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Route Choice Behavior in a Driving Simulator With Real-time Information

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ROUTE CHOICE BEHAVIOR IN A DRIVING SIMULATOR WITH REAL-TIME INFORMATION

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by
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ABSTRACT

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This research studies travelers' route choice behavior in a driving simulator with real-time information en-route. We investigate whether travelers plan strategically for real-time information en-route or simply select a fixed path from origin to destination at the beginning of a trip, and whether network complexity and a parallel driving task affect subjects' strategic thinking ability. In this study, strategic thinking refers to a traveler's route choice decision taking into account future diversion possibilities downstream enabled by information at the diversion node. All of the subjects in this study participated in driving-simulator-based tests while half of the subjects participated in additional PC-based tests. Three types of maps were used. The first type required a one-time choice at the beginning of a trip to test the traveler's risk attitude. The other two types offered route choices both at the beginning of and during a trip to test the traveler's strategic thinking.

The study shows that a significant portion of route choice decisions are strategic in a realistic driving simulator environment. Furthermore, different network complexities impose different cognitive demands on a subject and affect his/her strategic thinking ability. A subject tends to be more strategic in a simple network. Lastly, a parallel driving task does not significantly affect a subject's strategic thinking ability. This seemingly counterintuitive conclusion might be caused by the simplicity of the tested network.

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CHAPTER 1

INTRODUCTION

1.1 Background and Literature Review

A traffic network is subject to significant delays resulting from crashes, construction, inclement weather, special events, and so forth, and is inherently an uncertain system. Traffic delays will consume travelers' time and fuel and increase environmental pollution. An advanced traveler information system (ATIS) can provide travelers with real-time information on prevailing and predictive traffic conditions and are designed with the assumption that more information might help travelers make better route choice decisions (e.g., Koppelman and Pas, 1980; Kanninen, 1996). In general, the deployment of variable message signs (VMSs) to inform drivers of traffic conditions has been proven successful in terms of improving network travel times (Chatterjee and McDonald, 2004). While the presence of real-time information will affect a traveler's route choice decisions, the collective route choice decisions of travelers will in turn impact the overall performance of traffic systems. In order to investigate the effectiveness of an ATIS, the route choice behavior of drivers in an uncertain network should be studied thoroughly.

Most route choice models are only based on deterministic networks. They assume that a traveler makes a complete route choice at the origin of a trip and do not account for any real-time information provided en-route. Examples of such models are Path Size Logit (e.g., Ben-Akiva and Ramming, 1998; Ben-Akiva and Bierlaire, 1999), C-Logit (Cascetta et al., 1996), Cross-Nested (Vovsha and

Bekhor, 1998), and Logit Mixture (e.g., Ramming, 2001; Bekhor et al., 2002; Frejinger and Bierlaire, 2007).

It is hypothesized that travelers' route choice behavior in an uncertain network with real-time information will be different from that in a deterministic network. With real-time information provided en-route, travelers could make route choice decisions at decision nodes based on the current situation in order to avoid delay downstream (McQueen et al., 2002). One recent overview of models which account for real-time information en-route can be found in Abdel-Aty and Abdalla (2006).

Gao et al. (2008) studied two types of models that account for travelers' adaptation to real-time information. An adaptive path model assumes route choice is a series of path choices at every decision node. Although an adaptive path model could account for diversion from an initial chosen path, it assumes that travelers are simply reactive to information on the spot and do not plan ahead for real-time information that will be available later in the trip. A strategic route choice model is based on a rule that maps network conditions in a stochastic network to routing decisions. Contrary to the adaptive path model, such a model assumes that travelers have some expectations for the real-time information downstream and travelers are strategic or proactive in planning ahead for future events.

While many studies have addressed the problem of optimal strategies (e.g., Hall, 1986; Polychronopoulos and Tsitsiklis, 1996; Marcotte and Nguyen, 1998; Pretolani, 2000; Miller-Hooks and Mahmassani, 2000; Miller-Hooks, 2001; Waller and Ziliaskopoulos, 2002; Gao, 2005; Gao and Chabini, 2006), econometric models of strategic route choice have not been studied thoroughly (Gao et al., 2008). Such an econometric model was recently proposed by Gao (2005) and analyzed using synthetic data by (Gao et al., 2008). More recently, stated preference (SP) data from a PC-based survey were gathered and a route choice model was estimated in Razo and Gao (2010). where two latent classes of travelers, strategic and non-strategic are both taken into account.

This research will use stated preference data from human subjects in driving-simulator-based tests. The driving simulator is located in the Human Performance Laboratory at the University of Massachusetts Amherst. It consists of an actual car connected to three projectors that display a virtual traffic database (Figure 1.1). Reviews of comparisons between driving simulator tests and field data indicate that such a simulator is able to provide route choice data with high validity (Kaptein et al., 1995). It is believed that this driving simulator environment could induce a more realistic level of cognitive load than a traditional paper-and-pencil or PC-based survey. Research shows that subjects' route choice behavior in a driving simulator test that demands high cognitive load was dramatically different from that in a paper-and-pencil survey which demands low cognitive load (e.g., Szymkowiak et al., 1997; Katsikopoulos et al., 2000). Compared with paper-and-pencil surveys, the relative importance of expected travel time over travel time variability is more significant in the driving simulator test. It is also shown in some psychology studies that people's ability to make an informed intuitive judgment is impaired by time pressure (Finucane et al., 2000) and concurrent pressure (Gilbert, 1989; Gilbert, 1991; Gilbert, 2002). As to this study, we will investigate whether network complexity and a parallel driving task affect people's ability to make an informed route choice decision.

1.2 Research Objectives

The objective of this research is to investigate whether travelers plan strategically in a driving simulator environment and how this strategic thinking can be affected by certain factors. For the purpose of this research, "strategic" is defined as considering future diversion possibilities. The specific questions being addressed are:

1. Do travelers think strategically when they plan for a trip in uncertain networks with probabilistic travel time distributions?
2. Does network complexity (the number of routes involved at the time a decision is made) affect travelers' strategic thinking ability?
3. Does a parallel driving task (pre-trip versus en-route) affect travelers' strategic choices?

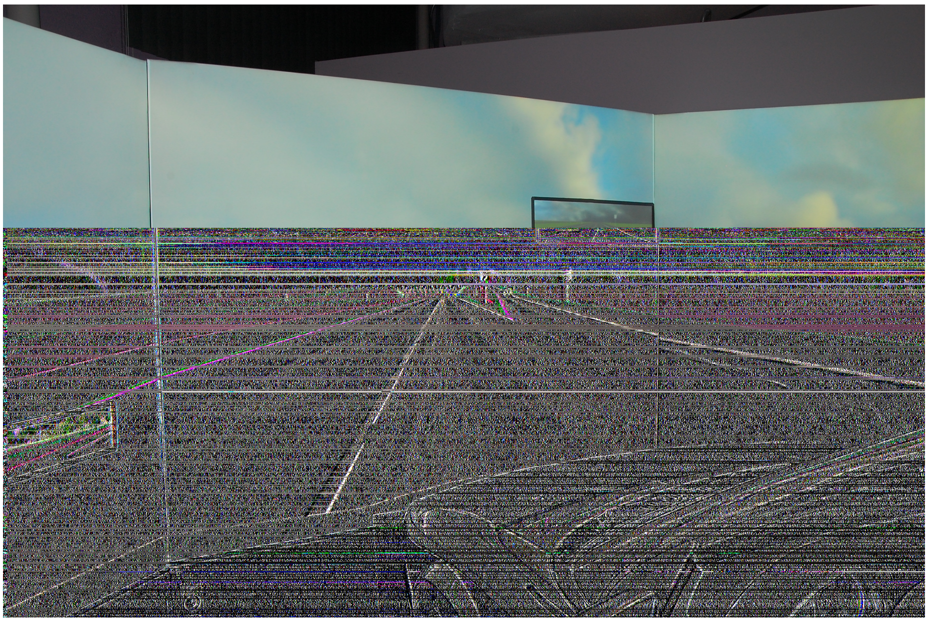

Figure 1.1. The driving simulator

CHAPTER 2

TEST DESIGN

2.1 Overall

There are three types of maps in the tests, shown in Figure 2.1. A single number beside a route denotes a deterministic travel time, while $(m,\ n)$ a random travel time with two ordered out comes m or n $(m < n)$, each with probability 50%. From the origin node in each map, two options are available: either the safe Route 1 with a deterministic travel time t_b, or the risky branch involving random travel times on one or more routes.

The risky branch gets more complicated in topology from Map A through C, containing one, two and three routes respectively. In Map A it contains one single Route 2, with a possible low travel time t_L and high travel time t_H. In Map B, a bifurcation is added to the risky branch, where the safe detour (Route 2) has a deterministic travel time t_H. The risky Route 3 has a low travel time t_L and a prohibitively long delay t_M, probably due to an incident. At Node i, a subject receives real-time information on the realization of the travel time on Route 3. If t_M is realized, Route 2 can serve as a diversion from Route 3. A traveler who takes into account the value of information at Node i when making the route choice at the origin is deemed as strategic. Map C adds another bifurcation to the risky branch, upstream of the one in Map B, with two possible outcomes t_b and t_M. Real-time information is available at Node i1 on the realized travel time on Route 2, and Node i2 on the realized travel time on Route 4. Similarly the information at either node could help travelers avoid the extremely high travel time t_M on Route 2 or 4, and a traveler who takes into account the these facts in route choice decisions at the origin is deemed as strategic. Note that a subject could behave strategically in one scenario and non-strategically in another, therefore strictly speaking we can only talk about strategic choices, not strategic subjects. However in the remainder of the paper, these two terms will be used interchangeably if no confusion will arise.

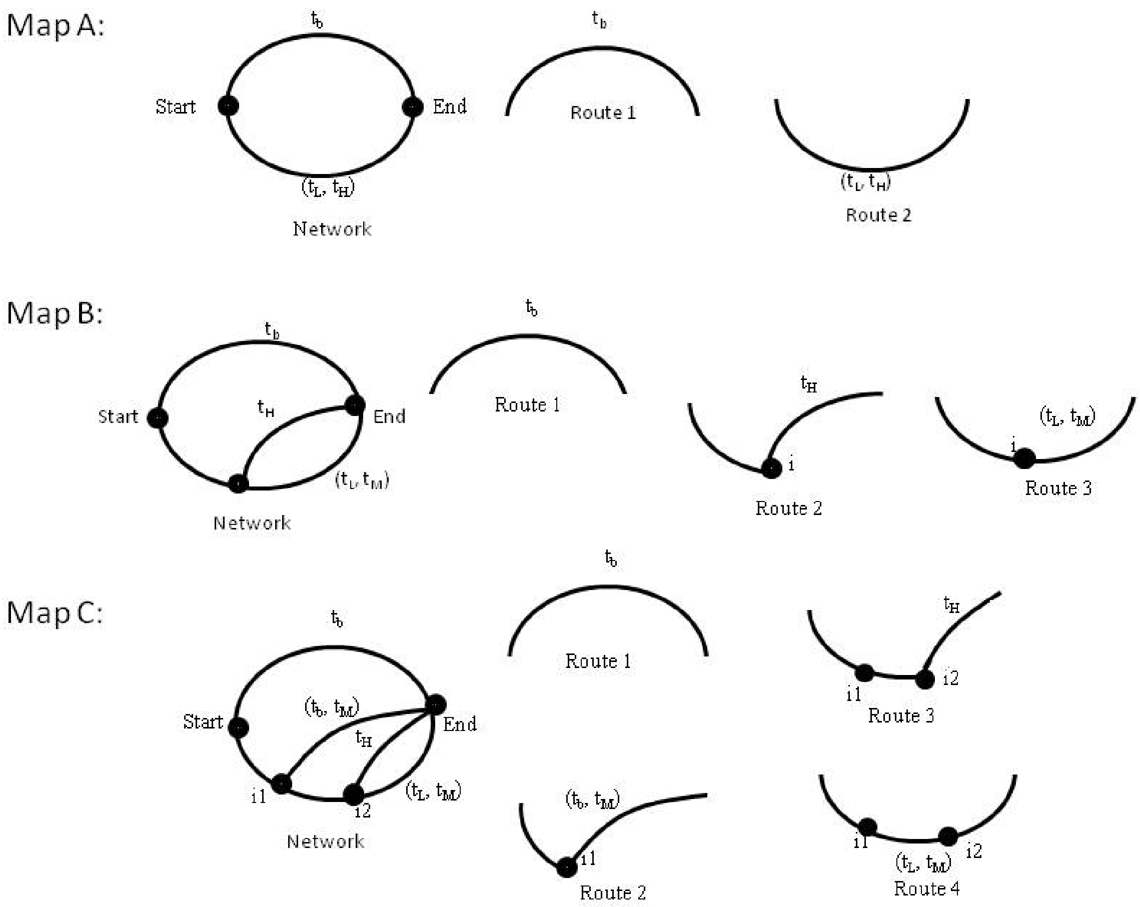

Figure 2.1. Three types of maps in the test

Each type of map appeared six times with different travel times as shown in Table 2.1. The relationships between travel times in each scenario are $t_L < t_b < t_H << t_M$ and $(t_L+t_H)/2 < t_b << (t_L+t_M)/2$. The rationale behind the travel time design is detailed in the subsection **Test Design Revisited** after the discussion of strategic choice identification in the next section. Travel times denoted with the same symbol in three different map types have the same numerical value.

Table 2.1. Travel time combinations in 6 groups of scenarios

	t_L	t_H	t_b	t_M
#1	30min	50min	45min	120min
#2	30min	60min	50min	120min
#3	30min	60min	55min	120min
#4	30min	70min	55min	120min
#5	30min	70min	60min	120min
#6	30min	70min	65min	120min

There are two factors in this study each with two levels: the test environment (Driving simulator versus PC, approximating the en-route and pre-trip decision context respectively) and the network complexity (Map B versus C). Map A is used to gauge subjects' risk attitudes that are critical in identifying strategic choices and always tested in combination with Map B or C, but not a level of a factor by itself.

The driving-simulator-based tests are set up with pre-fabricated blocks of road geometries and street scenes from the simulator program. Our subjects generally reported that they felt the experiences fairly close to real ones. Subjects were required to drive slowly at the beginning of each scenario to observe a map of the entire network with risky travel times before arriving at an intersection where a route choice decision has to be made. This map was shown as a picture on the up-right corner of the middle screen for exactly 10 seconds. In addition, there were two identical roadside billboards shortly before each real-time information node in Maps B and C, namely Nodes i, i1 and i2, where the actual travel times on links immediately out of the information node were revealed, while risky travel times further downstream remained unchanged. The two identical billboards were intended for the subjects to have enough time to acquire the correct information. In order to implement different travel times for the same route, lead vehicles with pre-specified speeds were assigned in every intersection in each scenario, and subjects were instructed to follow lead vehicles. The simulator time that a subject actually spent on driving on any route in a map was scaled down from the displayed travel time by controlling the lead vehicle speeds. All route travel times in the same map were scaled by the same factor, so that subjects bore the consequences of their choices. Different maps had different scales due to the limitations of the simulator software, however we believe this would not affect subjects' understanding of the trade-offs between routes in the same map. On average, a subject spent 2 minutes in each scenario, and the complete test took around 1 hour including the time for instruction, rest and entry- and exit-questionnaires.

In PC-based tests, subjects were required to view the map of the entire network with risky travel times for exactly ten seconds at the beginning of each scenario with all mouse or keyboard operations disabled. After ten seconds, all travel time labels disappeared and subjects then clicked on one of the routes to make a choice. An animated dot showed the movements along the routes, and upon the arrival at an information node, actual travel times on immediate outgoing links were revealed. The time spent in the PC-based tests for each subject was fixed and not proportional to the displayed travel time. However, we asked the subjects to put these travel times in their regular work-to-home commute context and make choices as they would in real life. On average, a subject spent 20 seconds in each scenario.

As Table 2.2 shows, the first group of subjects participated in both the simulator-based and PC-based tests using Maps A&B. Subjects in this group were presented with six Map A scenarios and then six Map B scenarios in simulator-based tests followed by six Map A scenarios and six Map B scenarios in PC-based tests. The second group subjects were only presented with six Map A scenarios followed by six Map C scenarios in the driving simulator. Two, three, and four warm up scenarios were scheduled before Map A, B, and C scenarios respectively to help subjects familiarize himself/herself with each route in these three maps. Subjects are randomly assigned to either of the two groups.

Table 2.2. Two factors in the test design

	Maps A&B (first group)	Maps A&C (second group)
Driving simulator	✓	✓
PC	✓	

In order to eliminate any potential bias resulting from one specific scenario sequence, each subject experienced a different scenario sequence in each map type. The six scenarios were divided into three blocks, where block 1 contained scenarios 1 and 4, block 2 contained scenarios 2 and 5, and block 3 contained scenarios 3 and 6. A randomization was applied to the three blocks with permutations of two scenarios for each block. No randomization was conducted across map types, i.e., all Map A scenarios were presented before Map B or C scenarios.

CHAPTER 3

DATA PROCESSING AND STRATEGIC CHOICE IDENTIFICATION

3.1 Data Cleaning

In total, we ran this study with 66 subjects. Data for one of the subjects were deleted due to a misunderstanding and data for five other subjects were deleted because of the extreme risk-seeking route choices in the Map A scenario with highly risky travel times (t_L, t_M) in the risky branch. This scenario was set up to identify highly risk-seeking subjects in addition to the main 6 scenarios.

We have two explanations for subjects' choices of the risky branch in Map B or C if they chose the highly risky route, (t_L, t_M), in this Map A scenario. The first one is that these subjects did not realize the value of information, but were highly risk-seeking and thus willing to take Route 3 (Map B) or 4 (Map C) and bear the risk of the prohibitively long delay just to get a possible low travel time t_L. The other one is that these subjects realized that the prohibitively long delay could always be avoided by utilizing the real-time information and thus the risky branch was pretty attractive. Therefore, we could not draw a definitive conclusion as to whether these subjects are strategic and the data had to be deleted.

After the first round of data cleaning, we had 60 subjects, 30 subjects for each group and a gender balance within each group with 15 males and 15 females.

3.2 Identification of Strategic Route Choice

A strategic route choice is made with the consideration of a future diversion possibility, while a non-strategic route choice is not. Conclusions about strategic or non-strategic route choices are only concerned about route choice decisions in Map B or C. Map A is used to test subjects' attitude towards risk and no strategic choices can be identified in Map A alone. However, all the conclusions about strategic route choices in Map B or C should take into account results in matched Map A scenarios. Next we discuss first the cases where the risky branch is chosen in Map A, and then those where the safe route is chosen in Map A.

3.2.1 Map A Risky Branch Chosen for Group 1 (Maps A&B)

For the first group with Map A and B, if a subject chose the risky branch in Map A but the safe route in Map B when these two maps used the same travel time combination in TABLE 2.1, we conclude that this route choice in Map B is non-strategic. The fact that this subject chose the risky branch in Map A implies that he/she considered the risky branch (t_L, t_H) more attractive than the safe route, t_b. If this subject realized that the real-time information at Node i could help avoid t_M in Route 3 and further help simplify the risky branch as a travel time combination (t_L, t_H), he/she should take the risky branch again in Map B. Assuming that a subject's risk attitude will not change in a short time period, the fact that a subject can tolerate the risk in Map A but appear not to in Map B suggests non-strategic thinking.

On the other hand, if a subject chose the risky branch twice in the paired Map A and B scenarios, we consider the route choice in Map B as a strategic route choice. Because if he/she did not realize the value of real-time information at Node i, three fixed routes were considered. The value of t_M in Map B was set to be very large so that Route 3 was much slower on average with a mean travel time $(t_L + t_M)/2$ and also involved an extremely high risk. Risk averse and risk neutral subjects would not take Route 3 because of the non-zero risk and slower mean travel time compared to the safe Route 1. Risk-seeking subjects also would be highly unlikely to choose Route 3 due to the extremely large risk involved. As mentioned before, in rare cases some subjects were indeed highly risk seeking and have been identified from corresponding Map A scenarios and deleted. Furthermore, the deterministic travel time on Route 2 (t_H) was longer than that on Route 1 (t_b). Therefore, only strategic thinking would lead one to choose the risky branch in Map B.

3.2.2 Map A Risky Branch Chosen for Group 2 (Maps A&C)

For the second group with Maps A and C, regardless of whether a subject realized the future diversion possibility provided by the real-time information at Node i1, Route 2 could not have added to the attractiveness of the risky branch. Route 2 of Map C served only as a decoy to make the route choice situation more complicated. Note that the strategic parts of Maps B and C (Routes 2&3 in Map B and Routes 3&4 in Map C) are the same. Route 2 of Map C hides the strategic part further downstream and a strategic route choice requires more forward thinking. Therefore similar analysis of strategic behavior could be conducted in Map C.

Specifically, if a subject chose the risky branch in Map A but the safe route in the paired Map C, we conclude that this route choice in Map C is a non-strategic. If one subject chose the risky branch twice in the paired Maps A and C, we consider the route choice in Map C as a strategic one.

Note that if t_b is realized on Route 2 and revealed to a subject at Node i1, he/she would essentially be facing the same decision problem as at the origin, except that the strategic parts (Routes 3&4) are immediately downstream. We would expect that if a subject is strategic at the origin, he/she would continue being strategic downstream at Node i1 and choose the risky branch again. However several Route 2 (safe) choices were observed in Map C in such situations, and the inconsistency in behavior might be explained by different amount of decision time (more time at the origin than en-route), among others. These choices are still considered strategic as our focus is on the behavior at the origin. The inconsistent behavior however will be an interesting topic for future research.

3.3 Measurement Error

In Maps B&C, if the attractiveness of the safe route and the risky branch are similar for a strategic subject, a measurement error will occur that will lead to wrong conclusions about subjects' strategic route choices. Assume the safe route and the risky branch are equally attractive for a strategic subject, e.g. *40* vs. (*30*, *50*), and thus he/she is indifferent between the two options and there is a 50% chance of choosing either of them in Map B or C, regardless of his/her choices in Map A. Following our logic in the previous two subsections, we would conclude that out of the Map B or C observations with corresponding Map A risky choices, 50% of them are strategic. However in fact 100% of them could be strategic, but just do not all appear so due to the indifference to travel times. This measurement error does not exist for non-strategic subjects who do not see the favorable prospect of the risky branch at the very first place, and thus no problems result from the indifference towards it against the safe route.

In order to avoid this measurement error, we delete travel time combinations where the risky branch for a strategic subject is not exceedingly more attractive than the safe route. During the study, we observed non-negligible safe route choices in Map A with travel time combinations #1 and #4, which were subsequently deleted from further analysis.

3.4 Map A Safe Route Chosen: Indeterminate Observations

If a subject chose the safe route in Map A, his/her route choice in the paired Map B or C cannot be determined as strategic or non-strategic. This subject did not accept the risk in Map A, and thus even if he/she was strategic in Map B or C and realized the risky branch in Map B or C presented the same travel time prospect as that in Map A, he/she was still not going to take the risk. In other words, the strategic behavior was dominated by the risk aversion behavior and could not be inferred. On the other hand, if he/she indeed takes the risky branch in Map B or C, but not in A, there is an internal inconsistency in the behavior, which might be explained by more detailed studies, e.g., an innate bias towards flexible options even if no real benefit can be generated. However in the current study with limited observed variables, it only complicates the strategic choice identification. Therefore we treat any Map B or C observation with a matching Map A safe route choice as missing.

All the analysis above is summed up in TABLE 3.1. R refers to the risky branch and S refers to the safe route.

Table 3.1. Inferences on strategic choices based on paired Map A and B/C choices

Map A	Map B/C	Inference
R	R	Strategic
R	S	Non-strategic
S	R	N/A
S	S	N/A

A subject might not select the risky branch in all the four remaining scenarios, even though the risky branch is exceedingly more attractive. We are concerned that such a subject tends to have a volatile risk attitude, which could undermine our method of identifying strategic choices that relies on the assumption of a stable risk attitude during the experiment. Furthermore, such a subject will provide fewer valid observations than other subjects due to missing observations, which complicates the statistic analysis. Therefore we kept only subjects who chose the risky branch in the remaining four Map A scenarios. We then counted the number of times a subject was strategic in either Map B or C (a value between 0 and 4). Finally, we ended up with 22 valid subjects from Map A&B group and 23 valid subjects from Map A&C group. The final results for these 45 subjects are shown as follows.

First Group, Map A&B:(22 subjects)

Driving simulator:	3, 4, 4, 4, 4, 3, 4, 4, 3, 4, 4, 4, 4, 1, 4, 0, 3, 1, 2, 4, 4, 4
PC:	2, 4, 4, 3, 1, 3, 4, 4, 4, 4, 4, 4, 4, 4, 4, 0, 4, 4, 3, 4, 4, 4

Second Group, Map A&C: (23 subjects)

Driving simulator:	0, 4, 2, 4, 2, 4, 3, 1, 3, 0, 4, 2, 3, 3, 3, 4, 3, 3, 4, 4, 2, 0, 4

3.5 Test Design Revisited

In this subsection we discuss the design of the experiment in a higher level. The previous discussions on data cleaning and strategic choice identification provide a basis for understanding the big picture in the design.

We do not directly observe a subject's thinking process, but only its outcome in different situations. Strategic route choices by definition include multiple outcomes contingent on revealed information. One way to investigate this process is to conduct in-depth personal interviews and ask the subjects to describe the process in detail. This method is suitable for an initial exploratory research phase, however not so much in large-scale data collection.

We adopt another approach where through carefully designed networks and travel time situations, we can equate strategic choices with choices of a certain alternative. Our definition of a strategic choice is one that takes into account future information value on route switching, and thus Map B in Figure 2.1 is the simplest possible network for the study where the risky branch provides information and diversion possibility and the safe route provides an alternative to the risky branch for a non-strategic subject. The idea is to make the risky branch more attractive to a strategic subject and the safe route more attractive to a non-strategic subject. As strategic planning is useful only when there are uncertainties, some travel times must be random. However with random travel times, subjects' decisions are also influenced by their risk attitudes, which we do not know. The analyses in the previous subsections deal with the problem of disentangling strategic thinking from risk attitudes.

The travel time combination design is made with the above points in mind. To make the risky branch more attractive for a strategic subject than the safe route, it must have a smaller average travel time and thus $(t_L + t_H)/2 < t_b$. However this condition alone is not enough, so we make safe route travel time t_b very close to the higher travel time on the risky branch t_H so that the possible benefit of taking the risk is very high. However some very risk-averse subjects might still prefer the safe route, and therefore we set up Map A just to gauge a subject's risk attitude under the same travel time combinations, yet without the complications of information and the detour. Note that we cannot make t_b greater than t_H, in which case the fixed route with travel time t_H in the risky branch (Route 2 in Map B and Route 3 in Map C) is better than the safe route and even a non-strategic subject who only see fixed routes will choose the risky branch.

To make the safe route more attractive for a non-strategic subject, we ensure the two fixed routes in the risky branch are both worse than the safe route. The one with a fixed travel time t_H is trivial as $t_H > t_b$. The route with a possibly low travel time t_L has to be combined with an extremely high travel time t_M to make it highly unattractive. However some extremely risk seeking subjects might still want to take the risk, therefore we set up an additional scenario in Map A with the same high risk profile and delete subjects if they take the extreme risk.

CHAPTER 4

RESULT ANALYSIS

1: Do travelers think strategically when they plan for a trip in uncertain networks with probabilistic travel time distributions?

Most route choice models assume that a traveler makes a complete route choice at the origin of a trip and do not account for any real-time information en-route. In this study, if a traveler does not think strategically in an uncertain network, he/she should always take the safe Route 1 with a deterministic travel time t_b in Map B or C. However, the final results show that a significant number of route choices take the risky branch in Map B or C.

Null hypothesis

H_0: The median of the number of strategic choices for each subject in Map B or C equals 0 .

Alternative hypothesis

H_1: The median of the number of strategic choices for each subject in Map B or C is greater than 0.

We performed a Wilcoxon Signed-Ranks Test on the counts of strategic route choices from Map B or C in the driving simulator test. The null hypothesis is rejected with a p-value of 3.388e-05 (one-sided) in Map B and a p-value of 7.71e-05 (one-sided) in Map C.

To sum up, the answer to the first question above is affirmative. Travelers think strategically when they plan for a trip in uncertain networks with probabilistic travel time distributions.

2: Does network complexity (the number of routes involved at the time a decision is made) affect travelers' strategic thinking ability?

By comparing the first group's and second group's strategic route choice counts in the driving-simulator-based tests, we could investigate whether network complexity affects travelers' strategic thinking. Map C is more complicated than Map B with Route 2 serving a decoy.

Null hypothesis

H_0: The median of the number of strategic choices for each subject in Map B equals that in Map C.

Alternative hypothesis

H_1: The median of the number of strategic choices for each subject in Map B is greater than that in Map C.

The alternative hypothesis is one-sided because we have a strong a priori belief that network complexity cannot improve a subject's strategic thinking ability. We perform a Wilcoxon-Mann-Whitney test on strategic choice counts in two independent samples from Map B and C respectively in the driving-simulator-based tests. The null hypothesis is rejected with a p-value of 0.03749 (one-sided). We thus conclude that network complexity adversely affects subjects' strategic thinking. This is intuitively understandable as recognizing the value of information from a part of the network that is further downstream is more difficult and requires higher cognitive demand.

An interesting future research topic would be to study a variety of more complicated networks and find some systematic relationship between the level of strategic thinking and network complexity. The result will be instrumental in estimating strategic route choice models from revealed preference data in real-life networks.

3: Does a parallel driving task (pre-trip versus en-route) affect travelers' strategic choices?

We gave each subject in the Map A&B group exactly ten seconds to observe the map topology and travel time distribution at the beginning of each scenario in both the driving simulator test and the PC-based test. In the driving-simulator-based tests, subjects were required to drive slowly during the ten seconds while reading the map on the screen. This approximated an en-route decision-making context. In the PC-based tests, there were no parallel driving tasks during the ten seconds and subjects simply read the computer screen. This approximated a pre-trip decision-making context. We hypothesize that a parallel driving task will add to a subject's cognitive load, and cause him/her to be less strategic.

Null hypothesis

H_0: The median of the number of strategic route choices for each subject without a parallel driving task (PC-based) equals that with a parallel driving task (driving-simulator-based).

Alternative hypothesis

H_1: The median of the number of strategic route choices for each subject without a parallel driving task (PC-based) is greater than that with a parallel driving task (driving-simulator-based).

A Wilcoxon Matched-Pairs Signed-Ranks Test gives a p-value of 0.7864 (one-sided). The null hypothesis cannot be rejected. In other words, a parallel driving task did not affect a subject's strategic thinking ability. This conclusion contradicts common sense. As mentioned before, Map B is the simplest possible network to study travelers' strategic thinking. It is possible that Map B is simple enough that a subject can make a strategic route choice in well below ten seconds. In other words, even if the traveler's cognitive capacity has been consumed by the driving task to some extent, the remaining capacity is still enough for making a strategic decision in such a simple situation as Map B. In order to thoroughly investigate a parallel driving task's influence on travelers' strategic thinking ability, we plan to conduct another PC-based test using the more complicated network, Map C. Based on our conclusion to the second question, we believe that the cognitive demand needed for strategic thinking in Map C is more than that in Map B. Ten seconds will be given to each subject taking this new PC-based test. We expect that the added network complexity could differentiate the number of strategic choices made with and without a parallel driving task.

CHAPTER 5

CONCLUSIONS AND FUTURE DIRECTIONS

Through the driving-simulator and PC-based tests for two groups of subjects using three types of network, we studied travelers' strategic route choice behavior in uncertain traffic networks. We find that a non-negligible portion of route choices were made with strategic thinking in a realistic driving simulator. This is consistent with a previous study using PC-based tests only. This demonstrates that some travelers plan for real-time information en-route and negates the assumption of many route choice models that travelers just simply select a fixed route at the beginning of the trip. It also suggests that a more realistic route choice model in a risky network with real-time information should include both strategic and non-strategic behavior. Furthermore, we find that network complexity does affect travelers' strategic thinking ability. In this study, travelers tended to make fewer strategic route choices in a complex situation, such as Map C. This provides guidance to the development of strategic route choice models in real-life networks. Current studies in the literature focus on generating optimal strategies in a general network, however an optimal strategy can be extremely complicated and thus behaviorally unrealistic. The questions such as what is the limit of a traveler's strategic planning capability and whether a traveler simplifies a network to allow for a high-level strategic planning would be interesting topics for future research.

Although we hypothesized that travelers' strategic thinking ability should be affected by parallel driving tasks, data collected during the study did not support this hypothesis. This problem possibly results from the simplicity of the network (Map B) used in this test and a more complex Map C will be used in future research.

The findings of this study will help us arrive at a better understanding of travelers' route choice behavior in risky networks. More accurate route choice models could be constructed and estimated, which will serve as a building block of a more accurate system-wide traffic prediction model. Finally, all the work will eventually lead to better decisions regarding ATIS placement and investment to serve transportation networks more efficiently.

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