Validation of Instantaneous Journey Time Estimates: A Journey Time Indication System in Hong Kong

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Abstract: Current traffic information such as instantaneous journey time estimates are usually provided to road users in advanced traveler information systems. However, it is difficult to validate these instantaneous journey time estimates. This is because instantaneous journey time reflects the traffic condition in terms of current travel time at different road segments at the same instant. No single driver can normally experience the instantaneous journey time except for travelling on a very short section of road under light trafficked condition. In this paper, a survey method is proposed to demonstrate how to validate instantaneous journey time estimates. Observed instantaneous data have been collected by floating car surveys for validation of the instantaneous path journey time estimates provided by the Journey Time Indication System in Hong Kong (JTISHK). The results show that the proposed method can validate the instantaneous path journey time estimates satisfactorily with adequate sample sizes at a significant level statistically.

Key Words: Instantaneous journey time, journey time indication system, validation, survey

1. INTRODUCTION

Short-term travel time information is becoming increasingly important for a variety of real-time Intelligent Transportation System (ITS) applications. Given the instantaneous or predicted traffic information, road users would have a better idea on their arrival times at the destinations, and can then choose the potentially fastest routes to avoid traffic congestion in urban road network. Moreover, road users can react to the traffic incidents immediately after they occur. The benefits of ITS have been studied by several researches (e.g. Chorus et al. 2006; Toledo and Beinhaker, 2006). It was found that provision of real-time traffic information can save the travel times of road users up to 14% (Toledo and Beinhaker, 2006).

In many countries/cities, advanced traveler information systems (ATIS) have been operated with providing various types of traffic information to road users. The traffic information consists of instantaneous or predicted journey times on selected paths, travel speed intervals by different colours and sections of roads, etc. They can be updated once every two or five minutes in most of the existing ATIS. For examples, the real-time traffic information systems (RTIS) in Hong Kong (http://tis.td.gov.hk/rtis/ttis/index/main.jsp), Singapore (http://interactivemap.onemotoring.com.sg/mapapp/index.html), New York (http://www.511ny.org/traffic.aspx), England (http://www.trafficengland.com/index.aspx), and Portland (http://www.katu.com/traffic/mapsportland).
In general, the predicted journey time is referred to as the expected travel time required for a vehicle arrived at the exit point of the path with respect to the current departure time at the entry point of the path. Therefore, it can be easily validated by directly comparing the actual journey times of probe vehicles on the path concerned. However, it is difficult to validate the instantaneous journey time estimates in practice. This is because instantaneous journey time should be measured in the manner similar to taking snapshot at different road segments at the same instant. It reflects the current traffic condition in terms of travel times at different road segments. In other words, it is a combination of travel times of different vehicles traveling along a selected path or route. Therefore, this instantaneous journey time cannot be measured by a single vehicle except for traveling on a very short route under light trafficked condition.

Figure 1 shows the difference between the instantaneous journey time estimates and the actual journey time of a vehicle traveling along a given path. For example, the vehicle departed at 15:14 at the entry point of the path. The instantaneous average journey time at 15:12-15:14 is equal to 1.6+5.6+4.1+2.8+2.7+5.0 ≈ 22 minutes. However, the actual completed journey time of this vehicle is approximately 18 minutes. As this vehicle is arrived at the exit point of the path after 9 two-minute intervals, this actual journey time is not appropriate for directly comparison with the instantaneous average journey time estimate.

![Figure 1: Instantaneous journey time estimates vs. actual completed journey time of a vehicle traveling on a selected path](image)

To validate the accuracy of the instantaneous travel time estimates, the previous related works are mainly concerned with comparison of the estimates against the real-time data collected by advanced technologies, from floating car surveys or by simulation model (Bar-Gera, 2007; Liu et al., 2008; Maerivoet and Logghe, 2007; Narupiti and Mustafa, 2007). However, independent real-time datasets collected by other traffic detectors are usually not available in
practice. Floating car method can generally collect instantaneous travel times on relatively short road sections due to the budget constraints on the survey costs and the fleet size of the test vehicles available. Simulation may not reflect the real-time traffic condition. In view of these difficulties on the collection of observed data for validation of instantaneous travel time estimates, most of the previous studies focused on validation of their travel time estimates against the actual completed journey times or sectional travel times of probe vehicles (e.g. Li et al., 2006; Liu et al., 2008; Xiong and Davis, 2009). Little attention has been paid for collection of observed data for validation of instantaneous path journey time estimates. However, in order to deliver reliable traffic information to the public, it is necessary to validate the instantaneous path journey time estimates provided in the RTIS.

This paper presents the approach and the validation results of the instantaneous path journey time estimates provided by the Journey Time Indication System in Hong Kong (JTISHK). The JTISHK was firstly commissioned by the Transport Department of the Hong Kong Government in 2003. The purpose of the system is to disseminate real-time traffic information to road users for their route choice to cross the harbour. It provides the estimated instantaneous average journey times from Hong Kong Island to the exit of three cross-harbour tunnels in Kowloon Peninsula. The journey times are displayed at three sets of on-gantry indicators at major roads of Hong Kong Island north and updated at five-minute intervals. Recently, the JTISHK was re-developed with use of a novel algorithm for path journey time estimation. In this algorithm, path journey times are estimated using data collected from two types of traffic detectors on real-time basis together with the offline travel time data. The refresh rate of the displays of the journey time indicators is also increased to every two minutes. The re-developed JTISHK has been launched to the public in mid-2009. One of the on-gantry indicators of the JTISHK is shown in Figure 2.

![Figure 2 One of the On-gantry journey time indicators in Hong Kong](image)

### 1.1 Journey Time Indication System in Hong Kong (JTISHK)

As mentioned in previous section, the JTISHK was re-developed in 2009. Two types of traffic detectors have been adopted for collection of real-time data for journey time estimation in the re-developed JTISHK. These traffic detectors are the automatic vehicle identification (AVI) tag reader by radio frequency identification (RFID) technology and the video detector by video image processing (VIP) technology. AVI tag reader captures the time stamps of
vehicles passing that AVI reader together with their identification information. By matching the identification information of the vehicles, journey times of vehicles passing between two consecutive tag readers are computed at two-minute intervals. However, AVI data only provide time stamps at vehicles pass successive tag readers, it is necessary to have some forms of filtering in order to remove the outliers. The outliers may be due to stops or detour made along the paths. Thus, a data filtering method has been developed for capturing the valid AVI data for journey time estimation in the JTISHK. The data filtering method considers various factors at previous and current time intervals for generating stochastic thresholds of valid time windows (Tam and Lam, 2008; 2011).

The VIP data are collected by a number of video detectors installed along the selected paths. The VIP data include the traffic counts and the spot speeds of vehicles travelled at particular locations. Those spot speed data are aggregated into two-minute intervals to obtain the time mean speeds. However, time mean speed is the average speed of vehicles passing a particular point on a road over same specified time period. It does not represent the speed of vehicles travelled across the length of a road segment. To estimate travel time, space mean speed which represents the average speed of vehicles occupying a road section over some specified time periods should be adopted. Based on the assumption of constant speed within the road segment, space mean speed can be approximated from spot speed data. In the JTISHK, relationship between the estimated space mean speeds and the travel speeds measured over various road segments of the selected paths has been calibrated. The estimated space mean speeds are then further adjusted by the calibrated relationship so as to improve the accuracy of the estimated space mean speeds. Such adjusted space mean speeds are used to estimate the travel times on a road segment between two video detectors together with the spatial relationships between different road segments and the spacing of two video detectors in the JTISHK algorithm.

The offline data used in the JTISHK are extracted from the database of link speed estimates of the RTIS for Hong Kong (http://tis.td.gov.hk/rtis/ttis/index/main.jsp) (Tam and Lam, 2008; 2011). This RTIS database includes the average link travel time/speed estimates and their spatial variance-covariance relationships. As journey time on a road segment may relate to journey time on an adjacent segment due to the network topology, such dependency which can be represented by the covariance can provide useful information for instantaneous journey time estimation. Moreover, use of offline data can complement the real-time database particularly when both of the real-time AVI and VIP data are limited under abnormal conditions.

The JTISHK algorithm integrates three types of traffic data; including real-time AVI data collected from tag readers, real-time VIP data from video detectors and the offline estimates based on historical traffic data, for estimation of instantaneous average journey time on the selected paths. In general, the instantaneous average journey time estimate is the weighted average of the estimates based on the above three types of traffic data. The weightings of AVI and VIP data are dependent on the sample sizes of these input data. In the other words, the more samples of that type of data, the higher weighting is given on the journey time estimated on the basis of this type of input data. The weighting of the offline data is equal to (1 - weightings of the estimates by AVI and VIP data).
1.2 Structure of the Paper

The remainder of the paper is structured as follows. The proposed survey method for collection of observed data to validate the instantaneous average journey time estimates is given in the next section. The third section presents the validation results. Finally, conclusions are given together with recommendations for further study.

2. SURVEY DESIGN

The JTISHK provides the instantaneous average journey times on seven selected paths from Hong Kong Island to Kowloon Peninsula. The locations of the seven selected paths (JHK1-CHT, JHK1-EHC, JHK2-CHT, JHK2-EHC, JHK2-WHC, JHK3-CHT and JHK3-WHC) as set out in the JTISHK project are shown in Figure 3.

Floating car surveys were adopted for collection of the observed instantaneous journey times for validation of the estimates on these seven selected paths. According to the contract requirement of the JTISHK project, surveys were conducted during two peak and one non-peak periods on typical weekdays and weekends (Saturday or Sunday) respectively. Each of the survey periods was scheduled with three hours. In order to minimize the survey cost, limited number of test vehicles was deployed for observed data collection. In the survey, six to eight test vehicles were adopted for each journey time measurement. In general, each of the test vehicles started the trip at intervals of two-minute or more. The purpose of departing the test vehicles separately at different intervals is intended to make the vehicles evenly distribute on different road segments along the path. During the surveys, the test vehicles were driven at similar speeds of the surrounding traffic on the selected paths. Hence, the journey time measured on each of the selected paths can be considered as an observed average travel time of the traffic stream as a whole.

Surveyors in test vehicles used synchronized watches to record the arrival time at each predetermined checkpoint of the selected path. Based on the times recorded, journey times used between two checkpoints could be obtained. These observed journey times of different test
vehicles are then used to obtain the observed instantaneous journey times on the selected path. They would be used to validate against the instantaneous average journey times estimated by the JTISHK algorithm at the same time interval.

The observed instantaneous test-car journey time on each selected path is obtained by the sum of the travel times of different test vehicles arrived at various checkpoints at the same time interval, at which all the checkpoints on each path are covered. For instance, Figure 4 shows the time-distance diagram for various test vehicles travelled on the selected path of JHK2-CHT. On this path, four checkpoints (except the origin JHK2) were pre-determined for the survey. In Figure 4, four test vehicles (Cars 1-4) arrived at the four checkpoints respectively within the same time interval of 08:48-08:50. These four sectional journey times collected by Car 1 to Car 4 covered the whole path. Thus, the valid instantaneous journey time sample is equal to \((A + B + C + D)\) minutes at the time interval of 08:48-08:50. This journey time sample is then compared with the estimated instantaneous average journey time on this selected path at the same time interval.

In general, the samples of the instantaneous test-car journey times with full set of observed data (i.e. covering the whole path) are not adequate for the validation purpose as they are not easily obtained due to the limited number of test vehicles deployed and the variation of traffic conditions during the survey periods. It can be seen in Figure 4 that only two test vehicles (Cars 3 and 5) arrived at checkpoints 3 and 4 respectively within the time interval of 08:54-08:56.

![Figure 4 Journey times of different test vehicles on the selected path of JHK2-CHT](image)

In order to increase the number of valid samples for validation, the partial observed instantaneous test-car journey times have been used together with the estimated travel times on the road segments without observed test-car data. For example, it is supposed that the estimated instantaneous travel times of the two road segments without observed data (i.e. road segments from JHK2 to Checkpoint 1 and from Checkpoint 1 to Checkpoint 2) at 08:54-08:56 is \(G\) and \(H\) minutes. The valid sample of path instantaneous journey time for validation is equal to the total travel times by test vehicles \((E + F\) minutes\) at 08:54-08:56 plus the
estimated travel times on the road segments without observed test-car data (G + H minutes). In other words, the instantaneous path journey time of (E + F + G + H) minutes is compared with the estimated instantaneous journey time on the whole selected path at the time interval of 08:54-08:56. However, in order to avoid the domination of the observed data collected on the long section of the road such as the tunnel section, the valid observed journey time samples should fulfill the following criteria. Otherwise, the journey time samples are considered as invalid.

- If the tunnel distance is longer than 50% of the total path distance (for the two selected paths of JHK1-CHT and JHK2-CHT), the sum of the distance of the road sections, which partial observed data are collected, should be at least 65% of the total distance of that selected path.
- Otherwise, the sum of the distance of the road sections, which partial observed data are collected, is at least 50% of the total distance of that selected path (for the five selected paths of JHK1-EHC, JHK2-EHC, JHK2-WHC, JHK3-CHT and JHK3-WHC).

The adequacy of the proportion of path distance covered in the partial set of the observed journey time samples are justified in the latter section.

3. VALIDATION OF INSTANTANEOUS AVERAGE JOURNEY TIME ESTIMATES

Based on the survey approach, validation surveys were carried out on the seven selected paths in Hong Kong from June to August in 2009. The detailed results are summarized as follows. According to the contract requirement of the project, the accuracy level of the journey time estimates on each of the selected paths should be within +/- 20% errors with a compliance of 95% in two survey days. Moreover, the total number of valid samples collected within the two surveys should be adequate for journey time validation.

3.1 Sample Sizes

Table 1 shows the number of valid samples on instantaneous journey times on each of the seven selected paths obtained in the surveys. It can be seen that more than 90 samples were collected in the two survey days on each of the seven selected paths. To check the adequacy of the sample size required for each of the selected paths within the two survey days, Equation (1) is adopted for sample size checking (Li and McDonald, 2007; Transport Department, 2008).

\[
N \geq \left( \frac{z_{\alpha/2} s}{e} \right)^2
\]

(1)

where

- \( N \) = minimum sample size required for a (1-\( \alpha \)) level of confidence for each selected path within two survey days;
- \( z_{\alpha/2} \) = confidence coefficient corresponding to \( \alpha /2 \) for normal distribution;
- \( s \) = standard deviation of the absolute percentage errors of instantaneous journey time estimates on each selected path within two survey days; and
- \( e \) = permitted error of the average absolute percentage errors of instantaneous journey time estimates on each selected path within two survey days.
In Equation (1), the absolute percentage error (APE) of instantaneous journey time estimate is defined as follows.

\[
APE = \frac{|Observed - Estimated|}{Observed} \times 100\%
\]

where \(Observed\) is the observed instantaneous test-car journey times while \(Estimated\) is the instantaneous average journey time estimated by the JTISHK.

In the sample size checking, a 20% of permitted error of the average absolute percentage errors of instantaneous journey time estimates at 95% level of confidence (i.e. \(\alpha = 0.05\)) was adopted. Thus, the test statistic is equal to \(z_{0.05/2} = z_{0.025} = 1.96\) and the permitted error \(e = 0.2 \times\) average absolute percentage errors of instantaneous journey time estimates. As shown in Table 1, it was found that the number of valid samples collected in the two survey days is much more than the minimum sample size required for each of the seven selected paths. Thus, the requirement of the adequacy of sample sizes for journey time validation is fulfilled.

### Table 1 Number of valid samples collected on the seven selected paths in the surveys

<table>
<thead>
<tr>
<th>Route</th>
<th>Weekday</th>
<th>Weekend</th>
<th>Overall two survey days</th>
<th>Minimum samples required within two survey days based on Equation (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JHK1-CHT</td>
<td>49</td>
<td>45</td>
<td>94</td>
<td>58</td>
</tr>
<tr>
<td>JHK1-EHC</td>
<td>48</td>
<td>43</td>
<td><strong>91</strong></td>
<td>64</td>
</tr>
<tr>
<td>JHK2-CHT</td>
<td>76</td>
<td>44</td>
<td>120</td>
<td>55</td>
</tr>
<tr>
<td>JHK2-EHC</td>
<td>52</td>
<td>50</td>
<td>102</td>
<td>52</td>
</tr>
<tr>
<td>JHK2-WHC</td>
<td>61</td>
<td>49</td>
<td>110</td>
<td>56</td>
</tr>
<tr>
<td>JHK3-CHT</td>
<td>49</td>
<td>54</td>
<td>103</td>
<td>45</td>
</tr>
<tr>
<td>JHK3-WHC</td>
<td>69</td>
<td>45</td>
<td>114</td>
<td>57</td>
</tr>
</tbody>
</table>

### 3.2 Adequacy of the Percentage of Path Distance Covered in the Partial Set of Observed Data Collected

To justify the adequacy of at least 50% (for JHK1-EHC, JHK2-EHC, JHK2-WHC, JHK3-CHT and JHK3-WHC) or 65% (for JHK1-CHT and JHK2-CHT) of path distance covered in the partial set of observed data collected in the surveys, statistical test was conducted as below for each selected path. The statistical test is to examine whether the average absolute percentage errors of instantaneous journey time estimates on these partial path segments with coverage of 50% or 65% only are statistically different from that with a higher percentage (at least 65%, 75% and 85%) of path distance covered. The test statistic \(Z\) adopted is given in Equation (3) (Johnson et al., 2005) as follow,

\[
Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}
\]

where \(\bar{x}_i\), \(s_i\) and \(n_i\) are the average absolute percentage errors, standard deviation of the
absolute percentage errors and the sample size of the instantaneous journey time estimates for the observed samples with at least 50% or 65% of the total path distance covered, respectively; and

\( \bar{x}_2, s_2 \) and \( n_2 \) are the average absolute percentage errors, standard deviation of the absolute percentage errors and the sample size of the instantaneous journey time estimates for the observed samples with a higher percentage (at least 65%, 75% and 85%) of the total path distance covered, respectively.

If the test statistic is greater than the \( z_{\alpha/2} \) value which is corresponding to \( \alpha \) level of significance for normal distribution, it means that the differences in the average absolute percentage errors of two sets of samples are statistically significant at \( \alpha \) level of significance. Otherwise, there is no difference in the average absolute percentage errors of two sets of samples. In the statistical test, 5% level of significance (i.e. \( z_{0.05/2} = 1.96 \)) was adopted. The results of the statistical tests for the seven selected paths are summarized in Table 2.

Table 2 Results of the statistical tests for the percentage of path distance covered in partial set of observed data

<table>
<thead>
<tr>
<th>Route</th>
<th>Test statistic Z (No difference if Z &lt; 1.96)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic* vs. ( \geq 65% )</td>
</tr>
<tr>
<td>JHK1-CHT</td>
<td>-</td>
</tr>
<tr>
<td>JHK1-EHC</td>
<td>1.08</td>
</tr>
<tr>
<td>JHK2-CHT</td>
<td>-</td>
</tr>
<tr>
<td>JHK2-EHC</td>
<td>1.06</td>
</tr>
<tr>
<td>JHK2-WHC</td>
<td>0.20</td>
</tr>
<tr>
<td>JHK3-CHT</td>
<td>1.47</td>
</tr>
<tr>
<td>JHK3-WHC</td>
<td>0.09</td>
</tr>
</tbody>
</table>

*Note: Basic scenario refers to the percentage of \( \geq 50\% \) of path distance covered for JHK1-EHC, JHK2-EHC, JHK2-WHC, JHK3-CHT and JHK3-WHC, whereas percentage of \( \geq 65\% \) of path distance covered for JHK1-CHT and JHK2-CHT.

As the values of test statistics for all the seven selected paths are less than 1.96, it can be concluded that there is no statistically difference between the average absolute percentage errors of journey time estimates in the two samples with different percentages of total path distance covered for all these selected paths at the 5% level of significance. The use of at least 50% or 65% of total path distance covered in the partial set of observed data in the surveys is therefore adopted for collection of more samples so as to obtain representative and reliable validation results.

3.3 Overall Performance of the JTISHK

The overall results for validation of the instantaneous average journey time estimates on the seven selected paths are summarized in Table 3. It was observed that all the seven selected paths have met the targeted accuracy level of +/- 20% errors with a compliance of 95% within
the two survey days. Such accuracy requirement on the performance of the re-developed JTISHK was set by the Hong Kong Transport Department. From the above results, it can be concluded that the re-developed JTISHK has been performed satisfactorily.

Table 3 Overall results of the validation of instantaneous average journey time estimates

<table>
<thead>
<tr>
<th>Route</th>
<th>Percentages of samples within ± 20% errors</th>
<th>Weekday</th>
<th>Weekend</th>
<th>Overall two survey days</th>
</tr>
</thead>
<tbody>
<tr>
<td>JHK1-CHT*</td>
<td></td>
<td>98.0%</td>
<td>97.8%</td>
<td>97.9%</td>
</tr>
<tr>
<td>JHK1-EHC</td>
<td></td>
<td>97.9%</td>
<td>100.0%</td>
<td>98.9%</td>
</tr>
<tr>
<td>JHK2-CHT*</td>
<td></td>
<td>96.1%</td>
<td>93.2%</td>
<td><strong>95.0%</strong></td>
</tr>
<tr>
<td>JHK2-EHC</td>
<td></td>
<td>96.2%</td>
<td>98.0%</td>
<td>97.1%</td>
</tr>
<tr>
<td>JHK2-WHC</td>
<td></td>
<td>100.0%</td>
<td>89.8%</td>
<td>95.5%</td>
</tr>
<tr>
<td>JHK3-CHT</td>
<td></td>
<td>91.8%</td>
<td>98.1%</td>
<td>95.1%</td>
</tr>
<tr>
<td>JHK3-WHC</td>
<td></td>
<td>97.1%</td>
<td>100.0%</td>
<td>98.3%</td>
</tr>
</tbody>
</table>

*Note: Partial set of observed journey time samples for JHK1-CHT and JHK2-CHT is defined as ≥ 65% of the total path distance covered.

4. CONCLUSIONS

This paper presented the approach and the results of the validation of the instantaneous average journey time estimates provided by the Journey Time Indication System in Hong Kong (JTISHK). Comprehensive survey has been designed to collect the observed instantaneous journey times for validating the instantaneous average journey time estimates on seven selected paths (JHK1-CH, JHK1-EH, JHK2-CH, JHK2-EH, JHK2-WH, JHK3-CH and JHK3-WH) in a typical weekday and a representative weekend. Adequate sample sizes of valid observed data were collected on each of the seven selected paths by the proposed survey method with limited number of test vehicles. The validation results showed that the JTISHK meets the requirement of the targeted accuracy level (i.e. +/- 20% errors with a compliance of 95%) for all the seven selected paths throughout the survey periods within the two survey days.

Further works are being carried out to expand the journey time indication system to the New Territories of Hong Kong. Validations of the instantaneous average journey time together with sectional speed estimates will be conducted before the launch of the new system in the New Territories of Hong Kong in early 2012.

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