Validation of ATIS Journey Time and Traffic Speed Estimates by Floating Car Survey

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Abstract: Traffic congestion is a re-current problem in densely populated cities. To alleviate congestion, many countries/cities have developed advanced traveler information systems (ATIS) to provide the latest traffic information to road users. However, the traffic information such as instantaneous journey time and traffic speed provided by ATIS is difficult to be validated. In particular, instantaneous journey time reflects the current traffic condition in terms of 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. This paper proposes a methodology for validating the instantaneous journey times and traffic speeds with independent observed data. The results show that the proposed method can validate the instantaneous journey time and traffic speed estimates satisfactorily with adequate sample sizes at a significant level statistically.

Keywords: Instantaneous journey time, Traffic speed, Validation, Floating car survey, Advanced traveler information systems

1. INTRODUCTION

Advanced traveler information systems (ATIS) are the most widely deployed intelligent transportation system (ITS) applications. ATIS provide vital traffic information to road users for their trip planning and route choice decisions (Yu *et al*., 2010). Given instantaneous or predicted traffic information, road users can know roughly when they may arrive at their destinations. They can choose the potentially fastest routes to avoid traffic congestion in urban road networks. Road users can also react to the traffic incidents immediately after they occur. The benefits of ATIS 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 up to 14% and reduce the travel time variability up to 50% (Toledo and Beinhaker, 2006). ATIS were also found to be an efficient tool to reduce the effects of non-recurrent incidents in a transportation network (Fernandez *et al.*, 2009; Kusuhashi *et al.*, 2012).

A wide variety of travel time estimation and short-term travel time prediction problems has been investigated during past decades. For example, Coifman (2002) estimated travel times on freeways using dual loop detector data on the basis of the basic traffic flow theory. van Lint and van der Zijpp (2003) extended the traditional trajectory method to estimate the journey time on motorway corridors. Other approaches include statistical models (e.g. linear, non-linear and Bayesian) to estimate link travel times as a function of the traffic characteristics (free-flow speeds, saturation flows) and loop detector data (Frechette and Khan, 1998; Turner *et al.*, 1996; Zhang, 1999). However, some of these models are quite site specific and may not be readily applied to other environments. With advancements in sensor technology, considerable research efforts have been spent on traffic estimation and prediction using data from fixed sensors (Dion and Rakha, 2006; Li *et al.*, 2006; Lin *et al.*, 2004). Various methods such as data fusion, Kalman filtering, simulation and neural networks have been developed (Bachmann *et al.*, 2013; Liu *et al.*, 2006). Recently, use of multiple data sources (e.g. loop detectors, probe vehicles, license plates, electronic tag readers) has become popular for instantaneous travel time/speed estimation and prediction for ATIS applications (Bachmann *et al.*, 2013; Kong *et al.*, 2009; Soriguera and Robuste, 2011). This kind of fusion-based method provides a more effective approach for instantaneous traffic estimation and short-term prediction, which can overcome the limitations of the data from single data source.

However, the success of ATIS is heavily dependent on the accurate estimation/ prediction of traffic conditions. Thus, it is necessary to validate the traffic information such as instantaneous or predicted journey times and traffic speeds provided by ATIS before launch of the systems. 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 provided by ATIS and the actual journey time experienced by a driver on a given path. For example, a vehicle departed at the entry point of the path at 18:33. The instantaneous average journey time estimated at the two-minute interval of 18:32-18:34 is equal to sum of the estimated average journey times at the four road segments (i.e. 1.3+2.3+5.2+5.4) ≈ 14 minutes. However, the actual experienced journey time of the vehicle is approximately 18 minutes. As this vehicle arrived at the exit point of the path after 9 two-minute intervals from departure, this actual journey time is not appropriate for directly comparison with the instantaneous average journey time estimate.

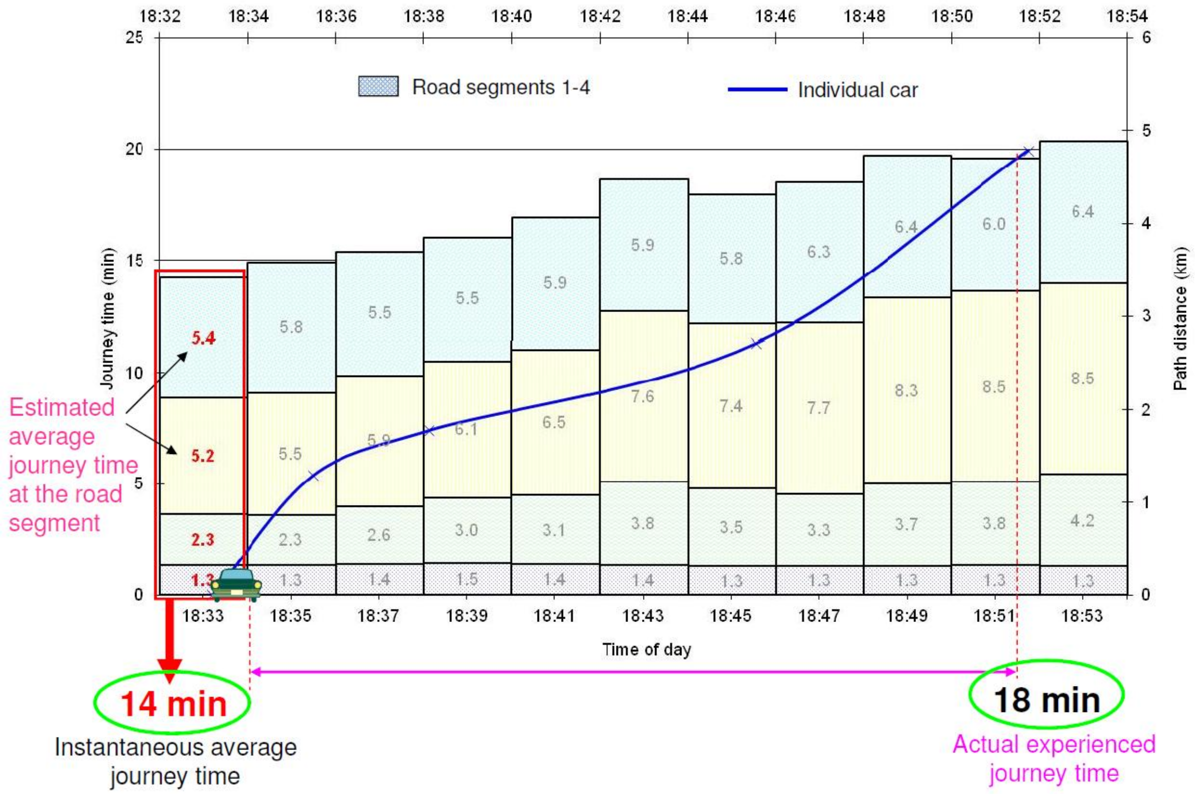


Figure 1. Difference between instantaneous journey time and actual experienced journey time

In this paper, one of the ATIS in Hong Kong, namely Speed Map Panels (SMP) system, is presented. A survey method is proposed for validation of the instantaneous path journey time and segmental traffic speed estimates provided by the SMP system in Hong Kong. The previous related works are mainly concerned with comparison of the estimates against the real-time data collected by advanced technologies or conducted floating car surveys (Bar-Gera, 2007; Liu and Ma, 2009; 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 cars available. In view of these difficulties on the collection of observed data for validation of instantaneous journey time/speed estimates, most of the previous studies focused on validation of their journey time estimates against the actual experienced 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, with the use of the proposed method, adequate sample size of independent observed data can be collected for both instantaneous path journey time and segmental speed validation with limited resources.

The rest of the paper is organized as follows. The SMP system is briefly introduced in the next section. The proposed survey method for collection of observed instantaneous path journey times and segmental traffic speeds are described in the third section. The results of validation of instantaneous path journey time and segmental traffic speed ranges for the major roads in the New Territories (NT) East of Hong Kong are presented in the forth section. Finally, conclusions are given together with some possible directions for potential ITS applications.

2. SPEED MAP PANELS (SMP) SYSTEM IN HONG KONG

The SMP system is implemented by the Transport Department of the Hong Kong Government (http://www.td.gov.hk/en/transport_in_hong_kong/its/its_achievements/speed_map_panels/). The purpose of the SMP system is to provide road users with real-time traffic information at critical diversion points of major roads in the New Territories (NT) of Hong Kong. This can help road users to choose the faster route for their travel in advance or when driving and hence to alleviate the traffic congestion on the roads.

The system consists of five sets of gantry-mounted SMP which show the average traffic speeds at various road segments in form of three colors (red, amber and green) to represent different congestion levels. Three sets of SMP are set up at the major roads in the NT East of Hong Kong, while another two are located at the major roads of the NT West. In conjunction with each SMP, on-gantry indicators are also installed for displaying the estimated average journey times from the indicator locations to the destinations via the paths shown on the SMP. Both the journey times and traffic speeds are estimated based on real-time traffic data collected by automatic license plate recognition technology and video image processing technology together with offline historical traffic data (Tam and Lam, 2008; 2011). The journey time estimates and traffic speed colors are updated at two-minute intervals as required by the Transport Department of the Hong Kong Government. This SMP system has been launched to the public in January 2013. Comprehensive validation of instantaneous journey time estimates and traffic speed colors was conducted in the NT East and the NT West of Hong Kong before launch of the system.

This paper focuses on the validation of the instantaneous journey times and traffic speed colors provided by the SMP system in the NT East of Hong Kong. The locations of the three sets of SMP in the NT East together with the corresponding road network are shown in Figure 2. In the SMP system, nine selected paths are pre-determined for estimation of the instantaneous average journey times in the NT East of Hong Kong. The starting points of the respective paths for journey time estimation are the locations of the journey time indicators for each SMP. The destinations of the paths are the exit of the respective tunnels. These nine selected paths are referred to SMP1-LRT, SMP1-TSCA, SMP1-SMT, SMP2-TCT, SMP2-LRT, SMP2-TSCA, SMP3-TCT, SMP3-LRT and SMP3-TSCA in the paper. In addition, a total of 40 road segments are defined in the road network of the NT East for computation of traffic speed colors in the SMP system. Among these 40 road segments, 35 road segments are classified as major roads while 5 road segments are urban roads. The traffic speed colors and the corresponding speed ranges for these two types of roads are defined as follows.

(a) Major roads [Red: 0-25km/h; Amber: 25-50km/h, Green: >50km/h]
(b) Urban roads [Red: 0-15km/h; Amber: 15-30km/h, Green: >30km/h]

According to the contract requirement of the SMP system set by the Transport Department of the Hong Kong Government, the accuracy level of the journey time estimates and computed speed colors/ranges on each of the selected paths and road segments should be within +/- 20% with a compliance of 95%.

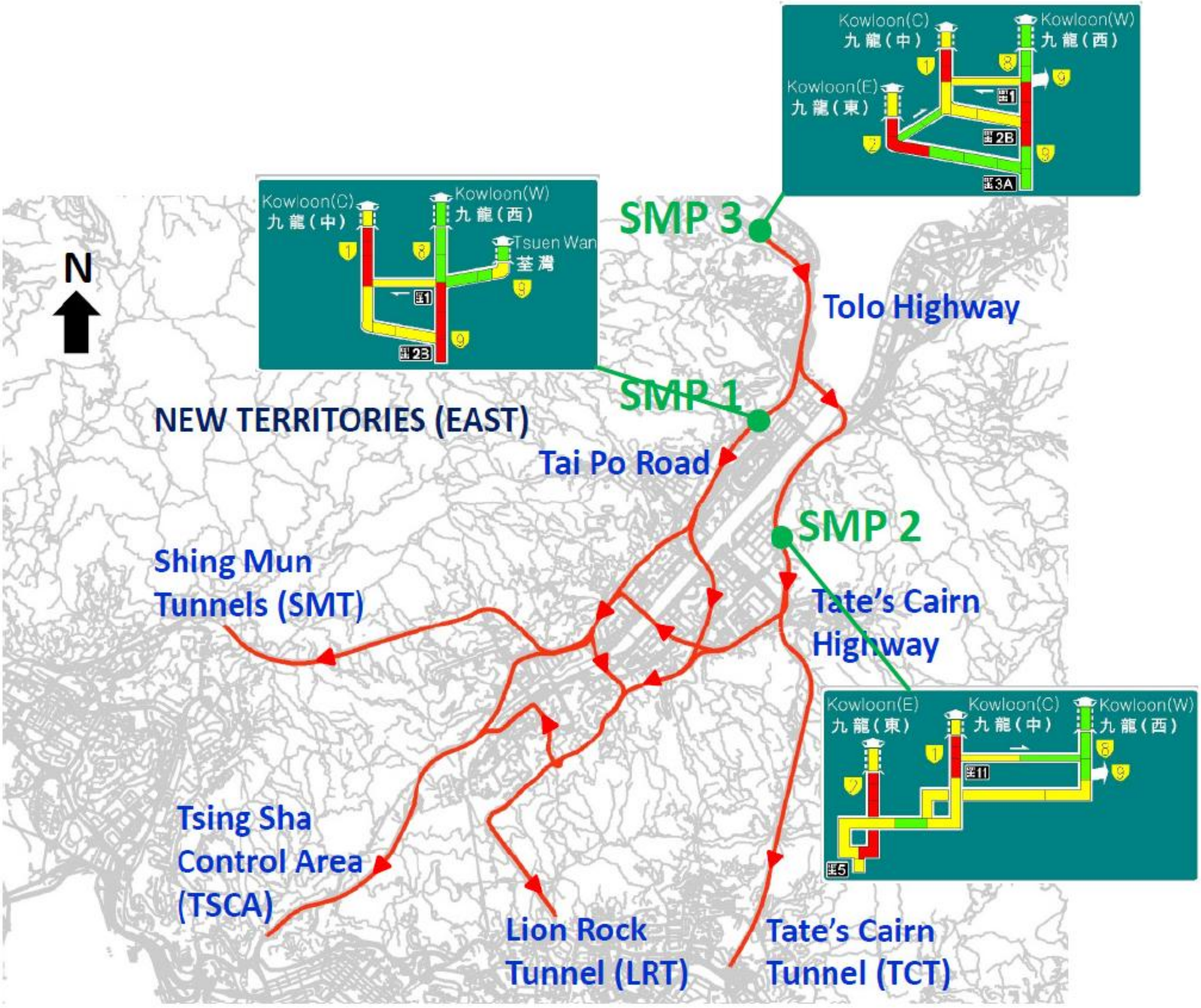


Figure 2. Locations of the SMP and the selected paths in the New Territories East of Hong Kong

3. SURVEY DESIGN FOR COLLECTION OF INSTANTANEOUS OBSERVED DATA

Floating car surveys were deployed for collection of the observed instantaneous journey times for validation of the instantaneous journey time estimates on the nine selected paths for SMP system together with the traffic speeds on the road segments of the corresponding paths. The 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 surveys, six to eight test vehicles were adopted for each journey time and traffic speed measurements. In general, each of the test vehicles started the trip with at least two minutes apart. The purpose of departing the test vehicles separately at different time 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/speed measured on each of the selected paths can be considered as an observed average travel time/speed of the traffic stream as a whole.

Surveyors in test vehicles used synchronized watches to record the arrival time at each pre-determined checkpoint of the selected path. The locations of these checkpoints were set on the end points of the road segments where were defined based on the contract requirement and the constraints of the site locations. Based on the times recorded, journey times 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 paths and the observed instantaneous traffic speeds on road segments. The method of how to obtain the observed instantaneous journey time at two-minute time interval is explained in Section 3.1. Such observed data collected in the two survey days would be used to validate against the instantaneous average path journey times and the segmental traffic speed colors/ranges estimated by the SMP system at the same time interval. It is required that, according to the contract requirement, the targeted accuracy level for SMP system, as indicated in Section 2, should be achieved.

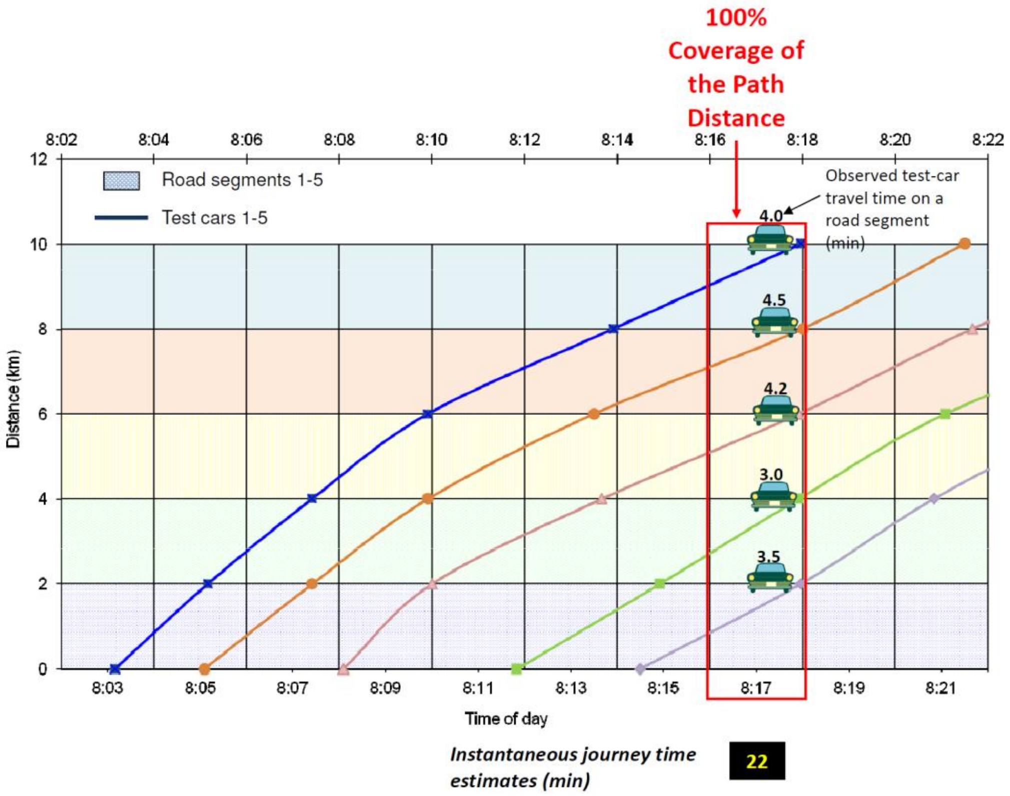
3.1 Approach for Journey Time Validation

The observed instantaneous test-car journey time of each selected path is obtained by the sum of the travel times of different test cars between two successive checkpoints at the same two-minute time interval, which all checkpoints on the path are covered. If the travel times of more than one test cars are obtained at the same road segment within the same two minutes, average value of these test-car travel times is taken.

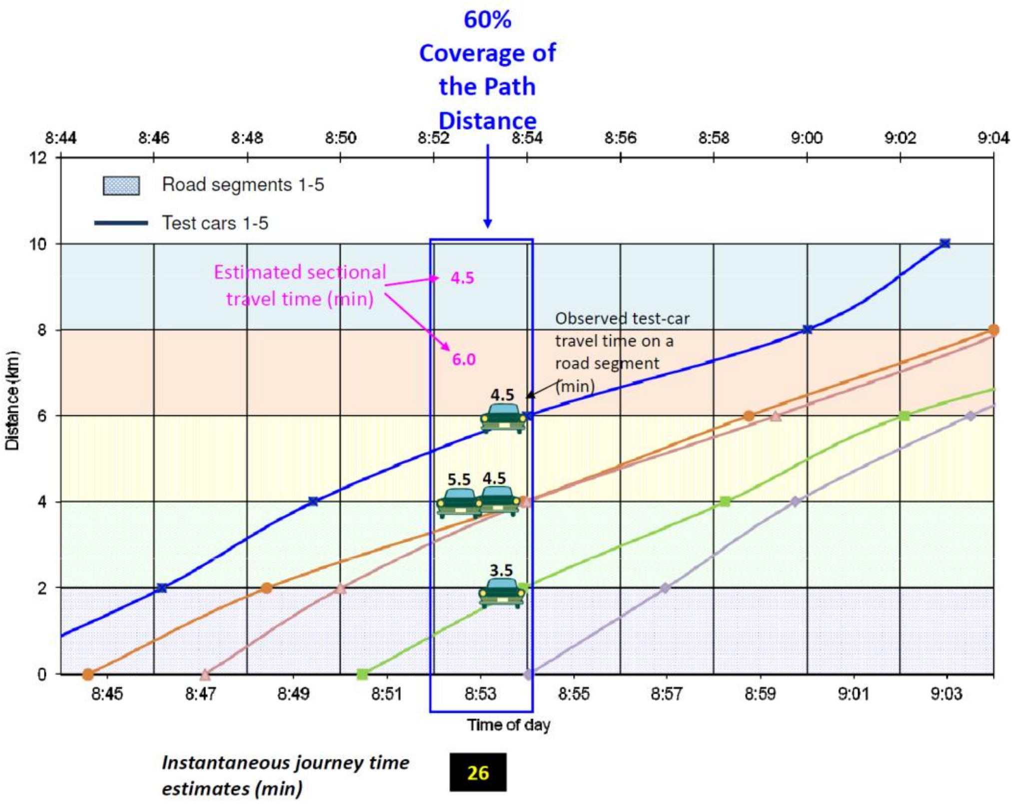
Figure 3 shows artificial examples for explanation of the coverage of path distance with observed test-car data for instantaneous journey time validation. In this example, there is a path with five road segments and the lengths of the five road segments are equal. As shown in Figure 3a, the observed instantaneous test-car journey time for this path at the time interval of 8:16:00-8:17:59 is equal to sum of travel times of different test-cars on different road segments along the path (i.e. 3.5 + 3.0 + 4.2 + 4.5 + 4.0 = 19.2 minutes). This observed instantaneous journey time is then compared with the estimated instantaneous journey time of 22.0 minutes for the path at the same two-minute time interval as shown in Table 1.

In general, the observed instantaneous test-car journey time samples with 100% coverage of the path distance (i.e. the artificial example in Figure 3a) on the selected path are not adequate for validation as they are not easily obtained due to the variation of traffic conditions during the survey periods. It can be seen in Figure 3b that the 3rd test car caught up the 2nd test car on the 2nd road segment at the time interval of 8:52:00-8:53:59. The observed instantaneous test-car travel times at only three out of five road segments (i.e. 60% coverage) are thus obtained for the path at this time interval.

In order to increase the number of samples for validation, the observed instantaneous test-car journey times on partial segments of the selected path are used together with the estimated travel times on the rest of the road segments for comparing with the path instantaneous journey time estimates. For example, the validation of the instantaneous journey time estimate against the observed instantaneous test-car journey time sample with 60% coverage of the path distance at the time interval of 8:52:00-8:53:59 is given in Table 1. The segmental travel times of 6.0 and 4.5 minutes for the 4th and the 5th road segments (i.e. the road segments without observed test-car data), respectively, are estimated by the SMP system.



(a) 100% coverage of the path distance with observed test-car data



(b) 60% coverage of the path distance with observed test-car data

Figure 3. Examples of 100% and 60% coverage of the path distance with observed test-car data

Table 1. Examples for validation of the instantaneous journey time estimates based on 100% and 60% coverage of the path distance with observed test-car data

Observed data	Two-minute time interval	Observed instantaneous test-car journey time (T_o), min	Estimated instantaneous journey time by SMP system***** (T_e), min	Absolute percentage error, % $\lvert T_o - T_e \rvert / T_e * 100$
100% coverage of the path distance	08:16:00 -08:17:59	3.5+3.0+4.2+4.5+4.0 = **19.2**	**22.0**	12.7
:	:	:	:	:
:	:	:	:	:
60% coverage of the path distance	08:52:00 -08:53:59	3.5+(5.5+4.5)/2+4.5 +***6.0****+***4.5**** = **23.5**	**26.0**	9.6
:	:	:	:	:
:	:	:	:	:

** The estimated instantaneous journey times and the segmental travel time estimates are directly extracted from the SMP system.*

However, in order to avoid the domination of the observed data collected on long section of the road such as the tunnel section, the observed instantaneous journey time samples must fulfill the following criteria (as referred to base scenario in the paper). Otherwise, the journey time samples are discarded for validation.

1) If the tunnel distance is longer than 50% of the total path distance, the sum of the distance of the road sections, which partial observed data are collected, is at least 75% of total distance of the selected path.
2) Otherwise, the sum of the distance of the road sections, which partial observed data are collected, is at least 50% of total distance of the selected path.

3.2 Approach for Traffic Speed Color Validation

The observed instantaneous average traffic speeds on road segments are obtained based on the results of the floating car surveys. The observed test-car journey times on the road segments have been used to calculate the observed test-car speeds based on the distances of the road segments. The observed instantaneous traffic speed of each selected road segment is then obtained by averaging the observed speeds of different test cars, if any, on the same road segment at the same two-minute time interval. The corresponding speed color for the observed speed ranges has then been validated against the speed color for the speed ranges computed by the SMP system.

Tables 2 and 3 demonstrate the possible results of the traffic speed range validation for major and urban roads, respectively. In particular, the results of road segment 2 shown in Table 2 demonstrate a computed speed range sample on a major road segment exceeded 20% error. Similar case for an urban road segment is also illustrated in Table 3. However, the probability of exceeding 20% error for all the road segments should not be greater than 5%. Otherwise, the accuracy requirement of the SMP system cannot be achieved.

It should be noted that, in order to be consistent with data collected for journey time validation, only the corresponding observed segmental traffic speeds of the path journey time samples (i.e. the valid samples achieved the minimum coverage of the paths) have been used to validate the computed speed colors/ranges of the road segments on the nine selected paths.

Table 2. Examples for validation of the computed traffic speed colors on major road segments

Major road segments	1	2	3	4
Computed speed by the SMP System, km/h	13	32	42	65
Color for computed speed range with allowance of +/- 20% errors[1]	**R***	**A***	A* or **G***	**G***
Observed test-car speed, km/h	15	18	55	70
Color for observed speed range[2]	**R**	**R**	**G**	**G**
Targeted accuracy level required	✓	×	✓	✓

[1] Computed speed range: R* – Red (0-30km/h); A* – Amber (20-60km/h); G* – Green (>40km/h)
[2] Observed speed range: R – Red (0-25km/h); A – Amber (25-50km/h); G – Green (>50km/h)

Table 3. Examples for validation of the computed traffic speed colors on urban road segments

Urban road segments	1	2	3	4
Computed speed by the SMP System, km/h	6	19	26	35
Color for computed speed range with allowance of +/- 20% errors[1]	**R***	**A***	A* or **G***	**G***
Observed test-car speed, km/h	8	10	32	40
Color for observed speed range[2]	**R**	**R**	**G**	**G**
Targeted accuracy level required	✓	×	✓	✓

[1] Computed speed range: R* – Red (0-18km/h); A* – Amber (12-36km/h); G* – Green (>24km/h)
[2] Observed speed range: R – Red (0-15km/h); A – Amber (15-30km/h); G – Green (>30km/h)

4. VALIDATION RESULTS OF INSTANTANEOUS JOURNEY TIME ESTIMATES AND COMPUTED TRAFFIC SPEED COLORS

The floating car surveys were conducted on the nine selected paths in the NT East of Hong Kong in September 2012. To evaluate the accuracy of the instantaneous journey time estimates, the mean absolute error (MAE) and the mean absolute percentage error (MAPE) are used. These two performance measures are defined in Equations (1)-(4). For the accuracy of the computed traffic speed colors, it is easily compared the speed colors with those of the observed speed ranges at the same time intervals.

$$AE = |T_o - T_e| \tag{1}$$

$$APE = \frac{|T_o - T_e|}{T_e} \times 100\% \tag{2}$$

$$MAE = \frac{\sum AE}{n} \tag{3}$$

$$MAPE = \frac{\sum APE}{n} \tag{4}$$

where,

T_o : observed instantaneous test-car journey times;
T_e : instantaneous average journey time estimated by the SMP system; and
n : number of samples collected.

4.1 Sample Size

4.1.1 Instantaneous journey time

Table 4 shows the total number of the instantaneous journey time samples on each of the nine selected paths collected in the two-day surveys. The valid samples of journey time on the selected paths are varied and dependent on the traffic conditions during the floating car surveys and the path distances. It can be seen, however, that more than 100 samples were collected in the two survey days on each of the nine selected paths. To check the adequacy of the sample size required for each of the selected paths within the two survey days, Equation (5) was adopted for sample size checking (Li and McDonald, 2007; Transport Department, 2008).

$$N_{\min} \geq \left(\frac{z_{\alpha/2} s}{e} \right)^2 \tag{5}$$

where,

N_{min} : minimum sample size required for a (1-α) level of confidence for each selected path within two survey days;
$z_{\alpha/2}$: confidence coefficient corresponding to α/2 for normal distribution;
s : standard deviation of the APE of instantaneous journey time estimates on each selected path within two survey days; and
e : permitted error of the MAPE of instantaneous journey time estimates on each selected path within two survey days.

Table 4. Number of journey time samples collected on the selected paths

Selected path	Samples collected in two survey days	Minimum samples required
SMP 1-LRT	180	60
SMP 1-TSCA	178	130
SMP 1-SMT	140	56
SMP 2-TCT	116	54
SMP 2-LRT	181	45
SMP 2-TSCA	168	88
SMP 3-TCT	135	70
SMP 3-LRT	176	61
SMP 3-TSCA	127	118

In the sample size checking, a 20% of permitted error of the MAPE of instantaneous journey time estimates at 95% level of confidence (i.e. α = 0.05) was adopted. Thus, the test statistic is equal to $z_{0.05/2}$ = 1.96 and the permitted error e = 0.2 × MAPE of instantaneous journey time estimates. It was found in Table 4 that the number of samples collected in the two survey days is much more than the minimum sample size required for most of the selected paths. The samples collected for journey time validation are thus statistically adequate at 5% level of significance.

4.1.2 Instantaneous traffic speed color

In addition to the provision of instantaneous average journey times on the nine selected paths, traffic speed colors at 40 road segments in the road network of the NT East of Hong Kong are displayed on the SMP. Therefore, the traffic speed colors are also required to be validated. In order to minimize the resources for data collection, observed data for validations of path journey time and segmental traffic speed are collected in the same survey.

Similar to instantaneous journey time samples, sample sizes of segmental traffic speeds are varied due to the variation of traffic conditions during the survey periods and the different road segment distances. The sample sizes for validation of traffic speed colors/ranges on these 40 selected road segments are summarized in Table 5. For example, the first row of Table 5 shows that 81-100 samples were collected on 9 out of 40 road segments in the two survey days. It was found from the survey results that over 100 traffic speed samples were collected at the majority of road segments (77.5%). These traffic speed samples on the road segments are corresponded to the samples for journey time validation as defined in Section 3.1. In other words, only the corresponding observed segmental travel times (speeds) of the path journey time samples (i.e. the valid samples achieved the minimum coverage of the selected paths) have been used to validate the computed speed colors/ranges of those road segments on the selected paths.

It is also noted that some road segments are common for different selected paths. The samples collected at different survey paths in different survey days (weekday and weekend) but on the same road segment are all used for validating the accuracy of the traffic speed ranges on that road segment. This is why the number of traffic speed samples on some road segments is much more than that on the other road segments.

Table 5. Distribution of samples collected on the selected road segments for traffic speed color/range validation

Number of samples collected on each road segment in two survey days	Number of road segments	Cumulative percentage of road segments
81-100	9	22.5%
101-120	11	50.0%
121-140	3	57.5%
141-160	3	65.0%
161-180	6	80.0%
181-220	4	90.0%
221-260	2	95.0%
261-300	2	100.0%
Total	40	-

4.2 Adequacy of Coverage of Path Distance with Instantaneous Observed Data

As mentioned in Section 3.1, the minimum coverage of the path distance with observed test-car data was set as 50% for the selected paths with tunnel distance not greater than 50% of their total path distance (i.e. SMP1-LRT, SMP1-TSCA, SMP1-SMT, SMP2-LRT, SMP2-TSCA, SMP3-TCT, SMP3-LRT and SMP3-TSCA) and 75% for the path with tunnel distance greater than 50% of the total path distance (i.e. SMP2-TCT). In order to justify the adequacy of this minimum coverage of path distance with test-car data (i.e. the base scenario) in the observed instantaneous journey time samples, statistical tests were conducted by comparing with a larger coverage. The statistical test is to examine whether the MAPE of instantaneous journey time estimates on these partial path segments with coverage of 50% or 75% only are statistically different from that with a larger coverage (at least 75% and 95%) of path distance. The test statistic Z adopted is given in Equation (6) (Johnson *et al*., 2005).

$$Z = \frac{\left|\overline{x}_1 - \overline{x}_2\right|}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \tag{6}$$

where,

$\overline{x}_1$: MAPE of the instantaneous journey time estimates for the observed samples with at least 50% or 75% coverage of the total path distance (base scenario);

s_1 : standard deviation of the APE of the instantaneous journey time estimates for the observed samples with at least 50% or 75% coverage of the total path distance (base scenario);

n_1 : sample size of the instantaneous journey time estimates for the observed samples with at least 50% or 75% coverage of the total path distance (base scenario);

$\overline{x}_2$: MAPE of the instantaneous journey time estimates for the observed samples with a larger coverage (at least 75% and 95%) of the total path distance;

s_2 : standard deviation of the APE of the instantaneous journey time estimates for the observed samples with a larger coverage (at least 75% and 95%) of the total path distance; and

n_2 : sample size of the instantaneous journey time estimates for the observed samples with a larger coverage (at least 75% and 95%) of the total path distance.

If the test statistic is greater than the $z_{\alpha/2}$ value which is corresponding to α level of significance for normal distribution, it means that the differences in the MAPEs of two sets of samples are statistically significant at α level of significance. Otherwise, there is no difference in the MAPEs 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 nine selected paths are summarized in Table 6.

It can be seen from Table 6 that the greatest values of test statistics among the nine selected paths for the two statistical tests (Base vs. ≥ 75% coverage and Base vs. ≥ 95% coverage) are less than 1.96. Therefore, it can be concluded that there is no statistically difference between the MAPEs of journey time estimates in the two samples with different coverage of total path distance for all these selected paths at the 5% level of significance.

However, it is obvious that the number of samples would be reduced if larger coverage of path distance was adopted. Therefore, in the validation of instantaneous journey time estimates, at least 50% or 75% coverage of total path distance with observed test-car data was adopted for collection of more samples so as to obtain more representative and reliable validation results.

Table 6. Results of statistical tests

Selected path	Test statistic Z (No difference if Z < 1.96)	
	Base* vs. ≥ 75%	Base* vs. ≥ 95%
SMP 1-LRT	1.10	1.67
SMP 1-TSCA	**1.57 < 1.96**	1.11
SMP 1-SMT	0.74	0.66
SMP 2-TCT	NA**	0.14
SMP 2-LRT	0.53	1.37
SMP 2-TSCA	1.04	1.72
SMP 3-TCT	0.16	0.74
SMP 3-LRT	0.62	0.97
SMP 3-TSCA	0.49	**1.91 < 1.96**

** Base scenario refers to the coverage of ≥ 50% of the path distance with observed test-car data for SMP1-LRT, SMP1-TSCA, SMP1-SMT, SMP2-LRT, SMP2-TSCA, SMP3-TCT, SMP3-LRT and SMP3-TSCA whereas coverage of ≥ 75% of the path distance with observed test-car data for SMP2-TCT.*

*** Not applicable as the base scenario for this path is ≥ 75% of path distance coverage with observed test-car data.*

4.3 Validation Results

The validation results for instantaneous average journey time estimates on the nine selected paths are summarized in Table 7. It was observed that the MAEs are less than one minute whereas the MAPEs are about 3-5% for all the selected paths. Moreover, the APEs in 95% of the collected samples are less than 16% for all the selected paths. In the other words, all the nine selected paths have met the targeted accuracy level of +/- 20% errors with a compliance of 95% within the two survey days. From the above results, it can be concluded that the SMP system can provide accurate instantaneous journey time estimates on the selected paths in the NT East of Hong Kong.

The speed colors of the computed traffic speed ranges are compared with those of the observed traffic speed ranges on the same road segments at the same time intervals. With allowance of +/-20% errors on the computed traffic speed ranges, the validation results are illustrated in Figure 4. It can be seen in Figure 4 that the accuracy level is over 96% for all the selected road segments throughout the survey periods within the two survey days. The results indicate that the traffic speed range calculation of the SMP system has been performed satisfactorily.

Table 7. Validation results of the estimated journey times on the selected paths

Selected path	MAE (min)	MAPE (%)	Maximum APE (%) with a compliance of 95%
SMP 1-LRT	0.34	4.30	10.7
SMP 1-TSCA	0.43	4.33	14.3
SMP 1-SMT	0.38	4.72	11.9
SMP 2-TCT	0.31	5.31	13.3
SMP 2-LRT	0.33	4.55	10.5
SMP 2-TSCA	0.66	5.12	15.3
SMP 3-TCT	0.35	3.60	9.8
SMP 3-LRT	0.43	3.69	8.9
SMP 3-TSCA	0.59	4.28	13.1

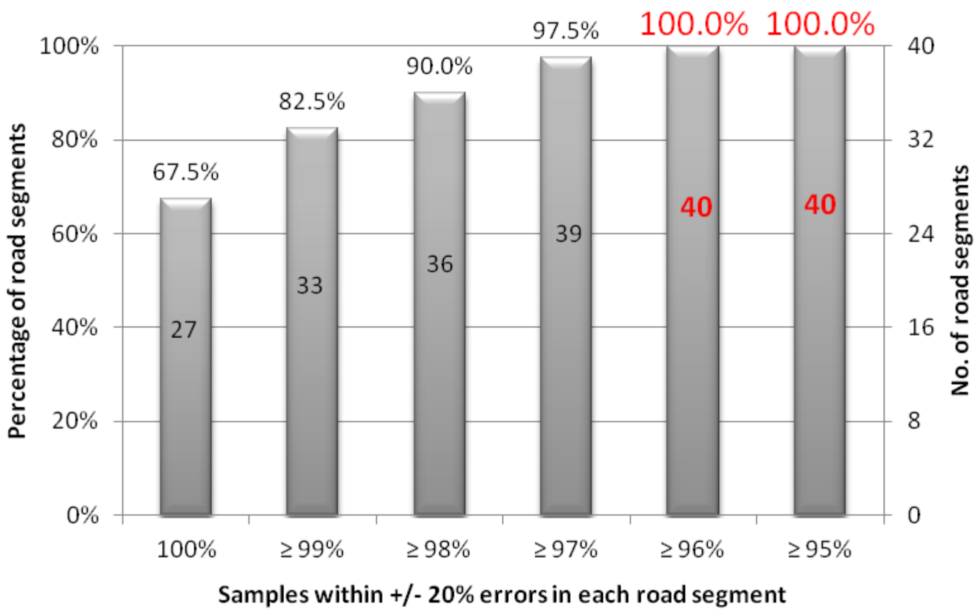


Figure 4. Validation results of the computed traffic speed colors/ranges

5. CONCLUSIONS

This paper presented the approach and the results of the validation of the instantaneous average path journey time estimates and segmental speed ranges (in form of color) provided by the Speed Map Panels (SMP) system in Hong Kong. Comprehensive survey has been designed to collect the observed instantaneous journey times and traffic speeds for validating the instantaneous average journey time estimates and traffic speed ranges on nine selected paths in the New Territories East of Hong Kong. The surveys were conducted in a typical weekday and a representative weekend for each of the selected paths in September 2012. Adequate sample sizes of observed data were collected on each of the selected paths by the proposed method with limited number of test vehicles. The validation results showed that the accuracy requirements on the journey times and the traffic speed ranges/colors are all fulfilled at these selected paths and road segments throughout the survey periods within the two survey days.

Further works on some potential ITS applications are being carried out. For example, automatic road closure and incident detection algorithms are being developed based on the real-time traffic data and the estimated traffic information for incident management purposes. Short-term journey time prediction is also being conducted with consideration of the spatio-temporal variance and covariance relationships of journey times simultaneously.

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