CHAPTER V

CONCLUSIONS AND FUTURE WORKS

5.1 CONCLUSIONS

This research demonstrates the quality of travel time data from probe vehicles as compared to the "true" travel time obtained from other methods. The research tested the assumption that the probe vehicles could provide reliable and sufficient amount of data that could represent accurate travel time information. In the study, quality (accuracy) of the travel time data by probe vehicles were determined at various traffic conditions, as indicated by level of congestion of the links under study. Also, the travel time were examined at link and route levels. The case study was carried out to investigate the travel time quality under traffic situation similar to the real world. The accuracy of travel time data from probe vehicles could be determined by comparing the travel time from probe vehicles with the 'true' average travel time, which gathered from all vehicles traversing the corresponding links.

A study methodology was developed, based on the simulated traffic environment. A variety of traffic environments were created in order to represent various "actual" travel time situations. However, this section of the study did not attempt to replicate the real world, rather to study the accuracy of travel time generated by probe vehicles in various driving environments. The key point under examination was the quality of the travel time received from probe vehicles under various traffic and probe (market penetration) conditions. The analyses were divided into three parts: Link travel time, Route travel time, and OD travel time (Case study). The average travel time on link, route and Origin Destination (OD) were analyzed and compared to the 'true' average travel time. From the Paramics V5 microscopic simulation the data sets consisted of individual vehicle travel times were obtained. A variety of probe vehicles sample size was considered. The benchmark was, of course, the 100% data set. However, only 2.5%, 5%,

10% and 20% of probe sample were specified, which in terms of number of vehicles were significant. The analysis made used of 'bootstrapping' method where the variation of the travel times resulting from probe vehicles could be studied. The bootstrap method displays the variations in travel time according to the "sampling", and thus the confidence in travel time obtained from probe vehicles at a traffic and probe (market penetration) condition.

From the analysis, the plots of probe vehicle average travel time versus 'true' link average travel time agree well which implies that sufficient accuracy of average travel time could be gained by probe vehicles in a wide range of traffic volumes (situations) (Figure 4.1). Exception is placed at high congestion situation where travelling on the links and routes experiences extensive queue (formation).

Accuracy of the travel time by probe vehicles can also be seen from standard deviation of the average (travel time). The results indicate trends of the variation in the standard deviation as the travel time on a link increases. The low percentage of probe vehicles would yield the higher scattering in standard deviation of the average travel time by probe vehicles (Figure 4.3). This clearly illustrates the reliability of travel time data obtained and its variability as a results of (the sampling of) the data obtainment from certain percentage of vehicles on streets. There is no discernable pattern observed from the standardized variance of the travel time (Figure 4.4).

Looking at the results of 'bootstrapping' (individual average travel time of each re-sampling), the results demonstrate the close similarity between bootstrapped predicted average travel times and 'true' average travel times. It can be seen that the variation of average travel time for every link is wider when having percentage of probe vehicles to be 2.5% and this variation becomes narrower as the percentage of probe vehicles increases. Therefore, the conclusion infers that the average travel time from probe vehicles can be used for the representation of the 'true' average travel time.

The results indicate various conclusions under travelling circumstances of traffic levels and links under consideration. Under poor level of service, especially during the instance when the network starts to load with vehicles and exceeds the capacity, the average travel time given by probe vehicle was not well equivalent to the 'true' travel time. There were queues extending back into the release zones and consequently only a small percentage of vehicle can enter the network. Moreover, even though all vehicles were still released on that link and once a vehicle was generated, it could not disappear until it reaches its destination, most of the vehicles could not complete their journey until the end of simulation. Thus, only a small number of probes could be obtained to gather the travel time data. Conversely, in the internal link, which could be considered as a "stable" link, the average travel time from the probe vehicle did not vary as much as in the entrance link. For the exit link, the deviation of the travel time was varying not so much even though the traffic volume increased. "Free" flow traffic condition could be expected in the exit link because all vehicles passed through all the intersections and the vehicle did not have any obstruction at the end of the network which could delay them to reach their destination.

Testing the average travel time on route basis, the average travel time generated from the probe vehicles appeared to perform reasonably well given that at least some percentages of probe vehicles were available for the travel time data collection. However, under some situations the probe vehicle performed less accurately. One limitation of the evaluation in this study was that, the tests did not attempt to examine the variation of 'true" travel time under various turning movement situations. The 'true' travel time of a link is an average of travel times of traffic in all directions. The 'true' travel time could not distinguish the 'average' travel time in each direction. Under route travel time consideration, there may be large discrepancies between travel times of through traffic and travel times of turning traffic, especially under poor level of service. Since the left turn, right turn and through movement might experience a larger difference in their time to traverse the intersection, it makes more sense to measure the travel time based on route

(a corridor consisting of multiple links) rather than link; or in other words used probes vehicle to gather the travel time data. It is important that the summation of all link travel times on the route may have discrepancies from the 'true' travel time of vehicle actually completing the route. Adding average link travel times together would certainly propagate the variance of the total travel time of the route. Consequently, with larger variance on travel time estimates, the link based average travel times are more likely to produce less satisfactory results from the probe vehicle results. With the increasing of probe vehicle percentage could somewhat improve the prediction accuracy for route travel time however, this improvement is not significant as the increasing of number probe vehicle is not linearly increased with the increasing of traffic volume (up to highly congested network). Therefore, having link by link average travel time, the observation could provide similar estimates of travel time and might shed some light on the implementation of travel time information system without a high market penetration of such devices.

The approximation of confidence intervals to the average travel times by probe vehicles in the "bootstrap" analysis is worthwhile addition to the standard analysis where the analysts can have comparable information for both, the probe vehicle average travel time and the 'true' travel time. In general, the 95-percent confidence interval ranges about plus or minus 20% from the 'true' value for percentage of probe vehicle 20% and the overall bootstrap distribution is focused somewhat below the 'true' value estimation. However, the confidence intervals range is considerably large for the network with high congestion.

In case of origin destination (OD), a case study with close network, traffic flow level, and signal control condition to the real world, it is important to take note that the calculations made did not deal with sampled dataset, as it would be the case for probe vehicle based estimation. The connotation that can be made about these results was whether the accuracy of the combination of route travel time and the link by link travel

time to be apply in the real world. From the findings, it was clear that when having all vehicles in the link to be probes, the OD estimates are rather reliable. While the above results seem to paint a rather bleak picture, it is noteworthy that all link by link average travel times are inside the range of 20% off from the OD travel time basis. This is a good start as in the real world where it is very difficult to reliably estimate the travel time due to the high variability in the traffic stream that results from the flow conditions coupled with the interrupted flow nature of signalized links. Therefore, the analysis have shown that, even though in some circumstances the link by link average travel time can appear to provide unreliable results, some indication can be obtained on the quality of the data by providing even some vehicles in the network to track the travel time data. Some variation of the deviation may be caused by variations in traffic volume, although not so large.

5.2 FUTURE WORKS

Based on this study, the approach for calculating the travel time on network links, route and OD using probe vehicle is simple and can be easily used. The scheme proved the travel time accuracy using probe vehicle as travel time measurement. The study provides an encouraging result where it could become a good start in the real world in terms of the understanding of the data accuracy provided by probe vehicle. In the real world, if the traffic conditions vary tremendously, one can pick a part of it to examine and look deeply as to what could happen. Therefore, an underlying assumption in this study in terms of potential future field applications is that since the variation probe vehicle data accuracy involved is not too high, some indicator of looking at the differences of the 'true' average travel time and the probe vehicles average travel time in terms of link and route can be made (by using the results from the study).

It is beneficial to conduct future works to extend the present knowledge. Further theoretical developments are possible with the model, such as using statistical techniques

to smoothen the probe vehicle data and using traffic flow theory based concepts for finding the averaging parameter that might affect the accuracy of the transmitted data by probe vehicle.

While the concept of a simulation as a test bed provides an unlimited environment to collect, test and validate the travel time generated, the model cannot put into practice without a validation with 'real' traffic environment. In this study, very small travel time data was used; while in the validation stage, a large amount of travel time data was needed. Therefore, it might be useful to conduct future research by providing large amount of data set for validation purpose. The validation and adjustment in building the network can be done by testing the model with the 'real' environment at various time steps, under various traffic conditions with variety types of road characteristics.

The results with the very simple scheme of using simulation approach itself yields good numbers, thus the method is already useful from a purely practical viewpoint. Yet, the problem is that microsimulation in traffic is a relatively new way of modeling. Very often it happens that some models do not model certain traffic behavior properly. Therefore, it would good to calibrate the model which might give better results and match the "real" life conditions more accurately. It would be helpful to continue to explore ways that microsimulation tools such as Paramics to be used to simulate larger multimodal freeway/arterial corridors.

In spite of this, since most delays take place at intersections, the turning movement has a significant effect on travel time estimation. Therefore, further study should be carried out to determine the extent of the variations related to the turning movement type, as well as to investigate the significance of factors affecting one type of movement only (e.g., opposing traffic for left turn movement, sequence for through traffic, etc.).

In addition, for link and route average travel time in this study, 100% passenger car was assumed as the vehicle composition in the simulation network with the speed limit of 90km/h. However, in real world, a mixture of vehicles is available with different desired speeds. Hence, it is likely these mixtures would result in sufficient variation in speeds to affect the accuracy of the date given by probe vehicles as quoted above and this should be further examined. Analysis on the characteristics of probe vehicle data from other types of commercial vehicles will be an interesting task to carry out.