INSIGHTS FROM COMMERCIAL DRIVER PARKING DECISIONS IN A TRUCK SIMULATOR TO INFORM CURB MANAGEMENT DECISIONS

Draft Project Report

by

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16. Abstract

As e-commerce and urban deliveries spike, there is an increasing demand for curbside loading/unloading space. However, commercial vehicle drivers face numerous challenges while navigating dense urban road networks. Literature on the topic of how commercial vehicle drivers make choices about when and where to park is scarce, and data from those available studies usually come from field studies in which limited situations can be observed, without experimental controls, and there is an absence of known driver characteristics. Therefore, this study used a heavy vehicle driving simulator to examine the behavior of commercial vehicle drivers in various parking and delivery situations. A heavy vehicle driving simulator experiment examined the behaviors of commercial vehicle drivers under various parking and delivery situations. The heavy vehicle experiment was completed by 14 participants. The experiment included 24 scenarios with several independent variables, including number of lanes (two-lane and four-lane roads), with/without a bike lane, available/unavailable passenger vehicle parking space, CVLZs (no CVLZ, occupied CVLZ, and unoccupied CVLZ), and delivery time (3-5 mins and 20-60 mins). By collecting speed, eye-movement, and stress data during the experiment, the project produced results that support the development of more effective curb management strategies that will maintain efficient delivery operations while balancing the needs of all road users.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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LIST OF ABBREVIATIONS

CDL:	Commercial driver's license
CV:	Connected vehicle
CVLZ:	Commercial vehicle load zone
FDA:	U.S. Food and Drug Administration
GPS:	Global Positioning System
GSR:	Galvanic skin response
HMI:	Human-machine interface
IRB:	Institutional Review Board
LMM:	Linear Mixed Model
LSD:	Least significant difference
NACTO:	National Association of City Transportation Officials
OSU:	Oregon State University
PacTrans:	Pacific Northwest Transportation Consortium
PC:	Passenger vehicle
PPG:	Photoplethysmogram
SD:	Standard deviation
TFD:	Total fixation duration
UW:	University of Washington
VSL:	Variable speed limit
WSDOT:	Washington State Department of Transportation

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EXECUTIVE SUMMARY

Millions of people who live and work in cities purchase goods online. As e-commerce and urban deliveries spike, there is an increasing demand for curbside loading and unloading space. To better manage city curb spaces for urban freight, city planners and decision makers need to understand commercial vehicle driver behaviors and the factors they consider when parking at the curb.

Urban freight transportation is a diverse phenomenon. Commercial vehicle drivers must overcome several obstacles and adapt to various rules and policies to properly navigate the intricate metropolitan network and make deliveries and pick-ups. However, other road users and occasionally municipal planners generally view them as contributing considerably to urban congestion, , responsible for unauthorized parking, double parking, and exceeding their legal parking time.

These realities reflect the need for a thorough comprehension of commercial vehicle operators' core decision-making procedures and parking habits to inform and adjust curb management policies and procedures. However, more robust corroborated literature on the subject is needed. The information used in these studies is typically obtained from empirical field research, which, while valuable, is limited to certain situations and case scenarios. Therefore, to improve the operation of urban transportation networks, it is necessary to study commercial vehicle drivers' parking behavior in a controlled environment.

This project used a heavy vehicle driving simulator to examine commercial vehicle drivers' curbside parking behaviors in various environments in shared urban areas. Also observed were the interactions between commercial vehicle drivers and other road users.

The experiment was successfully completed by 12 participants. Five independent variables were included in this experiment: number of lanes (two-lane and four-lane roads), bike lane existence, passenger vehicle parking space availability, commercial vehicle loading zones (CVLZs) (no CVLZ, occupied CVLZs, and unoccupied CVLZs), and parking time (short-term parking: 3 to 5 minutes and long-term parking: 20 to 60 minutes). The heavy vehicle driving simulator also collected data regarding participants' driving speed, eye movement, and stress level.

Results from the heavy vehicle driving simulator experiment indicated that the presence of a bike lane had significant effects on commercial vehicle drivers' parking decisions., but only

a slight effect on fixation duration times. The average fixation duration time, representing how long participants looked at a particular object, on the road with a bike lane was 4.81 seconds, whereas it was 5.25 seconds on roads without a bike lane. Results also showed that the frequency of illegal parking (not parking in the CVLZs) was greater during short-term parking activities, occurring 60 times (45 percent of parking maneuvers). Delivery times also had a slight effect on commercial vehicles' speed while searching for parking (short-term parking was 17.7 mph; long-term parking was 17.2 mph) and on drivers' level of stress (short-term parking was 8.16 peaks/mins; long-term parking was 8.36 peaks/mins). Seven percent of participants chose to park in the travel lane, which suggested that commercial vehicle operators prioritize minimizing their walking distance to the destination over the violation of parking regulations.

The limited sample size demonstrated the value of our experimental approach but limited the strength of the recommendations that can be applied to practice. With that limitation acknowledged, our preliminary recommendations for city planners include infrastructure installation (i.e., convex mirrors installed at the curbside and CVLZ signs) to help drivers more easily identify legal parking spaces, and pavement markings (i.e., CVLZs, buffered bike lanes) to improve safety when parking. Parking time limits and buffers for bike lanes could improve efficient operation and safety for cyclists and other road users.

For future work, larger sample sizes should be collected. Additional factors could be considered, such as increased traffic flow, pedestrian traffic, conflicts among multiple delivery vehicles simultaneously, various curb use type allocations, and different curb policies and enforcement. Including a larger variety of commercial vehicle sizes and loading, zone sizes would also be of value. A combination of field observations and a driving simulator study could also help validate this investigation's outcomes

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CHAPTER 1. INTRODUCTION

One thematic emphasis area of the Pacific Northwest Transportation Consortium (PacTrans) is system-wide efficiency and traffic safety. This research project addressed this thematic emphasis by helping city planners develop better curb management policies to accommodate safe and efficient operations for all road users in the shared urban environment.

Dramatic increases in e-commerce, especially in urban areas, presents increased convenience for consumers. However, the resulting increase in freight movement to meet this demand has presented challenges because of limited parking availability. Commercial vehicles have to cruise for a parking space to load/unload goods; meanwhile, a lack of curbside loading zones significantly contributes to competition among various modes. Commercial vehicle drivers have to change parking behaviors to adapt to complex urban environments and maintain efficient delivery operations. These conflicts are contributing to urban congestion, illegal parking, double parking, and violations of parking time limits. A recent study by the University of Washington (UW) showed that many commercial vehicle loading zones (CVLZs) are often occupied by passenger vehicles, and competition among commercial vehicle drivers for limited parking space presents ever-present obstacles (Dalla Chiara, et al, 2021). It is necessary to develop a deeper understanding of commercial vehicle drivers' parking behaviors that could help to improve the operation of urban transportation networks. To study commercial vehicle drivers' parking behaviors in a controlled environment, a driving simulator experiment was conducted. The use of laboratory investigation allowed researchers to observe commercial vehicle drivers' parking behaviors with higher resolution sensors, thereby aiding in the development of explanatory mechanisms for the observed behavior.

This report discusses commercial vehicle drivers' parking behaviors in the following chapters: literature review, methodology, results, and conclusions to provide more information and help city planners improve urban transportation.

CHAPTER 2. LITERATURE REVIEW

The purpose of this research was to improve the existing understanding of commercial vehicle drivers' parking behaviors and the interactions among a commercial vehicle and other road users in an urban environment. The literature review was intended to provide a summary of previous documented research to better understand the project topic. Additionally, alternative methods for collecting and analyzing data were considered. Reviewed topics included but were not limited to safe parking behaviors and curb management policies.

Freight movement in the urban environment can be affected by the geometric characteristics and parking regulations (e.g., curb space type and location), human factors (e.g., parking behaviors and interaction with other road users), and other factors (e.g., time of day and weather). This chapter reviews the literature with a focus on commercial vehicle drivers' parking behaviors and interactions between commercial vehicles and other road users. In addition, this review compares different analysis methods, and it discusses how truck simulators have been applied to advance the state of knowledge in these areas.

2.1 Commercial Vehicle Loading Zones (CVLZs)

The advantages of curbside parking in comparison to off-street parking include flexibility, conservation of space, and convenience. This is particularly true for commercial vehicles that do not need parking for durations in excess of 30 minutes to load/unload goods. City planners must ensure the safety of both commercial vehicle drivers and other road users, while simultaneously providing convenient parking options. To address this need, cities have implemented commercial vehicle loading zones (CVLZs) on curbsides, which provide exclusive short-term parking access for commercial vehicles. Commercial vehicle drivers can apply for and purchase permits to use CVLZs for their loading and unloading operations. Nourinejad et al. (2014) stated that designating part of the curbside or individual spaces for commercial vehicles can dramatically improve the curb's operational efficiency.

2.1.1 CVLZ Size

The presence of a curbside loading zone does not mean that it is a sufficient size for loading activities. McCormack et al. (2019) suggested that because of limited curb space in comparison to vehicle size, couriers may overlap into space allocated to bicycle and pedestrian facilities. The authors found that the availability of open space near the driver and passenger doors, commercial vehicles type, loading accessories such as ramps, and location and type of cargo door on the vehicle all affect the safe and workable range of an operating envelope for a commercial motor vehicle. The results suggested that city planners could add a loading envelope that accounts for the typical size of commercial vehicles that serve the urban environment.

2.1.2 CVLZ Safety

The size of CVLZs can affect other road users. For example, commercial vehicle parking at the curbside may cause bicyclists to shift their lateral position and come into conflict with other vehicles or pedestrians. Jashami et al. (2020) tested the size of CVLZs (no CVLZ, minimum CVLZ, and maximum CVLZ), courier positions (no person, person behind the commercial vehicle, and person beside the commercial vehicle), and the use of an accessory (with or without a hand cart) to study their effects on cyclist behavior and speed. Results showed that when there is a courier on the driver's side of commercial vehicles, the smallest CVLZs often cause the greatest behavioral response in cyclists because they tend to drive the cyclist from their exclusive lane to the adjacent vehicle lane. Therefore, it is necessary for city planners to consider CVLZ size and bike lane width to reduce cyclist risk.

Jashami et al. (2020) also looked at the interaction between commercial motor vehicles and bicycles when there was no CVLZ, a situation in which the driver may use the bicycle lane itself for loading and unloading operations. This staging location entirely obstructs a bicyclist's path, forcing the cyclist to diverge into either the travel lane or onto the sidewalk, with two-thirds preferring the travel lane. It is therefore necessary to study the frequency of commercial vehicles parking in the bicycle lane in a variety of scenarios in order to appropriately address the safety issues that unauthorized parking may cause. Abadi et al. (2019) emphasized that the presence of trucks does affect cyclist behavior in the form of speed and lateral position, and at urban CVLZs, the risk of collision associated with truck operations may increase, as four crashes between bicycles and exiting trucks were observed during the bicycling simulator study.

Unauthorized curbside parking in urban areas can result in safety problems such as limited visibility for other road users. Mukherjee and Mitra (2020) concluded that pedestrian to vehicle volume ratio, vehicle overtaking, roadside parking obstructing pedestrian line of sight, insufficient line of sight, encroachment on the sidewalk, and pedestrian crossings are the most important factors that affect pedestrian safety.

The width of the motorway lane also influences safety. When commercial vehicle drivers enter/exit parking spaces, motorways with narrower lanes experience additional congestion for other vehicles. Sisiopiku (2001) pointed out that over time traffic lanes are being replaced by parking lanes, or traffic lane widths are being reduced to allow for on-street parking, all of which contribute to increased congestion.

2.2 Traffic Congestion

2.2.1 Congestion Due to Curb Demand

A growing challenge is the demand for curb space regularly exceeding capacity (Holguín-Veras, 2016). Because of COVID-19, many people have transitioned to remote working, which hascontributed to a sharp growth in e-commerce and direct-to-home deliveries. UPS estimated that 74 percent of customers prefer delivery to home over delivery to access points (Mukherjee and Mitra, 2020). Researchers tested a few blocks of New York City for residential demand and found demand rates of 200 to 600 packages per day (Chen, et al., 2017). Not only commercial vehicles but also passenger vehicles, buses, electric charging stations, and restaurants/cafes with outdoor seating areas need access to curb space.

2.2.2 Congestion Causing Cruising

For business districts, commercial vehicle drivers prefer to choose a location from which it is easy to load/unload goods and often choose the nearest location parking, even if they have to spend additional time searching for a desirable space. Parking in an urban area requires more time to find a legal space for delivery.

Dalla Chiara and Goodchild (2020) used GPS data and Google Maps Distance Matrix API simulation to test different policy scenarios. A primary result of this study was the determination that a positive cruising time for commercial vehicles exists, with 2.3 minutes on average spent cruising for parking per delivery trip and 28 percent of total trip time devoted to cruising. This indicated that commercial vehicle drivers do prefer to look for curbside parking rather than park in the travel lane. Dalla Chiara et al. (2021) also observed through ride-alongs in a separate study on commercial vehicle driver behaviors that drivers parked in the travel lane only 4.5 percent of the time, with four out of six drivers never parked in the travel lane. However, unauthorized curbside parking happened at a much higher rate of 20.5 percent. Because drivers did cruise for parking and rarely chose to park in the travel lane, it was clear that drivers constantly weighed and evaluated their available options while considering the risks and impacts of their decisions. The aforementioned study named three factors, based on qualitative reports from the drivers, that drivers consider when looking for parking: safety, conflicts, and competition. Results showed that an increase in commercial vehicle parking spaces can decrease delivery time for drivers. Moreover, the study compared estimated and real travel times and concluded that the addition of one CVLZ could reduce cruising time, i.e., time spent looking for parking, by 1.3 percent to 6.5 percent.

2.2.3 Congestion Affecting Behavior

In the study by Dalla Chiara et al. (2021) of delivery driver behavior through ride-alongs, it was also observed that at different levels of congestion (before and during COVID-19 related lockdowns), the same delivery driver might make significantly different parking decisions. One driver increased the authorized parking rate from 0 percent to 56.2 percent as a result of less traffic and more curb availability.

If the curbside does not have enough available space, commercial vehicles may double-park, which can negatively contribute to congestion and safety. A simulation study showed that after eliminating double-parking, the average speed increased 10 percent to 15 percent, and delay and stopped time decreased by 15 percent to 20 percent (Gao and Ozbay, 2016).

2.3 Operating Speed and Speed Limits

Vehicle speed directly influences the safety of all road users. It can be affected by lane width, parking behavior, other road users, weather, speed limit, and double-parking, among others. To improve curbside parking safety and reduce traffic delay, it is necessary to fully understand the relationship between speed and contributing factors.

Several characteristics of curbside parking can directly influence driving speed. Ye and Chen (2013) used video data to construct a hazard-based duration model to analyze the distribution of travel speeds influenced by curbside parking. When the effective lane width was reduced from 4.5 m to 2.2 m, driving speeds decresed by 37.5 percent. The authors also tested inbound and outbound parking maneuvers, e-bike and bicycle volumes, and time influence ratio. The results showed a negative effect on travel speed as the related factors increased.

Amer and Chow (2017) studied downtown Toronto and found that ignoring truck operator behavior may overestimate driving speed and cruising capacity for motorways overall, contributing to traffic congestion and influencing space distribution. Because of the positive impact of reduced speed limits on the social welfare of commuters' parking and truck transport costs, New York City implemented a reduction in speed limits from 30 mph to 25 mph in 2016.

2.4 Parking Fees

When commercial vehicles deliver goods, the total cost of the trip includes a variety of factors, e.g., labor, parking, fuel, and insurance. It is possible that when curbside parking fees or parking fines are lower than the cost of parking lots and the delivery fee, drivers prefer to pay for fines and continue parking on-street. Drivers compare not only parking fees but also the expected penalty and the cost of lost time. Auchincloss et al. (2015) analyzed data from 107 cities in America and concluded that only 36 percent of small cities had higher parking charges/fines, while 67 percent of big cities had higher parking charges/fines. The average hourly charge for street parking meters was very low—$1.17—and only about 25 percent of big cities charged $2 per hour or more. Additionally, Amer and Chow (2017) pointed out that package delivery services like FedEx and UPS paid parking fines of more than $1.5 million in Toronto in 2006. Private operators can pay millions of dollars a year in parking fines: in 2011, for example, operators paid $8.2 million in Chicago and $2.5 million in Toronto in 2009 (Dalla Chiara et al, 2020).

Commercial vehicle drivers sometimes consider parking fees when selecting a location for loading/unloading goods. Possible parking locations can include space at the curbside or in a garage, which are often associated with different cost structures. Drivers often prefer on-street parking because of the comparatively low price. It was determined that the price efficiency gap in Barcelona was between EUR 0.45 ($0.54 US) and EUR 1.05 ($1.25 US) because of the mismatch between roadside and garage pricing systems (Gragera and Albalate, 2016). The low price of curbside parking can contribute to congestion. Except for some lucky drivers who occasionally find cheap and convenient parking spaces, all other drivers who cruise to find open space waste time and fuel, contributing to congestion and air pollution. The high price and insufficient occupancy of parking spaces also cause problems. When roadside spaces remains vacant, businesses lose potential customers (Pierce and Shoup, 2013).

2.5 Peak and Off-Peak Hours

When commercial vehicle drivers need to coordinate their loading and unloading activities with the work schedules of businesses, they are constrained by the operating hours of those businesses. Thus, commercial vehicle parking tends to conflict with peak hour congestion.

Dalla Chiara et al. (2020) stated that the receiving enterprise usually wants goods delivered within its operation time, which commonly overlaps with traffic peak hours. Therefore, commercial vehicles often encounter parking congestion when they arrive, especially in the loading area. The driver then chooses between waiting in line to enter the loading area, illegally parking elsewhere, or parking in a passenger vehicle (PC) space. Moreover, peak hour on-street parking does not provide enough space for commercial vehicles, as they are in direct competition with passenger vehicles and other vehicles.

Sometimes commercial vehicle drivers need to deliver goods late at night or early in the morning; this requires good in situ lighting to promote safe and efficient operations. For example, the Early Bird Special varies for each garage, but it usually allows arrivals before 10:00 a.m. (sometimes even 11:00 a.m.) and departures before 7:00 p.m. (sometimes as late as midnight). This pricing strategy may optimize earnings by reducing turnover and labor expenses for firms that operate off-street parking lots (Roth, 2004).

Recommendations to mitigate the congestion produced by commercial vehicle deliveries include off-peak delivery, reducing passenger vehicle demand through demand management practices, improving public transport to reduce private passenger vehicles, creating “truck only” areas (such as in the Clothing District of New York City), using integrated information systems, and introducing integration centers outside the city (Amer and Chow, 2017). The off-peak hour delivery may reduce cruising for parking, congestion, and delay, but it has disadvantages such as inconvenience for employees to load or unload goods. A pilot study in New York (Chen et al., 2017) looked at non-working time delivery to reduce the demand for curb space during peak hours. These strategies produced mixed results. Smart meters and commercial meters effectively improved vehicle turnover rate, but in areas where non-compulsory service vehicles occupied these spaces for extended periods of time, the effect of delivery windows proved to be very small. While the pilot clearly demonstrated the benefits of off-peak delivery, the expansion of the program was limited by barriers to receiving deliveries during off-peak periods..

Therefore, scheduled deliveries for the peak hour and off-peak hour both have advantages and disadvantages. As such, it is necessary for further study to take into consideration highly variable local conditions.

2.6 Dwell Time

Policy makers usually deal with the problem of parking demand exceeding supply by controlling time limits and pricing parking to promote parking turnover (Nourinejad et al., 2014). For commercial vehicles, time limits may not negatively influence operations because commercial vehicles typically park for short durations.

Dalla Chiara et al. (2021) found that the duration of parking, also known as dwell time, depended on a variety of factors, including the type of package being delivered, the number of packages delivered at each stop, and the type of building that was being delivered to. However, dwell time was also affected by the choice of parking type, with authorized parking having a median dwell time of 15 minutes in comparison to unauthorized curb parking and travel lane parking, each at less than 5 minutes. This may indicate that drivers are able to choose to shorten their dwell time when they know they may be fined, or that their authorized parking choices often result in longer dwell times because of distance from the target building. For either scenario, further study could illuminate how drivers decide the length of time they will stay parked. Parking fees could be combined with limits on parking duration, and the threat of penalties tied to parking duration might encourage greater parking efficiency. Roth (2004) also mentioned that time limits encouraged turnover, and research results showed that parking duration was reduced by about 10 percent when time limits were implemented in areas where there had been no time limit before. Thus, time limited parking could provide other road users with a more positive experience while protecting commercial vehicle drivers' working time and efficiency.

2.7 Parking Angle

On-street parking includes parallel and angled parking. For perpendicular parking, the reduction of lateral clearance can cause tension and line of sight issues for the driver, so drivers operating in the adjacent through -lane must slow down. In a field investigation, parking facilities were modified from parallel to perpendicular. This kind of conversion greatly reduces the side clearance and adjacent lane width. However, the risk of traffic crashes increases because of sight distance limitations (Guo et al. 2012). Yousif and Purnawan (1999) evaluated variations of 90° angle parking (perpendicular) and emphasized that when parking perpendicular, drivers are required to reverse. In addition, these maneuvers can contribute to operational problems such as congestion, delays, and crashes. Especially during the high traffic flow period, the risk increases.

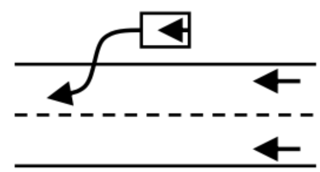
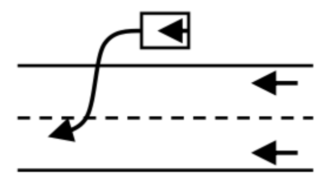
Type of parking	Leaving time manoeuvre (second)								
	Pattern I				Pattern II				Total
									
	Mean	St.Dev	Sample	Range	Mean	St.Dev	Sample	Range	
Parallel on-street parking	6.3	2.5	63	2.3-15.2	5.5	2.0	10	4.0-10.1	73

Figure 2-1 Leaving maneuver times for parallel parking (Yousif and Purnawan, 1999)

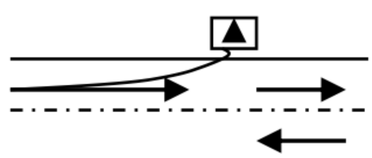
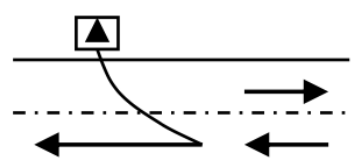
Type of parking	Leaving time manoeuvre (second)								
	Pattern I				Pattern II				Total
									
	Mean	St.Dev	Sample	Range	Mean	St.Dev	Sample	Range	
Angle on-street parking	9.6	5.2	121	4.2-45.6	11.8	3.8	20	6.0-21.6	141

Figure 2-2 Leaving maneuver times for angle parking (Yousif and Purnawan, 1999)

Parallel parking is one of the most common curbside parking methods. Drivers need to park next to the curb, often between two other cars. In many congested areas, limited space is available. Parallel parking also requires a greater degree of proficiency than other parking maneuvers. Parallel parking can require the driver or passengers to exit the vehicle into the travel way (Oregon Department of Transportation, 2001). Some transportation engineers have advocated for avoiding curbside parallel parking. Box and Levinson (2004) pointed out that parallel curbside parking reduces the width of pavement, potentially contributing to congestion. During parallel parking maneuvers, a single vehicle can block the entire travel lane. Meanwhile, with the increasing demands on curb space, the optimization of this limited resource is important. Parallel parking cannot make full use of this resource. From this perspective, angled parking can increase parking capacity. Moreover, angled parking improves safety for pedestrians entering or exiting parked vehicles (Sisiopiku, 2001).

2.8 Possible Research Methods and Analysis

The goal of this research was to identify commercial vehicle parking behavior and the relationship between commercial vehicles and other road users in urban areas. Commonly applied research methods were identified from the reviewed literature, technical reports, and guidebooks produced by state and federal transportation agencies. Brief discussions of the relevant methods are highlighted in the following subsections.

2.8.1 Heavy Vehicle Driving Simulator

Driving simulators provide researchers a safe method with which to evaluate the performance of drivers in relation to uniquely configurable scenarios. Also, driving simulators allow researchers controllability, reproducibility, and standardization because of the laboratory nature of these tools. The behavior of virtual traffic, weather conditions, and road layout can be configured (offline or in real time) according to training needs or research objectives (de Winter et al. 2012).

A number of studies have been conducted with a truck simulator, Gillberg et al. (1996) compared the daytime and night-time performance of truck drivers, and the research team also studied whether napping or rest breaks affected performance. Panerai et al. (2001) studied truck speed and headway to a preceding vehicle in the Renault-V.I. truck simulator and in real-world tests. The simulation environment included a motion platform, truck mockup with acoustic feedback, and a sophisticated visual rendering for the frontal display. Yang et al. (2020) studied the effects of the human-machine interface (HMI) of a connected vehicle (CV) on truck drivers' cognitive distraction and driving behaviors through a driving simulator experiment. By using a truck simulator and eye-tracking technology, Raddaoui and Ahmed (2020) quantified the workload requirements and distractions of professional truck drivers with field weather impact warning (SWIW) and work area warning (WZW) applications. Yao et al. (2019) established an eco-driving training system by using a driving simulator to test fuel consumption and motor vehicle emissions to provide guidance on reducing emissions. Yang et al. (2019) tested a variable speed limit (VSL) warning system for connected vehicle applications in a truck simulator. The purpose was to evaluate the impacts of connected vehicle-based VSL (CV-VSL) application in Wyoming on truck driver behavior under severe weather conditions. This body of work suggests growing interest in the application of driving simulators for understanding truck driver behavior.

2.8.2 Field Observation and Video Data

Field observation and video data collection are often used in research to determine the behaviors of road users in different environments and the interactions between road users. McCormack et al (2019) used field observations of deliveries in urban areas in Seattle, Washington, with a particular focus on CVLZs adjacent to sidewalks and bike and transit lanes. Low et al. (2020) used field observation through roadside video recordings, combined with electronic parking records, to build a regression model to predict the parking time of commercial vehicles in the loading area of retail stores and to identify important contributing factors. Holguín-Veras (2016) verified the information obtained in a database of parking availablity and regulations through field visits and found ways to better manage the existing infrastructure and provide the additional space required. Dalla Chiara et al. (2021) used filed data to find that mail and heavy goods delivery typically required greater dwell times than other deliveries, and dwell times associated with approved parking areas were much longer than those of other parking places.

2.8.3 GPS Data

Global Positioning System (GPS) data are commonly used in research because of their accurate tracking of vehicle movements. It is relatively easy to capture time, route, and destination data for analysis and management of transportation systems. Dalla Chiara and Goodchild (2020) used GPS data from 2,900 trips taken by a fleet of commercial vehicles as they delivered and picked up parcels in downtown Seattle, Washington. By comparing estimated and observed trip times, they produced trip time deviations, analyzed their empirical distribution, and performed regression analysis. In a study by Nevland et al. (2020), GPS data were collected through a mobile application installed on the observer’s mobile phone to estimate the average cruising time of a trip between delivery/pickup locations. GPS data were also used to identify where trucks parked in the study area. With this information, a new classification scheme was developed to categorize each location by using the GPS data collected from the GPS data record that tracked the movement of commercial vehicles. In another study, to improve the management of commercial vehicle parking and ensure correct parking space utilization, truck GPS data were used to predict the utilization rates of commercial vehicle parking in 46 rest areas (Haque et al. 2017).

Dalla Chiara and Goodchild (2020) used real trip times from GPS data To estimate the respective truck driving times by querying the Google Maps Distance Matrix API. Then they used regression analysis to observe how trip time deviations were affected by parking infrastructure at the respective trip destinations. Nevland et al. (2020) used a data-driven systematic approach, combined with literature,e to classify commercial vehicle parking locations and maintained that the proposed scheme was designed to be general. However, these methods could not provide robust details about drivers' demographics or parking behavior, nor about the relationship between commercial vehicles and other road users. Therefore, GPS data were not an appropriate approach for this project.

2.8.4 Microscopic Traffic Simulation

Microscopic traffic simulation is a computer method whereby individual vehicle-level parameters, such as vehicle speed and headway, are modeled and analyzed (Toledo et al. 2001). Lopez et al. (2019) implemented a microscopic traffic simulation of a Manhattan network and the network of Lyon, France, to explore the relationship among searching time, parking probabilities, and the region's parking density. On the basis of the research results, an application of a last-mile cost function was proposed. However, this method was limited in its accuracy of modeling drivers' parking behaviors, in the absence of substantive calibration and validation.

2.8.5 Generalized Model Analysis

Generalized model analysis includes many different statistics models that researchers use to analyze data. For example, Gopalakrishnan et al. (2020) used a multinomial logit model framework and SimMobility to assess the impacts of changes in overnight parking supply on traffic. A regression model was developed to predict the parking times of commercial vehicles in the loading area of retail stores and to determine factors that affect parking time (Low et al. 2020). These models are good for data analysis and could have been implemented in this work, but would have had to be applied to available or collected data.

2.8.6 Empirical/Theoretical Analysis

Empirical or theoretical analysis is another method that has been used to evaluate transportation system performance. Aljohani and Thompson (2016) summarized the empirical results of increasing truck travel distance due to logistics facility expansion in several European and North American cities. The work outlined the measures and policies implemented in major urban areas to reintegrate small logistics facilities into more central areas. However, this method cannot meet the needs of observing commercial vehicle drivers' parking behaviors.

2.9 Summary

This literature review considered previous studies related to commercial vehicle drivers' parking behaviors and the relationship between commercial vehicles and other road users in urban environments to provide guidance on curb management for city planners. The review included topics ranging from loading zone size and safety to strategies for addressing high urban freight demand.

Previous research has indicated that the demand for curb space in urban areas has outstripped the corresponding growth of capacity, contributing to problems such as cruising and congestion. Consideration should be given to how best to support the parking needs of commercial vehicles. During the pandemic, dramatic shifts to remote working and studying changed the travel habits of many. Additionally, delivery-to-home for goods increased the volumes of delivery vehicles, predominantly in residential areas. These shifts in travel and freight delivery patterns may well have shifted safety risks across the transportation network; however, it is too soon to analyze this comprehensively. Meanwhile, in commercial districts, many commercial vehicle drivers want to save time by parking in locations where it is easy to load/unload goods in proximity to their destinations. City planners must establish a commercial vehicle envelope to protect both couriers and other road users such as bicyclists and pedestrians. Moreover, research has found that the existence of CVLZs could improve adjacent roadway efficiency. Assigning enough curbside space (e.g., CVLZs) or actively managing curbside space (e.g., parking time limits based on performed activities) for commercial vehicles could increase commercial vehicle drivers' working efficiency.

Safety also plays a clear role in commercial vehicle parking. Especially, in business areas, curbside parking for trucks potentially affects cyclists and pedestrians because of decreased lines of sight and conflicts resulting from parking activity. Parking angle is another vital factor that influences safety because perpendicular parking may cause sight distance limitations for drivers and increase the operational difficulty of performing certain parking maneuvers.

Different parking facilities and corresponding driver parking behaviors produce different speed profiles on the adjacent road. For example, double-parking can reduce traffic speed, increasing congestion and delay. Other confounding factors that affect driver speed selection include lane width, weather, and many others. Several studies have mentioned that parking fees can dramatically influence driver’s parking decisions. Because of different pricing schemes for parking lots and curbside spaces, drivers who have short parking stays prefer the curbside, and even occasional parking fines may still result in net benefits in comparison to the costs of parking lots. Therefore, the prices for different parking options need to be well balanced. The peak hours and off-peak hours for commercial vehicle curbside parking can also affect adjacent traffic flow, depending on travel lane width and parking maneuver type. Previous research has shown that peak hour deliveries have a high probability of producing congestion. However, commercial vehicles tend to schedule delivery times during the typical workday. Therefore, if possible, it would be good to encourage, possibly through incentives, the delivery of goods by truck during off-peak hours to reduce the pressure on urban curbs. Finally, several studies have pointed out that time limited parking is another good way to better manage curbside parking, not only to reduce cruising time but also to increase curb parking turnover.

Although different methods have been used in commercial vehicle studies, not all methods could provide insight into commercial vehicle drivers’ perspectives when they were parking curbside in urban areas. This project aimed to study commercial vehicle drivers’ decisions and parking behaviors to help city planners make/change curb planning and policies. Therefore, after comparing several methods, this study selected a heavy vehicle driving simulator as the best choice for the study of commercial vehicle drivers’ parking behaviors and interactions between commercial vehicles and other road users in an urban environment. A heavy vehicle driving simulator would provide data on drivers’ parking behaviors, eye-movements, and stress needed to resolve existing research questions.

CHAPTER 3. METHODOLGY

3.1 Simulator Equipment

This study used the Quarter Cab Heavy Vehicle Driving Simulator for collecting data. the following subsections detail each of the relevant equipment.

3.1.1 Desktop Development Simulator

Before being transmitted to the computers powering the heavy vehicle simulator, the finalized simulated environments were tested on a desktop simulator. The multimonitor desktop development simulator and the Quarter Cab Heavy Vehicle Driving Simulator are the two primary elements of the OSU driving simulator facility that were leveraged for this research project. The desktop simulator with a steering wheel and floor pedals was used by the researchers to build and test-drive the experimental environment (figure 3.1). This preliminary testing process allowed for quicker and more seamless iterative design and troubleshooting (Hurwitz et al., 2021).

Figure 3-1 Desktop Development Driving Simulator at OSU

3.1.2 Heavy Vehicle Simulator

The FAAC/Realtime Technologies TT-1000 research class heavy vehicle (Class 9, five-axle, semi-tractor with trailer; box.) driving simulator was designed to provide meaningful training experience for operators. Multiple high-definition (HD) displays provide an extended, geometric correct +210 ° field of view and adjustable embedded mirrors. The cab is universal and is similar to many vehicle brands and models. Our specific version of this includes a digital dashboard that uses the Altia design to present any dashboard configuration. The simulator can be operated with SimDriver. This means that the vehicle can operate at different levels of automation, which promotes research into cab automation systems of heavy vehicles.

Figure 3-2 Quarter Cab Heavy Vehicle Driving Simulator at OSU

Meanwhile, a Tobii Pro Glasses 3 eye-tracker, and a Shimmer3 galvanic skin response sensor were used to collectively assess driver behavior such as speed, parking decision, response to other road users, and stress. Eye movement data were collected with the Tobii Pro Glasses 3.

3.1.3 Eye-Tracker

Tobii Pro Glasses 3 incorporate 16 illuminators and four eye cameras into scratch-resistant glasses, allowing for optimal placement and an unobstructed view for the wearer. The scene camera has full HD resolution and a combined field of view of 106°. It also provides clear and tinted additional protective lenses. Therefore, participants who wear glasses also can join the study and wear their corrective lenses. Meanwhile, tinted lenses can protect participants who need to work in the sun. Head and eye motions are distinguished by the built-in accelerometer, gyroscope, and magnetometer sensors, which remove the influence of head movement on eye tracking data.

In Figure 3-3 the subject's eye movements are shown by orange lines, and the green circle is the target that the subject was watching. We were able to interface the glasses with galvanic skin response (GSR) devices and heartrate monitors (EXG). We used the iMotions platform to interact with and operate them, which synchronized all of the data collected from the various sensors and merged them into a single, time-stamped dataset.

Figure 3-3 Tobii Pro Glasses 3

Figure 3-4 Example eye tracker record while driving

3.1.4 Galvanic Skin Response (GSR)

Galvanic skin response (GSR) and photoplethysmogram (PPG) signals were measured by the Shimmer3 GSR+. Two electrodes linked to two distinct fingers on one hand collected GSR data. These electrodes detected stimuli in the form of changes in moisture, which increased skin conductance and changed the electric flow between the two electrodes. As shown in figure 3-5, the Shimmer3 GSR+ GSR and PPG sensors were attached to an auxiliary input that was strapped to the participant's wrist and fingers. The data were wirelessly transmitted to a host computer running the iMotions EDA/GSR Module software, which included automated peak detection and temporal synchronization with other experimental data. For statistical analysis, the findings were exported to various file types (e.g., Excel and RStudio).

Figure 3-5 Shimmer3 GSR+ sensor strapped to the researcher's wrist

3.2 Heavy Vehicle Simulator Experimental Design

In this section, relevant experimental design processes are introduced, including research questions, driving simulator experiment design, and scenario details.

3.2.1 Human Subjects Work Approval

According to U.S. Food and Drug Administration (FDA) regulations, research involving human beings must be authorized by the Institutional Review Board (IRB). This project was approved by the Oregon State University Human Research Protection Program with IRB (Study number IRB-2021-1008), and the approval document can be found in Appendix A.

3.2.2 Research Questions

The research questions for this experiment related to the assessment of commercial vehicle drivers' parking location decisions based on the effects of the independent variables. Equipment mentioned in the previous section were used to examine parking behavior, visual attention, and level of stress across the independent variables.

Illegal/Legal Parking Decision

- *Research Question 1 (RQ_1)*: If all curbside parking spaces are occupied and no conflicting bike lane is present between vehicle parking and the adjacent travel lane, what percentage of commercial motor vehicle operators will double park?
- *Research Question 2 (RQ_2)*: If all curbside parking spaces are occupied and a bike lane is present between vehicle parking and the adjacent travel lane, what percentage of commercial motor vehicle operators will double park?
- *Research Question 3 (RQ_3)*: With what frequency do commercial motor vehicle operators select an illegal parking space in comparison to circling to find a legal space?

Visual Attention and Level of Stress

- *Research Question 4 (RQ_4)*: How do physiological measures such as visual attention and stress, as well as the decision making of commercial motor vehicle operators, vary in different parking scenarios?

Parking Location Decision

- *Research Question 5 (RQ_5)*: Do commercial motor vehicle operators prioritize minimizing walking distance to the destination over violation of parking regulations?

3.2.3 Driving Simulator Experimental Design

Five independent variables were proposed for the experiment: Number of lanes, presence of a bike lane, presence of a passenger car parking space, presence of a commercial vehicle loading zones (CVLZ), and delivery time.

This experiment explored the interaction among independent variables that affect commercial vehicle drivers' curbside parking behavior in an urban area. Each independent variable had corresponding levels, as shown in table 3-1.

Table 3-1 Independent variables table

Independent Variables	Level	Description
Number of Lanes	1	2-Lane road (Both directions)
	2	4-Lane road
Bike Lane	1	Yes
	2	No
Passenger Car (PC) Parking Space	1	Available
	2	Unavailable
Commercial Vehicle Loading Zones (CVLZs)	1	No CVLZ
	2	Occupied (40 ft long)
	3	Unoccupied (40 ft long)
Delivery Time	1	3-5 mins
	2	20-60 mins

According to the National Association of City Transportation Officials (NACTO), the numbers of lanes in downtown areas are designed as one-way streets (one-lane road) and two-way streets (four-lane road), and many of these streets suffer from the impacts of double parking and loading/unloading conflicts (National Association of City Transportation Officials, 2013). This study determined that the relationship between other road users (e.g., bicycles, passenger vehicles, and other commercial vehicles) and commercial vehicle curbside parking behavior is predominantly absent in the existing literature. This experiment was intended to address that gap in knowledge. This experimental design also included the presence and absence of a bike lane; presence and absence of passenger vehicle parking spaces; and the presence and absence of CVLZs. According to NACTO (National Association of City Transportation Officials, 2013), lane widths less than 12 feet can decrease capacity. Therefore, the travel lane width in this experiment was 12 feet, the bike lane width was 5 feet, the parking lane width was 8 feet, and the sidewalk width was 8 feet. Additionally, the passenger vehicle parking space was 18 feet long. According to truck size and length limits (Oregon Department of Transportation, 2020), the load length for CVLZs is 40 feet (single truck unit length). Therefore, this experiment used a 40-foot length to design scenarios. To distinguish the relationship between delivery time and parking behavior, we selected short-term parking (3 to 5 mins) and long-term parking (20 to 60 mins) as the last independent variable, which was communicated verbally to the commercial vehicle drivers during the experiment.

The factorial design for the four independent variables yielded a total of 24 scenarios (2*2*2*3), Delivery time was verbally communicated with participants during the experiment. Three of the grids were designated for short-term parking situations and three were designated for long-term parking situations. A total of 24 scenarios were separated into grid grids randomly, and the order of the grids was assigned randomly during the experiment to control the practice or for carryover effects. Example scenarios are presented in figure 3-6.

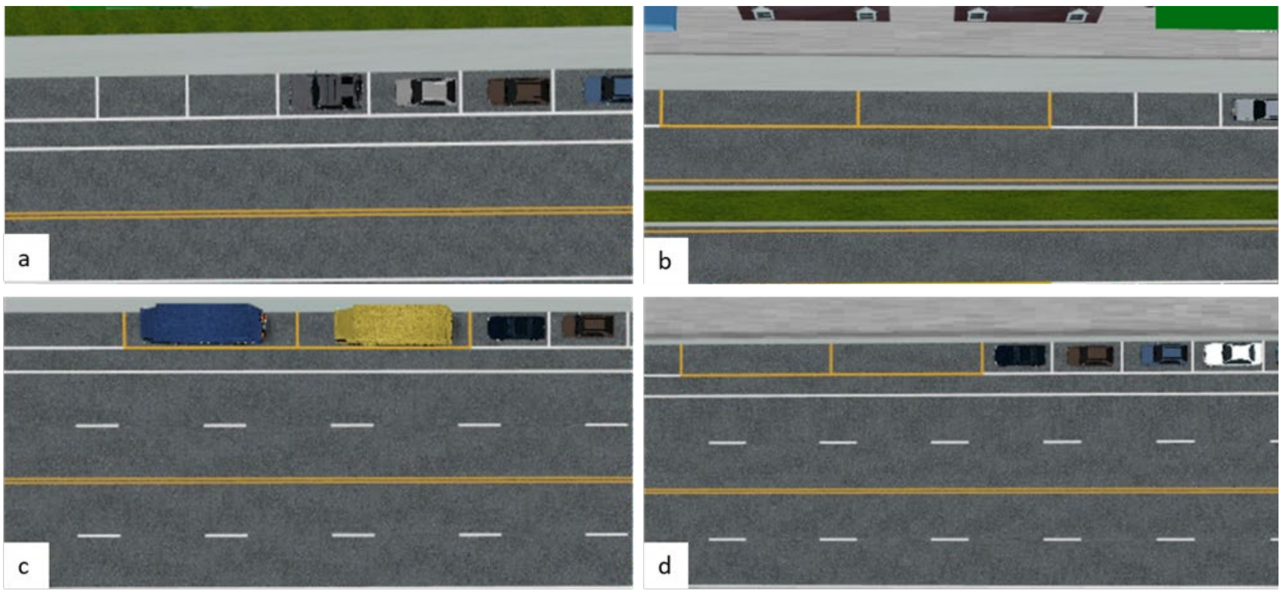


Figure 3-6 Example of top view scenarios: a) two lanes, bike lane, available parking space for PC, and no CVLZ; b) two lanes, no bike lane, available parking space for PC, and unoccupied CVLZ; c) four lanes, bike lane, unavailable parking space for PC, and occupied CVLZ; d) four lanes, bike lane, unavailable parking space for PC, and unoccupied CVLZ

3.2.4 Details of Scenarios

Table 3-2 Details of scenarios

Scenario	Number of Lanes	Bike Lane	Parking Space	CVLZs
		Grid 1		
1	2	Have	Available	No CVLZ
21	4	Have	Unavailable	Occupied
6	2	No	Available	No CVLZ
20	4	Have	Available	No CVLZ
		Grid 2		
19	4	No	Available	No CVLZ
15	4	No	Unavailable	No CVLZ
13	2	Have	Available	Occupied
3	4	Have	Unavailable	Available
		Grid 3		
2	2	No	Available	Available
22	4	No	Available	Occupied
17	2	No	Unavailable	No CVLZ
7	2	Have	Unavailable	No CVLZ
		Grid 4		
23	2	No	Available	Occupied
10	2	No	Unavailable	Occupied
4	2	No	Unavailable	Available
18	2	Have	Available	Available
		Grid 5		
9	4	Have	Unavailable	No CVLZ
16	2	Have	Unavailable	Available
12	4	No	Unavailable	Occupied
11	4	Have	Available	Available
		Grid 6		
14	4	No	Available	Available
8	2	Have	Unavailable	Occupied
5	4	No	Unavailable	Available
24	4	Have	Available	Occupied

A total of 24 scenarios were separated into six grids, and the details of each grid are shown below in table 3-2. Each road was 700 ft long, and the design speed was 25 mph. The adjacent land had dense suburban development, with a mix of residential and commercial land uses. Some scenarios had pedestrians on the sidewalk, and some had bicyclists in the bike lane. Moving automobiles and trucks were also incorporated to replicate a more authentic road scenario. The intersections were used in scenarios to connect each road in each grid, as shown in figure 3-7. Each participant experienced 24 scenarios in different orders to gauge the impacts of the experimental factors.

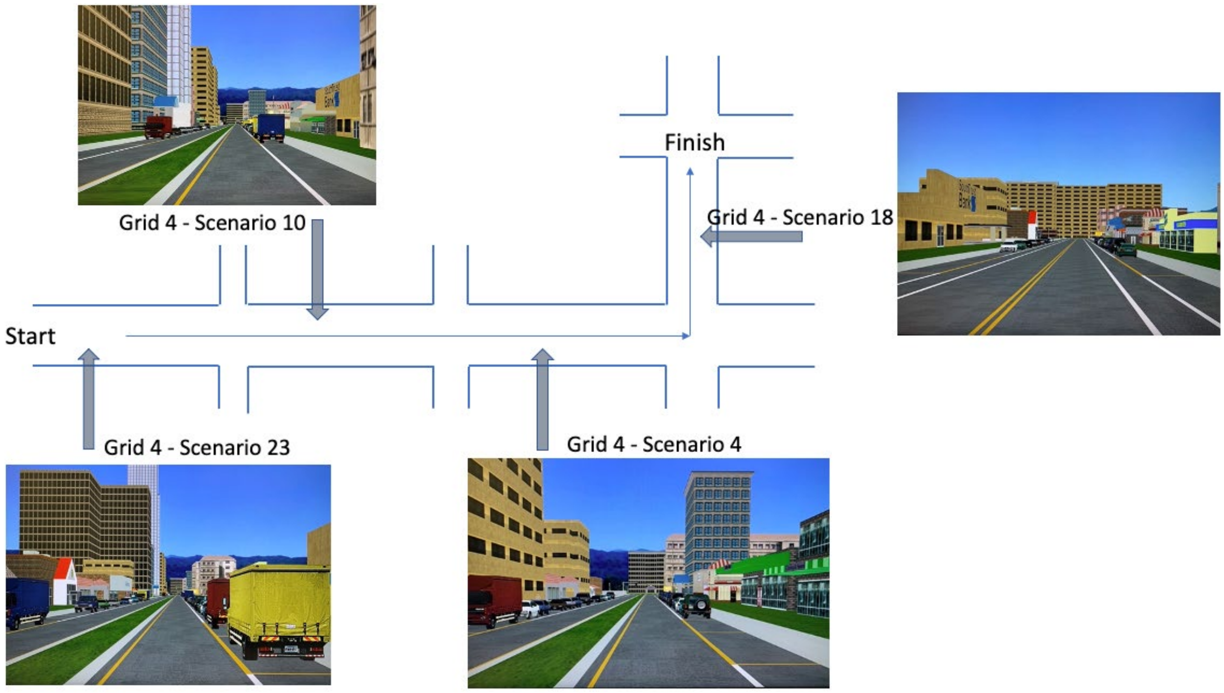


Figure 3-7 Example scenarios in grid 4

3.2.5 Survey Questionnaire

This experiment included two questionnaires, one administered before the drive and one after the drive. The questions were administered to the participants to better understand their experience with the designed scenarios and curbside parking. Participants were asked a few basic demographics during the pre-drive questionnaire, as well as the type of motor vehicle they operated, their usual driving conditions, and their frequency of driving. In the post-drive questionnaire, participants were asked about their experiences with curbside parking during the experiment and their recommendations on how to make the situation better. For example, one question during the experiment asked whether the truck was involved in a collision. By using an ordinal ranking scale response, the post-drive questionnaire aimed to improve the internal consistency of the data gathered with the aforementioned techniques.

3.3 Data Collection

This project included 24 scenarios separated into six grids; all grids (24 scenarios) for each participant were presented in a random order. The data collection included several parts, described in the following section.

3.3.1 Recruitment

A total of 14 individuals, primarily from the community surrounding Corvallis, Oregon, were recruited as test participants for the heavy vehicle driving simulator experiment. The experiment duration was approximately one hour, and subjects were compensated $40 for their participation. Commercial vehicle licensed drivers or urban area delivery drivers (with a commercial driver's license (CDL) training) were recruited for the experiment. In addition to driving licensure, participants were required to not have eye glass prescriptions higher of than five and to be physically and mentally capable of legally operating a commercial motor vehicle. Participants also needed to be deemed competent to provide written, informed consent. Recruitment of participants was accomplished by distributing flyers posted around campus, sending emails to different campus organizations, and using a wide range of email listservs and social media. Most of the participants were specifically recruited by emails with organizations and freight companies such as the Oregon Trucking Associations (OTA) and Bigfoot Beverages.

The researchers did not screen interested participants by gender. Participants of all ages in the range of 18 to 75 years were included. Throughout the study, information related to participants was held in a double-locked secure manner in accordance with OSU's Institutional Review Board (IRB) procedures (Study Number IRB-2021-1008). Each participant was randomly assigned a number to remove any uniquely identifiable information from the recorded data.

3.3.2 Informed Consent and Compensation

All individuals gave their consent before any experimental procedures could start. When the participant arrived at the simulator laboratory, the IRB-approved consent document was presented and explained. A summary of the study and its goals was provided as an element of the consent document. After signing the document, participants received $40 in cash as payment for taking part in the experiment. Participants were free to leave if they became ill from the simulator or were unable to continue for any reason.

3.3.3 COVID-19 Protocols

The process of the experiment followed the OSU Driving and Bicycling Simulator Laboratory's approved Research Resumption Plan. According to the plan, to ensure safety for both researchers and participants, this experiment was conducted in strict accordance with OSU policy. To provide a comfortable environment in the simulator laboratory, the researchers used alcohol and ultraviolet light to disinfect the equipment the volunteers had touched, and HEPA-grade air filtration was used in all rooms in which the experiment occurred.

3.3.4 Calibration Drive

The participants were encouraged to customize the position of the seat, rearview mirror, and steering wheel to enhance comfort and driving performance during the experiment. Participants then performed a calibration drive to familiarize themselves with the simulator and determine whether they were susceptible to simulator sickness. This stage of the experiment lasted approximately three to five minutes. The participants were also told to follow all traffic regulations and drive as they normally would. The calibration drive was carried out in a generic virtual suburban central business district with turning maneuvers comparable to the experiment so that participants could become accustomed to the vehicle's mechanics and the heavy vehicle simulator's virtual reality. Figure 3-8 shows a researcher demonstrating the calibration of the heavy vehicle simulator. No data were gathered during this part of the experiment. The experimental trials were terminated at this stage for any participant who experienced simulator sickness or discomfort during the calibration drive. (Hurwitz et al., 2022)

Figure 3 8 Calibration of the Heavy Vehicle Simulator at OSU

3.3.5 Calibration of the Eye-Tracker

For participants who fulfilled the requirements for inclusion in the trial, a Tobii Pro Glasses 3 eye-tracker was calibrated. Wearing the spectacles and focusing directly on a target card was required of participants. The eye-tracking recording could proceed if the calibration was successful, as shown in figure 3-9. The calibration process took less than 10 seconds. Recalibration was needed if the initial calibration failed. If the eye tracker could not complete the calibration after multiple attempts, the experimental trial was conducted, but the eye-tracking data would not be used. The participants were allowed to take off the glasses during breaks between drives without affecting system accuracy. After the eye-tracking equipment had been calibrated, participants were asked to sit in the vehicle and prepare for the experimental trials. (Hurwitz et al, 2022) Figure 3-10 shows a researcher wearing the eye-tracker glass.

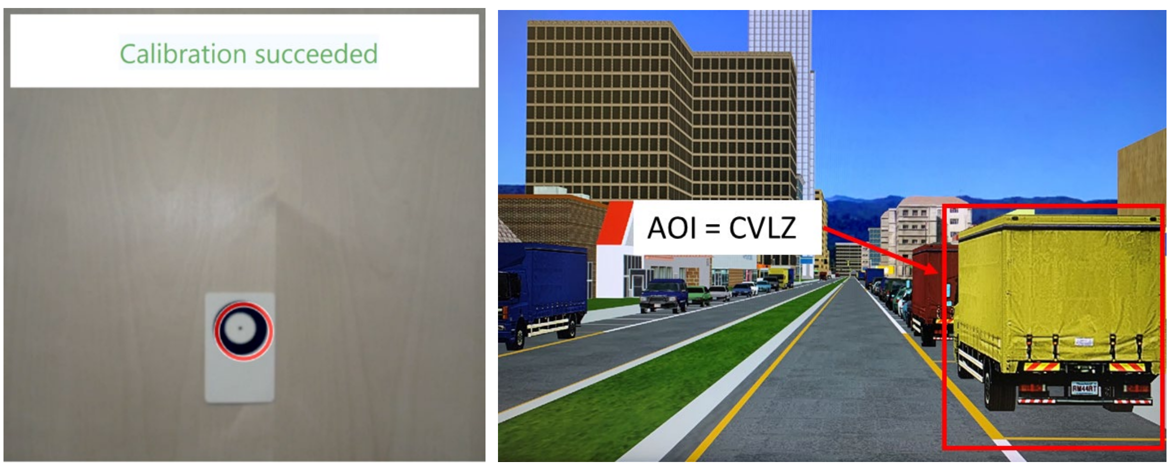


Figure 3-9 Left: Eye-tracker glass calibration; Right: Areas of interest (AOIs) example (e.g., the target here is a CVLZ)

Figure 3-10 Wearing the eye-tracker glass

CHAPTER 4. RESULTS

This section presents the results of the simulator experiment and includes participant data, questionnaire results, eye-tracker results, GSR, speed results, the parking situation, and statistical modeling. The following sections discuss each of the results.

4.1 Participants Data

Table 4-1 shows the total number of participants and the final analyzed sample size of the dataset for this experiment. Fourteen participants were recruited from Corvallis, Oregon, and the surrounding area. All 14 participants were men, and none of the participants identified as non-binary. Four of the participants had experience driving commercial vehicles but no CDL, and ten participants had CDLs. The participants' ages ranged from 29 to 60 years old, with an average age of 40.93 and a standard deviation (SD) of 9.92 years. Two participants were not able to complete the experiment because of simulation sickness. The total sample size was 12.

The final analyzed samples for three data sets were different because of data lost during the experiment. Therefore, the final analyzed sample size for speed data was 12 participants; for the eye-tracker was 11 participants; and for GSR was five participants.

Table 4-1 Participants and sample sizes

	Total	Male	Female
Total Enrolled	14 (100%)	14 (100%)	0
Simulation Sickness	2 (14%)	2 (14%)	0
Total Sample	12 (86%)	12 (86%)	0
Age Range		29-60	
	Speed	Eye-Tracker	GSR
Lost Data	0	1	6
Final Analyzed Sample	12	11	5

4.2 Questionnaire Results

This study included two questionnaires: pre-drive and post-drive. The details of the results from both questionnaire are provided below.

4.2.1 Pre-Drive Questionnaire Results

The pre-drive questionnaire showed participants' demographic and driving experience information. Table 4-2 and table 4-3 present the details of each question and participants' driving habits. The total sample size was 12, all participants were men, and all had different backgrounds and experiences with commercial vehicles. Of the participants, 8.33 percent were long-haul drivers, 25 percent were short-haul drivers, and 67 percent were local drivers (i.e., they returned home every night). They all had experience in transporting various kinds of goods by using different types of motor vehicles. Fifty percent of the participants drove a commercial vehicle five to ten times per week.

Table 4-2 Demographic information

Category	Demographic Variable	Count	Percentage
Gender	Male	12	100.00%
	Female	0	0.00%
	Transgender	0	0.00%
	Non-binary/non-conforming	0	0.00%
	Prefer not to answer	0	0.00%
Age	18-24	0	0.00%
	25-34	5	41.67%
	35-44	4	33.33%
	45-54	2	16.67%
	55-64	1	8.33%
	65+	0	0.00%
Race	American Indian or Alaska Native	0	0.00%
	Asian or Pacific Islander	2	16.66%
	Black or African American	0	0.00%
	Hispanic or Latino/a	2	16.67%
	White or Caucasian	8	66.67%
	Other	0	0.00%
	Prefer not to answer	0	0.00%
Income	Less than $25,000	1	8.33%
	$25,000 to less than $50,000	3	25.00%
	$50,000 to less than $75,000	1	8.33%
	$75,000 to less than $100,000	2	16.67%
	$100,000 to less than $200,000	3	25.00%
	$200,000 or more	0	0.00%
	Prefer not to answer	2	16.67%
Education	Some high school or less	0	0.00%
	High school diploma or GED	2	16.67%
	Some college	2	16.67%
	Trade / vocational school	1	8.33%
	Two-year Degree	2	16.67%
	Four-year Degree	2	16.67%
	Master's Degree	1	8.33%
	PhD Degree	2	16.67%
	MD or JD	0	0.00%
	Prefer not to answer	0	0.00%

Table 4-3 Participants' driving habits

Category	Demographic Variable	Count	Percentage
How many miles did you drive last year?	0 - 5,000 miles	1	8.33%
	5,000 - 10,000 miles	1	8.33%
	10,000 - 15,000 miles	5	41.67%
	15,000 - 20,000 miles	2	16.67%
	More than 20,000 miles	3	25.00%
What type of motor vehicle do you typically drive for commercial use?	Passenger Car	1	8.33%
	SUV	1	8.33%
	Pickup Truck	0	0.00%
	Van	1	8.33%
	Heavy Vehicle (e.g., city transit bus, heavy semi-tractor, and tow)	9	75.00%
What type of goods are transport commercially? (Multiple choice)	Documents	3	25.00%
	Packages	3	25.00%
	Heavy goods	4	33.33%
	Meals/Grocery	3	25.00%
	Prefer not to answer	2	16.67%
	Other	4	33.33%
Which of the following better describes you?	Long-haul driver (Sleep away from home for work)	1	8.33%
	Short-haul driver (Sleep at home)	3	25.00%
	Local driver	8	66.67%
How often do you drive a commercial vehicle in a week?	Once a week	3	25.00%
	2 - 4 times per week	2	16.67%
	5 - 10 times per week	6	50.00%
	More than 10 times per week	1	8.33%

4.2.2 Post-Drive Questionnaire Results

All participants were asked to respond to a post-drive questionnaire after they had completed the simulator drive. These questions asked about participants' experience with curbside parking and feelings about parking location and safety level. Table 4-4 shows the participants' questionnaire responses.

As shown in table 4-4, 67 percent of the participants felt comfortable while finding a location to park the heavy vehicle. Most participants (83 percent) first considered whether a space had enough room to enter and exit, while 17 percent looked for CVLZ or specific signs. One participant was involved in a collision during the experiment. Half of the participants felt comfortable while parking next to a passenger vehicle. Most participants felt that exclusive truck parking should be provided at the curbside, and 67 percent thought that providing convex mirrors, reminder signs, and painted bicycle lanes would be beneficial to drivers' detection of other road users while parking. Also, safety, authorized parking space, and the effects of parking maneuvers on roadway traffic were the top three factors that drivers considered while choosing a place to park. Of the participants, 58.33 percent thought that they might park in a bicycle lane in real life, and 50 percent stated that they would keep searching to find authorized parking if no authorized parking spaces were available in real life. During the simulation, 8.33 percent of the participants parked in the travel lane, and 25 percent parked in the bicycle lane at least once.

Table 4-4 Post-drive questionnaire results

Questions	Options	Count	Percentage
How comfortable did you feel while finding the location to park the truck?	Very comfortable	1	8.33%
	Comfortable	8	66.67%
	Neutral	3	25.00%
	Uncomfortable	0	0.00%
	Very uncomfortable	0	0.00%
Which situation did you consider first when you chose a space to park	There is enough room for me to get in and out of available spaces	10	83.33%
	CVLZ spaces have parking available	2	16.67%
	The parking facility has the features I need (CVLZ or Specific sign)	0	0.00%
	CVLZ spaces are used only by trucks	0	0.00%
How comfortable did you feel while parking next to a passenger car?	Very comfortable	0	0.00%
	Comfortable	6	50.00%
	Neutral	1	8.33%
	Uncomfortable	2	16.67%
	Very uncomfortable	3	25.00%
Should exclusive truck parking be provided at the curbside?	Yes	9	75.00%
	No	2	16.67%
	Other	1	8.33%
During the experiment, was your vehicle involved in any collision?	Yes	1	8.33%
	No	11	91.67%
Select all the features that you think would be beneficial to your detection of other road users while parking	Convex mirrors	2	16.67%
	Reminder signs	0	0.00%
	Painted Bicycle lanes	0	0.00%
	Other	0	0.00%
	All	8	66.67%
	None	2	16.67%
Select TOP 3 factors you consider while choosing a place to park	Safety	9	75.00%
	Authorized parking space	7	58.33%
	Effect of my parking maneuver on roadway traffic	7	58.33%
	The number, weight, and size of goods I have to deliver	5	41.67%
	Walking distance to destination (if you are already within 2 blocks)	3	25.00%

Questions	Options	Count	Percentage
	Time spent searching for parking	1	8.33%
	Other	1	8.33%
When making a real-life delivery, do you usually have to search for parking?	Yes. Short time parking (less than 15 minutes)	6	50.00%
	Yes. Long time parking (over 60 minutes)	3	25.00%
	No	2	16.67%
	Not much	1	8.33%
In real-life, how often do you park in a bicycle lane? (How many times per week)	0	7	58.33%
	1-2	3	25.00%
	3-4	2	16.67%
When performing a real-life delivery, if you can't find an authorized parking space, where would you rather park?	No-parking zone	3	25.00%
	In the travel lane	0	0.00%
	In the bicycle lane	1	8.33%
	Neither. I'll keep searching as much as it takes to find an authorized parking.	6	50.00%
	Other	2	16.67%
During the simulation, did you ever park in the bicycle lane?	Yes	3	25.00%
	No	9	75.00%
During the simulation, did you ever park in the travel lane?	Yes	1	8.33%
	No	11	91.67%

4.3 Eye-Tracker Results

Eye-tracker data included four different Areas of Interest (AOIs) based on the different scenarios, which included passenger vehicles (PC), No CVLZ, Occupied CVLZ (Occ), and CVLZ available. Each AOI included two-lane and four-lane scenarios.

Table 4-5 shows the mean and standard deviation of total fixation duration times for No CVLZ, Occupied CVLZ, and CLVZ available with/without PC space and with/without a bike lane for two-lane and four-lane roads.

Two-lane roads with PC spaces, a bike lane, and No CLVZ had the largest mean of fixation duration (M=7.14, SD= 4.80); the road without PC spaces and with a bike lane had the smallest mean fixation duration (M=3.84, SD=2.58). For occupied CVLZs, the mean fixation duration time for roads with PC spaces but no bike lane was the largest (M=4.80); whereas roads without PC spaces but with a bike lanes had the smallest (M=4.55). For CVLZs, the largest mean fixation duration occurred without PC spaces and with a bike lane (M=9.25, SD=10.78); the smallest mean fixation duration occurred with PC spaces and a bike lane (M=5.39, SD=3.54).

On four-lane roads with No CVLZ, the largest mean fixation duration occurred on roads without PC spaces but with a bike lane (M=7.30, SD=7.17); the smallest mean fixation duration occurred when roads had PC spaces and a bike lane (M=4.48, SD=3.88). For occupied CVLZs, the largest mean fixation duration occurred on roads without PC spaces but with a bike lane (M=2.17, SD=1.84), and the smallest mean occurred on roads with PC spaces but without a bike lane (M=1.70, SD=1.07). For CVLZs, the largest mean fixation duration occurred on roads with PC spaces but without a bike lane (M=8.80), and the smallest mean fixation duration occurred on roads with PC spaces and a bike lane (M=4.49).

Table 4-5 Mean and standard deviation fixation durations

(M: Mean, SD: Standard Deviation)

Description		**Two Lanes**			
		Space/ Bike Lane	No space/ Bike Lane	Space/ No Bike Lane	No Space/ No Bike Lane
No CVLZ	M	7.14	3.84	5.43	6.27
	SD	4.80	2.58	4.61	3.91
Occ	M	4.55	2.20	4.80	2.21
	SD	7.69	1.53	3.13	1.42
CVLZs	M	5.39	9.25	6.56	6.84
	SD	3.54	10.78	3.85	4.42
Description		**Four Lanes**			
		Space/ Bike Lane	No space/ Bike Lane	Space/ No Bike Lane	No Space/ No Bike Lane
No CVLZ	M	4.48	7.30	6.79	6.47
	SD	3.88	7.17	4.01	4.65
Occ	M	1.71	2.17	1.70	2.11
	SD	1.33	1.84	1.07	1.65
CVLZs	M	4.49	5.15	8.80	4.99
	SD	5.71	3.43	5.10	3.21

4.3.1 Fixation Durations for Passenger Cars (PC)

Figures 4-1 and 4-2 present the participants' fixation duration times for PCs on two-lane and four-lane roads while driving.

The boxplots in figure 4-1 show different times for drivers' fixation durations on PCs in two-lane scenarios, which included having/no PC space and having/no bike lane. There were three types of road conditions: No CVLZ, Occupied CVLZ (Occ), and CVLZ available. The boxplots show that when drivers were on two-lane roads with an occupied CVLZ, their fixation duration time on PCs was lower than that with No CVLZ and CVLZ available. In addition, the mean fixation duration time on the road with a bike lane was higher than that on the road without a bike lane. The mean fixation duration time for the road with PC space was higher than that for the road without PC space.

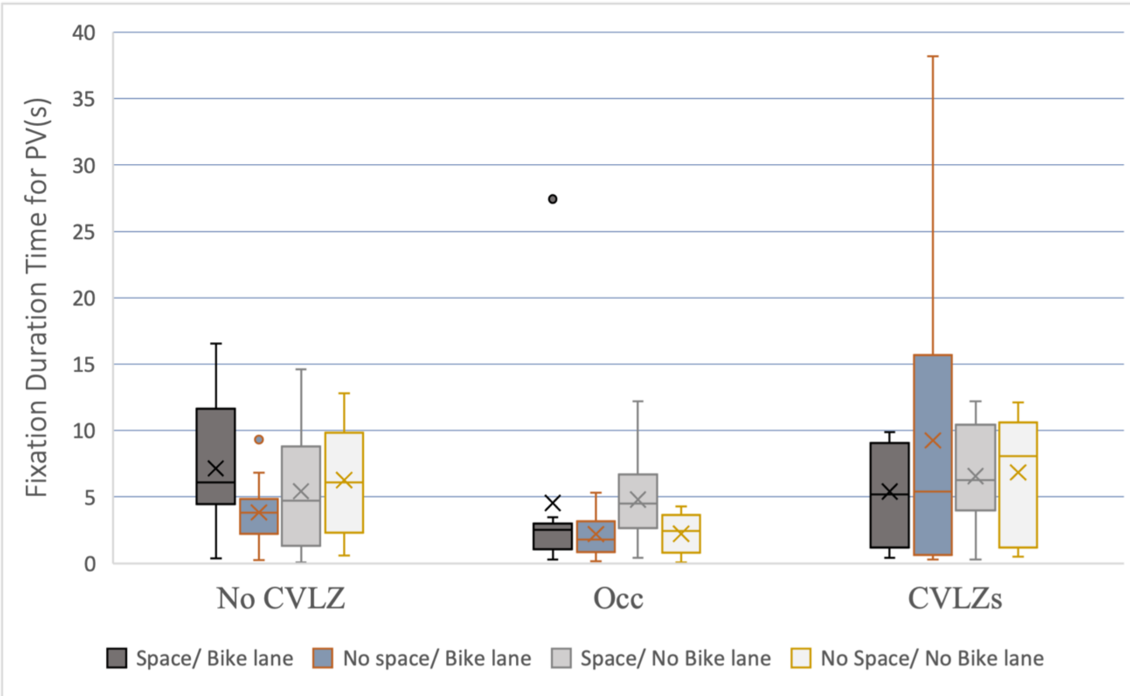


Figure 4-1 Fixation duration times for passenger vehicles on two-lane roads

Figure 4-2 shows the times drivers spent fixating on passenger vehicles (PC) in the four-lane road scenarios. When the CLVZ was occupied, the fixation duration time on PCs was lower than that for the No CVLZ and CVLZ available scenarios. The fixation duration time on PCs with a bike lane was lower than that on roads without a bike lane. Also, the fixation duration time on PCs for roads with PC spaces was less than that for roads without PC spaces. Time drivers spent fixating on the passenger vehicle parked along the travel lane when a CVLZ was available was less when there were four lanes than when there were two lanes.

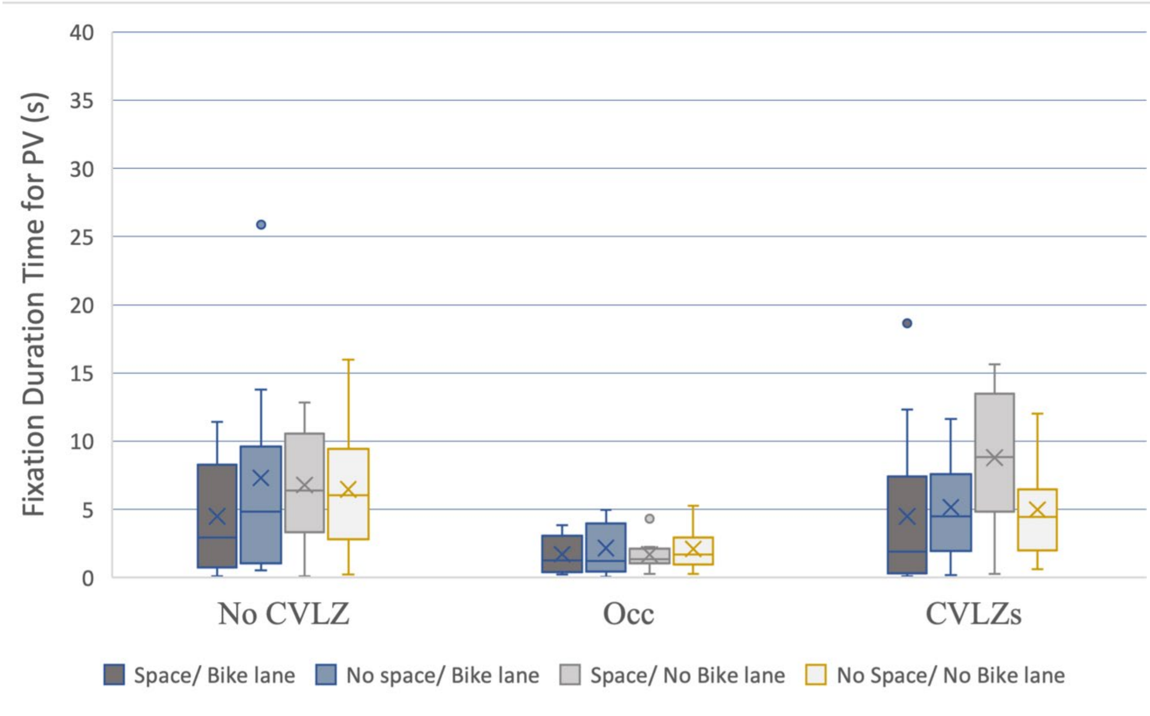


Figure 4-2 Fixation duration times for passenger vehicle on four-lane roads

4.3.2 Fixation Durations for No CVLZ

As figure 4-3 shows, when No CVLZ was present, the time drivers spent fixating was higher when PC spaces and a bike lane were present and lowest with no PC space but still a bike lane. In contrast, figure 4-4 shows that the fixation duration time for no CVLZ on four-lane roads with no PC spaces and no bike lane was lowest, and on the road without PC spaces but with a bike lane was highest.

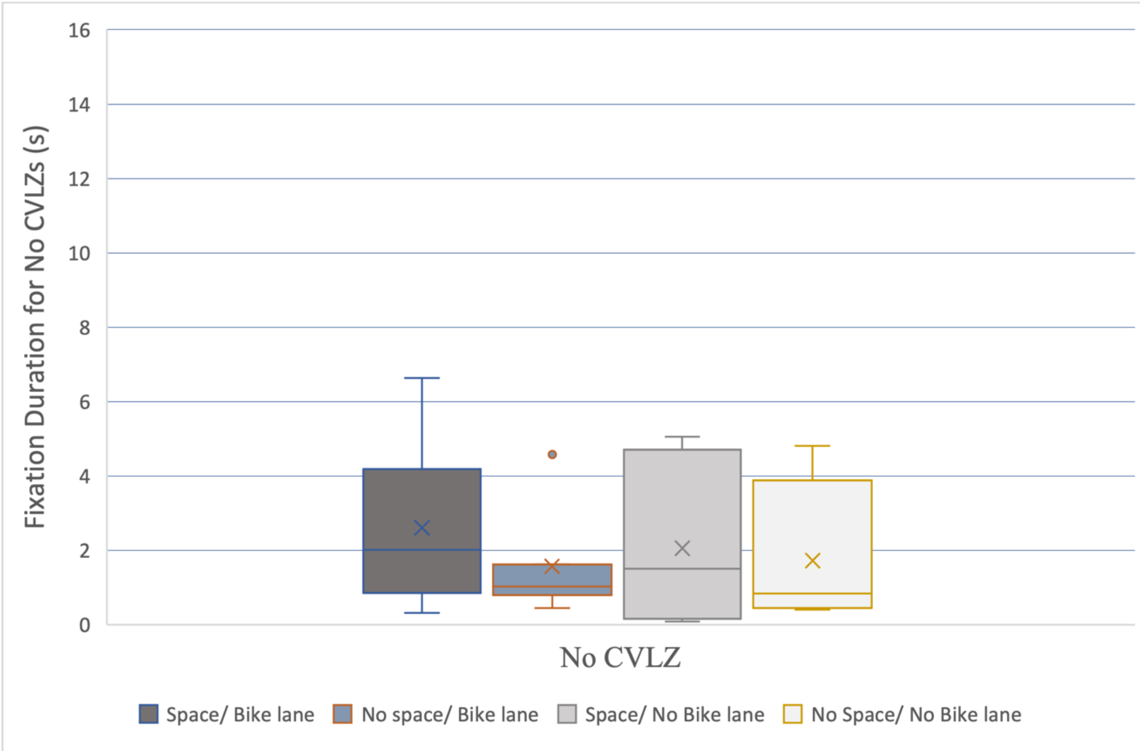


Figure 4-3 Fixation duration times for no CVLZ on two-lane roads

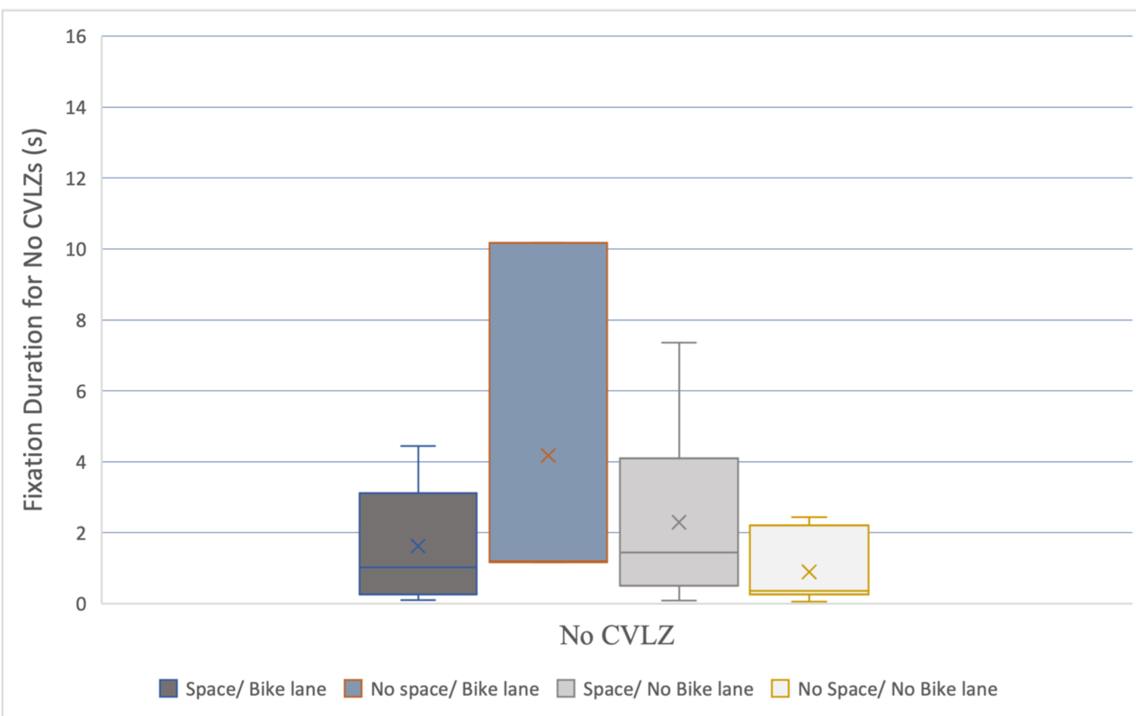


Figure 4-4 Fixation duration times for no CVLZ on four-lane roads

4.3.3 Fixation Durations for Occupied CVLZs (Occ)

Figure 4-5 shows that when the road had PC spaces, the participants' fixation duration time on occupied CVLZs was higher than when the road had no PC spaces. The mean time drivers spent fixating on occupied CVLZs when the road had PC spaces and a bike lane was highest; on the road without PC spaces but with bike lane it was lowest.

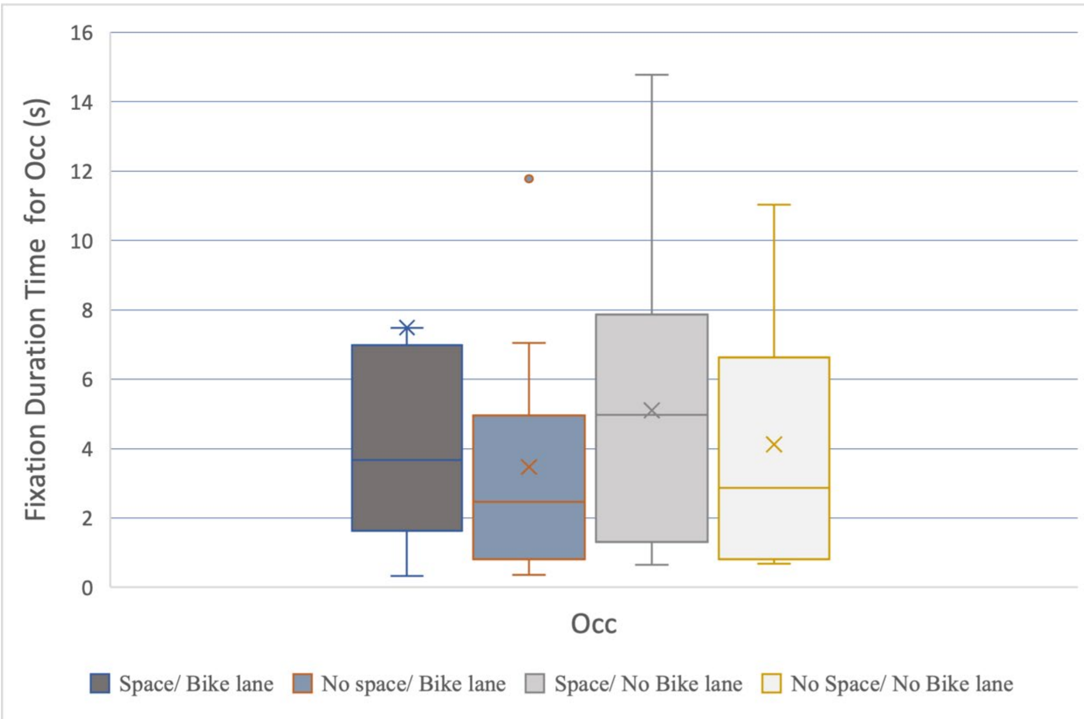


Figure 4-5 Fixation duration times for occupied CVLZs on two-lane roads

As for four-lane roads, the drivers' fixation duration time for occupied CVLZs with a bike lane was more than that with no bike lane. Also, the mean time drivers spent fixating on occupied CVLZs on roads with PC spaces was less than that on roads without PC spaces. In addition, on roads with PC spaces but without a bike lane, the mean of time drivers spent fixating on occupied CVLZs was lowest; that on roads without PC spaces and with a bike lanes was highest. However, the mean times for roads with and without PC spaces when a bike lane was present were not drastically different, which is graphically presented in figure 4-6.

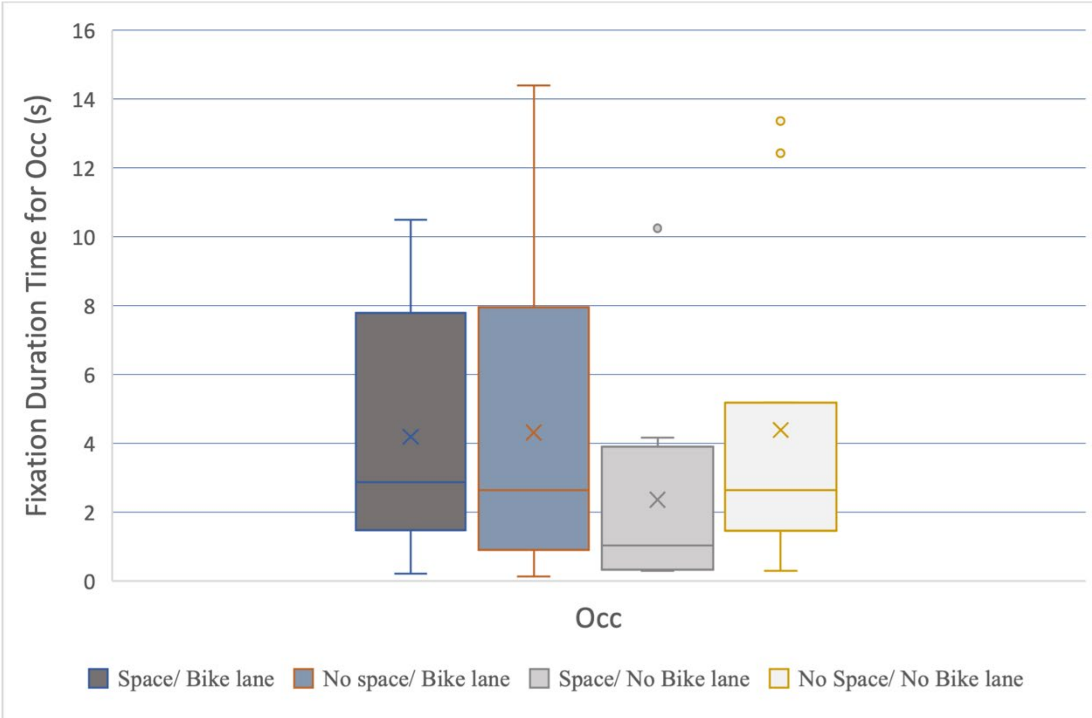


Figure 4-6 Fixation duration times for occupied CVLZs on four-lane roads

4.3.4 Fixation Durations for CVLZs Available

Figures 4-7 and 4-8 present drivers' fixation duration times when CVLZs were available on two-lane and four-lane roads. The results showed that total time looking at CVLZs on two-lane roads was longer than on four-lane roads. The mean time for roads with no bike lane was greater than that for roads with a bike lane.

Figure 4-7 shows that on two-lane roads with a bike lane, there was a difference between having and not having a PC space. The mean time drivers spent fixating on CVLZs when a road with PC spaces and a bike lane was lowest; on a road without PC spaces but with a bike lane the mean time was highest. The mean fixation time on roads with a bike lane was higher than that on roads without a bike lane.

Figure 4-8 shows that fixation duration times on four-lane roads with a bike lane were not significantly different based on PC presence. The mean of time drivers spent fixating on CVLZs on roads with PC spaces and no bike lane was highest, whereas it was lowest on roads without PC spaces and with a bike lane.

Figure 4-7 Fixation duration times for CVLZs available on two-lane roads

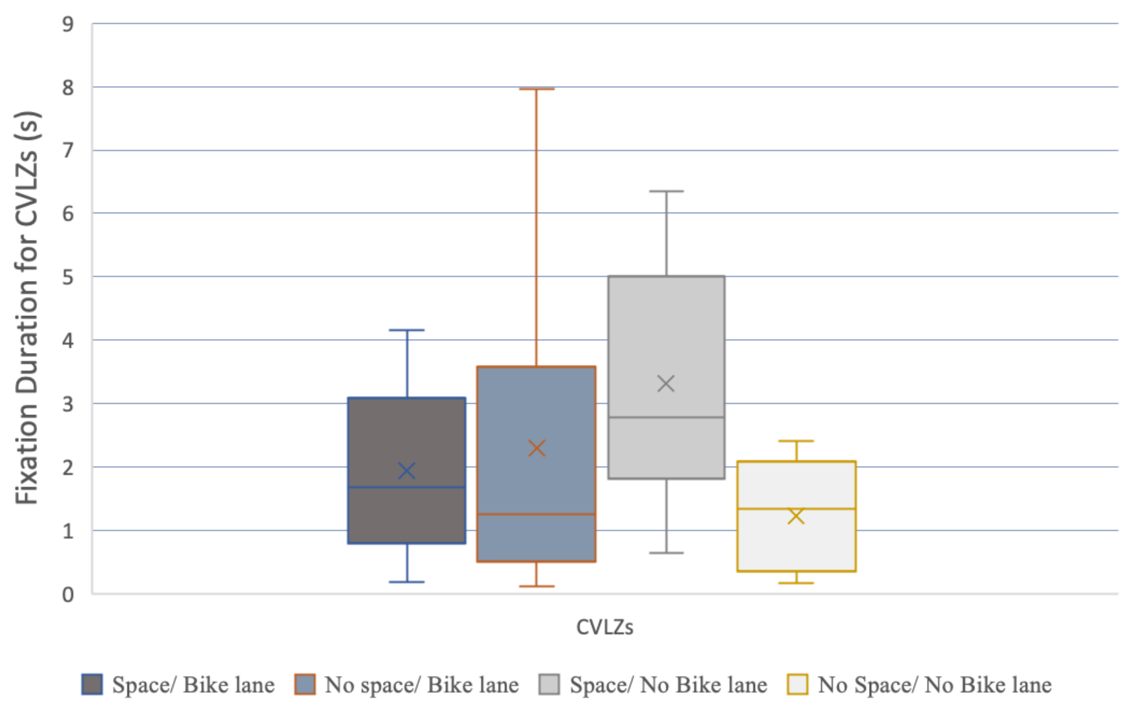


Figure 4-8 Fixation duration times for CVLZs available on four-lane roads

4.3.5 Fixation Durations for Different Delivery Times

The two levels of delivery time were short-term parking (3 to 5 minutes) and long-term parking (20 to 60 minutes). Drivers' behaviors were separated into three categories: no parking, illegal parking, and legal parking. No parking meant that participants did not stop during that scenario. Illegal parking meant that participants parked during that scenario, but their parking choice was illegal (no CVLZ was present). Legal parking meant that participants parked during that scenario and parked in a legal space. The following figures present fixation times with two levels of delivery times.

Figure 4-9 shows the participants' fixation durations when they were parking illegally parking, not parking, and parking legally. When drivers were legally parking, their fixation duration times were highest; when drivers were not parking, their fixation duration times were lowest. The fixation duration times were higher for short-term parking than for long-term parking. For long-term parking, most participants did not want to park illegally, so they chose not to park, failing the delivery. However, for short-term parking, participants had a high rate of choosing illegal and legal parking.

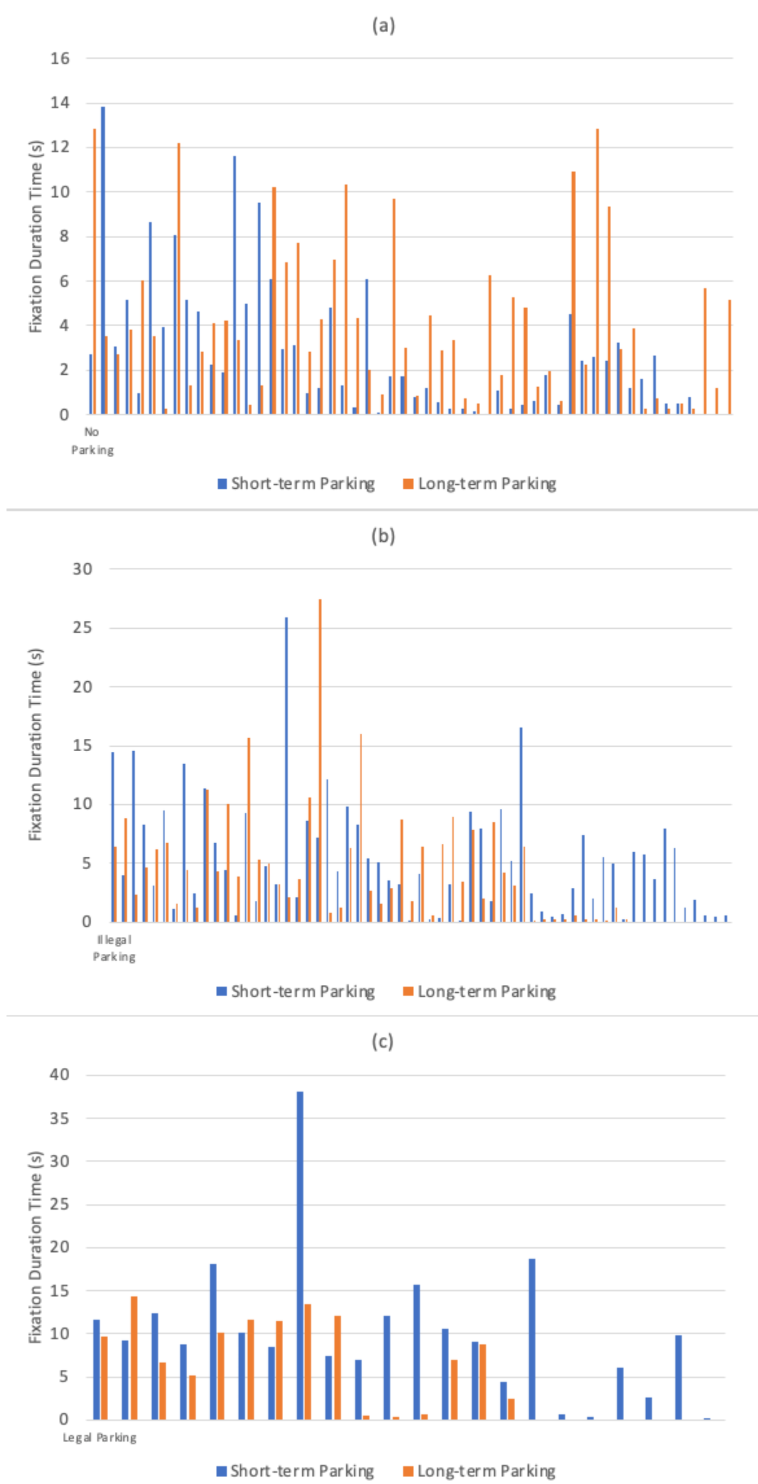


Figure 4-9 Fixation durations for delivery times

Figure 4-10 shows the mean fixation durations for short-term parking and long-term parking. The figure shows that when participants were involved in short-term parking, they had a higher rate of choosing illegal parking than with long-term parking. In addition, when they needed long-term parking, they had a higher rate of choosing no parking than when they needed short-term parking. Also, short-term legal parking was chosen more frequently than than long-term legal parking.

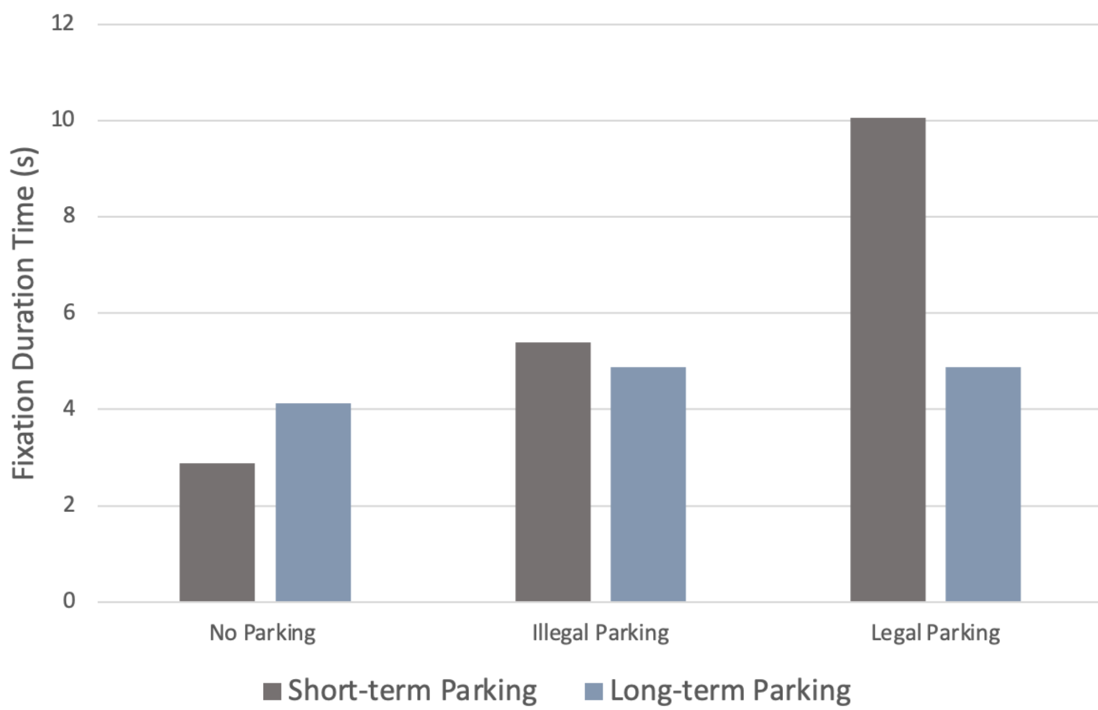


Figure 4-10 Fixation durations with delivery times

4.4 GSR Results

The GSR results showed the stress levels of participants recorded in peak times per minute. Table 4-6 summarizes the mean (M), standard deviation (SD), and maximum levels of stress.

On two-lane roads, the combination of no CVLZ, no PC space, and no bike lane produced the largest mean and standard deviation of stress level (M=8.94, SD=5.53). The maximum stress level observed was 15.80; the minimum mean occurred on the road without PC spaces and with a bike lane (M=7.98, SD=4.4). For occupied CVLZs, the maximum mean level of stress occurred on the road without PC spaces and with a bike lane (M=9.53, SD=6.50), and the maximum stress level was 19.07. The minimum mean stress level occurred on roads without PC spaces and no bike lane (M=5.42, SD=4.58). For CVLZs, the maximum mean stress level occurred on the road without PC spaces and with a bike lane (M=11.37, SD=5.39), and the maximum stress level was 19.04 on the road with PC spaces and without a bike lane. The minimum mean stress level occurred on the road without PC spaces and no bike lane (M=6.97, SD=4.02).

On four-lane roads, for no CVLZ, the road with PC spaces and a bike lane had the largest mean stress level and the smallest standard deviation (M=10.19, SD=5.53). The maximum stress level was 14.88 on the road without PC spaces but with a bike lane; the minimum mean occurred on the road without PC spaces and no bike lane (M=4.36). For occupied CVLZs, the maximum mean stress level occurred on the road with PC spaces and without a bike lane (M=10.89, SD=5.84), and the maximum stress level was 18.53. The minimum mean level of stress occurred on the road PC spaces and a bike lane (M=5.93). When a CVLZ was available, the maximum mean stress level occurred on the road without PC spaces and with a bike lane (M=10.77), and the maximum stress level was 16.86. The minimum mean stress level occurred on the road with PC spaces and a bike lane (M=7.85).

Table 4-6 Mean, standard deviation, and maximum GSR results

Description		**Two Lanes**			
		Space/ Bike Lane	No space/ Bike Lane	Space/ No Bike Lane	No Space/ No Bike Lane
No CVLZ	Mean	8.55	7.98	8.77	8.94
	SD	3.98	4.40	3.20	5.53
	Max	14.23	12.78	13.20	15.80
Occ (Occupied CVLZs)	Mean	7.99	9.53	7.52	5.42
	SD	3.50	6.50	2.37	4.58
	Max	14.26	19.07	10.84	13.91
CVLZs	Mean	8.04	11.37	10.38	6.97
	SD	2.65	5.39	5.64	4.02
	Max	12.31	16.18	19.04	11.56
		Four Lanes			

Description		Space/ Bike Lane	No space/ Bike Lane	Space/ No Bike Lane	No Space/ No Bike Lane
No CVLZ	Mean	10.19	7.15	5.67	4.36
	SD	1.38	4.92	3.86	4.20
	Max	11.54	14.88	11.77	10.87
Occ (Occupied CVLZs)	Mean	5.93	10.47	10.89	7.52
	SD	4.63	5.68	5.84	3.11
	Max	13.19	17.01	18.53	11.12
CVLZs	Mean	7.85	10.77	10.69	8.71
	SD	5.17	4.18	3.82	4.32
	Max	14.71	16.86	14.42	15.53

Figure 4-11 shows stress levels on roads with and without a bike lane. The participants felt more stress on roads with a bike lane than on roads without a bike lane.

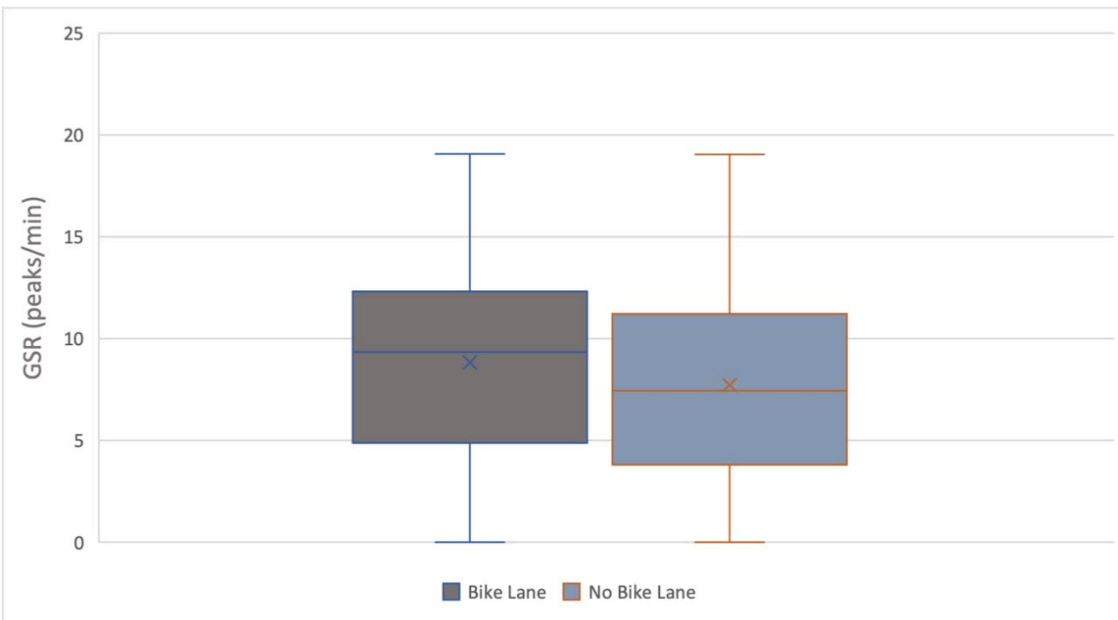


Figure 4-11 Level of stress with and without a bike lane

Figure 4-12 shows levels of stress across the two delivery times, short-term parking and long-term parking, on different roads (No CVLZ, Occupied CVLZs, and CVLZ available). The average stress level for roads with no CVLZ and short-term parking was higher than that for long-term parking. With occupied CVLZs, short-term parking produced less stress than long-term parking. With CVLZs available, short-term parking produced less stress than long-term parking. The total average stress levels for short-term parking and long-term parking were similar.

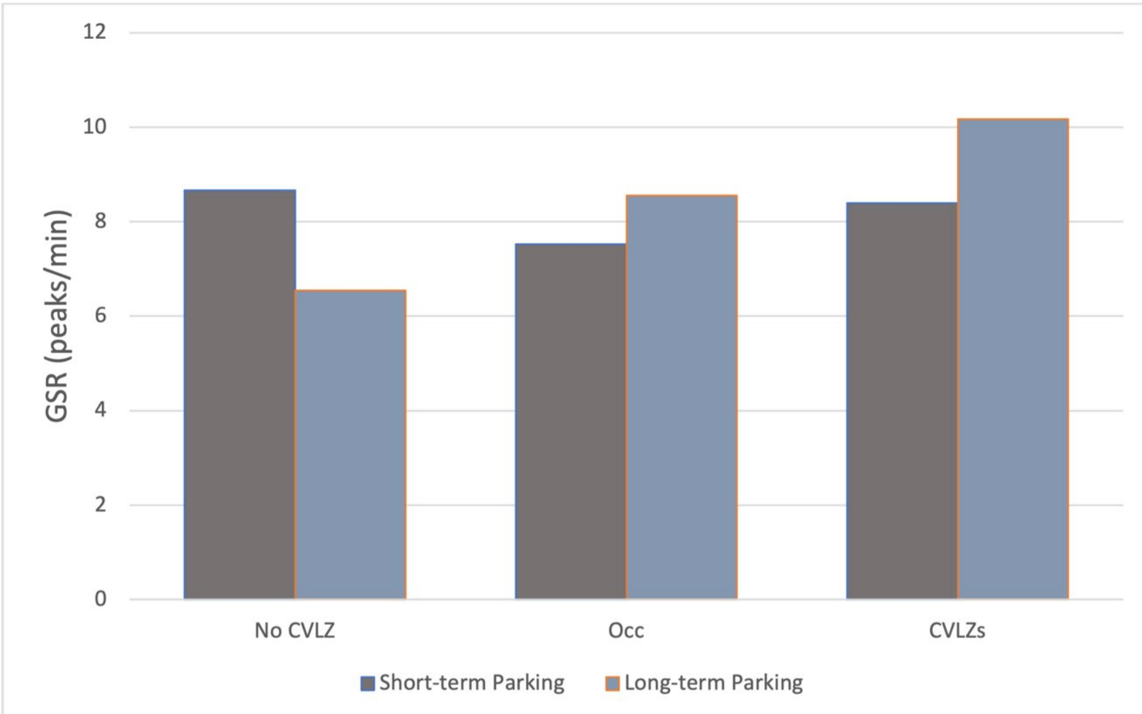


Figure 4-12 Levels of stress with delivery times on different roads

Figure 4-13 shows the stress levels for the two levels of delivery times. The mean peaks per minute were not significantly different between the two levels.

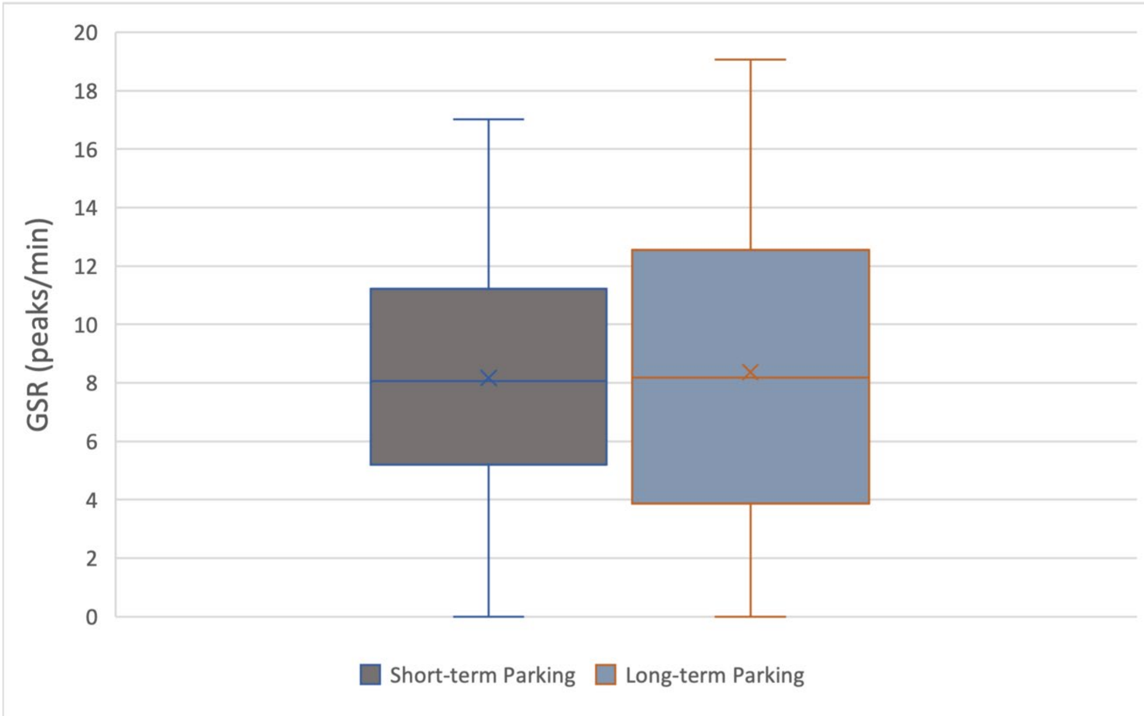


Figure 4-13 Levels of stress with delivery times

<u>4.5 Speed Results</u>

For each scenario, the average speed (mph) of the commercial vehicles was recorded. Table 4-7 shows the mean (M) and standard deviation (SD) values, as well as the minimum (Min) average speed for both lanes.

On two-lane roads, the highest mean speed for no CVLZ occurred when there were no PC spaces and no bike lane (M=22.23), and the minimum average speed was 5.03. The lowest mean speed occurred on roads with PC spaces and a bike lane (M=12.66, SD=3.37). When CVLZs were occupied, the highest mean speed occurred on roads with PC spaces but without a bike lane (M=15.41), and the standard deviation was the smallest (SD=2.91) and the minimum average speed was 3.86. When CVLZs were available, the highest mean speed and standard deviation occurred on roads without PC spaces and no bike lane (M=19.29, SD=8.97). The minimum average speed was 4.92 on roads with PC spaces and no bike lane.

On four-lane roads, the largest mean speed for no CVLZ occurred on roads without PC spaces and no bike lane (M=21.69), and the minimum average speed was 6.03. The lowest mean speed occurred on roads with PC spaces and no bike lane (M=13.56, SD=4.96). When CVLZs were occupied, the highest mean speed occurred on roads with PC spaces and a bike lane

(M=22.24, SD=9.17), and the minimum average speed was 9.03. When CVLZs were available, the highest mean speed occurred on roads with PC spaces and a bike lane (M=19.08). The minimum average speed was 4.39 on roads without PC spaces and with a bike lane.

Table 4 7 Mean, standard deviation, and minimum average speeds

Description		**Two Lanes**			
		Space/ Bike Lane	No space/ Bike Lane	Space/ No bike Lane	No Space/ No Bike Lane
No CLVZ	Mean	12.66	20.46	17.49	22.23
	SD	3.37	4.58	7.60	7.26
	Min	7.79	13.01	5.03	11.14
Occ (Occupied CVLZs)	Mean	17.70	18.68	15.41	23.81
	SD	6.22	7.41	2.91	6.80
	Min	3.86	9.90	9.29	12.32
CVLZs	Mean	19.04	12.06	8.48	19.29
	SD	7.11	2.29	2.86	8.97
	Min	6.61	8.95	4.92	6.09
Description		**Four Lanes**			
		Space/ Bike Lane	No space/ Bike Lane	Space/ No bike Lane	No Space/ No Bike Lane
No CLVZ	Mean	18.14	15.46	13.56	21.69
	SD	7.22	6.29	4.92	8.44
	Min	6.03	6.51	6.67	9.50
Occ (Occupied CVLZs)	Mean	22.24	18.70	21.19	19.21
	SD	9.17	6.73	6.77	7.48
	Min	9.44	9.75	9.47	9.03
CVLZs	Mean	19.08	16.04	7.69	17.66
	SD	6.97	7.61	2.83	8.56
	Min	7.78	4.39	4.58	7.07

Figure 4-14 presents the average speeds across short- and long-term parking with no CVLZ, occupied CVLZs, and CVLZs available. For no CVLZ, the average speed for short-term parking was lower than that for long-term parking. As for occupied CVLZ roads, the average speeds did not differ significantly between short-term parking and long-term parking. For roads with CVLZs available, the average speed for short-term parking was faster than that for long-term parking.

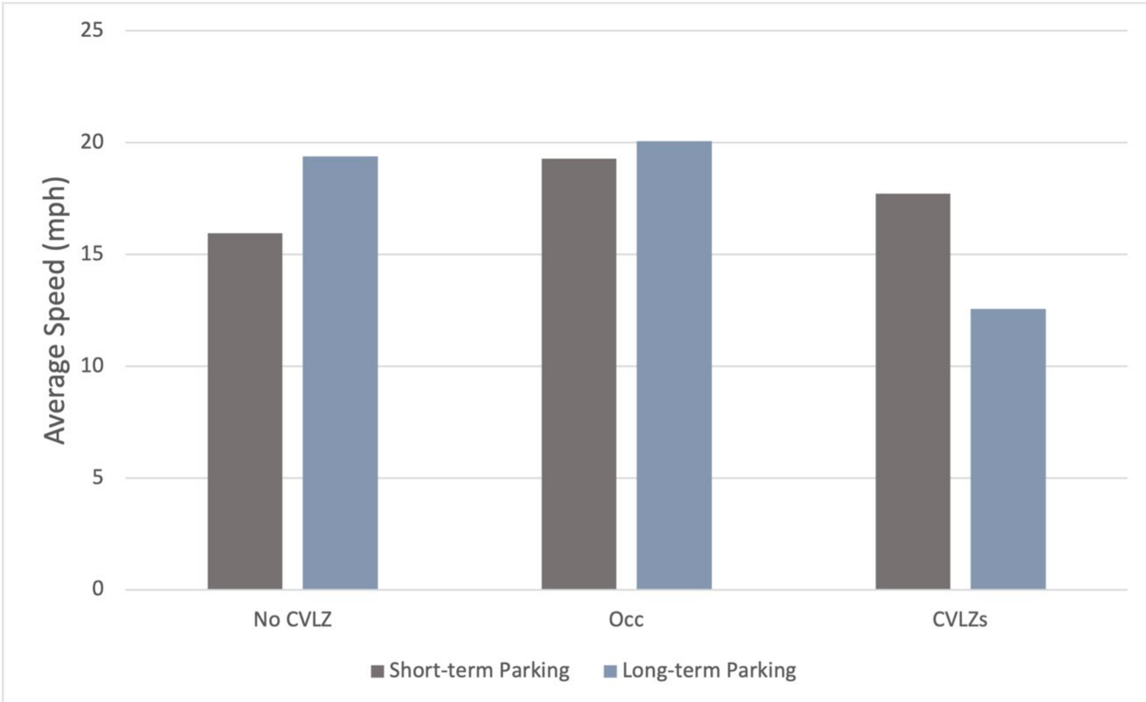


Figure 4-14 Speeds with delivery times on different roads

The boxplots in figure 4-15 show a comparison between short-term parking and long-term parking. The mean speed for short-term parking was similar to the mean speed for long-term parking.

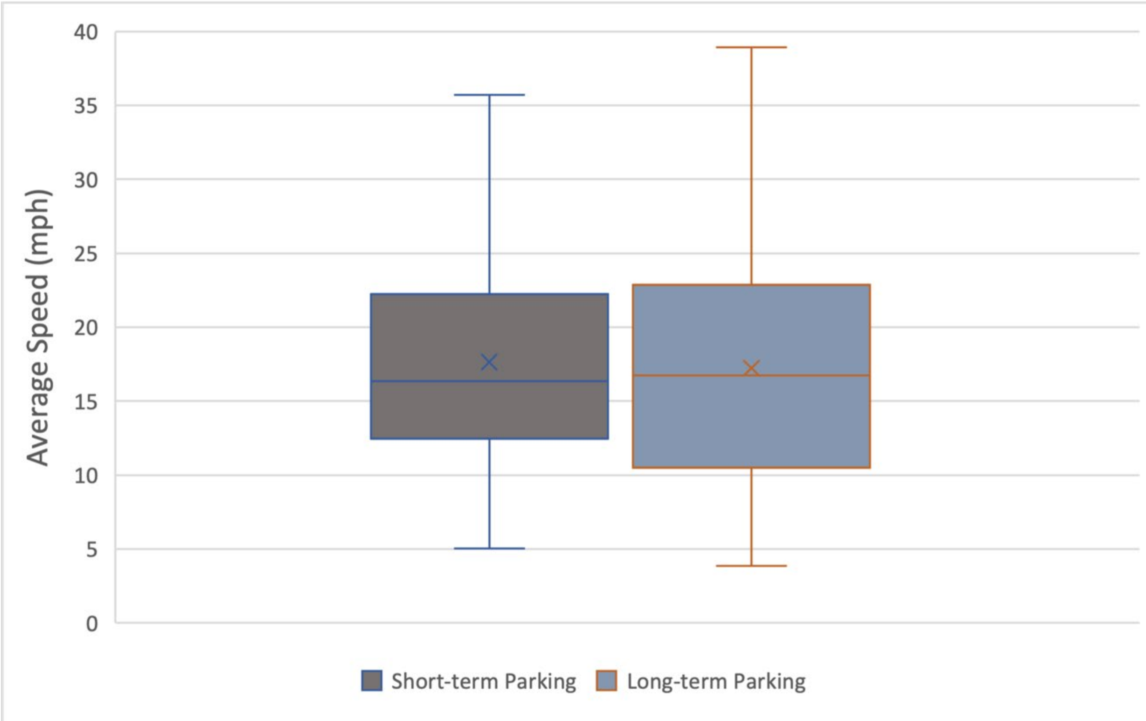


Figure 4-15 Average speeds with delivery times

4.6 Delivery Times and Parking Information

This section shows the results for two levels of delivery times (3- to 5-minute parking and 20- to 60-minute parking) with other independent variables, including parking choice, delivery time with eye-tracker, GSR, and speed results.

Table 4-8 Parking choice information

	Short-term Parking	Long-term Parking
Illegal Parking	60	57
Legal Parking	21	17
No Parking	51	54

One of the participants double-parked in the travel lane, one parked in the PC space, and nine of the participants illegally parked near the intersection. Stopping near the intersection was not included in the speed results because this was outside the study area. Each participant experienced scenarios in random order, and each grid randomly assigned delivery times.

4.7 Statistical Modeling

To better understand the relationship between the dependent and independent variables, a Linear Mixed Model (LMM) was used to analyze the data for the following reasons:

1. It can handle the errors generated from repeated subject variables as participants are exposed to all scenarios.
2. It can handle fixed and random effects.
3. Categorical and continuous variables can easily be accommodated.
4. The probability of Type I errors occurring is low (Jashami et al., 2020).

The following formula was used for the analysis:

$$y_{ij} = \beta_0 + \beta_1 X_{ij} + b_{i0} + \varepsilon_{ij},$$

$$b_{i0}\ iidN(0, \sigma_0^2),$$

$$\varepsilon_{ij}\ iidN(0, \sigma_\varepsilon^2).$$

where β_0 is the intercept at the population level and β_1 is the slope (both are for the fixed effect). $b_{i0}$is the random intercept of the i^{th}participant, which follows a mean normal distribution with variance σ_{b0}^2. ε_{ij} is the error term. Therefore, the assumption of $b_{i0}$and ε_{ij}being independent is made.

R software was used to develop the model, given the independent variables of bike lane, passenger vehicle space availability, CVLZ availability, and number of lanes. These variables were included in the model as fixed effects. The model also included random effects for the participant variable (Jashami et al., 2020).

LMM could be used to estimate how the experimental variables affected drivers' speed and total fixation duration (TFD), which was appropriate given the repeated measures nature of the experimental design in which each participant experienced every scenario. Both fixed and random effects were necessary to include in the model. Pearson's correlation coefficient was used to determine any correlated variables. Regarding the statistical effects, custom post hoc contrasts were performed for multiple comparisons using Fisher's least significant difference (LSD). All statistical analyses were conducted at a 95 percent confidence level, and the restricted maximum likelihood estimate was used to develop this model (Jashami et al., 2020).

4.7.1 Total Fixation Duration

The average TFD at the passenger vehicle was statistically analyzed. The results of the LMM model are shown in table 4-9. Results showed that the CVLZ variable was statistically significant (p-value <0.05), but that was not the case for the other variables. The results are graphically illustrated in figure 4-16. Two-way, three-way, and four-way interactions among the treatment variables were also considered in the analysis. The random effect was substantial (Wald $Z=2.01$, $p<0.05$). Regardless of other variables, participants passing by an occupied CVLZ fixated about 5 second less on the PC than in the no CVLZ scenario (p-value= 0.017).

Table 4-9 Summary of estimated LMM model of TFD (AOI: PC)				
Variable	**Estimate**	**SE**	**T-Value**	**P-Value**
Participant random effect (Var)	6.66	3.31	2.01	**0.022**
Constant	6.51	1.51	4.32	**0.000**
Bike				
No	Baseline			
Yes	-2.43	1.82	-1.33	**0.184**
Space				
No	Baseline			
Yes	-1.16	1.82	-0.64	0.524
CVLZ				
No CVLZ	Baseline			
Occupied	-4.30	1.78	-2.41	**0.017**
Unoccupied	0.33	1.78	0.19	0.853
No of Lanes				
2	Baseline			
4	-0.36	1.83	-0.20	0.844
Bike(b)*space(s)				
b1 s1	4.21	2.55	1.65	**0.099**
bike*cvlz				
b1 Occ	2.41	2.52	0.96	0.339
b1 unocc	4.84	2.52	1.92	**0.056**
bike*lane				
b1 l4	3.58	2.55	1.41	**0.161**
space*cvlz				
s1 Occ	3.75	2.52	1.49	**0.138**
s1 unocc	1.13	2.55	0.44	0.660
space*lane				
s1 l4	1.80	2.55	0.71	0.481
cvlz*lane				
Occ l4	-0.14	2.55	-0.05	0.957
unocc l4	-1.49	2.52	-0.59	0.554
bike*space*cvlz				
b1 s1 Occ	-4.85	3.56	-1.36	**0.174**
b1 s1 unocc	-8.03	3.56	-2.26	**0.025**
bike*space*lane				
b1 s1 l4	-7.67	3.56	-2.16	**0.032**
bike*cvlz*lane				

b1 Occ l4	-3.11	3.56	-0.87	0.383
b1 unocc l4	-6.15	3.56	-1.73	**0.086**
space*cvlz*lane				
s1 Occ l4	-4.57	3.61	-1.27	**0.206**
s1 unocc l4	2.05	3.56	0.58	0.566
bike*space*cvlz*lane				
b1 s1 Occ l4	8.03	5.04	1.59	**0.112**
b1 s1 unocc l4	7.33	5.01	1.47	**0.144**
Summary Statistics				
R2	44%			
-2 Log Likelihood	1378.41			

**Bold: significance level at 0.20*

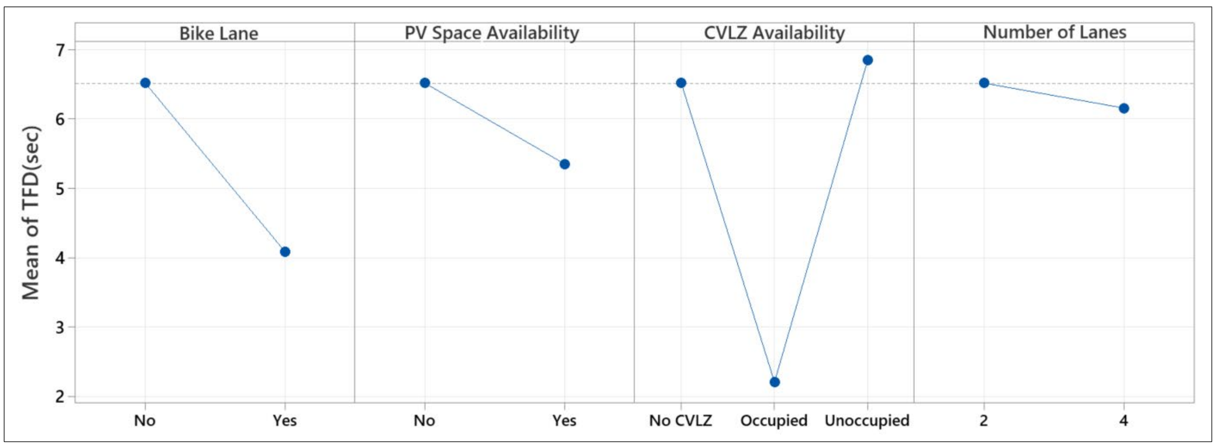


Figure 4-16 Main effects on mean total fixation duration

Two-way interactions between each pair of the independent variables were also investigated and are illustrated in figure 4-17. The y-axis in this figure shows the mean TFD. The x-axis (a, b, and c) shows the two levels of bike lane treatment, d and e show the two levels of the PC space treatment, and f shows the three levels of the CVLZ treatment. The line types indicate the levels of the pair treatment (e.g., figure 4-17 a shows the interaction between the bike lane on the x-axis and PC space availability represented by the blue and red line). In general, mixed results were observed among treatments, but two key findings were observed. Drivers tended to fixate more when there was either no CVLZ or an unoccupied CVLZ in comparison to an occupied CVLZ. However, they fixated more on the PC when no space for a PC was available at all.

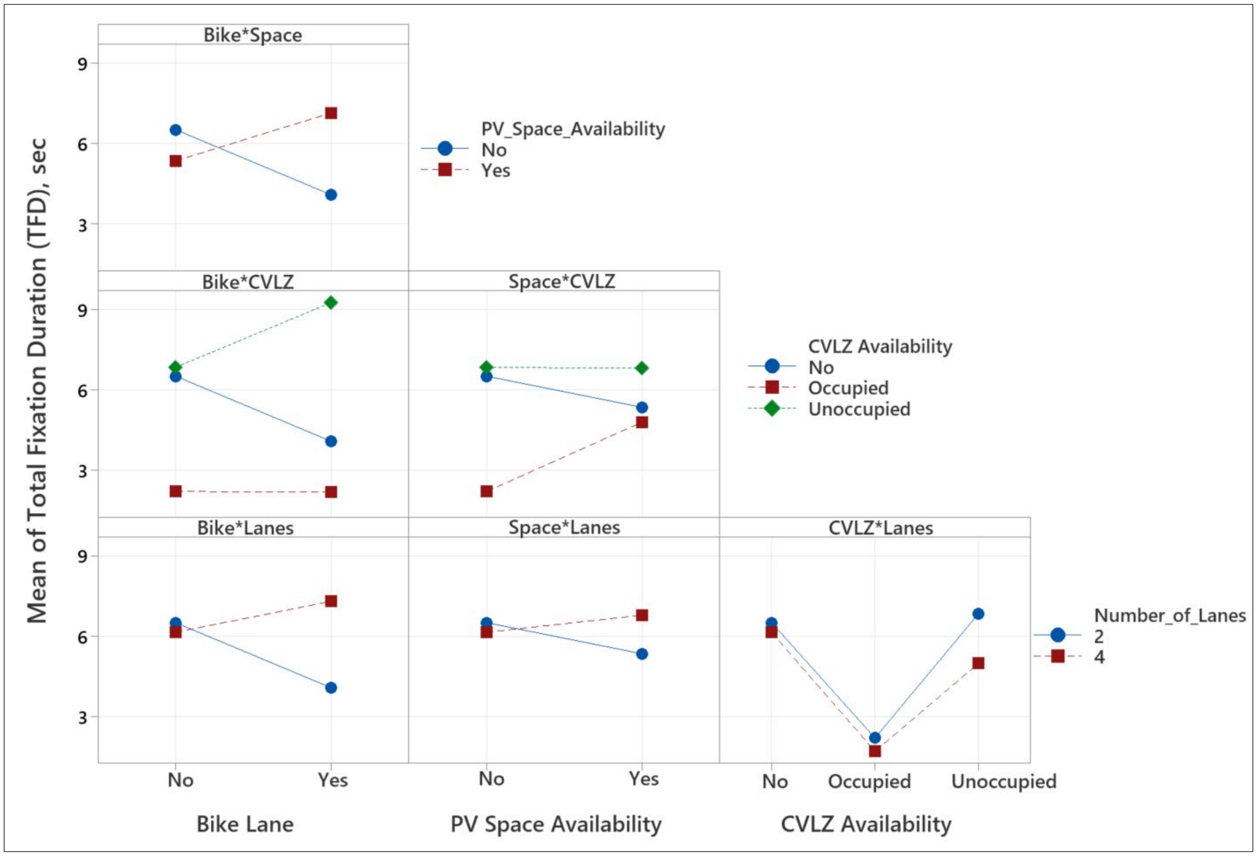


Figure 4-17 Two-way interactions on mean total fixation duration

4.7.2 Speed

The results of the LMM model for the driver's speed are shown in table 4-10. Results showed that space and CVLZ were both significant (p-value <0.20). Two- and three-way interactions among the treatment variables were also investigated. The random effect was significant (Wald Z=2.19, p<0.05). Regardless of other variables, participants' speeds passing by available car spaces were about 5 mph lower than when no spaces were available (p-value = 0.041). The presence of a CVLZ was statistically significant (p-value < 0.001). Participants tended to decrease their speed when encountering unoccupied CVLZs, which might indicate that they were about to park (figure 4-18).

Table 4-10 Summary of estimated LMM model of speed (mph)

Variable	Estimate	SE	T-Value	P-Value
Participant random effect (Var)	19.95	9.09	2.19	**0.014**
Constant	22.16	2.09	10.63	**0.000**
bike				
No	Baseline			
Yes	-0.71	2.37	-0.30	0.765
space				
No	Baseline			
Yes	-4.67	2.27	-2.06	**0.041**
CVLZ				
No CVLZ	Baseline			
Occ	1.65	2.27	0.73	0.468
Unoccupied	-2.87	2.27	-1.27	**0.206**
No of Lanes				
2	Baseline			
4	-0.47	2.27	-0.21	0.837
Bike (b) *space (s)				
b1 s1	-4.12	3.25	-1.27	**0.205**
bike*cvlz				
b1 Occ	-3.94	3.28	-1.20	0.231
b1 unocc	-4.63	3.37	-1.37	**0.171**
bike*lane				
b1 l4	-5.52	3.25	-1.70	**0.090**
space*cvlz				
s1 Occ	-3.73	3.17	-1.18	0.241
s1 unocc	-6.20	3.21	-1.93	**0.054**
space*lane				
s1 l4	-3.47	3.17	-1.09	0.275
cvlz*lane				
Occ l4	-4.13	3.17	-1.30	**0.194**
unocc l4	-1.16	3.17	-0.37	0.714
bike*space*cvlz				
b1 s1 Occ	12.64	4.59	2.75	**0.006**
b1 s1 unocc	20.09	4.63	4.34	**0.000**
bike*space*lane				
b1 s1 l4	14.93	4.51	3.31	**0.001**
bike*cvlz*lane				
b1 Occ l4	9.65	4.54	2.13	**0.034**
b1 unocc l4	9.24	4.60	2.01	**0.046**

space*cvlz*lane				
s1 Occ l4	13.77	4.48	3.07	**0.002**
s1 unocc l4	4.37	4.48	0.98	0.330
bike*space*cvlz*lane				
b1 s1 Occ l4	-21.82	6.40	-3.41	**0.001**
b1 s1 unocc l4	-17.90	6.40	-2.79	**0.006**
Summary Statistics				
R2	57%			
-2 Log Likelihood	1663.05			

**Bold: significance level at 0.20*

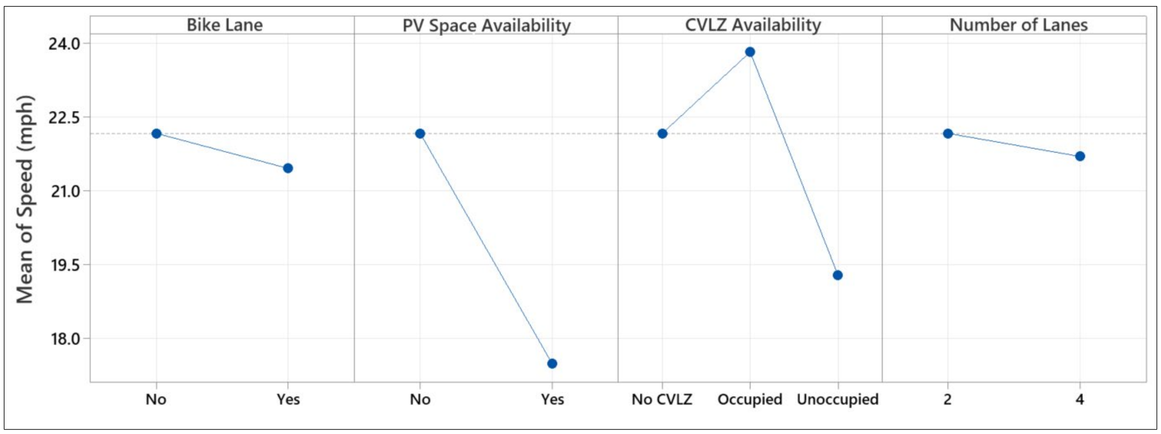


Figure 4-18 Mean effects on mean speed

All possible interactions among the independent variables were investigated and are graphically illustrated in figure 4-19. The y-axis in this figure shows the mean speed (mph). The x-axis (plots a, b, and c) shows the three levels of bike lane, d and e show the three levels of space availability, and f shows the three levels of CVLZ. In general, participants tended to decrease their speed when there was 1) a bike lane, 2) a four-lane environment, 3) a space available, and 4) an unoccupied CVLZ.

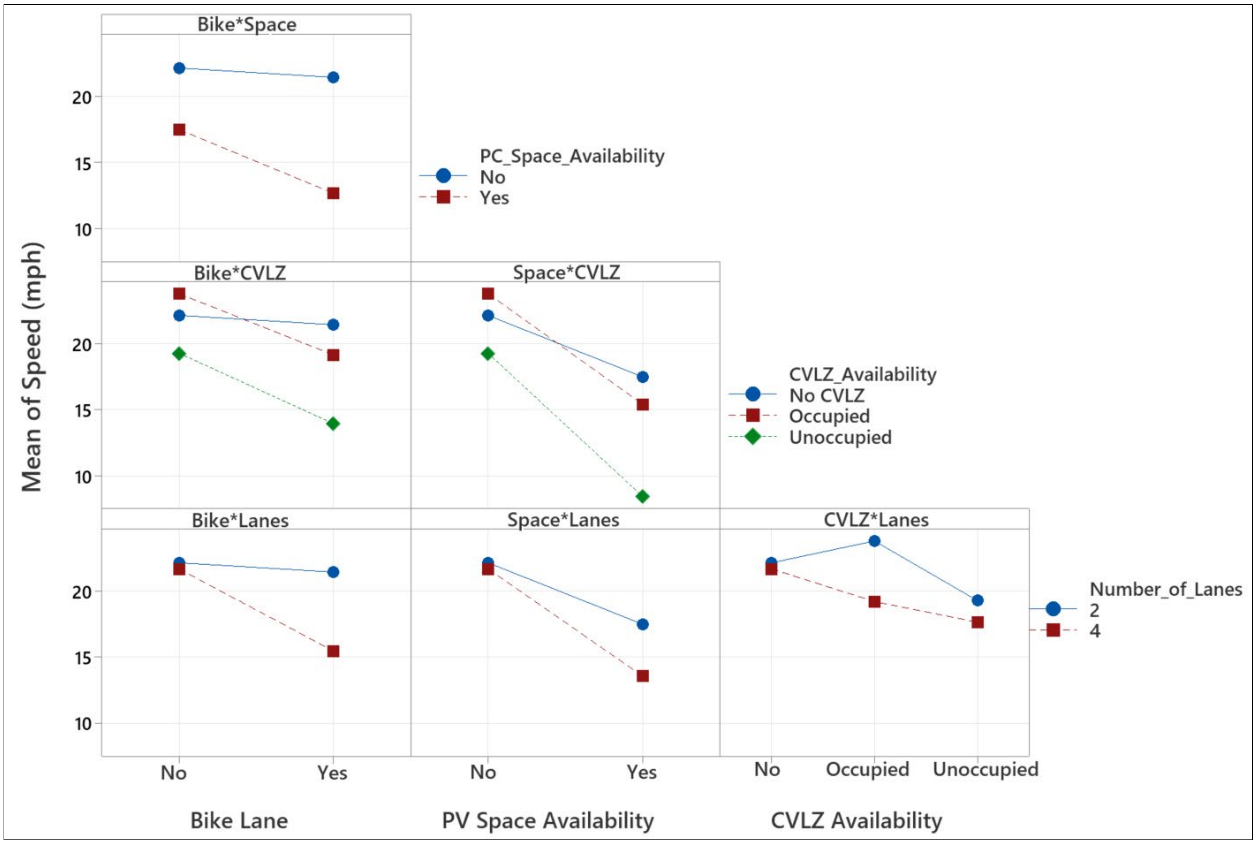


Figure 4-19 Two-way interactions on mean speed

CHAPTER 5. CONCLUSION

The current study's findings pertaining to commercial vehicle drivers' curbside parking behaviors in urban areas are summarized in this chapter. This research aimed to provide empirical evidence that would allow policy makers, transportation engineers, and urban planners to better understand commercial vehicle curbside parking behaviors and safety in relation to commercial vehicle drivers and other road users.

5.1 Heavy Vehicle Simulator Findings

A heavy truck simulator experiment was used to conduct 12 experiments. Each participant drove through 24 scenarios that featured various combinations of experimental elements (i.e., no CVLZ, occupied CVLZs, CVLZs available, number of lanes, with/without a bike lane, available/unavailable passenger vehicle spaces, and delivery times). The information gathered was examined to determine how the variables affected the speeds, levels of stress, and visual attention of commercial vehicle drivers when they were making parking decisions. All other design aspects were coded using ISA version 2.0, while Blender version 2.79 was used to create the roadway geometry and pavement markings. The environments of the scenarios were intended to be as close to actual driving as feasible. On the basis of the literature review and available design manuals (e.g., NACTO and ODOT limits), the travel lane width in this experiment was 12 feet, the block faces were 700 feet long, the bike lane width was 5 feet, the parking lane width was 8 feet, and the sidewalk width was 8 feet. Additionally, the passenger vehicle parking space was 18 feet long. A 40-foot length was used to design the CVLZs, and two levels of delivery time (3 to 5 minutes and 20 to 60 minutes) were chosen as the last independent variable.

The findings of this study provide a coherent narrative about the interaction between delivery-specific needs and commercial vehicle drivers' parking behaviors during vehicle loading and unloading in urban environments, as well as the efficacy of various allocations of space and nearby treatments.

Overall, the findings indicate that the presence of CVLZs and the size of designated loading zones have an impact on drivers' parking decision-making. This impact varies depending on the applied treatments. The following are some of the study's main conclusions:

- *A bike lane has significant effects on commercial vehicle drivers' parking decisions.* The questionnaire showed that 25 percent of the participants parked in a bike lane 1 to 2 times per week; 16.7 percent of the participants parked in a bike lane 3 to 4 times per week; 58.3 percent of the participants did not park in a bike lane. During the experiment, none of the participants parked in the bike lane. Drivers experienced additional stress when operating on roads with a bike lane (8.82 peaks/mins on roads with a bike lane; 7.72 peaks/mins on roads without a bike lane). The presence of a bike lane also increased eye fixation duration time.
- *For short-term parking, drivers demonstrated a higher rate (45 percent) of illegal parking.* In the post-drive questionnaire, 8.33 percent of participants said they parked in the travel lane during the experiment. Across all scenarios, illegal parking occurred more often for short-term delivery times than for long-term delivery times.
- *Delivery times have a slight effect on commercial vehicles' speed and drivers' level of stress*. During the experiment, when road conditions changed (i.e., among no CVLZ, occupied CVLZ, and CVLZ available), the results showed larger changes. For example, the mean stress level for short-term parking observed in the simulator experiment was 8.16 peaks/mins; for long-term parking it was 8.36 peaks/mins. However, on a road with no CVLZ, the mean stress level for short-term parking was 8.67 peaks/mins and for long-term parking was 6.54 peaks/mins.
- On roads with occupied CVLZs, the eye fixation duration time was significantly less than when the road had CVLZs available (2.68 seconds for occupied CVLZs and 6.43 seconds for available CVLZs).The average fixation duration time for a two-lane road was less than that on a four-lane road because the four-lane road had more spaces than the two-lane road, and drivers worried less about finding a space to park/deliver than on the two-lane road.
- The survey results showed that 50 percent of participants drove a commercial vehicle five to ten times per week; 14 percent of participants drove more than ten times per week. Also, about 36percent of participants delivered heavy goods and 21 percent delivered meals/groceries. Therefore, most participants had regular delivery behaviors, which made the results helpful for studying curbside parking behavior.

- Not all commercial vehicle operators may recognize CVLZs. Some participants mentioned that they did not know what CVLZs looked like, causing them to choose to park illegally or in other curbside spaces.

5.2 Recommendations

The results can be used to provide various recommended remedies for curbside parking on urban roadways. These suggestions may help improve CVLZ curbside parking and roadway design standards, enabling our urban street system to function more effectively, reliably, and safely for all users.

- **Truck safety equipment:** To avoid collisions, equipment such as convex mirrors (at the curbside) could be installed for road users' safety when drivers are parking.
- **CVLZ signs:** In areas where commercial vehicles are present, CVLZ signs could be installed to deter illegal parking by all road users.
- **Scheduling delivery times:** In the absence of CVLZs, space limitations necessitate commercial vehicle parking in a bike lane or passenger vehicle parking spaces. Setting aside particular times of day explicitly for commercial vehicle deliveries in a few spots on a curb face could help mitigate the challenges.
- **Buffered bike lane:** If there are no CVLZs for commercial vehicles, drivers may choose to use a bike lane instead, which contributes to increased conflicts between cyclists and passenger cars.
- **Hand truck:** Drivers should always have access to a hand truck that enables them to go farther and make many deliveries rapidly from a single parked space because long-term parking reduces the need for illegal parking.
- **Educational campaigns:** For city planners, this project coul help improve urban curbside parking management by increasing curbside parking spaces (CVLZs). For commercial vehicle drivers, it would be helpful to provide educational flyers/posters to inform them about the locations of legal CVLZs when they deliver goods. For researchers, the results could enhance their understanding of commercial vehicle parking behaviors and safety in relation to commercial vehicles and other road users.

5.3 Limitations

The following are the primary limitations of this project:

- This project was initiated during COVID-19, when e-commerce and urban delivery rates increased. Therefore, commercial vehicle drivers were in higher demand, making subject recruitment for this project very challenging. A larger sample size could increase the validity of the results and conclusions from this work.
- Fatigue is another potential drawback that could have influenced participants' performance during the experimental trials if they became bored or exhausted from the repetitive measurements. To reduce these effects, the situations were somewhat randomized in sequence, and the test drives were only a few minutes long.
- The experiment was carried out in a simulated setting. Despite the fact that the developed situations were based on real-world conditions and were constructed as faithfully as feasible, participants may still have acted differently than they would have in real life. Even under those circumstances, the relative validity of scenarios offered a way to distinguish the experimental components.
- All 14 participants were men, which was skewed. However, the population of commercial vehicle operators is skewed toward males, with only 7 percent being women. (Global, 2020)

5.4 Future Work

Understanding the interactions between delivery vehicles and other users in an urban context is a crucial mobility and efficiency problem that requires further study. To further the work of this study, it is essential to consider how CVLZ operations interfere with other road users' activities, as well as how CVLZ signs affect drivers' parking choices. Potential research directions that could be added to this investigation include the following:

- Numerous additional factors could be considered, such as various types of curb use, different curb policies, increased/decreased traffic flow enforcement, and shifts in delivery hours. To objectively analyze the efficacy of various design strategies, various types of bike lanes, such as buffered bike lanes and contra-flow bike lanes, could also be replicated in a virtual environment.
- A larger variety of commercial vehicle sizes and loading zone configurations could be included.
- The outcomes of this investigation could be validated by combining simulator experiments with field observations in an urban setting.

- The data sample could be expanded to increase data validity.

REFERENCE

Abadi, M. G., Hurwitz, D. S., Sheth, M., McCormack, E., and Goodchild, A. (2019). Factors impacting bicyclist lateral position and velocity in proximity to commercial vehicle loading zones: Application of a bicycling simulator. *Accident Analysis and Prevention*, *125*(May 2018), 29–39. https://doi.org/10.1016/j.aap.2019.01.024

Aljohani, K., and Thompson, R. G. (2016). Impacts of logistics sprawl on the urban environment and logistics: Taxonomy and review of literature. *Journal of Transport Geography*, *57*, 255–263. https://doi.org/10.1016/j.jtrangeo.2016.08.009

Amer, A., and Chow, J. Y. J. (2017). A downtown on-street parking model with urban truck delivery behavior. *Transportation Research Part A: Policy and Practice*, *102*, 51–67. https://doi.org/10.1016/j.tra.2016.08.013

Arnott, R., and Rowse, J. (2013). Curbside parking time limits. *Transportation Research Part A: Policy and Practice*, *55*, 89–110. https://doi.org/10.1016/j.tra.2013.07.009

Auchincloss, A. H., Weinberger, R., Aytur, S., Namba, A., and Ricchezza, A. (2015). Public Parking Fees and Fines: A Survey of U.S. Cities. *Public Works Management and Policy*, *20*(1), 49–59. https://doi.org/10.1177/1087724X13514380

Box, P. C., and Levinson, H. S. (2004). Curb-Parking Problems : Overview. *Journal of Transportation Engineering*, *130*(February), 1–5.

Chen, Q., Conway, A., and Cheng, J. (2017). Parking for residential delivery in New York City: Regulations and behavior. *Transport Policy*, *54*(October 2016), 53–60. https://doi.org/10.1016/j.tranpol.2016.12.005

Cobb, D. P., Jashami, H., and Hurwitz, D. S. (2021). Bicyclists' behavioral and physiological responses to varying roadway conditions and bicycle infrastructure. *Transportation research part F: traffic psychology and behaviour*, 80, 172-188.

D. S. Hurwitz, E. Chai, H. Jashami, C. M. Monsere, S. Kothuri, F. B. A. (2022). *SAFEST PLACEMENT FOR CROSSWALKS AT INTERSECTIONS Draft Final Report*.

Dalla Chiara, G., and Goodchild, A. (2020). Do commercial vehicles cruise for parking? Empirical evidence from Seattle. *Transport Policy*, *97*, 26–36. https://doi.org/10.1016/j.tranpol.2020.06.013

Dalla Chiara, G. D., Cheah, L., Azevedo, C. L., and Ben-Akiva, M. E. (2020). A Policy-Sensitive Model of Parking Choice for Commercial Vehicles in Urban Areas. *Transportation Science*, *54*(3), 606–630. https://doi.org/10.1287/trsc.2019.0970

Dalla Chiara, G., Krutein, K. F., Ranjbari, A., and Goodchild, A. (2021). Understanding Urban Commercial Vehicle Driver Behaviors and Decision Making. *Transportation Research Record: Journal of the Transportation Research Board*, 036119812110035. https://doi.org/10.1177/03611981211003575 de Winter, J. C. F., van Leeuwen, P. M., and Happee, R. (2012). Advantages and Disadvantages of Driving Simulators: A Discussion. *Proceedings of the Measuring Behavior Conference*, *2012*, 47–50.

Gao, J., and Ozbay, K. (2016). Modeling Double Parking Impacts on Urban Street. *Transportation Research Board's 95th Annual Meeting*, *12*(August).

Gillberg, M., Kecklund, G., and Åkerstedt, T. (1996). Sleepiness and performance of professional drivers in a truck simulator - Comparisons between day and night driving. *Journal of Sleep Research*, *5*(1), 12–15. https://doi.org/10.1046/j.1365-2869.1996.00013.x

Global, T. N. (2020, March 1). *Why women are critical to the future of trucking*. Bizjournals.com. Retrieved August 12, 2022, from https://www.bizjournals.com/charlotte/news/2020/03/01/why-women-are-critical-to-the-future-of-trucking.html

Gopalakrishnan, R., Alho, A. R., Sakai, T., Hara, Y., Cheah, L., and Ben-Akiva, M. (2020). Assessing overnight parking infrastructure policies for commercial vehicles in cities using agent-based simulation. *Sustainability (Switzerland)*, *12*(7). https://doi.org/10.3390/su12072673

Gragera, A., and Albalate, D. (2016). The impact of curbside parking regulation on garage demand. *Transport Policy*, *47*, 160–168. https://doi.org/10.1016/j.tranpol.2016.02.002

Guo, H., Gao, Z., Yang, X., Zhao, X., and Wang, W. (2012). Modeling travel time under the influence of on-street parking. *Journal of Transportation Engineering*, *138*(2), 229–235. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000319

Haque, K., Mishra, S., Paleti, R., Golias, M. M., Sarker, A. A., and Pujats, K. (2017). Truck Parking Utilization Analysis Using GPS Data. *Journal of Transportation Engineering, Part A: Systems*, *143*(9), 04017045. https://doi.org/10.1061/jtepbs.0000073

Holguín-Veras, J. (2016). Impacts of Freight Parking Policies in Urban Areas: The Case of New York City. In *Utrc*. Retrieved from http://www.utrc2.org/sites/default/files/Final-Report-Impacts-of-Freight-Parking-Policies.pdf

Hurwitz, D., Ph, D., Hernandez, S., Ph, D., Breuer, H., Or, S., … Breuer, H. (2021). *PRELIMINARY INVESTIGATION OF HEAVY VEHICLE by 1200 New Jersey Avenue SE*. (June).

Jashami, H., Cobb, D., Hurwitz, D. S., McCormack, E., Goodchild, A., and Sheth, M. (2020). The Impact of Commercial Parking Utilization on Cyclist Behavior in Urban Environments. *Transportation Research Part F: Traffic Psychology and Behaviour*, *74*, 67–80. https://doi.org/10.1016/j.trf.2020.07.014

Jashami, H., Hurwitz, D. S., Monsere, C., and Kothuri, S. (2019). Evaluation of driver comprehension and visual attention of the flashing yellow arrow display for permissive right turns. *Transportation research record*, *2673*(8), 397-407.

Lopez, C., Zhao, C. L., Magniol, S., Chiabaut, N., and Leclercq, L. (2019). Microscopic simulation of cruising for parking of trucks as a measure to manage Freight Loading Zone. *Sustainability (Switzerland)*, *11*(5), 1–14. https://doi.org/10.3390/su11051276

Low, R., Tekler, Z. D., and Cheah, L. (2020). Predicting commercial vehicle parking duration using generative adversarial multiple imputation networks. *Transportation Research Record*, *2674*(9), 820–831. https://doi.org/10.1177/0361198120932166

Marcus, L., and Montgomery, W. (2018). Curbside Management. *Institute of Transportation Engineers*.

McCormack, E., Goodchild, A., Sheth, M., and Hurwitz, D. (2019). Developing design guidelines for commercial vehicle envelopes on urban streets. *International Journal of Transport Development and Integration*, *3*(2), 132–143. https://doi.org/10.2495/TDI-V3-N2-132-143

Mukherjee, D., and Mitra, S. (2020). A comprehensive study on identification of risk factors for fatal pedestrian crashes at urban intersections in a developing country. *Asian Transport Studies*, *6*(August), 100003. https://doi.org/10.1016/j.eastsj.2020.100003

National Association of City Transportation Officials. (2013). Retrieved July 3, 2022, from https://nacto.org/

Nevland, E. A., Gingerich, K., and Park, P. Y. (2020). A data-driven systematic approach for identifying and classifying long-haul truck parking locations. *Transport Policy*, *96*(February), 48–59. https://doi.org/10.1016/j.tranpol.2020.04.003

Ni, X. Y., and Sun, D. (2017). Agent-Based Modelling and Simulation to Assess the Impact of Parking Reservation System. *Journal of Advanced Transportation*, *2017*. https://doi.org/10.1155/2017/2576094

Nourinejad, M., Wenneman, A., Habib, K. N., and Roorda, M. J. (2014). Truck parking in urban areas: Application of choice modelling within traffic microsimulation. *Transportation Research Part A: Policy and Practice*, *64*, 54–64. https://doi.org/10.1016/j.tra.2014.03.006

Oregon Department of Transportation. (2001). *Oregon Department of Transportation Safety Comparison of Angle and Parallel Parking File Code : TRA 07-01-05*.

Oregon Department of Transportation. (2020). Truck Size and Length Limited. Retrieved July 3, 2022, from https://www.oregon.gov/odot/MCT/Documents/truck_size_weight_limits.pdf

Panerai, F., Droulez, J., Kelada, J. M., Kemeny, A., Balligand, E., and Favre, B. (2001). Speed and safety distance control in truck driving: comparison of simulation and real-world environment. *Proceedings of Driving Simulation Conference*, (September), 91–107.

Pierce, G., and Shoup, D. (2013). Getting the prices right. *Journal of the American Planning Association*, *79*(1), 67–81. https://doi.org/10.1080/01944363.2013.787307

Raddaoui, O., and Ahmed, M. M. (2020). Evaluating the Effects of Connected Vehicle Weather and Work Zone Warnings on Truck Drivers' Workload and Distraction using Eye Glance Behavior. *Transportation Research Record*, *2674*(3), 293–304. https://doi.org/10.1177/0361198120910743

Roe, M., and Toochek, C. (2017). Curbside Management Strategies for Improving Transit Reliability Curb Appeal. *National Association of City Transportation Officials*, (November), 1–12. Retrieved from https://nacto.org/wp-content/uploads/2017/11/NACTO-Curb-Appeal-Curbside-Management.pdf

Roth, G. (2004). An Investigation into Rational Pricing for Curbside Parking What will be the effects of higher curbside parking prices in A Thesis Presented to The Faculty of Architecture and Planning by. *New York*, (April).

Sisiopiku, V. P. (2001). On-Street Parking on State Roads. *ITE Annual Meeting Compendium*, (January 2001). Retrieved from http://www.researchgate.net/publication/242209128_ON-STREET_PARKING_ON_STATE_ROADS/file/72e7e528e1854351dc.pdf

The Shared-Use City: Managing the Curb. (2018). *The International Transport Forum*. Retrieved from www.itf-oecd.org

Toledo, Koutsopoulos, Ben-Akiva, and Jha. (2001). Microscopic Traffic Simulation: Models and Application. *Simulation*, (May), 1–11. https://doi.org/10.1007/0-387-24109-4

Yang, G., Ahmed, M. M., and Gaweesh, S. (2019). Impact of Variable Speed Limit in a Connected Vehicle Environment on Truck Driver Behavior under Adverse Weather Conditions: Driving Simulator Study. *Transportation Research Record*, *2673*(7), 132–142. https://doi.org/10.1177/0361198119842111

Yang, G., Ahmed, M. M., and Subedi, B. (2020). Distraction of connected vehicle human–machine interface for truck drivers. *Transportation Research Record*, *2674*(9), 438–449. https://doi.org/10.1177/0361198120929692

Yao, Y., Zhao, X., Ma, J., Liu, C., and Rong, J. (2019). Driving Simulator Study: Eco-Driving Training System Based on Individual Characteristics. *Transportation Research Record*, *2673*(8), 463–476. https://doi.org/10.1177/0361198119843260

Ye, X., and Chen, J. (2013). Impact of curbside parking on travel time and space mean speed of nonmotorized vehicles. *Transportation Research Record*, (2394), 1–9. https://doi.org/10.3141/2394-01

Yousif, S. and Purnawan, S. (1999). On-street parking: Effects on traffic congestion. *Traffic Engineering and Control*, *40*(9), 424–427.

APPENDIX A: IRB APPROVAL DOCUMENT

Oregon State University
Research Office

Human Research Protection Program
& Institutional Review Board
B308 Kerr Administration Bldg, Corvallis OR 97331
(541) 737-8008
IRB@oregonstate.edu
http://research.oregonstate.edu/irb

Date of Notification	July 06, 2021		
Notification Type	Approval Notice		
Submission Type	Initial Application	Study Number	IRB-2021-1008
Principal Investigator	David S Hurwitz		
Study Team Members	Ahmed, Ananna; Breuer, Helena; Chai, Eileen Pei Ying; Liu, Yujun; Milacek, McKenna; Scott-Deeter, Logan K; Woodside, Jasmin B; Wyman, Amy		
Study Title	Insights from Driver Parking Decisions in a Truck Simulator to Inform Curb Management Decisions		
Review Level	Expedited		
Expedited Category	6,7		
Waiver(s)	Informed Consent		
Risk Level for Adults	Minimal Risk		
Risk Level for Children	Study does not involve children		
Funding Source	Pacific Northwest Transportation Consortium (PacTrans)	Cayuse Number	21-0658

APPROVAL DATE: 06/29/2021 **EXPIRATION DATE:** 06/28/2026

A new application will be required in order to extend the study beyond this expiration date.

Comments: Waiver of informed consent for eligibility screening

The above referenced study was approved by the OSU Institutional Review Board (IRB). The IRB has determined that the protocol meets the minimum criteria for approval under the applicable regulations pertaining to human research protections. The Principal Investigator is responsible for ensuring compliance with any additional applicable laws, University or site-specific policies, and sponsor requirements.

Study design and scientific merit have been evaluated to the extent required to determine that the regulatory criteria for approval have been met [45CFR46.111(a)(1)(i), 45CFR46.111(a)(2)].

Principal Investigator responsibilities:

- Keep study team members informed of the status of the research.
- Obtain IRB approval for project revisions prior to implementing changes.
- Report all unanticipated problems involving risks to participants or others within three calendar days.
- Use only valid consent document(s).

OSU IRB FWA000039201HRPP Form | v. date August 2019