APPENDIX B: EFFECT OF LINK TRAVEL TIME ESTIMATE ERROR AND ROUTING UPDATE INTERVAL ON NETWORK MEASURES OF PERFORMANCE

INTRODUCTION

The potential benefits of a Route Guidance System such as TravTek is dependent on the routing efficiency of both the background (non-equipped) vehicles and TravTek equipped vehicles. Intuitively, if the initial background link travel time estimate error is large, a wider window of opportunity should exist for an RGS to provide substantial benefits. Alternatively, if the initial background link travel time estimate error is relatively small, only a rather narrow window of opportunity may exist for an RGS to provide substantial benefits. Unfortunately, the quantitative impact of different background and RGS link travel time estimate errors is relatively unknown and, therefore, requires further investigation. Consequently, this appendix attempts to establish the impact of equipped and non-equipped link travel time estimate errors on the potential benefits of an RGS. The link travel time estimate error was modeled by introducing a white noise error to the link travel time estimates prior to generating the minimum path trees.

Another factor, that may impact the potential benefits of an RGS, is the interval frequency at which routing updates are made. It can be argued, on the one hand, that if routes are updated more frequently that the vehicles will be able to respond quickly to any re-routing decisions. On the other hand, it can be argued that in re-routing frequently one can respond in an excessive fashion and over react to stochastic fluctuations in demand rather than actual trends, therefore creating certain instabilities. Consequently, this appendix performs a limited sensitivity analysis in an attempt to quantify the relative impact of the routing update interval on the potential benefits of an RGS.

EFFECT OF LINK TRAVEL TIME ESTIMATE ERROR ON NETWORK MEASURES OF PERFORMANCE

In order to study the impact of the background and equipped link travel time estimate error on the potential benefits of an RGS, a limited sensitivity analysis was conducted. The sensitivity analysis considered background link travel time estimate errors of 5, 10, and 20 percent; TravTek link travel time estimate errors of 1, 5, and 10 percent; and levels of market penetration (LMP’ s) of 0, 1, 10, 30, and 50 percent. These factor combinations resulted in a total of 45 (3x3x5) runs as summarized in table 3 1. The link travel time estimate error was simulated by superimposing a white noise error distribution based on a normal distribution on the most accurate link travel time estimates. The mean of the normal distribution was set to the actual link travel time and the Coefficient of Variation (COV) was in each case the target level of error associated with the link travel time estimate. Thus, for a 10-s target link travel time and a lo-percent link travel time estimate error, the mean of the normal distribution would be 10 s, the COV would be 10 percent and the standard deviation would be 1 s (0.1 x 10). Consequently, prior to building the trees each link's travel time was transformed to a stochastic link travel time estimate to be used in the minimum tree estimation. The stream of random numbers was held constant from one run to the next by using the same seed in all runs in order to minimize any differences in stochastic effects.

Table 31: Run coding scheme for link travel time estimate error sensitivity analysis

Background link travel time estimate error	Guided link travel time estimate error	Level of Market Penetration (LMP)				
		0%	1%	10%	30%	50%
5%	1%	1	2	3	4	5
	5%	6	7	8	9	10
	10%	11	12	13	14	15
10%	1%	16	17	18	19	20
	5%	21	22	23	24	25
	10%	26	27	28	29	30
20%	1%	31	32	33	34	35
	5%	36	37	38	39	40
	10%	41	42	43	44	45

Average Trip Duration

Figure 77 illustrates the variation in the average travel time relative to the results of run 21, for the three levels of background link travel time estimate error, the three levels of error in the routing of the equipped vehicles and the five LMP's. The three thick continuous lines correspond to a background link travel time estimate error of 5 percent, the three thin continuous lines correspond to a background link travel time estimate error of 10 percent, and the thin dotted lines correspond to a background link travel time estimate error of 20 percent. The box symbols correspond to a TravTek link travel time estimate error of 1 percent, the triangles correspond to a TravTek link travel time estimate error of 5 percent, and the x-shapes correspond to a TravTek link travel time estimate error of 10 percent. Therefore, for example, a thick continuous line with box symbols corresponds to a background link travel time estimate error of 5 percent and a TravTek link travel time estimate error of 1 percent (legend 5-l in figure 77).

In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent (the thick continuous versus thin continuous lines) it appears that the difference in the trip travel times for all LMP's is very similar as any difference is less than 1 percent. However, there exists a significant difference for a background link travel time estimate error of 20 percent, that is represented by the dotted lines, especially for the lower LMP's. The difference in the average travel time for a background link travel time estimate error of 20 percent versus 10 percent was in the range of 42 percent at a O-percent LMP, this difference was reduced to within 2 percent at a 50-percent LMP. The benefits of TravTek are therefore shown to vary considerably based on the level of error associated with the background routing. In this example, the introduction of 50 percent TravTek vehicles would, for a background link travel time estimate error of 10 percent, result in a 13-percent reduction in the average travel time, while for a background link travel time estimate error of 20 percent a 5 1 -percent reduction in the average travel time would be expected.

The effect of varying the TravTek link travel time estimate error was less drastic, as the error was only varied from 1 percent to 10 percent. It is possible that for an error of 20 percent the results would have been more different.

In summary, it was found that a change in the background link travel time estimate error from 10 percent to 20 percent could change a reduction in travel time due to an LMP of 50 percent from 13 percent to 5 1 percent.

Average Trip Length

Figure 78 illustrates the variation in the average trip length relative to the base case, for the same three levels of background link travel time estimate errors, equipped vehicle link travel time estimate errors and the five LMP's. In comparing the background link travel time estimate error scenarios of 5 percent, 10 percent and 20 percent it appears that the differences in the average trip length for all LMP's are all within 1 percent. Thus, unlike the average trip duration, the average trip length appears to be less sensitive to the level of link travel time estimate error in the background traffic. However, it does appear that the average trip length increases slightly as the background link travel time estimate error increases. In addition, the effect of the level of TravTek link travel time estimate error was also minor, as illustrated in figure 78.

In summary, it was found that a change in the link travel time estimate error in the range of 5 to 20 percent had a minor impact on the average trip length, as it only increased these times by 1 percent.

Average Number of Stops

Figure 79 illustrates the variation in the average number of vehicle stops relative to the base case. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent, that are the thick continuous versus thin continuous lines, it appears that the differences in the average number of vehicle stops for all LMP's are all very similar and less than 1 percent. However, this minor difference becomes much more accentuated for a background link travel time estimate error of 20 percent, dotted lines. Specifically, the difference in average number of vehicle stops for background link travel time estimate errors of 20 percent and 10 percent changed fi-om 26 percent to 11 percent as the LMP was increased from 0 percent to 50 percent. Thus, the benefits are again shown to vary considerably based on the level of error associated with the background routing. In this example, a background link travel time estimate error of 10 percent versus 20 percent would result in a 23 percent versus 38 percent reduction in the average number of vehicle stops.

The effect of the TravTek link travel time estimate error was again less drastic, as in the case of the average trip duration, because the error was only varied from 1 percent to 10 percent.

In summary, it was found that a change in the background link travel time estimate error from 10 percent to 20 percent could result in an estimated reduction in the average number of vehicle stops from 23 percent to 3 percent at an LMP of 50 percent.

Average Number of Wrong Turns

Figure 80 illustrates the variation in the average number of wrong turn maneuvers relative to the base. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent (thick continuous versus thin continuous lines) it appears that the difference in the average number of wrong turns for all LMP's is very similar (difference less than 1 percent). However, this difference is approximately 4 percent for a background link travel time estimate error of 20 percent (dotted lines). This 4-percent difference was reduced to 2 percent at an LMP of 50 percent.

In summary, it is, therefore, concluded that the impact of the link travel time estimate error on the number of wrong turns would be minor (maximum 4 percent) compared to the effect of LMP on the number of wrong turns (20 percent).

Average Fuel Consumption

Figure 81 illustrates the variation in the average fuel consumption rate relative to the base. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent it appears that the difference in the average fuel consumption for all LMP's are very similar (less than 1 percent). However, this difference for a background link travel time estimate error of 20 percent is approximately 9 percent at an LMP of 0 percent and is reduced to a difference of 3 percent at an LMP of 50 percent. Again, the impact of the TravTek link travel time estimate error was minor for all scenarios, potentially because of the rather small range of errors that were evaluated (1 percent to 10 percent).

In summary, the impact of the link travel time estimate error on the average fuel consumption would be equivalent to the impact of introducing a 50-percent LMP. For example, for a l0-percent background link travel time estimate error, a 50-percent LMP resulted in a g-percent reduction in fuel consumption, as opposed to a 15-percent reduction when a 20-percent background link travel time estimate error was assumed.

Average HC Emissions

Figure 82 illustrates the variation in the average HC emissions relative to the base case. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent it appears that the difference in the average HC emissions for all LMP's are less than 1 percent. However, for a background link travel time estimate error of 20 percent this difference is approximately 20 percent at an LMP of 0 percent and is reduced to a difference of 4 percent at an LMP of 50 percent. Again, the impact of the TravTek link travel time estimate error was minor for all scenarios, potentially because of the rather small range of errors that was evaluated (1 percent to 10 percent).

In summary, it was found that the impact of the link travel time estimate error on the average HC emissions exceeded the impact of introducing a 50-percent LMP. For example, for a lo-percent background link travel time estimate error, a 50-percent LMP resulted in a 12-percent reduction in HC emissions, as opposed to a 28-percent reduction when a 20-percent background link travel time estimate error was assumed.

Average CO Emissions

Figure 83 illustrates the variation in the average CO emissions relative to the base case. In comparing the background link travel time estimate error scenarios of 5 percent and 10 it appears that the difference in the average CO emissions for all LMP's are all very similar as the difference less than 1 percent. However, the impact of LMP appears to produce a different trend for a background link travel time estimate error of 20 percent. This difference could have resulted from the rather peculiar CO sin-face presented in chapter 3   Again, the impact of the TravTek link travel time estimate error was minor for all scenarios that were evaluated.

In summary, there appears to be no particular trend to the CO emissions as a function of the background link travel time estimate error.

Average NOx Emissions

Figure 84 illustrates the variation in the average NOx emissions relative to the base case. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent it appears that the difference in the average NOx emissions for all LMP's is very similar, as the differences are less than 1 percent. However, for a background link travel time estimate error of 20 percent, this difference, relative to the 10 percent background error, is approximately 6 percent at an LMP of 0 percent and is reduced to a difference less than 1 percent at an LMP of 50 percent. The impact of the TravTek link travel time estimate error was again minor.

In summary, it was found that the impact of the link travel time estimate error on the average NOx emissions exceeded the impact of introducing a 50 percent LMP. For example, for a lo-percent background link travel time estimate error a 50-percent LMP resulted in a 1 -percent increase in NOx emissions, as opposed to an 8-percent increase for a 20-percent background link travel time estimate error.

Average Accident Risk

Finally, figure 85 illustrates the variation in the average accident rate relative to the base case. In comparing the background link travel time estimate error scenarios of 5 percent and 10 percent it appears that the difference in the average accident rate for all LMP's are less than 1 percent. However, for a background link travel time estimate error of 20 percent this difference, relative to a background link travel time estimate error of 10 percent, is approximately 5 percent at an LMP of 0 percent, but is reduced to a difference of only 3 percent at an LMP of 50 percent. The impact of the TravTek link travel time estimate error was minor for all scenarios.

In summary, it was found that the background link travel time estimate error would affect the results significantly as the increase in accident risk for a 20-percent versus a lo-percent background link travel time estimate error was in the range of 3 percent. In contrast, the reduction in accident risk for a 50 percent LMP was in the range of 1 percent.

Summary

In this section a limited sensitivity analysis of the effect of background link travel time estimate error in the range of 5 percent to 20 percent, and of RGS link travel time estimate error in the range of 1 percent to 10 percent was conducted. The results indicated that for the S-percent to

20-percent background link travel time estimate error, the average trip duration, average number of stops, fuel consumption, HC emissions, NO_x emissions, and accident rate were significantly affected by the assumed level of background link travel time estimate error. Where significant indicates that the impact is at least equivalent to the effect of introducing a 50 percent LMP. However, the average trip length, number of wrong turns and CO emissions were not significantly affected by the background link travel time estimate error in the range of 5 percent to 20 percent. The sensitivity analysis also concluded that all nine MOP's were not significantly impacted by the link travel time estimate error of the TravTek vehicle in the range of 1 percent to 10 percent.

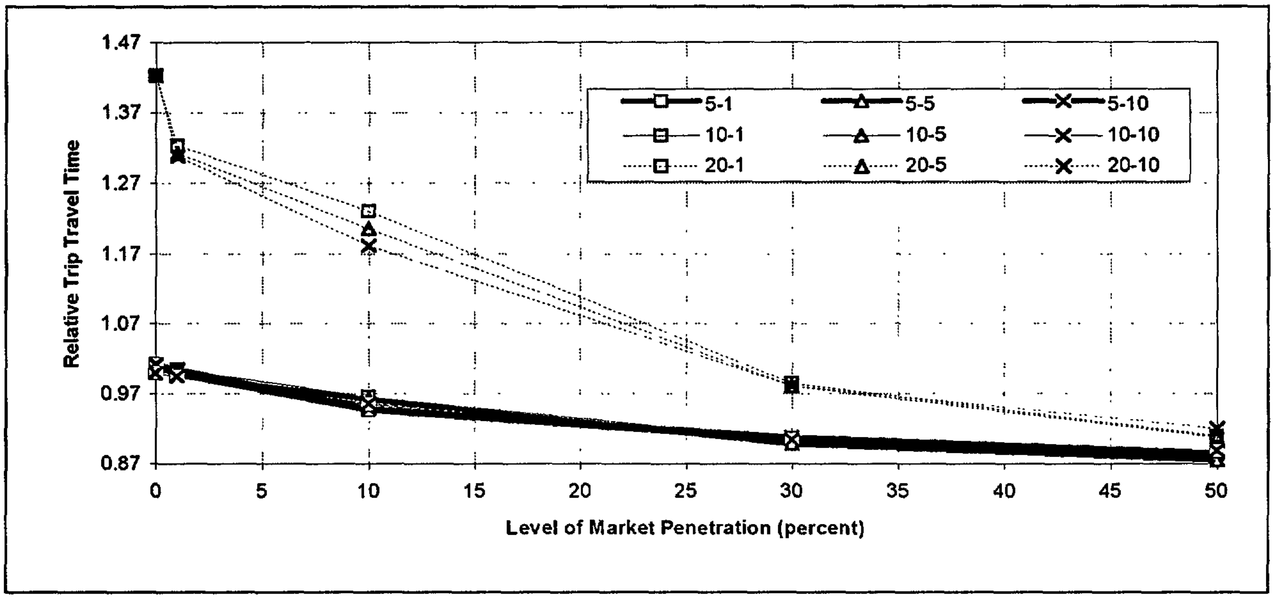

Figure 77: Effect of link travel time estimate error and LMP on the average trip duration

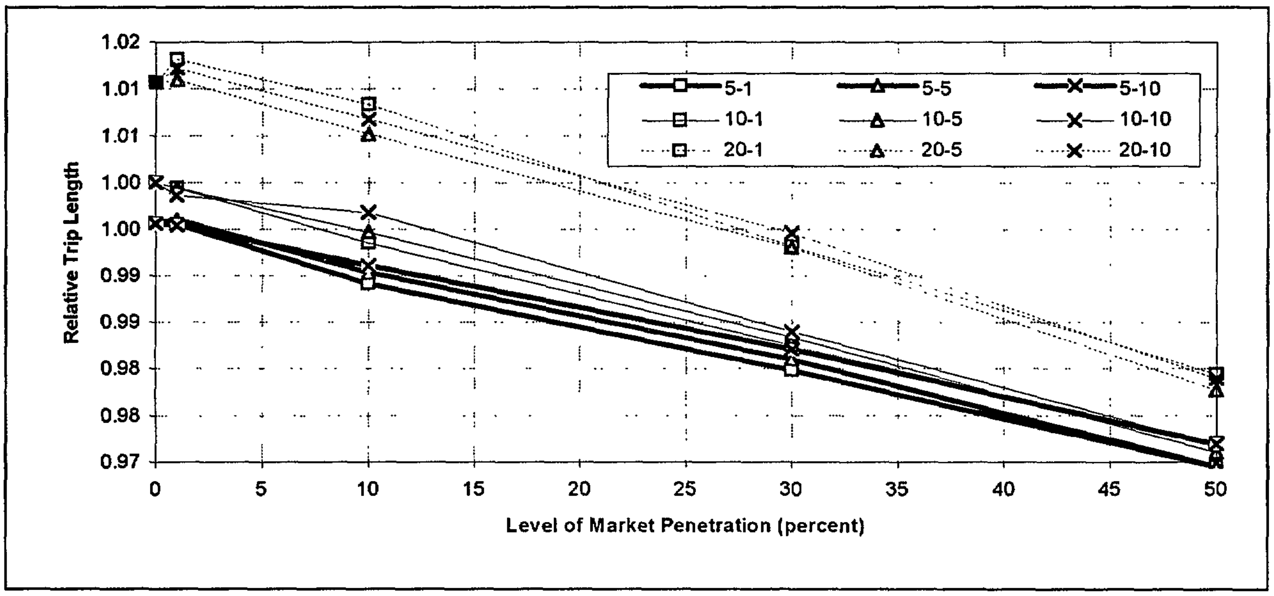

Figure 78: Effect of link travel time estimate error and LMP on the average trip length

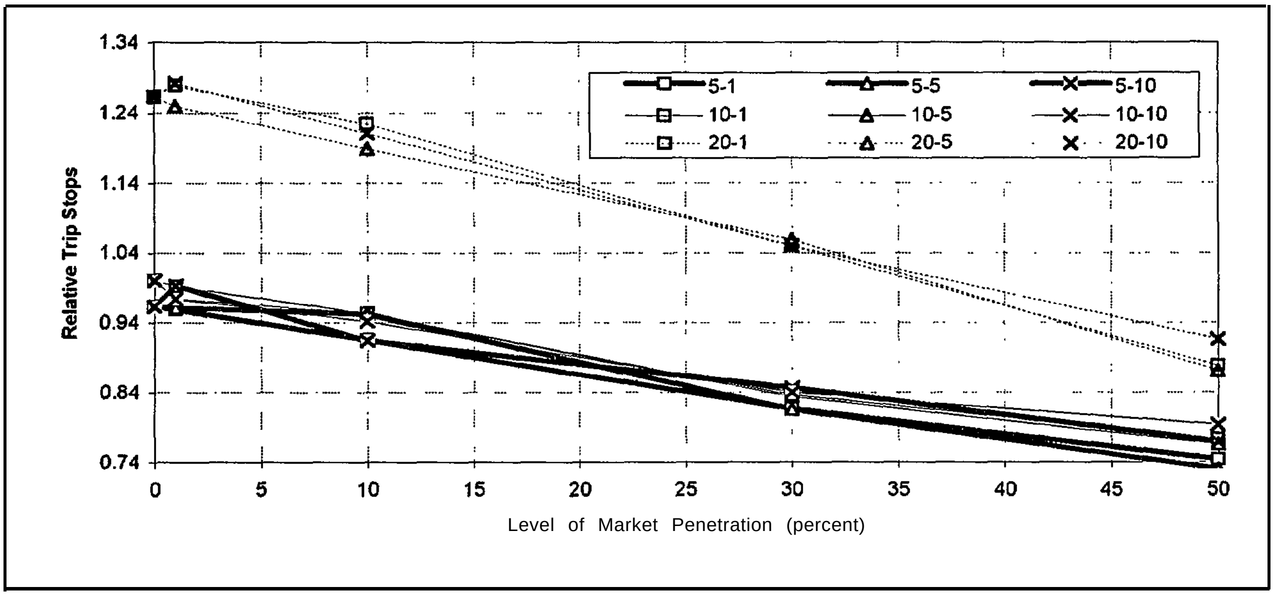

Figure 79: Effect of link travel time estimate error and LMP on the average number of vehicle stops

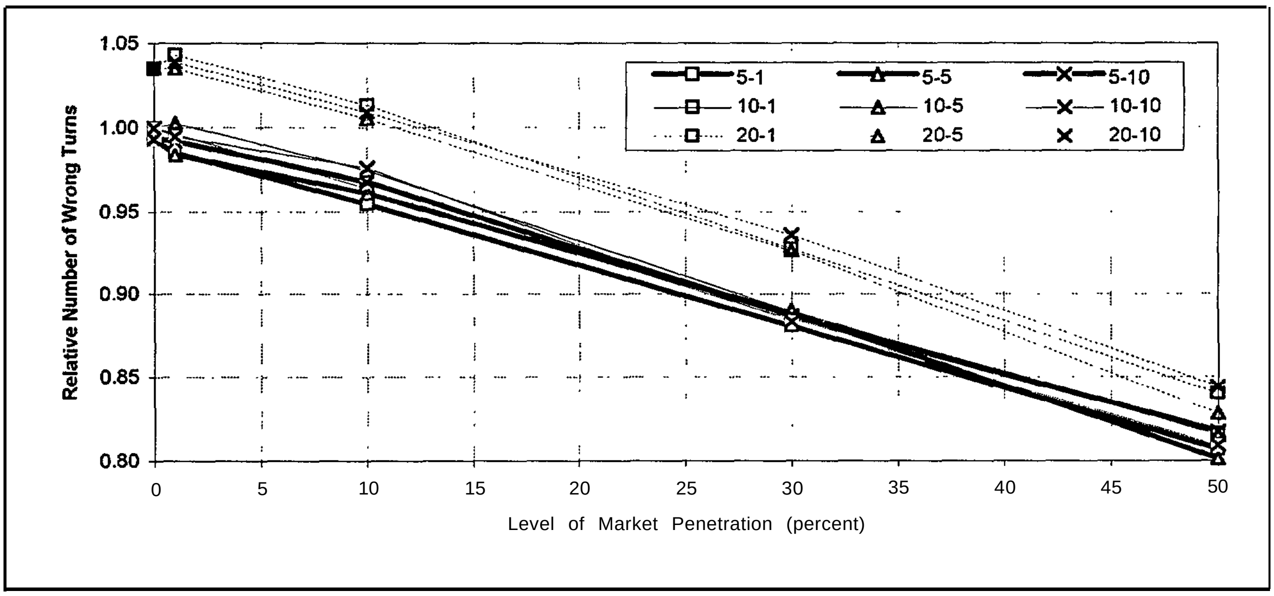

Figure 80: Effect of link travel time estimate error and LMP on the average number of wrong turns

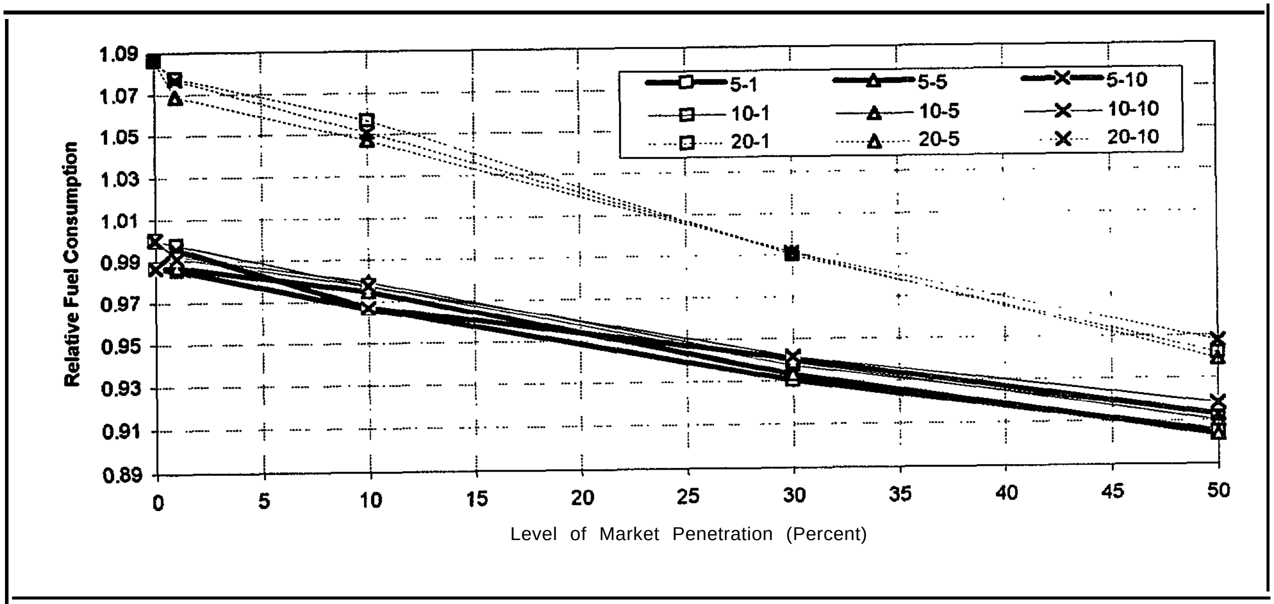

Figure 81: Effect of link travel time estimate error and LMP On the average fuel consumption

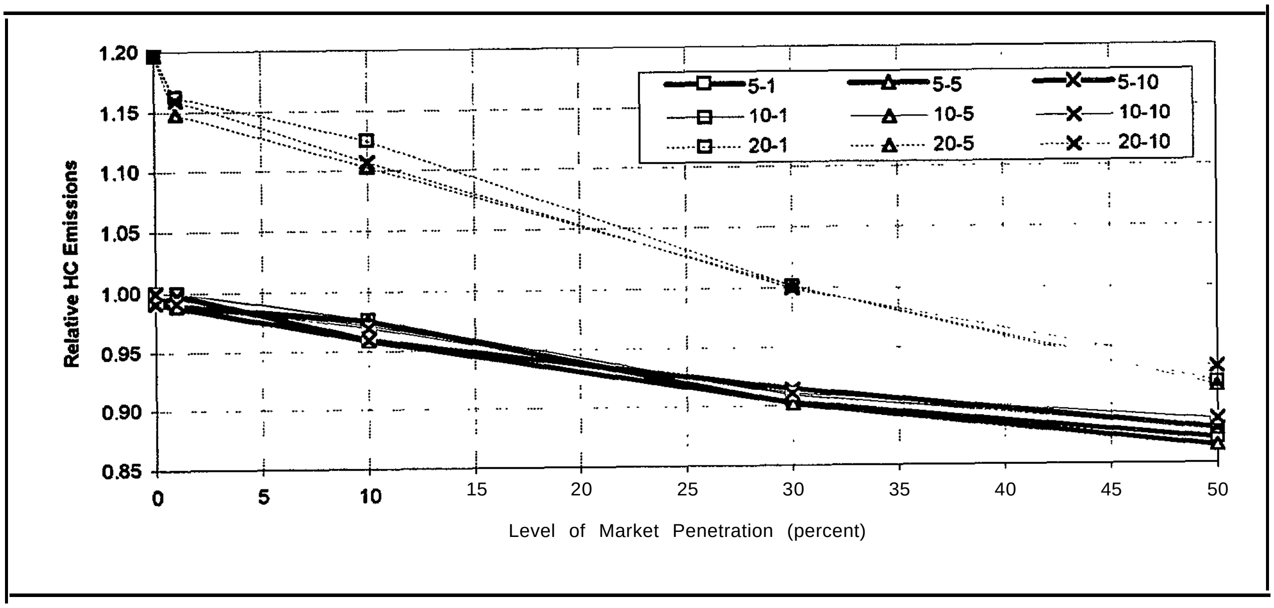

Figure 82: Effect of link travel time estimate error and LMP on the average HC emissions

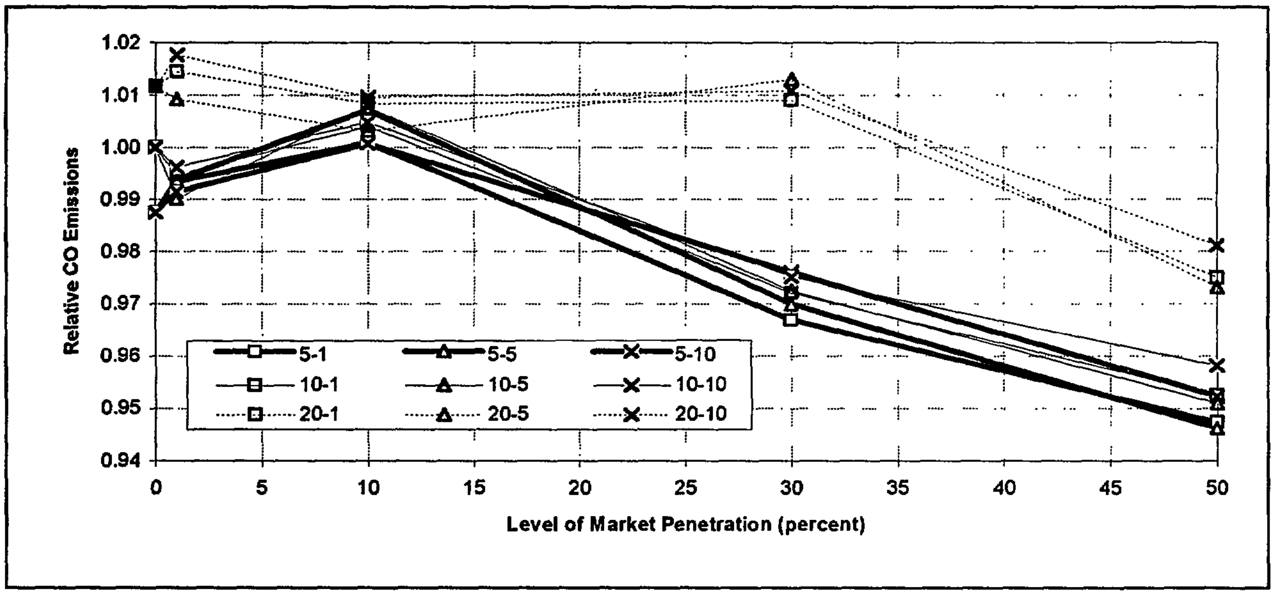

Figure 83: Effect of link travel time estimate error and LMP on the average CO emissions

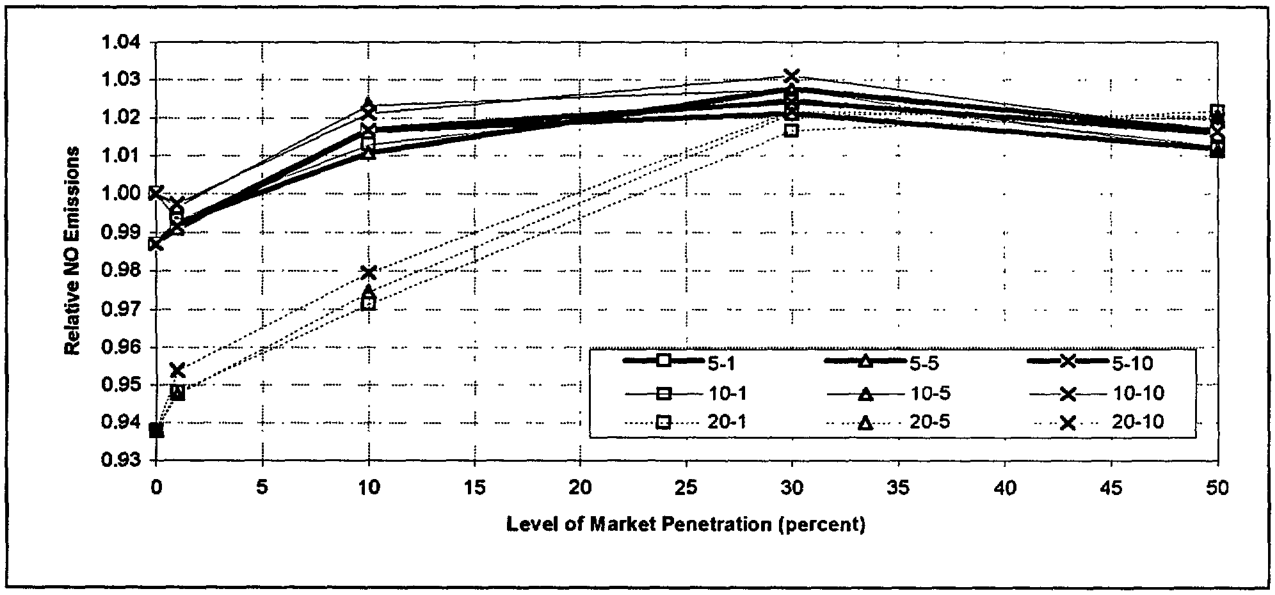

Figure 84: Effect of link travel time estimate error and LMP on the average NO emissions

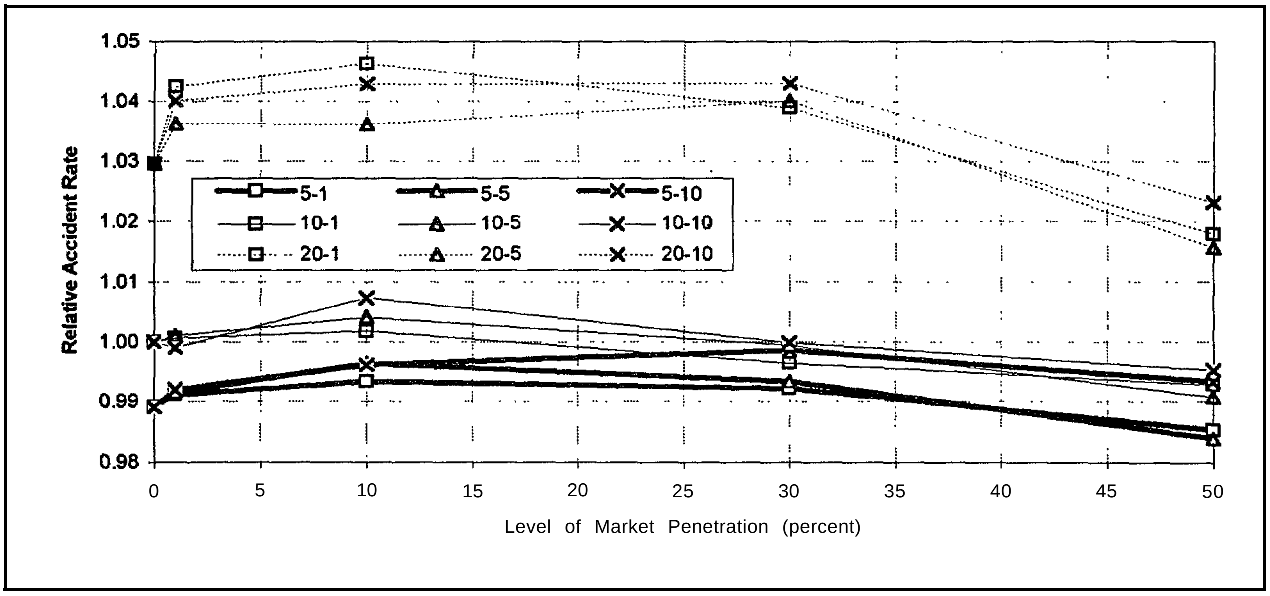

Figure 85: Effect of link travel time estimate error and LMP on the average accident rate

EFFECT OF ROUTING UPDATE FREQUENCY ON NETWORK MEASURES OF PERFORMANCE

In order to study the effect of the routing update interval of an RGS on the different network MOP's, a limited sensitivity analysis of six simulation runs was conducted as indicated in table 32. In this sensitivity analysis the routing update interval ranged from 1 to 30 min. In each run the vehicles were provided with the same real-time information but were not allowed to update their routes until the required update interval had elapsed.

Figure 86 illustrates how the relative network MOP's vary as a function of the routing update interval. A relative MOP was estimated relative to the base case in which routing updates were conducted every minute (run 8). It was found that the update interval had a relatively minor effect of approximately 2 percent on most of the network MOP's because there were no drastic dynamic changes in the demand during the coarse of the 3-h simulation period, as illustrated in figure 86. The MOP's impacted most were the average trip duration experienced a reduction of 2 percent, the average HC emissions which was reduced by 2 percent, and the average number of vehicle stops which experienced a reduction of 6 percent. It appears that these measures were reduced most at a routing update interval of 5 min.

The same findings appear to arise from examining the MOP's for background non-equipped vehicles, as illustrated in figure 87. In examining the MOP's for the RGS equipped vehicles in figure 88 it appears that most of the measures are within 4 percent of the base 1-min update scenario. It, therefore, appears that because the traffic conditions did not vary considerably over the 3 h simulation period, the routing update interval had only a minor impact on the network MOP's.

Table 32: Run coding scheme for routing update interval sensitivity analysis

Routing update interval (min)					
1	2	5	10	15	30
8	66	67	68	69	70

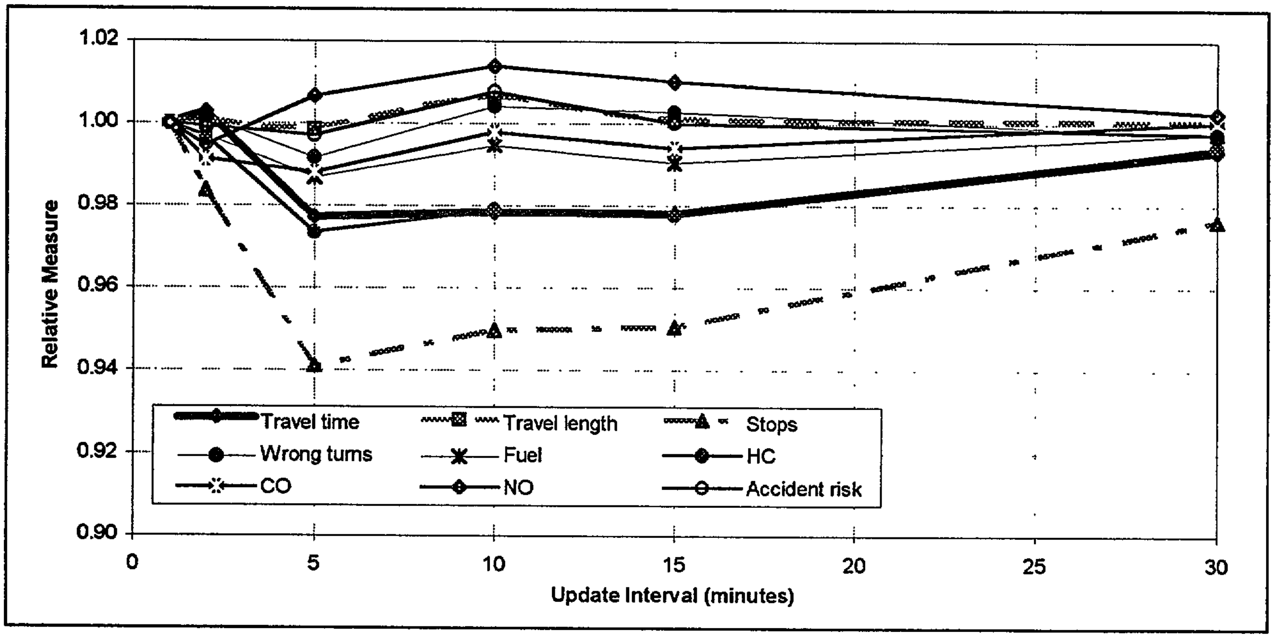

Figure 86: Effect of routing interval on network MOP's

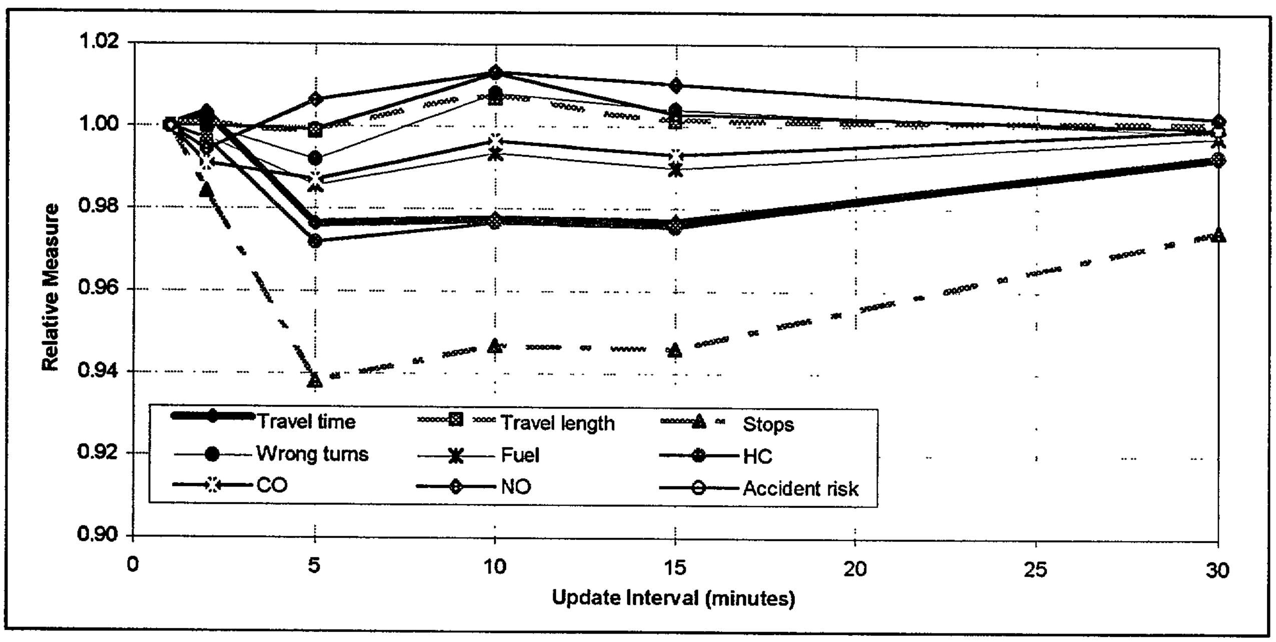

Figure 87: Effect of routing interval on network MOP's for non-guided vehicles

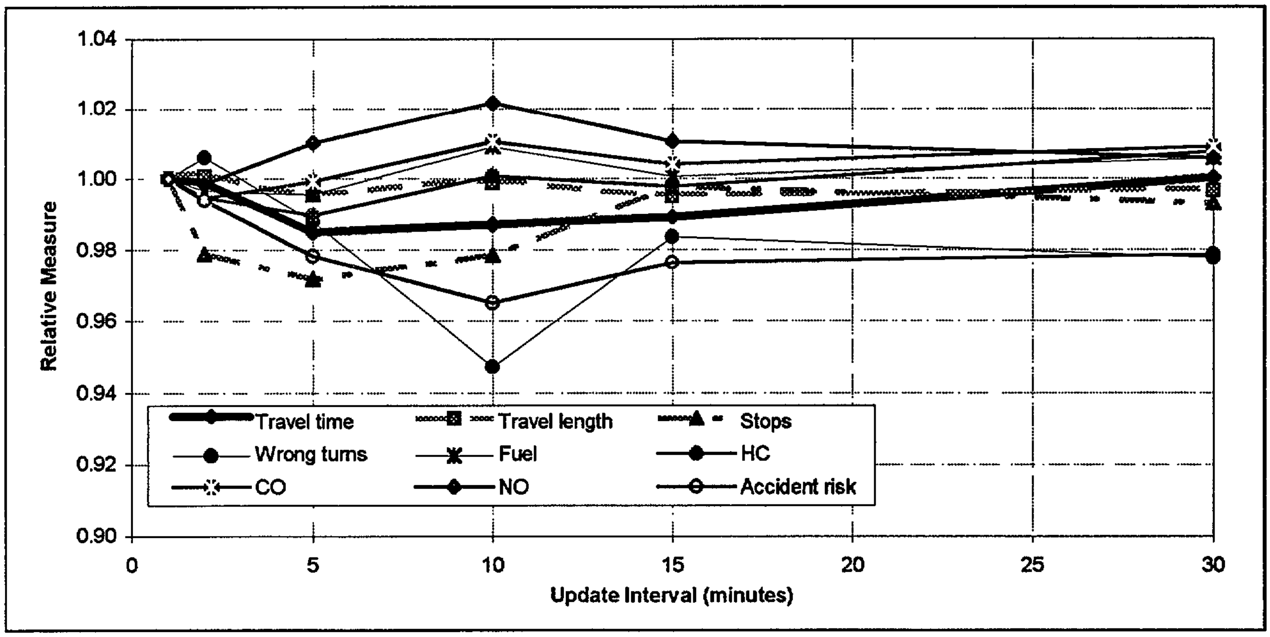

Figure 88: Effect of routing interval on network MOP's for guided vehicles

SUMMARY AND CONCLUSIONS

In this appendix a limited sensitivity analysis of the effect of background link travel time estimate error (in the range of 5 percent to 20 percent), and of TravTek link travel time estimate error (in the range of 1 percent to 10 percent) showed that background link travel time estimate error significantly affected the average trip duration, average number of stops, fuel consumption, HC emissions, NO_x emissions and the accident risk. Where significantly affected implies that the background link travel time estimate error effect was at least equivalent to the effect of 50-percent LMP. However, the average trip length, number of wrong turns and CO emissions were not significantly affected by the background link travel time estimate error in the range of 5 percent to 20 percent. The sensitivity analysis also concluded that all nine MOP's were not significantly impacted by the assumed TravTek link travel time estimate error when it was varied in the range of 1 percent to 10 percent.

In order to study the impact of the routing update interval of the TravTek system on the network MOP's, a limited sensitivity analysis was conducted. In this sensitivity analysis the routing update interval ranged from 1 to 30 min. It was concluded that, because the traffic conditions did not vary considerably over the 3 h simulation period, the routing update interval had a relatively minor impact on the network MOP's.