EXPLORATORY STUDY OF DISTRACTED BEHAVIORS OF TRANSIT OPERATORS

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ABSTRACT

Bus transit driving is an occupation that requires high concentration in driving and is demanding due to work overload, time pressure, and responsibility for lives. In 2006, there were 103 fatal crashes involving transit buses. As the number of distraction-related crashes increases, it is important to conduct a transit distraction study to reduce future crashes.

This thesis focused on the analysis of the likelihood of the operator distraction behaviors and the analysis to find a predictive model to classify different distraction categories. An ordinal logistic regression was carried out to evaluate how age, gender, driving experience of the operators, and their driving frequencies accounts for the likelihood of 17 potential distracted driving behaviors. The results of this analysis showed that there were only 5 best models (p-value of model fit less than 0.005 and p-value of parallel line test more than 0.005) that could be constructed, including: *listening to the radio/ CD/DVD/MP3 player (D1)*; *picking Up and Holding 2-way Radio (D5)*; *listening to the Dispatch Office broadcast (D6)*; *adjusting switches/controls on dashboard (D15)*; and *utilizing mentor ranger (D16).*

On the other hand, a discriminant analysis was performed to predict how different transit operator driving behaviors when exposed by 10 different distraction activities and 16 predictors were considered in this analysis. The final results showed that there are 4 predictors that seem to be able to classify distraction groups across all 4 models; those include segment length, average duration of idling time/stop delay at speed interval 0 – 4 km/hr, frequency of speed transitions that deviate by ± 0 to 4 km/hr from its speed, and frequency of speed transitions that deviate by ± 8 to 12 km/hr from its speed.

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"For indeed, with hardship [will be] ease. Indeed, with hardship [will be] ease."
(Surat Ash-Sharĥ: 5 - 6)

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CHAPTER I INTRODUCTION

1.1. Motivation

Transit system has been improved significantly as an alternative for sustainable transportation in the last several years. Since 1995 until 2012, public transportation ridership increased by 34% based on the American Public Transportation Association (APTA) data. Most of the current improvements in transit system were applied to develop information technology and fuel efficiency. In fact, the human factor safety in transit system has not been fully investigated, and the author found that the literatures are limited. The most related-references to the human factor in transit are those that were conducted in studying driving behavior in commercial motor vehicle such as heavy trucks and motor coach buses.

Bus driving is an occupation that requires high concentration in driving, and is demanding due to work overload, time pressure, and responsibility for lives. In 2006, there were 299 buses involved in fatal crashes and 11,000 buses involved in injury crashes in the U.S. (NHTSA, 2007). Of the 299 fatal crashes reported, 103 involved transit buses. When the bus is involved in an accident, the size of transit buses and potential number of passengers in danger is worth attention. APTA reported that 40% of all preventable accidents [1] in 2012 involving Metro buses were the result of distracted driving. In 2013, a suburb New Jersey bus driver who was talking on a cell phone while driving, jumped the curb and stroke a light pole. This incident resulted in the death of an 8-month-old baby and the injury of 7 other people [24]. Between 2007 and 2009, in California and Massachusetts, there were two major distractions–related-crashes that resulted in the death of 25 people, injuries to hundreds, and extensive property damage [9].

To create a safer driving environment for transit and reduce future crashes, it is very important to focus and understand potential distracted driving behaviors in transit. In 2009, APTA developed a recommended practice of “Reducing Agency-Controlled Distractions While Operating a Vehicle on Agency Time” to improve transit safety and as shared responsibility between the transit agency and the operator [2]. With respect to driver and passenger safety, the study of relationship between on-board transit distractions and driving behavior needs to be conducted to have a better understanding of distraction in transit.

1.2. Problem Statement

A study by Eboli & Mazulla [7] showed that driving competence of bus operator ranked first as the most important transit service according to bus riders. Yet, there are some issues that have been raised related to transit performance versus the safety-convenience of passengers. As an operator, driving the bus could create time-pressure situation to keep on-time service. When in this situation, the operator tends to drive faster and more aggressively, which is potentially dangerous for both driver and passengers.

Furthermore, the bus operation task does not only include driving, but other secondary tasks as well. The secondary tasks are mainly to support on-board transit service such as technology-related services (e.g., ticket machine and radio handset operation), operational-related services (e.g., general broadcast, communication with TOC, opening and closing the bus doors, being aware to the stopping alert, keeping on-time performance), passenger-related services (e.g., monitoring passengers, assisting senior and disabled people), and driver personal entertainment.

In September 2010, texting while driving activity was banned by the Federal Motor Carrier Safety Administration (FMSCA) for commercial truck and bus drivers. In November 2011, all hand-held cell phone use by commercial drivers was banned as well. Virginia does have state law regarding the ban of all cellphone use (handheld and hands-free). However, the primary law only restricted for school bus drivers and the secondary law applied for novice drivers (drivers under the age of 18).

Above all, cell phone use can potentially result in crashes. Still, it is not the only distraction for transit operator, especially when this activity is banned by the Government. There are some other distractions that potentially have significant effects in driving behavior changes. These distractions can randomly occur and are bound to happen due to the uncontrolled situations. This paper presents the analysis of the likelihood of transit operator distracted driving and the analysis on the effects of potential distractions on bus operator driving performances in their natural driving environment.

1.3. Study Objectives

The objectives of this study are to analyze the likelihood of transit operators' distracted driving behaviors and to find a predictive model for classifying type of distractions. The method used in this study includes the survey and naturalistic-driving-data collections. An ordinal logistic regression and discriminant analysis were carried out to evaluate the results. **Figure 1** illustrates the step-by-step procedures conducted for this study.

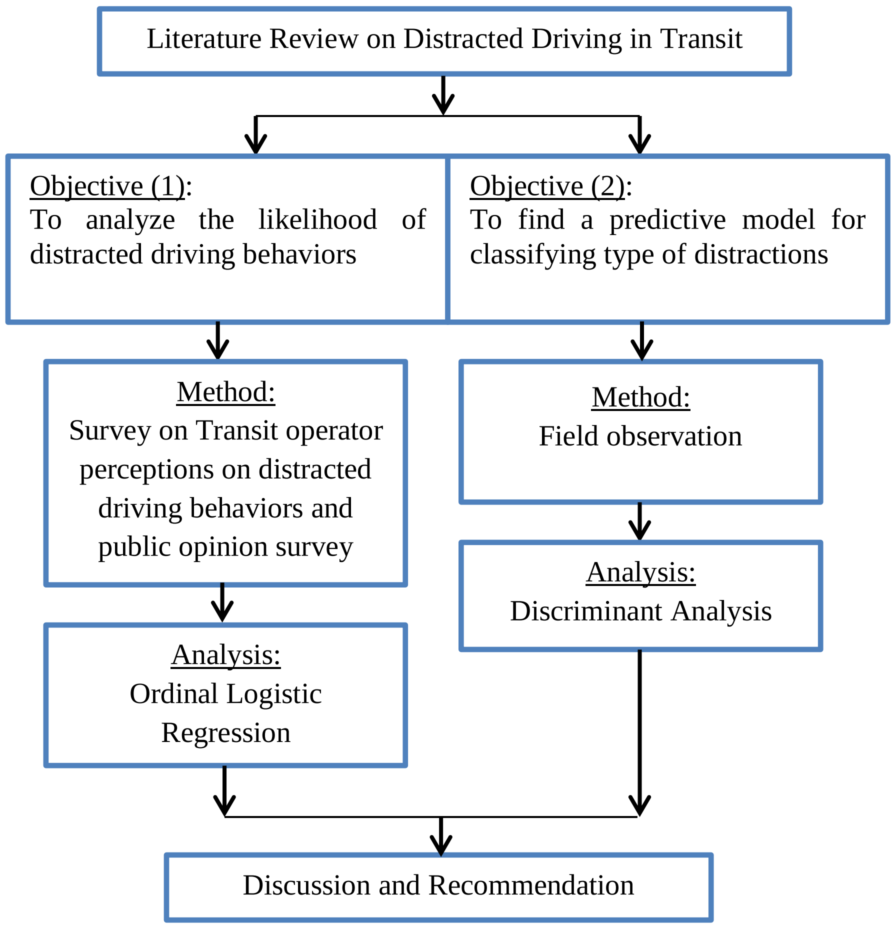


Figure 1 Study Flowchart

1.4. Report Organization

This report contains six chapters. CHAPTER I gives the introduction of the study, including motivation, problem statement, objective of the study, and the report organization. CHAPTER II presents the literature review of previous distracted driving study for transit. CHAPTER III and CHAPTER IV presents the results of survey on transit operator perceptions on distracted driving behaviors and public opinion survey. CHAPTER V describes the results of discriminant analysis of distracted driving behaviors using naturalistic driving data during BT's Full-Service. CHAPTER IV describes the results of discriminant analysis of distracted driving behaviors using naturalistic driving data during BT's Summer-Service. CHAPTER VII presents the conclusion and recommendations for future study.

CHAPTER II   LITERATURE REVIEW

The National Highway Traffic Safety Administration (NHTSA) defines distraction as a specific type of inattention that occurs when drivers divert their attention away from the driving task to focus on another activity instead (NHTSA, 2010). Generally, distractions can be categorized into three (3) types:

1. Visual distraction : Tasks that require the driver to look away from the roadway to visually obtain information;
2. Manual distraction : Tasks that require the driver to take a hand off the steering wheel and manipulate a device;
3. Cognitive distraction : Tasks that require the driver to avert their mental attention away from the driving task.

2.1. Driving Behavior Studies of Bus Transit Drivers

Pettitt et al. [29] indicated that a more comprehensive definition of distraction included the following four components: the difference between distraction and inattention; the recognition that distraction can be internal or external to the vehicle; that distraction can be categorized into four types (visual, cognitive, biomechanical, and auditory); and the effect of distraction on the driving task. Drivers are also more likely to collide with stationary vehicles when attention is disrupted by a secondary task [20]. Driver distraction and driving inattention may be involved in 78 percent of light-vehicle crashes [18].

Salmon, Yang, and Regab conducted a study [28] about distraction ‘on the buses’. The study found that there were 48 potential sources of driving distraction for transit driver. The sources of distraction are technology-related distractions, operation distractions, passenger-related distractions, environmental distractions, bus cabin-related distractions, infrastructure-related distractions, and personal distraction. Out of 48 distractions, this research assesses 17 operators’ driving tasks as following in **Table 1**:

Table 1 Potential Distraction

No.	Potential Activities	Category
1	Listening to the radio/ CD/DVD/MP3 player	Personal
2	Adjusting the radio station/CD/MP3 player	Personal
3	Text messaging	Technology
4	Conversing on a cell phone	Technology
5	Holding the two way radio	Operational
6	Listening to the Dispatch Office broadcast	Operational
7	Communicating with Dispatch Office	Operational
8	Being aware of passenger's stopping signal	Operational
9	Listening to the passenger conversation	Passenger
10	Talking to passenger	Passenger
11	Interacting with infants/kids (including looking at them)	Passenger
12	Actively scanning passenger approaching the bus stop	Operational
13	Manipulating sun visor	Bus cabin
14	Adjusting seat and/or seat belt	Bus cabin
15	Manipulating dashboard	Bus cabin
16	Utilizing mentor ranger	Operational
17	Disruptive passenger behavior	Passenger

Of the 48 sources of distraction, 6 sources come from outside the vehicle (see **Table 2**). In the study, they also identified distraction-related errors using SHERPA analysis. The results of this analysis showed that there 18 safety critical errors (6 driving-behavior-related errors) and 15 operational errors. Driving-behavior-related errors include failure to maintain appropriate position in lane, failure to change lanes or at the wrong time, failure to check current speed or speed limit, failure to brake in time, braking too sharply, and failure to monitor traffic and pedestrians around the bus.

Table 2 Salmon Distraction Study [28]

Category	Source of Distraction	Category	Source of Distraction
Technology	– Radio; – Radio handset; – Ticket machine; – Mobile phone; – Personal entertainment; – Passenger technology.	Bus cabin	– Rattles; – Faulty sun visor; – Adjusting seat; – Adjusting seat belt; – Adjusting steering column; – Operating climate controls.
Operational	– Issuing ticket; – General broadcasts; – Personal broadcasts; – Recording broadcast details; – Communication with Transit Operation Center; – Timetable; – Reading route journal; – Changing route section points; – Bus stopping alert; – Hand brake warning alert; – Raising/lowering the bus; – Opening and closing the bus doors.	Infrastructure Environmental	– Roadside advertising; – Lane width; – Road layout; – Road signage – Weather conditions
Passenger	– Passenger conversations; – Passenger enquiries; – Talking to passengers; – Unruly passengers; – Non-paying passengers; – School children; – Elderly and disabled passengers; – Passengers with infants; – Monitoring bus stops; – Assisting passengers.	Personal	– Fatigue; – Incapacitation; – Sickness; – Medication; – Inexperience; – Eating; – drinking

Technology-related distractions are also the most conducted studies. Morgan [23] focused the study on synthesizing the references related to cellular phone use in commercial truck and bus operations. In his report he stated that much of the literature covering commercial driving only examines the effects of distraction on the truck driver; little published literature is specifically related to the bus driver. Talking on the cell-phone may involve both cognitive and manual distractions. Even worse, texting activity may involve all 3 distractions – visual, cognitive, and manual. Supporting the idea of cell-phone use distraction, Fitch et al [8] investigated the effects of this distraction while driving. The cell-phone use activities include hand-held (HH), portable hands-free (PHF), and integrated hands-free (IHF). The results showed that an HH cell-phone was the most influence to the visual distraction. Moreover, driver using HH cell-phone produced wider range of speed and decreasing in deceleration performance.

In 2009, Olson et al conducted a similar study [27] using naturalistic driving data. Interestingly, it was indicated from the study that reaching for or dialing a cellphone was a high-risk task. Likewise, when drivers used cell phones their reactions were 18% slower, their following distance was 12% greater, and they took 17% longer to recover the speed that was lost following braking. The cellular-phone use disrupts [driving] performance by diverting attention to an engaging cognitive context other than the one immediately associated with driving [33].

After all things considered for further study, there are many interesting things that are missing from the literature. In transit, some activities are prohibited to do on bus (e.g., cell-phone use while driving, eating, drinking, etc. Interestingly, most of literatures focused on something which is currently under control by regulations. Most of the researches also discussed distraction rating based on driver perception. Only few related distractions to the change of driving behavior.

Driving behavior parameters that are commonly used within the literatures include driving speed, acceleration, headway, lane position, steering, and perception-reaction time. All studies associated each parameter to specific variable that may affect the change in driving behavior. In 2007, Wahlberg conducted a bus driving behavior study [35] with number of passenger as independent variable towards speed. The results showed that speed change behavior was not significantly affected by the number of passengers on-board, but traffic density does affect celebration behavior. Meanwhile, the result seems to be contradictory since according to D'Souza [6] the passenger activities ranked the first, second, third, and fourth as the most distracted sources for bus driver.

Dorn and Stannard [5] conducted a study related to driving behavior between experienced and novice bus drivers using simulator. Driving parameters measured in this study were speed, acceleration, lane position, steering, and braking. The results showed that experienced drivers demonstrated greater caution but more confident behavioral strategies at layby and parallel bus stops. Likewise, at the right hand junction, experienced drivers drove slower and further away from the curb and used the brake significantly more often than novice bus drivers did. McKnight [21] seems to support the idea of novice driver's driving behavior, which is the issue of failure in adjusting speed by young and inexperienced drivers led them frequently to the crashes (20.8 %).

A study by Divekar [4] highlights the fact that looking away from the forward roadway at the distraction task has a major impact on the drivers' ability to anticipate hazards at the same level as they would have otherwise in the absence of an external distractor and that peripheral vision is not enough to get critical driving related information from the forward roadway. The other study by Wang [37] tried to see the effects of bus types to speed and acceleration behavior. The buses compared in this study were hybrid buses and regular diesel buses. The results showed that the hybrid buses accelerated slower than regular buses.

Overall, it showed that most of driving behavior parameters has correlation to driver's hours worked and driving experience. Most of independent variables used in analyzing driving behavior are distractions. Yet, those are not explicitly stated. Driving behavior parameters were mostly related to incidents with little discussion on what triggers the change in behavior. Parameters used are independently analyzed, separating macroscopic & microscopic analysis in describing driving behavior. Authors concluded that transit operator driving behavior was analyzed separately with their on-board services which can trigger the deviated behavior in driving.

2.2. Driving Behavior Data Collection: Naturalistic Driving vs Simulator Data

Analysis of driving behavior using naturalistic driving data has been extensively conducted in recent studies. Within the literatures used in this proposed study, Olson et al conducted driver distraction analysis in commercial vehicle operation [27] using naturalistic data. Sayer et al [31] noted in their study that the driver behavior observed in a real-world environment was not necessarily consistent with what was observed in controlled data collection-environments such as test track or driving simulator. Naturalistic data is a key method for understanding driver behavior as controlled studies cannot account for the effects of driver choice and perceived risk.

Hanowski et al [11] conducted the first known distraction-related analysis using 41 naturalistic CMV data. The purpose of their study was to identify the sources of distraction for truck drivers. One-hundred-seventy-eight distractions were identified related to critical events. Data collected included driver's view and road view videos, speed, braking, and steering. Then, in 2012, Hanowski et al conducted similar study with naturalistic data collected from 183 commercial truck and bus fleets [12]. This time, they tried to analyze the influenced driving behavior of cell-phone use. There were 2 cameras set up on the fleet: driver face-view camera and forward road-facing view. The driver face-view camera recorded driver's lower waist and head that could identify specific tertiary tasks; while the forward road-facing view camera recorded outside events including the situation during which the truck was involved in hard braking, hard concerning, a hard swerve, collision, rough road, etc. Driving behavior data recorded from these event recorders including GPS data, speed, time, accelerometer data, driver ID number, and truck ID number, and event recorded logs.

Comparatively, simulator data method has been used for years because of the simplicity in term of data collection and the ease of adjusting driving environment in the experiment. The simulators are also used as mandatory training tool for bus drivers. FTA published guidelines for acquiring and using transit bus operator driving simulators in 2001[3]. In simulator, driving parameters that can be collected include speed, acceleration, deceleration, lane position, steering wheel angle, perception reaction time, headway, etc. The flexibility for adjusting weather condition to be applied in experiment was easy as well. Disregards of all advantages, Sahami et al [30] noted that learning how to control a simulated vehicle requires practice which will put some mental load on drivers and can distract them from their main task – driving.

CHAPTER III SURVEY: TRANSIT OPERATOR PERCEPTION ON DISTRACTED DRIVING BEHAVIORS

3.1. Survey Overview

The main purpose of the survey in this study is to analyze the perception of the operators on the likelihood of operators' distracted driving behaviors. The survey was conducted for two weeks from October 7th 2013 until October 21st 2013, in which included both online survey and survey questionnaires. All participants in the study were at least 19 years of age and had a valid Commercial Driver's License with experience in driving transit buses. The questionnaires were given to the local transit agency to be distributed to the bus operators who were working for the agency. The online survey was also provided for those operators who prefer to access the internet to complete the survey, while the others who prefer to complete the survey offline can fill up the paper version questionnaire. The survey contained 21 questions and took approximately 20 to 30 minutes to complete. There were 55 returned questionnaires; 22 from online survey and 35 form questionnaires. After validation process of those 55 questionnaires, 50 were used for the study.

3.2. Demographic Profile

Fifty operators from local transit agency participated in this survey, consisting of 88% males and 12% females. Most of the participants were in the age group of 19 – 24 years (young) and 55 – 64 years (old). Those who are in young group mostly had transit driving experience less than 6 months; while those in the other group mostly had driven transit up to 5 years (see **Figure 2**).

For further analysis, all participants were categorized based on their age group and level of driving experience as follows:

- Younger operator : Operator aged between 19 and 44 years;
- Older Operator : Operator aged more than 45 years;
- Novice operator : Operator who has driven transit for less than a year;
- Experienced operator: operator who has driven transit for less than 5 years but more than a year;
- Very experienced operator: operator who has driven transit for more than 5 years.

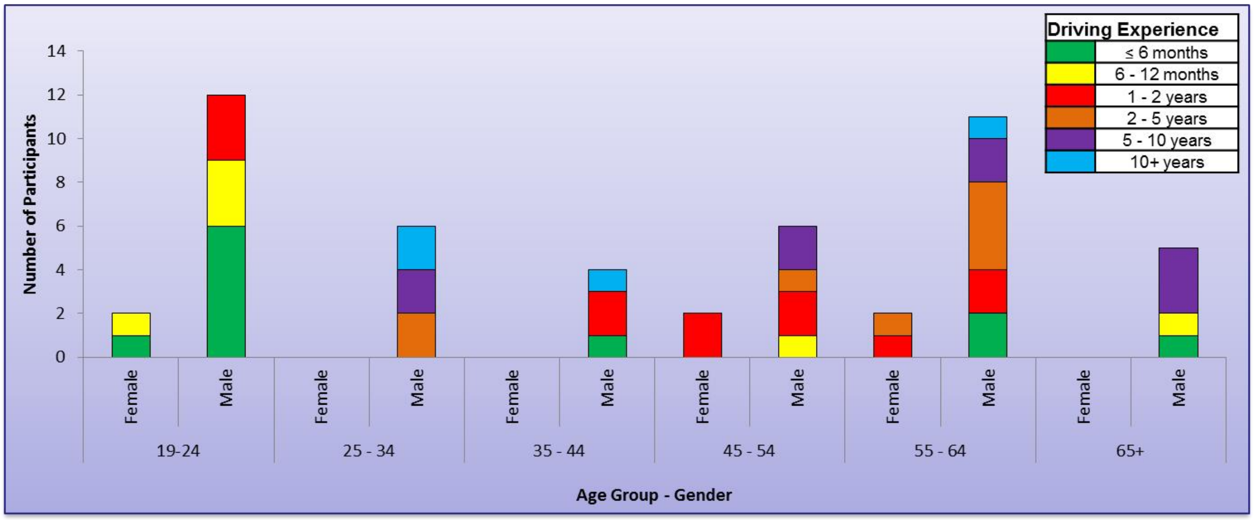


Figure 2 Demographic Profile of Participating Transit Operators

3.3. Result 1: Awareness of Distracted Driving Regulation

As stated in the homepage of Official US Government Website for distracted driving[1], The Federal Motor Carrier Safety Administration (FMCSA) banned commercial truck and bus drivers from texting while driving in September 2010, and later banned all hand-held cell phone use by commercial drivers in November 2011. By cross-referencing Virginia State Law on Distracted Driving policies, it was found that cell-phone use was banned primarily for school bus drivers. Text messaging while driving is banned for all drivers in 38 states including Virginia.

The survey result showed that 86% of all participants were aware of distracted driving regulation for commercial drivers. In addition, 94% participants supported any law enforcement toward distracted driving behaviors. Age and gender did not seem to have an impact on awareness of the regulations.

3.4. Result 2: Perception of Distracted Driving Behaviors

3.4.1. Perception of Distracted Driving Frequency

Participants were asked about their perception on how often transit operators engaged in each of a series of activities presented while driving. The options were *never, rarely, sometimes,* and *always*. The most common (*always*) distracted behaviors that operators involved in are *awareness of stop request* (41% responses) and *scanning the bus stop* (35%), followed by

[1] Official US Government Website for Distracted Driving. http://www.distraction.gov/content/dot-action/regulations.html (accessed November 23, 2014)

listening to Dispatch Office (DO) Broadcast (32%) and *communication with DO* (12%). On the other hand, the least commonly performed distracted behavior according to transit operators are *texting* (43% responses), *calling* (39%), and *adjusting the entertainment devices* (13%). **Table 3** below shows in detail the perception of distracted driving behaviors frequency.

Table 3 Perception of Distracted Driving Behaviors Frequency

Code	How frequently do you think bus operators do the activities below while driving?	Number of Responses (%)			
		Never	Rarely	Sometimes	Always
D1	Listen Entertainment Device	16.0	24.0	60.0	0.0
D2	Adjust the Entertainment Device	28.0	48.0	24.0	0.0
D3	Texting	86.0	10.0	4.0	0.0
D4	Calling	78.0	18.0	4.0	0.0
D5	Pick & hold 2-way radio	0.0	8.0	72.0	20.0
D6	Listen to DO broadcast	0.0	4.0	32.0	64.0
D7	Communicate with Dispatch Office	0.0	6.0	68.0	26.0
D8	Awareness of Stop Request	0.0	2.0	16.0	82.0
D9	Passengers Conversations	0.0	42.0	52.0	6.0
D10	Talk to passenger	0.0	32.0	58.0	10.0
D11	Interact with children passenger	16.0	52.0	26.0	4.0
D12	Scanning Bus Stop	0.0	2.0	28.0	70.0
D13	Adjust sun visor	2.0	46.0	52.0	0.0
D14	Adjust Seat/Seat belt	18.0	44.0	36.0	2.0
D15	Adjust dashboard control	0.0	28.0	66.0	6.0
D16	Use Mentor Ranger	14.0	24.0	42.0	20.0
D17	Disruptive Passengers	6.0	54.0	38.0	2.0

Further analysis of perceived distracted driving behavior frequency was continued based on gender (**Table 4**). Notice that the number of female participants was only 12% of the overall number of participants. Generally, the results showed that men were more likely to be engaged in distracted driving activities than women, including cell phone use ("never" *text messaging*: 84.1% men, and 100% women; "never" *making/accepting a call*: 75% men, and 100% women).

Table 4 Perception of Distracted Driving Behaviors Frequency by Gender

How frequently do you think bus operators do the activities below while driving?		Gender				How frequently do you think bus operators do the activities below while driving?		Gender			
		Male		Female				Male		Female	
		Count	Column %	Count	Column %			Count	Column %	Count	Column %
D1	Always	-	-	-	-	D10	Always	5	11.40%	-	-
	Sometimes	28	63.60%	2	33.30%		Sometimes	26	59.10%	3	50.00%
	Rarely	9	20.50%	3	50.00%		Rarely	13	29.50%	3	50.00%
	Never	7	15.90%	1	16.70%		Never	-	-	-	-
D2	Always	-	-	-	-	D11	Always	2	4.50%	-	-
	Sometimes	11	25.00%	1	16.70%		Sometimes	12	27.30%	1	16.70%
	Rarely	21	47.70%	3	50.00%		Rarely	23	52.30%	3	50.00%
	Never	12	27.30%	2	33.30%		Never	7	15.90%	2	33.30%
D3	Always	-	-	-	-	D12	Always	31	70.50%	4	66.70%
	Sometimes	2	4.50%	-	-		Sometimes	12	27.30%	2	33.30%
	Rarely	5	11.40%	-	-		Rarely	1	2.30%	-	-
	Never	37	84.10%	6	100.00%		Never	-	-	-	-
D4	Always	-	-	-	-	D13	Always	-	-	-	-
	Sometimes	2	4.50%	-	-		Sometimes	25	56.80%	1	16.70%
	Rarely	9	20.50%	-	-		Rarely	18	40.90%	5	83.30%
	Never	33	75.00%	6	100.00%		Never	1	2.30%	-	-
D5	Always	10	22.70%	-	-	D14	Always	1	2.30%	-	-
	Sometimes	30	68.20%	6	100.00%		Sometimes	17	38.60%	1	16.70%
	Rarely	4	9.10%	-	-		Rarely	19	43.20%	3	50.00%
	Never	-	-	-	-		Never	7	15.90%	2	33.30%
D6	Always	30	68.20%	2	33.30%	D15	Always	4	9.10%	-	-
	Sometimes	13	29.50%	3	50.00%		Sometimes	29	65.90%	3	50.00%
	Rarely	1	2.30%	1	16.70%		Rarely	11	25.00%	3	50.00%
	Never	-	-	-	-		Never	-	-	-	-
D7	Always	13	29.50%	-	-	D16	Always	11	25.00%	-	-
	Sometimes	28	63.60%	6	100.00%		Sometimes	19	43.20%	1	16.70%
	Rarely	3	6.80%	-	-		Rarely	10	22.70%	2	33.30%
	Never	-	-	-	-		Never	4	9.10%	3	50.00%
D8	Always	37	84.10%	4	66.70%	D17	Always	1	2.30%	-	-
	Sometimes	7	15.90%	1	16.70%		Sometimes	18	40.90%	1	16.70%
	Rarely	-	-	1	16.70%		Rarely	22	50.00%	5	83.30%
	Never	-	-	-	-		Never	3	6.80%	-	-
D9	Always	3	6.80%	-	-						
	Sometimes	22	50.00%	4	66.70%						
	Rarely	19	43.20%	2	33.30%						
	Never	-	-	-	-						

When analyzing "sometimes and rarely" responses, it seems that there are some variations of the responses for particular behaviors. This means that for some activities, participants' responses were significant toward specific answers (for example: 86% participants agreed not to text while driving). Thus, demographic profiles like age group and driving experiences of participants were used as categorical variables. Despite the differences in transit driving experiences, it was found that all participants are more likely to *listen to the entertainment devices (ED)* than *adjust the ED*: "sometimes" *listening to ED* (56.3% novice, 60% experienced, 64.3% very experienced operators), compared to "sometimes" *adjusting ED* (18.8% novice, 20% experienced, 35.7% very experienced operators). However, when investigated according to the age group, operators aged under 25 years are more likely to *listen to ED* ("sometimes" 78.6%) than the other operator groups respectively ("sometimes" 69.2%, 43.5%). Maintaining the *communication with Dispatch Office* seems to be favored more by novice and very experienced operators (respectively, "always" 68.8%, and 71.4%); as well by operators under 25 years and between 25 – 45 years (respectively, "always" 42.9%, and 38.5%).

In addition, about 50% of participants, regardless of age and driving experience, were more likely to be engaged in the *conversation with the passengers*. Between 60% – 70% of experienced-very experienced and operators aged over 25 years are more likely "sometimes" *talk to passengers*. Experienced and operators aged between 25 – 45 years were more likely to *interact with children passengers* than the other operator groups. **Table 5** presents the perception of distracted driving behaviors frequency based on operators' age groups and driving experience groups.

Table 5 Perception of Distracted Driving Behaviors Frequency by Age Group and Driving Experience Group

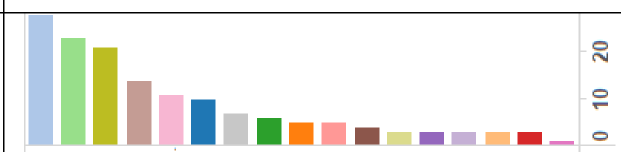
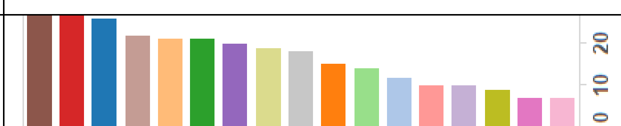
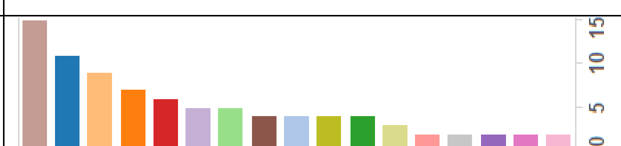
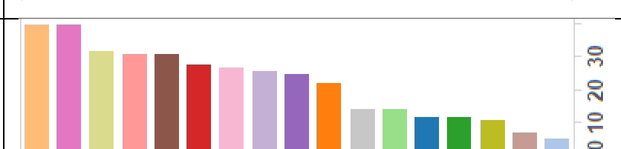
How frequently do you think bus operators do the activities below while driving?		**Experience Group**						**Age Group**					
		Novice operator		**Experienced operator**		**Very experienced operator**		**Under 25 years**		**Between 25 - 50 years**		**Over 50 years**	
		Count	**Column %**	**Count**	**Column %**	**Count**	**Column %**	**Count**	**Column %**	**Count**	**Column %**	**Count**	**Column %**
B1	Always	-	-	-	-	-	-	-	-	-	-	-	-
	Sometimes	9	56.3%	12	60.0%	9	64.3%	11	78.6%	9	69.2%	10	43.5%
	Rarely	2	12.5%	7	35.0%	3	21.4%	3	21.4%	1	7.7%	8	34.8%
	Never	5	31.3%	1	5.0%	2	14.3%	-	-	3	23.1%	5	21.7%

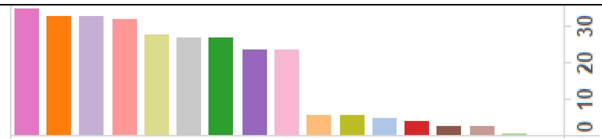
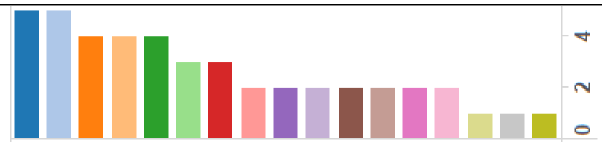
How frequently do you think bus operators do the activities below while driving?		Experience Group						Age Group					
		Novice operator		Experienced operator		Very experienced operator		Under 25 years		Between 25 - 50 years		Over 50 years	
		Count	Column %	Count	Column %	Count	Column %	Count	Column %	Count	Column %	Count	Column %
B2	Always	-	-	-	-	-	-	-	-	-	-	-	-
	Sometimes	3	18.8%	4	20.0%	5	35.7%	3	21.4%	4	30.8%	5	21.7%
	Rarely	7	43.8%	12	60.0%	5	35.7%	9	64.3%	6	46.2%	9	39.1%
	Never	6	37.5%	4	20.0%	4	28.6%	2	14.3%	3	23.1%	9	39.1%
B5	Always	5	31.3%	4	20.0%	1	7.1%	6	42.9%	3	23.1%	1	4.3%
	Sometimes	7	43.8%	16	80.0%	13	92.9%	8	57.1%	8	61.5%	20	87.0%
	Rarely	4	25.0%	-	-	-	-	-	-	2	15.4%	2	8.7%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B6	Always	11	68.8%	11	55.0%	10	71.4%	11	78.6%	7	53.8%	14	60.9%
	Sometimes	4	25.0%	8	40.0%	4	28.6%	3	21.4%	5	38.5%	8	34.8%
	Rarely	1	6.3%	1	5.0%	-	-	-	-	1	7.7%	1	4.3%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B7	Always	4	25.0%	5	25.0%	4	28.6%	6	42.9%	5	38.5%	2	8.7%
	Sometimes	12	75.0%	13	65.0%	9	64.3%	7	50.0%	7	53.8%	20	87.0%
	Rarely	-	-	2	10.0%	1	7.1%	1	7.1%	1	7.7%	1	4.3%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B9	Always	1	6.3%	2	10.0%	-	-	1	7.1%	1	7.7%	1	4.3%
	Sometimes	6	37.5%	12	60.0%	8	57.1%	8	57.1%	8	61.5%	10	43.5%
	Rarely	9	56.3%	6	30.0%	6	42.9%	5	35.7%	4	30.8%	12	52.2%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B10	Always	1	6.3%	1	5.0%	3	21.4%	1	7.1%	2	15.4%	2	8.7%
	Sometimes	7	43.8%	13	65.0%	9	64.3%	6	42.9%	9	69.2%	14	60.9%
	Rarely	8	50.0%	6	30.0%	2	14.3%	7	50.0%	2	15.4%	7	30.4%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B11	Always	-	-	1	5.0%	1	7.1%	-	-	-	-	2	8.7%
	Sometimes	2	12.5%	5	25.0%	6	42.9%	2	14.3%	5	38.5%	6	26.1%
	Rarely	11	68.8%	10	50.0%	5	35.7%	9	64.3%	6	46.2%	11	47.8%
	Never	3	18.8%	4	20.0%	2	14.3%	3	21.4%	2	15.4%	4	17.4%
B13	Always	-	-	-	-	-	-	-	-	-	-	-	-
	Sometimes	7	43.8%	13	65.0%	6	42.9%	5	35.7%	6	46.2%	15	65.2%
	Rarely	8	50.0%	7	35.0%	8	57.1%	9	64.3%	7	53.8%	7	30.4%
	Never	1	6.3%	-	-	-	-	-	-	-	-	1	4.3%
B14	Always	1	6.3%	-	-	-	-	1	7.1%	-	-	-	-
	Sometimes	5	31.3%	8	40.0%	5	35.7%	4	28.6%	5	38.5%	9	39.1%
	Rarely	5	31.3%	10	50.0%	7	50.0%	7	50.0%	6	46.2%	9	39.1%
	Never	5	31.3%	2	10.0%	2	14.3%	2	14.3%	2	15.4%	5	21.7%
B15	Always	-	-	4	20.0%	-	-	-	-	3	23.1%	1	4.3%
	Sometimes	10	62.5%	12	60.0%	10	71.4%	9	64.3%	7	53.8%	16	69.6%
	Rarely	6	37.5%	4	20.0%	4	28.6%	5	35.7%	3	23.1%	6	26.1%
	Never	-	-	-	-	-	-	-	-	-	-	-	-
B16	Always	4	25.0%	5	25.0%	2	14.3%	3	21.4%	5	38.5%	3	13.0%
	Sometimes	4	25.0%	7	35.0%	9	64.3%	4	28.6%	3	23.1%	13	56.5%
	Rarely	5	31.3%	6	30.0%	1	7.1%	3	21.4%	4	30.8%	5	21.7%
	Never	3	18.8%	2	10.0%	2	14.3%	4	28.6%	1	7.7%	2	8.7%

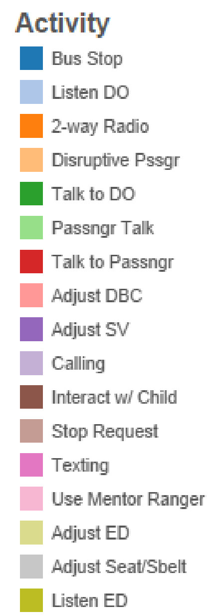
3.4.2. Perception of Distracted Driving Effects on Driving Performances

In this part of the questionnaire, the participants were asked on how they would drive the bus when involved in each of the 17 distracted driving behaviors. The question focuses on 7 driving performances, including *no difference*, *drive slower*, *drive faster*, *apply the brake more*, *eyes-off-the-road less, eyes-off-the-road more, hands-off-the-steering wheel less, hands-off-the-steering wheel more, and increase distance with the lead vehicle*. **Table 6** shows how distracted driving behaviors affect participants' driving performances. In this table (column 2), Y-axis represents number of responses and each bar in the X-axis explains the more common distracted driving behaviors (from right to left) that might cause such an effect (column 1) on driving performances.

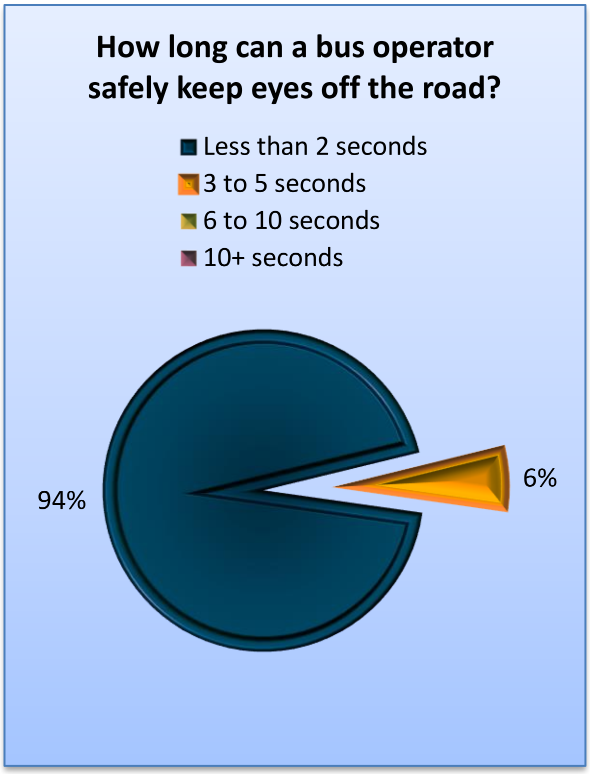
Table 6 Effect of Distracted Driving Behaviors on Driving Performances

Effect on Driving Performances	Responses (multiple responses)
No Difference	
Drive Slower	
Drive Faster	
Apply the brake more	
Eyes-off-the-road Less	
Eyes-off-the-road More	

Effect on Driving Performances	Responses (multiple responses)
Hands-off-the-Steering Wheel Less	
Hands-off-the-Steering Wheel More	
Increase distance with the lead vehicle	



Almost half of the responses (40%) agreed that listening activities (*listening to Dispatch Office, conversation, and music*) seems to have *no effect* on driving performance. On the other hand, some operators would *drive faster* (20.9%) when *listening to entertainment device. Interacting with passengers* (including child passenger), *scanning bus stop*, and *awareness of stopping alert* would cause operators to *driver slower* (35% of responses). The graph also showed that *stop request* and *scan bus stop* affect braking behavior of operators every time they approached the stop. *Text messaging* and *disruptive passenger behavior* seem to divert operator's *eyes-off-the-road more* often than the other activities. The majority of participants (94%) indicate that a bus operator can safely divert his/her eyes off the road in less than 2 seconds; while the operator can also safely keep his/her one or both hands of the steering wheel in less than 5 seconds (see **Figure 3**).



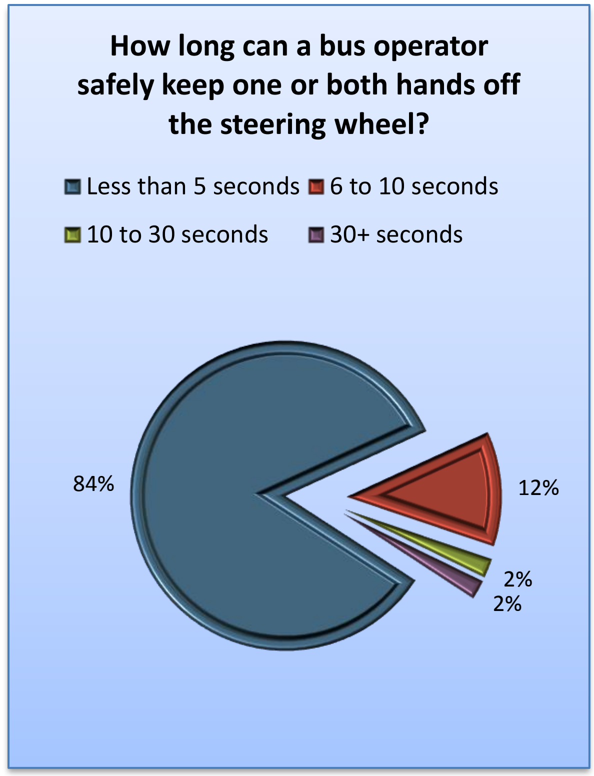


Figure 3 Perception on Safe Duration of Eyes-off-Road and Hands-off-Steering Wheel

3.4.3. Perception of Distracted Driving Safety and Potential Risk

Each response of potential risk and safety perceptions of distracted driving behaviors were assigned with the following values: no risk & very safe = 1; minimal risk & safe = 2; moderate risk & unsafe = 3; and extensive risk & very unsafe = 4. Fisher's LSD and Turkey's HSD (with an α value of 0.05) methods were used to investigate the difference of the mean responses. The total numbers of responses from both questions are 1,700 observations (see **Table 7**).

Table 7 Means Comparison between Responses of Perception of Distracted Driving Behaviors Safety and Potential Risk

No.	Activity	Mean		Fratio	Prob>F	Means Comparison Conclusion	
		Risk	Safety			Fisher's LSD	Turkey's HSD
1	Listen to entertainment devices	2.2800	2.3000	0.0125	0.9113	No Difference	No Difference
2	Adjust the entertainment devices	3.0800	3.0800	0.0000	1.0000	No Difference	No Difference
3	Text messaging	4.0000	3.9000	2.3333	0.1299	No Difference	No Difference
4	Talk on a cell phone	3.8200	3.7200	1.0443	0.3093	No Difference	No Difference

No.	Activity	Mean		Fratio	Prob>F	Means Comparison Conclusion	
		Risk	Safety			Fisher's LSD	Turkey's HSD
5	Pick Up & hold 2-way radio	2.4200	2.2200	2.6659	0.1057	No Difference	No Difference
6	Listen to Dispatch Office (DO) Broadcast	1.8400	1.8000	0.0773	0.7816	No Difference	No Difference
7	Communicate with Dispatch Office	2.0800	1.9800	0.5743	0.4504	No Difference	No Difference
8	Aware of stop request	1.5400	1.6000	0.2899	0.5915	No Difference	No Difference
9	Passenger conversations	2.0000	2.1400	1.1999	0.2760	No Difference	No Difference
10	Talk to passenger	2.3800	2.4000	0.0308	0.8610	No Difference	No Difference
11	Interact with children	2.8400	2.9400	0.6196	0.4331	No Difference	No Difference
12	Scan the bus stop	1.4400	1.6800	5.6000	0.0199	Safety is different from Risk	
13	Adjust sun visor	2.2400	2.3400	0.6742	0.4136	No Difference	No Difference
14	Adjust seat/seat belt	2.3800	2.4400	0.1630	0.6873	No Difference	No Difference
15	Adjust dashboard controls	2.3600	2.1600	3.4703	0.0655	No Difference	No Difference
16	Use the mentor ranger	2.4000	2.3800	0.0159	0.9000	No Difference	No Difference
17	Disruptive passengers behavior	3.1600	2.9600	2.1012	0.1504	No Difference	No Difference

Table 7 shows that there was no difference in participants' responses towards the perception of safety and risk of distracted driving behaviors questions. About 94% of participants agreed that *text messaging* was a very unsafe activity, followed by *talking on a cell phone* (76%), *adjusting entertainment devices* (26%) and *disruptive passenger behaviors* (16%). In term of risk perception, all participants mentioned *text messaging* might cause an extensive risk while driving. This result was also followed by *talking on a cell phone* (82%), *disruptive passenger behaviors* (36%), and *adjusting entertainment devices* (34%).

Total scores of each distracted driving behavior perception on safety and potential risks were added according to the given weights and the average score was calculated. The weights were as following: (a) *No Risk – Very Safe* = 1; (b) *Minimal Risk – Safe* = 2; (c) *Moderate Risk – Unsafe* = 3; (d) *Extensive Risk – Very Unsafe* = 4. Then, quintiles of the average scores were calculated resulting 4 risk zones (**Table 8**). Based on those zones, each activity was ranked. Risk Zone 1V (very high risk) was defined as distraction with the threshold score of 114.5. The other activities in Risk Zone III (high risk) have the average score between 114.5 – 101.5. Risk Zone II (moderate risk) has threshold score between 101.5 – 89.25. The remaining zone, Zone I (low risk) distraction was any activity that has average score below 89.25. Detailed ranking of each distracted driving behavior is showed in **Table 9**. In average, the responses of risk perception were 4% greater than those of safety perception.

Table 8 Risk Zone Classification of Distracted Driving Behaviors

Activity	Risk	Safety	Average Score	Risk Zone
Text messaging	140	157	149	**Zone IV**
Talking on a cell phone	132	150	141	
Interacting with infants/kids (including looking at them)	131	113	122	
Disruptive passenger behavior	123	109	116	
Adjusting the radio station/CD/MP3 player	117	109	113	**Zone III**
Adjusting seat and/or seat belt	111	108	110	
Talking to passenger	109	98	104	
Manipulating dashboard	104	99	102	
Holding the two way radio	110	94	102	
Listening to the radio/ CD/DVD/MP3 player	95	97	96	**Zone II**
Listening to the passenger conversation	96	95	95.5	
Utilizing mentor ranger	93	93	93	
Manipulating sun visor	84	99	91.5	
Communicating with Dispatch Office	94	80	87	**Zone I**
Listening to the Dispatch Office broadcast	79	82	80.5	
Actively scanning passenger approaching the bus stop	78	76	77	
Being aware of passenger's stopping signal	67	76	71.5	

Table 9 Ranking of the Most Dangerous Distracted Driving Behaviors

Activity	Ranking (Most to Least Dangerous Behaviors)	
	Potential Risk	**Safety**
Text messaging	1	1
Talk on a cell phone	2	2
Disruptive passenger behavior	3	4
Adjust the entertainment devices	4	3

Activity	Ranking (Most to Least Dangerous Behaviors)	
	Potential Risk	Safety
Interact with children	5	5
Pick Up & hold 2-way radio	6	11
Talk to passenger	7	7
Adjust seat/seat belt	8	6
Use the mentor ranger	9	8
Adjust dashboard controls	10	12
Listen to entertainment devices	11	10
Adjust sun visor	12	9
Communicate with DO	13	14
Passenger conversations	14	13
Listen to DO Broadcast	15	15
Aware of stop request	16	17
Scan the bus stop	17	16

3.5. Result 3: Passenger-related Distraction

In this part of the questionnaire, participants were asked some questions related to passenger-distraction. About 70% of participants agreed that the number of passengers on the bus could affect bus operator's driving performance. There was a possibility that it relates to the ability of bus operator to listen to the bus stop requested alert clearly. The majority of respondents (62%) indicated that when the bus was full the bus operator was still able to listen clearly to the stop request. Rule of thumbs about when to signalize the stop request was also asked to the participants. Thirty-eight percent of participants suggested that passengers should signalize operator to stop the bus in about 2 blocks away from the destination bus stop, following 28% said 1-block away from the stop, 22% said immediately after the prior bus stop, and the rest 12% chose 250 feet away from the stop. About 43% out of 42% of participants identified drunk-passengers as the most distracting occupant for the operators.

3.6. Discussion: Transit Bus Operator Distraction Policies

In transit, some activities are prohibited to perform on the bus (e.g., *cell-phone use while driving*, *eating/drinking*, *passenger talking to driver while driving* or vice versa). Interestingly, major completed research focused on something which is currently under control by regulations. The top 5 most dangerous distracted driving behaviors showed in **Table 10** were mostly prohibited either by national regulation or in the level of local agency regulation. A recent study by FTA [19] supported the results found from the survey in this study. Out of 33 participating agencies (over 20 states) in TCRP study, 90.9% prohibited use an MP3 player while driving the bus and about 78.8% have rules that operator is prohibited to have a conversation with passengers. About 72.7% of participating agencies would not allow their operators to use hand-held radio.

Table 10 Distracted Driving Behaviors Prohibited by Transit Agencies **[**19**]**

Activity: while bus is moving	**Agencies prohibiting the activity (%)**
Use of hand-held cell-phones	97
Use of hands-free cell-phones	78.8
Use of hand-held radio	72.7
Eating	87.9
Drinking	87.9
Using an MP3 Player with headphones	90.9
Using an MP3 Player without headphones	90.9
Having a conversation with passengers	78.8

These potentially high-risk behaviors need to be addressed such that the safety of transit occupants is improved while still maintaining the efficiency of transit operation. Further study as a follow up from these results will be conducted using naturalistic driving data. The purpose of the study includes investigating how distracted driving behaviors affect operators' driving performances in their natural driving environment. It also becomes important to notice if the operators change their driving style to compensate for the distractions.

3.7. Ordinal Logistic Regression Analysis

Collection of operators' responses specifically on perceived frequency of operators' exposure on distracted driving was investigated further. This analysis aims to determine the relationship between predictors and the ordinal nature of the categorical responses: operators' distracted driving frequency. Since the natural data of responses variables are in ordinal form, this study used ordinal logistic regression as an extension of the general linear model to ordinal categorical data. Survey-response data on distracted driving frequency are ordered from *never, rarely, sometimes,* and *always*. Predictor variables here include operator' age (years), gender, transit driving experience (exp - months), and driving frequency (FreqHW - hours/week).

In ordinal logistic regression, it is common to consider "cumulative probability" to convert the multicategory outcome model into a sequence of 2 category comparisons [16]. This can be shown in the following equation:

$$Pr(y_i = 1|X_i) = \frac{1}{1+e^{-(b_0+b_1X_i)}} \quad \textbf{(Eq. 1)}$$

Or

$$ln\left[\frac{Pr(y_i=1|X_i)}{1-Pr(y_i=1|X_i)}\right] = b_0 + b_1X_i \quad \textbf{(Eq. 2)}$$

where:

$Pr(y_i = 1|X_i)$ = probability of the responses is in category 1 compared to those in the base category X_i.

B_0 = estimated coefficient of threshold intercept

B_1 = estimated coefficient of predictor

3.7.1. Running an Ordinal Logistic Regression Analysis in SPSS

Before running the analysis, all variables had to be defined clearly, whether the variables were scale (continuous), nominal, or ordinal. The rest predictor variables here were continuous variables, except gender variable as a nominal factor. Continuous independent variables were entered as covariates and categorical independent variables as factor.

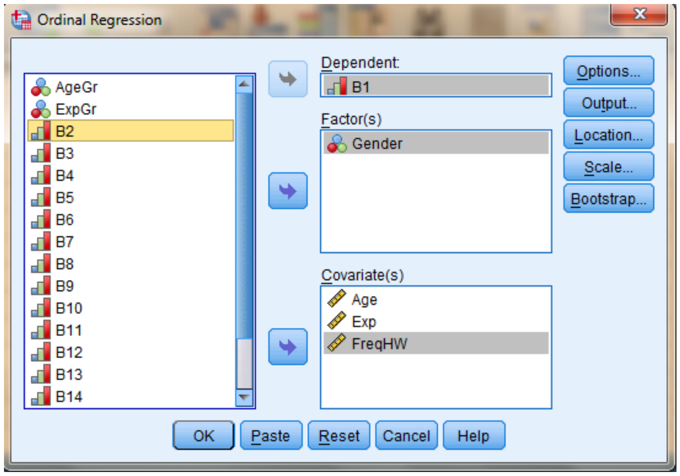


Figure 4 Ordinal Regression Main Menu in SPSS

In **Figure 4**, D1 (frequency of *listening to entertainment devices*) was moved to "Dependent" box, gender to "Factor" box, and age, experience, freqHW to "Covariate" box. In the "Options" button, we linked the model to "Logit". In the "Output" button, goodness of fit statistics, summary statistics and parameter estimates were chosen by default. In addition, we specifically added test of parallel lines to test proportional odds assumption. This test assumes that each independent variable has an identical effect to each cumulative split of the ordinal response variables. New variables can be saved if selected independent variables are nominal (**Figure 5**). This can be useful to diagnose the best fit of the model.

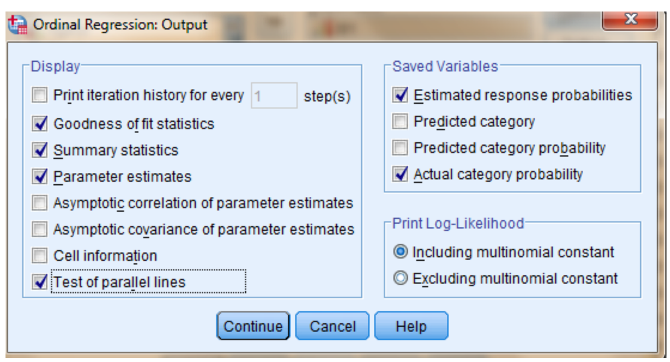


Figure 5 Ordinal Regression Output Submenu in SPSS

There were 3 main outputs that are very important to examine: *Model Fit, Parameter Estimate, and Test of Parallel Lines*. If the outputs successfully meet the requirement to test the test, the final output is determined to be appropriate for the ordinal model. These steps are illustrated in the following chart below (**Figure 6**):

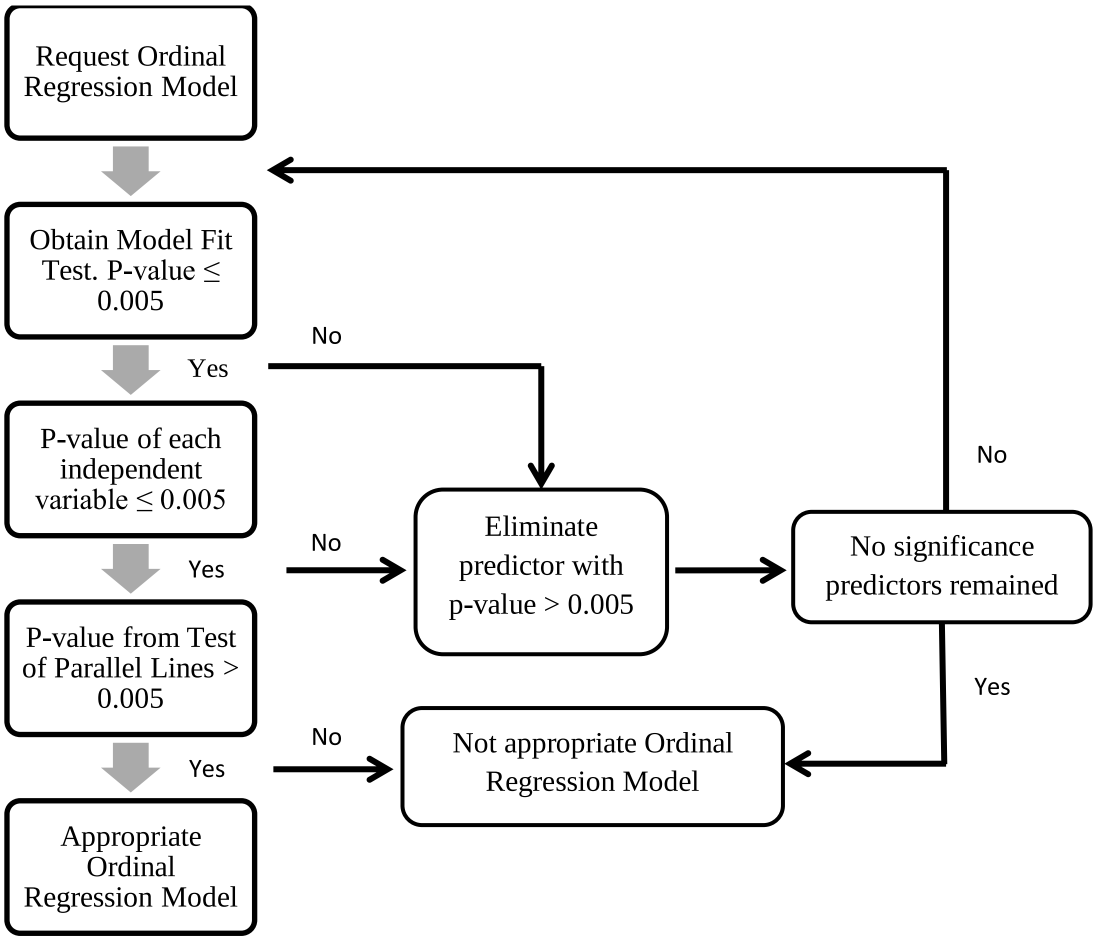


Figure 6 Ordinal Regression Workflow

a) Model Fitting Information

This table gives the information of the -2 log likelihood values associated with the model. This indicates how model fit is calculated. "Intercept Only" describes how the model fits only an intercept to predict the response variables. "Final" describes how the model fits to predict the response variables by including all specified predictor variables. The difference in "-2 Log Likelihood" should be improved after fitting the Final model. The likelihood of the model is used to test of whether all predictors' regression coefficients in the model are simultaneously zero and in tests of nested models [14]. "Chi-square" or the so called the Likelihood Ratio tests if at least one of the predictors' coefficients is not equal to zero or in other words at least one of the predictors is able to predict the responses. The significant chi-square value is shown as p-value ($p < 0.005$), indicating that the Final model is significantly improved the models in term of giving the better predictions for the ordinal responses. Degree of freedom or "df" is defined by the number of predictors in the model.

b) Parameter Estimates

Parameter estimates table contains the estimated coefficient of the ordinal regression model. There are 2 types of estimate coefficients: "Threshold" and "Location". "Threshold" estimates represent the cutoff value between the responses in its specified category over the lower category or called the intercept equivalent terms. On the other hand, "Location" estimate represents the ordered log-odds regression coefficient. This means that for one unit increase in the predictor variables will change the response variable level by its coefficient in the ordered log-odds while the other variables are held constant. Exponentiations of these estimates result in the odds ratio of each predictor. "Wald" test is the chi-square test; the null hypothesis (H_0) states that the regression coefficient is equal to zero. If H_0 is rejected, we can conclude that the predictor has been found statistically different from zero in estimating the response variable when the other predictors are constant. "Sig" is an associated p-value of Wald test. Significance of the predictors is shown when p-value is less than 0.005.

c) Test of Parallel Lines

Parallel lines test is the proportional odds assumption of the ordinal regression model, in which H_0 states that the location parameters (slope coefficients) are the same across response categories. If we fail to reject H_0, it means that the logit coefficients are equal across response levels and our decision of using ordinal regression as the model is appropriate.

Table 11 Summary of Model Significance of Each Activity

Activities	Model with Particular Predictors	P-value of the Model	P-Value of Parallel Lines Test
Listening to the radio/ CD/DVD/MP3 player (D1)	All predictors	0.002	0.765
	Age	0.002	0.769
Adjusting Entertainment Device (D2)	All predictors	0.369	0.266
	Frequency	0.111	0.137
Picking Up and Holding 2-way Radio (D5)	All predictors	0.007	0.001
	Age	0.000	0.584
Listening to the Dispatch	All predictors	0.100	0.000

Activities	Model with Particular Predictors	P-value of the Model	P-Value of Parallel Lines Test
Office broadcast (D6)	Frequency-Gender	0.047	0.870
Communicating with Dispatch Office (D7)	All predictors	0.253	0.069
	Age	0.046	0.037
Listening to the passenger conversation (D9)	All predictors	0.583	0.178
	Age	0.095	0.910
Talking to Passenger (D10)	All predictors	0.414	0.726
	Experience	0.115	0.598
Interacting with Infants/children (D11)	All predictors	0.590	0.833
	Experience	0.167	0.767
Adjusting sun visor (D13)	All predictors	0.044	0.007
	Age - Experience - Gender	0.026	0.011
Adjusting Seat/ Seat belt (D14)	All predictors	0.493	0.068
	Gender	0.183	0.936
Adjusting switches/controls on dashboard (D15)	All predictors	0.176	0.710
	Frequency	0.041	0.619
Utilizing mentor ranger (D16)	All predictors	0.055	0.222
	Gender	0.005	0.819

Table 11 shows the significance of the model with all 4 predictors and with only significance predictors. For the example on how to obtain the table, below are the steps to predict the probability of *Listening to Entertainment Device (D1)* frequency with regards to the particulars predictors:

i. Step 1: select ordinal regression analysis from SPSS through Analyze → Regression → Ordinal. Select D1 as dependent variable, gender as factors, and age, exp, and freqHW as covariates.
ii. Step 2: In the option button, choose goodness of fit statistics, summary statistics, parameter estimates, and test of parallel lines to test proportional odds assumption.
iii. Step 3: **Run** the analysis

iv. Step 4: Evaluate Model fitting information table (shown in **Table 12)**. This table showed that the final model using all 4 predictors is significance to predict the frequency of *Listening to Entertainment Device (D1)* with the **p-value of 0.002**.

Table 12 Model Fitting Information of D1

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	94.222			
Final	77.261	16.961	4	0.002

Link function: Logit.

v. Step 5: Evaluate Parameter estimate table (see **Table 13).** The base category here is level 4 of response or *Never* response. In this interpretation, it is important to assume that operators' responses represent their own experience. Thus, the results showed that men are less likely to assign higher level of response, meaning men operators are somewhat confident that they are more frequently exposed to listen to entertainment devices while driving than women. In addition, it also seems that the more experience the operator is, he/she will less likely to listen to entertainment devices while driving. Age and frequency of driving appeared to be positively related toward the responses. An increase of age and frequency of driving is positively increasing the probability of them to listen to entertainment devices while driving.

- Threshold [D1 = 2]: the cumulative predicted probability of *female* operator (gender = 1) to give response 2 (*Sometimes*) is the exponential of **3.112**.

  $Pr(D1 = 2) = \frac{1}{1+e^{-(3.112)}}$ =0.957

- Threshold [D1 = 3]: the cumulative predicted probability of *female* operator to give response 2 (*Sometimes*) **or** 3 (*Rarely*) is the exponential of **4.722**.

  $Pr(D1 = 3\ or\ 2) = \frac{1}{1+e^{-(4.722)}}$ =0.991

- The odds ratio of being in a higher category of D1 responses for male operator versus female operator is the 0.453($e^{-0.792}$) with 95% Confidence Interval (CI) between 0.378 – 5.845, and a statistically significant of 0.026. In other words, the odds of male operators to be *more likely* involved in *listening to entertainment devices* is 0.453 times that of female operators.

Table 13 Parameter Estimates of D1

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[D1 = 2]	3.112	1.395	4.979	1	.026	.378	5.845
	[D1 = 3]	4.722	1.489	10.061	1	.002	1.804	7.639
Location	Age	.046	.029	2.574	1	.109	-.010	.102
	FreqHW	.062	.020	9.208	1	.002	.022	.102
	Exp	-.017	.010	2.868	1	.090	-.036	.003
	[Gender=0]	-.792	.874	.821	1	.365	-2.506	.922
	[Gender=1]	0[a]	.	.	0	.	.	.

Link function: Logit.

a. This parameter is set to zero because it is redundant.

- Location [Age]: A one unit increase in age would result in a 0.046 increase in the ordered log-odds of responding higher level of response; this means an increase in age would increase the probability of being "less frequently" involved in *Listening to entertainment device* activity while driving.
- Location [FreqHW]: A one unit increase in driving frequency per week would result in a 0.062 increase in the ordered log-odds of responding higher level of response; this means an increase in frequency of driving per week would increase the probability of being "less frequently" involved in *Listening to entertainment device* activity while driving.
- Location [Exp]: A one unit increase in experience would result in a -0.017 decrease in the ordered log-odds of responding higher level of response; this means an increase in experience would decrease the probability of being "less frequently" involved in *Listening to entertainment device* activity while driving.
- Location [Gender]: men operators are somewhat confident that they are more frequently exposed to listen to entertainment devices while driving than women by the ordered log-odds of -0.792.
- Sig: It seems that experience and gender predictors are not giving significance relation to predict the responses.

vi. Step 6: Eliminate insignificance predictors from the model. In this case, eliminate experience and gender variables. Repeat step 1 – 5. See results in **Table 14** and **Table 15**. Both tables show that all predictors in this model are significance to predict the responses.

Table 14 Model Fitting Information of D1 after 2 Predictors Eliminated

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	80.252			
Final	70.602	9.650	1	0.002

Link function: Logit.

Table 15 Parameter Estimates of D1 after 2 Predictors Eliminated

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Threshold	[D1 = 2]	2.777	.935	8.818	1	.003	.944	4.610
	[D1 = 3]	4.224	1.040	16.504	1	.000	2.186	6.262
Location	Age	.053	.019	8.056	1	.005	.016	.089

Link function: Logit.

vii. Step 7: Evaluate Test of Parallel Lines table (see **Table 16**). The "Sig" value is 0.769, meaning the null hypothesis is fail to reject and the ordinal regression model is appropriate for this model.

Table 16 Test of Parallel Lines of D1 after 2 Predictors Eliminated

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	70.602			
General	70.516	.086	1	.769

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.

a. Link function: Logit.

Table 17 and **Table 18** present the result summaries of ordinal logistic regression analysis and the interpretation of the operators' likelihood to not being involved in each potential distracted activity while driving.

Table 17 Summary of Ordinal Logistic Model of Each Potential Distraction

Activity Code (Di)		D1	D2	D5	D6	D7	D9	D10	D11	D13	D14	D15	D16
P-Value of Model Fit		0.002	0.111	0.000	0.047	0.046	0.095	0.115	0.167	0.026	0.183	**0.041**	**0.005**
P-Value of Parallel Line Test		0.769	0.137	0.584	0.870	0.037	0.910	0.598	0.767	0.011	0.936	**0.619**	**0.819**
Estimate	Threshold [Di = 1]			1.384	-1.976	0.412	-1.705	-2.706	-3.603		-4.890	-1.354	-3.475
	Threshold [Di = 2]	2.777	-0.300	6.380	0.862	4.459	1.478	0.373	-1.216	-2.768	-1.458	2.262	-1.586
	Threshold [Di = 3]	4.224	1.884						1.218	1.521	0.608		-0.032
	Location [Age]	0.053		0.075		0.035	0.026			-0.039			
	Location [FreqHW]		0.037		-0.042							0.050	
	Location [Exp]							-0.011	-0.009	0.015			
	Location [Gender = 0]				-1.738					-2.064	-1.082		-2.359
	Location [Gender = 1]				0*					0*	0*		0*
P-Value of predictor	Threshold [Di = 1]			0.108	0.077	0.592	0.046	0.000	0.000		0.000	0.068	0.000
	Threshold [Di = 2]	0.003	0.630	0.000	0.455	0.000	0.057	0.335	0.004	0.029	0.071	0.004	0.059
	Threshold [Di = 3]	0.000	0.006						0.004	0.289	0.434		0.968
	Location [Age]	0.005		0.002		0.052	0.104			0.042			
	Location [FreqHW]		0.103		0.103							0.051	
	Location [Exp]				0.055			0.133	0.176	0.066			
	Location [Gender = 0]				.					0.045	0.192		0.007
	Location [Gender = 1]*										.		.
	*This parameter is set to zero because it is redundant.												

Table 18 Summary of Operators' Likelihood of Being Involved in the Potential Distractions

Activities	Likelihood of Being Involved in the Following Activities	
	MORE	**LESS**
Listening to the radio/ CD/DVD/MP3 player (D1)	Younger operator	**1.054x** Older operator
Adjusting Entertainment Device (D2)	Operator driving bus *less* frequently	**1.038x** Operator driving bus *more* frequently
Picking Up and Holding 2-way Radio (D5)	Younger operator	**1.078x** Older operator
Listening to the Dispatch Office broadcast (D6)	**5.686x** Male operator **1.043x** Operator driving bus *more* frequently	Female operator Operator driving bus *less* frequently
Communicating with Dispatch Office (D7)	Younger operator	**1.036x** Older operator
Listening to the passenger conversation (D9)	Younger operator	**1.026x** Older operator
Talking to Passenger (D10)	**1.011x** More experienced operator	Less experienced operator
Interacting with Infants/children (D11)	**1.009x** More experienced operator	Less experienced operator
Adjusting sun visor (D13)	**1.04x** Older operator **7.877x** Male operator Less experienced operator	Younger operator Female operator **1.015x** More experienced operator
Adjusting Seat/ Seat belt (D14)	**2.951x** Male operator	Female operator
Adjusting switches/controls on dashboard (D15)	Operator driving bus *less* frequently	**1.051x** Operator driving bus *more* frequently
Utilizing mentor ranger (D16)	**10.58x** Male operator	Female operator

3.7.2. Cross-Validation of Ordinal Logistic Regression Models

Cross validation was done only for those models that have p-value of model fit less than 0.005 and p-value of parallel line test more than 0.005. The models included *listening to the radio/ CD/DVD/MP3 player (D1)*; *picking Up and Holding 2-way Radio (D5)*; *listening to the Dispatch Office broadcast (D6)*; *adjusting switches/controls on dashboard (D15)*; and *utilizing mentor ranger (D16).* The results are shown in **Table 19** below. In cross validation, each response was classified by the final models that consist of all significant independent variables. In model D1, 64% of original responses are correctly predicted; while for other models, there are 72% correctly predicted response of model D5, 60% of model D6, 64% of model 15, and 44% of model D16. In addition, it seems that each model is more likely to classify most of the incorrectly-predicted responses into the most common category: category *sometimes* for model D1, D5, D15, and D16, and category *always* for model D6.

Table 19 The Contigency Table of Validated OLR Models

Listening to the radio/ CD/DVD/MP3 player (D1)		Predicted Response Category			
		Always	Sometimes	Rarely	Never
		Count	Count	Count	Count
Actual Response Category	Always	0	0	0	0
	Sometimes	0	29	1	0
	Rarely	0	10	2	0
	Never	0	6	1	1
Predicted Response Category	Always	0	0	0	0
	Sometimes	0	45	0	0
	Rarely	0	0	4	0
	Never	0	0	0	1
Picking Up and Holding 2-way Radio (D5)		Predicted Response Category			
		Always	Sometimes	Rarely	Never
		Count	Count	Count	Count
Actual Response Category	Always	0	10	0	0
	Sometimes	0	36	0	0
	Rarely	0	4	0	0
	Never	0	0	0	0

Predicted Response Category	Always	0	0	0	0
	Sometimes	0	50	0	0
	Rarely	0	0	0	0
	Never	0	0	0	0
Listening to the Dispatch Office broadcast (D6)		Predicted Response Category			
		Always	Sometimes	Rarely	Never
		Count	Count	Count	Count
Actual Response Category	Always	30	2	0	0
	Sometimes	16	0	0	0
	Rarely	2	0	0	0
	Never	0	0	0	0
Predicted Response Category	Always	48	0	0	0
	Sometimes	0	2	0	0
	Rarely	0	0	0	0
	Never	0	0	0	0
Adjusting switches/controls on dashboard (D15)		Predicted Response Category			
		Always	Sometimes	Rarely	Never
		Count	Count	Count	Count
Actual Response Category	Always	0	4	0	0
	Sometimes	0	30	2	0
	Rarely	0	12	2	0
	Never	0	0	0	0
Predicted Response Category	Always	0	0	0	0
	Sometimes	0	46	0	0
	Rarely	0	0	4	0
	Never	0	0	0	0
Utilizing mentor ranger (D16)		Predicted Response Category			
		Always	Sometimes	Rarely	Never
		Count	Count	Count	Count
Actual Response Category	Always	0	11	0	0
	Sometimes	0	19	0	1
	Rarely	0	10	0	2
	Never	0	4	0	3
Predicted Response Category	Always	0	0	0	0
	Sometimes	0	44	0	0
	Rarely	0	0	0	0
	Never	0	0	0	6

CHAPTER IV SURVEY: PUBLIC OPINION ON DISTRACTED DRIVING BEHAVIORS IN TRANSIT

4.1. Survey Overview

This second survey was conducted to have the knowledge on public opinion about distraction in transit system. Different from the previous survey, this survey was designed to understand public knowledge on distraction and their experience as transit riders. Different from the first survey, "Transit operators perception on distracted driving", this survey was specifically created to observe 10 distracted driving behaviors.

The survey was conducted for three weeks on February 6th 2014 until February 27st 2014 in online survey format. There is no special criterion for choosing the population; rather all participants must be at least 18 years old. Participants were asked to answer 4 personal questions regarding their demogrpahic profil and transit use frequency. Then, there are 10 other questions related to their experience/observation of distracted driving behaviors of transit operator. There are about 130 returned survey collected all are validated to be use in analysis.

4.2. Demographic Profile of Participants

Total participants in this study are 151 people from across the USA. All of them are classified by their regional origin. This study uses Census Bureau-designated areas to categorize participants' origin: Region 1 (Northeast – NE), Region 2 (Midwest – MW), Region 3 (South – S), and Region 4 (West – W). About 101 people (66.9%) come from South region, 26 people (17.2%) from West, 14 people (9.3%) from Northeast, and the others 10 people (6.6%) from Midwest. **Table 20** and **Table 21** show the transit use frequency by US region, age, and gender.

Table 20 Transit Use Frequency by Region

Region	Transit Use									
	At least once every day		a few days a week		a few days a month		a few days a years		Never	
	Count	Row %	Count	Row %	Count	Row %	Count	Row %	Count	Row %
MW	7	70.0%	2	20.0%	-	-	-	-	1	10.0%

Region	Transit Use									
	At least once every day		a few days a week		a few days a month		a few days a years		Never	
	Count	Row %	Count	Row %	Count	Row %	Count	Row %	Count	Row %
NE	3	21.4%	6	42.9%	3	21.4%	-	-	2	14.3%
S	24	23.8%	27	26.7%	19	18.8%	-	-	31	30.7%
W	12	46.2%	3	11.5%	6	23.1%	-	-	5	19.2%

Table 21 Transit Use Frequency by Gender and Age Group

Age Group	Gender	Transit Use									
		At least once every day		a few days a week		a few days a month		a few days a years		Never	
		Count	Row %	Count	Row %	Count	Row %	Count	Row %	Count	Row %
Under 20	Female	-	-	1	100.0%	-	-	-	-	-	-
	Male	3	75.0%	-	-	1	25.0%	-	-	-	-
20 - 25	Female	12	57.1%	5	23.8%	1	4.8%	-	-	3	14.3%
	Male	8	38.1%	7	33.3%	4	19.0%	-	-	2	9.5%
26 - 30	Female	3	13.0%	10	43.5%	5	21.7%	-	-	5	21.7%
	Male	6	28.6%	6	28.6%	6	28.6%	-	-	3	14.3%
31 - 35	Female	3	21.4%	-	-	5	35.7%	-	-	6	42.9%
	Male	4	30.8%	4	30.8%	2	15.4%	-	-	3	23.1%
36 - 40	Female	1	33.3%	1	33.3%	1	33.3%	-	-	-	-
	Male	-	-	-	-	-	-	-	-	2	100.0%
41 - 45	Female	-	-	-	-	-	-	-	-	3	100.0%
	Male	-	-	-	-	1	100.0%	-	-	-	-
46 - 50	Female	1	100.0%	-	-	-	-	-	-	-	-
	Male	-	-	-	-	-	-	-	-	3	100.0%
51 - 55	Female	-	-	-	-	1	33.3%	-	-	2	66.7%
	Male	2	66.7%	-	-	-	-	-	-	1	33.3%
56 - 60	Female	-	-	1	100.0%	-	-	-	-	-	-
	Male	-	-	1	20.0%	1	20.0%	-	-	3	60.0%
Above 60	Female	1	50.0%	-	-	-	-	-	-	1	50.0%
	Male	2	33.3%	2	33.3%	-	-	-	-	2	33.3%

4.3. Discussion: Public Opinion Survey

4.3.1. Cross-reference: Prediction vs Public Opinion

A follow-up online survey was designed to collect public opinion on the likelihood of transit operator distracted driving behaviors. The survey was specifically created to observe 9 particular distracted driving behaviors (D1, D2, D3, D4, D5, D10, D13, D14, and D15). It was conducted for three weeks from February 6th 2014 until February 27th 2014. Total respondents in this survey are 151 people. About 101 respondents (66.9%) come from South region, 26 people (17.2%) from West, 14 people (9.3%) from Northeast, and the others 10 people (6.6%) from Midwest.

The first part of the questionnaire focused on public understanding on distracted driving behaviors. Participants were asked the definition of distracted driving behaviors. About 59% responses showed that most people agree that driving distraction is defined as any activity that takes driver eyes and minds off the road, and takes driver hands off the steering wheel. The other 17% responses define distraction as an activity that diverts driver minds off the road; which was categorized as cognitive distraction by USDOT.

All respondents were asked if bus driver's ordinary tasks such as awareness of passenger stop request and scanning for passenger approaching the bus stop while driving are NOT distractions. About 68% agreed that those ordinary tasks were not categorized as distractions, which is contradictory to Salmon et al study that categorized monitoring bus stops as passenger-related distraction, and bus stopping alert as operational-related distraction. These ordinary tasks can naturally take a number of distinct forms such as visual, cognitive, and auditory. Failures to check bus stop for waiting passengers and to hear bus stopping alert could potentially be made by drivers and affect the efficiency of their operational performances. Such distractions might lead to the conflict with the other road users, or could potentially trigger other operational errors.

The other question assessed distracted drivers, in which about 51% of people agree that novice bus driver gets more easily distracted while driving, followed by young driver (24%), old driver (11%), experienced driver (9%), very experienced driver (3%), male driver (1%), and female driver (1%). Considering the numbers of potential sources of distractions derived from within the bus itself (technology, passenger distractions), it seems to be true that novice bus driver might get overwhelmed with noises from the in-vehicle devices and passengers. However, they also tend to drive slower to compensate those "undeniable" distractions.

4.3.2. Comparison of Responses between Public and Transit Operators

Overall (see **Table 22**), it seems that public perceptions on the frequency of operator distracted driving behaviors are not different from those of transit operators themselves. In addition, some activities are prohibited to perform on the bus (e.g., cell-phone use, unnecessary interaction with passengers) in the national scale or in the level of local agency. For example, in **Table 22**, it showed that the operators are rarely discovered using cell phone by the riders (read public). This statement seems to be true since the economic risk of violating this regulation is very strict for the operators.

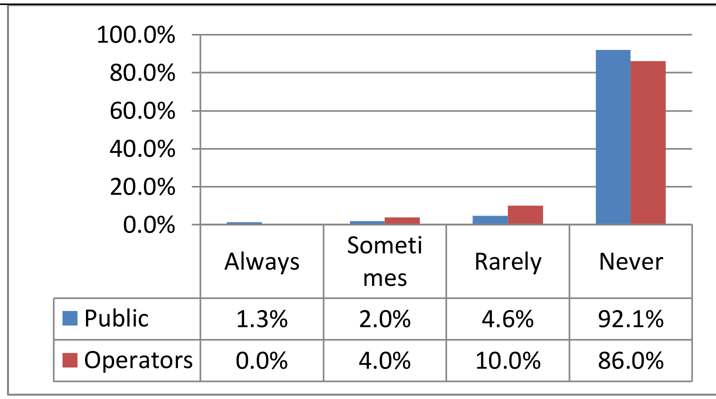
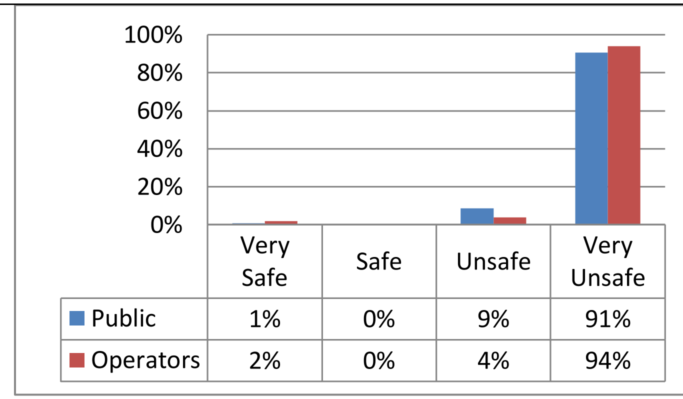
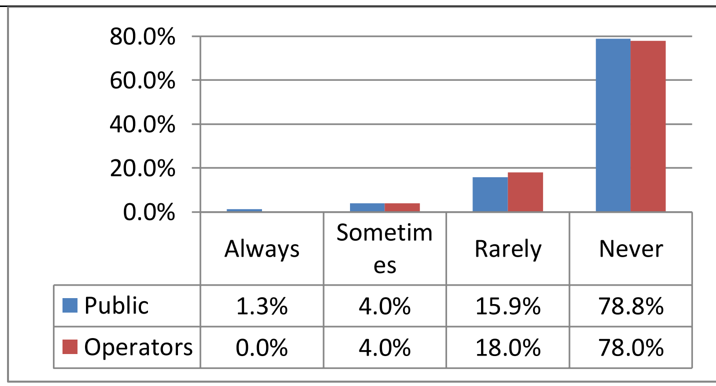
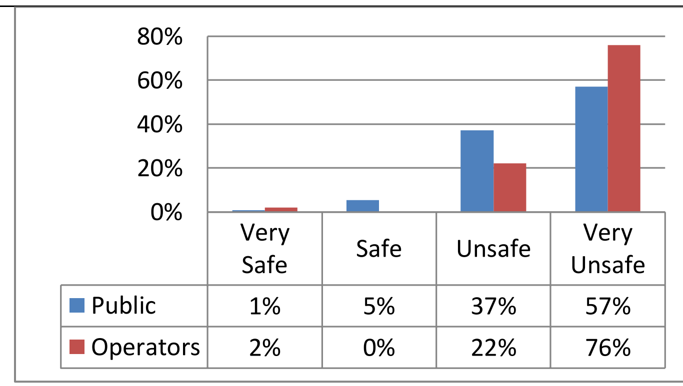
About 60% of operators mentioned that *sometimes* they listen to the entertainment devices (radio/MP3 player), while about 47% of the riders would feel unsafe if their drivers are listening to the entertainment devices while driving. Adjusting the entertainment devices is considered to be a very unsafe activity according to the operators themselves and the riders. Thus, most of the operators (about 76%) would rarely or never involve in such activity while driving. **Table 18** indicated that the operators that have less driving hours per week tend to be exposed in this activity than those with more driving hours per week.

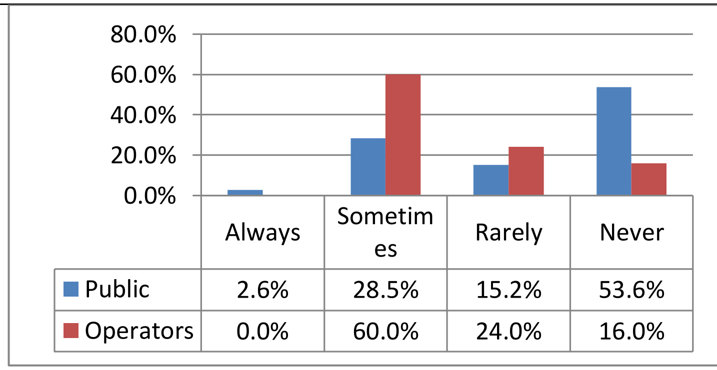
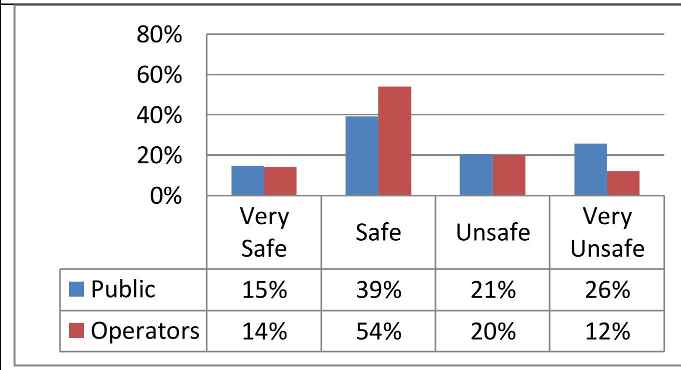
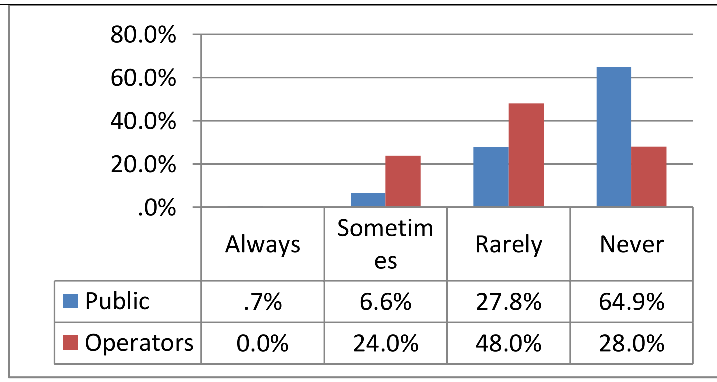
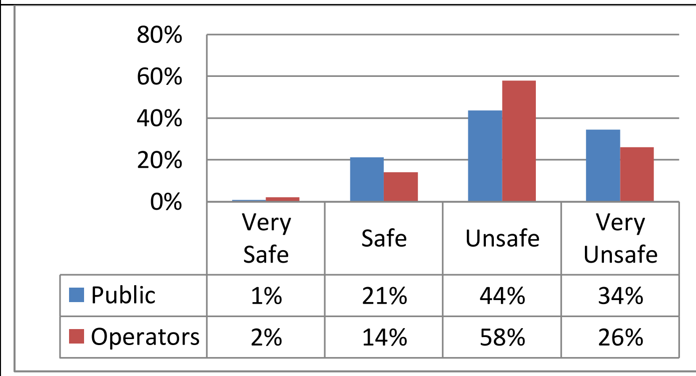
Interaction with passengers is also considered an unsafe distraction. Still, about 58% of operators said that sometimes they talk to passengers while driving and about 63% of the riders confirmed of this discovery. The logistic analysis of D10 estimated that the more experience operators tend to interact with the passengers. While some might argue that interactions with passengers are similar to customer service interaction, it becomes very important to distinguish such interactions. The primary task of the operators is driving the bus. The schedule and route of the bus are usually provided and displayed to the customers on the agency website, bus stops, and on the bus itself to avoid unnecessary interactions with passengers when the bus is in motion. Even though when in this situation the operators tend to drive slower to compensate an increase in driving loads, it is suggested to avoid the interaction while driving.

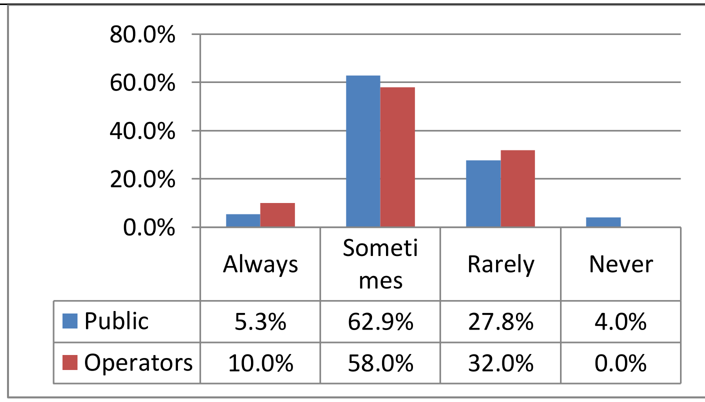
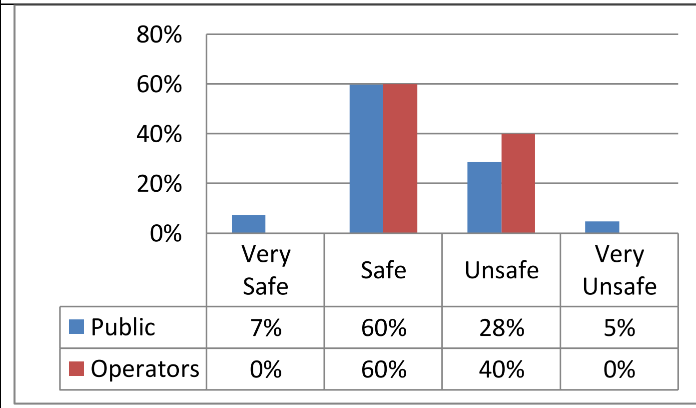
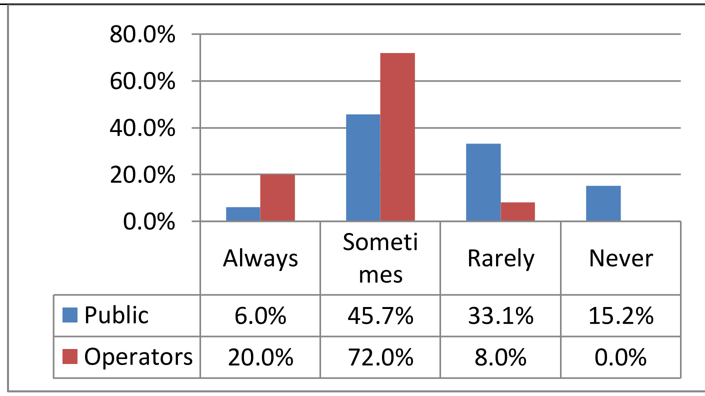
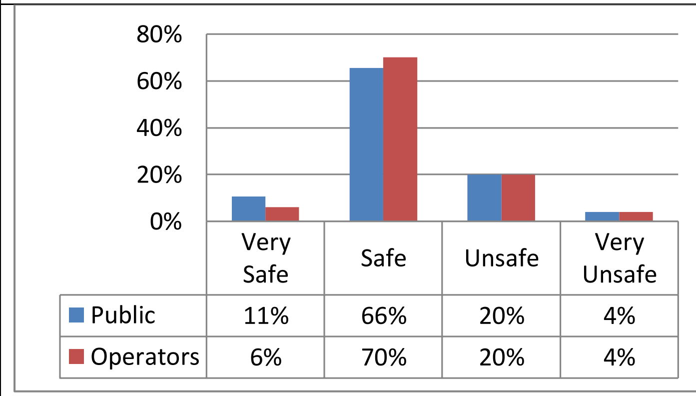
The other activities that are considered to be unsafe distractions by the riders are adjusting sun visor and seat/seat belt. The OLR of D13 and D14 showed that male operators tend to do those activities more. In addition, older and less experienced operators seem to adjust the sun visors more often than the others. According to an on-going observation on distracted behaviors, it is discovered that usually it takes less than 5 seconds to adjust the sun visor or seat belt while driving. Also, when they need to adjust sun visor/seat belt, they usually do that when they are approaching to a complete stop (signalized intersection or stop sign).

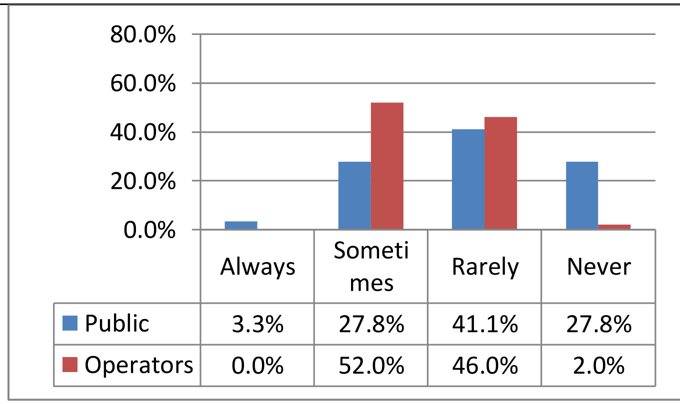
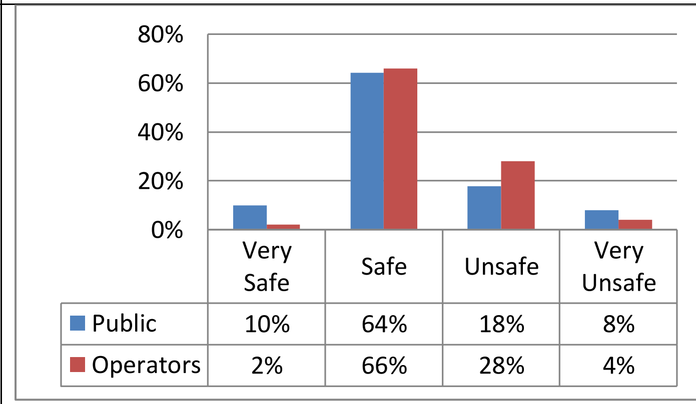
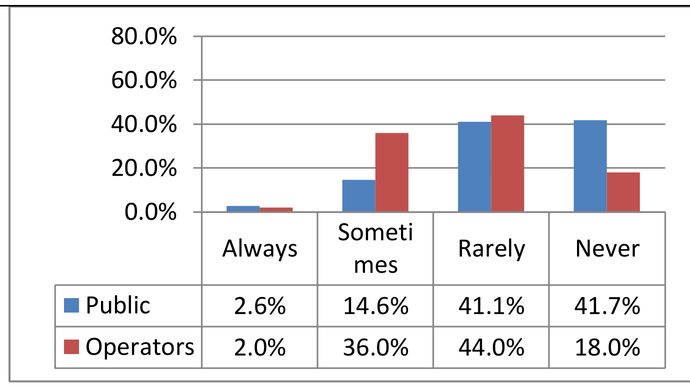
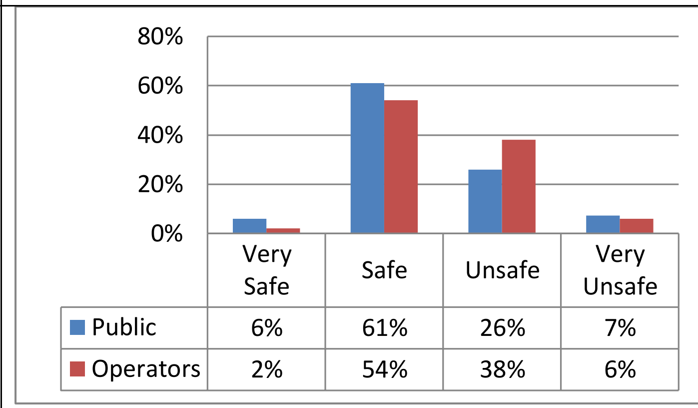
The following **Table 22** is the comparison responses on each distraction. The red bar on the chart represents the responses of transit operators; while the blue bar represents the responses from public:

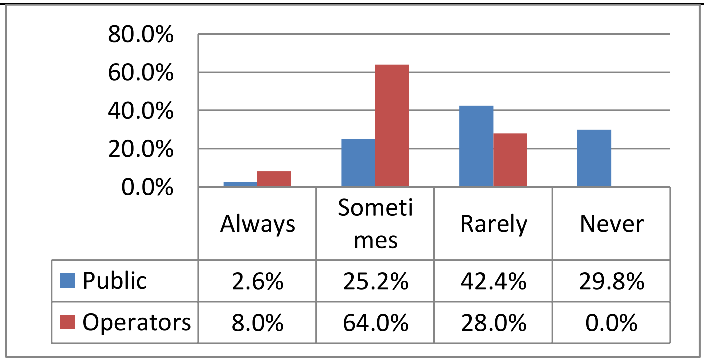
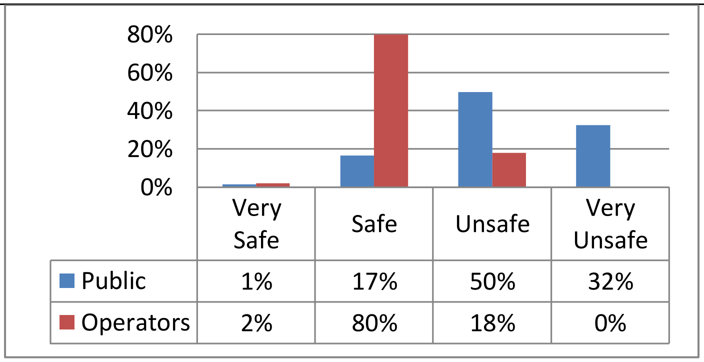
Table 22 The perception of Public and Transit Operators on Operator Distracted driving

Distraction	**How often bus driver is involved in:**	**How safe would you feel if bus driver is involved in:**
Text Messaging		
Talking on a cell phone		

Distraction	How often bus driver is involved in:	How safe would you feel if bus driver is involved in:
Listening to the radio/ CD/DVD/MP3 player		
Adjusting the radio/ CD/DVD/MP3 player		

<table>
<tr><th>Distraction</th><th>How often bus driver is involved in:</th><th>How safe would you feel if bus driver is involved in:</th></tr>
<tr><td>Interacting with passengers / talking to passengers</td><td>
</td><td>
</td></tr>
<tr><td>Using two way radio to communicate with Dispatch Office</td><td>
</td><td>
</td></tr>
</table>

<table>
<tr><th>Distraction</th><th>How often bus driver is involved in:</th><th>How safe would you feel if bus driver is involved in:</th></tr>
<tr><td>Adjusting Sun visors</td><td>
</td><td>
</td></tr>
<tr><td>Adjusting Seat/Seat Belt</td><td>
</td><td>
</td></tr>
</table>

Distraction	**How often bus driver is involved in:**	**How safe would you feel if bus driver is involved in:**
Adjusting Controls/Switches on the Dashboard		

CHAPTER V OBSERVATIONAL STUDY OF DISTRACTED DRIVING BEHAVIORS DURING BT'S FULL-SERVICE

5.1. Observation Procedure

An observational data collection was conducted in which no treatment was given to participants to affect the outcomes. Prior to the observation, the observer entered the bus from particular bus stop. Consenting occurred before the observation started and when the bus was not in motion. After participants provided their verbal consents to proceed, the observer selected the seat inside the bus that was the most suitable vantage point from which to observe driver (see **Figure 8**). For the duration of 1-hour, the observer was observing and taking a note if the driver was exposed to anyone/anything while driving. The observations were conducted during BT's full-service period. Full service is a peak service of BT during the Fall and Spring Semesters. Data collection times ranged from 1:00 PM to 8:00 PM, and included weekdays and weekend days, on clear days. Observed buses are 40' standard buses from New Flyer Manufacture Company (see **Figure 7**). Articulated buses were excluded from the sample frame selection.

All participants in this study were recruited from the local transit agency, Blacksburg Transit (BT). They must be at least 19 years of age, have a valid Commercial Driver's License with experience in driving transit bus. The criteria of the subject in this study are not restricted to gender, age, ethnicity, etc. Participating operators consist of 1 young operator and 3 old operators. Of those, 2 are novice operators (less than a year of experience), 1 experienced operator (1 – 5 years of experience), and another is a very experienced operators (more than 5 years of experience).

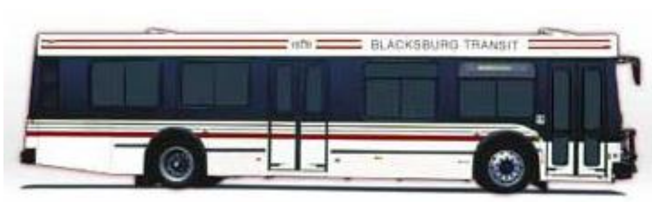


Figure 7 Observed 40' standard bus[2]

[2] Blacksburg Transit. http://www.blacksburg.gov/Index.aspx?page=1027 (accessed June 21, 2014) Used with permission from Blacksburg Transit; email attached.

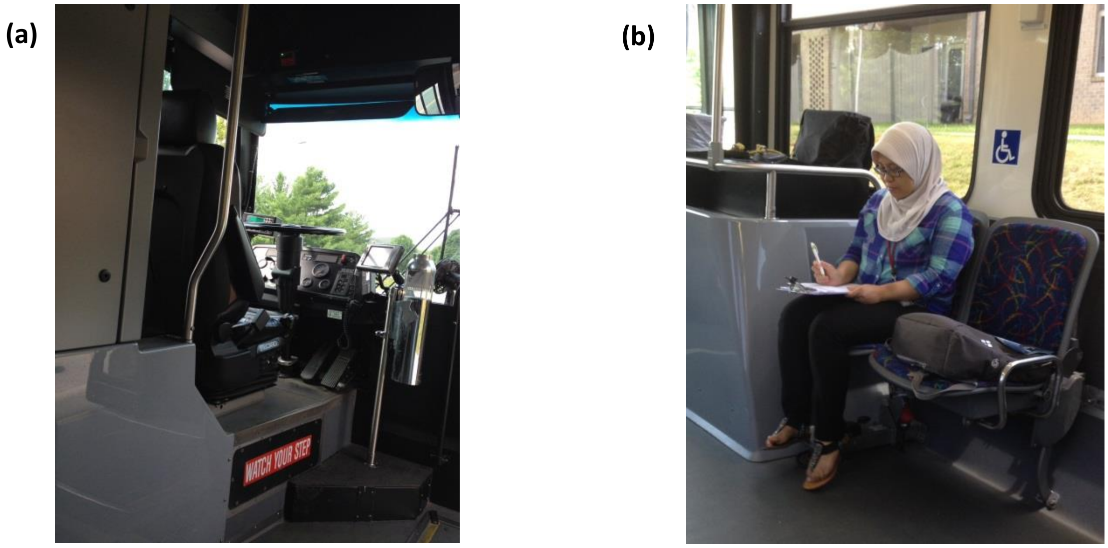


Figure 8 Documentary of Field Observation (a) Observer's view (b) Observer Seat Position inside the Bus (April, 2014)

5.2. Observed BT Routes

Observed BT routes were selected based on the types of service area coverage. Hokie Express (HXP) bus circulates between central Virginia Tech campus and the Oak Lane Community. This HXP bus serves in a very high pedestrian activity area. Toms Creek B (TCB) route provides service along University City Boulevard shopping centers and Progress Street to campus. It serves about 1550 riders in average on the weekend. Two Town Trolley (TTT) route was also selected because the route connects VT campus with the shopping centers in Blacksburg and Christiansburg. TTT bus serves the longest route of 14.4 miles. Following is the description of each observed route:

Table 23 Observed BT routes

No.	Route Abbreviation	Route Full Name	Number of Stops	Route Length (feet)	Average Bus Stop Spacing (ft/stop)
1	HXP	Hokie Express	7	10032	1433.143
		Hokie Express (return trip)	8	12144	1518.000
2	TCB	Toms Creek	12	10560	880.000
		Toms Creek (return trip)	10	15312	1531.200
3	TTT	Two Town Trolley	8	38544	4818.000
		Two Town Trolley (return trip)	9	37488	4165.333

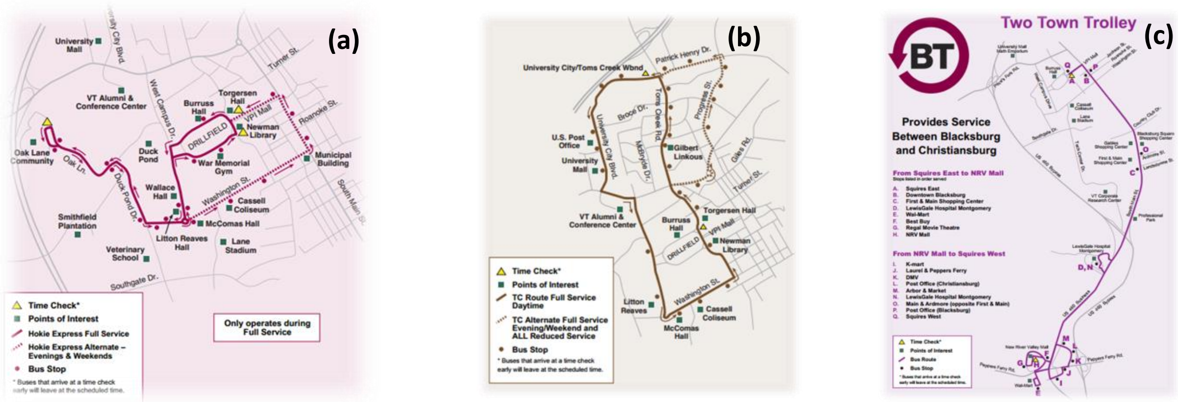


Figure 9 (a) Hokie Express route[3]; (b) Toms Creek B Route[4]; and (c) Two Town Trolley Route[5]

5.3. Data Reduction

In the process of data reduction, we have 2 types of velocity dataset. The first dataset was defined as the velocity profile of operator on the first roundtrip of each route. The second dataset was that of the second roundtrip on the same route. Each segment was completed in 30-minutes period. The author focused the analysis on the segments of the routes that were showing significant difference between 2 velocity dataset and the subject exposed by 2 different exposures.

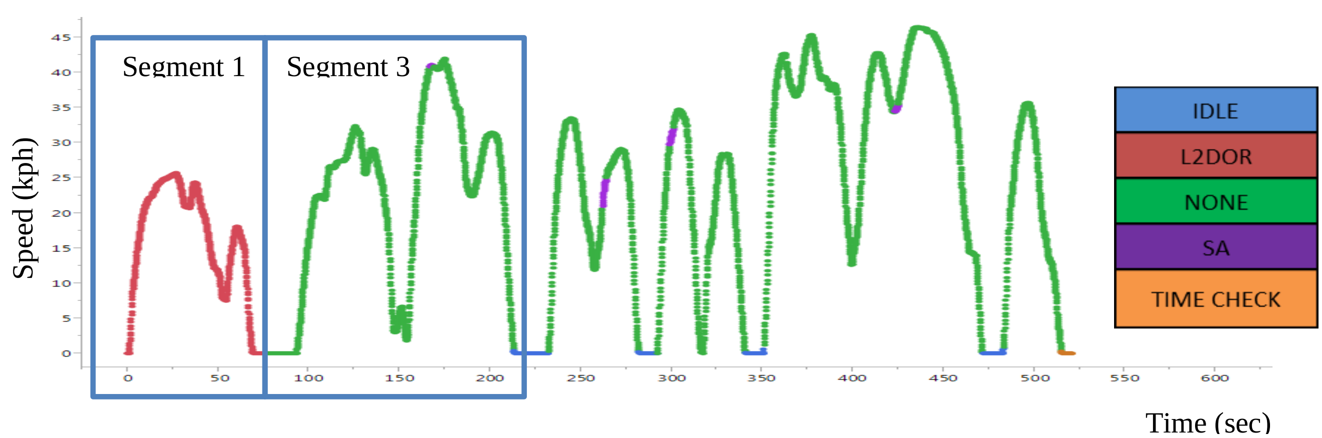


Figure 10 Velocity Profile of HXP Route (from Newman Library - Trial 1)

[3] Blacksburg Transit. http://www.blacksburg.gov/Modules/ShowDocument.aspx?documentid=4120 (accessed June 23, 2014) Used with permission from Blacksburg Transit; email attached.
[4] Blacksburg Transit. http://www.blacksburg.gov/Modules/ShowDocument.aspx?documentid=4128 (accessed June 23, 2014) Used with permission from Blacksburg Transit; email attached.
[5] Blacksburg Transit. http://www.blacksburg.gov/Modules/ShowDocument.aspx?documentid=3433 (accessed June 23, 2014) Used with permission from Blacksburg Transit; email attached.

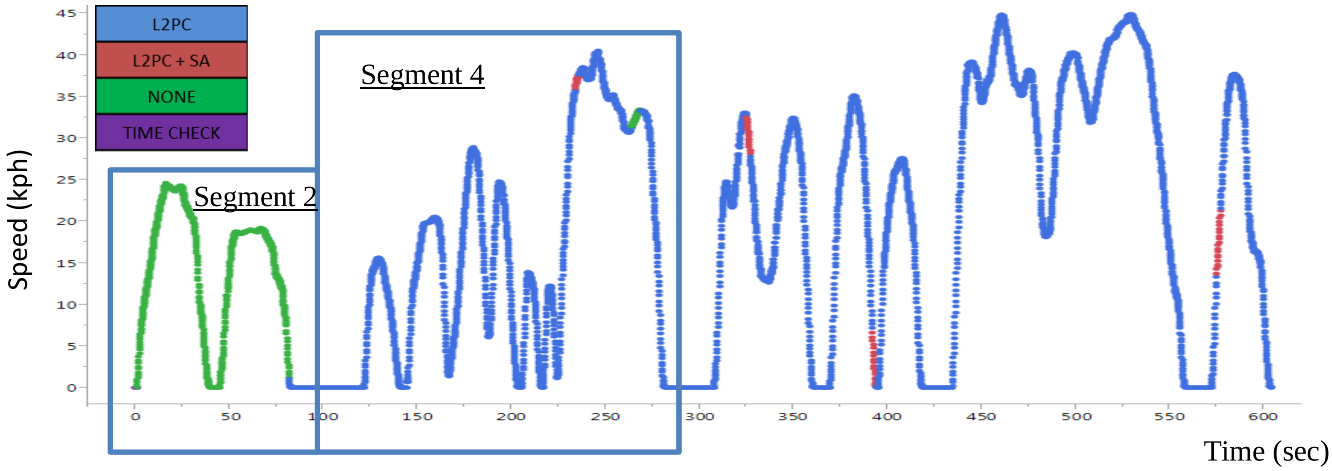


Figure 11 Velocity Profile of HXP Route (from Newman Library - Trial 2)

Figure 10 and **Figure 11** are the example to illustrate data reduction process. Each figure describes the velocity profile of HXP route from Newman Library to the Oak Lane Area. The order of the trial represents driving repetition along this route. Between trial 1 and trial 2, there are 2 significance differences in term of velocity profile. Segment 1 and segment 2 shows pattern difference, in which segment 1 is velocity performance when the operator was exposed by DO Radio and segment 2 when he was just driving. Similarly, segment 3 shows the velocity performance when the operator was just driving and segment 4 when he was exposed by passenger conversation. Notice that in this study, the author particularly defines passenger conversation exposure as any conversation activity of the passengers in the priority seating area of the bus. In addition, the remaining segments of this route seem to not behaving differently in the first and second trial. Thus, those remaining segments were excluded from the sample of discriminant analysis.

From this data reduction process, there were18 segments used for the analysis as following: (a) 6 segments extracted from HXP route; (b) 4 segments extracted from TC route; and (c) 8 segments extracted from TTT route. These segments were summarized in **Table 25**, **Table 26**, and **Table 27**.

5.4. Data Synchronization

There are 3 categories of dataset collected in this study. The observation dataset included demographic profile of operators and exposure events occurred on the bus. The other dataset is CAN-bus data acquired using HEM data logger installed on the buses. Average time stamps difference between HEM data and observation recordings ranged between 32 – 35 seconds. GPS dataset was also collected, combined with HEM Data. HEM data logger used in this study is the DAWN J1939 Mini Logger (**Figure 12**) from HEM Data Corporation. It is designed to collect CAN bus data from heavy duty trucks and off-road-vehicles and it is connected directly on the J1939 connector on the bus.

Table 24 J1939 Mini Logger Specifications[6]

Protocols	
SAE J1939 CAN	Yes
SAE J1708/1587	Yes
No. of Protocol Ports (Channels)	One CAN channel and one for J1708.
Real-time PC data	Yes
Connections to PC	WiFi
Stand-alone Logger	Yes
Store Messages	Yes. Convert to scaled engineering parameters as a post process
On-board Storage	Micro SD card 4GB standard. Up to 32GB allowed.
Auto Start-up	Yes
LEDs for status	RGB
Operating system	Proprietary RTOS
GPS (NMEA 0183)	Option. Internal to Mini Logger.
Wireless (Wi-Fi) or equivalent	Option. Internal to Mini Logger
Cellular modem	Option. Connects with WiFi or serial cable.
Wake-up Input	Yes
Real-time clock (RTC)	Yes
Analog Inputs	
Cabin Temperature Sensor	Option
3-axis MEMS Accelerometer	Option
Expansion	Optional 8 channel **ADAQ Mini Logger**
Environment	
Size (inches) Size (mm)	J1939 Connector: 1.5 Diameter x 2.3 Long 38.1 Diameter x 58.4 Long
Supply Current:	80 mA. Up to 200mA with WiFi
Operating Temperature C	-40 to +70

[6] HEM Data. http://www.hemdata.com/products/dawn/j1939-mini-logger (accessed June 22, 2014) Used with permission from HEM Data Company; email attached.

Operating voltage	6 to 36V
Power Draw while sleeping	3 mA
Warranty	1 Year

Figure 12 HEM Data Logger[7]

5.5. Quantifying Patterns of Speed Transition and Speed Stability

5.5.1. Markov Chains: Speed Transition Probabilities

Markov chains were introduced in 1906 by Andrei Andreyevich Markov (1856–1922) and were named in his honor [26]. The calculations of these transition probabilities were performed in Matlab R2012a software. For this procedure, we define a set of speed state, S, that starts from the value of 0 km/hr with the increment of 4km/hr (S = {0-4, 4-8, 8-12, 12-16,...Si}). The interval of 4 km/hr was selected to ease visual comparison between the transition matrices. The number of states depends on the maximum velocity of each segment. The scanning process starts from one state and moves to another state in sequence.

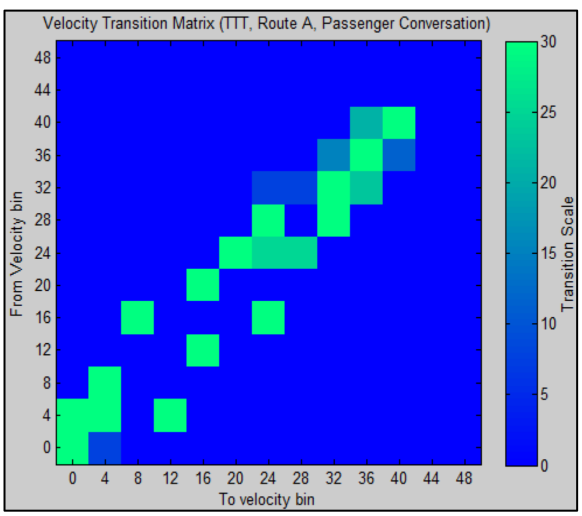


Figure 13 Speed Transition Graph

[7] HEM Data. http://hemdata.com/wp-content/uploads/2012/j1939-high.png (accessed June 22, 2014) Used with permission from HEM Data Company; email attached.

5.5.2. Quantifying Patterns of Speed Transitions

In this part, we designed a system for recognizing speed behavior of the operators based on its speed transition matrix in Matlab. We focused to implement our system (**Figure 15**) to particular segments where the operators were exposed by potential distraction activities. These activities include Dispatch Office (DO) radio, passenger conversation, talking to passenger, and/or other combined activities. The system consists of 7 rules to classify the speed transition pattern, including:

1. Calculate total diagonal transition frequencies (transition1). Diagonal transition represents the stability of speed maintenance. Considering the unequal size of transition matrix, this criterion is then normalized with the total transition frequencies.

```
DiagElements = diag(A); % get diagonal elements from Matrix A
TotFreqDiag = sum(DiagElements); % count all diagonal elements
TotFreq = sum(sum(A)); % count all elements
Criteria1 = TotFreqDiag/TotFreq;
```

2. Count numbers of zero-frequency bins in diagonal (transition2). This second rule detects the numbers of missing transition speed. The result obtained was then normalized with the numbers of non-zero frequency bins in diagonal.

```
ZeroDiagBin = sum(DiagElements(:)==0); % count diagonal elements with zero entries
NonZeroDiagBin = nnz(DiagElements); % count diagonal elements with non-zero entries
Criteria2 = ZeroDiagBin/NonZeroDiagBin;
```

3. Calculate the area of non-zero transition (transition3). This is defined as the total numbers of non-zero transition bins multiplied by 16. The value of 16 is determined by the interval area of transition speed.

```
c = nnz(A);
Criteria3 = c*16;
```

4. Total transition frequencies that deviate by ± 4 km/h (±1 bin) from diagonal transitions (transition4).

```
Diagk1 = sum(diag(A,1)); % get elements in sub diagonal (k=1)
DiagkM1= sum(diag(A,-1)); % get elements in sub diagonal (k=-1)
Criteria4 = (Diagk1 + DiagkM1)/TotFreqDiag;
```

5. Total transition frequencies that deviate by ± 8 km/h (±2 bins) from diagonal transitions (transition5).

```
Diagk2 = sum(diag(A,2)); % get elements in sub diagonal (k=2)
```

```
DiagkM2= sum(diag(A,-2)); % get elements in sub diagonal (k=-2)
Criteria5 = (Diagk2 + DiagkM2)/TotFreqDiag;
```

6. Total transition frequencies that deviate by ± 12 km/h (±3 bins) from diagonal transitions (transition6).

```
Diagk3 = sum(diag(A,3)); % get elements in sub diagonal (k=3)
DiagkM3= sum(diag(A,-3)); % get elements in sub diagonal (k=-3)
Criteria6 = (Diagk3 + DiagkM3)/TotFreqDiag;
```

7. Each of criteria 2, 4, 5, and 6 is normalized with the total transition frequencies in diagonal.

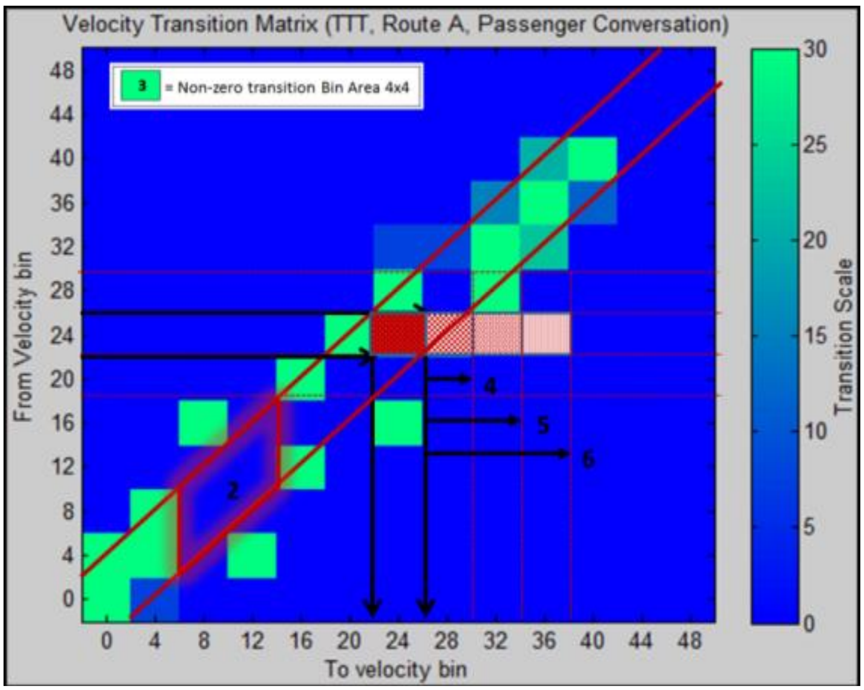


Figure 14 Rules of Pattern Recognition for Speed Transition

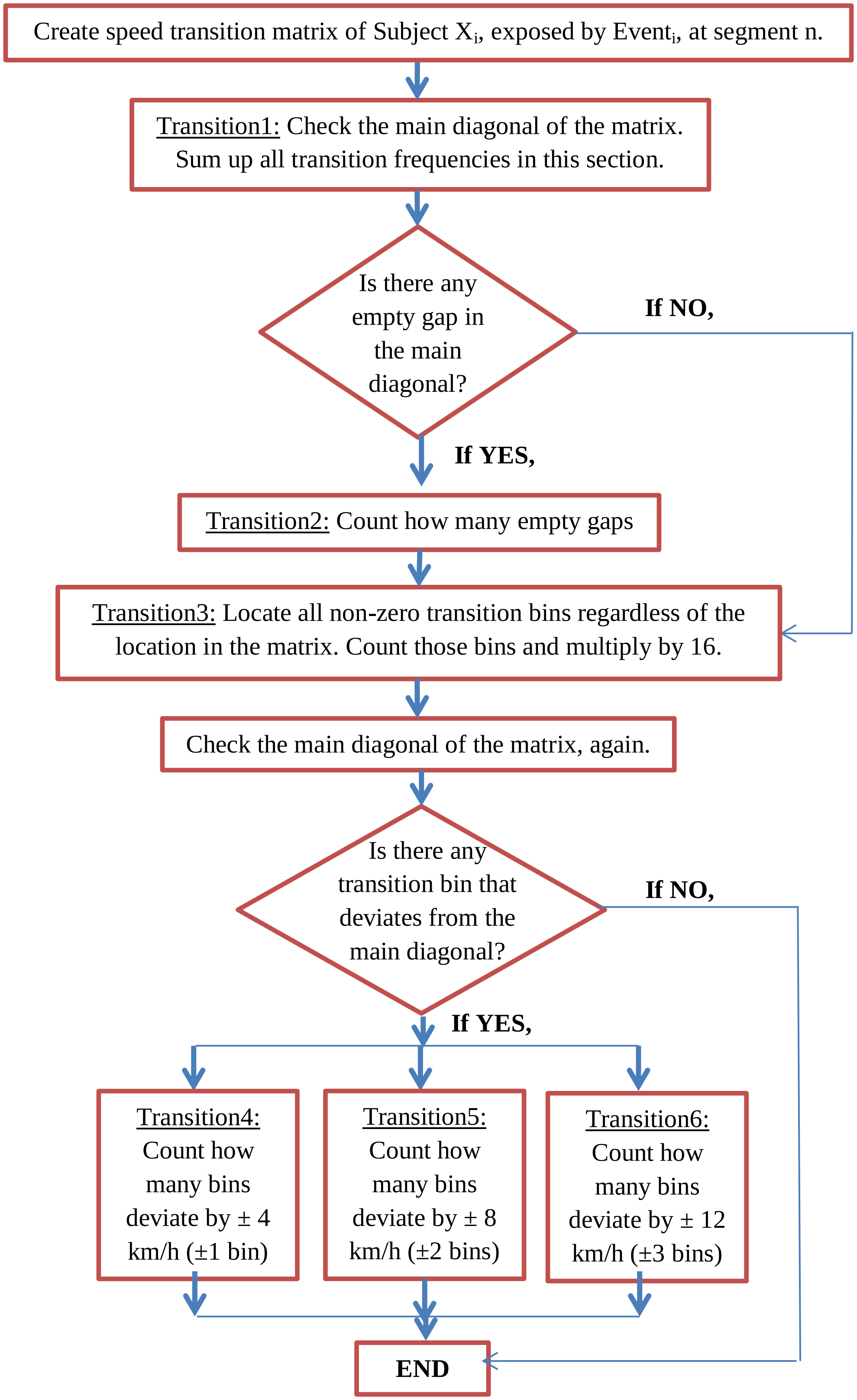


Figure 15 Flowchart of Pattern Recognition for Speed Transition

5.5.3. Quantifying Patterns of Speed Stability

The speed stability pattern is used to substitute missing information from transition speed matrices. The speed stability histogram (see **Figure 16**) displays the average duration of speed maintenance that is organized in a grouped speed interval. Particularly for transit vehicle, we can expect a long average duration in the first speed interval (0-4 km/h) because of the frequent stop. We then grouped second-by-second speed data into the same number of groups of those in speed transition matrices. **Table 25**, **Table 26**, and **Table 27** show the summary of speed transitions and speed stability along the three studied routes. Detailed of these 3 figures are provided in

There are 3 rules to categorize the speed stability pattern between each group:

1. Calculate the average duration of all speed intervals;
2. Calculate the average duration of the first sped interval;
3. Calculate the average duration of the most stable speed interval (defined as the speed interval with the longest average stability duration, excluding the first speed interval).

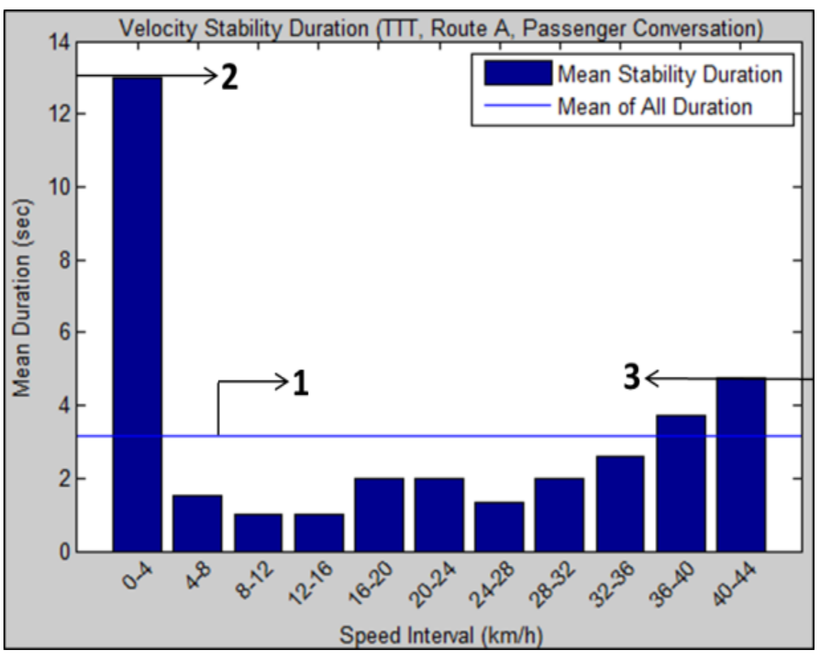


Figure 16 Speed Stability Patterns

Table 25 Summaries of Speed Transition and Speed Stability along TC Route

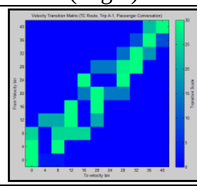
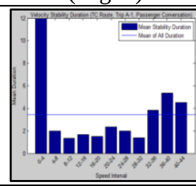
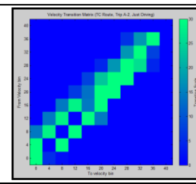
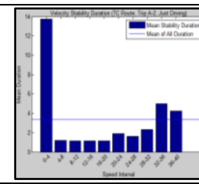
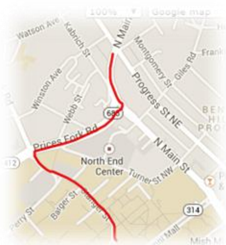
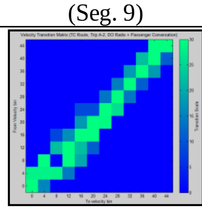
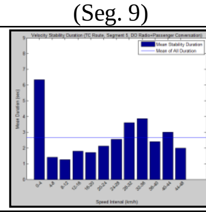
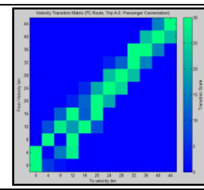
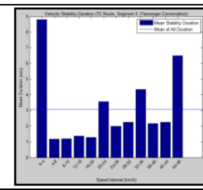
Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Passenger Conversation" (Seg.7)	"Passenger Conversation" (Seg. 7)	"Just Driving" (Seg.8)	"Just Driving" (Seg.8)
				
	"DO Radio + Passenger Conversation" (Seg. 9)	"DO Radio + Passenger Conversation" (Seg. 9)	"Passenger Conversation" (Seg. 10)	"Passenger Conversation" (Seg. 10)
				

Table 26 Summaries of Speed Transition and Speed Stability along HXP Route

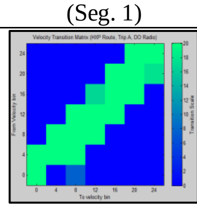
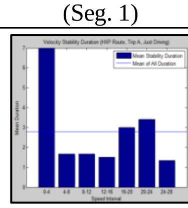
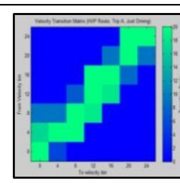
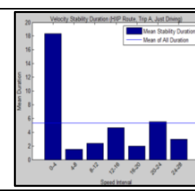
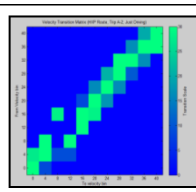
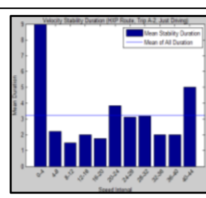
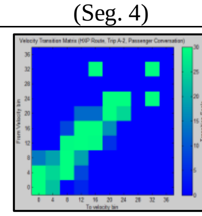
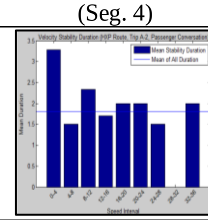
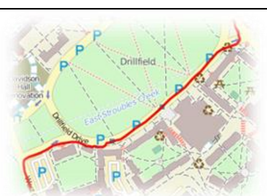
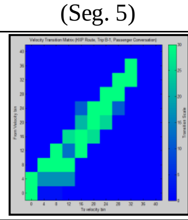
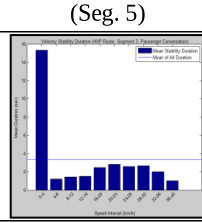
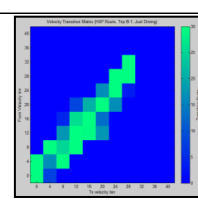
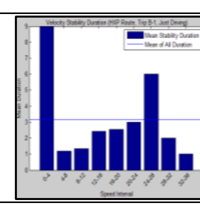
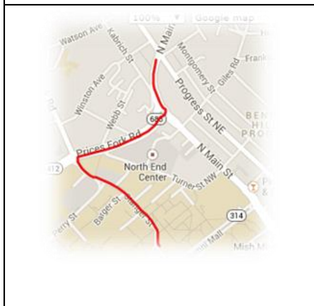
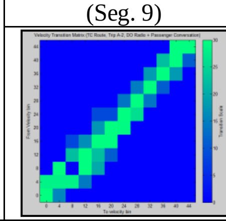
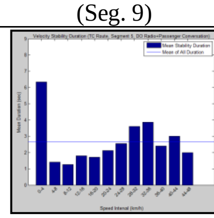
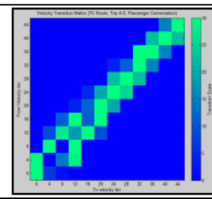
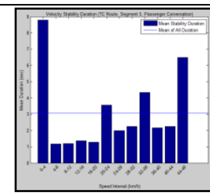
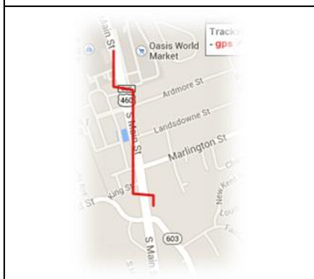
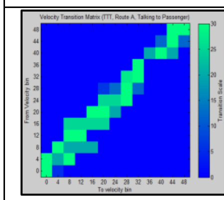
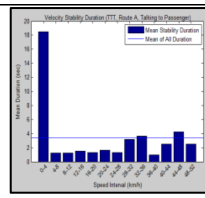
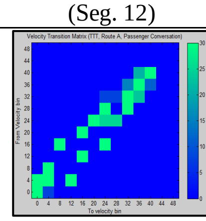
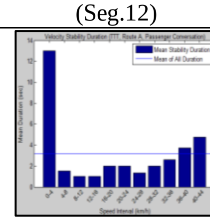
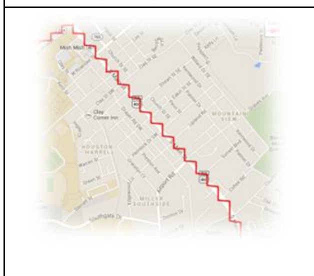
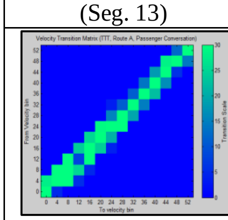
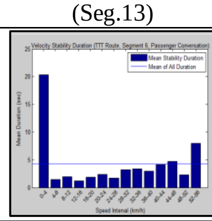
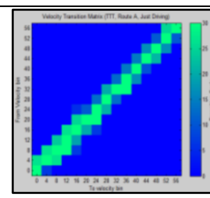
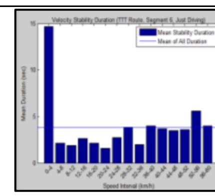
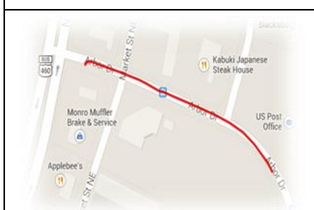
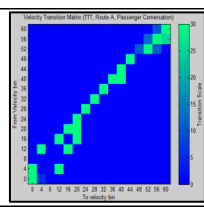
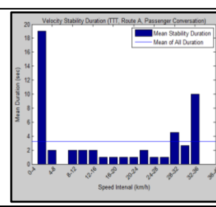
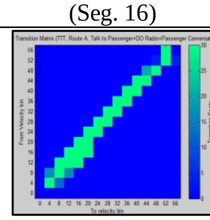
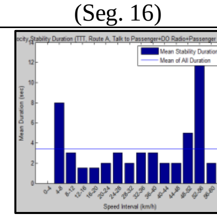
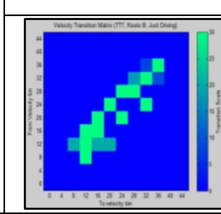
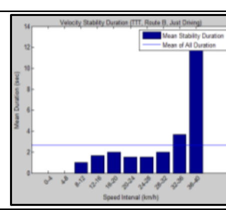
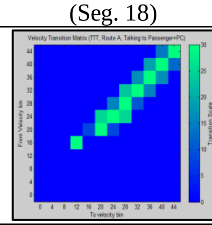
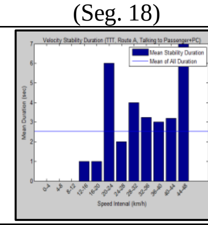
Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Passenger Conversation" (Seg. 1)	"Passenger Conversation" (Seg. 1)	"Just Driving" (Seg. 2)	"Just Driving" (Seg. 2)
				
	"Just Driving" (Seg. 3)	"Just Driving" (Seg. 3)	"Passenger Conversation" (Seg. 4)	"Passenger Conversation" (Seg. 4)
				
	"Passenger Conversation" (Seg. 5)	"Passenger Conversation" (Seg. 5)	"Just Driving" (Seg. 6)	"Just Driving" (Seg. 6)
				

Table 27 Summaries of Speed Transition and Speed Stability along TTT Route

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"DO Radio + Passenger Conversation" (Seg. 9)	"DO Radio + Passenger Conversation" (Seg. 9)	"Passenger Conversation" (Seg. 10)	"Passenger Conversation" (Seg. 10)
				
	"Talk to Passenger" (Seg. 11)	"Talk to Passenger" (Seg. 11)	"Passenger Conversation" (Seg. 12)	"Passenger Conversation" (Seg.12)
				
	"Passenger Conversation" (Seg. 13)	"Passenger Conversation" (Seg.13)	"Just Driving" (Seg. 14)	"Just Driving" (Seg. 14)
				
	"Passenger Conversation" (Seg. 15)	"Passenger Conversation" (Seg. 15)	"Talk to Passenger + DO Radio + Passenger Conversation" (Seg. 16)	"Talk to Passenger + DO Radio + Passenger Conversation" (Seg. 16)
				
	"Just Driving" (Seg. 17)	"Just Driving" (Seg. 17)	"Talk to Passenger + Passenger Conversation" (Seg. 18)	"Talk to Passenger + Passenger Conversation" (Seg. 18)
				

5.6. Discriminant Analysis of Transit Operator Exposure Events

5.6.1. Covariate and Category Variables in Discriminant Analysis

In this section, we employ discriminant analysis to distinguish a set of exposures (read potential distractions) using a set of measurement variables in JMP Pro 11 software from SAS. In this analysis, we introduce 6 exposure categories, consisting of: *Just Driving* (1), *DO Radio* (2), *Passenger Conversation* (3), combination of *DO Radio and Passenger Conversation* (4), combination of *Passenger Conversation and Talking to Passenger* (5), and combination of *DO Radio, Passenger Conversation, and Talking to Passenger* (6). Seventeen covariates (must be continuous variables) were considered to construct a classifier model using linear stepwise variable selection method (*p-value* $\leq$ 0.05). To construct a model, we use 18 segments extracted from 4-hour of observation data along HXP, TC, and TTT routes.

5.6.2. Interpretation of Discriminant Analysis Result

As part of discriminant analysis, the canonical coefficients are used to create the discriminant functions in the model. The number of the discriminant functions produced is the number of groups minus 1. The canonical plots show the points and multivariate means in the two dimensions that best separate the groups (JMP Support Page). The accuracies of the discriminant functions are evaluated based on the number of misclassifications. In addition, the eigenvalue table represents the ability of each discriminant function to explain data variance. The Wilks' Lambda test indicates the significance of the functions; while the value of Wilks' Lambda provides the information of total unexplained variability.

5.6.3. Discriminant Analysis of Trial 1

Trial 1 performs the discriminant with all 6 groups of exposures considered behaving differently. **Figure 17** shows that the discriminant function uses *duration of exposures, segment length, idle time, stability1, stability2, transition2, transition4, transition6, and stop spacing* to construct the model. The canonical plot in this figure clearly shows that the centroids of *Just Driving* (JD) and *Passenger Conversation* (PC), and combination of *DO Radio and Passenger Conversation* (DR_PC), combination of *Passenger Conversation and Talking to Passenger* (PC_T2P) exposures are closed enough to be considered not behaving differently.

Discriminant Analysis

Column Selection

Click to select columns into discriminant model

Columns In	9	Smallest P to Enter	0.4811325
Columns Out	7	Largest P to Remove	0.0934841

Step Forward | Enter All | Step Backward | Remove All | Apply This Model

Lock	Entered	Column	F Ratio	Prob>F
☐	☑	Duration of Exposure (sec)	4.234	0.0934841
☐	☑	Segment Length (m)	7.444	0.0372742
☐	☑	Idle time (sec) w/ V<1 km/h	14.136	0.0118857
☐	☐	Driver Age	0.499	0.7682163
☐	☐	Driver Experience	1.109	0.4978623
☐	☑	Stability1	281.476	0.0000350
☐	☑	Stability2	42.781	0.0014473
☐	☐	Stability3	0.588	0.7188409
☐	☐	Transition1	1.162	0.4811325
☐	☑	Transition2	9.318	0.0252203
☐	☐	Transition3	0.273	0.9017547
☐	☑	Transition4	24.664	0.0041833
☐	☐	Transition5	0.799	0.6154883
☐	☑	Transition6	36.396	0.0019804
☐	☑	Stop Spacing (m)	9.837	0.0229118
☐	☐	No.Stop	0.240	0.9205292

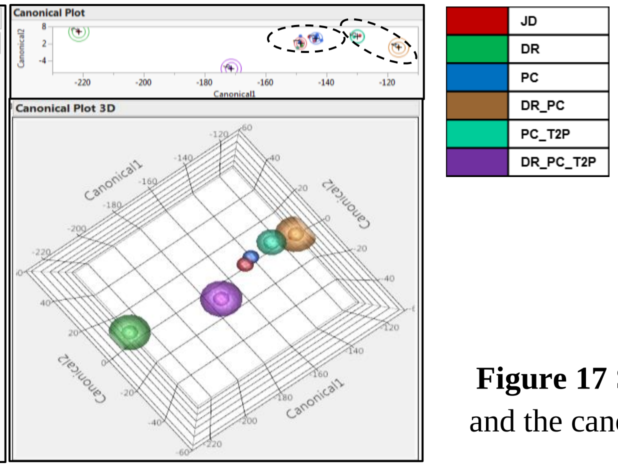


Figure 17 Selected predictors and the canonical plot (Trial 1)

In **Figure 18**, the eigenvalues describes the variability produced from the discriminant functions. For example, the first discriminant function (Canon1) can explain 97.8166% of data variance, while the others can explain the remaining 2.1834%. The Wilks' Lambda test shows that using 9 predictors in the discriminant functions can significantly distinguish between 6 exposures (p-values < 0.0001); and about 0.00148% of variance is left unexplained. Misclassification rate from this model is zero percent.

Eigenvalue	Percent	Cum Percent	Canonical Corr	Likelihood Ratio	Approx. F	NumDF	DenDF	Prob>F
642.642207	97.8166	97.8166	0.99922287	1.47925e-5	5.1396	45	20.996	<.0001*
10.2545301	1.5608	99.3774	0.95454015	0.00952106	1.5856	32	20.034	0.1405
2.9984122	0.4564	99.8338	0.86596808	0.10715503	0.9962	21	17.779	0.5083
0.78233744	0.1191	99.9529	0.66252473	0.42844997	0.6157	12	14	0.7972
0.30951343	0.0471	100.0000	0.48616621	0.76364242	0.4952	5	8	0.7723

Test	Value	Approx. F	NumDF	DenDF	Prob>F
Wilks' Lambda	0.0000148	5.1396	45	20.996	<.0001*
Pillai's Trace	3.3347906	1.7801	45	40	0.0331*
Hotelling-Lawley	656.987	58.3988	45	4	0.0006*
Roy's Max Root	642.64221	571.2375	9	8	<.0001*

▷ Within Matrix

▷ Between Matrix

	Training
Number Misclassified	0
Percent Misclassified	0
-2LogLikelihood	0.076

Training

Counts: Actual Rows by Predicted Columns

	1	2	3	4	5	6
1	6	0	0	0	0	0
2	0	1	0	0	0	0
3	0	0	7	0	0	0
4	0	0	0	1	0	0
5	0	0	0	0	2	0
6	0	0	0	0	0	1

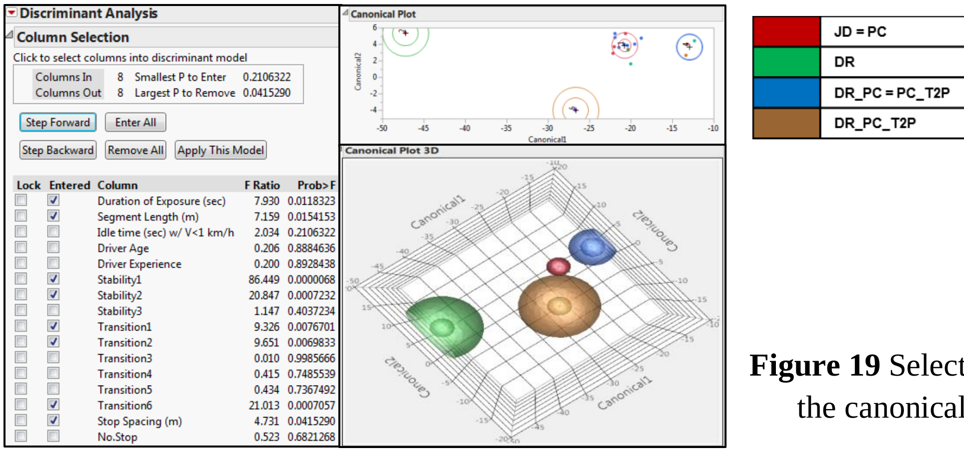
Scoring Coefficients

	Duration of Exposure (sec)	Segment Length (m)	Idle time (sec) w/ V<1 km/h	Stability1	Stability2	Transition2	Transition4	Transition6	Stop Spacing (m)
Canon1	0.0514123	-0.005632	0.2761855	-47.09074	1.5906999	-9.327277	-43.8894	-1440.959	0.0008614
Canon2	0.0415102	-0.006844	0.0052558	0.1311549	0.2204093	3.2722112	-2.944321	190.729	8.957e-5
Canon3	0.0158985	-0.002033	-0.069247	-1.43601	0.1162444	-2.915352	-4.145687	-88.95687	0.0003066
Canon4	0.0153248	0.0002346	-0.062842	0.2350888	0.073748	0.8574565	4.9677268	-50.33092	-3.436e-5
Canon5	-0.009681	0.0009335	0.0183331	-0.129824	0.0367737	0.0555622	-2.730532	172.004	8.3229e-5

Figure 18 Discriminant Functions and Classification Accuracy (Trial 1)

5.6.4. Discriminant Analysis of Trial 2

In trial 2, we included only 4 groups of exposures in the analysis, of which 2 groups consist of 4 merged exposures from trial 1 (combination of JD+PC and DR_PC+PC_T2P). Ten predictors are considered to construct the model (see **Figure 19**). The canonical plot in trial 2 shows better separation distances of the exposures. The first function of this model can explain 92.531% of data variance with zero misclassification rates.



Lock	Entered	Column	F Ratio	Prob>F
☐	☑	Duration of Exposure (sec)	7.930	0.0118323
☐	☑	Segment Length (m)	7.159	0.0154153
☐	☐	Idle time (sec) w/ V<1 km/h	2.034	0.2106322
☐	☐	Driver Age	0.206	0.8884636
☐	☐	Driver Experience	0.200	0.8928438
☐	☑	Stability1	86.449	0.0000068
☐	☑	Stability2	20.847	0.0007232
☐	☐	Stability3	1.147	0.4037234
☐	☑	Transition1	9.326	0.0076701
☐	☑	Transition2	9.651	0.0069833
☐	☐	Transition3	0.010	0.9985666
☐	☐	Transition4	0.415	0.7485539
☐	☐	Transition5	0.434	0.7367492
☐	☑	Transition6	21.013	0.0007057
☐	☑	Stop Spacing (m)	4.731	0.0415290
☐	☐	No.Stop	0.523	0.6821268

Figure 19 Selected predictors and the canonical plot (Trial 2)

Eigenvalue	Percent	Cum Percent	Canonical Corr	Likelihood Ratio	Approx. F	NumDF	DenDF	Prob>F
65.3528434	92.5310	92.5310	0.99243592	0.00146934	7.3848	24	20.903	<.0001*
4.36250199	6.1767	98.7077	0.90195337	0.09749457	2.5173	14	16	0.0397*
0.91272307	1.2923	100.0000	0.6907859	0.52281484	1.3691	6	9	0.3222

Test	Value	Approx. F	NumDF	DenDF	Prob>F
Wilks' Lambda	0.0014693	7.3848	24	20.903	<.0001*
Pillai's Trace	2.2756341	3.5342	24	27	0.0010*
Hotelling-Lawley	70.628069	18.6686	24	9.4419	<.0001*
Roy's Max Root	65.352843	73.5219	8	9	<.0001*

Training

Counts: Actual Rows by Predicted Columns

	1	2	4	6
1	13	0	0	0
2	0	1	0	0
4	0	0	3	0
6	0	0	0	1

▷ Within Matrix

▷ Between Matrix

Scoring Coefficients

	Duration of Exposure (sec)	Segment Length (m)	Stability1	Stability2	Transition1	Transition2	Transition6	Stop Spacing (m)
Canon1	0.0368331	-0.002704	-18.2251	0.6678406	43.08304	-5.601178	-654.3293	0.0003979
Canon2	0.0347112	-0.00507	-0.213842	0.1534459	2.496933	2.6793573	55.14148	-0.000045
Canon3	0.0037071	-0.001721	-1.585716	0.053753	21.354968	-1.972499	16.781064	9.8531e-5

Figure 20 Discriminant Functions and Classification Accuracy (Trial 2)

CHAPTER VI OBSERVATIONAL STUDY OF DISTRACTED DRIVING BEHAVIORS DURING BT'S SUMMER-SERVICE

6.1. About the Observation

The same observation procedures were conducted during Blacksburg Transit (BT)'s Summer-service period. The study data were collected on weekdays from 12:00 PM to 7:00 PM, for a total of 12-hour observation. Participating BT operators consist of 3 young and 4 old operators; of those, 1 is novice, 4 experienced and the other 2 are very experienced operators.

During summer service session, each route provides 30 minute or hourly service. In addition, some routes do not operate or are combined with other routes. Hokie Express does not operate in Summer, while Toms Creek B (TCB) route is combined with University City Boulevard (UCB) route. In this particular observation, there are 2 routes selected: Hethwood (HWD) route and TCB route. During this service, HWD buses serve two routes – HWD A and HWD B – with timecheck at Burrus Hall and Stroubles Circle. This route has the highest average daily ridership among the other routes with a 30-minute frequency service. The TCB route connects with UCB route and serves the Virginia Tech campus, University Mall area, Patrick Henry, and Progress Street. Following (**Table 28**) is the description of each observed route:

Table 28 Observed BT routes during Summer Session

No.	Route Abbreviation	Route Full Name	Number of Stops	Route Length (feet)	Average Bus Stop Spacing (ft/stop)
1	HWD	Hethwood	13	17952	1353.23
		Hethwood (return trip)	12	15840	1320.00
2	TCB	Toms Creek B	8	8976	1122.00
		Toms Creek B (return trip)	10	10032	1003.20

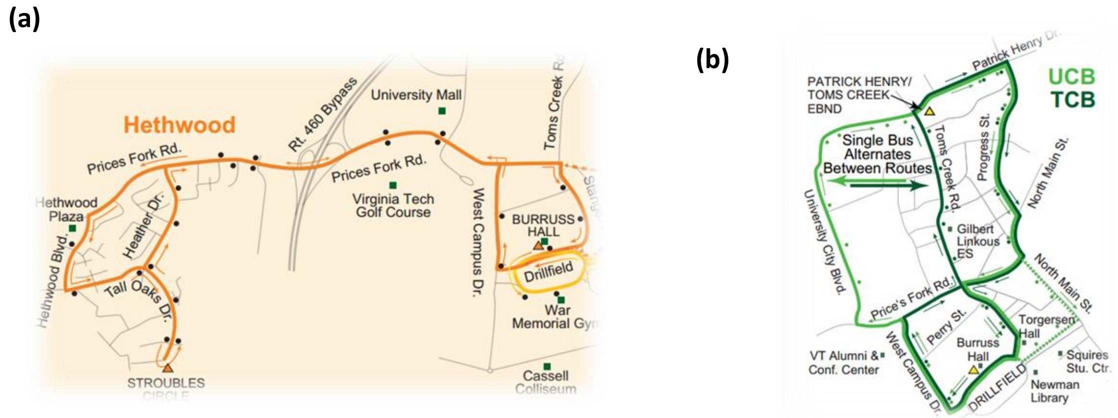
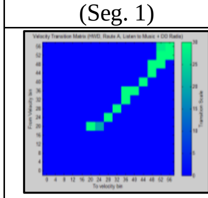
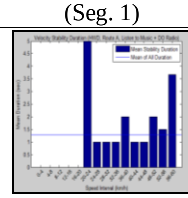
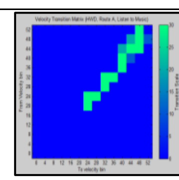
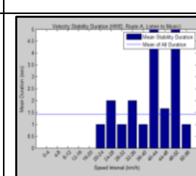
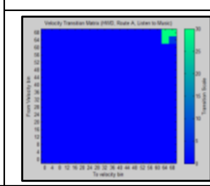
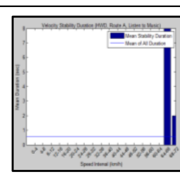
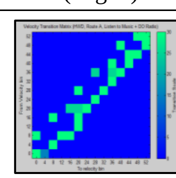
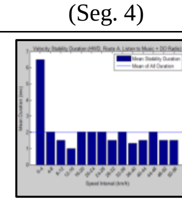


Figure 21 (a) HWD route[8]; (b) TCB route[9]

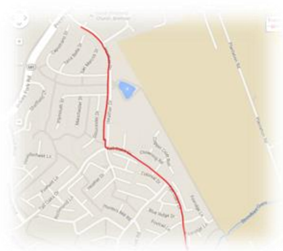
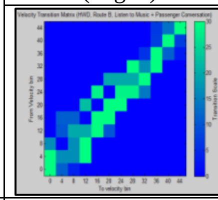
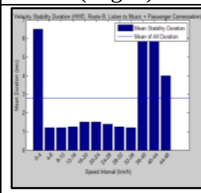
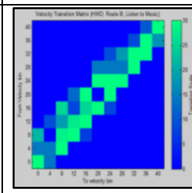
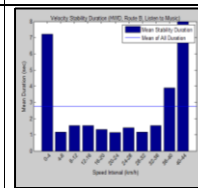
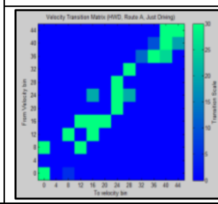
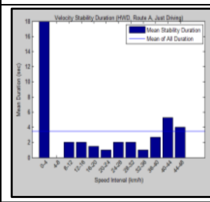
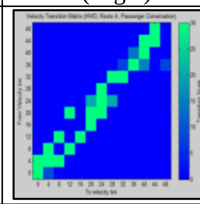
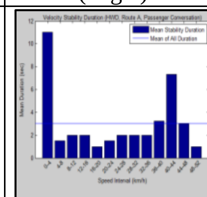
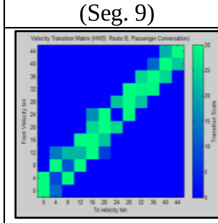
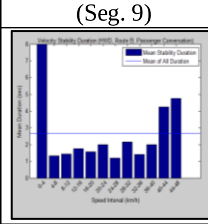
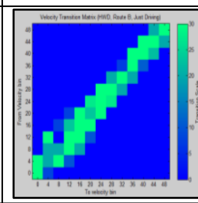
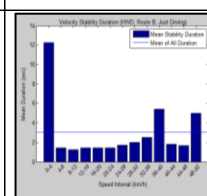
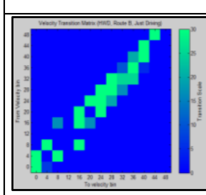
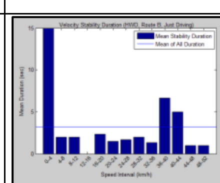
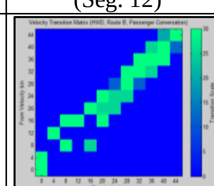
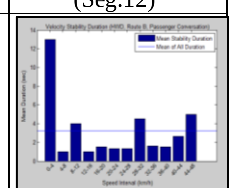
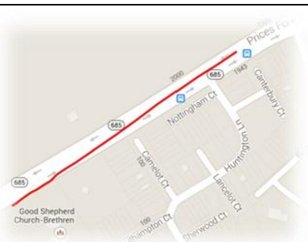
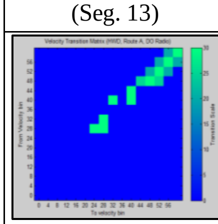
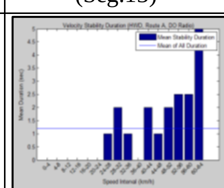
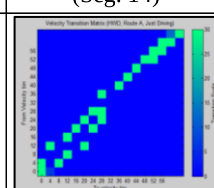
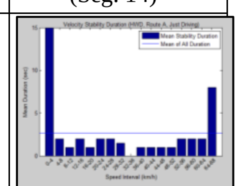
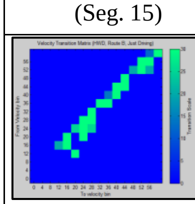
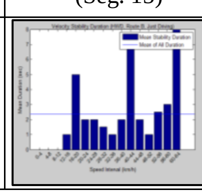
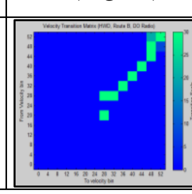
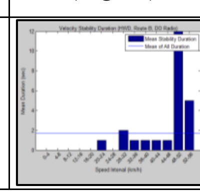
6.2. Quantifying Patterns of Speed Transition and Speed Stability

To quantify the patterns of both speed transition and speed stability, the rules explained in section 5.5.2 and 5.5.3 were applied to the study data. Out of 12-hour observation, about 43 segments were extracted and used for model analysis, namely: (a) 22 segments extracted from HWD route; (b) 16 segments extracted from TCB route; and (c) 14 segments extracted from UCB route. These segments were summarized in **Table 29**, and **Table 30**.

Table 29 Summaries of Speed Transition and Speed Stability along HWD Route (Summer)

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Listen to Music + DO Radio" (Seg. 1)	"Listen to Music + DO Radio" (Seg. 1)	"Listen to Music" (Seg. 2)	"Listen to Music" (Seg. 2)
				
	"Listen to Music" (Seg. 3)	"Listen to Music" (Seg. 3)	"Listen to Music + DO Radio" (Seg. 4)	"Listen to Music + DO Radio" (Seg. 4)
				

[8] Blacksburg Transit. http://www.blacksburg.gov/Modules/ShowDocument.aspx?documentid=3719 (accessed July 3, 2014) Used with permission from Blacksburg Transit; email attached.
[9] Blacksburg Transit. http://www.blacksburg.gov/Modules/ShowDocument.aspx?documentid=3918 (accessed July 3, 2014) Used with permission from Blacksburg Transit; email attached.

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Listen to Music + Passenger Conversation" (Seg. 5)	"Listen to Music + Passenger Conversation" (Seg. 5)	"Listen to Music" (Seg. 6)	"Listen to Music" (Seg. 6)
				
	"Just Driving" (Seg.7)	"Just Driving" (Seg.7)	"Passenger Conversation" (Seg.8)	"Passenger Conversation" (Seg.8)
				
	"Passenger Conversation" (Seg. 9)	"Passenger Conversation" (Seg. 9)	"Just Driving" (Seg. 10)	"Just Driving" (Seg. 10)
				
	"Just Driving" (Seg. 11)	"Just Driving" (Seg. 11)	"Passenger Conversation" (Seg. 12)	"Passenger Conversation" (Seg.12)
				
	"DO Radio" (Seg. 13)	"DO Radio" (Seg.13)	"Just Driving" (Seg. 14)	"Just Driving" (Seg. 14)
				
	"Just Driving" (Seg. 15)	"Just Driving" (Seg. 15)	"DO Radio" (Seg. 16)	"DO Radio" (Seg. 16)
				

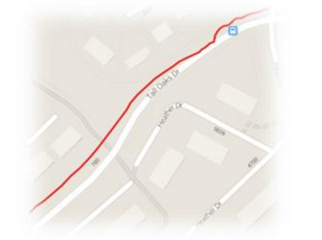
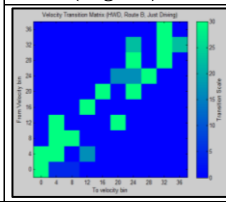
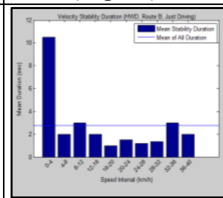
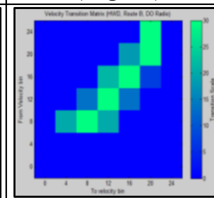
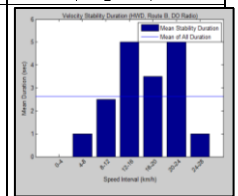
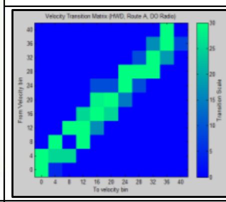
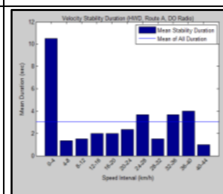
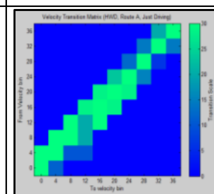
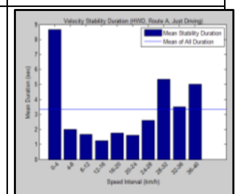
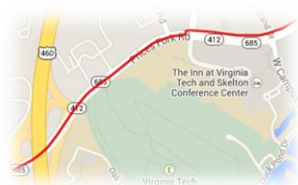
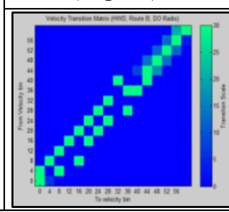
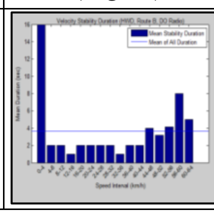
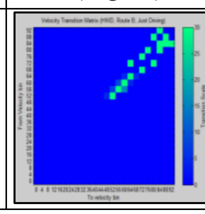
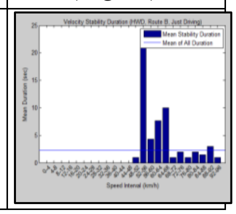
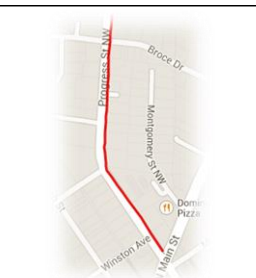
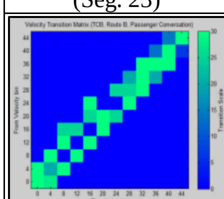
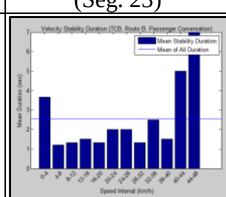
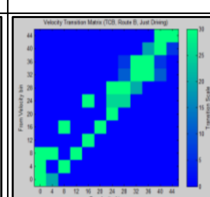
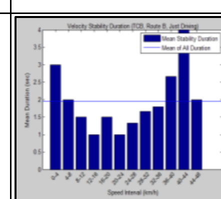
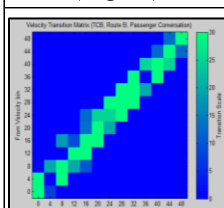
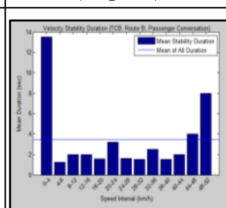
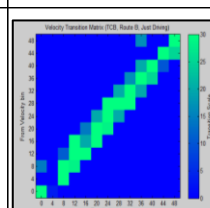
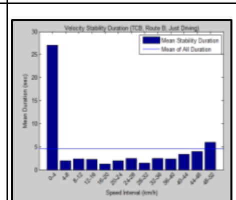
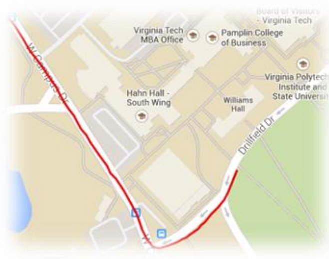
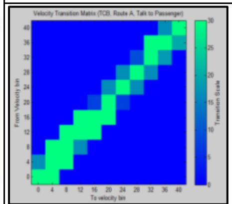
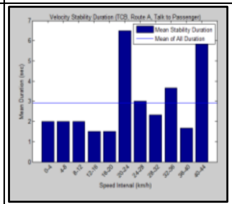
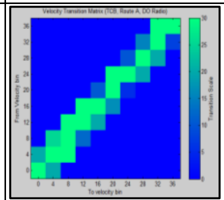
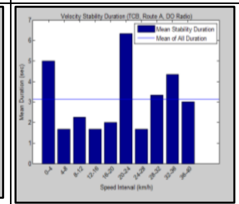
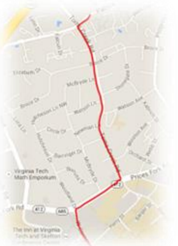
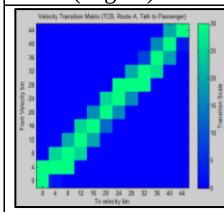
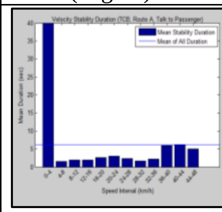
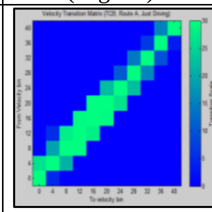
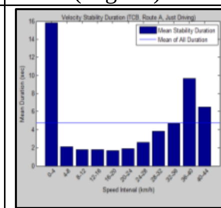
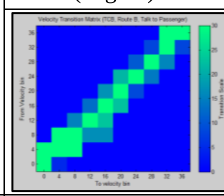
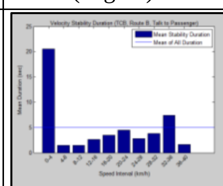
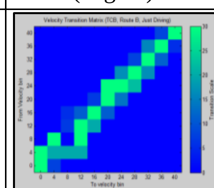
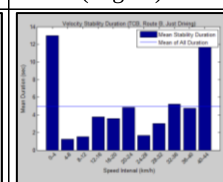
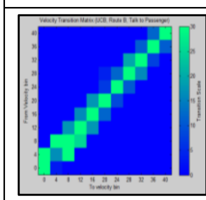
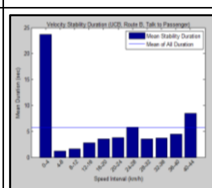
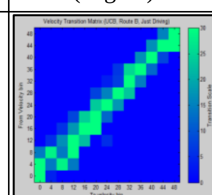
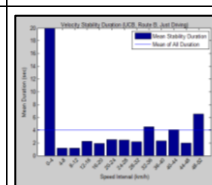
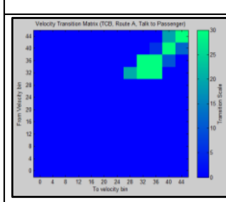
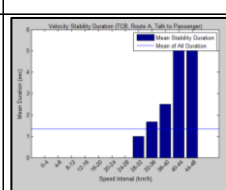
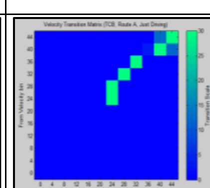
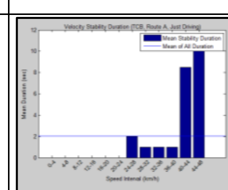
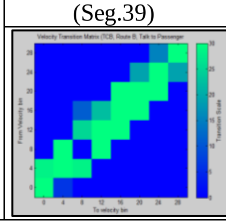
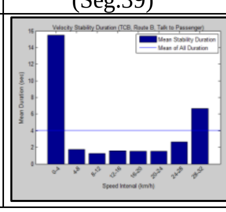
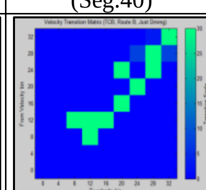
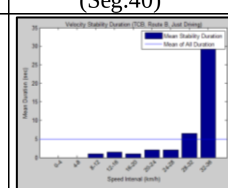
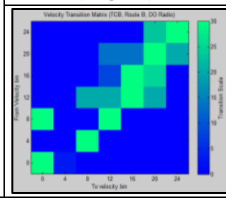
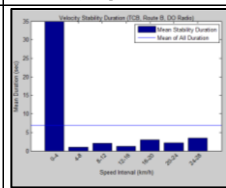
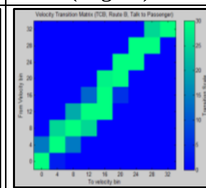
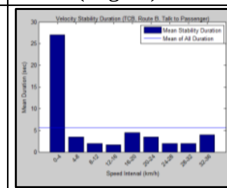
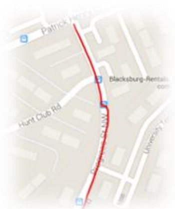
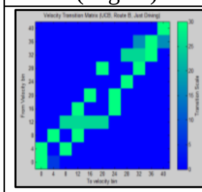
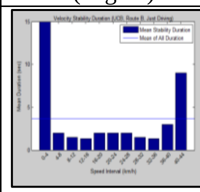
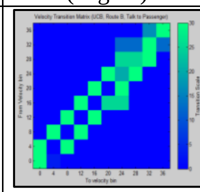
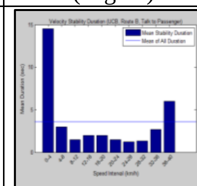
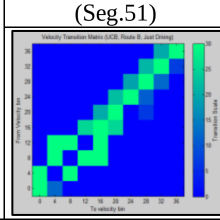
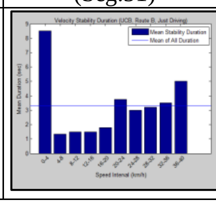
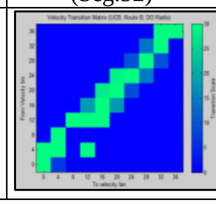
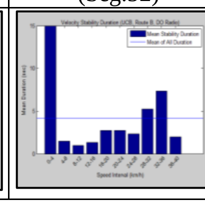
Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Just Driving" (Seg. 17)	"Just Driving" (Seg. 17)	"DO Radio" (Seg. 18)	"DO Radio" (Seg. 18)
				
	"DO Radio" (Seg. 19)	"DO Radio" (Seg. 19)	"Just Driving" (Seg. 20)	"Just Driving" (Seg. 20)
				
	"DO Radio" (Seg. 21)	"DO Radio" (Seg. 21)	"Just Driving" (Seg. 22)	"Just Driving" (Seg. 22)
				

Table 30 Summaries of Speed Transition and Speed Stability along TCB Route (Summer)

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"Passenger Conversation" (Seg. 23)	"Passenger Conversation" (Seg. 23)	"Just Driving" (Seg. 24)	"Just Driving" (Seg. 24)
				
	"Passenger Conversation" (Seg. 25)	"Passenger Conversation" (Seg. 25)	"Just Driving" (Seg. 26)	"Just Driving" (Seg. 26)
				

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	“Talk to Passenger” (Seg.27)	“Talk to Passenger” (Seg.27)	“DO Radio” (Seg.28)	“DO Radio” (Seg.28)
				
	“Talk to Passenger” (Seg.29)	“Talk to Passenger” (Seg.29)	“Just Driving” (Seg. 30)	“Just Driving” (Seg. 30)
				
	“Talk to Passenger” (Seg.31)	“Talk to Passenger” (Seg.31)	“Just Driving” (Seg.32)	“Just Driving” (Seg.32)
				
	“Talk to Passenger” (Seg.35)	“Talk to Passenger” (Seg.35)	“Just Driving” (Seg.36)	“Just Driving” (Seg.36)
				
	“Talk to Passenger” (Seg.37)	“Talk to Passenger” (Seg.37)	“Just Driving” (Seg.38)	“Just Driving” (Seg.38)
				
	“Talk to Passenger” (Seg.39)	“Talk to Passenger” (Seg.39)	“Just Driving” (Seg.40)	“Just Driving” (Seg.40)
				

Location	Speed Transition (1)	Speed Stability (1)	Speed Transition (2)	Speed Stability (2)
	"DO Radio" (Seg.41) 	"DO Radio" (Seg.41) 	"Talk to Passenger" (Seg.42) 	"Talk to Passenger" (Seg.42) 
	"Just Driving" (Seg.45) 	"Just Driving" (Seg.45) 	"Talk to Passenger" (Seg.46) 	"Talk to Passenger" (Seg.46) 
	"Just Driving" (Seg.51) 	"Just Driving" (Seg.51) 	"DO Radio" (Seg.52) 	"DO Radio" (Seg.52) 

6.3. Discriminant Analysis of Transit Operator Exposure Events (Summer Session)

The objective of conducting the second survey was to collect more data with less variability. Then, discriminant analyses were carried out to each of route data. *Bus stop spacing, number of stops predictors*, *driver age*, and *driver experience* were not considered to create the model. The same principals of discriminant analysis (DA) in section 5.6 were applied in this process. The study data were divided into 2 categories: (1) model data that are used to construct a DA model and (2) validation data that are used to validate the results.

6.3.1. Dividing Observation Set

To select the samples for model and validation, a stratified random sampling method was chosen. In stratified random sampling, the categories (strata) are formed based on distraction/exposure group. This method was selected considering the importance of having each of distraction sample groups in validation dataset. An adds-in "*Stratified Random Row Selection"* SAS program developed by Jong-Seok Lee was applied in this process [21]. A sampling rate of 15%

was set into the program. As a result, there were a total of 22 segments selected on TCB and HWD route with 8 segments used for validation dataset.

6.3.2. Discriminant Analysis of Trial 1 (TCB Route)

In this section, a *step forward* Discriminant Analysis method was performed in JMP Pro 11. Trial 1 considered *Just Driving (1), DO Radio (2), Passenger Conversation (3),* and *Talk to Passenger (7)* behaving differently. **Figure 22** showed that there are 4 independent variables included in DA: *stability2, transition4, transition5, and transition6*; they were considered able to significantly distinguish the distraction groups. The results (see **Figure 23**) showed that a significance of model (α = 0.1) was achieved with the value of 0.0978. About 79.33% of data variability was able to be explained by this model. A misclassification rate of 21.43% was obtained.

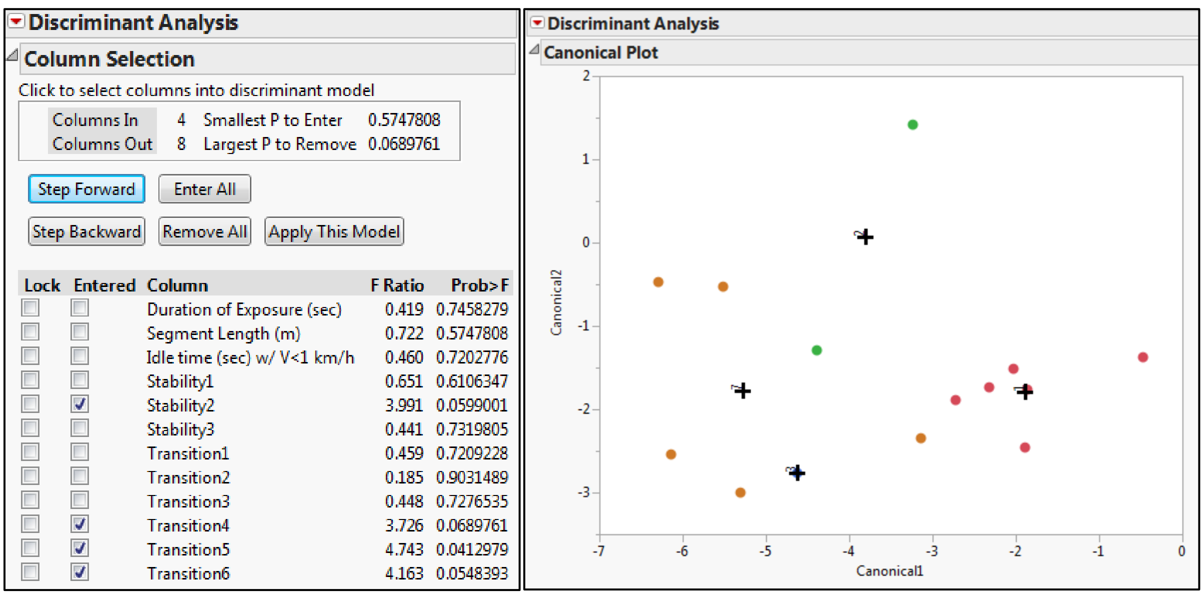


Figure 22 Selected Predictors and the Canonical Plot of Trial 1 (TCB Route)

Eigenvalue	Percent	Cum Percent	Canonical Corr	Likelihood Ratio	Approx. F	NumDF	DenDF	Prob>F
3.2817438	79.3309	79.3309	0.87547147	0.11981659	1.9281	12	18.812	0.0978
0.72514566	17.5292	96.8601	0.64833541	0.51302395	1.0564	6	16	0.4273
0.1298911	3.1399	100.0000	0.33905598	0.88504104	0.5845	2	9	0.5772

Test	Value	Approx. F	NumDF	DenDF	Prob>F
Wilks' Lambda	0.1198166	1.9281	12	18.812	0.0978
Pillai's Trace	1.3017481	1.7247	12	27	0.1166
Hotelling-Lawley	4.1367806	2.2408	12	8.6667	0.1202
Roy's Max Root	3.2817438	7.3839	4	9	0.0064*

▷ Within Matrix

▷ Between Matrix

Scoring Coefficients

	Stability2	Transition4	Transition5	Transition6
Canon1	-0.134681	-9.767311	66.565148	483.3583
Canon2	0.0562273	-7.316686	24.445268	-152.4178
Canon3	0.0131028	1.5564848	19.567883	-76.64161

	Training
Number Misclassified	3
Percent Misclassified	21.43
-2LogLikelihood	11.2

Training

Counts: Actual Rows by Predicted Columns

	1	2	3	7	Other
1	6	0	0	0	0
2	0	1	0	1	0
3	0	0	0	1	0
7	1	0	0	4	0
Other	0	0	0	0	0

Figure 23 Discriminant Functions and Classification Accuracy of Trial 1 (TCB Route)

6.3.3. Discriminant Analysis of Trial 2 (HWD Route)

In trial 2, distraction groups here included *Just driving (1), DO Radio (2), Passenger Conversation (3), Talk to Passenger (7), Listening to Music (8), combined Listening to Music and DO Radio (9),* and *combined Listening to Music and Passenger Conversation (10).* Predictors in the model were *segment length*, *transition3*, and *transition4* as shown in **Figure 24**. A significance of discriminant function is achieved with Wilk's Lambda value of 0.0024 (**Figure 25**). This provides a total of 81.77% explained variability. The classification results also revealed that 14.29% of exposure events (distractions) were misclassified.

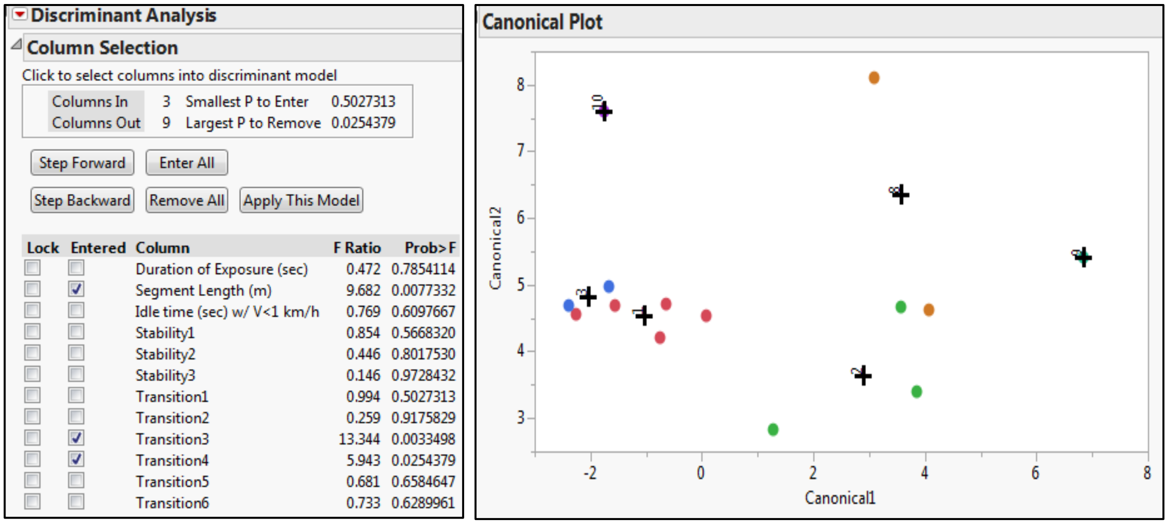


Figure 24 Selected Predictors and the Canonical Plot of Trial 2 (HWD Route)

Eigenvalue	Percent	Cum Percent	Canonical Corr	Likelihood Ratio	Approx. F	NumDF	DenDF	Prob>F
13.043222	81.7665	81.7665	0.96373818	0.0128918	4.3390	15	16.965	0.0024*
2.16133254	13.5492	95.3157	0.82684805	0.18104236	2.3629	8	14	0.0762
0.74722816	4.6843	100.0000	0.65396093	0.5723351	1.9926	3	8	0.1937

Test	Value	Approx. F	NumDF	DenDF	Prob>F
Wilks' Lambda	0.0128918	4.3390	15	16.965	0.0024*
Pillai's Trace	2.0401339	3.4007	15	24	0.0037*
Hotelling-Lawley	15.951783	5.8875	15	7.2075	0.0112*
Roy's Max Root	13.043222	20.8692	5	8	0.0002*

Within Matrix

Between Matrix

Scoring Coefficients

	Segment Length (m)	Transition3	Transition4
Canon1	0.0113029	-0.032603	11.786133
Canon2	0.0035158	0.0013226	4.2780769
Canon3	-0.0023	0.0048672	5.1516286

	Training
Number Misclassified	2
Percent Misclassified	14.29
-2LogLikelihood	9.211

Training

Counts: Actual Rows by Predicted Columns

	1	2	3	8	9	10
1	5	0	0	0	0	0
2	0	3	0	0	0	0
3	1	0	1	0	0	0
8	0	1	0	1	0	0
9	0	0	0	0	1	0
10	0	0	0	0	0	1

Figure 25 Discriminant Functions and Classification Accuracy of Trial 2 (HWD Route)

6.3.4. Model Validation

The next step of this analysis is to validate discriminant equations from Trial 1 and Trial 2 using validation dataset. After applying the discriminant formula of original dataset to a new validation dataset, a contingency table is provided to estimate the expected error rate of the computed classifications. Misclassified data were shown on the off diagonal of the contingency table.

The results showed that when using the discriminant model created from Trial 1, the expected error rate is 37.5% with a hundred percent accuracy in classifying *Passenger Conversation (3)* and *Talk to passenger (7)* activities. Similarly, Trial 2 model also has 37.5% expected rate on validation dataset. Distraction groups that were classified correctly include 66.7% of *Just Driving (1)*, 100% of *DO Radio (2)*, *Listening to Music (8)*, and *combined Listening to Music and DO Radio (9)* activities. In addition, this 37.5% of misclassification was obtained using only 22 segments. Therefore, if more data were added to model dataset, we could expect smaller misclassification rate.

Contingency Table

Pred Exposure	Count / Total % / Col % / Row %	Exposure 1	2	3	7	
1	Count	1	0	0	0	1
	Total %	12.50	0.00	0.00	0.00	12.50
	Col %	33.33	0.00	0.00	0.00	
	Row %	100.00	0.00	0.00	0.00	
3	Count	0	0	1	0	1
	Total %	0.00	0.00	12.50	0.00	12.50
	Col %	0.00	0.00	100.00	0.00	
	Row %	0.00	0.00	100.00	0.00	
7	Count	2	1	0	3	6
	Total %	25.00	12.50	0.00	37.50	75.00
	Col %	66.67	100.00	0.00	100.00	
	Row %	33.33	16.67	0.00	50.00	
	Count	3	1	1	3	8
	Total %	37.50	12.50	12.50	37.50	

(a) Trial 1

Contingency Table

Pred Exposure	Count / Total % / Col % / Row %	Exposure 1	2	3	8	9	
1	Count	2	0	0	0	0	2
	Total %	25.00	0.00	0.00	0.00	0.00	25.00
	Col %	66.67	0.00	0.00	0.00	0.00	
	Row %	100.00	0.00	0.00	0.00	0.00	
2	Count	0	2	0	1	0	3
	Total %	0.00	25.00	0.00	12.50	0.00	37.50
	Col %	0.00	100.00	0.00	100.00	0.00	
	Row %	0.00	66.67	0.00	33.33	0.00	
3	Count	1	0	0	0	0	1
	Total %	12.50	0.00	0.00	0.00	0.00	12.50
	Col %	33.33	0.00	0.00	0.00	0.00	
	Row %	100.00	0.00	0.00	0.00	0.00	
8	Count	0	0	1	0	0	1
	Total %	0.00	0.00	12.50	0.00	0.00	12.50
	Col %	0.00	0.00	100.00	0.00	0.00	
	Row %	0.00	0.00	100.00	0.00	0.00	
9	Count	0	0	0	0	1	1
	Total %	0.00	0.00	0.00	0.00	12.50	12.50
	Col %	0.00	0.00	0.00	0.00	100.00	
	Row %	0.00	0.00	0.00	0.00	100.00	
	Count	3	2	1	1	1	8
	Total %	37.50	25.00	12.50	12.50	12.50	

(b) Trial 2

Figure 26 The Contingency Tables of Validation Datasets

The following **Table 31** is the summary of discriminant analysis (DA) models constructed using the study data during BT's Full-Service period and during BT's Summer-Service period. The value of each predictor in the table represents the value of DA Canon 1 model coefficients.

Table 31 Summary of Discriminant Analysis Models

Type of Predictor	Predictor	Full-Service		Summer-Service	
		Trial 1	Trial 2	Trial 1	Trial 2
		Classification: • JD: Just Driving (1) • DR: Listen to DO Radio (2) • PC: Passenger Conversation (3) • DR_PC: Combination of DR and PC (4) • PC_T2P: Combination of DR and Talk to Passenger (5) • DR_PC_T2P: Combination of DR, PC, and T2P (6)	Classification: • JD (1) = PC (3) • DR (2) • DR_PC (4) = PC_T2P (5) • DR_PC_T2P (6)	Classification: • JD (1) • DR (2) • PC (3) • T2P (7)	Classification: • JD (1) • DR (2) • PC (3) • T2P (7) • L2M: Listening to Music (8) • L2M_DR: Combination of L2M and DR (9) • L2M_PC: Combination of L2M and PC (10)
Characteristics of Exposure Events	Duration of Exposure	0.0514123	0.0368331	-	-
	Segment Length	-0.005632	-0.002704	-	0.0113029
Driver Profile	Driver Age	-	-	-	-
	Driver Experience	-	-	-	-
Speed Performance	Idle time	0.2761855	-	-	-
	Stability1	-47.09074	-18.2251	-	-
	Stability2	1.5906999	0.6678406	-0.134681	-
	Stability3	-	-	-	-
	Transition1	-	43.08304	-	-
	Transition2	-9.327277	-5.601178	-	-
	Transition3	-	-	-	-0.032603
	Transition4	-43.8894	-	-9.767311	11.786133
	Transition5	-	-	66.565148	-
	Transition6	-1440.959	-654.3293	483.3583	-
Route Characteristics	Stop Spacing	-	0.0003979	-	-
	Number of Stops	0.0008614	-	-	-
Wilks' Lambda Significance		<0.0001	<0.0001	0.0978	0.0024
Explained Variability (%)		97.8166	92.5310	79.33	81.77
Model Misclassification Rate (%)		0.00	0.00	21.43	14.29
Validation Misclassification Rate (%)		-	-	37.50	37.50

CHAPTER VII CONCLUSION AND RECOMMENDATION

7.1. Conclusion

This thesis presents the results of exploratory study on distracted driving behaviors of transit operators. The study generally covered the literature review on transit-distraction-related studies, two surveys to analyze the likelihood of the operators to involve/be exposed by potential on-board distractions, and the observational “naturalistic” study to find the predictive models for classifying type of distractions.

An ordinal logistic regression was carried out to evaluate how age, gender, driving experience of the operators, and their driving frequencies accounts for the likelihood of distracted driving. The results show that younger operators are more likely to *listen to the entertainment devices, picking up and holding 2-way radio, communicating with Dispatch Office (DO),* and *listening to passenger conversation*; while older operators are more likely to *adjust sun visor while driving* than older operators. In term of gender, male operators are more likely to *use mentor ranger, adjust seat/seat belt, adjust sun visors,* and *listen to DO* than female operators. In addition, more experienced operators are more often *to talk to passengers* and *interact with children passengers*; while the other operators who drive the bus more frequently are more likely *to listen to entertainment devices* while driving.

On the other hand, a discriminant analysis was performed to predict how different transit operator driving behaviors when exposed different distraction activities: *Just Driving* (1), *DO Radio* (2), *Passenger Conversation* (3), combination of *DO Radio and Passenger Conversation* (4), combination of *Passenger Conversation and Talking to Passenger* (5), and combination of *DO Radio, Passenger Conversation, Talking to Passenger* (6), *Talking to Passenger (7), Listening to Music (8), combined Listening to Music and DO Radio (9),* and *combined Listening to Music and Passenger Conversation (10)*. Sixteen (16) parameters were considered in this analysis, including duration of exposure (sec), segment length (m), idle time (sec), driver age (years), driving experience (months), index stability pattern 1, index stability pattern 2, index stability pattern 3, index transition 1, index transition 2, index transition 3, index transition 4, index transition 5, index transition 6, average stop spacing along the observed route (m), and number of stop along the observed route.

Discriminant analysis results showed that there are 4 predictors that seem to be able to classify distraction groups across all 4 models; those include segment length, average duration of idling time/stop delay at speed interval 0 – 4 km/hr (stability2), frequency of speed transitions that deviate by ± 0 to 4 km/hr from its speed (transition4), and frequency of speed transitions that deviate by ± 8 to 12 km/hr from its speed (transition6). In addition, validation results of predictive models produced a 37.5% of misclassification rate. This error rate was obtained using only 14 segments to construct the model. Therefore, if more data were added to model dataset, we could expect smaller value.

7.2. Recommendation

The followings are some recommendations that might be considered for future research:

a. An important thing to consider when conducting an observation on the bus is how wide the observer's view towards the driver. Selecting the seat with the most suitable vantage point from which to observe the driver depends on the number of passengers inside the bus (crowded/not crowded bus). If the observation is conducted when the bus is full, it is possible that observer's view towards the driver will be blocked by passengers and some data might be missing. To avoid this, the author recommends using at least 1 camera with audio ability to record all potential distractions on the bus.

b. Account for and collect other driving parameters as the predictors for discriminant analysis (e.g., lane deviation, throttle position, and traffic conditions). Particularly to obtain traffic condition, the author recommends using a dual-view camera that can record both inside and outside of the bus.

c. Add more segment samples to cover all possible scenarios of distracted activities in transit.

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Appendix A. Driving Behavior and Distraction of Transit Operator Survey

DRIVING BEHAVIOR AND DISTRACTION OF TRANSIT OPERATOR SURVEY

The questionnaire is a part of our research intended to investigate the relationship between transit operator's driving behavior and on-board transit distractions. The information in this survey is private and will be used to improve the safety for all transit occupants. Your sincerity and seriousness taking this survey is greatly appreciated. Random as well as careless answers will affect the accuracy of the results obtain. This survey will take 20 to 30 minutes to complete.

Thank you for your cooperation.
If you have any question regarding this survey, please send an email to arbien@vt.edu.

A. Demographic Profile

Q1. What is your age (year)? ____________

Q2. What is your gender?

a) Male
b) Female

Q3. How long have you been driving the bus? Please fill the appropriate time (Years and/or Months)?

How long have you been driving the bus?	Years	Month

Q4. How many days a week and hours a day on average do you drive a bus during **full-service** period? Please fill the appropriate time.

a) Day/Week : _______________
b) Hour/Day : _______________

Q5. How many days a week and hours a day on average do you drive a bus during **reduced-service** period? Please fill the appropriate time.

a) Day/Week : _______________
b) Hour/Day : _______________

B. <u>Driving Behavior and Potential Sources of Distraction</u>

Q6. How frequently do you think bus operators do the activities below while driving? Please check (√) the appropriate boxes.

Potential Activities	**Never**	**Rarely**	**Sometimes**	**Always**
Listening to the radio/ CD/DVD/MP3 player				
Adjusting the radio station/CD/MP3 player				
Text messaging				
Talking on a cell phone				
Picking up and holding the two way radio				
Listening to the Dispatch Office broadcast				
Communicating with Dispatch Office				
Awareness of passengers stop request				
Passenger conversations				
Talking to passenger				
Interacting with infants/children				
Actively scanning for passenger approaching the bus stop				
Adjusting sun visor				
Adjusting seat and/or seat belt				
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control				
Using mentor ranger				
Disruptive passenger behavior				

Q7. For each activity please indicate how you think this activity could affect bus operator's driving? Please check (√) the appropriate boxes. You can choose at most TWO (2) answers in each row.

Potential Activities	No difference	Drive slower	Drive Faster	Apply the brakes MORE	Eyes-off the road MORE	Eyes-off the road LESS	Hands-off the steering wheel MORE	Hands-off the steering wheel LESS	Increase distance with lead vehicle
Listening to the radio/ CD/DVD/MP3 player									
Adjusting the radio station/CD/MP3 player									
Text messaging									
Talking on a cell phone									
Picking up and holding the two way radio									
Listening to the Dispatch Office broadcast									
Communicating with Dispatch Office									
Awareness of passengers stop request									
Passenger conversations									
Talking to passenger									
Interacting with infants/children									
Actively scanning for passenger approaching the bus stop									
Adjusting sun visor									
Adjusting seat and/or seat belt									
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control									
Using mentor ranger									
Disruptive passenger behavior									

Q8. In which driving situation should the bus operators not do the following activities? Please check (√) the appropriate boxes. You can choose at most TWO (2) answers in each row.

Potential Activities	**Bad weather**	**At night**	**Fast-moving traffic**	**Congestion /Work Zone**	**Crowded Bus**
Listening to the radio/ CD/DVD/MP3 player					
Adjusting the radio station/CD/MP3 player					
Text messaging					
Talking on a cell phone					
Picking up and holding the two way radio					
Listening to the Dispatch Office broadcast					
Communicating with Dispatch Office					
Awareness of passengers stop request					
Passenger conversations					
Talking to passenger					
Interacting with infants/children					
Actively scanning for passenger approaching the bus stop					
Adjusting sun visor					
Adjusting seat and/or seat belt					
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control					
Using mentor ranger					
Disruptive passenger behavior					

Q9. Do you think that number of passengers on the bus affect bus operator's driving performance?

a) Yes
b) No

Q10. Select which type of occupant that is the most distracting while driving the bus? (e.g. talking to driver, asking question, making noise)

a) Infants
b) Child
c) Adult
d) Senior/disabled passenger
e) Others, ________________________ (please state)

Q11. When the bus is full, do you think the bus operator is able to listen to the bus stop requested alert clearly?

a) Yes
b) No

Q12. Where do you think the passenger should signalize the bus operator to stop the bus?

a) Immediately after the prior bus stop
b) 2 blocks from destination bus stop
c) 1 block from destination bus stop
d) 250 feet from destination bus stop

Q13 Does the type of the bus stop (bus stop, shelter, and pull-off) affect bus operator's ability to monitor the stop?

a) Yes
b) No

C. <u>Perception of Safety</u>

Q14. If you were a passenger riding in a bus, how safe you would feel if the bus operator was doing the following activities: Please check (√) the appropriate boxes.

Potential Activities	**Very unsafe**	**Unsafe**	**Safe**	**Very safe**
Listening to the radio/ CD/DVD/MP3 player				
Adjusting the radio station/CD/MP3 player				
Text messaging				
Talking on a cell phone				
Picking up and holding the two way radio				
Listening to the Dispatch Office broadcast				
Communicating with Dispatch Office				
Awareness of passengers stop request				
Passenger conversations				
Talking to passenger				
Interacting with infants/children				
Actively scanning for passenger approaching the bus stop				
Adjusting sun visor				
Adjusting seat and/or seat belt				
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control				
Using mentor ranger				
Disruptive passenger behavior				

Q15. Rate potential risk for each of the following activities: Please check (√) the appropriate boxes.

Potential Activities	**No risk**	**Minimal risk**	**Moderate risk**	**Extensive risk**
Listening to the radio/ CD/DVD/MP3 player				
Adjusting the radio station/CD/MP3 player				
Text messaging				
Talking on a cell phone				
Picking up and holding the two way radio				
Listening to the Dispatch Office broadcast				
Communicating with Dispatch Office				
Awareness of passengers stop request				
Passenger conversations				
Talking to passenger				
Interacting with infants/children				
Actively scanning for passenger approaching the bus stop				
Adjusting sun visor				
Adjusting seat and/or seat belt				
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control				
Using mentor ranger				
Disruptive passenger behavior				

Q16. Choose the FIVE (5) most dangerous activities to do while driving and rank them? Rank from 1 to 5 within those 5 activities [“1” = extremely dangerous activity; “5” = least dangerous activity].

Potential Activities	**Rank (1-5)**
Listening to the radio/ CD/DVD/MP3 player	
Adjusting the radio station/CD/MP3 player	
Text messaging	
Talking on a cell phone	
Picking up and holding the two way radio	
Listening to the Dispatch Office broadcast	
Communicating with Dispatch Office	
Awareness of passengers stop request	
Passenger conversations	
Talking to passenger	
Interacting with infants/children	
Actively scanning for passenger approaching the bus stop	
Adjusting sun visor	
Adjusting seat and/or seat belt	
Adjusting controls and/or switches on the dash (Ex. Windshield wipers/Climate control	
Using mentor ranger	
Disruptive passenger behavior	

Q17. How long can a bus operator safely keep eyes off the road?

a) Less than 2 seconds
b) 3 – 5 seconds
c) 6 – 10 seconds
d) 10+ seconds

Q18. How long can a bus operator safely keep one or both hands off the steering wheel?

a) Less than 5 seconds
b) 6 – 10 seconds
c) 10-30 seconds
d) 30+ seconds

D. <u>Distracted Driving Laws</u>

Q19. Based on your knowledge, is there any law related to distracted driving (e.g. ban on cell phone use, etc) for commercial drivers?

a) Yes
b) No
c) Don't know

Q20. Based on your experience, what percentage of bus operators do you think occasionally violate distracted-driving regulation? *If you refuse to answer, please type "Refuse"

____

Q21. Do you support any law enforcement of distracted driving especially for commercial drivers?

a) Yes
b) No

Appendix B. Public Opinion on Bus Transit Operator Distracted Driving Survey

Public Opinion on Bus Transit Operator Distracted Driving

With respect to transit occupants' safety, the study of transit operator distracted driving behaviors needs to be conducted to have a better understanding of some potential risky-driving behavior. Your responses are completely anonymous and confidential. The survey should take about 5 minutes to complete. Thank you very much for your participation.
* Required

In what state or U.S. territory do you live? *

What year were you born? *

What is your gender? *

How often do you use bus transit in your city?

- ○ At least once every day
- ○ A few days a week
- ○ A few days a month
- ○ A few days a year
- ○ Never

Distracted Driving in Transit

A driving distraction is any activity that... *
Please check all that apply

- ☐ takes driver eyes off the road
- ☐ takes driver minds off the road
- ☐ takes driver hands off the steering wheel
- ☐ All above
- ☐ None of the above

Bus driver's ordinary tasks such as awareness of passenger stop request and scanning for passenger approaching the bus stop while driving are NOT distractions. *

- True
- False

As a passenger riding in a bus, how often do you observe the bus driver is involved in following distracted driving behaviors? *

	Never	Rarely	Sometimes	Always
Text messaging				
Talking on a cell phone				
Listening to MP3 player/radio				
Adjusting MP3 player/radio				
Interacting with passengers				
Using two-way radio to communicate with transit Center				
Adjusting sun visors and/or mirrors				
Adjusting seat/seat belts				
Adjusting control and/or switches on the dash				
Eating/drinking				

As a passenger riding in a bus, how safe would you feel if the bus driver was involved in following activities while driving? *

	Very unsafe	Unsafe	Safe	Very safe
Text messaging				
Talking on a cell phone				
Listening to MP3 player/radio				
Adjusting MP3 player/radio				
Interacting with passengers				
Using two-way radio to communicate with transit Center				
Adjusting sun visors and/or mirrors				
Adjusting seat/seat belts				
Adjusting control and/or switches on the dash				
Eating/drinking				

When the bus driver who has driven is distracted, what are the most common errors that you observed as a result of that distraction? * You can choose at most 2 (TWO) answers.

- Missed stops
- Ran red lights

- Hard brake
- Bus weaved
- Missed fares
- Hit street fixtures and other fixed objects
- Nearly missed hitting pedestrians and/or cars
- Not open/close the bus doors
- I don't know
- Other:

Which bus driver do you think get more easily distracted while driving? *

- Old driver
- Young driver
- Novice driver
- Experienced driver
- Very experienced driver
- Male driver
- Female driver

As a passenger of bus transit, have you ever been involved in a crash or near-crash? *

- Yes
- No

Did that crash/ near-crash happen because the bus driver was distracted while driving? *

- Yes
- No
- I don't know

If yes, what kind of distraction that caused the accident? *

- Cell phone use
- Driver-passenger interaction
- MP3 player/radio use
- Adjust sun visors/mirrors
- Adjust seat/seat belt
- Adjust control/switches on the dash

- Eating/drinking
- Other: ____

Could you please elaborate on that accident? *

____

Appendix C. Observational Study: Informed Consent Form and Observation Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
in Research Projects Involving Human Subjects

Study Topic	**:**	*Observational Study: Driving Behaviors of Transit Operator*	
Investigator(s)	**:**	Montasir Abbas Name	abbas@vt.edu / (540) 231-9002 E-mail / Phone number
		Nurlayla Arbie Name	arbien@vt.edu / (540) 577-1676 E-mail / Phone number

I. Purpose of this Research Project

The objectives of this study are to (1) to identify potential sources of bus driver distractions and (2) develop guidelines to minimize these distractions.

II. Procedures

The following is the procedure of the study:

1. Prior to the observation, you will be read a verbal version of this consent form by the researcher.
2. Should you agree to participate, you will be asked to provide your verbal consent to participate in this 1-hour observational study.
3. Please note that this is an observational study which no treatment is given to you to affect the outcome. Rather, you are asked to drive as you normally would.
4. For the duration of 1-hour, the researcher would be observing you and periodically take a note if anyone/anything distracts you while you are driving.
5. In addition, you will be asked to provide some information regarding your age, transit experience, and driving frequency.

III. Risks

There may be a risk of emotional discomfort while you are being observed. When in this situation, please tell the researcher to stop the observation. The observation may be continued when you are ready.

We are required to inform you that there is a possible of the economic and legal risk for your participation. If you violate any of your transit agency rules during the observation, there may be a potential effect on your employment. In addition, there may be a legal risk including the possibility of discovering activities that may require reporting to authorities To minimize both economic and legal risk, none of your identifying information will be released to anyone other than the research team of this project. Only the researchers working on this project have the access to all of your data.

IV. Benefits

You may not directly benefit from this research; however, it is our hope that your participation will improve driving behaviors and the safety for all transit occupants. No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

Please know that the information provided will remain strictly confidential. The study data will not include any of your identifying information (e.g., name, email address). However, in this study, we will collect the information on the bus number that you will be driving along with its specific route. These data could be used to identify you as participant in this study. Please note that the research team will present the study data to BT. To keep your anonymity, a coding scheme will be applied to any of your identifiable data. You are advised not to disclose your participation to anyone associated at BT. Only researchers working on this project have the access to your data. All of your data will be retained for future research.

The Virginia Tech (VT) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

Participants in a study are considered volunteers and you will not be compensated.

VII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

VIII. Questions or Concerns

Should you have any questions about this study, you may contact one of the research investigators whose contact information is included at the beginning of this document.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

Observation of Driving Behaviors

GENERAL INFORMATION			
OBSERVER: ____________________			SUBJECT NO : ______________ BUS NUMBER: _____________ BUS ROUTE : _____________
Date: ______________ Day: ______________	Time (from): ______________ Time (to): ______________	Bus Stop (from): ______________ Bus Stop (to): ______________	Weather: ☐ Clear ☐ Cloudy ☐ Rain ☐ Snow ☐ Other: __________________

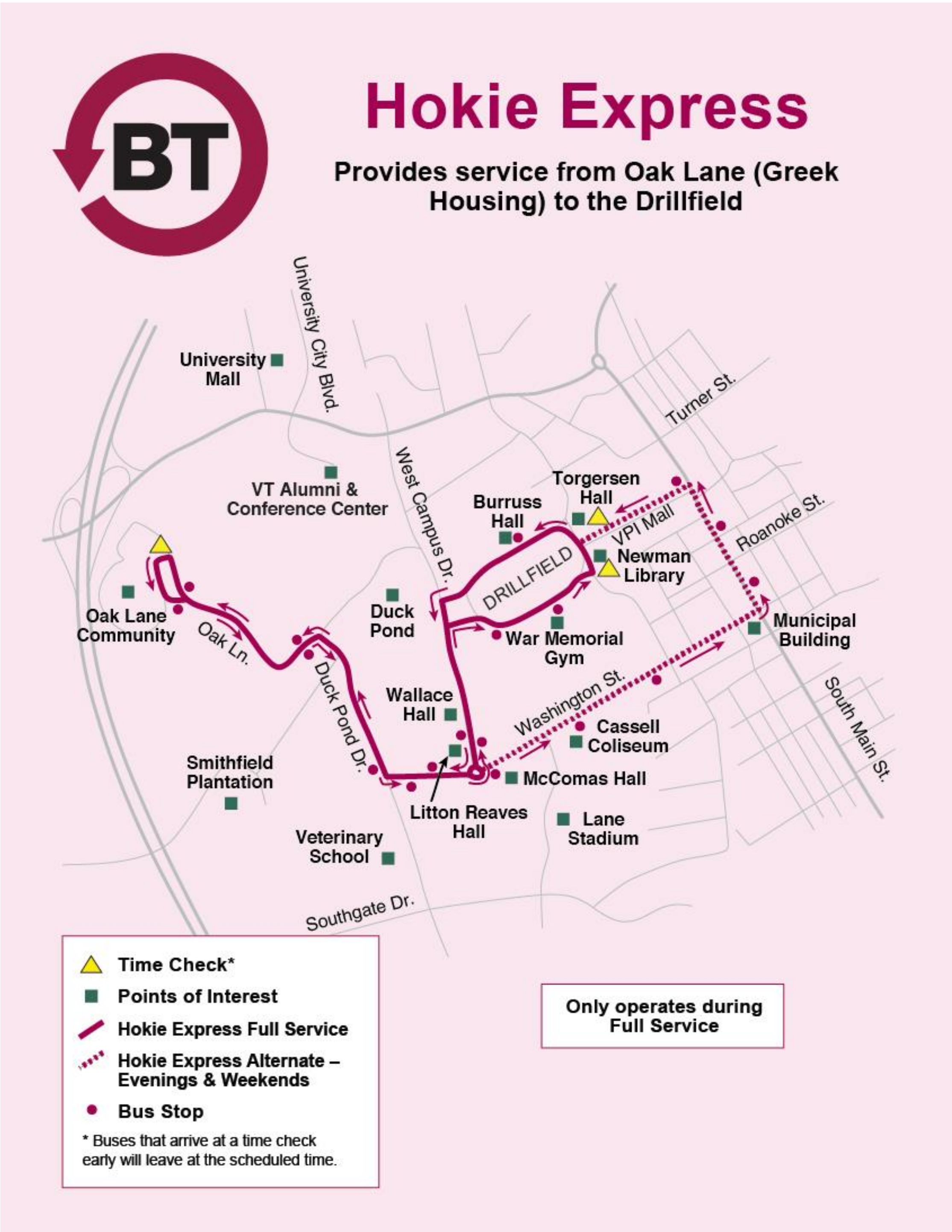
BUS DRIVER DEMOGRAPHIC PROFILE		
Gender: ☐ Male ☐ Female		
Q1	When was the subject born (years)?	
Q2	How long has the subject been driving the bus?	Number of Years : __________________ Number of Months: _____________________
Q3	How many hours a week does the subject drive the bus during full-service period?	

OBSERVED DRIVING BEHAVIORS				
No.	Observed Behaviors	Time (starts at hh/mm/ss)	Time (ends at hh/mm/ss)	Comments

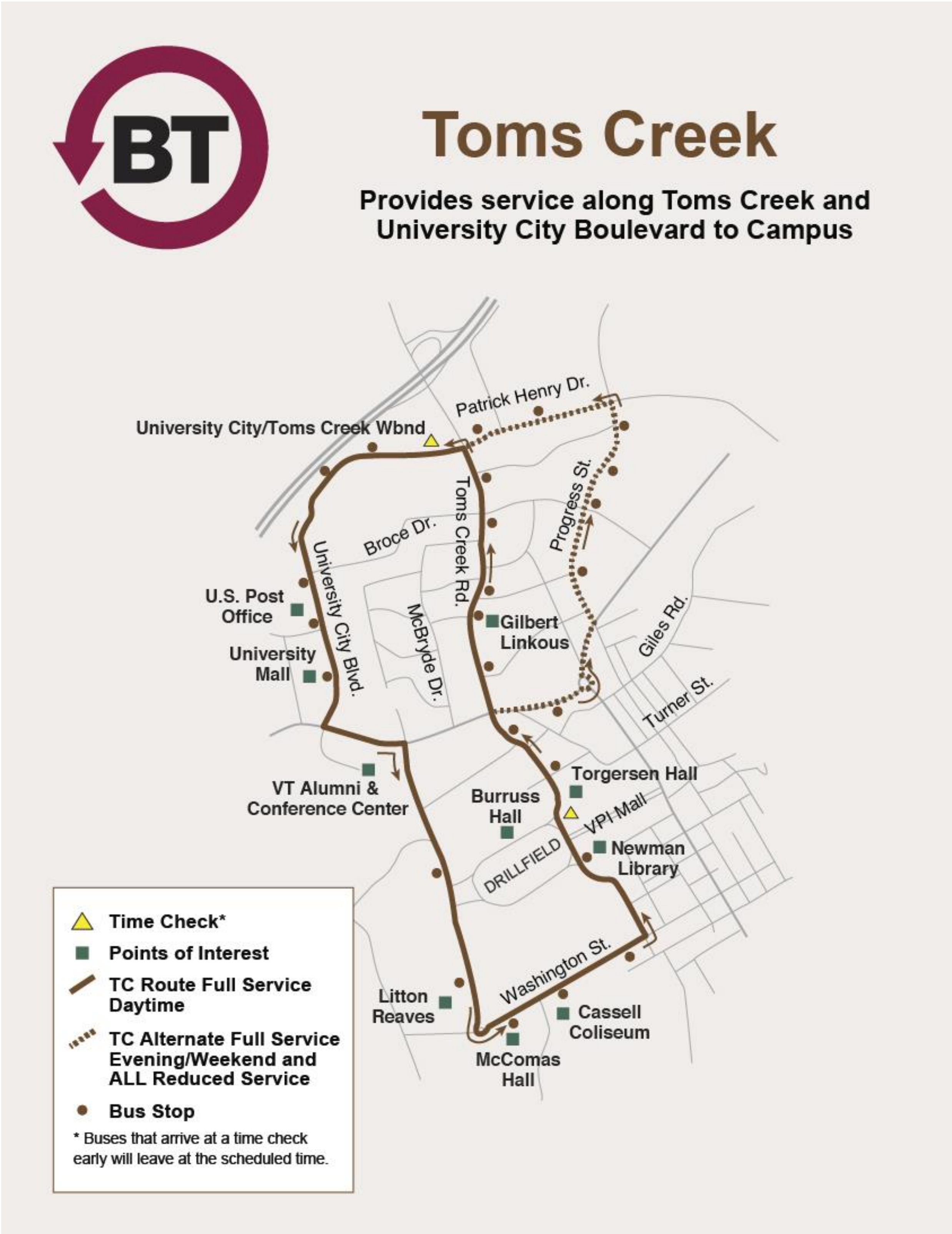
Appendix D. Route Maps of HXP, TC, and TTT Routes

(Used with permission from Blacksburg Transit; email attached)

HXP Route

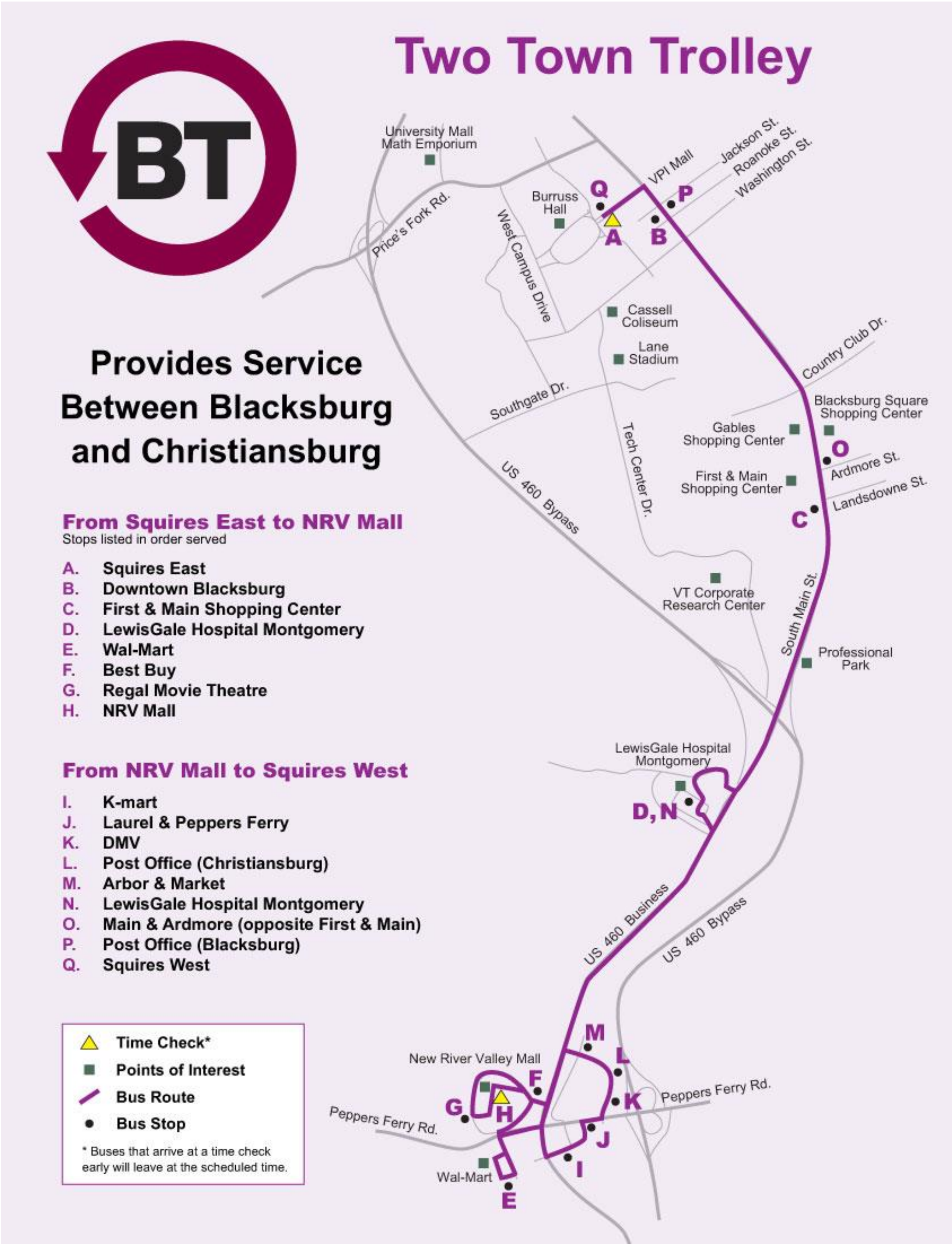


TC Route



BT
Toms Creek
Provides service along Toms Creek and University City Boulevard to Campus
Patrick Henry Dr.
University City/Toms Creek Wbnd
Toms Creek Rd.
Progress St.
Broce Dr.
University City Blvd.
U.S. Post Office
University Mall
McBryde Dr.
Gilbert Linkous
Giles Rd.
Turner St.
VT Alumni & Conference Center
Torgersen Hall
Burruss Hall
VPI Mall
DRILLFIELD
Newman Library
Washington St.
Litton Reaves
Cassell Coliseum
McComas Hall
Time Check*
Points of Interest
TC Route Full Service Daytime
TC Alternate Full Service Evening/Weekend and ALL Reduced Service
Bus Stop
* Buses that arrive at a time check early will leave at the scheduled time.

TTT Route

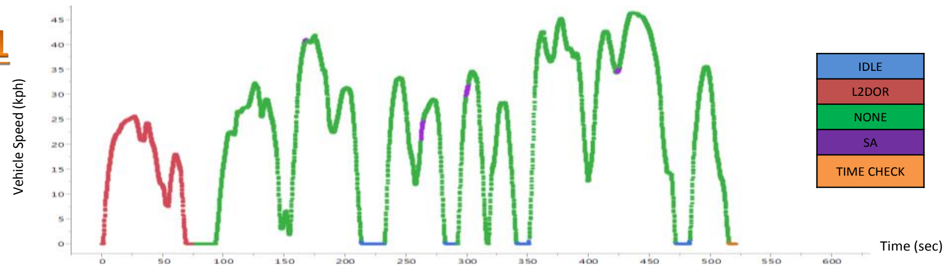


Two Town Trolley
BT
Provides Service Between Blacksburg and Christiansburg
From Squires East to NRV Mall
Stops listed in order served
A. Squires East
B. Downtown Blacksburg
C. First & Main Shopping Center
D. LewisGale Hospital Montgomery
E. Wal-Mart
F. Best Buy
G. Regal Movie Theatre
H. NRV Mall
From NRV Mall to Squires West
I. K-mart
J. Laurel & Peppers Ferry
K. DMV
L. Post Office (Christiansburg)
M. Arbor & Market
N. LewisGale Hospital Montgomery
O. Main & Ardmore (opposite First & Main)
P. Post Office (Blacksburg)
Q. Squires West
Time Check*
Points of Interest
Bus Route
Bus Stop
* Buses that arrive at a time check early will leave at the scheduled time.
University Mall
Math Emporium
Price's Fork Rd.
West Campus Drive
Burruss Hall
VPI Mall
Jackson St.
Roanoke St.
Washington St.
Cassell Coliseum
Lane Stadium
Country Club Dr.
Southgate Dr.
Blacksburg Square Shopping Center
Gables Shopping Center
Ardmore St.
First & Main Shopping Center
Landsdowne St.
Tech Center Dr.
US 460 Bypass
VT Corporate Research Center
South Main St.
Professional Park
LewisGale Hospital Montgomery
D, N
US 460 Business
US 460 Bypass
New River Valley Mall
Peppers Ferry Rd.
Peppers Ferry Rd.
Wal-Mart

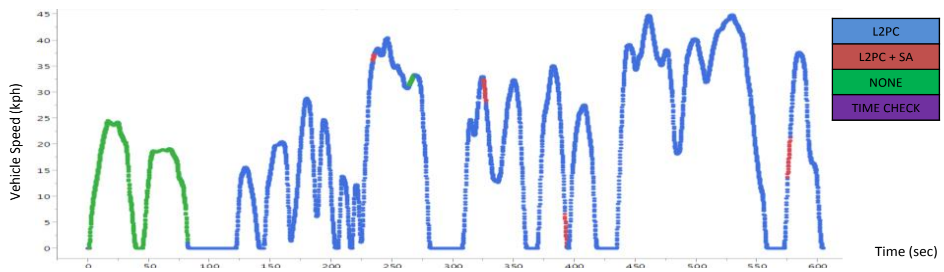
Appendix E. Velocity Profiles of 4-hour Observation along HXP, TC, and TTT Routes during BT'S Full-Service

A. Velocity Profile along Hokie Express (HXP) Route from Newman Library to Oaklane Community Area

Trial 1

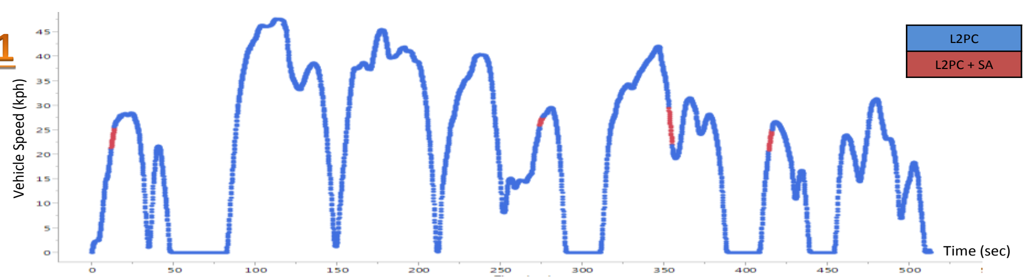


Trial 2

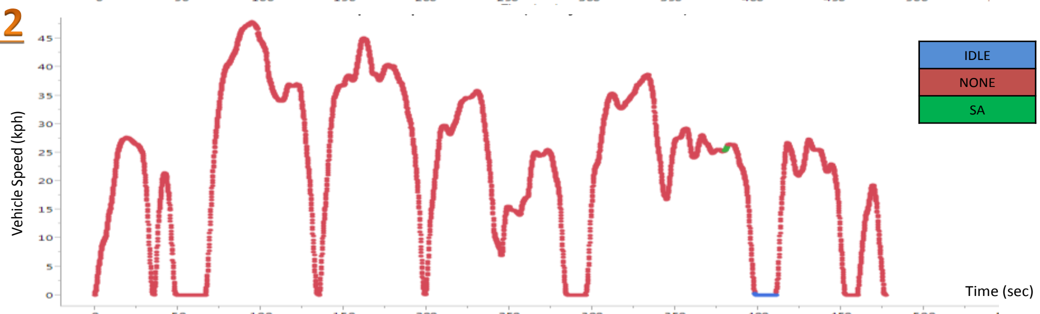


B. Velocity Profile along Hokie Express (HXP) Route from Oaklane Community Area to Newman Library

Trial 1

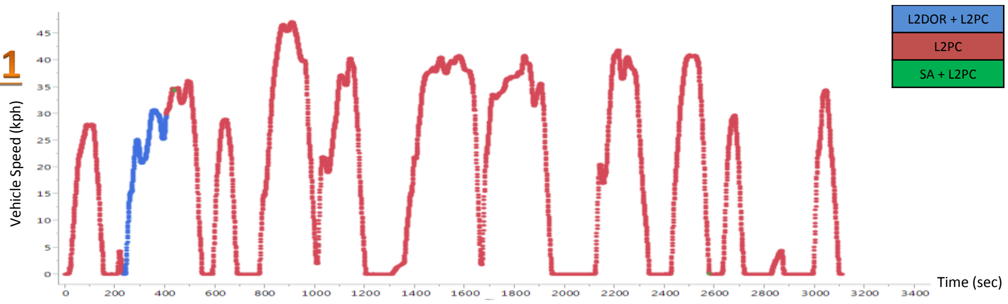


Trial 2

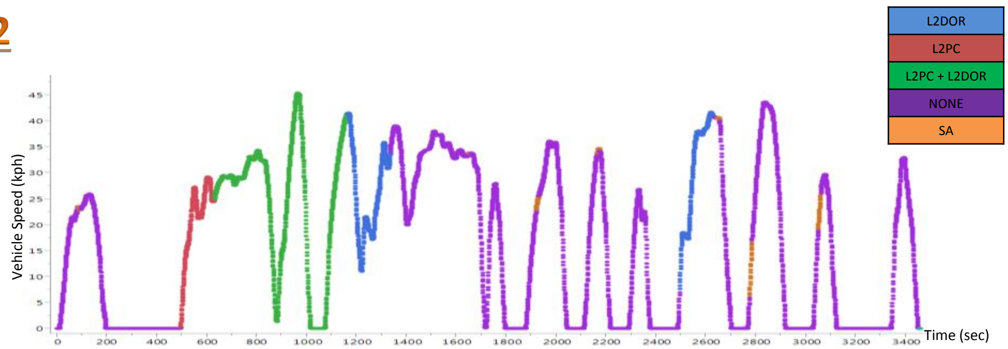


C. Velocity Profile along Toms Creek B (TCB) Route Newman Library to Toms Creek WBND

Trial 1

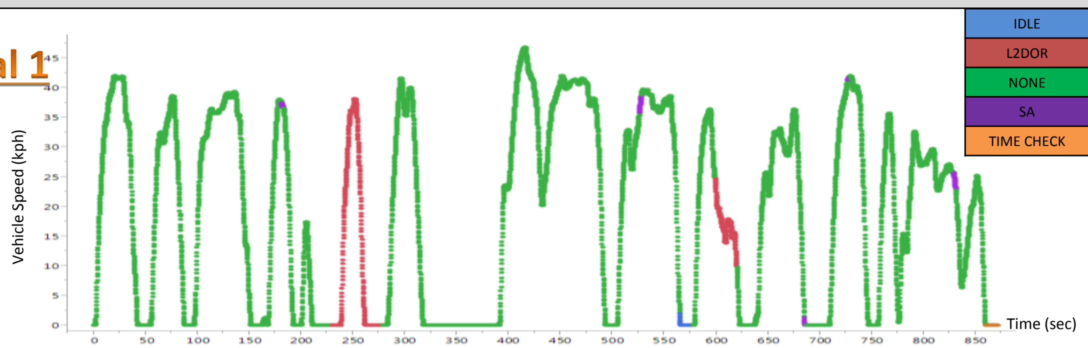


Trial 2

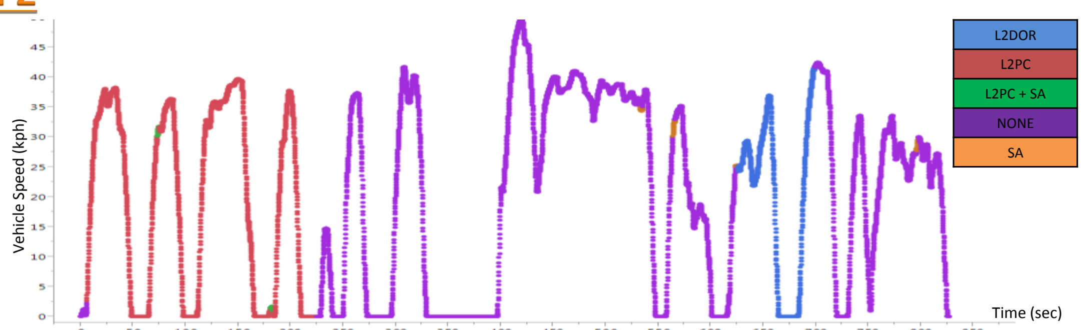


D. Velocity Profile along Toms Creek B (TCB) Route from Toms Creek WBND to Newman Library

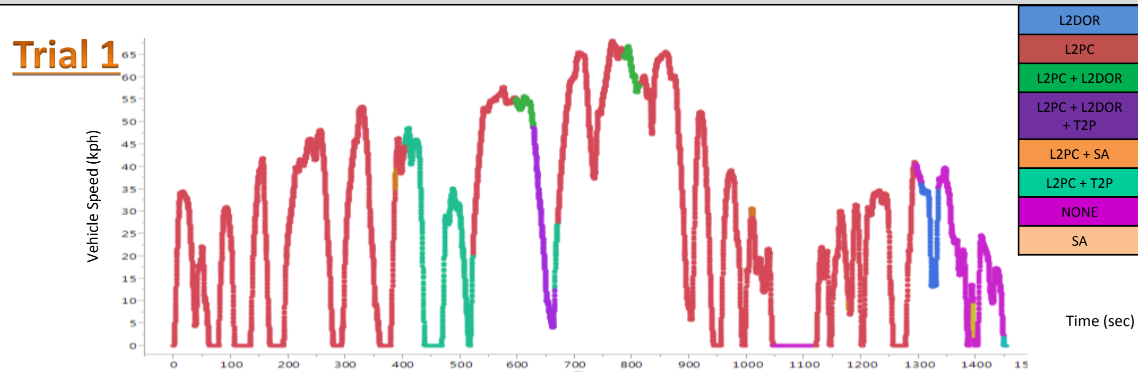
Trial 1

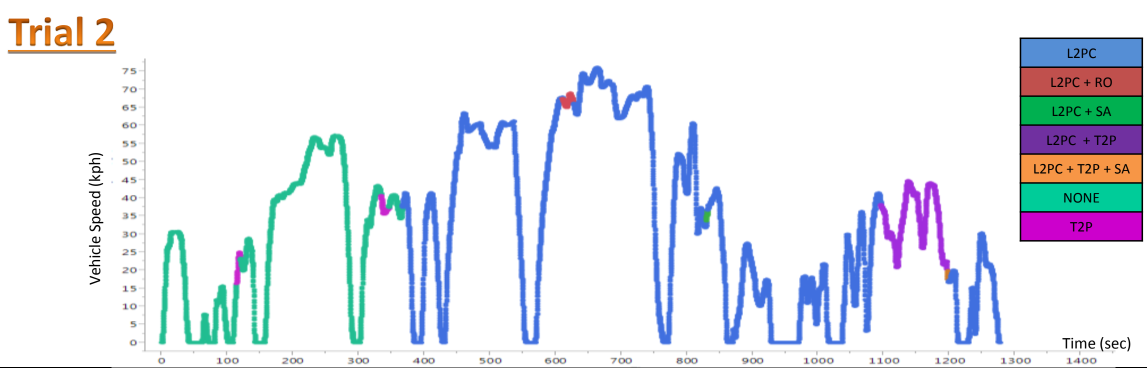


Trial 2

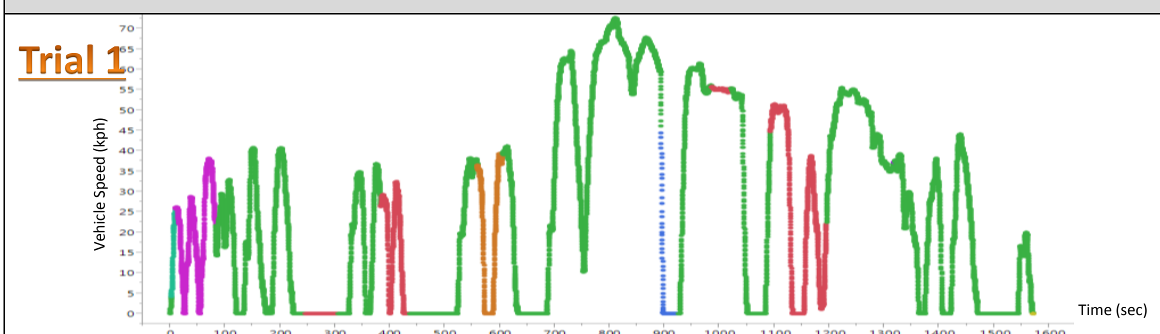


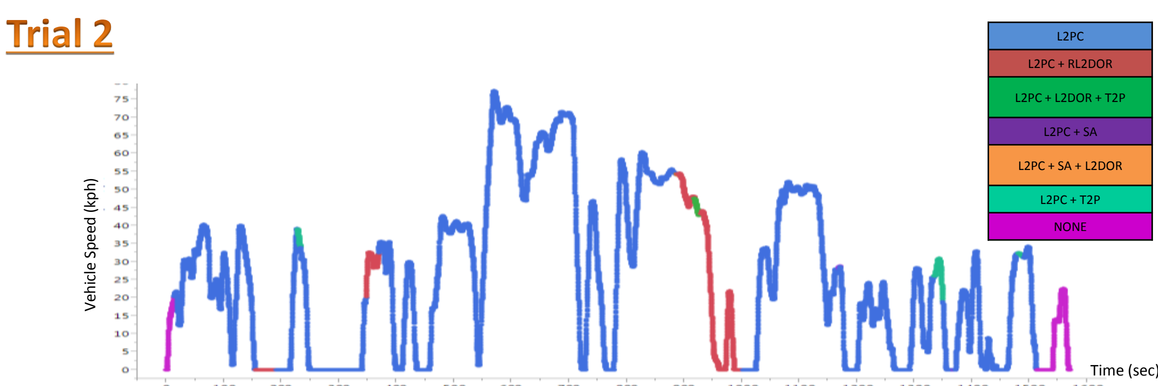
E. Velocity Profile along Two Town Trolley (TTT) Route from Squires Student Center to New River Valley Mall





F. Velocity Profile along Two Town Trolley (TTT) Route from New River Valley Mall to Squires Student Center

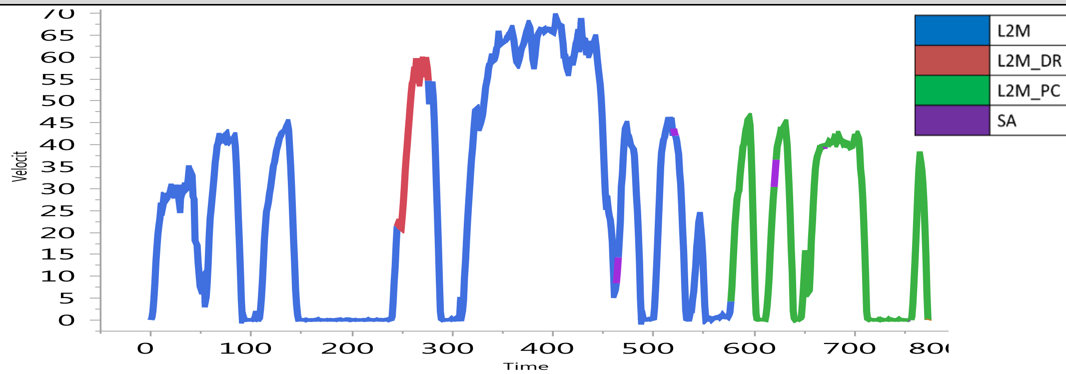




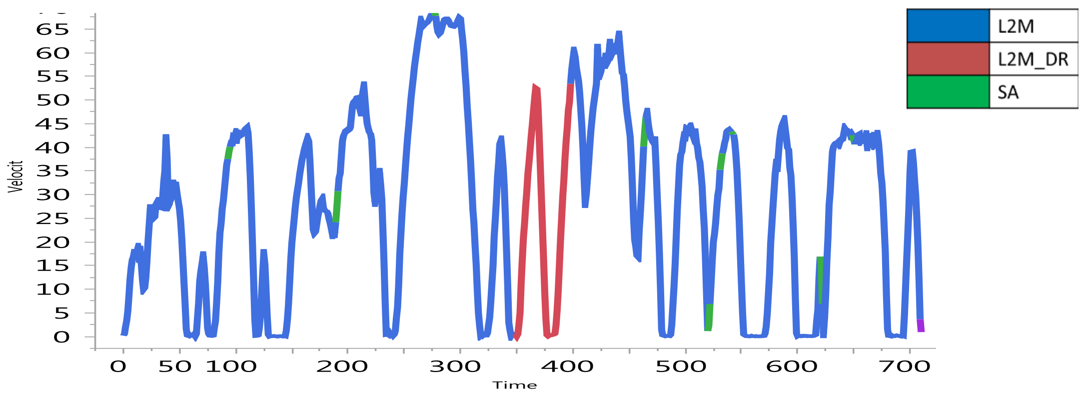
Appendix F. Velocity Profiles of 12-hour Observation along HWD and TCB Routes during BT'S Summer-Service

A. Velocity Profile along Hethwood (HWD) Route from Burrus Hall to Stroubles Circle

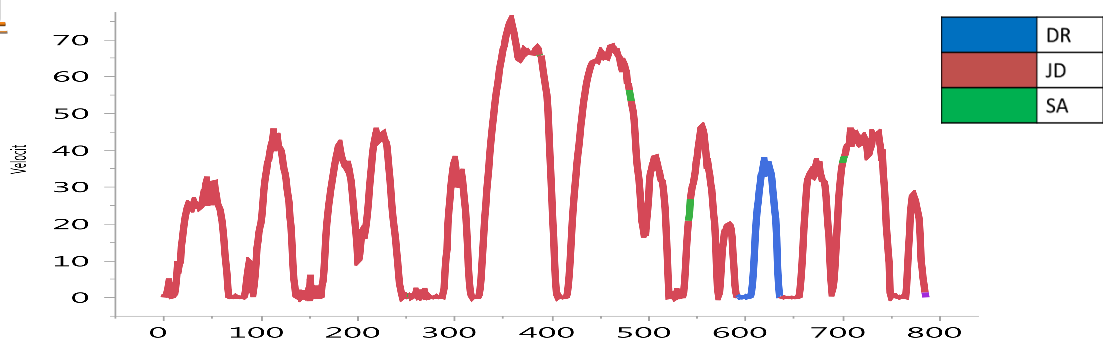
Trial 1



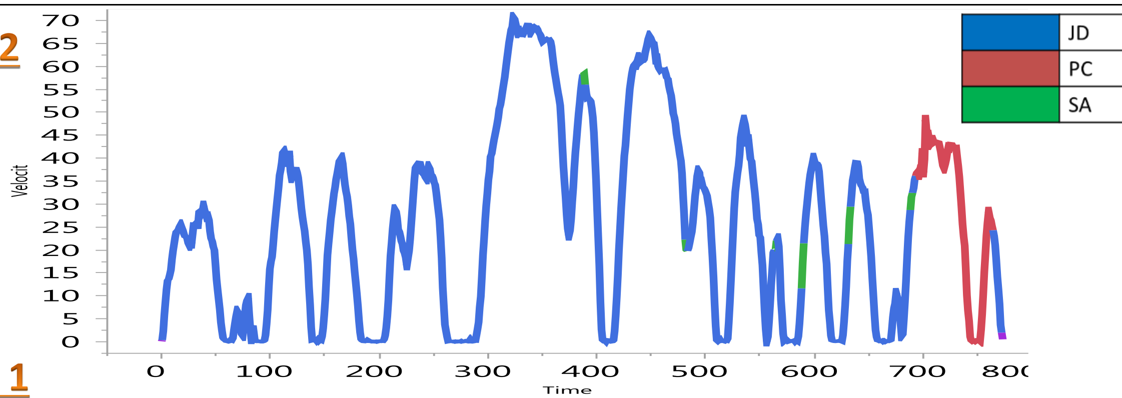
Trial 2



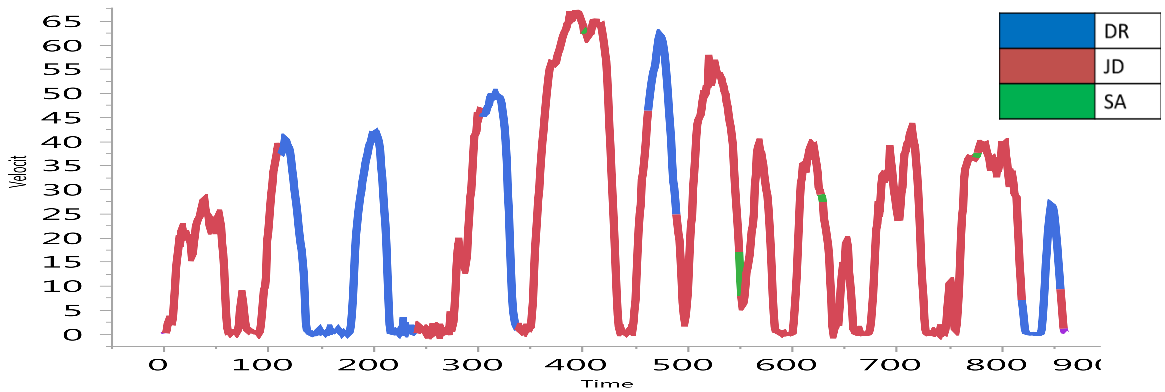
Trial 1



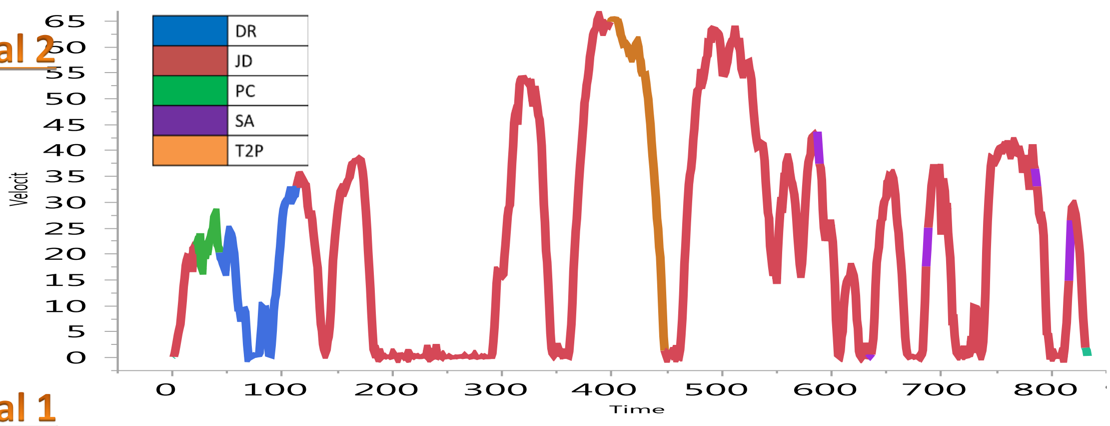
Trial 2



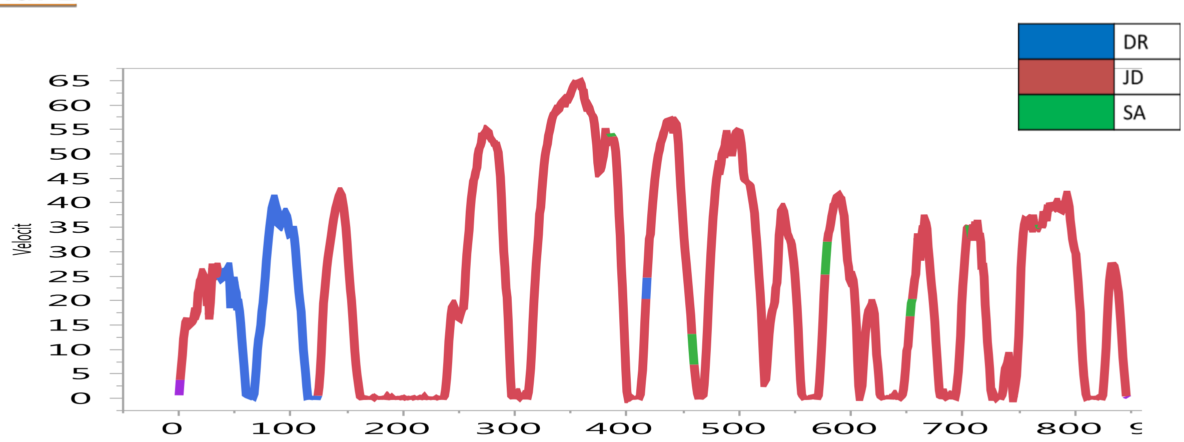
Trial 1

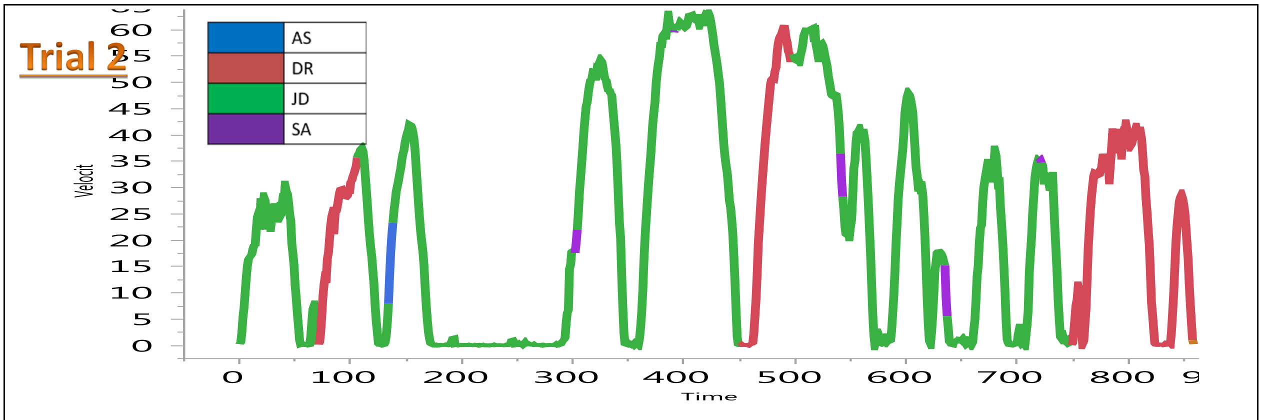


Trial 2

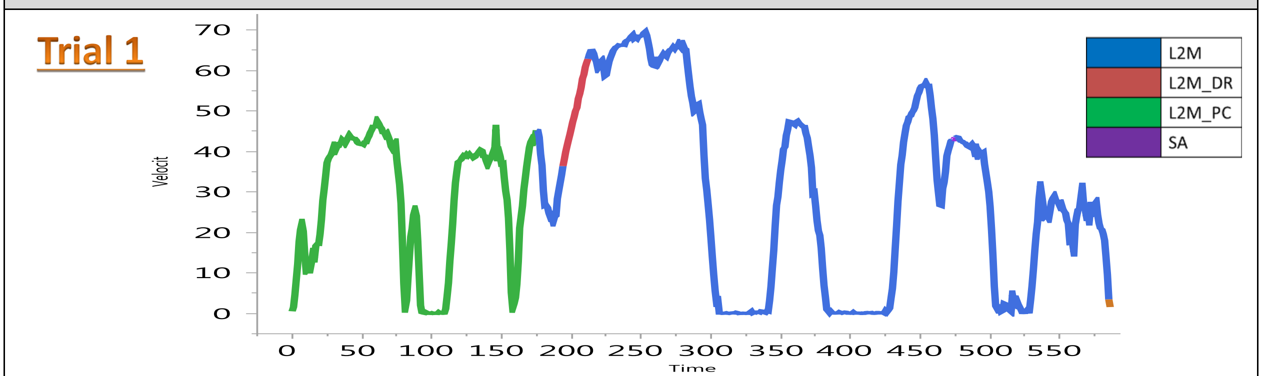


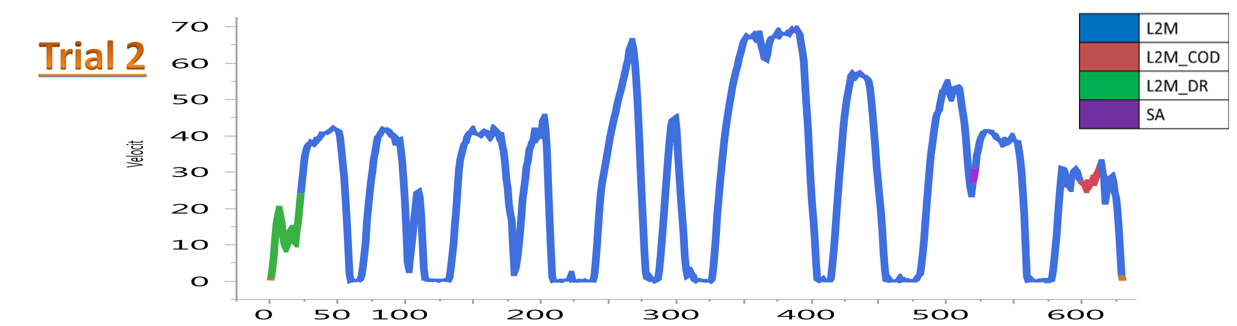
Trial 1

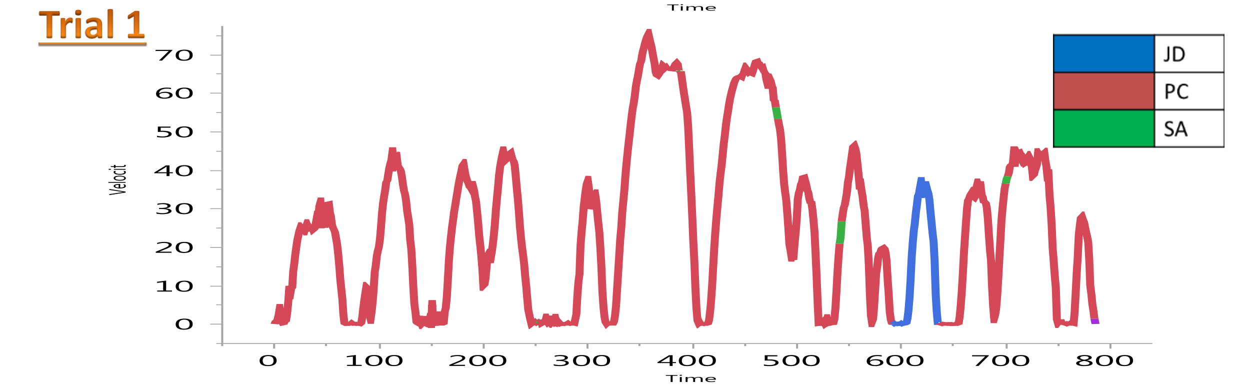




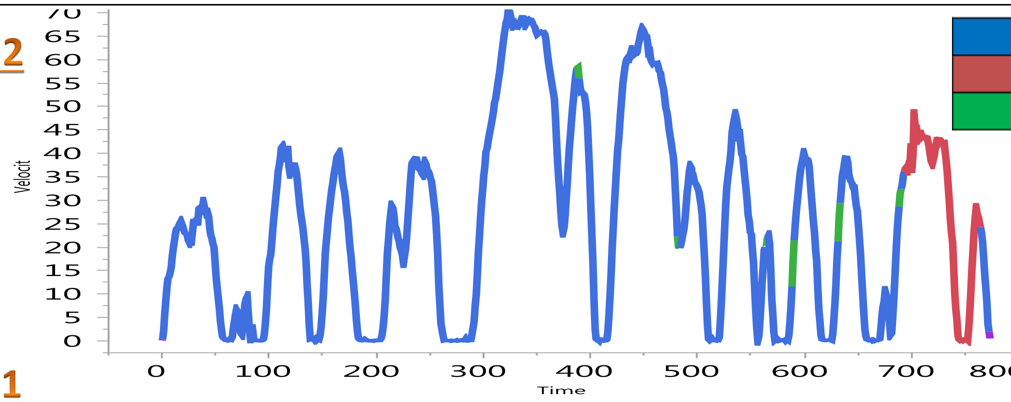
B. Velocity Profile along Hethwood (HWD) Route from Stroubles Circle to Burrus Hall



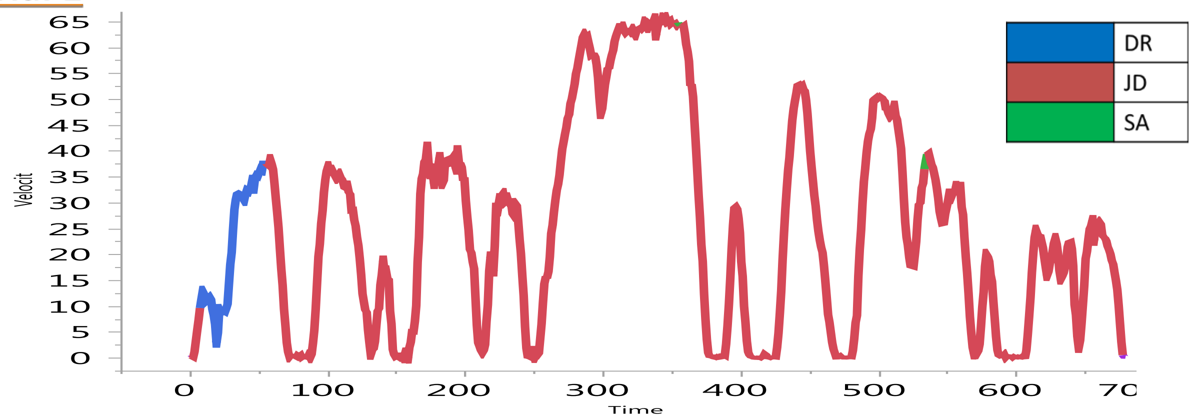




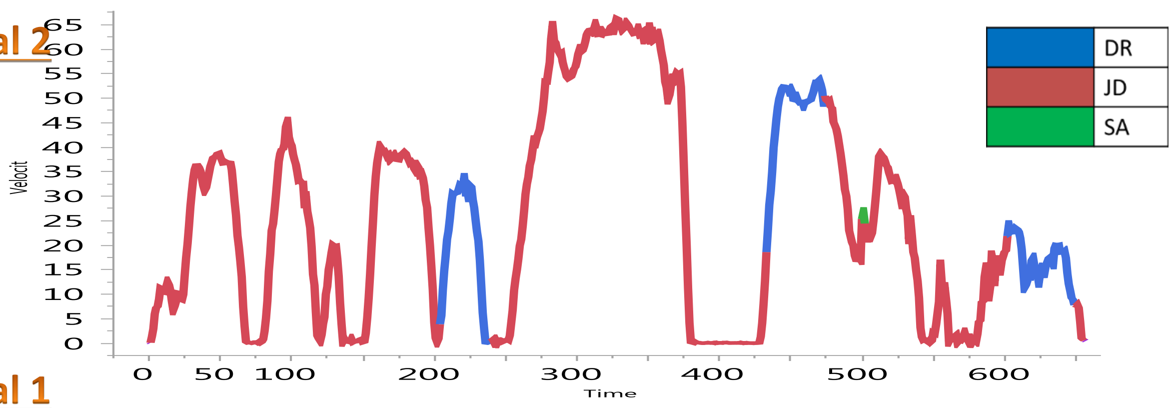
Trial 2



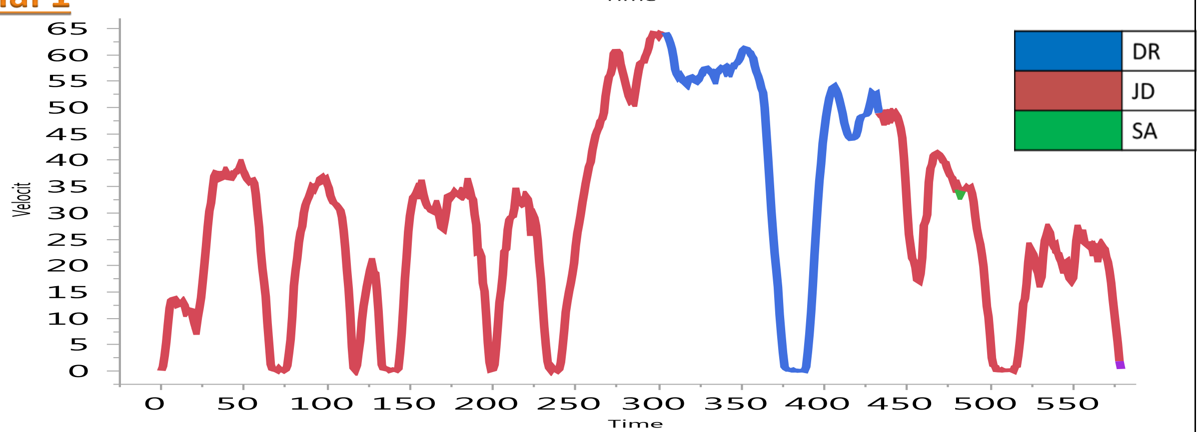
Trial 1

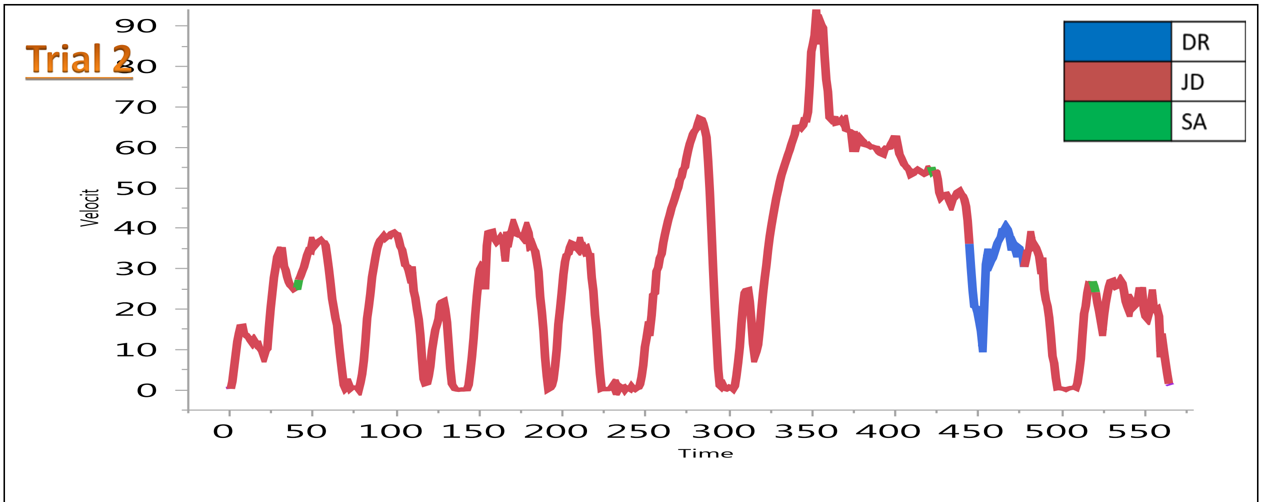


Trial 2

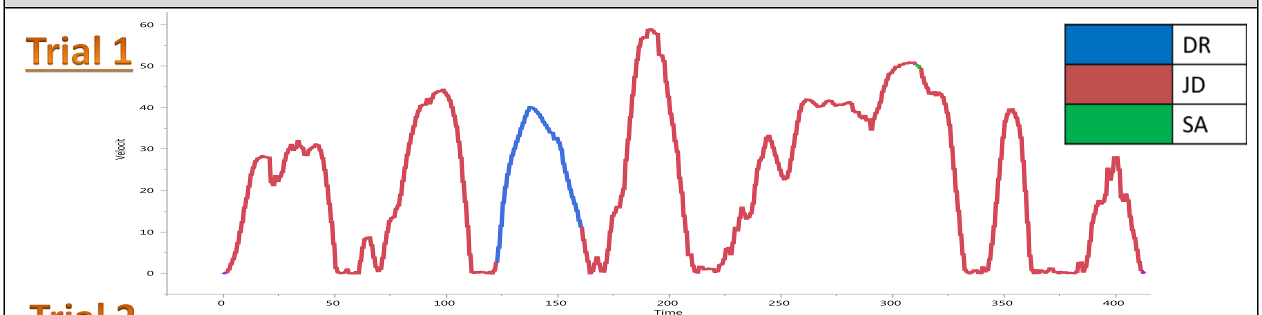


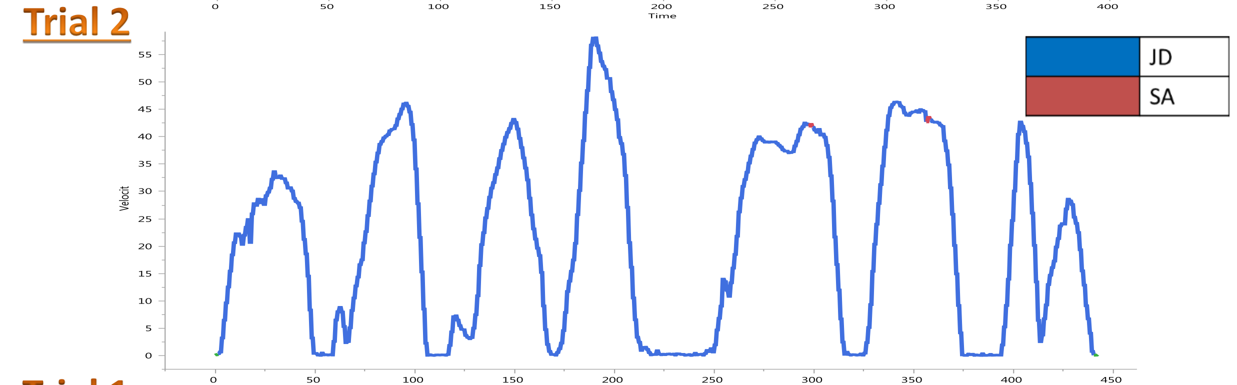
Trial 1

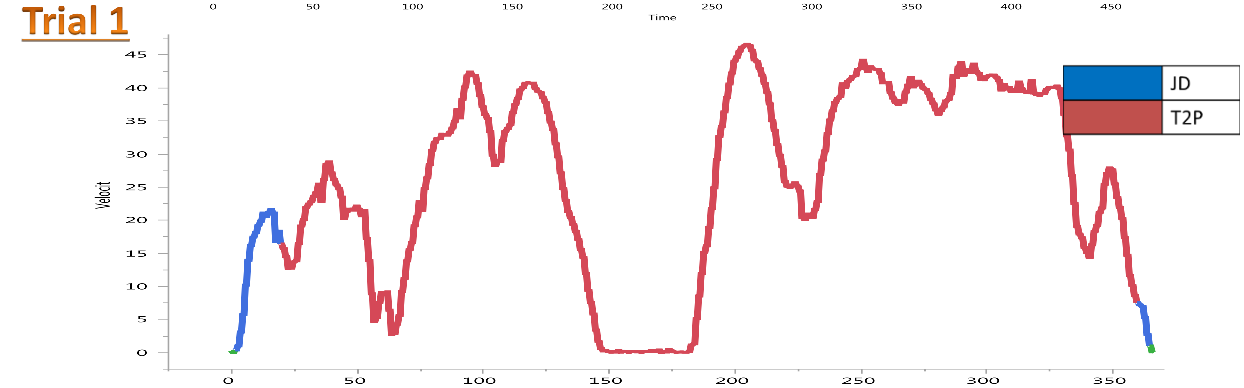




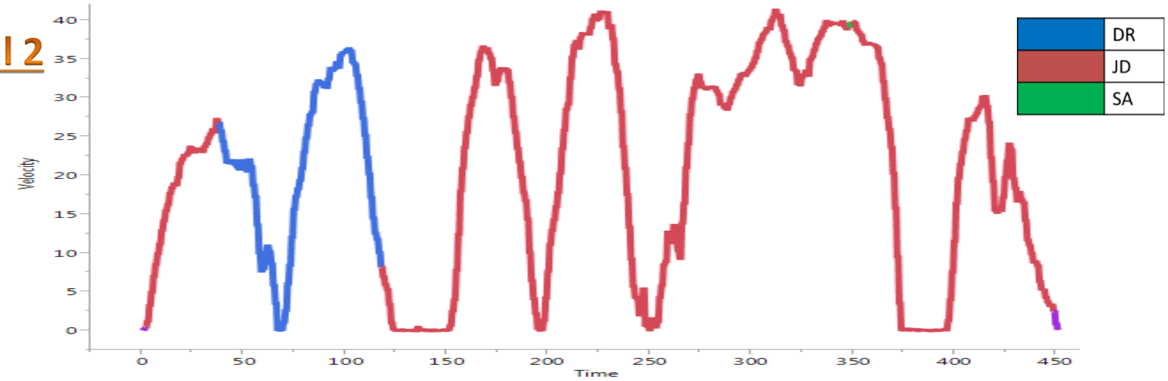
C. Velocity Profile along Toms Creek B (TCB) Route from Burrus Hall to Toms Creek WBND



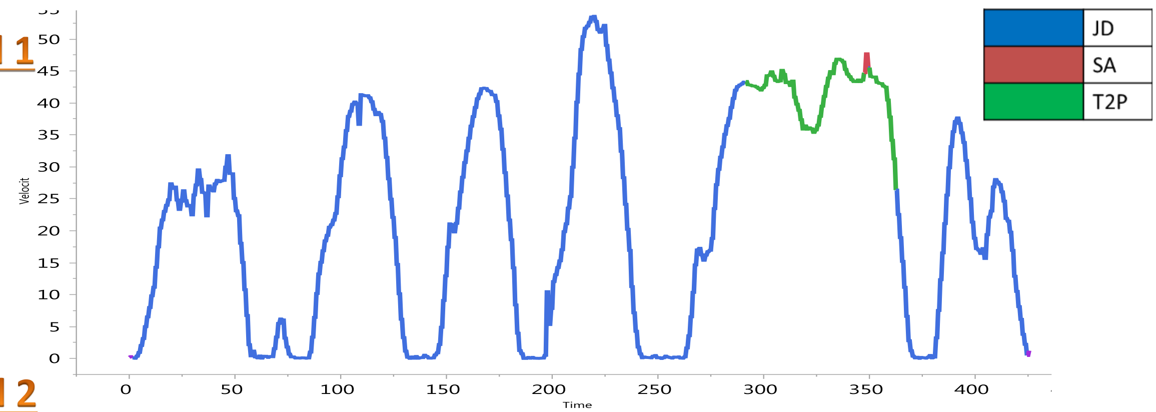




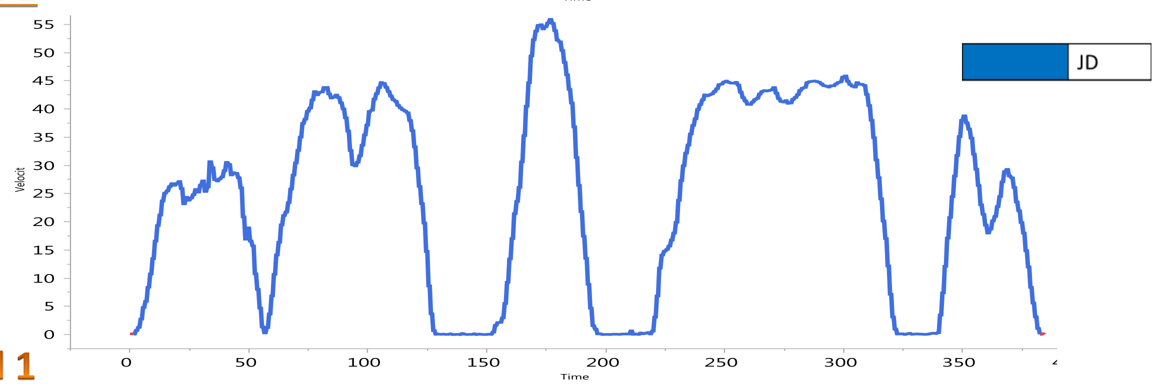
Trial 2



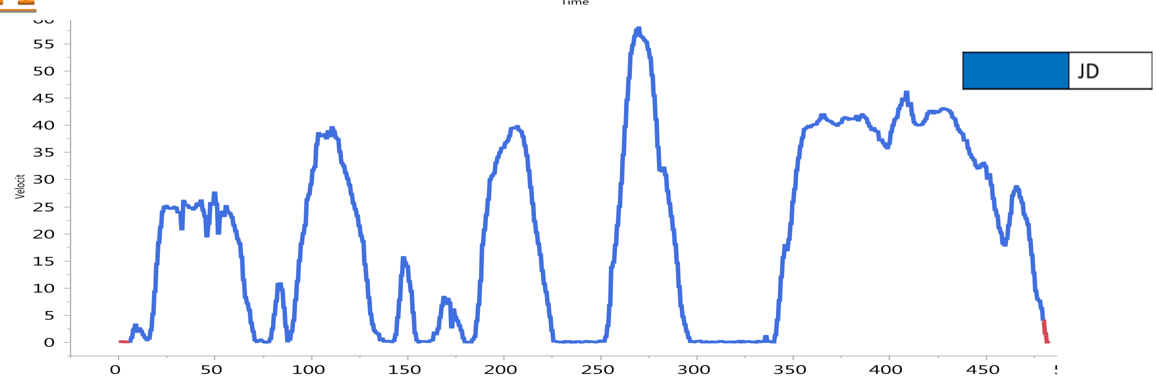
Trial 1

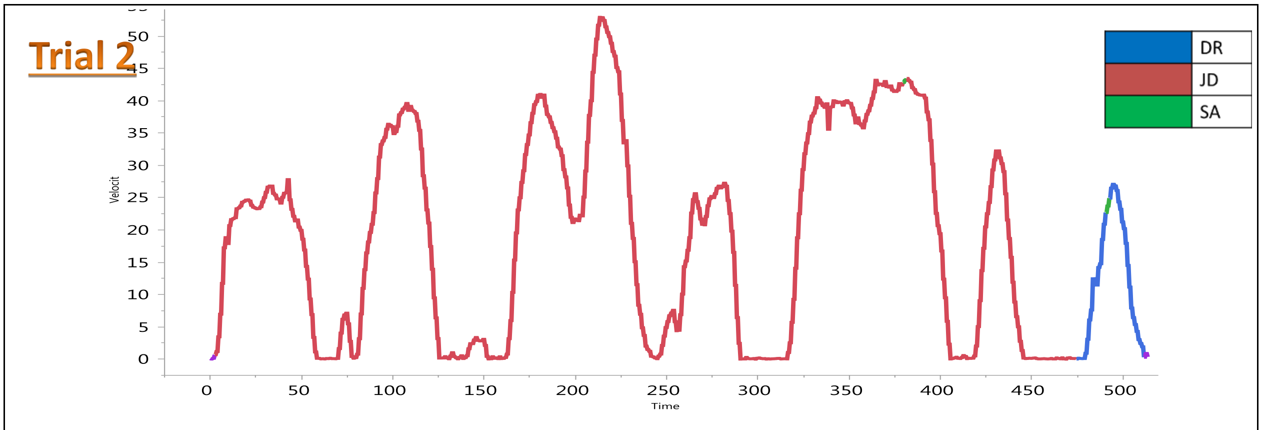


Trial 2

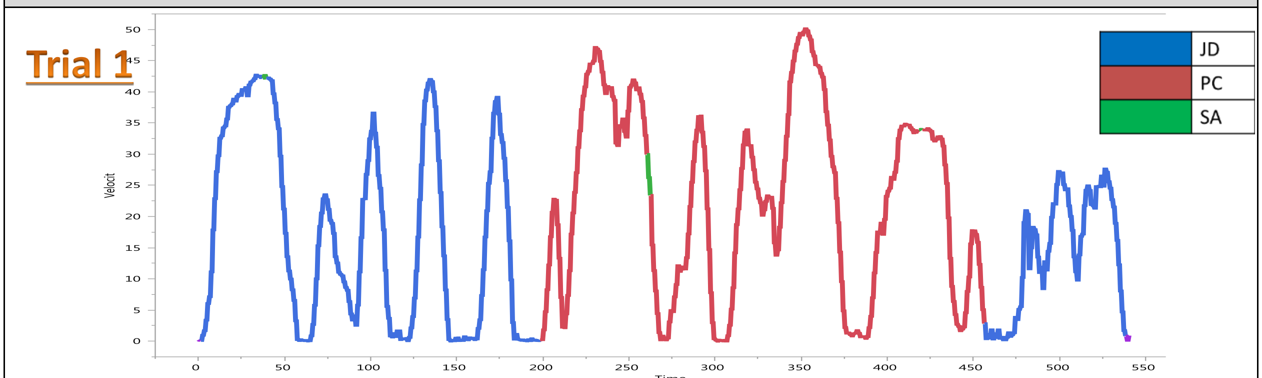


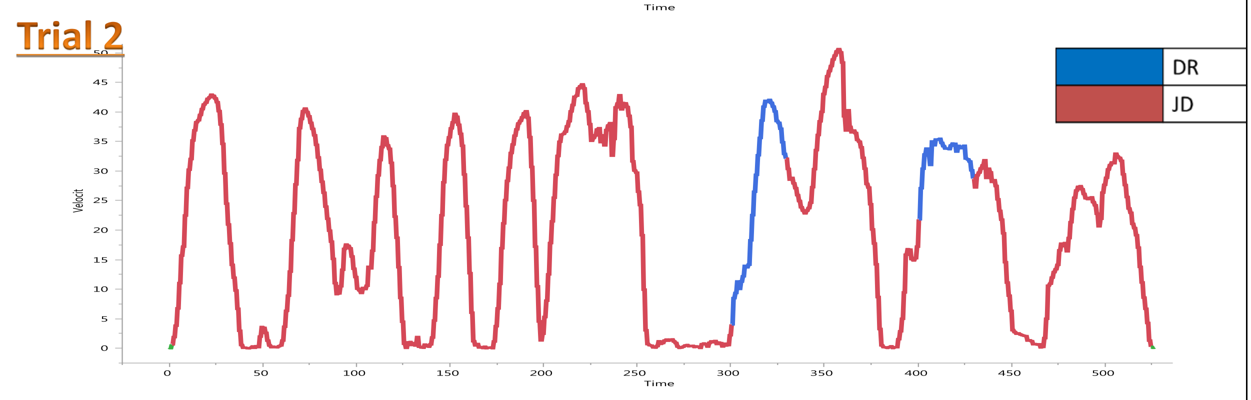
Trial 1

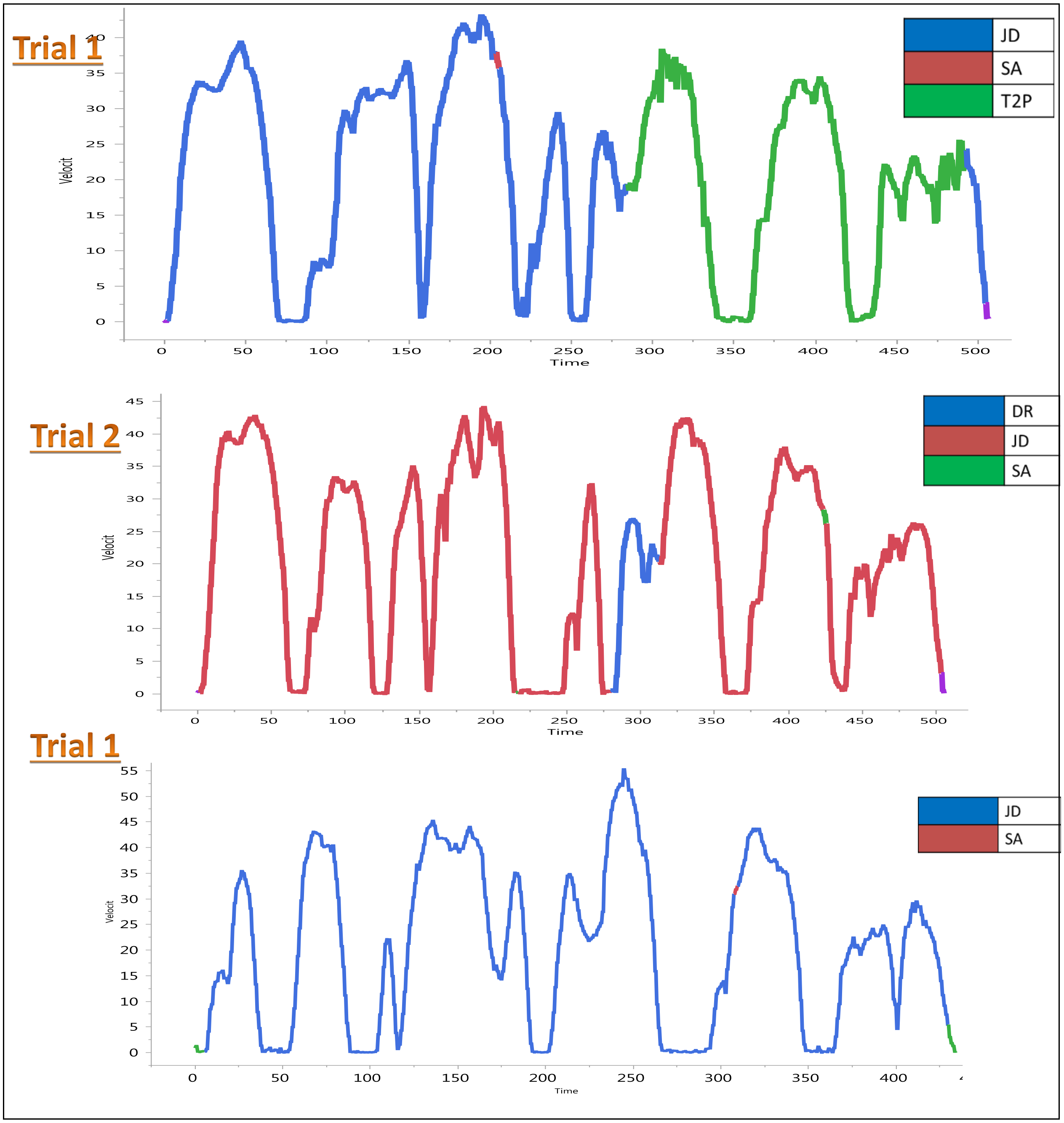




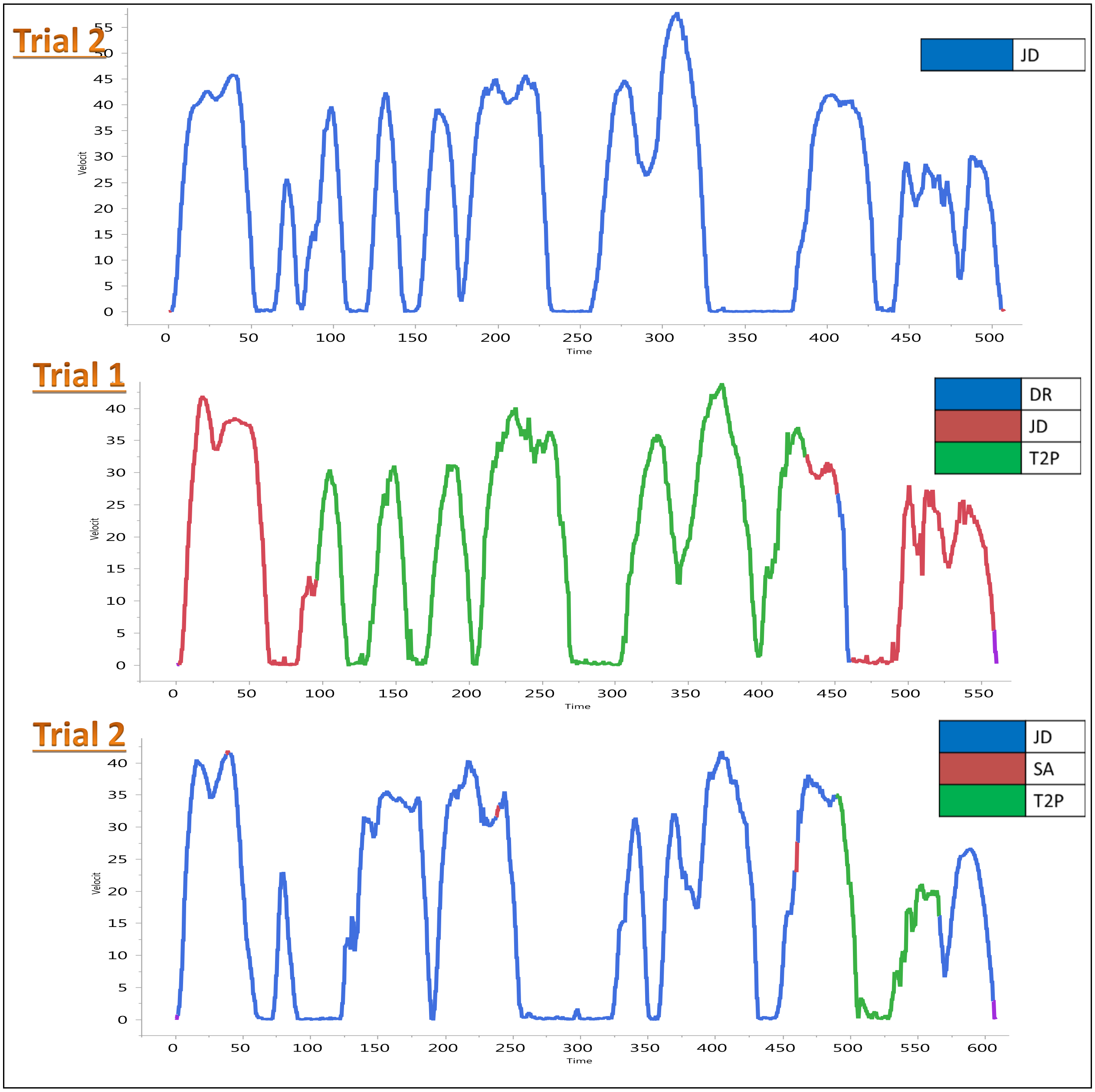
D. Velocity Profile along Toms Creek B (TCB) Route from Toms Creek WBND to Burrus Hall



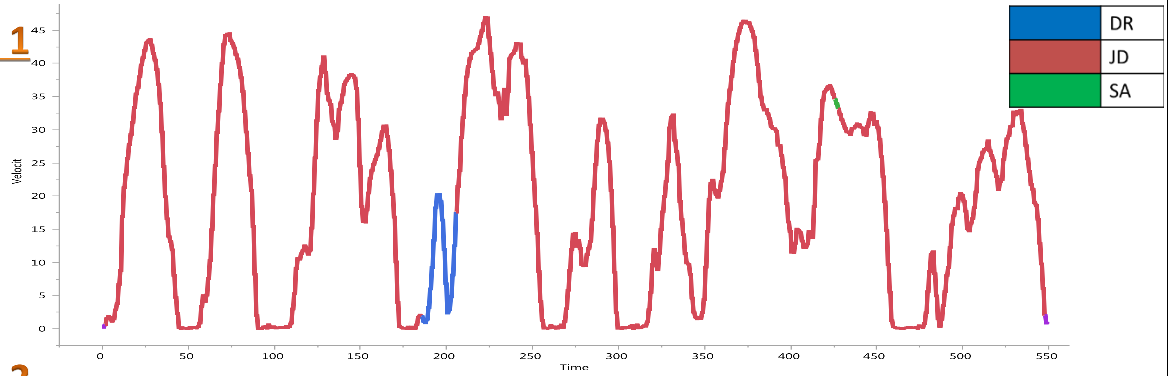




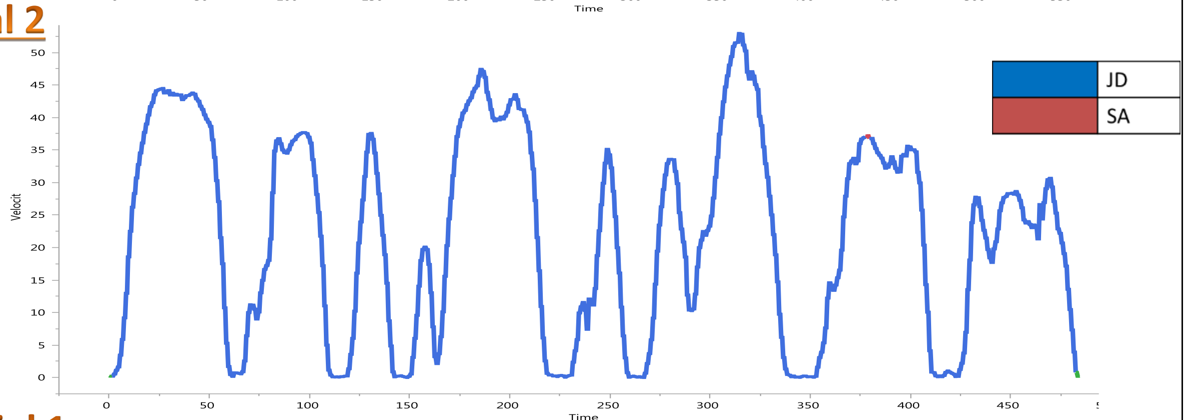
Trial 1
JD
SA
T2P
Velocit
Time
Trial 2
DR
JD
SA
Velocit
Time
Trial 1
JD
SA
Velocit
Time


Trial 2
JD
Velocit
Time
Trial 1
DR
JD
T2P
Velocit
Time
Trial 2
JD
SA
T2P
Velocit
Time

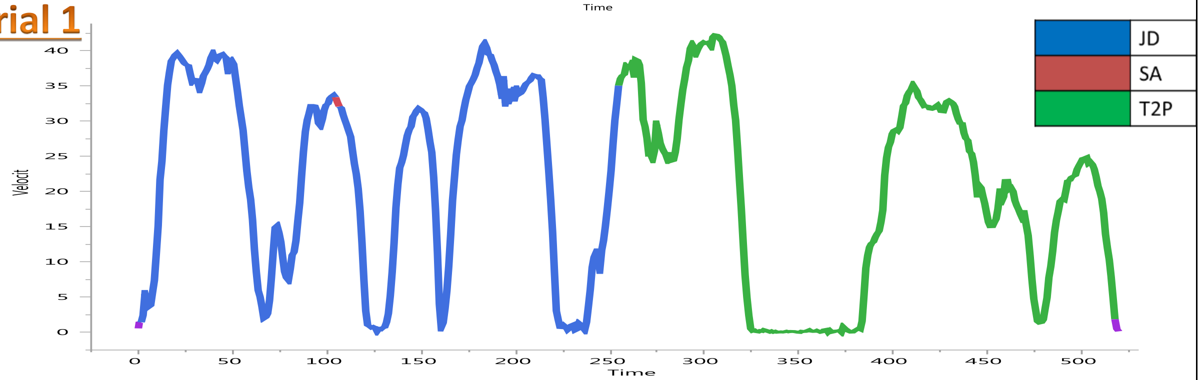
Trial 1



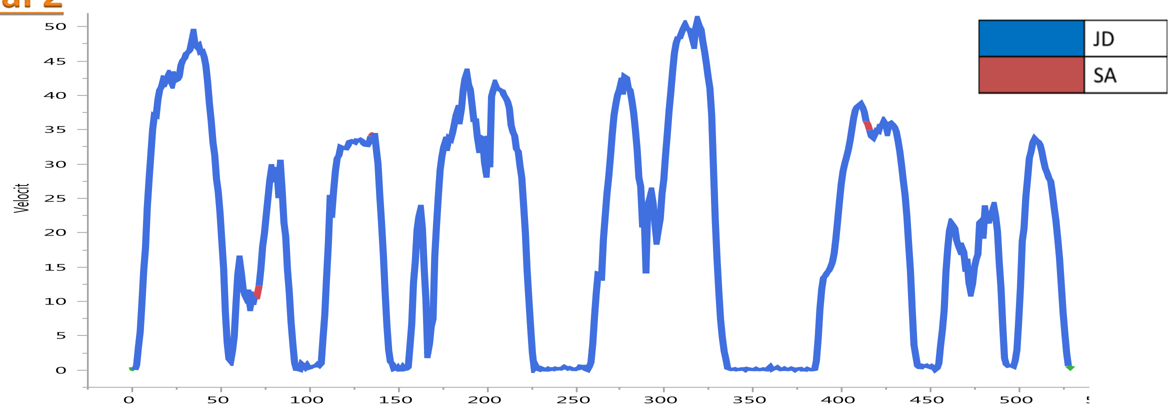
Trial 2



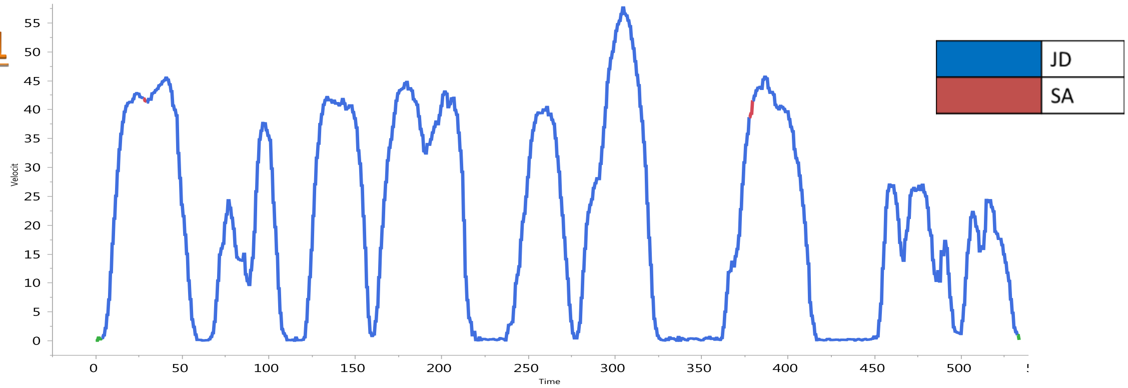
Trial 1



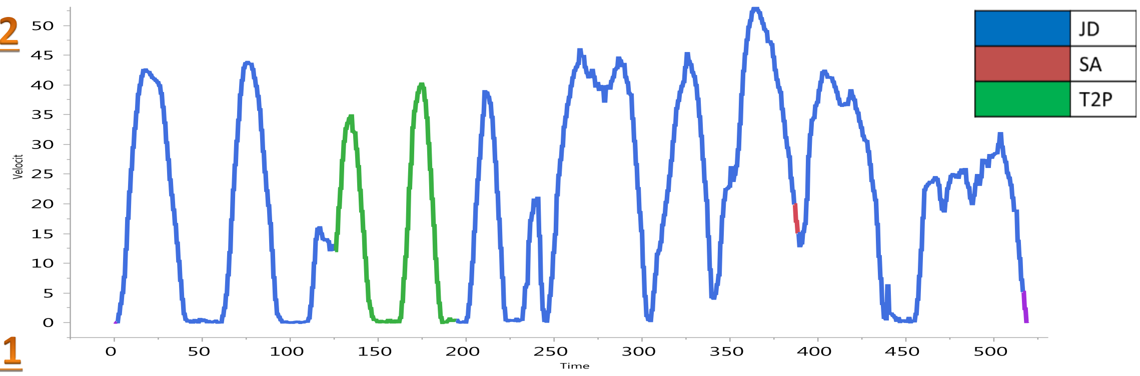
Trial 2



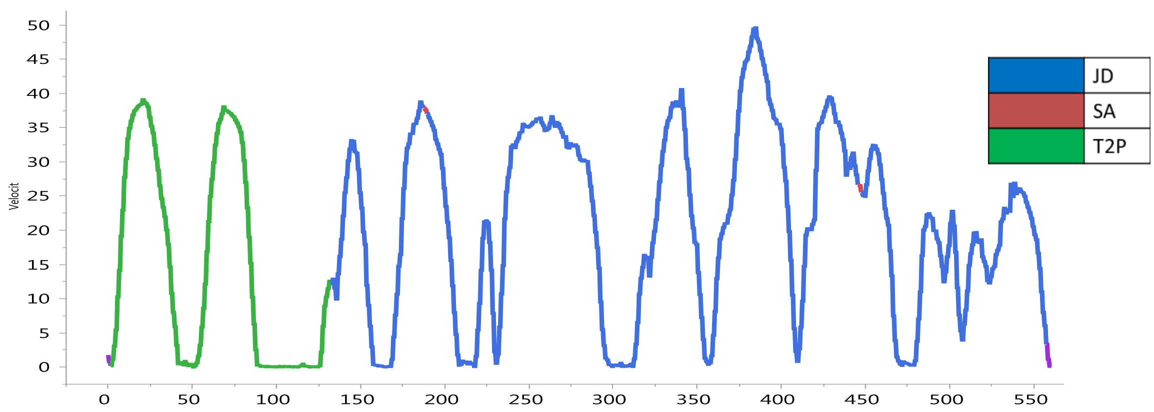
Trial 1



Trial 2



Trial 1



Trial 2