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Analysis of taxi drivers' driving behavior based on a driving simulator experiment

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ANALYSIS OF TAXI DRIVERS'DRIVING BEHAVIOR BASED ON A DRIVING SIMULATOR EXPERIMENT

by

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ABSTRACT

Due to comfort, convenience, and flexibility, taxis become more and more prevalent in China, especially in large cities. According to a survey reported by Beijing Traffic Development Research Center, there were 696 million taxi person-rides in Beijing in 2011. However, many violations and road crashes that were related to taxi drivers occurred more frequently. The survey showed that there were a total of 17,242 taxi violations happened in Beijing in only one month in 2003, which accounted for 56% of all drivers' violations. Besides, taxi drivers also had a larger accident rate than other drivers, which showed that nearly 20% of taxi drivers had accidents each year. This study mainly focuses on investigating differences in driving behavior between taxi drivers and non-professional drivers.

To examine the overall characteristics of taxi drivers and non-professional drivers, this study applied a hierarchical driving behavior assessment method to evaluate driving behaviors. This method is divided into three levels, including low-risk level, medium-risk level, and high-risk level. Low-risk level means the basic vehicle control. Medium-risk level refers to the vehicle dynamic decision. High-risk level represents the driver avoidance behavior when facing a potential crash.

The Beijing Jiatong University (BJTU) driving simulator was applied to test different risk level scenarios which purpose is to find out the differences between taxi drivers and non-professional drivers on driving behaviors. Nearly 60 subjects, which include taxi drivers and non-professional drivers, were recruited in this experiment. Some statistical methods were applied to analyze the data and a logistic regression model was used to perform the high-risk level.

The results showed that taxi drivers have more driving experience and their driving style is more conservative in the basic vehicle control level. For the car following behavior, taxi drivers have smaller following speed and larger gap compared to other drivers. For the yellow indication judgment behavior, although taxi drivers are slower than non-professional drivers when getting into the intersection, taxi drivers are more likely to run red light. For the lane changing behavior, taxi drivers' lane changing time is longer than others and lane changing average speed of taxi drivers is lower than other drivers.

Another different behavior in high-risk level is that taxi drivers are more inclined to turn the steering wheel when facing a potential crash compared to non-professional drivers. However, non-professional drivers have more abrupt deceleration behaviors if they have the same situation.

According to the experiment results, taxi drivers have a smaller crash rate compared to non-professional drivers. Taxi drivers spend a large amount of time on the road so that their driving experience must exceed that of non-professional drivers, which may bring them more skills. It is also speculated that because taxi drivers spend long hours on the job they probably have developed a more relaxed attitude about congestion and they are less likely to be candidates for road rage and over aggressive driving habits.

To my parents
Ruiming Wu and Jingli Bai
Who encourage me to realize my dream

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CHAPTER ONE: INTRODUCTION

1.1 Background

With the rapid development of urbanization and motorization, the taxi transport industry has also highly developed and plays an important role in the urban public transportation system in China, especially in big cities. According to the statistics from Beijing Municipal Bureau (2008), there are more than 69,000 taxis in Beijing, which is six times compared to 20 years ago. Meanwhile, with the improvement of people's living standard, taxi is getting more and more popular among general public transportation for its comfort, convenience, and flexibility and number of those who choose taxi for their travelling increases steadily. As reported by Beijing Traffic Development Research Center (2012), there were 650 million taxi person-rides in Beijing in 2005, increasing to 696 million in 2011.

Generally, there is no difference between taxis and ordinary cars because of their same outlook and vehicle performance. When collecting traffic volume data, a taxi is also considered as one passenger-car that is the same as the ordinary car. Therefore, few studies have been conducted in examining taxi drivers' behavior and work conditions. In fact, in terms of driving behaviors, taxi drivers are quite different from others. Compared to non-professional drivers, taxi drivers need to stop, accelerate, or decelerate more frequently in order to seek customers, which may result in some traffic problems and safety issues. The taxi industry is highly dependent on taxi drivers, who not only safely control the vehicle but also need to provide service. According to a violation investigation, there were a total of 17,242 taxi violations happened in Beijing in only one month in 2003, which accounted for 56% of all drivers' violations. The same study also indicated that 27% of taxi drivers got tickets in only one month (Chinese People's Political Consultative Conference (CPPCC) Member Proposal, 2006). It is speculated that the high violation rates can be attributed to two reasons. The first reason is that the agency that grants licenses to taxi drivers is not demanding of high standards of drivers' qualifications. They only need to acquire normal driver licenses and complete a short-term training before being a qualified taxi driver. The second reason is that taxi companies employ taxi drivers and they need to pay a fairly large amount of money each month to their companies. However, the income of taxi drivers is relatively low compared to their workload (Shi et al., 2014). Although taxi violation phenomenon has become slightly less in recent years, it is still a big issue.

Furthermore, taxi drivers also had a larger accident rate than non-professional drivers. The data showed that nearly 20% of taxi drivers had accidents each year, which was a large proportion of all traffic accidents (Shi et al., 2014). Due to the particularity of taxi industry, taxi drivers have flexible work schedule, which means they can arrange their time according to their will. On the surface, taxi drivers could have a rest when they feel tired, which may help to reduce traffic accidents and avoid drowsy driving. However, reality is that in China taxi drivers usually work on the average 11 hours per day and 27.8 days per month, which is far more than the legal limit of 8 hours per day and 21.75 days per week. This high work hour rate may be a reflection of the typically taxi drivers' work condition in China (Deng and Ou, 2009). Therefore, it can be inferred that nearly 25% of work time for taxi drivers is drowsy driving conditions in Beijing. Although taxi drivers often claimed and portrayed that they were aware of traffic safety requirements, they were driving in a fatigued condition (R.Dalziel & Job, 1997), and it in many studies it was proved to be more dangerous on the road (Connor et al., 2011; Lucidi et al., 2013; T.McCartt et al., 1996).

1.2 Research Approaches

Firstly, a literature review of relevant domain information was conducted, including traffic safety research related to taxi drivers, and driver behavior research based on a driving simulator experiment.

Secondly, a series of scenarios were designed in the driving simulator to collect data on both taxi drivers' behaviors and non-professional drivers' behaviors. A hierarchical driving performance assessment method was adopted during the simulator experiment, which was classified into three different risk levels. About 55 participants were recruited in this experiment and data was collected during the experiment.

Finally, several software packages including Microsoft EXCEL, SPSS, Minitab, and SAS were used to analyze the data and build statistical models.

1.3 Research Objectives

The main objectives of this research are:

(1) Set up several scenarios in the driving simulator to test the drivers' behavior, including taxi drivers and non-professional drivers. The scenarios are divided into different levels of the traffic safety, including the low risk (basic vehicle control), the medium risk (dynamic decision) and the high risk (collision avoidance response behavior).

(2) Extract the drivers' behavior from the raw data in different scenarios, such as vehicle velocity, deceleration, reaction time and other relevant information.

(3) Find the difference between taxi drivers and non-professional drivers in driving behaviors under different levels of traffic safety.

(4) Summarize the basic characteristics of the taxi drivers' behavior and analyze some typical scenarios for the traffic safety.

1.4 Thesis Organization

This chapter presents an introduction to the subject matter to be discussed as well as a description of the research approaches and objectives. Chapter 2 delves into literature to discuss the framing of the problem addressed by this research. Chapter 3 describes the driving simulator study methodology, including equipment, experimental design, experiment procedure, and subject. Chapter 4 presents the data collection procedure and describes every variable in each scenario. Chapter 5, 6, and 7 analyze each scenario by using driving simulator data and discuss the statistical models developed. Finally, Chapter 8 provides the conclusions and recommendations derived from the driving simulator experiment.

CHAPTER TWO: LITERATURE REVIEW

2.1 Traffic Safety Research Related to Taxi Drivers

In recent years, many studies focused on taxi drivers' behaviors related to the traffic safety. There were two main aspects, including car crashes or violations. Maag et al. (1997) developed a regression model to estimate taxi road traffic crashes for each factor by using 6 years crash data in Canada. They found that taxi drivers have an average of 0.252 crashes per year compared to 0.07 of all drivers, which was similar to the findings of Nordjaern et al. (2012). Similarly, taxi drivers also had a high average number of victims per crash than others. Moreover, some factors associated with vehicle crashes and injuries were also identified among taxi drivers, such as binocular vision problem (Maag et al., 1997), fatigue (R.Dalziel and Job, 1997), emotional well-being (Machin and De Souza, 2004), and driving at night and driving without any passengers (Lam, 2004).

In addition, Goudine (1997) investigated the taxi drivers' attitudes to traffic laws and penalties in North Africa. It was found that there was a poor communication between law enforcers and taxi drivers, which may lead to high-risk driving behaviors among taxi drivers. Another study also attempted to identify the attitude towards traffic violation in male taxi drivers in Israeli (Rosenbloom and Shahar, 2007). The results indicated that non-professional drivers paid more attention to the traffic violations or penalties than taxi drivers did, especially in minor-severity traffic regulations, which would also raise driving risks among taxi drivers. Furthermore, those taxi drivers, who enjoyed taking more risks while driving, were more likely to commit speeding violations (Burns and Wilde, 1995).

Some studies in developing countries also focused on the taxi drivers. In Vietnam, La et al. (2013) used a structural questionnaire to interview drivers from five different companies during 2006-2009. They found that education on traffic rules and seat-belt usage could improve the taxi drivers' safety and element of time pressure could also impact on crashes for taxi drivers. In Sri Lanka, Akalanka et al. (2012) used bivariate and multivariate logistic regression to examine the sociodemographic factors related with aggressive driving behaviors among 3-wheeler taxi drivers. They demonstrated that the level of education and aggressive driving practice were the significant factors that affected road traffic crashes. Besides, marital status was also associated with some violations, such as running red lights, and drinking while driving.

Although few previous studies analyzed the effect of taxi drivers on traffic safety, most of them only focused on the effects of taxi drivers on crashes or violations using questionnaires or crash reports but did not pay attention to the taxi drivers' driving behaviors. Several previous studies demonstrated the potential of using driving simulators to assess traffic safety. However, none of these studies focused on taxi drivers.

2.2 Driver Behavior Research Based on Driving Simulator

The driving simulator is a research and development experiment device used to test driving behaviors, safety performance and the condition of the road. In general, the simulator consists of several subsystems: a real-time vehicle simulation system, vehicle motion, visual and audio systems, a control loading system, an operator console, and data collection system (Lee et al., 1998). The use of an advanced driving simulator has many advantages on testing drivers' behaviors, including experimental control, efficiency, expense, safety, and ease of data collection (Godley et al., 2001).

In recent years, more and more researchers used a driving simulator to test the driving behaviors that are not easy tested in the reality. Several conditions were usually to be considered to use a driving simulator to collect data, including environmental factors, dangerous scenarios, the new application installed on road, and some particular groups.

Some environmental factors are difficult to test in reality, such as the adverse weather and roadside vegetation. Therefore, a number of previous studies have focused on driving behaviors related to the environmental factors based on driving simulator. Yan et al. (2014) investigated the effects of foggy conditions under different risk levels on drivers' speed behaviors according to the driving simulator experiment. They found that drivers intended to reduce their speed under foggy condition, but speed compensation cannot sufficiently reduce the risk of crash involvement, which concurred with the study by Hoogendoorn et al. (2010). Broughton et al. (2007) also used a driving simulator to test the car following behaviors under foggy conditions. They also found that drivers were more likely to fail to maintain following distance under foggy conditions. Another study related to the foggy condition based on driving simulator found that experienced drivers had a larger speed than novice drivers just under clear conditions (Mueller and Trick, 2012). Under foggy conditions, experienced drivers reduced their speed more than novice drivers. In addition, roadside vegetation is also one of the environmental factors that are usually used driving simulator to examine the influence on driver behavior. Fitzpatrick et al. (2014) found that trees were the most harmful roadside objects that might lead to some crashes and drivers drove closer to the edge line as the clear zone size increased.

Car accidents are one of the biggest issues in the transportation field. However, it is also hard to test drivers' response before the crash. Therefore, the driving simulator can be a good tool to assess behavior of drivers in such a dangerous traffic situation. Several studies tested driving behaviors for different pre-accident situations in the driving simulator (Guzek et al., 2009; Lee et al., 2002; McGehee et al., 2000). Besides, the other dangerous situation that is suitable for testing in the driving simulator, not in the reality is that drivers are driving while using cell phones. Alm and Nilsson (1995) used the driving simulator to test whether there was a negative effect on drivers' behaviors when drivers used cell phones while driving. It is found that drivers had a longer reaction time when using cell phones and accident risk could increase because of the use of cell phones. The similar researches related to the cell phones based on driving simulator experiment were also studied by Strayer and Drews (2004), Lesch and Hancock (2004), Haigney et al. (2000), and Stein et al. (1987). Similarly, there are also other dangerous situations that need to test in the driving simulator, including work zones (Bella, 2005; McAvoy et al., 2007), and the curve condition (Reymond et al., 2001).

Some new applications before the application in the reality also need to be tested in the driving simulator to assess the effect of the new applications. The pavement marking, which is one of the new applications in Florida, is to place a marking with a word "Signal Ahead" upstream of a signalized intersection. This method is also tested in the driving simulator by Yan et al. (2009). They found that pavement marking had a positive effect on drivers' behaviors at signalized intersection, which can reduce the probabilities of both conservative-stop and risky-go decisions. Another example for new applications is the in-vehicle warning message to help drivers lower the red light running violations. Some researchers also used a driving simulator to verify the effectiveness of this new application (Philippus et al., 2009; Yan et al., 2014).

The driving simulator is also a useful tool to study the particular group on driving behaviors. For example, drivers with Alzheimer Disease are the uncertain group for driving safety. Rizzo et al. (1997) used high-fidelity driving simulator to measure relevant performance factors and found that drivers with Alzheimer Disease were more than twice as likely to have crashes compared to the normal drivers, which is the same finding with Cox et al. (1998). Besides, some other groups are also tested in the driving simulator, including novice drivers and experienced drivers (Chan et al., 2010; Parmet et al., 2014), old drivers and young drivers (Lee et al., 2003; Pradhan et al., 2005).

CHAPTER THREE: EXPERIMENT METHODOLOGY

3.1 Equipment

A high-fidelity driving simulator, which consists of a full-size cabin, a digital sound simulation system, a vibration system and the center console, located in MOE Key Laboratory for Urban Transportation Complex Systems of the Beijing Jiaotong University was used in the study, as shown in Figure 1. It is suitable for conducting interactive driving simulation experiments under lab-control conditions and is good for analyzing driving behavior.

The driving simulator has a linear motion base capable of operation with one degree of freedom. It is composed of a visual system with 300 degree of front view and three rear view mirrors, a full-size cabin of Ford Focus with real operation interface, a digital sound simulation system, a vibration system, and the center console. The visual system allows resolution equal to 1400 x 1050 pixels for each channel. The software, including Simvista and Simcreator, is provided for modeling road networks and driving scenarios. The data sampling frequency is up to 60 Hz.

In addition, five cameras are installed inside and outside the cabin to supervise the experimental process. An emergency stop button is installed both inside cabin beside the driver seat and in the front of control desk in order that either subject or researcher can discontinue the experiment immediately in case the subject suffers driving simulation sickness.

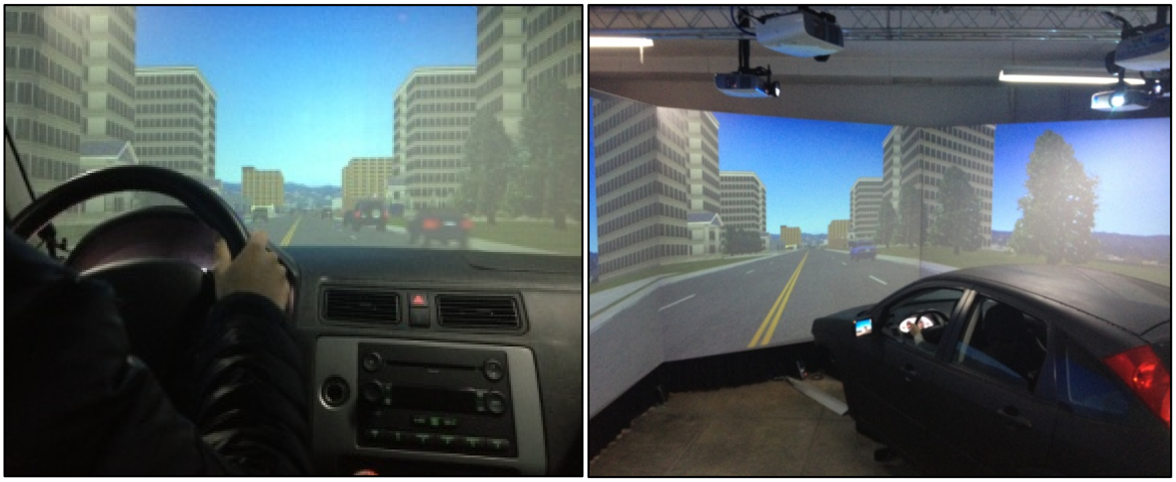

Figure 1: BJTU driving simulator

3.2 Experimental Design

Although a number of previous studies focused on the driving behavior by using driving simulators, most of them lack of a systematic analysis according to risk level. Yan et al. (2014) adopted a hierarchical driving performance assessment method to evaluate driving behavior under foggy conditions. However, they only paid attention to different speed-related situations. In this study, an updated concept of hierarchical driving behavior assessment method was proposed to estimate the taxi driver behavior, as shown in Figure 2. It is classified into three different risk levels. The first level is low-risk level, which means drivers require basic vehicle control according to the roadway alignment, such as acceleration, braking, steering. The second level is medium-risk level, which relates to moderate risk and dynamic decision. For example, in the yellow light judgment scenarios, drivers need to make decisions to stop or go according to the distance to the stop line and vehicle speed. If drivers make wrong decisions like running the red light, a serious crash may occur. Some other typical scenarios such as car following scenarios, and lane-changing scenarios are also considered as medium-risk scenarios. The third level is high-risk level, which corresponds to the Collision Avoidance Scenario, indicating that when an immediate crash is present, drivers need to take emergency response to avoid crash. Since it is hard to get driver emergency reaction data in real world, driving simulator is a good tool to evaluate driver emergency reaction in this kind of scenario.

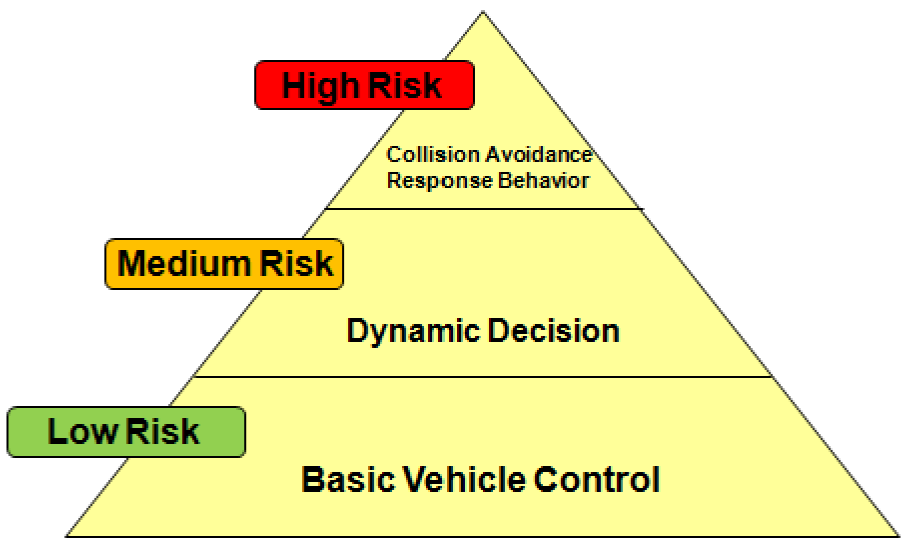

Figure 2: Hierarchical driving behavior assessment method

3.2.1 Low-Risk Scenario Design

To investigate basic vehicle control behaviors, the low-risk scenario was designed, as shown in Figure 3.The low-risk scenario consisted of three sub-scenarios, including uphill and downhill scenario (15° slope), right angle turn scenario, and S-type continuous curve scenario. All the roads were two-way with two lanes. The speed limits were 50 km/h on the uphill and downhill segments, and 30 km/h on the S-type continuous scenario. The subject needed to drive from the Start point to the End point, and there was no other vehicle in front of the simulator vehicle in order that drivers could control vehicles by themselves. Additionally, some other vehicles on the opposite direction were added into the scenario in order to improve the scene reality.

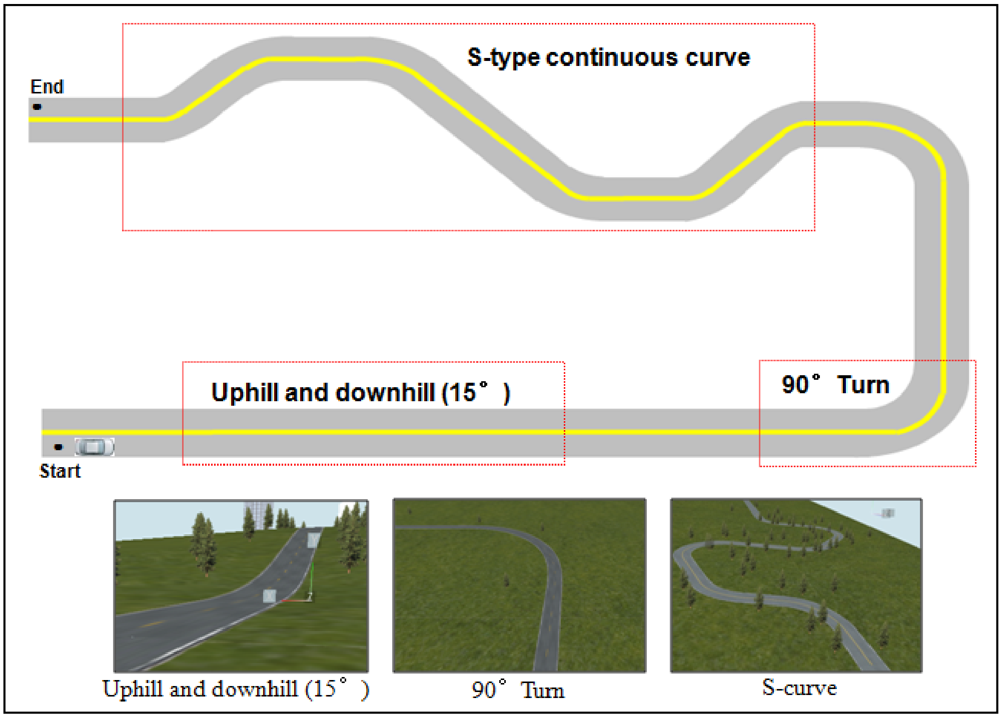

Figure 3: Low-risk scenario design

3.2.2 Medium-Risk Scenario Design

The medium-risk scenario was divided into three parts, including the yellow indication judgment scenario, the car following scenario, and the lane-changing scenario. Each scenario was used to explore drivers' behaviors related to moderate risk or dynamic decision.

3.2.2.1 Yellow Indication Judgment Scenario

To investigate driving behaviors when facing the potential red light running violation during the yellow phase at a signalized intersection, the yellow indication judgment scenario was designed, as shown in Figure 4, which was composed of two-lane road segments with the 80 km/h speed limit. The duration of yellow signal was set to be 4.5s, which was calculated by the formula recommended by Institute of Transportation Engineers (ITE). For the simulator experiment, if subjects were located 5, 5.5, and 6 seconds away from the intersection stop line respectively, and if they kept their current posted speed along their presumed path, the signal would have changed into the yellow indication and lasted 4.5 seconds, which meant that if subjects didn’t take any action and still drove at their present speed, they would have run the red light. Therefore, a Time-To-Collision sensor was used to realize this scenario. TTC is defined as the time that remains until a collision between two vehicles would have occurred if collision course and speed difference are maintained (Minderhoud and Bovy, 2001), which was widely used in many simulation studies (Gelau et al., 2011; Yan et al., 2014; Yan et al., 2014). TTC was also seen as the time to the intersection stop line (TTI) in this scenario and was equal to 5, 5.5, and 6 seconds in each intersection, respectively. The TTC sensor would trigger the traffic signal to change into the yellow phase and last 4.5 seconds in advance of the intersection. Meanwhile, there was no other vehicle in front of the simulator vehicle in order that drivers could decide whether to stop or go by themselves. In order to counterbalance the temporal order effect during the experiment operation, three intersections were randomly assigned to the road network and some other intersections, which displayed continuous green phases, were intermingled between each test intersection, which has the same design method as Yan et al. (2009).

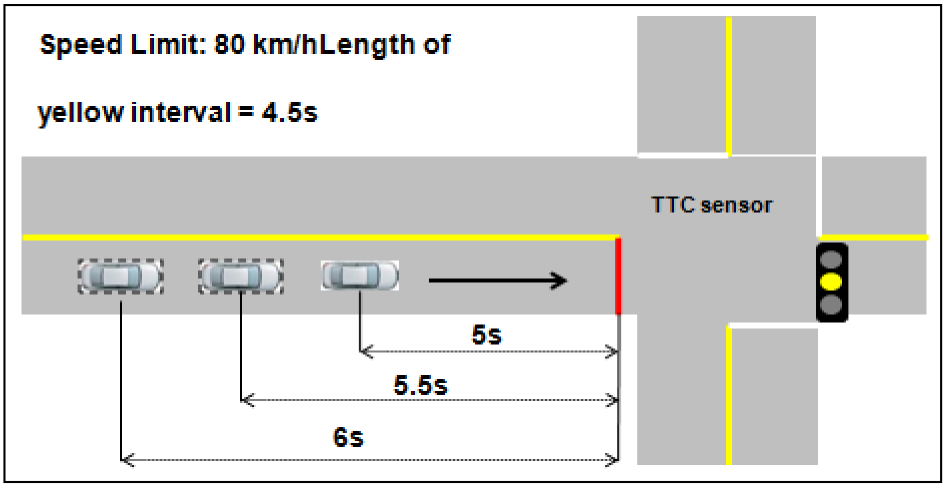

Figure 4: Yellow indication judgment design

3.2.2.2 Car Following Scenario

The car following scenario was designed to test drivers' car following behaviors between taxi drivers and non-professional drivers, as shown in Figure 5. The test road was arranged on a two-way segment with two lanes, and its total length was about 2.5 km. A platoon of system vehicles stopped at the beginning of the scenario, waiting for the simulator vehicle to join the queue. All of system vehicles are general vehicles, not taxis. When the simulator vehicle arrived at this point, Sensor 1 was triggered and system vehicles would start to accelerate at 1 m/s^2 along the segment. In order to ensure the simulator vehicle could follow the leading vehicle all the time and not pass the front vehicle in the opposite lane, several vehicles were added in the opposite direction. During the car following process, 10 different periods, including three accelerate periods, two decelerate periods, and five constant speed periods, were used to investigate car following behaviors in different car following situations. Five sensors were applied to realize the scenario. Ten periods were described as follows:

- **Period 1:** The leading vehicle would accelerate at 1 m/s^2 until the speed was up to 40 km/h.
- **Period 2:** The leading vehicle would keep a constant speed of 40 km/h.
- **Period 3:** The leading vehicle would decelerate at 4 m/s2 until the speed was 30 km/h.
- **Period 4:** The leading vehicle would keep a constant speed of 30 km/h.
- **Period 5:** The leading vehicle would accelerate at 2 m/s^2 until the speed was up to 50 km/h.
- **Period 6:** The leading vehicle would keep a constant speed of 50 km/h.
- **Period 7:** The leading vehicle would decelerate at 2 m/s2 until the speed was 30 km/h.
- **Period 8:** The leading vehicle would keep a constant speed of 30 km/h.
- **Period 9:** The leading vehicle would accelerate at 1.5 m/s^2 until the speed was up to 40 km/h.
- **Period 10:** The leading vehicle would keep a constant speed of 40 km/h.

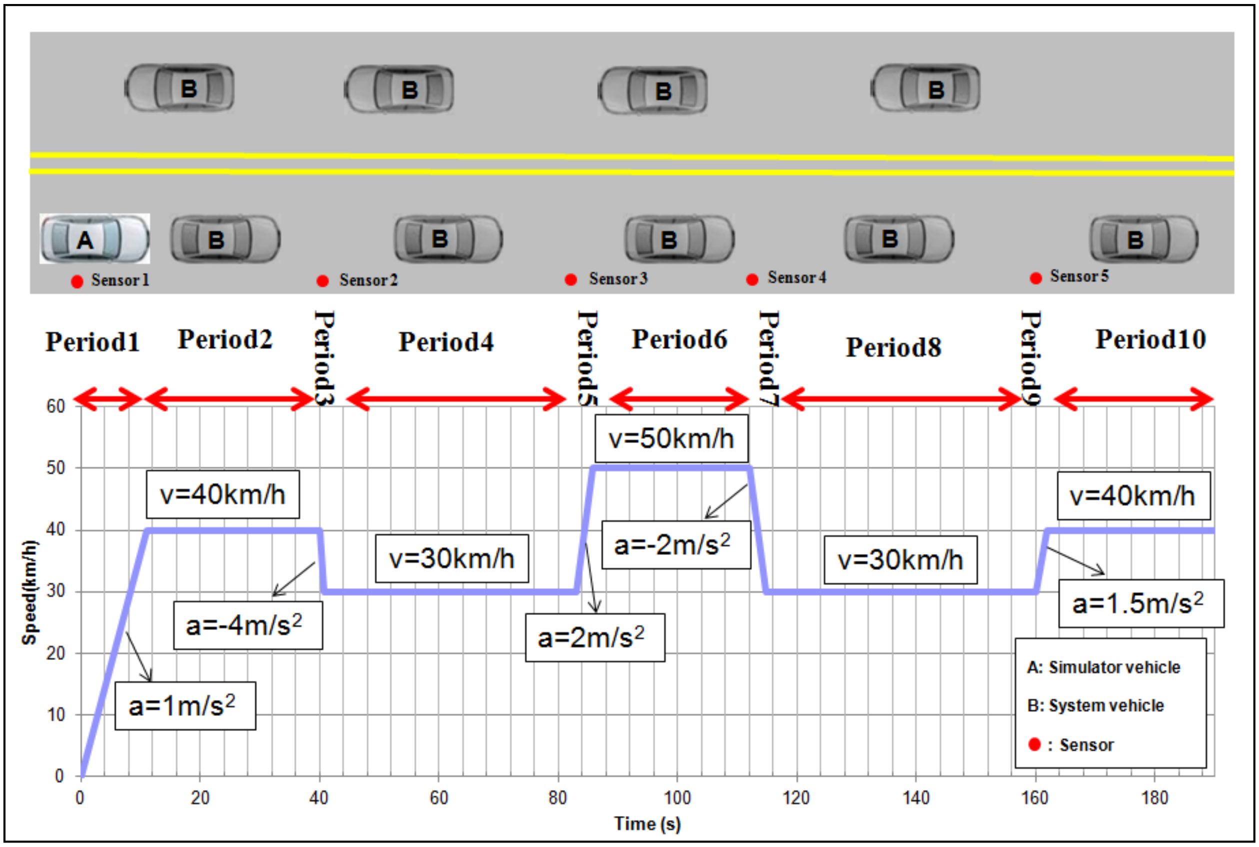

Figure 5: Car following scenario design

3.2.2.3 Lane-Changing Scenario

To investigate the differences between taxi drivers and non-professional drivers on lane-changing behaviors, a road network was designed, as shown in Figure 6, which was also used in the previous study (Yan and Wu, 2014). This road network was composed of a four-lane road segments with the 80 km/h speed limit. Subjects would depart at the start point and get to the end point. Additionally, two variable message signs (VMS) were installed in the network, which displayed the current congestion state of the network. VMS-I showed that BEIJING ROAD was congested (see Figure 7) and VMS-II showed that HANGZHOU ROAD was congested (see Figure 8). If subjects wanted to choose the uncongested road, they needed to change from inside lane into outside lane in the Test Segments. In order to avoid that other vehicles disturbed the experiment, no other vehicle would appear in the Test Segments. Besides, each subject would drive three times in the network and go through the Test Segments six times. Only when subjects had lane-changing behaviors, the data was collected.

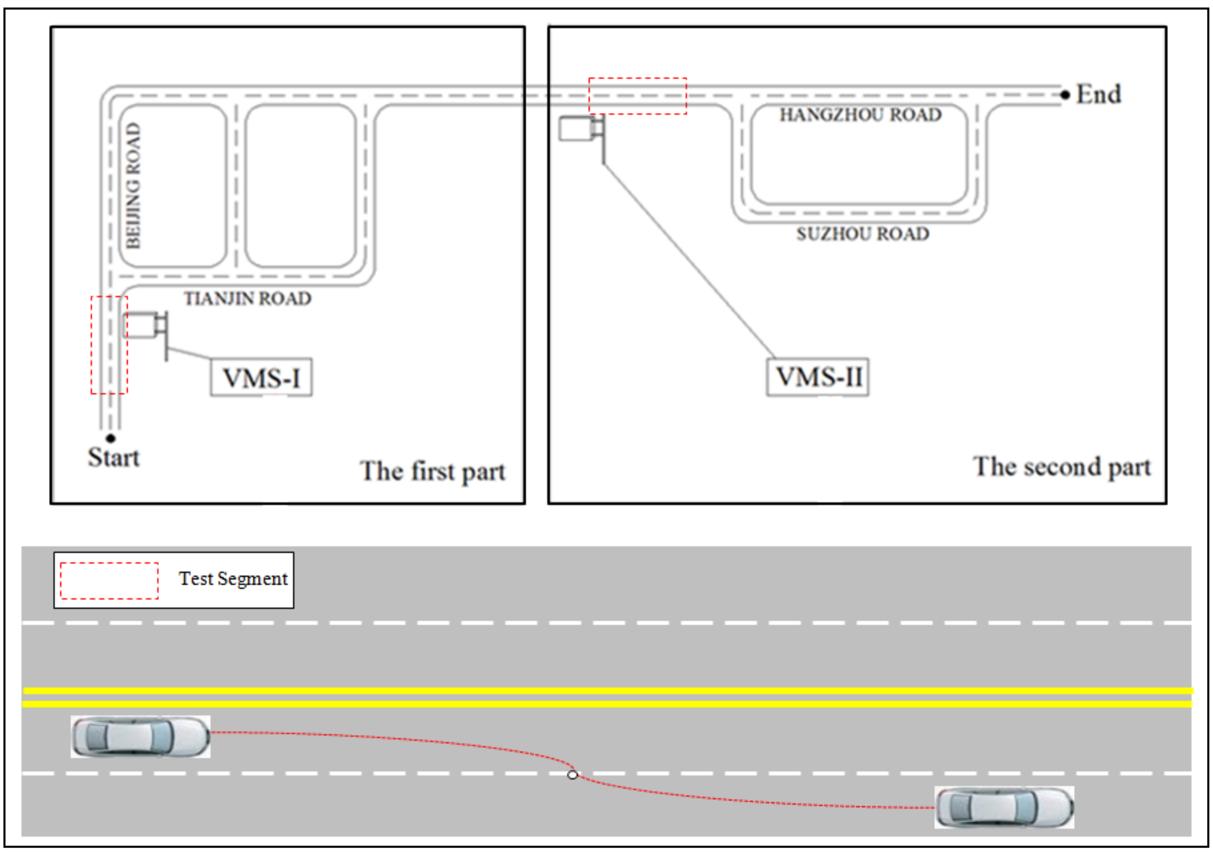

Figure 6: Lane-changing scenario design

Figure 7: VMS-I display

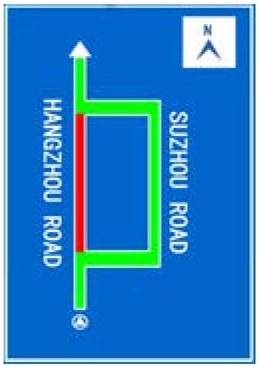

Figure 8: VMS-II display

3.2.3 High-Risk Scenario Design

At high-risk level, collision avoidance scenario was designed to examine driving behaviors when facing an emergency crash, which was shown in Figure 9. The simulator vehicle entered the signalized intersection during the green phase and drove normally. Meanwhile, the other system vehicle was crossing this intersection from the right side at a velocity of 60 km/h during the red phase. In order to create a right-angle crash at the intersection, a TTC sensor was used in this scenario as well. TTC was set at seven seconds in advance of the TTC point. Therefore, when subjects left 7 seconds temporal separation to the conflict point, TTC would trigger the system vehicle to start to cross the intersection with a velocity of 60 km/h. According to the calculation, the system vehicle was 116 meters away from the conflict point on the right side of the intersection. Meanwhile, all other vehicles were cleared up before the simulator vehicle and the system vehicle so that any other vehicle did not interfere with the drivers' behavior. Thus, if subjects kept a present speed along their presumed path to the conflict point, there would be a crash between the simulator vehicle and the system vehicle. Additionally, all the roads were two-way with two lanes and the speed limits were set at 80 km/h along the simulator path.

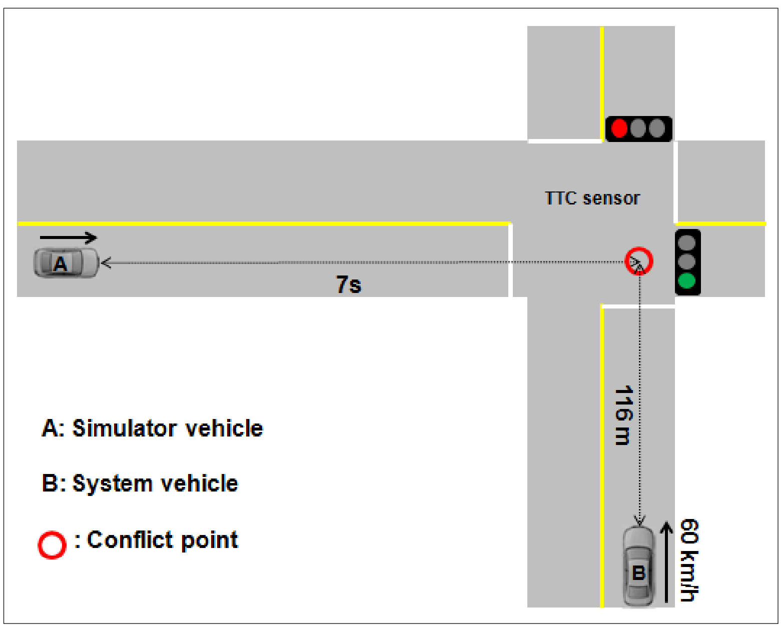

Figure 9: Collision avoidance scenario design

3.3 Experiment Procedure

Upon arrival, all subjects were asked to read and sign an informed consent form, which is approved in China for the human subjects' experiments. Each subject in this study was asked to take a short training session, including the Traffic Regulation Education, the Safety Notice and the Familiarity Training. In the Traffic Regulation Education session, each subject was advised to drive and behave as they normally would and to follow traffic rules as they would in real-life situations. In the Safety Notice session, each subject was told that they could quit the experiment at any time if they had any motion sickness symptoms and any kind of discomfort. In the Familiarity Training session, each subject was requested to have at least 10 minutes training to familiarize with the driving simulator operation, including straight driving, acceleration, deceleration, left/right turns, and other basic driving behaviors.

After completing the short training course, subjects could start formal experiments with two scenarios in a random sequence so as to eliminate the time order effect. For security and liability reasons, the escort would send every subject into the simulator cabin to commence the experiment and keep an eye on the surveillance system during the whole experiment. Moreover, all subjects were requested to rest at least 15 min between each scenario.

3.4 Subjects

First, researchers enlisted a group of about 55 people in this experiment, who were local drivers in Beijing, China, with at least one year of driving experience. All taxi drivers were full-time job drivers from different taxi companies. The other non-professional drivers were from different vocations, such as teachers, company employees, students. Most subjects could finish the experiment successfully but some subjects could not complete some parts of scenarios because of the motion sickness so that they cannot follow the instructions. The gender and occupation distribution for each scenario was shown in Table 1, which showed that the subject gender distribution was balanced in each occupation group for each scenario.

Table 1: Gender and occupation distribution of each scenario

<table>
<tr><th colspan="2" rowspan="2">Scenario</th><th colspan="2">Male</th><th colspan="2">Female</th></tr>
<tr><th>Taxi</th><th>Non-professional</th><th>Taxi</th><th>Non-professional</th></tr>
<tr><td colspan="2">Low-risk scenario</td><td>13</td><td>13</td><td>8</td><td>12</td></tr>
<tr><td rowspan="3">Medium-risk scenario</td><td>Yellow indication Judgment</td><td>14</td><td>13</td><td>9</td><td>13</td></tr>
<tr><td>Car following</td><td>13</td><td>11</td><td>13</td><td>10</td></tr>
<tr><td>Lane-changing</td><td>16</td><td>14</td><td>9</td><td>13</td></tr>
<tr><td colspan="2">High-risk scenario</td><td>14</td><td>13</td><td>9</td><td>13</td></tr>
</table>

Besides, the average age of all the subjects was 34, ranging from 20 to 52 years old (S.D. = 10). Taxi drivers had an average mileage of 72.6 thousand kilometers per year and an average driving experience of 15 years. By contrast, non-professional drivers had an average mileage of 12.6 thousand kilometers per year and an average driving experience of 4 years. Each subject was required to finish all the scenarios in the driving simulator in order to get 500 Chinese RMB (around 80 U.S. dollars) as a compensation for their participation.

CHAPTER FOUR: DATA COLLECTION

4.1 Simulator Data Collection Procedure

The driving simulator data collection included the experiment sampling time, vehicle speed, acceleration, vehicle position, steering angle and many other related parameters. The data sampling frequency is up to 60 Hz, and the collected raw data was stored in PLT type file, which was not directly used for data analyses. First of all, PLT type files were manually converted to EXCEL type files. Then, by using .NET framework, which is software developed by Microsoft that runs primarily on Microsoft Windows, a program written by C Sharp language was developed to automatically extract the experiment data, organize it, and easily process the raw data. From the raw data, some significant variables were derived.

4.2 Low-Risk Scenario Data Collection

In the low-risk scenario design, there were three sub-scenarios, which were uphill and downhill scenario (15° slope), right angle turn scenario, and S-type continuous curve scenario. Data collection was based on 46 subjects' behaviors in each sub-scenario (See Appendix A).

4.2.1 Uphill and Downhill Scenario Data Collection

The dependent measures for data analyses during the uphill period were defined as follows:

- USS (km/h): Uphill starting speed. The vehicle's operating speed when the driver started to go uphill.
- UES (km/h): Uphill ending speed. The vehicle's operating speed when the driver finished the uphill.
- USD (km/h): Uphill speed difference. The difference between the uphill starting speed and uphill ending speed, which was the uphill ending speed minus the uphill starting speed.
- UAS (km/h): Uphill average speed. Average speed during the uphill period.
- UAD (m/s^2): Uphill average deceleration. Average deceleration during the uphill period.

The dependent measures for data analyses during the downhill period were defined as follows:

- DSP (km/h): Downhill starting speed. The vehicle's operating speed when the driver started to go downhill.
- DES (km/h): Downhill ending speed. The vehicle's operating speed when the driver finished the downhill.
- DSD (km/h): Downhill speed difference. The difference between the downhill starting speed and downhill ending speed, which was measured as the downhill ending speed minus the downhill starting speed.
- DAS (km/h): Downhill average speed. Average speed during the downhill period.

- DAA (m/s^2): Downhill average acceleration. Average acceleration during the downhill period.

4.2.2 Right Angle Turn Scenario Data Collection

The dependent measures for data analyses during right angle turn period were defined as follows:

- RASS (km/h): Right angle starting speed. The vehicle's operating speed when the driver started to enter the right angle turn.
- RAES (km/h): Right angle ending speed. The vehicle's operating speed when the driver finished the right angle turn.
- RASD (km/h): Right angle speed difference. The difference between the right angle starting speed and ending speed, which was measured as the right angle ending speed minus the right angle starting speed.
- RAAD (m/s^2): Right angle average deceleration. Average deceleration during the right angle turn period.
- Out-of-lane (yes = 1; no = 0): Whether the vehicle went out of lane during the right angle turn period.

4.2.3 S-type Continuous Curve Scenario Data Collection

The dependent measures for data analyses during S-type continuous curve period were defined as follows:

- SCSS (km/h): S-type continuous curve starting speed. The vehicle's operating speed when the driver started to enter the S-type continuous curve.
- SCES (km/h): S-type continuous curve ending speed. The vehicle's operating speed when the driver finished the S-type continuous curve.
- SCAS (km/h): S-type continuous curve average speed. Average speed during the S-type continuous curve period.
- SCDE (cm): S-type continuous curve average deviation. Average deviation during the S-type continuous curve period.

4.3 Medium-Risk Scenario Data Collection

4.3.1 Yellow Indication Judgment Scenario Data Collection

Data collection was based on each subject driving three test intersections in the road network. Each subject would meet different test scenarios three times and the total of 49 subjects produced 147 records (See Appendix B). The related dependent measures for data analyses were defined as follows:

- Speed (km/h): The vehicle's operating speed at the onset of the yellow phase.
- RLR (no = 0; yes = 1): Whether the driver ran a red light or not.

4.3.2 Car Following Scenario Data Collection

There were three kinds of periods in the car following process, including constant periods, deceleration periods and acceleration periods (See Appendix C).

For the constant periods, there were a total of 5 periods. The dependent measures for data collection in these periods were defined as follows:

- AS30 (km/h): Average speed during the constant period when the front vehicle is 30 km/h.
- ASH30 (m): Average space headway between the simulator vehicle and the front vehicle during the constant period when the front vehicle is 30 km/h.
- AS40 (km/h): Average speed during the constant period when the front vehicle is 40 km/h.
- ASH40 (m): Average space headway between the simulator vehicle and the front vehicle during the constant period when the front vehicle is 40 km/h.
- AS50 (km/h): Average speed during the constant period when the front vehicle is 50 km/h.
- ASH50 (m): Average space headway between the simulator vehicle and the front vehicle during the constant period when the front vehicle is 50 km/h.

For the deceleration periods, there were two periods during the car following process. The dependent measures for data collection in each period were defined as follows:

- RT3 (s): Reaction time during the deceleration period 3, which was measured as the time between the start brake time of the front vehicle and the start brake time of the simulator vehicle during the deceleration period 3.
- ADD3 (m/s^2): Average deceleration during the deceleration period 3, which was measured as the average deceleration during the deceleration period 3.
- RT7 (s): Reaction time during the deceleration period 7, which was measured as the time between the start brake time of the front vehicle and the start brake time of the simulator vehicle during the deceleration period 7.
- ADD7 (m/s^2): Average deceleration during the deceleration period 7, which was measured as the average deceleration during the deceleration period 7.

For the acceleration periods, there were three periods during the car following process. The dependent measures for data collection in each period were defined as follows:

- RT1 (s): Reaction time during the acceleration period 1, which was measured as the time between the start accelerate time of the front vehicle and the start accelerate time of the simulator vehicle during the acceleration period 1.

- AAD1 (m/s^2): Average acceleration during the acceleration period 1, which was measured as the average acceleration during the acceleration period 1.
- RT5 (s): Reaction time during the acceleration period 5, which was measured as the time between the start accelerate time of the front vehicle and the start accelerate time of the simulator vehicle during the acceleration period 5.
- AAD5 (m/s^2): Average acceleration during the acceleration period 5, which was measured as the average acceleration during the acceleration period 5.
- RT9 (s): Reaction time during the acceleration period 9, which was measured as the time between the start accelerate time of the front vehicle and the start accelerate time of the simulator vehicle during the acceleration period 9.
- AAD9 (m/s^2): Average acceleration during the acceleration period 9, which was measured as the average acceleration during the acceleration period 9.

4.3.3 Lane-Changing Scenario Data Collection

Data collection in this scenario was based on each subject driving three times in the simulated road network. Each subject was likely to change lanes in the Test segments. Finally, there were 136 lane-changing behaviors collected among all the subjects (See Appendix D). The related dependent measures during the lane-changing period were defined as follows:

- LCT (s): Lane changing time, which was measured as lane-changing duration if a subject has a lane changing behavior.
- LCD (m): Lane changing distance, which was measured as the longitudinal distance of lane changing.
- LCS (km/h): Lane changing speed, which was measured as the average speed during lane changing period.
- MLS (m/s): Maximum lateral speed, which was measured as the largest lateral speed during lane changing period.
- ALS (m/s): Average lateral speed, which was measured as the average lateral speed during lane changing period.
- MLA (m/s^2): Maximum lateral acceleration, which was measured as the largest lateral acceleration during lane changing period.
- ALA (m/s^2): Average lateral acceleration, which was measured as the average lateral acceleration during lane changing period.

4.4 High-Risk Scenario Data Collection

In this scenario, data collection was based on 49 subjects' behavior during the whole collision period (See Appendix E). The dependent measures for data analyses were defined as follows:

- Speed (km/h): The vehicle's operating speed at each second before the collision. Five seconds before the collision are recorded.
- Deviation (m): The vehicle's lane deviation at each second before the collision, which was measured as distance between the vehicle location and the center of the lane. The positive value means the vehicle is on the right side of the lane. Five seconds before the collision are recorded.
- BD (m): The distance between the start brake location and the conflict point. The value could be 0 if drivers didn't press the brake pedal.
- BS (km/h): The operating speed at the onset of the brake point. The value could be 0 if drivers didn't press the brake pedal.
- BRT (s): Brake response time to collision, which was measured as the time between the start brake time and the expected collision time. The value could be 0 if drivers didn't press the brake pedal.
- DEC (m/s^2): Average deceleration during the brake period. The value could be 0 if drivers didn't press the brake pedal.
- Crash (crash = 1; not = 0): Whether a crash occurred between the driver and the system vehicle.

CHAPTER FIVE: ANALYSES OF LOW-RISK SCENARIOS

This part of the thesis focuses on comparing driving behaviors between taxi drivers and non-professional drivers in the low-risk scenarios. As explained before, the low-risk scenarios consisted of three sub-scenarios: uphill and downhill analysis, right angle turn analysis, and S-type continuous curve analysis. The hypothesis testing in the following analyses were based on a 0.1 significance level according to the limitations of the sample size.

5.1 Uphill and Downhill Analysis

For the uphill period, five dependent variables were chosen as potential factors, which might be influenced by the subject occupation. The basic statistical descriptions of these five factors for taxi drivers and nonprofessional drivers are listed in Table 2.

Table 2: Descriptive statistics of five factors related to the uphill period

Occupation	Factor	Mean	Standard Deviation	Maximum	Minimum
Taxi drivers	USS	60.48	3.10	78.156	36.72
	UES	38.56	2.89	65.844	25.92
	USD	21.89	1.65	31.86	8.676
	UAS	43.56	3.51	71.964	25.848
	UAD	-0.59	0.22	-0.13	-1.04
Non-professional drivers	USS	66.71	2.70	86.148	46.512
	UES	46.26	2.35	66.996	31.032
	USD	20.45	1.53	30.636	6.84
	UAS	52.52	3.08	74.124	32.724
	UAD	-0.64	0.23	-0.16	-1.06

An analysis of variance (ANOVA) for each factor is conducted to analyze whether there is a difference between taxi drivers' behaviors and non-professional drivers' behaviors during the uphill period (see Table 3).

Table 3: Analysis of variance (ANOVA) for dependent variables related to the uphill period

Variables	Df	Mean Square	F-Value	Sig.
USS	1	34.331	4.131	0.048
UES	1	51.926	7.614	0.008
USD	1	1.814	0.721	0.400
UAS	1	40.624	3.776	0.058
UAD	1	0.026	0.519	0.475

The ANOVA results show the significant difference between taxi drivers and non-professional drivers on USS ($p=0.048<0.1$), UES ($p=0.008<0.1$), and UAS ($p=0.058<0.1$). The difference on USS, UES, and UAS are shown in Figures 10, 11, and 12. For taxi drivers, the uphill starting speed is only 60.48 km/h and the ending speed is only 38.56 as well. In comparison, both the uphill starting speed and the ending speed of non-professional drivers are much higher than that of taxi drivers. In addition, non-professional drivers also have a higher average speed during the uphill period. However, there is no obvious difference in USD and UAD between taxi drivers and non-professional drivers. The results indicate that taxi drivers had more driving experience and they perform better in controlling vehicles so that they have lower starting speed and average speed.

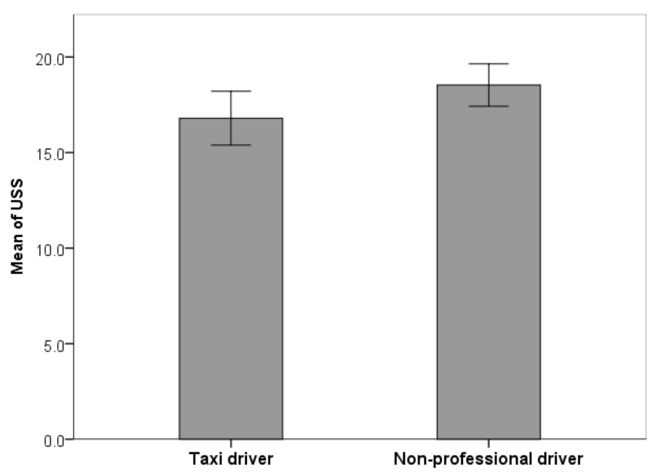

Figure 10: Mean of the uphill starting speed (USS)

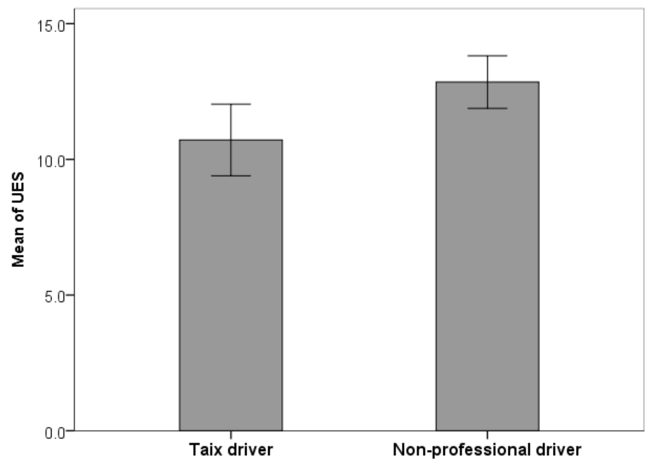

Figure 11: Mean of the uphill ending speed (UES)

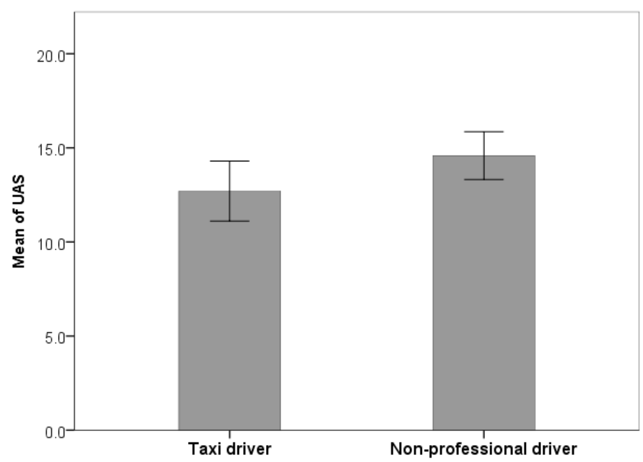

Figure 12: Mean of uphill average speed (UAS)

Similarly, five dependent variables for the downhill period are also chosen to analyze the difference between taxi drivers and non-professional drivers. The basic statistical descriptions for the downhill period are listed in Table 4. Table 5 lists the ANOVA variance analysis for each dependent variable, which shows that DSS, DES, and DAS are significant factors. Therefore, the downhill scenario has the same conclusion with the uphill scenario, which shows taxi driver have a better vehicle control than non-professional drivers.

Table 4: Descriptive statistics of five factors related to the downhill period

Occupation	Factor	Mean	Standard Deviation	Maximum	Minimum
Taxi drivers	DSS	41.61	2.65	65.00	22.58
	DES	63.92	2.34	76.43	42.22
	DSD	22.30	2.29	32.04	0.62
	DAS	50.94	2.00	64.69	34.98
	DAA	2.39	0.25	3.73	0.06
Non-professional drivers	DSS	52.03	2.11	70.86	39.53
	DES	71.44	2.90	87.44	48.85
	DSD	19.42	2.30	31.34	-3.24
	DAS	59.43	2.72	77.98	37.92
	DAA	2.53	0.33	4.39	-0.35

Table 5: Analysis of variance (ANOVA) for dependent variables related to the downhill period

Variables	Df	Mean Square	F-Value	Sig.
DSS	1	95.503	16.997	0.000
DES	1	49.885	7.055	0.011
DSD	1	7.342	1.398	0.243
DAS	1	63.528	10.838	0.002
DAA	1	0.017	0.203	0.655

5.2 Right Angle Turn Analysis

The basic statistical descriptions of the right angle turn for taxi drivers and nonprofessional drivers are listed in Table 6. Table 7 lists the ANOVA variance analysis for each dependent variable, which shows that there is no significant difference between taxi drivers and non-professional drivers during the right angle turn.

Table 6: Descriptive statistics of five factors related to the right angle turn period

Occupation	Factor	Mean	Standard Deviation	Maximum	Minimum
Taxi drivers	RASS	41.51	10.45	60.99	23.71
	RAES	10.47	1.66	13.97	6.33
	RASD	31.04	9.46	49.87	16.03
	RAAD	-0.12	0.23	0.23	-0.65
Non-professional drivers	RASS	45.27	14.01	75.34	21.57
	RAES	11.58	3.39	18.42	5.62
	RASD	33.69	11.76	57.59	10.56
	RAAD	-0.13	0.34	0.48	-0.81

Table 7: Analysis of variance (ANOVA) for dependent variables related to the right angle turn period

Variables	Df	Mean Square	F-Value	Sig.
RASS	1	161.578	1.031	0.316
RAES	1	14.263	1.895	0.176
RASD	1	79.830	0.688	0.411
RAAD	1	0.001	0.012	0.913

The out-of-lane rate is also an important indication of the ability of vehicle control. 13 taxi drivers out of 25 taxi drivers have an out-of-lane behavior during the right angle turn. However, 18 non-professional drivers out of 21 non-professional drivers drove out-of-lanes during the right angle turn. Therefore, the probability of driving out of lanes for taxi drivers is:

$p=\frac{13}{25} = 52\%$

and the probability of driving out of lanes for non-professional drivers is:

$p=\frac{18}{21} = 85.7\%$

Z-test is applied to analyze whether there is a significant difference between two ratios. Figure 13 is the output from MINITAB for z-test with 95% confidence interval. The resulting p-value is 0.007, which is less than $\alpha=0.05$. To conclude, there is significantly difference between taxi drivers and non-professional drivers, which shows the out-of-lane behavior ratio of taxi drivers is smaller than that of non-professional drivers.

```
Test and CI for Two Proportions

Sample    X   N  Sample p
1        13  25  0.520000
2        18  21  0.857143


Difference = p (1) - p (2)
Estimate for difference:  -0.337143
95% CI for difference:  (-0.583623, -0.0906630)
Test for difference = 0 (vs not = 0):  Z = -2.68  P-Value = 0.007
```

Figure 13: MINITAB output: z-test for out-of-lane ratios

5.3 S-type Continuous Curve Analysis

Five dependent variables during the S-type continuous curve are measured to analyze a significant difference between taxi drivers and non-professional drivers. The basic descriptive results are descriptive in the Table 8.

Table 8: Descriptive statistical results of SCSS, SCES, SCAS, and SCDE for taxi drivers and non-professional drivers

Occupation	Factor	Mean	Standard Deviation	Maximum	Minimum
Taxi drivers	SCSS	21.71	6.93	34.33	11.41
	SCES	5.02	1.00	6.75	3.04
	SCAS	5.33	.96	7.18	3.76
	SCDE	.67	.63	2.78	.15
Non-professional drivers	SCSS	29.02	10.65	60.24	12.21
	SCES	5.49	1.72	9.00	2.51
	SCAS	5.90	1.56	8.95	3.57
	SCDE	.82	.56	2.30	.18

An analysis of variance (ANOVA) is also conducted of SPSS software to determine the statistical significance of the four dependent variables. Table 9 lists the ANOVA results from SPSS, which indicates that SCSS was a significant factor but SCES, SCAS, and SCDE are not under the 95% confidence level. Therefore, taxi drivers have a smaller starting speed than non-professional drivers (see Figure 14), which means taxi drivers have a better feeling of the potential risk when they see a S-type curve in front. However, taxi drivers have the same ending speed, average speed, and average deviation with non-professional drivers, indicating that taxi drivers have the same performance on average speed and deviation with non-professional drivers in this condition.

Table 9: Analysis of variance (ANOVA) for dependent variables related to the S-type continuous curve period

Variables	Df	Mean Square	F-Value	Sig.
SCSS	1	609.43	7.277	0.010
SCES	1	2.566	1.230	0.273
SCAS	1	3.798	2.179	0.147
SCDE	1	0.040	1.611	0.211

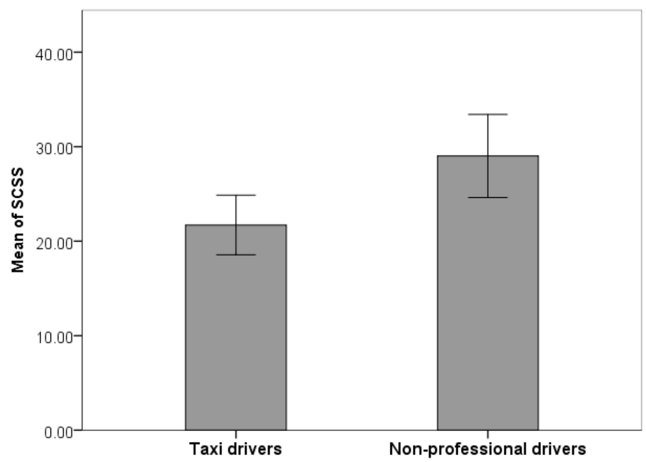

Figure 14: Mean of the S-type continuous curve starting speed (SCSS)

CHAPTER SIX: ANALYSES OF MEDIUM-RISK SCENARIOS

This part of the thesis focuses on comparing driving behaviors between taxi drivers and non-professional drivers in the medium-risk scenarios. As explained before, the medium-risk scenarios consist of three sub-scenarios: yellow indication judgment analysis, car following analysis, and lane-changing analysis. The hypothesis testing in the following analyses are based on a 0.1 significance level according to the limitations of the sample size.

6.1 Yellow Indication Judgment Analysis

In the Yellow Indication Judgment Scenario, two dependent variables are chosen as potential factors, which might be influenced by the subject occupation. One is the speed at the onset of yellow phase, which is a continuous variable and the other is the RLR, which is a categorical variable.

6.1.1 Speed at the Onset of Yellow Phase Analysis

The basic statistical descriptions of operating speed for taxi drivers and non-professional drivers at three test intersections are listed in Table 10. For all of taxi drivers, the mean speed at the onset of yellow phase at all the three intersections is 69.46 km/h with a standard deviation of 15.37 km/h. For all of non-professional drivers, the mean speed at the onset of yellow phase in all the three intersections is 74.14 km/h with a standard deviation of 15.06 km/h. A two-sample t-test was performed to compare the mean speed of the occupation at all three-test intersections. From the results, the resulting p-value is 0.065 (t = 1.86), which is smaller than 0.1. Therefore, there is a significant difference between taxi drivers and non-professional drivers in the operating speed. In addition, a two-sample t-test was examined in each intersection respectively. It is also found that the average operating speed for taxi drivers is significantly smaller than that of non-professional drivers in each intersection (see Figure 15), which concurs with the study by Yan et al. (2014).

Table 10: Descriptive statistical results of speed at the onset of yellow phase for taxi drivers and non-professional drivers

Occupation	TTI	Mean (km/h)	N	Standard Deviation	Maximum	Minimum
Taxi drivers	5s	70.36	23	14.67	115.38	40.02
	5.5s	72.05	23	16.96	107.73	40.25
	6s	65.97	23	14.37	97.22	43.94
	Total	69.46	69	15.37	115.38	40.02
Non-professional drivers	5s	74.46	26	11.86	109.59	57.73
	5.5s	78.25	26	18.77	150.87	42.38
	6s	69.71	26	12.95	111.89	50.59
	Total	74.14	78	15.06	150.87	42.38

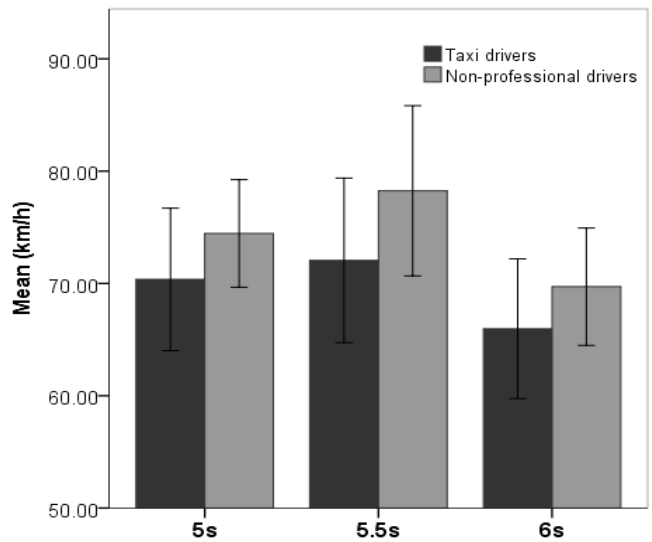

Figure 15: Mean of the speed at the onset of the yellow phase

6.1.2 RLR Analysis

Red light running (RLR) is defined as an event that the vehicle is beyond the stop line at the onset of red signal, which is one of the most important measures related to traffic safety. The basic description of RLR for taxi drivers and non-professional drivers are summarized in Table 11. For taxi drivers, 51 RLR violations were found at three intersections, which is 73.9% of all intersection crossing behaviors. In comparison, only 25.6% of all intersection crossing behaviors among non-professional drivers ran a red light. Using Chi-Square test to compare the RLR rate between taxi drivers and non-professional drivers, it is found that the resulting p-value is 0.000 ($\chi^2_{1,147} = 34.165$), indicating that the RLR rate of taxi drivers is statistically larger than of non-professional drivers. Similarly, for each intersection, there is also a significant difference between taxi drivers and non-professional drivers of RLR (for TTI = 5s: $\chi^2_{1,49} = 5.728$, p = 0.017; for TTI = 5.5s: $\chi^2_{1,49} = 14.750$, p = 0.000; for TTI = 6s: $\chi^2_{1,49} = 17.824$, p = 0.000).

Table 11: Descriptive statistical results of RLR for taxi drivers and non-professional Drivers

Occupation	TTI	RLR			
		Yes		No	
		Count	Row%	Count	Row%
Taxi drivers	5s	19	82.6%	4	17.4%
	5.5s	17	73.9%	6	26.1%
	6s	15	65.2%	8	34.8%
	Total	51	73.9%	18	26.1%
Non-professional drivers	5s	13	50%	13	50%
	5.5s	5	19.2%	21	80.8%
	6s	2	7.7%	24	92.3%
	Total	20	25.6%	58	74.4%

Additionally, for taxi drivers, the RLR rate at 5 seconds TTI is larger than that at 5.5 seconds TTI, which is also larger than that at 6 seconds TTI (82.6% Vs. 73.9% Vs. 65.2%). The downtrend also happens on non-professional drivers. Therefore, as the TTI increases, the RLR rate shows a downtrend on both taxi drivers and non-professional drivers. The reason is that as TTI increases, the distance between the stop line and the simulator vehicle at the onset of yellow phase increases so that drivers are more prone to stop before the stop line and have more time to decelerate. This finding is consistent with some studies (Koll et al., 2004; Long et al., 2011; Yan et al., 2014) .

6.2 Car Following Analysis

In the car following scenario, three different periods are discussed separately, including constant periods, acceleration periods, and deceleration periods. Each kind of period has its own characteristics.

6.2.1 Constant period

In the constant period, there are two important variables reflect driving behaviors. One is average speed during the constant period, the other one is average space headway during the constant period. Table 12 shows the description of the average speed and the average space headway during different constant periods.

Table 12: Descriptive statistical results of average speed and average headway for taxi drivers and non-professional drivers

Variable	Period	Occupation	Mean	Standard Deviation	Maximum	Minimum
Average speed	30 km/h	Taxi	34.94	8.69	61.53	27.93
		Non-pro	33.17	7.11	58.43	29.13
	40 km/h	Taxi	44.81	7.83	62.83	37.32
		Non-pro	42.61	6.14	66.18	38.46
	50 km/h	Taxi	55.55	9.39	80.84	43.20
		Non-pro	52.08	6.89	72.93	45.71
Average space headway	30 km/h	Taxi	26.50	15.92	86.45	10.18
		Non-pro	24.02	11.84	74.11	10.55
	40 km/h	Taxi	37.69	26.33	138.83	12.69
		Non-pro	30.41	16.87	102.68	10.80
	50 km/h	Taxi	47.13	29.22	117.23	13.75
		Non-pro	41.51	20.58	98.99	17.43

An analysis of variance (ANOVA) is applied to estimate whether there is a significant difference between taxi drivers and non-professional drivers. Table 13 lists the ANOVA results from SPSS, which indicates that average speed and average space headway for each period are not under the 95% confidence level. Therefore, taxi drivers and non-professional drivers have the same performance during the constant period.

Table 13: Analysis of variance (ANOVA) of average speed and average space headway during the constant period

Variables	Df	Mean Square	F-Value	Sig.
AS30	1	136.677	0.677	0.413
ASH30	1	5.385	1.087	0.300
AS40	1	8.325	2.122	0.149
ASH40	1	1178.263	2.301	0.133
AS50	1	10.279	1.897	0.176
ASH50	1	350.917	0.529	0.471

6.2.2 Deceleration period

In the deceleration period, there are also two important variables reflect driving behaviors. One is reaction time, the other one is average deceleration. Table 14 lists the details about the reaction time and average deceleration for each period.

Table 14: Descriptive statistical results of reaction time and average deceleration for taxi drivers and non-professional drivers

Variable	Period	Occupation	Mean	Standard Deviation	Maximum	Minimum
Reaction time	-4 m/s^2	Taxi	1.26	0.63	3.68	0.63
		Non-pro	1.15	0.40	2.00	0.72
	-2 m/s^2	Taxi	1.56	0.79	3.53	0.23
		Non-pro	1.70	1.04	5.07	0.67
Average deceleration	-4 m/s^2	Taxi	-2.07	1.52	-0.20	-5.24
		Non-pro	-1.38	1.16	-0.11	-4.57
	-2 m/s^2	Taxi	-2.1	0.96	-0.19	-3.29
		Non-pro	-1.56	0.90	-0.25	-4.14

From Table 15, the AAD7 for the deceleration period is 0.097, which means the average deceleration is significant different between taxi drivers (M=-2.1 m/s^2,S.D.=0.96) and non-professional drivers (M=-1.56 m/s^2,S.D.=0.90). However, there is no obvious difference in ADD3 (F=2.076, p=0.158). The results indicate that if the front vehicle in period 3 has -4 m/s^2 deceleration, the subject possibly see this event as an emergency brake. In this case, the taxi drivers and non-professional drivers may have the same response. However, if the deceleration is much smaller than the emergency brake, taxi drivers may be more sensitive to the speed reduction than non-professional drivers. Therefore, taxi drivers have a larger deceleration than non-professional drivers. For the reaction time, there is no significant difference between taxi drivers and non-professional drivers for reaction time.

Table 15: Analysis of variance (ANOVA) of reaction time and average deceleration during the deceleration period

Variables	Df	Mean Square	F-Value	Sig.
RT3	1	0.178	0.580	0.451
ADD3	1	3.667	2.076	0.158
RT7	1	0.292	0.331	0.568
ADD7	1	2.677	2.903	0.097

6.2.3 Acceleration period

In the acceleration period, there are also two related variables, which are similar to the deceleration period. One is reaction time, the other one is average acceleration. Table 16 shows the description of the reaction time and the average acceleration during each acceleration period.

Table 16: Descriptive statistical results of reaction time and average acceleration for taxi drivers and non-professional drivers

Variable	Period	Occupation	Mean	Standard Deviation	Maximum	Minimum
Reaction time	1 m/s^2	Taxi	9.15	1.76	12.07	4.60
		Non-pro	7.89	2.25	11.20	4.00
	1.5 m/s^2	Taxi	2.24	1.47	7.57	1.03
		Non-pro	2.12	1.31	6.65	0.73
	2 m/s^2	Taxi	1.86	1.11	5.03	0.02
		Non-pro	2.04	1.00	4.48	0.85
Average acceleration	1 m/s^2	Taxi	0.64	0.33	1.56	0.22
		Non-pro	0.58	0.20	1.10	0.20
	1.5 m/s^2	Taxi	0.74	0.35	1.47	0.29
		Non-pro	0.63	0.27	1.18	0.22
	2 m/s^2	Taxi	0.97	0.45	2.12	0.40
		Non-pro	0.92	0.33	1.31	0.38

Table 17 lists analysis of variance of reaction time and average acceleration during the acceleration period. According to the results, it is found that the reaction time of the 1 m/s^2 period is much higher than that of the other two periods. When the vehicle saw that there was a platoon of vehicles in front, they would brake and drove very slowly. However, the 1 m/s^2 acceleration of the front vehicle was also very small. Therefore, the reaction time is very high, which is much higher than the other two periods. Besides, the ANOVA results show the significant effects of RT1 (p=0.055<0.1) on acceleration period. Taxi drivers tend to have a slower response (M=9.15s, S.D.=1.76) compared to non-professional drivers (M=7.89s, S.D.=2.25) during the 1 m/s^2 acceleration period. However, there is no significant difference on reaction time between taxi drivers and non-professional drivers on the other two periods. The findings suggest that if the front vehicle has a smaller acceleration, the taxi drivers have a longer reaction time compared to non-professional drivers, which is due to that taxi drivers are more conservative than non-professional drivers when the gap between two vehicles is relatively small. But they have the same response time to the larger gap because of the larger acceleration of the front vehicle.

According to the ANOVA results, there is no significant effect on average acceleration during each period.

Table 17: Analysis of variance (ANOVA) of reaction time and average acceleration during the acceleration period

Variables	Df	Mean Square	F-Value	Sig.
RT1	1	15.959	3.919	0.055
AAD1	1	0.033	0.438	0.512
RT5	1	0.327	0.293	0.592
AAD5	1	0.028	0.178	0.675
RT9	1	0.148	0.076	0.784
AAD9	1	0.121	1.238	0.273

6.3 Lane-Changing Analysis

The measures of LCT, LCD, LCS, MLS, ALS, MLA, and ALA are used for exploring what are the different driving behaviors between taxi drivers and non-professional drivers. The basic statistical descriptions for measures are summarized in Table 18. In addition, ANOVA is also conducted to analyze whether there is a significant different between taxi drivers and non-professional drivers.

Table 18: Descriptive statistical results of lane-changing analysis for taxi drivers and non-professional drivers

Variable	Occupation	Mean	Standard Deviation	Maximum	Minimum
LCT	Taxi	16.55	6.49	32.10	5.10
	Non-pro	12.85	5.40	29.70	3.80
LCD	Taxi	193.22	110.29	468.15	18.30
	Non-pro	188.40	105.85	520.02	26.97
LCS	Taxi	11.48	5.24	23.90	2.23
	Non-pro	14.61	5.56	26.61	5.18
MLS	Taxi	0.063	0.119	0.528	0.002
	Non-pro	0.057	0.1101	0.604	0.0013
ALS	Taxi	0.0052	0.1513	0.0753	-0.0029
	Non-pro	0.0035	0.015	0.00926	-0.0116
MLA	Taxi	0.322	0.374	1.995	0.0634
	Non-pro	0.420	0.363	1.785	0.081
ALA	Taxi	0.018	0.447	0.215	-0.017
	Non-pro	0.023	0.058	0.374	-0.026

Table 19: Analysis of variance (ANOVA) of lane-changing analysis

Variables	Df	Mean Square	F-Value	Sig.
LCT	1	320.997	9.301	0.003
LCD	1	545.159	0.047	0.829
LCS	1	231.225	7.847	0.006
MLS	1	0.001	0.058	0.811
ALS	1	0.000	0.294	0.589
MLA	1	0.226	1.598	0.209
ALA	1	0.001	0.181	0.672

For the lane-changing period, LCT and LCS are the only two factors influenced by subject occupation. As shown in Figure 16 and 17, the lane-changing time of taxi drivers is obviously higher than that of non-professional drivers (M=16.55s, S.D.=6.49 Vs. M=12.85s, S.D.=5.40). However, the average lane-changing speed of taxi drivers is relatively smaller than that of non-professional drivers. The results indicate that taxi drivers may be more cautious about changing lane than non-professional drivers so that they have a lower average lane-changing speed, which leads to the longer time of taxi drivers during the lane-changing behaviors.

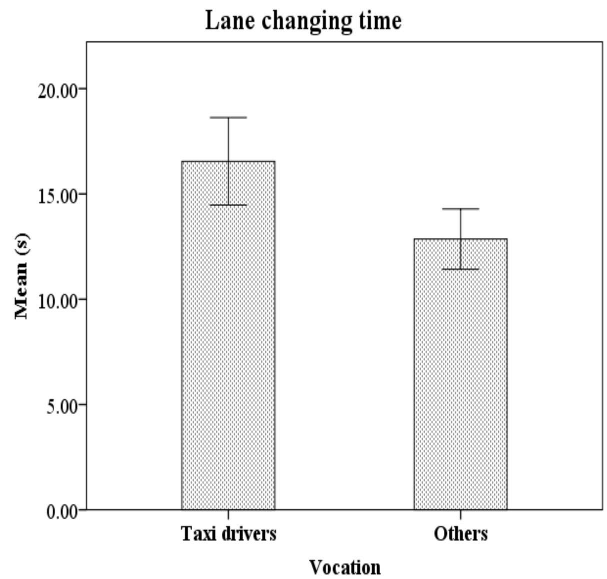

Figure 16: Mean of the lane changing time

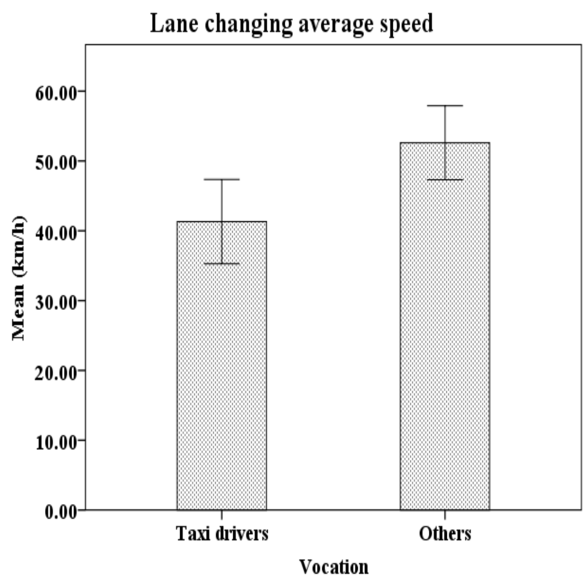

Figure 17: Mean of the lane changing average speed

CHAPTER SEVEN: ANALYSES OF HIGH-RISK SCENARIOS

This part of the thesis focuses on comparing driving behaviors between taxi drivers and non-professional drivers in the high-risk scenarios. As explained before, the collision avoidance scenario was designed as the high-risk scenario. The hypothesis testing in the following analyses are based on a 0.1 significance level according to the limitations of the sample size.

7.1 Operating Speed Analysis

The operating speed before the conflict for each second is shown in Table 20. The mean of the speed for taxi drivers and non-professional drivers appears to close to the speed limit, which seems realistic and reflects the same velocities in the real world. Figure 18 shows the trend of the speed for taxi drivers and non-professional driver. It is found that as the distance to the conflict point decreases, both taxi drivers and non-professional drivers start to slow down around 3 seconds before the conflict. The ANOVA was used to compare the mean of the speed for taxi drivers and non-professional drivers (see Table 21). The results show that there is no significant difference between taxi drivers and non-professional drivers on speed.

Table 20: Descriptive statistical results for deviation at each second before the conflict time

Variable	Occupation	Mean	Standard Deviation	Maximum	Minimum
5 second before conflict	Taxi	69.73	12.69	100.65	50.60
	Non-pro	71.85	10.8	90.15	44.18
4 second before conflict	Taxi	69.63	13.08	102.27	49.96
	Non-pro	71.88	11.10	90.99	43.61
3 second before conflict	Taxi	69.52	13.60	103.85	49.35
	Non-pro	71.60	11.23	90.23	43.04
2 second before conflict	Taxi	69.03	14.35	105.38	47.59
	Non-pro	70.36	11.49	88.46	40.91
1 second before conflict	Taxi	65.12	17.44	106.89	30.35
	Non-pro	64.25	15.63	87.52	16.09

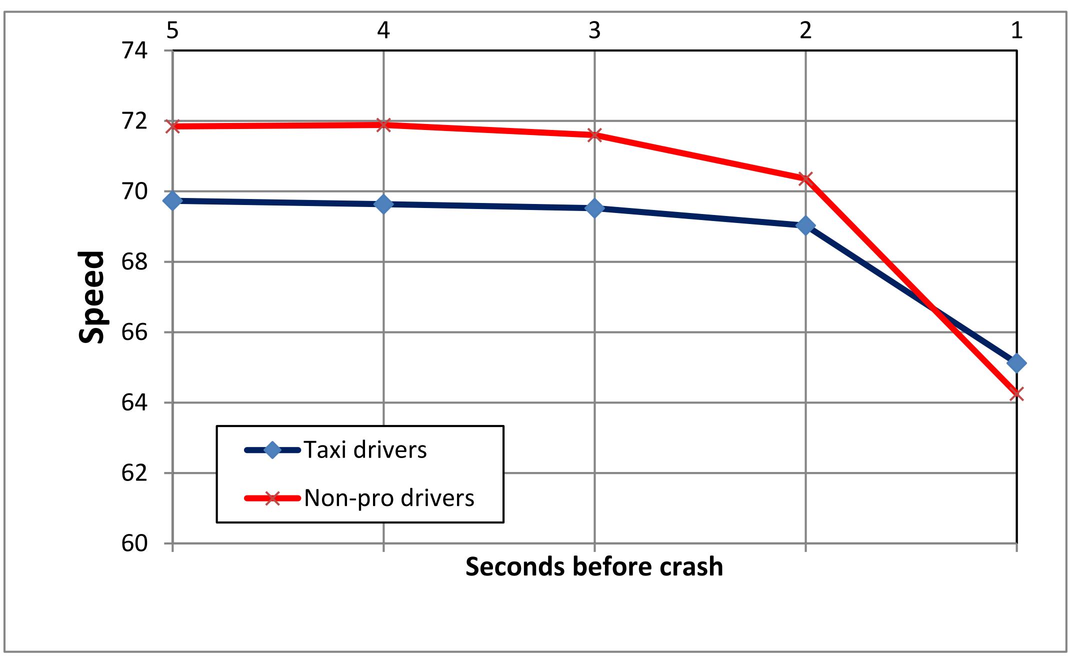

Figure 18: The trends of the speed for taxi drivers and non-professional drivers

Table 21: Analysis of variance (ANOVA) of operating speed analysis

Variables	Df	Mean Square	F-Value	Sig.
5 second before conflict	1	54.596	0.397	0.532
4 second before conflict	1	61.796	0.424	0.518
3 second before conflict	1	52.586	0.342	0.561
2 second before conflict	1	21.613	0.130	0.720
1 second before conflict	1	9.269	0.034	0.854

7.2 Lane Deviation Analysis

The basic statistical descriptions of each second deviation before the conflict time are listed in Table 22, and the trends of the deviation for taxi drivers and non-professional drivers are shown in Figure 17. The ANOVA was also used to compare the deviation for taxi drivers and non-professional drivers (see Table 23). The ANOVA result shows the significant difference between taxi drivers and non-professional drivers on the deviation of the last second, which is in accord with the Figure 19. It appears that taxi drivers have a larger deviation (M = -0.47m, S.D. = 0.23) than non-professional drivers (M = -0.32m, S.D. = 0.18) at 1 second before the collision. However, there is no obvious difference in the lane deviation at 2 seconds before the collision. The results indicate that when drivers find a potential crash risk on the right side, taxi drivers are more prone to steer to the different direction to avoid the crash.

Table 22: Descriptive statistical results for deviation at each second before the conflict time

Variable	Occupation	Mean	Standard Deviation	Maximum	Minimum
5 second before conflict	Taxi	-0.37	0.19	0.03	-0.76
	Non-pro	-0.34	0.16	0.05	-0.63
4 second before conflict	Taxi	-0.39	0.18	0.04	-0.75
	Non-pro	-0.33	0.15	0.03	-0.59
3 second before conflict	Taxi	-0.36	0.19	0.04	-0.73
	Non-pro	-0.33	0.16	0.01	-0.61
2 second before conflict	Taxi	-0.36	0.19	0.03	-0.72
	Non-pro	-0.32	0.17	0.02	-0.66
1 second before conflict	Taxi	-0.47	0.23	-0.01	-0.85
	Non-pro	-0.32	0.18	0.09	-0.73

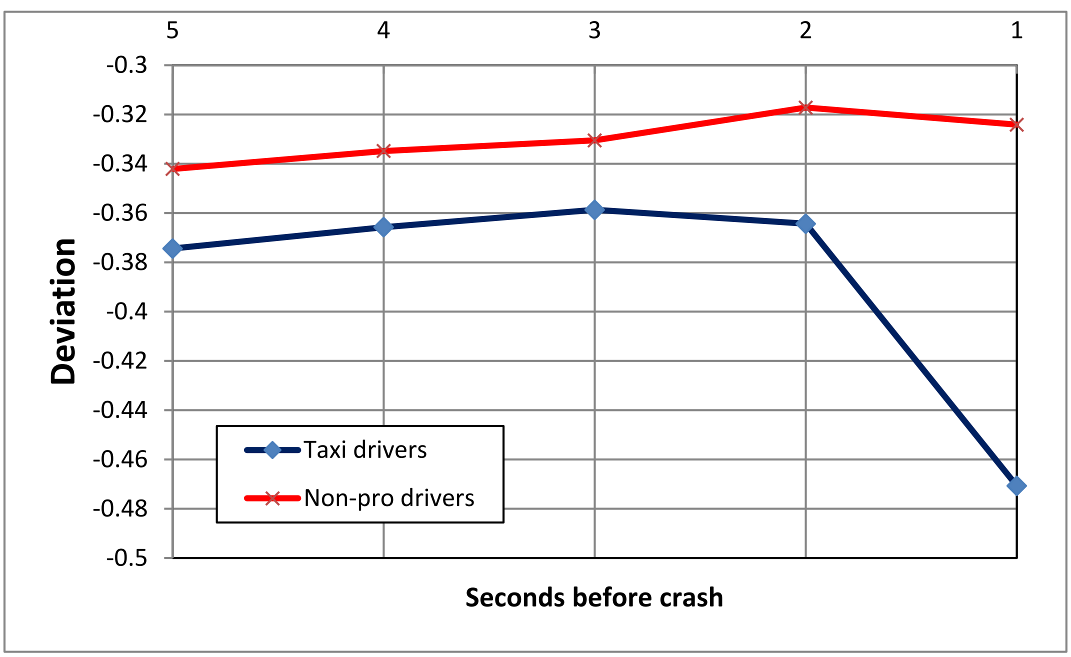

Figure 19: The trends of the deviation for taxi drivers and non-professional drivers

Table 23: Analysis of variance (ANOVA) of deviation analysis

Variables	Df	Mean Square	F-Value	Sig.
5 second before conflict	1	0.013	0.421	0.520
4 second before conflict	1	0.012	0.419	0.521
3 second before conflict	1	0.010	0.336	0.565
2 second before conflict	1	0.027	0.824	0.369
1 second before conflict	1	0.262	6.034	0.018

7.3 Deceleration Process Analysis

Four continuous variables are chosen as dependent variables, which might be influenced by the occupation during the deceleration process. The basic statistical descriptions of experiment results are shown in Table 24. In addition, ANOVA is applied to analyze whether there is a difference between taxi drivers' behaviors and non-professional drivers' behaviors during this period (see Table 25).

Table 24: Descriptive Statistical Results of four factors for taxi drivers and non-professional drivers

Variable		N	Mean	Std.D	Min	Max
BD	Taxi Drivers	23	10.85	19.78	.00	91.92
	Non-pro. Drivers	26	13.58	16.33	.00	59.14
BS	Taxi Drivers	23	42.74	36.39	.00	94.57
	Non-pro. Drivers	26	54.84	32.07	.00	90.04
BRT	Taxi Drivers	23	2.55	2.31	.00	5.80
	Non-pro. Drivers	26	3.23	1.94	.00	5.10
DEC	Taxi Drivers	23	1.39	1.48	.00	4.25
	Non-pro. Drivers	26	2.54	1.95	.00	5.91

Table 25: Analysis of variance (ANOVA) table for four factors

Variables	Df	Mean Square	F-Value	Sig.
BD	1	91.410	.281	.598
BS	1	1786.419	1.531	.222
BRT	1	5.692	1.264	.267
DEC	1	16.342	5.355	.025

The ANOVA result shows that only DEC is significantly influenced by the occupation ($F = 5.355$, $p = 0.025$). As shown in Figure 20, the DEC of non-professional drivers is obviously higher than that of taxi drivers during the deceleration process (M = 2.54 m/s^2, S.D. = 1.95 Vs. M = 1.39 m/s^2, S.D. = 1.48), indicating that non-professional drivers are more likely to have a hard brake than taxi drivers when they face the potential crash risk. However, there is no statistical difference in BD, BS, and BRT between taxi drivers and non-professional drivers. This finding illustrates that taxi drivers and non-professional drivers can identify the potential crash at the same time, and there is no difference on brake response time between taxi drivers and non-professional drivers either.

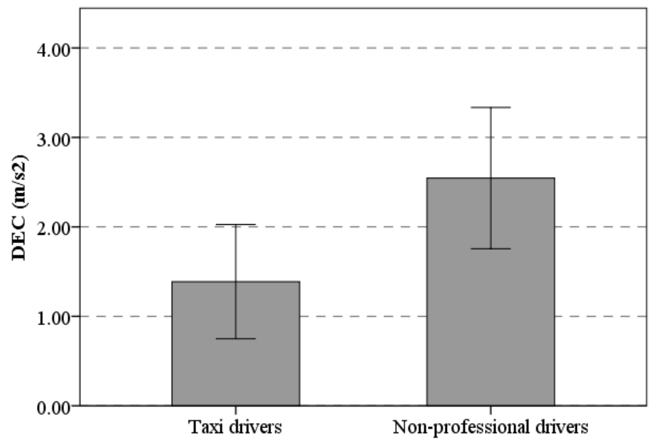

Figure 20: The influence of taxi drivers and non-professional drivers on DEC

7.4 Crash Probability Analysis Based on Logistic Regression

The logistic regression model is suitable for predicting the probability of occurrence of a crash because the occurrence of a crash can be described as a typical dichotomy dependent variable. Five independent variables, including occupation, BD, BS, BRT, and DEC, are potential factors related to the occurrence of a crash. In this study, stepwise selection methods are applied to identify significant variables in the logistic regression model. The regression results of the model are shown in Table 26.

Table 26: Logistic regression results between factors and the occurrence of a crash

Variable	Level	B	S.E.	Wald	df	Sig.	Exp(B)
Occupation	Non-pro. drivers Vs. taxi drivers	-1.996	1.048	3.628	1	.057	.136
BS	Continuous	.130	.057	5.228	1	.022	1.138
BD	Continuous	-.243	.099	5.961	1	.015	.785
DEC	Continuous	-1.519	.667	5.187	1	.023	.219
Constant		2.370	.985	5.793	1	.016	10.697
C-statistic value							0.888

The results show that four variables are significantly associated with the occurrence of a crash, including occupation, BS, BD, and DEC. Besides, the c-statistic value is 0.888, which is over 0.8, indicating that the model has a good prediction performance. The logistic regression model is shown in the equation blow:

$$p = \frac{e^{2.370-1.996\times Occupation+0.13\times BS-0.243\times BD-1.519\times DEC}}{1+e^{2.370-1.996\times Occupation+0.13\times BS-0.243\times BD-1.519\times DEC}}$$

Where p represents the probability of a crash between the driver and the system vehicle; $Occupation$ represents taxi drivers ($occupation = 0$) or non-professional drivers ($occupation = 1$).

Based on the model, the intercept of the occupation is -1.996, which indicates that non-professional drivers have a higher crash rate than taxi drivers. It means that taxi drivers have a better vehicle control than non-professional drivers when facing the potential crash risk. For the deceleration process, the results show that as the distance between the start brake location and the conflict point increases, the possibility of the collision occurrence decreases. This is due to the fact that the longer the advance distance to the potential crash location the higher the probability for the drivers to avoid this crash. Moreover, there is also a downtrend on the possibility of the collision occurrence as the operating speed decreases. In terms of the average deceleration, drivers are more likely to have a crash as the average deceleration decreases during the deceleration stage. Interestingly, it is found that taxi drivers have a lower crash rate but still have a lower average deceleration according to the analysis above. The possible explanation for this phenomenon is that the average deceleration is only one of several factors that may affect the possibility of a crash. Furthermore, taxi drivers have more experience than other drivers and decelerating effectively to avoid collisions. Overall, though, taxi drivers are more likely to avoid the crash.

CHAPTER EIGHT: CONCLUSIONS

Taxi is a very important part of urban transportation system in China, especially in some big cities. The objective of this study was to explore the differences between taxi drivers and non-professional drivers on driving behaviors. A hierarchical driving performance assessment method was adopted to evaluate taxi drivers' driving behaviors on different risk levels. Several scenarios were created in BJTU driving simulator on each level and a series of driving simulator experiments was designed to extract the data. Finally, the resulting data were thoroughly analyzed and conclusions were made.

8.1 Characteristics of Taxi Drivers on Low-Risk Level

Firstly, the analysis showed that there is a significant difference between taxi drivers and non-professional drivers on uphill starting speed and uphill ending speed. Taxi drivers have a smaller speed when they enter the uphill scenario and go out of the uphill scenario. Besides, taxi drivers also have a smaller average speed during the uphill period. However, there is no obvious difference on the uphill speed difference. Similarly, during the downhill period, taxi drivers still have a smaller starting speed, ending speed, and average speed.

Secondly, the results indicated that taxi drivers have a lower rate of out-of-lane behavior on the right angle turn. For the other behaviors on the right angle turn scenario, there is no difference between taxi drivers and non-professional drivers.

Thirdly, taxi drivers also have a smaller starting speed than non-professional drivers when they enter the S-type continuous curve. However, both taxi drivers and non-professional drivers have the same performance on average speed, average deviation, and ending speed.

8.2 Characteristics of Taxi Drivers on Medium-Risk Level

There are three sub-scenarios on medium-risk level, including yellow indication judgment scenario, car following scenario, and lane-changing scenario.

For the yellow indication judgment scenario, the results showed that the average operating speed at the onset of yellow phase of taxi drivers is significantly smaller than that of non-professional drivers. However, although taxi drivers have a smaller speed, they are more likely to run the red light according to the simulator experiment results.

For the car following scenario, it is found that taxi drivers and non-professional drivers have the same performance on average speed and average headway during the constant period. However, in the deceleration period, taxi drivers are more sensitive to the speed reduction. When the front vehicle has an emergency brake, taxi drivers will have a larger deceleration compared to non-professional drivers. In addition, there is no significant difference between taxi drivers and non-professional drivers on reaction time.

For lane-changing scenario, the only two variables that influenced by subject occupation are lane-changing time and lane-changing speed. The lane-changing time of taxi drivers is obviously higher than non-professional drivers and the average lane-changing speed of taxi drivers is relatively smaller than that of non-professional drivers.

8.3 Characteristics of Taxi Drivers on High-Risk Level

According to the results of the driving simulator experiment, there is no significant difference between taxi drivers and non-professional drivers on operating speed before the conflict. However, the results showed the significant difference between taxi drivers and non-professional drivers on the deviation of the last second. Obviously, taxi drivers have a larger deviation on the last second compared to the non-professional drivers.

For the deceleration process in the high-risk level scenario, it is found that average deceleration of non-professional drivers is obviously higher than that of taxi drivers. However, there is no statistical difference on brake distance, brake speed and brake reaction time.

Finally, logistic regression model is helpful to analyze the crash probability. Compared to non-professional drivers, taxi drivers have a smaller crash rate than non-professional drivers when facing the potential crash. Besides, the model also indicated that brake speed, brake distance, and average deceleration are the significant factors that influence the crash probability.

8.4 Summary

In summary, taxi drivers are slightly different from non-professional drivers in the three different risk levels. For the low-risk level, taxi drivers are more have a better feeling of the potential risk. For example, when drivers enter the uphill or S-type continuous, taxi drivers usually have a lower speed. Besides, taxi drivers also have a better vehicle control compared to non-professional drivers.

For the medium-risk level, this level mainly relates to moderate risk and dynamic decision. For the yellow judgment decision, although taxi drivers are slower than non-professional drivers when getting into the intersection, taxi drivers are more likely to run red light. Taxi drivers have a smaller following speed compare to non-professional drivers in the car following scenario. In general, taxi drivers often have more deceleration when the front vehicle has an emergency brake. For the lane changing behavior, taxi drivers' lane changing time is longer than others and lane changing average speed of taxi drivers is lower than other drivers. In conclusion, although taxi drivers have a good performance on most of the scenarios, they are more likely to red light running violation.

Taxi drivers are more inclined to turn the steering wheel when facing a potential crash compared to non-professional drivers. However, non-professional drivers have more abrupt deceleration behaviors if they have the same situation. In general, taxi drivers have a smaller crash rate compared to non-professional drivers according to the experiment results. Taxi drivers spend a large amount of time on the road so that their driving experience must exceed that of non-professional drivers, which may bring them more skills. It is also speculated that because taxi drivers spend long hours on the job they probably have developed a more relaxed attitude about congestion and they are less likely to be candidates for road rage and over aggressive driving habits.

APPENDIX A:
LOW-RISK SCENARIO DATA COLLECTION

Low-risk scenario Data Collection

ID	Occupation	Uphill Scenario					Downhill Scenario				
		USS	UES	USD	UAS	UAD	DSP	DES	DSD	DAS	DAA
1	0	21.52	18.29	3.23	20.00	-0.49	18.05	19.27	1.22	16.79	0.16
2	0	21.71	14.80	6.91	18.23	-0.97	13.44	17.20	3.76	14.24	0.41
3	0	17.22	9.77	7.45	11.54	-0.65	8.98	16.47	7.49	11.69	0.66
4	0	15.60	7.78	7.82	10.07	-0.60	10.89	15.51	4.62	14.19	0.50
5	0	16.62	10.11	6.51	12.24	-0.60	11.54	20.44	8.90	15.34	1.03
6	0	16.94	9.30	7.64	11.11	-0.65	9.67	18.04	8.37	13.37	0.85
7	0	14.40	8.02	6.38	8.58	-0.42	9.22	17.32	8.09	12.70	0.79
8	0	16.86	11.35	5.51	13.73	-0.58	13.82	20.47	6.65	16.92	0.86
9	0	16.47	10.76	5.71	12.73	-0.55	12.83	19.73	6.91	16.01	0.84
10	0	17.40	12.48	4.92	14.30	-0.54	11.83	18.82	6.99	14.81	0.79
11	0	15.09	8.41	6.69	9.57	-0.48	8.80	17.38	8.58	12.69	0.82
12	0	17.01	10.48	6.53	13.46	-0.67	11.20	16.34	5.15	12.60	0.49
13	0	14.63	10.02	4.60	9.75	-0.34	11.62	18.70	7.08	14.65	0.80
14	0	10.20	7.80	2.41	7.18	-0.13	6.27	13.21	6.94	9.72	0.51
15	0	11.47	8.11	3.35	9.52	-0.24	10.17	17.89	7.72	13.48	0.80
16	1	21.52	15.80	5.72	18.03	-0.80	17.26	22.56	5.30	19.96	0.80
17	1	17.34	13.39	3.95	15.19	-0.45	14.71	20.70	5.99	17.24	0.79
18	1	16.13	11.53	4.60	12.37	-0.43	14.65	20.33	5.68	17.18	0.75
19	1	16.10	8.62	7.48	9.09	-0.52	13.07	18.30	5.22	15.23	0.61
20	1	18.55	11.73	6.83	14.47	-0.75	11.73	13.57	1.84	11.03	0.15
21	1	12.92	11.02	1.90	9.99	-0.15	11.78	18.79	7.02	14.77	0.79
22	1	15.76	8.70	7.06	9.91	-0.54	11.32	15.50	4.18	10.53	0.33
23	1	19.65	14.33	5.32	15.56	-0.63	16.96	22.53	5.57	19.51	0.83
24	1	15.75	11.93	3.83	12.73	-0.37	15.39	21.65	6.25	18.41	0.88
25	1	21.30	16.15	5.16	18.97	-0.75	16.74	21.74	5.01	18.82	0.73
26	1	21.54	13.03	8.51	16.40	-1.06	14.64	23.34	8.71	17.82	1.18
27	1	18.22	12.54	5.69	14.72	-0.64	13.70	20.99	7.29	17.05	0.95
28	1	14.61	9.27	5.34	9.75	-0.40	10.98	15.94	4.96	13.79	0.52
29	1	23.93	18.61	5.32	20.60	-0.84	19.68	24.29	4.61	21.66	0.77
30	1	17.69	12.26	5.43	13.90	-0.58	14.64	23.18	8.54	18.90	1.22
31	1	15.83	12.02	3.81	11.83	-0.34	12.33	19.12	6.79	15.24	0.80
32	1	18.61	12.86	5.75	14.68	-0.65	13.87	20.82	6.95	16.74	0.89
33	1	22.53	15.22	7.31	18.39	-1.03	15.85	19.60	3.75	17.27	0.49
34	0	13.83	7.20	6.63	9.66	-0.49	8.73	16.06	7.33	12.02	0.67
35	0	20.91	12.70	8.21	16.60	-1.04	12.59	19.13	6.54	15.31	0.76
36	0	20.08	13.73	6.35	16.33	-0.78	15.54	21.23	5.69	17.97	0.78
37	1	19.00	14.64	4.36	16.55	-0.55	16.68	15.78	-0.90	14.20	-0.10

38	1	19.03	13.37	5.66	15.02	-0.64	15.97	23.10	7.13	19.26	1.05
39	0	15.78	9.83	5.95	11.94	-0.54	11.46	18.89	7.43	14.69	0.83
40	0	21.25	15.21	6.04	18.35	-0.85	14.52	19.01	4.48	15.60	0.53
41	0	17.72	8.88	8.85	11.89	-0.80	11.56	11.73	0.17	12.35	0.02
42	1	19.64	11.92	7.73	15.15	-0.90	12.69	17.37	4.68	13.87	0.49
43	1	18.21	11.77	6.44	14.17	-0.70	13.64	19.84	6.20	16.51	0.77
44	1	17.16	11.32	5.84	12.20	-0.54	13.01	20.34	7.34	16.44	0.93
45	1	20.35	15.42	4.93	17.97	-0.67	15.10	15.29	0.19	13.23	0.02
46	1	21.87	13.76	8.11	17.12	-1.05	14.90	21.45	6.55	18.06	0.91

APPENDIX B:
MEDIUM-RISK SCENARIO
YELLOW INDICATION JUDGMENT SCENARIO DATA COLLECTION

Medium-risk scenario: Yellow Indication Judgment Scenario Data Collection				
ID	**Occupation**	**Interval time**	**Operating speed**	**RLR**
1	0	5	62.315675	0
2	0	5	115.377745	1
3	0	5	72.363023	0
4	0	5	73.259102	1
5	0	5	73.489725	1
6	0	5	69.778056	1
7	0	5	64.453196	0
8	0	5	77.996386	1
9	0	5	78.344096	1
10	0	5	73.486073	1
11	0	5	77.657066	1
12	0	5	77.81207	1
13	0	5	55.786995	1
14	0	5	57.161525	1
15	0	5	65.578203	1
16	0	5	64.560004	1
17	0	5	40.018572	1
18	1	5	81.778203	1
19	1	5	76.730878	0
20	1	5	66.387792	0
21	1	5	70.034464	1
22	1	5	70.873922	1
23	1	5	57.728142	0
24	1	5	64.606737	1
25	1	5	83.143735	1
26	1	5	63.072029	0
27	1	5	62.647977	1
28	1	5	74.591091	1
29	1	5	58.448618	0
30	1	5	109.585128	0
31	1	5	77.032706	0
32	1	5	66.23695	0
33	1	5	72.709312	0
34	1	5	78.424015	0
35	1	5	81.114608	0
36	1	5	75.72946	1
37	0	5	52.723492	0
38	0	5	83.503249	1

39	0	5	86.325039	1
40	1	5	90.756354	1
41	1	5	88.162461	0
42	0	5	75.463646	1
43	0	5	63.496486	1
44	0	5	57.406143	1
45	1	5	66.230228	1
46	1	5	66.378825	0
47	1	5	62.250465	1
48	1	5	82.165567	1
49	1	5	89.098483	1
50	0	5.5	56.872547	0
51	0	5.5	94.754176	1
52	0	5.5	81.545766	0
53	0	5.5	66.647324	1
54	0	5.5	67.650499	1
55	0	5.5	68.766991	1
56	0	5.5	68.408768	0
57	0	5.5	46.520782	1
58	0	5.5	74.427237	1
59	0	5.5	76.877168	1
60	0	5.5	98.165403	1
61	0	5.5	76.255959	1
62	0	5.5	53.766166	0
63	0	5.5	57.386498	1
64	0	5.5	66.34417	1
65	0	5.5	76.068285	1
66	0	5.5	40.250864	1
67	1	5.5	74.705136	0
68	1	5.5	87.869469	0
69	1	5.5	69.688353	0
70	1	5.5	78.312586	0
71	1	5.5	84.849005	0
72	1	5.5	42.376444	0
73	1	5.5	74.416752	0
74	1	5.5	83.657085	0
75	1	5.5	68.943693	0
76	1	5.5	78.884445	1
77	1	5.5	72.606775	0
78	1	5.5	70.619746	0
79	1	5.5	150.865343	1
80	1	5.5	91.494292	0
81	1	5.5	68.728917	0

82	1	5.5	66.305202	0
83	1	5.5	75.930194	1
84	1	5.5	81.519324	1
85	1	5.5	80.367586	1
86	0	5.5	56.166243	0
87	0	5.5	94.774775	1
88	0	5.5	107.729043	1
89	1	5.5	92.297585	0
90	1	5.5	96.417849	0
91	0	5.5	75.711024	0
92	0	5.5	89.027147	1
93	0	5.5	62.939534	1
94	1	5.5	65.802104	0
95	1	5.5	57.616171	0
96	1	5.5	63.163992	0
97	1	5.5	82.842744	0
98	1	5.5	74.212324	0
99	0	6	52.637609	0
100	0	6	97.220229	1
101	0	6	72.622987	0
102	0	6	80.192422	1
103	0	6	61.307542	0
104	0	6	60.021091	1
105	0	6	59.168999	0
106	0	6	85.247946	1
107	0	6	67.93063	1
108	0	6	61.770177	1
109	0	6	49.273798	1
110	0	6	71.037241	1
111	0	6	44.060233	1
112	0	6	48.331213	1
113	0	6	64.790195	1
114	0	6	50.32678	1
115	0	6	43.935373	1
116	1	6	76.942831	1
117	1	6	67.818363	0
118	1	6	62.202427	0
119	1	6	68.973699	0
120	1	6	50.590705	0
121	1	6	53.701951	0
122	1	6	61.501891	1
123	1	6	84.414867	0
124	1	6	74.703165	0

125	1	6	54.752392	0
126	1	6	61.613278	0
127	1	6	57.003916	0
128	1	6	111.888906	0
129	1	6	58.134959	0
130	1	6	77.237292	0
131	1	6	65.070662	0
132	1	6	77.076803	0
133	1	6	71.408043	0
134	1	6	75.250724	0
135	0	6	61.068851	0
136	0	6	81.872102	0
137	0	6	77.50687	1
138	1	6	79.743432	0
139	1	6	86.142968	0
140	0	6	76.90554	0
141	0	6	67.039364	1
142	0	6	83.004895	0
143	1	6	67.021655	0
144	1	6	62.894394	0
145	1	6	57.597645	0
146	1	6	72.648983	0
147	1	6	76.158257	0

APPENDIX C:
MEDIUM-RISK SCENARIO
CAR FOLLOWING SCENARIO DATA COLLECTION

Medium-risk scenario: Car Following Scenario Data Collection Part I										
ID	Occupation	RT1	AAD1	AS40	AG40	RT3	ADD3	AS30	AG30	RT5
1	0	7.0164	1.0583	17.3214	72.9711	0.8166	-2.4904	12.3866	40.5516	0
2	0	0	0.136	10.9514	18.225	78.4969	-2.5543	0	0	1.1166
3	0	11.1829	0.7044	11.3249	13.7287	1.6833	-0.9791	8.1612	15.9107	0
4	0	8.7663	0.4257	11.4398	17.4684	1.2666	-0.195	8.1929	17.3137	2.5832
5	0	9.533	0.2382	10.9168	30.5274	1.2333	-1.8284	8.5036	18.2683	1.05
6	0	2.9499	1.2537	11.9022	43.671	0.6333	-5.0381	8.547	17.8691	1.4333
7	0	9.6496	0.5587	11.3107	27.0735	1.1333	-0.7221	8.3434	20.1034	2.4499
8	0	12.0662	0.2225	11.9931	25.5045	1.5666	-0.8826	7.7581	30.8895	1.4666
9	0	7.8164	0.4822	11.3209	39.2105	1	-2.0644	8.8273	24.442	2.3999
10	0	7.8997	0.8524	17.4536	38.6066	0.9	-4.0244	11.6087	17.6431	1.3166
11	0	8.3497	0.6831	11.7626	21.7652	0.8333	-0.8881	8.326	18.9758	1.4499
12	0	7.8997	1.2631	15.1924	113.6027	0.8833	-5.2385	13.7191	86.4478	1.1833
13	0	9.4496	0.6836	11.0478	33.8785	0.85	-1.6177	8.2304	25.7338	0.9666
14	1	9.8496	0.3738	0	0	0.8333	-1.8597	11.1481	23.1327	2.6332
15	1	6.0998	0.4897	11.1614	20.6175	1.9999	-1.0933	8.3536	16.3674	2.2999
16	1	8.3163	0.7542	11.3264	10.9947	0.8	-0.4043	8.4791	11.8309	0.9
17	1	10.5662	0.5214	11.235	36.8961	1.0666	-0.1083	8.2958	25.9533	2.0833
18	1	5.2165	0.6503	11.3485	57.9037	0.9166	-1.4187	8.682	22.0363	1.5333
19	1	5.8664	0.6332	11.8035	36.7651	0.8666	-1.1137	8.4418	13.5269	4.4832
20	1	4.6331	0.6494	10.8337	33.431	78.2302	-1.9631	0	0	1.3499
21	1	6.0498	0.3043	11.7075	36.5974	0	-0.9902	8.428	24.6029	1.3666
22	1	9.3996	0.7629	11.2426	21.4528	1	-1.4576	8.3837	20.3806	1.5166
23	1	6.2831	1.1016	11.4617	12.2435	0.8833	-4.5702	8.3625	11.3836	1.5999
24	1	10.1663	0.5818	11.0343	21.084	0.95	-1.9512	8.2245	20.0173	1.25
25	0	10.1663	0.9591	13.5898	49.5176	1.2666	-4.9343	11.9793	25.044	2.0833
26	1	5.6164	0.6944	11.5053	30.8902	0.8166	-3.5598	8.0928	19.9709	1.2333
27	0	10.3663	0.5348	17.0211	138.8259	2.1499	-1.2829	12.7295	53.7589	1.7666
28	1	9.6163	0.668	11.3422	17.4658	1.2	-0.565	8.3385	13.3951	3.7998
29	0	11.8329	0.2713	11.622	34.9779	1.1166	-2.182	8.3326	22.4762	3.4165
30	1	3.9998	0.6899	11.9357	40.0636	0.9	-2.1872	8.2035	30.5875	1.3166
31	0	10.8496	0.2875	10.7539	87.1484	95.1462	-0.4711	0	0	4.5665
32	1	6.4664	0.4317	11.2822	43.0134	1.5499	-0.534	8.6054	22.2324	1.9499
33	1	9.1496	0.4962	11.5182	20.2905	1.9333	-0.9422	8.5401	17.1577	1.6333
34	0	4.5998	1.5605	11.2588	15.0291	1.0833	-0.9054	8.2715	16.1067	2.6832
35	0	8.983	0.3512	15.0721	35.1933	3.6832	-0.7931	11.2397	16.5398	2.6999
36	1	9.433	0.5559	11.5963	28.7617	0.7166	-0.5894	8.426	30.857	3.1332
37	0	10.3329	0.737	11.7454	33.4741	1.7166	-0.6333	8.4148	13.2506	0.0167
38	0	8.283	0.5389	11.6605	14.9399	1.5833	-0.2639	8.274	11.7651	1.5999
39	0	10.9162	0.556	14.5962	72.578	1.2166	-2.5995	11.5454	25.6887	5.0331
40	0	7.933	0.5494	11.2296	18.1327	0.6333	-3.8564	8.2699	16.202	0.75

41	0	7.6664	0.6325	12.984	51.4129	0.9666	-2.0255	8.4188	36.6768	1.3833
42	1	10.3996	0.2656	11.465	42.7964	1.7833	-0.3905	8.3028	37.6249	1.8833
43	0	11.0662	0.5451	11.3973	12.6888	0.9666	-2.4384	8.2805	10.5302	1.2833
44	0	7.783	0.6252	11.242	43.2881	0.9666	-1.8253	8.2792	37.4622	1.1833
45	1	11.1996	0.1964	15.6648	102.6754	1.2999	-0.4939	12.9228	74.1104	1.7166
46	1	8.9996	0.3391	16.4076	39.7508	1.3999	-0.727	11.5765	26.1539	3.6165
47	1	6.5331	0.7284	11.4982	15.4091	0.9333	-2.3441	8.4368	11.8404	0.85

Medium-risk scenario: Car Following Scenario Data Collection Part II										
ID	**Occupation**	**AAD5**	**AS50**	**AG50**	**RT7**	**ADD7**	**AG30**	**AG30**	**RT9**	**AAD9**
1	0	1.2547	0	0	2.1666	-2.9967	15.4408	47.6283	3.1165	0.7098
2	0	0.4696	15.087	33.1524	1.25	-2.5543	8.3655	12.4684	0	0.2722
3	0	0.482	14.4107	18.7385	2.0333	-1.7544	8.2	13.4643	2.8832	0.8303
4	0	0.6944	14.0073	22.364	1.9166	-1.8766	8.2994	21.1875	1.8666	0.513
5	0	0.6668	13.5702	31.2563	2.0833	-2.7355	8.1221	25.1954	1.7333	0.458
6	0	1.3711	13.5035	42.3921	0	-2.7034	8.7947	25.1504	0	1.5213
7	0	0.7166	14.112	31.9872	2.4832	-1.5661	8.3231	18.9495	1.0333	0.2886
8	0	1.4141	14.9483	70.7681	1.0833	-1.0788	9.1332	20.2734	1.4166	1.1263
9	0	0.5706	11.9991	48.1229	1.3333	-0.873	8.5278	48.6756	7.5664	0.2914
10	0	1.5603	17.6384	64.1986	2.3499	-3.0373	0	0	3.3999	1.0285
11	0	0.8867	14.289	21.8264	1.4666	-3.1196	8.3891	18.8879	3.2999	0.7137
12	0	1.4095	16.1642	117.2347	0.8	-3.212	17.0903	67.6861	1.7333	1.3818
13	0	1.087	15.142	43.6284	0.6	-1.5054	8.5602	21.024	1.4499	1.1149
14	1	0.4173	0	0	0.8666	-2.0694	15.3766	36.8913	1.3999	0.4486
15	1	1.2996	13.8722	37.3364	1.1166	-1.0762	8.5127	16.9011	6.6497	0.4358
16	1	1.2601	13.7345	24.1222	0.8166	-1.2183	8.6508	20.0913	1.25	1.1785
17	1	1.0714	13.9933	43.3517	0.7166	-0.3587	8.6934	27.6436	2.3666	0.2197
18	1	1.1923	13.0846	61.2774	2.0666	-2.3106	8.6828	26.4873	3.0165	0.6516
19	1	0.4307	13.9095	26.8425	2.1166	-0.9122	8.3503	17.63	1.5666	0.5663
20	1	1.0116	13.9096	33.8516	0.9833	-1.9631	8.4263	21.1474	0.9333	0.7927
21	1	0.4469	13.8308	41.1028	1.5999	-1.304	8.6731	28.4587	0	0.3418
22	1	1.2873	13.8081	25.9181	0	-1.7373	8.4586	19.9188	2.3999	0.9541
23	1	1.3078	14.128	17.4277	1.3333	-4.141	8.4321	10.5543	2.1832	0.439
24	1	1.221	13.8849	24.6473	1.8833	-2.2723	8.4852	23.1209	1.7166	0.7769
25	0	2.1179	22.4563	40.9857	1.0166	-3.2863	13.8672	21.4467	1.1666	1.4675
26	1	1.2216	12.697	65.6698	0.6666	-2.1553	8.5802	20.6793	0.8166	0.971
27	0	1.2049	19.1271	112.0575	1.6833	-2.3079	13.5055	58.9779	1.2166	0.6327
28	1	1.0027	14.0466	20.5589	1.9166	-0.6948	8.4105	14.2252	2.4499	0.4597
29	0	0.3973	14.305	35.4839	2.9332	-0.4149	8.5088	20.7786	2.0666	0.7082
30	1	0.5457	13.2367	67.4869	1.6333	-2.1093	9.0853	55.6064	1.1833	0.9121
31	0	0.4076	14.0264	107.6432	17.8993	-0.4711	7.8828	47.1589	0	0.2767

32	1	0.3833	14.1715	39.5371	5.0665	-0.2483	8.4228	22.2228	2.8999	0.405
33	1	0.7011	14.3862	31.076	2.1499	-1.5136	8.2615	18.5332	2.8999	0.3266
34	0	1.1819	13.9342	23.0436	0	-2.1409	8.3357	15.6684	3.1499	0.7072
35	0	0.6493	20.3274	48.5307	1.8333	-3.2498	14.6405	22.3475	1.1833	0.5493
36	1	0.7119	15.0467	41.2084	2.1666	-0.3506	8.3084	23.8453	1.9166	0.7503
37	0	0.7548	14.3029	29.5955	3.5332	-0.1851	8.4793	13.8938	2.2666	0.5806
38	0	0.8975	14.0712	19.7205	0.2333	-1.6796	8.3836	13.7832	0	0.6711
39	0	1.2835	21.0646	55.181	1.05	-2.2002	14.5034	25.4668	3.3999	0.5709
40	0	0.5122	14.2808	22.1435	0.8833	-3.2492	8.339	13.9836	2.0333	0.7567
41	0	0.5269	14.135	63.0461	1.0166	-1.8199	8.7122	40.614	1.7666	0.4417
42	1	0.6561	14.0259	62.4983	3.3165	-1.8248	8.968	24.8145	3.1499	0.5094
43	0	1.2546	14.2969	13.7514	1.1166	-2.5398	8.3019	10.1846	1.4666	1.14
44	0	0.5362	14.5326	61.3643	1	-1.0123	8.2583	33.7319	1.6499	0.3744
45	1	0.7232	20.2591	98.9884	1.6499	-1.9185	16.2317	30.9647	1.8999	0.4574
46	1	1.2394	19.5001	45.2741	1.15	-1.6136	14.21	37.5376	1	1.02
47	1	0.6867	13.8237	22.001	0.7833	-1.2439	8.3527	14.4247	0.7333	0.3694

APPENDIX D:
MEDIUM-RISK SCENARIO
LANE-CHANGING SCENARIO DATA COLLECTION

Medium-risk scenario: Lane-changing Scenario Data Collection								
ID	Occupation	LCT	LCD	LCS	MLS	ALS	MLA	ALA
1	1	7.2997	14.6729	2.2780	0.3426	0.1802	1.4649	0.3905
2	0	5.3998	18.3045	3.4736	0.3107	0.0753	1.2906	0.2154
3	1	15.3994	19.3906	1.3162	0.2756	0.0624	0.6724	0.0893
4	0	3.1999	19.6836	6.3596	0.4607	0.2352	1.9440	1.1457
5	0	9.4996	21.0627	2.2311	0.1090	0.0154	0.1323	-0.0062
6	1	4.8998	26.9736	5.5172	0.1174	0.0156	0.4849	0.0575
7	1	6.5997	28.0576	4.3029	0.4663	0.0795	2.2291	0.3068
8	0	10.7996	28.5691	2.6624	0.2063	0.0463	0.5446	0.0513
9	1	3.8998	29.7175	7.6670	0.1326	0.0329	0.8897	0.2278
10	0	7.1997	31.0986	4.3376	0.0939	0.0112	0.2848	0.0158
11	0	5.0998	32.0878	6.3152	0.1248	0.0121	0.5594	0.0207
12	1	4.2998	35.0383	8.2707	0.3927	0.1094	2.8480	0.7962
13	1	6.7997	36.3935	5.4581	0.3559	0.0926	1.7249	0.3744
14	0	8.0997	38.0688	4.7363	0.1948	0.0305	0.9572	0.0830
15	1	3.7998	39.7851	10.4857	0.0452	0.0041	0.5257	0.0322
16	1	10.2996	39.9016	3.9438	0.3513	0.0558	2.5949	0.2028
17	0	13.6995	42.4695	3.1430	0.4262	0.0385	2.1222	0.1008
18	0	12.1995	43.8320	3.6345	0.3805	0.0520	1.2293	0.1348
19	1	9.2996	44.1780	4.8219	0.4673	0.0778	1.7073	0.2941
20	0	6.3997	46.2605	7.4063	0.4075	0.1395	1.1850	0.5081
21	0	20.9992	48.0940	2.2998	0.0621	0.0019	0.1023	-0.0015
22	0	8.7996	49.4482	5.6504	0.4452	0.0515	2.1441	0.2242
23	1	9.4996	53.0787	5.6175	0.1220	0.0100	0.4928	0.0465
24	0	9.2996	54.6227	5.8783	0.0255	0.0013	0.1217	0.0125
25	0	10.1996	58.2322	5.7419	0.2587	0.0374	1.4070	0.1557
26	0	12.3995	58.7592	4.7608	0.0320	0.0022	0.1159	0.0068
27	0	11.1996	60.1616	5.3791	0.0274	0.0008	0.0945	0.0094
28	1	15.3994	64.2344	4.1911	0.5032	0.0420	2.1050	0.1379
29	0	9.7996	65.0950	6.6822	0.0357	-0.0002	0.2108	0.0267
30	0	12.4995	66.2705	5.3479	0.3808	0.0434	1.3849	0.1110
31	0	12.9995	70.1877	5.4361	0.1059	0.0022	0.3992	0.0173
32	1	4.1998	70.7559	16.9282	0.0000	-0.0534	1.3006	0.1239
33	0	16.2993	71.9636	4.4358	0.0447	-0.0021	0.3529	0.0228
34	0	10.7996	74.6880	6.9404	0.6990	0.0459	2.8664	0.2533
35	1	11.6995	75.1311	6.4333	0.4504	0.0262	1.7028	0.1137
36	1	9.0996	75.3125	8.3155	0.3124	0.0432	1.1945	0.1525
37	0	7.1997	75.7312	10.5375	0.0120	-0.0029	0.1736	0.0174
38	1	15.4994	79.7525	5.1816	0.2259	0.0344	0.7405	0.0941

39	1	10.3996	80.0397	7.7075	0.0583	-0.0018	0.6616	0.0217
40	1	5.7998	81.2497	14.0240	0.0065	-0.0093	0.3294	0.0486
41	1	8.2997	83.8409	10.1130	0.0358	-0.0005	0.3769	0.0107
42	1	8.2997	83.8409	10.1130	0.0358	-0.0005	0.3769	0.0107
43	1	13.5995	88.1306	6.5201	0.2092	0.0352	0.7785	0.1320
44	1	7.4997	88.2930	11.8072	0.0073	-0.0104	0.5811	0.0462
45	1	5.8998	91.6797	15.5517	0.0123	-0.0043	0.5088	0.0186
46	0	14.5994	92.7617	6.3713	0.0865	0.0062	0.3924	0.0240
47	0	10.5996	95.8979	9.0698	0.0613	-0.0033	0.5228	0.0327
48	0	11.4995	96.7009	8.4532	0.5868	0.0610	2.4610	0.2969
49	0	15.5994	96.9079	6.2133	0.0331	0.0008	0.2521	0.0094
50	0	14.6994	98.1046	6.6688	0.0459	0.0032	0.2595	0.0224
51	1	13.7994	102.8127	7.4609	0.2436	0.0197	0.7911	0.0797
52	0	13.0995	103.9102	7.9457	0.0237	-0.0010	0.1587	0.0067
53	1	9.3996	106.1917	11.3205	0.0060	-0.0042	0.2769	0.0199
54	1	9.8996	106.2456	10.7359	0.0161	-0.0002	0.1951	0.0022
55	1	18.3993	106.5396	5.8092	0.6042	0.0340	1.7855	0.1248
56	0	5.8998	107.7061	18.2592	0.0160	-0.0001	0.2924	0.0018
57	0	18.1993	107.7453	5.9306	0.3290	0.0244	1.1437	0.0774
58	1	11.0996	109.7733	9.9249	0.0299	-0.0061	0.3327	0.0290
59	1	10.8996	112.0894	10.2819	0.0373	0.0034	0.3367	-0.0213
60	1	7.5997	116.5831	15.3499	0.0165	0.0022	0.5007	-0.0141
61	0	21.9991	118.5926	5.4103	0.0306	-0.0003	0.1703	0.0072
62	1	13.6995	119.2581	8.7082	0.0544	0.0003	0.5703	0.0162
63	0	12.4995	119.9663	9.6350	0.0128	-0.0014	0.1518	0.0067
64	1	6.8997	122.0000	17.7133	0.0031	-0.0116	0.4467	0.0296
65	1	9.7996	124.7731	12.7419	0.0112	-0.0017	0.3948	0.0090
66	1	7.2997	126.9045	17.3635	0.0094	-0.0043	0.5788	0.0371
67	1	11.7995	127.7807	10.8330	0.0414	0.0037	0.3018	-0.0262
68	1	8.1997	129.9783	15.8615	0.0037	-0.0007	0.3369	0.0042
69	1	9.0996	130.6417	14.3578	0.0349	0.0034	0.4440	-0.0224
70	1	10.5996	133.1350	12.5677	0.4250	0.0227	2.7926	0.2008
71	1	9.2996	135.9751	14.6223	0.0024	-0.0007	0.2011	0.0060
72	0	9.6996	137.1101	14.1223	0.0026	-0.0006	0.2349	0.0032
73	0	19.9992	137.7703	6.8976	0.0208	0.0020	0.1331	-0.0169
74	1	16.9993	139.7312	8.2161	0.0497	0.0018	0.0960	-0.0197
75	1	7.8997	141.2457	17.8846	0.0131	0.0017	0.1950	-0.0042
76	1	8.8996	145.8884	16.4489	0.0111	-0.0100	0.2838	0.0251
77	1	8.0997	147.5412	18.2043	0.0089	-0.0007	0.2547	0.0080
78	1	7.0997	148.4146	20.9039	0.0201	0.0015	0.2323	-0.0044
79	1	13.0995	152.3922	11.6472	0.0797	-0.0003	0.9143	0.0304
80	1	8.3997	154.1997	18.3736	0.0137	-0.0034	0.4331	0.0286
81	1	8.5997	158.3871	18.4173	0.0083	-0.0040	0.2261	0.0144

82	1	13.3995	159.2290	11.8918	0.0402	-0.0014	0.3772	0.0171
83	0	20.9992	161.5358	7.6982	0.0174	-0.0002	0.1231	0.0080
84	0	14.9994	162.9582	10.8651	0.0197	0.0005	0.2378	-0.0014
85	0	17.7993	163.5596	9.2139	0.4610	0.0377	1.6627	0.0978
86	0	17.4993	165.5750	9.4650	0.0156	-0.0010	0.2115	0.0116
87	1	8.9996	166.3031	18.4733	0.0345	-0.0003	0.4226	0.0089
88	1	8.8996	166.6145	18.7148	0.0149	-0.0008	0.3624	0.0085
89	0	20.6992	168.3228	8.1499	0.4286	0.0202	1.4053	0.0828
90	0	11.0996	170.3215	15.3447	0.0028	0.0004	0.1233	-0.0012
91	0	17.9993	174.7346	9.7372	0.3874	0.0372	1.1881	0.1240
92	0	12.3995	175.3445	14.1381	0.0029	-0.0004	0.1366	0.0032
93	0	17.7993	176.2097	9.9043	0.0055	-0.0010	0.1800	0.0086
94	0	17.2993	180.5241	10.4372	0.0161	0.0001	0.1879	0.0008
95	0	14.3994	184.8879	12.8440	0.0069	-0.0013	0.1967	0.0108
96	0	13.7994	185.8723	13.4657	0.0034	-0.0003	0.0779	0.0043
97	0	18.1993	187.0071	10.2767	0.0186	-0.0005	0.1209	0.0078
98	1	8.1997	188.9260	23.0447	0.0539	-0.0019	0.5268	0.0172
99	0	13.4995	190.7736	14.1332	0.0036	0.0000	0.1387	0.0000
100	1	9.8996	191.7573	19.3710	0.0080	-0.0002	0.1629	0.0023
101	0	14.2994	191.8772	13.4215	0.0135	-0.0019	0.2521	0.0132
102	0	25.3990	192.7092	7.6052	0.4211	0.0198	1.1801	0.0625
103	0	13.3995	197.5938	14.7422	0.0010	-0.0017	0.1209	0.0078
104	1	19.7992	197.7818	9.9862	0.0108	-0.0007	0.0814	0.0072
105	0	20.1992	199.3376	9.8968	0.4182	0.0323	1.1965	0.1064
106	1	11.3995	199.7261	17.5247	0.0064	0.0004	0.2674	-0.0018
107	0	22.9991	199.7947	8.6977	0.0114	-0.0018	0.2437	0.0127
108	1	12.7995	204.0548	15.9495	0.0031	-0.0008	0.3967	0.0051
109	0	14.6994	208.8148	14.2183	0.0406	0.0001	0.3655	0.0151
110	1	11.1996	209.7300	18.6828	0.0136	-0.0010	0.2371	0.0106
111	1	8.6997	210.4308	24.1885	0.0600	0.0006	0.4039	0.0014
112	1	13.4995	211.9512	15.7023	0.0285	-0.0009	0.4809	0.0478
113	0	18.8992	216.8164	11.4924	0.5284	0.0329	1.9949	0.1538
114	1	15.3994	224.2518	14.5552	0.0045	-0.0039	0.5943	0.0275
115	0	20.8992	225.1230	10.7664	0.0128	-0.0002	0.1531	0.0067
116	1	18.7992	225.4552	11.9918	0.0249	0.0017	0.1658	-0.0132
117	1	13.2995	225.8086	16.9496	0.0030	-0.0008	0.4469	0.0068
118	1	15.2994	226.3159	14.7913	0.0039	-0.0007	0.2194	0.0051
119	0	15.5994	229.7292	14.7258	0.0049	0.0007	0.1502	-0.0032
120	1	11.2995	232.9946	20.6442	0.0449	0.0010	0.5177	0.0007
121	1	8.7996	234.2586	26.6142	0.0510	0.0009	0.2434	-0.0021
122	0	18.4993	237.1129	12.8252	0.0060	-0.0007	0.1514	0.0045
123	0	11.4995	244.8380	21.2894	0.0068	0.0007	0.1843	-0.0018
124	0	24.0990	246.3505	10.2389	0.0487	0.0009	0.2124	0.0029

125	1	22.0991	246.6985	11.1555	0.0296	0.0001	0.4699	0.0087
126	1	13.1995	247.4512	18.7444	0.0054	0.0002	0.1361	-0.0003
127	1	13.1995	250.3893	18.9673	0.0175	-0.0003	0.2175	0.0011
128	1	12.7995	250.5069	19.5743	0.0255	-0.0007	0.7372	0.0045
129	0	19.3992	266.0965	13.7150	0.0106	-0.0003	0.3129	0.0020
130	0	11.5995	277.2935	23.8978	0.0270	0.0010	0.2387	-0.0025
131	0	21.2991	277.9177	13.0444	0.0068	0.0002	0.1503	-0.0010
132	1	14.8994	281.6790	18.9064	0.0078	-0.0006	0.1920	0.0018
133	1	15.0994	282.8876	18.7290	0.0048	-0.0004	0.2258	0.0025
134	1	12.0995	283.5247	23.4350	0.0225	-0.0009	0.2058	0.0020
135	0	13.2995	293.2316	22.0383	0.0250	-0.0002	0.3266	0.0047
136	0	14.4994	298.3409	20.5595	0.0117	-0.0001	0.1605	0.0008

APPENDIX E:
HIGH-RISK SCENARIO DATA COLLECTION

High-risk Scenario Data Collection															
ID	Occ-	S5	D5	S4	D4	S3	D3	S2	D2	S1	D1	BD	BS	BRT	DEC	Cra-
1	0	93.16	-0.42	93.59	-0.40	95.16	-0.32	95.00	-0.17	92.78	-0.01	13.19	94.57	4.40	1.85	1
2	0	64.03	-0.35	60.68	-0.36	57.23	-0.35	49.57	-0.34	34.77	-0.34	91.92	66.34	0.10	1.89	0
3	0	83.75	-0.32	82.88	-0.33	83.03	-0.31	82.70	-0.27	71.68	-0.56	25.58	82.70	4.00	3.34	0
4	0	74.05	-0.40	73.29	-0.39	72.54	-0.39	71.79	-0.39	71.46	-0.39	0.00	71.22	5.80	0.52	1
5	0	66.85	-0.56	67.29	-0.54	67.72	-0.55	68.14	-0.56	68.68	-0.65	0.00	0.00	0.00	0.00	1
6	0	60.00	0.03	59.85	0.04	59.26	0.04	59.17	0.02	60.13	-0.09	0.00	0.00	0.00	0.00	0
7	0	60.82	-0.43	60.05	-0.38	59.29	-0.42	58.56	-0.50	57.80	-0.72	0.00	0.00	0.00	0.00	1
8	0	67.95	-0.29	68.71	-0.35	69.47	-0.38	70.17	-0.40	70.85	-0.38	0.00	0.00	0.00	0.00	1
9	0	66.65	-0.10	66.75	-0.15	66.85	-0.24	66.94	-0.36	60.55	-0.51	10.84	66.58	4.40	3.28	1
10	0	65.79	-0.46	66.29	-0.44	66.70	-0.34	67.10	-0.23	67.44	-0.17	0.00	67.21	5.20	0.57	1
11	0	58.46	-0.57	57.86	-0.56	57.27	-0.56	56.03	-0.56	38.84	-0.64	21.81	56.70	3.80	3.67	0
12	0	60.14	-0.66	59.38	-0.66	58.63	-0.60	57.89	-0.48	54.24	-0.79	8.19	57.28	4.70	2.79	1
13	0	73.52	-0.57	74.08	-0.46	74.63	-0.39	75.16	-0.40	75.67	-0.51	0.00	0.00	0.00	0.00	1
14	0	69.26	-0.76	69.40	-0.75	69.73	-0.73	70.56	-0.72	69.66	-0.79	8.20	70.53	4.60	1.06	1
15	0	59.87	-0.22	59.12	-0.14	58.37	-0.06	57.67	-0.06	59.56	-0.58	0.00	0.00	0.00	0.00	1
16	0	67.40	-0.57	67.10	-0.51	66.41	-0.56	65.73	-0.71	64.24	-0.85	4.71	65.18	4.80	3.07	1
17	0	53.72	-0.18	55.17	-0.25	55.24	-0.28	54.55	-0.27	53.86	-0.25	0.00	0.00	0.00	0.00	0
18	1	64.80	-0.29	64.14	-0.32	63.49	-0.30	62.84	-0.28	46.57	-0.26	17.09	62.71	4.20	5.91	0
19	1	76.31	-0.13	76.38	-0.16	76.59	-0.16	76.80	-0.11	76.75	-0.10	0.00	76.29	5.10	3.28	1
20	1	65.79	-0.29	65.53	-0.25	65.13	-0.20	64.65	-0.16	59.02	-0.14	11.81	64.17	4.50	2.51	1
21	1	90.15	-0.41	91.00	-0.28	90.23	-0.25	85.54	-0.27	75.46	-0.34	43.91	90.04	3.20	2.37	1
22	1	90.15	-0.41	91.00	-0.28	90.23	-0.25	85.54	-0.27	75.46	-0.34	43.91	90.04	3.20	2.37	1
23	1	62.09	-0.34	61.46	-0.38	60.83	-0.40	60.21	-0.39	59.30	-0.40	5.42	59.60	4.90	3.69	1
24	1	66.20	-0.15	66.36	-0.15	66.52	-0.14	66.67	-0.12	57.73	-0.10	8.14	65.98	4.60	5.50	1
25	1	73.58	-0.23	73.89	-0.20	74.20	-0.19	74.51	-0.20	74.73	-0.24	0.00	0.00	0.00	0.00	1
26	1	64.21	0.05	63.55	0.03	62.90	0.01	62.26	0.00	60.97	-0.02	0.00	0.00	0.00	0.00	0
27	1	77.50	-0.29	77.17	-0.29	76.82	-0.30	77.18	-0.32	76.62	-0.35	4.41	76.87	4.90	0.64	1
28	1	76.46	-0.53	75.69	-0.49	74.89	-0.47	73.82	-0.45	53.20	-0.44	26.11	74.20	3.90	5.60	0
29	1	44.18	-0.54	43.61	-0.49	43.04	-0.45	42.48	-0.44	32.85	-0.49	12.25	42.25	4.20	3.28	0
30	1	86.71	-0.17	88.22	-0.20	89.40	-0.20	88.46	-0.17	87.52	-0.22	0.00	0.00	0.00	0.00	1
31	1	76.14	-0.37	76.98	-0.41	77.80	-0.42	78.60	-0.45	79.39	-0.51	0.00	0.00	0.00	0.00	1
32	1	52.70	-0.26	53.22	-0.28	55.79	-0.34	58.99	-0.35	62.01	-0.35	0.00	0.00	0.00	0.00	1
33	1	68.65	-0.37	69.42	-0.43	70.30	-0.49	71.22	-0.53	71.38	-0.55	0.00	71.81	4.90	2.99	1
34	1	60.30	-0.50	60.18	-0.42	61.41	-0.34	62.82	-0.27	53.67	-0.26	10.47	62.85	4.40	4.43	1
35	1	75.40	-0.48	75.54	-0.47	75.14	-0.46	74.37	-0.40	72.38	-0.30	9.99	73.90	4.60	2.04	1
36	1	79.49	-0.22	78.76	-0.21	77.95	-0.20	77.09	-0.19	74.73	-0.15	21.89	77.09	4.00	0.96	1
37	0	50.60	-0.34	49.96	-0.37	49.35	-0.41	47.56	-0.46	30.35	-0.60	19.18	48.73	3.80	4.25	0
38	0	92.43	-0.34	93.65	-0.27	93.06	-0.24	92.06	-0.23	90.60	-0.26	5.62	91.30	4.70	0.62	1

39	0	100.65	-0.39	102.27	-0.41	103.85	-0.43	105.39	-0.45	106.89	-0.50	0.00	0.00	0.00	0.00	0
40	1	78.99	-0.31	78.17	-0.38	77.36	-0.48	76.56	-0.51	74.11	-0.47	9.25	75.94	4.70	2.55	1
41	1	84.73	-0.36	85.46	-0.48	85.28	-0.51	77.91	-0.46	52.90	-0.48	34.02	84.69	3.50	5.75	0
42	0	79.51	-0.29	78.68	-0.32	77.87	-0.33	77.01	-0.37	66.41	-0.60	26.21	77.01	4.00	2.63	0
43	0	67.79	-0.11	67.59	-0.07	67.91	-0.04	67.97	-0.03	59.71	-0.15	14.03	67.64	4.30	2.36	1
44	0	67.44	-0.31	67.94	-0.33	69.44	-0.38	70.93	-0.44	71.61	-0.50	0.00	0.00	0.00	0.00	0
45	1	66.19	-0.58	65.14	-0.53	57.11	-0.46	40.91	-0.40	16.09	-0.39	59.14	65.64	1.80	4.22	0
46	1	71.66	-0.22	71.76	-0.13	71.09	-0.05	70.36	0.02	69.64	0.10	0.00	69.57	5.10	3.63	1
47	1	74.49	-0.63	73.73	-0.58	72.97	-0.56	71.84	-0.52	63.24	-0.51	27.12	72.36	3.80	2.04	0
48	1	65.42	-0.33	66.06	-0.34	67.63	-0.37	69.41	-0.37	65.64	-0.37	8.26	69.79	4.50	2.42	1
49	1	75.73	-0.55	76.58	-0.59	77.44	-0.61	78.28	-0.66	79.11	-0.73	0.00	0.00	0.00	0.00	1

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