17.2	17.1	30.4	13.2	8.5	61
Jul. 17(Holiday)	11.4	8.9	27.0	15.6	5.2	148
Jul. 18(Tue)	21.9	19.2	39.4	17.5	10.0	171
Jul. 19(Wed)	17.2	16.8	27.9	10.8	6.0	39
Jul. 20(Thu)	12.2	10.9	23.5	11.4	4.9	127
Jul. 21(Fri)	18.3	18.8	31.0	12.7	7.0	27
Jul. 22(Sat)	12.6	11.9	23.5	10.8	5.0	79
Jul. 23(Sun)	6.5	6.0	7.2	0.8	1.0	0
Jul. 24(Mon)	14.6	13.5	30.8	16.3	5.7	210
Jul. 25(Tue)	10.9	10.0	17.6	6.7	4.2	0
Jul. 26(Wed)	12.6	9.6	28.5	15.9	6.4	6
Jul. 27(Thu)	15.7	15.8	30.2	14.5	7.5	145
Jul. 28(Fri)	22.4	22.0	39.3	16.9	9.6	81
Jul. 29(Sat)	16.1	16.4	28.7	12.7	7.0	178
Jul. 30(Sun)	9.9	7.1	20.4	10.4	4.3	80
Jul. 31(Mon)	15.7	15.5	30.8	15.1	6.4	111
Average	*13.6*	*12.3*	*25.5*	*11.9*	*6.0*	*83.9*
Correlation with NAP	*0.478*	*0.287*	*0.686*	*0.771*	*0.656*	

Notice: Units are all minute, except *NAP*

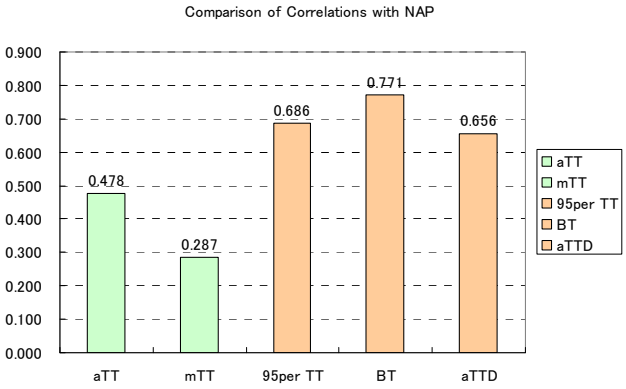

Figure 2: Comparison of Correlations with NAP

(2) Analysis of the 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. Earlier authors (FHWA, 2006; Maruyama, T., *et al*., 2007*;* Mehran, 2009) all mentioned the practical fact that unlike average travel times, travel time reliabilities more dependent on the control of non-recurrent congestions, often caused by accidents and other incidents.

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

Our results give out a simple but explicit 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.

6. Concluding Remarks

In the earlier works and the practical world as well, travel time reliability measures are widely used to show the effects of accident controls without explicit explanations. 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.

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