SIMULATION OF NAVIGATIONAL WASTE AND WRONG TURNS FOR ALTERNATIVE ATIS CONFIGURATIONS

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ABSTRACT

The impact of wrong turns, on the amount of navigational waste that arises from drivers utilizing the TravTek system, is analyzed in this paper with the objective of quantifying four factors. The first factor examines the amount of distance and time that is associated with trips being made using different display and routing configurations, as well as a base condition, when no wrong turns are made. Subsequently, a second factor investigates the likelihood that a driver's experience of missed turns be conditional on any previous missed turns. The third factor examines if the probability of making a wrong turn is dependent upon the type of ATIS display that is utilized. Finally, the fourth factor tracks whether the amount of extra travel associated with a wrong turn is also dependent upon the display type. In the analysis, display types are characteristized as a control group, which consists of a paper map, as well as a Turn-by-Turn and a Route Map display.

It is shown that the distance and time taken to make a trip, if no wrong turns are made, is the least for the Route Map and Turn-by-Turn displays, when compared to the Paper Map control condition. Subsequently, based on a goodness-of-fit test, it is shown that it is reasonable to assume that the probability of missing a turn is independent of having missed a turn during an earlier portion of the trip. It is also demonstrated that the probability of making a wrong turn is highest for the Paper Map control condition, and lowest for the Route Map condition. The probability of making a wrong turn is slightly higher for a Turn-by-Turn display than the Route Map display. Finally, it is also shown that once a wrong turn is made, drivers in the Control condition travel the greatest extra distance and time, while a Turn-by-Turn display results in the smallest amount of extra travel per missed turn.

It is also shown that in terms of travel time, the Nav (routing based on static information) and Nav+ (routing based on dynamic information) systems should be modelled as being equivalent in terms of time, but that both systems collectively are 19% more efficient than a system without a visual display, if no wrong turns are made. Once a wrong turn is made, the Nav and Nav+ systems should experience average trip travel time savings over drivers without a display of about 20%.

1. INTRODUCTION

The impact on navigational waste of an ATIS system such as TravTek is, for the purposes of analysis and simulation, broken down into three main components. The first component represents the inefficiencies that arise due to the fact that drivers, in the absence of an ATIS tool, may not be able to identify the most efficient routes from their trip origin to their destination. The second component represents the inefficiencies which arise when a driver without an ATIS follows a planned route, but has an increased likelihood of missing a turning movement along that route. The final inefficiency arises from the fact that, once a missed turn has occurred, drivers with an ATIS system may be able to limit the amount of extra travel that is incurred before the vehicle in question resumes the route that it had initially planned to follow.

In order to model the above process, the simulation model analysis associated with the TravTek evaluation study requires that the above components be quantified. Such quantified behaviour can then be translated into fundamental parameters for simulating the overall route selection/following behaviour of the users of the system. While the INTEGRATION model provides the modelling mechanisms for implementing the structure of these fundamental parameters, TravTek field study results are required to first calibrate the magnitude of the parameters involved.

This report presents a summary of the findings of the Yoked Driver Study and Orlando Test Network Studies as they relate to the number of wrong turns that drivers can be expected to make. This number of wrong turns is found to be different for different navigational aids. A further analysis is subsequently performed on the distance and travel time that would be associated with travel using each aid. This analysis is again performed separately for situations where wrong turns were present and for situations where they were not present.

The findings of this study are subject to many caveats which may restrict the generality of their application. These cavaets arise from the procedures for carrying out the study and for the recruitment of candidates for the Yoked and OTNS study. The reader is referred to the individual test plans and summary reports on each of those specific studies to find detailed descriptions of these cavaets, as they are not repeated here for a lack of space.

2. BACKGROUND

In order to measure the absolute and relative effects of alternative configurations of the TravTek system, a collection of drivers were required to make approximately 600 trips between three O-D pairs within Orlando during the fall and winter of 1992-1993.

a. Driver Classification based on type of Display

Some of the above drivers were provided with Turn-by-Turn (T-b-T) instructions to travel to their destination. Such Turn-by-Turn displays consisted of a simple graphical arrow display, which indicated the recommended turn movement at each intersection or diverge that was encountered. Other vehicles were provided with a detailed electronic road or route map (Map). In this case the recommended route was identified to the driver by means of assigning the recommended route a different colour on the display. Finally, other vehicles were not provided with any electronic aids

(No Display), and needed to find the optimum route towards their destination by means of a paper map.

b. Other Driver Classifications

For each of these three configurations, a subvariation was introduced in which some drivers were assisted by means of an electronic voice (Voice) while others were not (No Voice). Furthermore, for those configurations in which an electronic display was provided, this electronic display was sometimes driven based on a static link travel time data base (Nav), while at other times the display was driven by a dynamic link travel time data base (Nav+). Finally, it should be noted that some drivers travelled during the off-peak in the morning, others during the PM peak, while still others travelled after the PM peak had been completed.

c. Final Data Set

It should be noted that most drivers completed the required trips, and that some drivers either made too many or too severe wrong turns to permit them to arrive at their destinations within a reasonable time frame. The subsequent analysis concentrates exclusively on the former group of drivers who actually arrived at their intended destinations, albeit sometimes after having made one or more wrong turns.

3. RESULTS OF WRONG TURN FREQUENCY ANALYSIS

The wrong turn frequency analysis consisted of two components. The first analysis attempted to establish if, with the exception of those who never made it to their final destination, the probability of occurrence of a wrong turn at a given intersection was dependent or conditional on whether a particular driver had already made a previous wrong turn. The second analysis examined the extent to which the probability of making a wrong turn was dependent upon the particular vehicle's display.

a. Statistical Independence of Wrong Turns

In the first instance, it was desired to determine if the wrong turns that were made by drivers were independent of a driver having made previous wrong turns, or if a previous wrong turn made a subsequent wrong turn more likely. This analysis was performed by examining the probability of making 0, 1, 2, 3, 4 or 5 wrong turns, based on the field data. This probability was then compared against predictions of the number of wrong turns that could be computed from a Poission distribution for the expected number of wrong turns. A satisfactory fit of the latter Possion distribution to the former data would indicate that the acts of making wrong turns could be considered as statistically independent events. From a simulation point of view, this would mean that each time a vehicle approached a new potential routing decision point, the probability of that vehicle not following its intended route could be computed independent of whether that vehicle had made wrong turns in the past.

The statistical analysis of the actual data indicated that the average number of wrong turns per trip ranged between 0.60 to 0.90, depending upon the vehicle configuration. Furthermore, as shown in Table 1, the overall probabilities of making 0, 1, 2 , 3 , 4 or 5 wrong turns were found in the data to be, approximately, 0.556. 0.607, 0.265, 0.060, 0.034, and 0.017. These values were shown in a Chi

Squared type of analysis to be statistically consistent at the 95% confidence level with the predictions from a Poisson distribution. The Poission distribution, in turn, suggests that the occurrence of a wrong turn is an event which is statistically independent from any previous occurrence of that event.

It can therefore be concluded that, if the people who do not reach their final destination are removed from the analysis, the remaining drivers can be considered to follow a wrong turn distribution which is independently distributed. From a practical point of view, this indicates that the fact that a driver may have made an earlier wrong turn during a simulated trip, is not indicative of the fact that this specific driver should be simulated as being more likely to make another wrong turn during a later portion of his/her trip.

b. Dependency of Wrong Turn Frequency on Display / Voice Mode

The results of the display type factor were separated for the peak and off-peak periods because no Route Map observations were available during the peak period. A bias would therefore be included if data for one category included peak and off-peak data, while for another category only off-peak data were included. In addition, it should be noted that Nav+ observations were only available during the peak period.

The analysis of wrong turns by display mode, which is summarized in Table 2a, indicated that the average number of wrong turns per trip was least likely for a turn-by-turn display (0.62-0.68). The number of wrong turns per trip for a route map (0.81-0.88) or for no visual display (control) (0.68-0.93) were statistically higher, but the route map performance could not be statistically distinguished from the performance of drivers with no visual display. These aggregate results were also reinforced in a disaggregate analysis by time of day, except that in the PM off-peak the absence of a visual display resulted in a number of wrong turns which was closer to the turn-by-turn performance.

While in a further analysis the presence of a voice in the control group with no visual display was shown to have no impact as demonstrated in Table 2b. In the Nav modes (Turn-by-Turn and Route Map combined) the impact of a voice was to reduce the average number of wrong turns per trip by a statistically significant amount from 0.86 to 0.66. It also appears that there is no statistical difference between the three modes of routing (Nav+, Nav and No Display) during the PM peak.

c. Summary

The impact of display can perhaps be best described if the number of wrong turns for the control configuration of no display and no voice is set to be a base condition. In this case, a turn-by-turn display can be expected to reduce the relative number of wrong turns by 20%, while a route map may be expected to have no effect. For the electronic display configurations, the addition of voice is expected to decrease the number of wrong turns by 23%. The introduction of voice for the control group had no effect on the percent of wrong turns.

4. RESULTS OF TRAVEL DISTANCE ANALYSIS

Based on the above analysis of how frequently vehicles with a certain display make wrong turns, it can now be further investigated what the impact on trip distance is for each display type. This

analysis of trip distance is separated into two components. The first analysis examines what happens when drivers do not make wrong turns relative to their intended route, while the second analysis considers what happens when vehicles do make wrong turns.

a. Analysis when no Wrong Turns are Made

The analysis of trip length in kilometers indicated that, in the absence of wrong turns, the distance travelled for drivers using a turn-by-turn display ranged from 15.46 to 16.05 km as illustrated in Table 3a. This distance was slightly different than the distances travelled for drivers with a route map display (15.37 to 15.50 km) or those without a display (15.76 to 16.96 km). If the latter is considered a base condition, the former can provide on average improvements of 2.2 and 3.3%, respectively. However, these differences were not found to be statistically significant at the 95% confidence level.

A dissaggregation by time of day, as shown in Table 3a, indicated that drivers with the turn-by-turn display travelled shorter routes than those with no display (control) in the AM off peak (15.46 vs. 16.15) and in the PM peak (16.05 vs. 16.96). This effect was not found to be the case during the PM off-peak (15.79 vs. 15.76). However, these differences were not statistically significant at a 95% confidence level.

For those scenarios where no wrong turns occured, the presence of voice was advantageous to those without a display as demonstrated in Table 3b. However, the presence of voice was not an advantage for those in the Nav mode. None of these differences were found to be statistically significant. A direct comparision of Nav+ with voice to Nav with voice, indicated a relatively large distance penalty for travel under the Nav+ configuration (16.85 vs. 15.25), but the small number of observations (10) precluded making any statistically significant conclusions. This difference would represent 10.4% excess travel for the Nav+ vs. Nav configuration.

b. Analysis when Wrong Turns were Made

The analysis of trip length, with the presence of wrong turns, indicated that during the off-peak the distance travelled by vehicles equiped with turn-by-turn displays was 16.42 km. This distance was less than the Route Map display (16.70 km) and the control condition in which there was no display present (17.09 km). The difference relative to the control was statistically significant and represented an average saving of 4%. This pattern was most pronounced during the AM off peak and PM peak. The differences during the PM off peak were indistinguisable.

For vehicles travelling in the Nav mode, the marginal impact on extra distance of voice was not statistically significant. However, for the control condition the benefit of voice was significant and found to be 2%. Nav+ with voice performed much poorer than Nav with voice during the peak period (17.88 vs. 16.16). Unfortunately, the small number of observations (10) precluded any statistically significant conclusions, eventhough this benefit was computed to be 11%.

c. Comparison of Distance with and without Wrong Turns

The presence of wrong turns was found to increase, during the off peak conditions, the travel distance for turn-by-turn from 15.68 to 16.42 km, which represents a change of approximatley 5%. For the route map this change was from 15.44 to 16.70 km, and without a display the travel

distance increased from 16.05 to 17.09 km. Each of these differences were found to be statistically significant at a level of confidence of 95% assuming a normal distribution.

When the data for wrong turns and the absence of wrong turns was pooled, the turn-by-turn was found to involve an average distance travelled of 16.12 km. For the route map display this distance was 16.30 km, and when there was a lack of visual display this distance was 16.72 km. The difference between turn-by-turn vs. route map of 0.8% was marginally significant, while the difference between visual vs. no visual display of 3.4% was statistically significant.

d. Summary

The differences in the average distances travelled, when comparing configurations with and without wrong turns, was shown above to be consistently suprisingly low (ranging around 8%). However, while it is clear that any form of static electronic route guidance aids (Nav) are beneficial, the version of dynamic route guidance that was available as part of the TravTek (Nav+) required the vehicle to travel a considerable amount of extra distance (11% based on 26 observations). This finding is of concern for those measures of effectiveness that are distance based, and requires that this additional distance be traversed at a considerably higher speed than the default routes in order to result in net travel time savings.

For trips with wrong turns, it was found that the use of Turn-by-Turn display or Route Map display resulted in a 4% reduction in trip length over the control mode (based on 306 observations). This reduction was nearly statistically significant at the 95% confidence level and indicates that an electronic display is of assistance, even after the driver has missed an earlier display message.

5. RESULTS OF TRAVEL TIME ANALYSIS

The net impact of the extra distance travelled by vehicles utilizing a turn-by-turn vs. a route map and a Nav+ vs. Nav display is examined next in terms of the associated travel time implications. This analysis is performed next by segregating again the data for scenarios when wrong turns were present from those when they were not present. Tables 4a and 4b provide some overall summary results.

a. Travel Time Impact in the absence of wrong turns

During the AM off peak vehicles reached their destinations in roughly the same time for a turn-by-turn display (19.76 minutes) vs. a route map display (19.83 minutes) as demonstrated in Table 4a. However, during the PM off-peak conditions vehicles with the turn-by-turn map display reached their destinations slightly later (18.25 minutes) than those using a route map (17.72 minutes). In terms of overall off-peak averages, the turn-by-turn display (19.08 minutes) was slightly slower (1.7%) than the route map display (18.76 minutes), and both were considerably faster (9%) than when no visual was present (20.84 minutes).

The comparison of the incremental benefit of Nav vs. Nav+ indicated that, in the absence of wrong turns, trips taken with a Nav+ display (27.13 mins.) were slightly faster during the PM peak than those taken with a Nav display (27.18 minutes) as shown in Table 4b. This difference was not found to be statistically significant. Collectively these performance measures were not found to be statistically significant when compared to the performance of vehicles without any visual display (

29.36 minutes) due to the small number of observations, even though this difference represents a 7.5% savings in travel time.

During the off peak conditions the availability of more observations allowed the comparison of Nav (with or without voice) to the No Display configuration (with or without voice). It was found that the voice increased the average travel time from 18.76 to 19.05 minutes for the Nav condition, where this difference was not statistically significant. The presence of Voice reduced the average travel time from 23.39 to 18.77 minutes when no display was present, while for the Nav condition the average travel time was reduced by 19% when compared to the no display condition.

b. Impacts when wrong turns occurred

During the AM off peak vehicles travelling in the Nav configuration with voice reached their destinations in roughly the same time for a turn-by-turn display (21.91 minutes) vs. a route map display (22.42 minutes). However, during the PM off-peak vehicles with the turn-by-turn map reached their destinations slightly later (19.68 minutes) than those using a route map (19.62 minutes). These small differences were slightly greater (in favour of the turn-by-turn map) when no voice was present, but neither trend was statistically significant.

In terms of overall off-peak averages, drivers with the turn-by-turn display took 20.85 minutes, which was 1.4% faster than those travelling with the route map (21.1 minutes). Vehicles utilizing either display were considerably (12%) faster than when no visual was present (23.8 minutes).

The comparison of the incremental benefit of Nav vs. Nav+ indicated that, in the presence of wrong turns, Nav+ (29.1 mins.) was slightly slower than Nav (28.32 minutes) as demonstrated in Table 4b. This difference was not statistically significant. However, both of these performance measures were statistically significant when compared to the performance of vehicles without any visual display (32.69 mins). This difference represents a saving of 12.2%. The same trend occured for the off-peak periods. In this case the Nav condition reduced the average trip length by 21.6% from 26.80 to 21.06 minutes.

c. Comparison of Trips with and without wrong turns

In comparing the performance of vehicles with and without wrong turns, trip travel times decreased from an average of 21.9 minutes to 19.47 minutes (or by 11.1%). These results indicate that, all other things being equal, wrong turns were responsible for a 12.5% increase in travel time. This difference was 9% for turn-by-turn, 12.5% for the route map, and 15.5% for the vehicles without a visual display.

6. SUMMARY OF NET IMPACTS

Table 5a provides a summary of the net impacts of different display types. Specifically, without the occurrence of wrong turns, the base distance and time travelled is always less for the Turn-by-Turn display versus the control condition. Wrong turns are also more likely to occur for the control condition, and once they occur they involve a larger detour, when measured either in terms of distance or time.

Also shown is the fact that, in the absence of wrong turns, the users of the Route Map display travel a shorter distance and a shorter time than those who utilize the Turn-by-Turn display. However, the

users of the Route Map are more likely to experience a missed turn, and incur a greater time and distance penalty for each such wrong turn that is made.

Table 5b provides a summary of the net impacts of different routing types. It appears from the results that both the Nav+ and Nav configurations reduced the base distance and time travelled when no wrong turns occured. The Nav+ configuration resulted in a longer average trip length but a shorter average trip duration when compared to the Nav configuration. In addition, the results also demonstrate that the user of a Route Map is not only more likely to make wrong turns but that the extra distance and travel time associated with each wrong turn exceeds that for the Nav+ and Nav configurations.

It is noted from the results of Table 5b that although the Nav+ configuration results in a shorter base travel time when no wrong turns occur compared to the Nav configuration (27.13 vs. 27.18 min.), the penalty associated with each wrong turn is higher for the Nav+ configuration (2.94 vs. 2.04 min.).

CONCLUSIONS AND RECOMMENDATIONS

a. Conclusions

1. Based on the above analysis, it is concluded that the process of wrong turns should be modelled as being statistically independent in time with a mean of 0.650 wrong turns for a turn-by-turn display, and means of 0.85 and 0.81 for a route map or no visual display, respectively. If a distinction can be made between those systems with a voice, and those without, the former's probabilities should be increased by 14%, while the latter's probabilities should be increased by 14%.
2. For that subpopulation which experiences no wrong turns, their travel distance should be relatively independent of the method of route selection. When wrong turns are made, the two electronic display modes should modelled as being 4% more efficient than a driver without a display following a wrong turn, but this relative benefit should dissappear when a voice message is provided to the drivers without a display.
3. For both the situations in which there are wrong turns and when there are none, the Nav+ system should be modelled as experiencing potentially an extra 10% of distance travel, while the occurence of a wrong turn should be modelled as increasing the trip distance by 5 to 8%.
4. In terms of travel time, the Nav and Nav+ systems should be modelled as being equivalent in terms of time, but that both systems collectively are 19 % more efficient than a system without a visual display, if no wrong turns are made. Once a wrong turn is made, the Nav and Nav+ systems should experience an average trip travel time savings over drivers without a display of about 20%.
5. The presence of wrong turns is responsible for an increase in travel of 9% for turn-by-turn, 12.5% for the route map, and 15.5% for the vehicles without a visual display.

b. Recommendations

1. It is recommended that the marginally significant effect be investigated as part of future travel time studies, using the provided measures of statistical significance as guides to determine the number of additional subjects that would be required.
2. The overall measures of statistical significance that were found in this study should be directly incorporated in the design of any future operational field tests in order to determine at the start which effects can likely be studied with any measure of statistical significance, given the planned number of subjects, and which effects are beyond the budget of certain tests.

Table 1: Measured and Hypothesized Probability Distribution of Wrong Turns Per Trip

# wrong turns	Nav+		Nav		No Dispaly (Control)		All	
	Measured	Poisson	Measured	Poisson	Measured	Poisson	Measured	Poisson
0	0.615	0.599	0.615	0.569	0.590	0.554	0.556	0.574
1	0.282	0.307	0.256	0.321	0.256	0.327	0.607	0.319
2	0.000	0.079	0.103	0.091	0.077	0.096	0.265	0.089
3	0.077	0.013	0.000	0.017	0.026	0.019	0.060	0.016
4	0.000	0.002	0.026	0.002	0.026	0.003	0.034	0.002
5	0.000	0.000	0.000	0.000	0.000	0.000	0.017	0.000

Table 2a: Total Number of Wrong Turns and Number of Wrong Turns per Trip by Display Configuration

	Turn-by-Turn			Route map			No Display (Control)		
	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
AM off peak	0.47	0.63 (81)	0.79	0.71	0.88 (114)	1.06	0.74	0.93 (120)	1.12
PM off peak	0.51	0.67 (79)	0.84	0.63	0.81 (95)	0.99	0.51	0.68 (80)	0.85
AM/PM off peak	0.54	0.65 (160)	0.76	0.72	0.85 (209)	0.98	0.68	0.81 (200)	0.94
PM peak	0.37	0.62 (48)	0.86	n/a	n/a	n/a	0.34	0.74 (29)	1.15

Table 2b: Total Number of Wrong Turns and Number of Wrong Turns per Trip by Routing Configuration

		Nav+			Nav			No Display		
		Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
AM/PM off peak	Voice	n/a	n/a	n/a	0.55	0.66 (184)	0.77	0.65	0.81 (113)	0.97
	No Voice	n/a	n/a	n/a	0.73	0.86 (185)	1.00	0.60	0.81 (87)	1.02
PM peak	Voice	0.28	0.67 (26)	1.06	0.28	0.56 (22)	0.85	n/a	n/a	n/a
	No Voice	n/a	n/a	n/a	n/a	n/a	n/a	0.34	0.74 (29)	1.15

Table 3a: Average Trip Distance by Display Configuration in Kilometers with/without Wrong Turns

		Turn-by-Turn			Route map			No Display (Control)		
		Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
without wrong turns	AM off peak	15.06	15.46	15.87	14.89	15.39	15.84	15.35	16.15	16.95
	PM off peak	15.09	15.79	16.49	14.86	15.50	16.14	15.19	15.76	16.33
	AM/PM off peak	15.21	15.61	16.01	15.04	15.44	15.42	15.56	15.96	16.50
	PM peak	14.68	16.05	17.42	n/a	n/a	n/a	14.87	16.96	19.05
with wrong turns	AM off peak	15.87	16.28	16.69	16.27	16.71	17.15	16.64	17.34	18.05
	PM off peak	16.07	16.58	17.09	16.22	16.70	17.17	16.30	16.80	17.31
	AM/PM off peak	16.10	16.42	16.75	16.38	16.70	17.02	16.65	17.09	17.53
	PM peak	16.17	17.02	17.87	n/a	n/a	n/a	16.89	18.58	20.27

Table 3b: Average Trip Distance by Routing Configuration in Kilometers with/without Wrong Turns

		Nav+			Nav			No Display		
		Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
without wrong turns	Off peak (Voice)	n/a	n/a	n/a	15.29	15.68	16.07	15.00	15.53	16.06
	Off peak (No Voice)	n/a	n/a	n/a	14.92	15.30	15.67	15.57	16.43	17.28
	PM peak (Voice)	14.27	16.85	19.42	14.31	15.25	16.20	n/a	n/a	n/a
	PM peak (Voice)	n/a	n/a	n/a	n/a	n/a	n/a	14.87	16.96	19.05
with wrong turns	Off peak (Voice)	n/a	n/a	n/a	16.27	16.60	16.93	16.30	16.90	17.50
	Off peak (No Voice)	n/a	n/a	n/a	16.21	16.52	16.82	16.69	17.33	17.97
	PM peak (Voice)	16.32	17.88	19.43	15.47	16.16	16.84	n/a	n/a	n/a
	PM peak (Voice)	n/a	n/a	n/a	n/a	n/a	n/a	16.89	18.58	20.27

Table 4a: Average Trip Duration by Display Configuration in Minutes with/without Wrong Turns

		Turn-by-Turn			Route map			No Display (Control)		
		Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
without wrong turns	AM off peak	19.13	19.76	20.39	19.08	19.83	20.57	20.71	22.52	24.33
	PM off peak	17.54	18.25	18.96	17.06	17.72	18.38	18.35	19.28	20.21
	AM/PM off peak	18.48	19.08	19.68	18.26	18.76	19.25	19.80	20.84	21.89
	PM peak	23.50	27.16	30.81	n/a	n/a	n/a	25.71	29.36	33.01
with wrong turns	AM off peak	21.07	21.91	22.75	21.60	22.43	23.26	24.32	25.67	27.01
	PM off peak	19.00	19.68	20.36	18.94	19.62	20.31	20.69	21.82	22.96
	AM/PM off peak	20.31	20.85	21.40	20.56	21.10	21.64	22.96	23.85	24.74
	PM peak	27.00	28.71	30.42	n/a	n/a	n/a	29.50	32.69	35.88

Table 4b: Average Trip Duration by Routing Configuration in Minutes with/without Wrong Turns

		Nav+			Nav			No Display		
		Low limit	Avg.	Up limit	Low limit	Avg.	Up limit	Low limit	Avg.	Up limit
without wrong turns	Off peak (Voice)	n/a	n/a	n/a	18.60	19.04	19.49	18.01	18.77	19.53
	Off peak (No Voice)	n/a	n/a	n/a	18.22	18.76	19.30	21.37	23.39	25.40
	PM peak (Voice)	21.71	27.13	32.55	22.28	27.18	32.08	n/a	n/a	n/a
	PM peak (Voice)	n/a	n/a	n/a	n/a	n/a	n/a	25.71	29.36	33.01
with wrong turns	Off peak (Voice)	n/a	n/a	n/a	20.51	21.06	21.61	20.65	21.55	22.45
	Off peak (No Voice)	n/a	n/a	n/a	20.34	20.87	21.39	25.13	26.8	28.48
	PM peak (Voice)	26.58	29.10	31.62	26.00	28.32	30.64	n/a	n/a	n/a
	PM peak (Voice)	n/a	n/a	n/a	n/a	n/a	n/a	29.50	32.69	35.88

Table 5a: Summary of Net Wrong Turn Impacts by Display Configuration

		Turn-by-Turn		Route map		No Display (Control)	
		Average	Relative	Average	Relative	Average	Relative
Peak	Base distance (km)	16.05	0.95	n/a	n/a	16.96	1.00
	Base time (min)	27.16	0.93	n/a	n/a	29.36	1.00
	Wrong turns/Trip	0.62	0.83	n/a	n/a	0.74	1.00
	Wrong turns/km	0.038	0.874	n/a	n/a	0.044	1.00
	Extra distance/wrong turn	1.57	0.72	n/a	n/a	2.18	1.00
	Extra time/wrong turn	2.53	0.56	n/a	n/a	4.48	1.00
Off Peak	Base distance (km)	15.61	0.92	15.44	0.91	15.96	0.94
	Base time (min)	19.08	0.65	18.76	0.64	20.84	0.71
	Wrong turns/trip	0.65	0.88	0.85	1.14	0.81	1.09
	Wrong turns/km	0.042	0.95	0.055	1.26	0.051	1.16
	Extra distance/wrong turn	1.25	0.53	1.49	0.69	1.40	0.58
	Extra time/wrong turn	2.72	0.24	2.76	0.62	3.71	0.64

Table 5b: Summary of Net Wrong Turn Impacts by Routing Configuration

		Nav+ with voice		Nav with voice		No Display and no voice	
		Average	Relative	Average	Relative	Average	Relative
Peak	Base distance (km)	16.85	0.99	15.25	0.90	16.96	1.00
	Base time (min)	27.13	0.92	27.18	0.93	29.36	1.00
	Wrong turns/Trip	0.67	0.91	0.56	0.76	0.74	1.00
	Wrong turns/km	0.040	0.91	0.037	0.84	0.044	1.00
	Extra distance/wrong turn	1.54	0.70	1.63	0.74	2.19	1.00
	Extra time/wrong turn	2.94	0.65	2.04	0.45	4.50	1.00
Off Peak	Base distance (km)	n/a	n/a	15.68	0.92	16.43	0.97
	Base time (min)	n/a	n/a	19.04	0.65	23.39	0.80
	Wrong turns/trip	n/a	n/a	0.66	0.89	0.81	1.09
	Wrong turns/km	n/a	n/a	0.042	0.95	0.049	1.11
	Extra distance/wrong turn	n/a	n/a	1.40	0.64	1.11	0.51
	Extra time/wrong turn	n/a	n/a	3.06	0.68	4.21	0.94