



AN ABSTRACT OF THE THESIS OF

Julia Anne Kautz for the degree of Master of Science in Civil Engineering presented on March 18, 2015.

Title: Pedestrian Distraction: Pedestrian Behaviors at Midblock Crossings Considering Geometric and Environmental Conditions

Abstract approved:

---

David S. Hurwitz

Pedestrian distraction at roadway crossings has been correlated with a higher risk of pedestrian-vehicle collisions due to the pedestrian's cognitive, visual, and motor attention being drawn to a wide variety of secondary tasks.

This study is different from previous field studies of pedestrian midblock crossings in that the geometric layout of the crossing and the adjacent land use were modeled as factors contributing to the walking speeds of the observed pedestrians. This study focused on pedestrian distraction at midblock crossings located in Corvallis, Albany, and Eugene, Oregon. A combination of digital video and researcher field notes were used to obtain the data at each site. Of the 1407 pedestrians recorded, 1045 complete pedestrian records were used in the analysis. The overall walking speeds observed were between the values of 0.8 ft/s and 12.8 ft/s, with an average overall speed of 4.8 ft/s. The input variables (type of

distraction, cross walk configuration, zoning type, pedestrian demographics, and compliance rates) obtained through observations, were used to predict the output variable (walking speed). The final model was a multivariate linear regression equation, with the most significant variable being the headphones distraction with an estimate, or multiplicative value, of 1.149.

©Copyright by Julia Anne Kautz

March 18, 2015

All Rights Reserved

Pedestrian Distraction: Pedestrian Behaviors at Midblock Crossings Considering  
Geometric and Environmental Conditions

by  
Julia Anne Kautz

A THESIS

submitted to

Oregon State University

in partial fulfillment of  
the requirements for the  
degree of

Master of Science

Presented March 18, 2015  
Commencement June 2015

Master of Science thesis of Julia Anne Kautz presented on March 18, 2015

APPROVED:

---

Major Professor, representing Civil Engineering

---

Head of the School of Civil and Construction Engineering

---

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of  
Oregon State University libraries. My signature below authorizes release of my  
thesis to any reader upon request.

---

Julia Anne Kautz, Author

## ACKNOWLEDGEMENTS

The author expresses sincere appreciation to my advisor Dr. David Hurwitz, and to my committee members Professor Chris Bell, Professor Prasad Tadepalli, and Professor Haizhong Wang. I would also like to express my thanks to the GRAs Sarah McCrea and Jennifer Warner, and to the URAs Kayla Fleskes, Kathleen Mannion, and Amy Anne Wyman, without whom this research would never have been completed. They assisted me in collecting and transcribing the many hours of field data for this project, informed me of necessary changes to the field notes, and also pointed out the use of the Windows Live Movie Maker program. I also wish to express my thanks to my father, to my stepmother, to my siblings, and to my relatives who have helped me throughout my life. I would also wish to express my gratitude towards all of the professors, GTAs, and TAs who have helped me through my courses here at OSU. I would also like to thank the OSU faculty and staff for always assisting me as I navigated through my campus life here at OSU. I would also like to thank the Los Alamos County Traffic and Streets Division for providing me with excellent hands-on experience in the transportation field. I also thank the OSU ITE Student Chapter, the OSU AREMA student chapter, the OSU ASCE student chapter, and the OSU AGC student chapter for allowing me the opportunity to be involved while here at OSU. I would also like to express my deepest thanks to anyone else whom I may have forgotten about that helped me along my path.

## TABLE OF CONTENTS

	<u>Page</u>
1. Introduction.....	1
2. Literature Review .....	3
2.1 Driver Distraction .....	3
2.2 Pedestrian Distraction .....	5
2.3 Driving and Walking Task Comparison .....	6
2.4 Walking Speed.....	8
2.4 Midblock Crossing.....	12
2.5 Compliance .....	14
2.6 Pedestrian.....	17
2.7 Previous Research on Pedestrian Distraction .....	17
2.7.1 Dataset Data and Questionnaires .....	17
2.7.2 Laboratory Testing.....	22
2.7.3 Direct Observations .....	31
2.8 Literature Review Summary .....	36
3. Materials and Methods.....	39
3.1 Location Selection .....	39
3.2 Data Acquisition .....	42
3.3 Data Reduction.....	43
3.3.1 Limitations .....	44
3.4 Analysis.....	44
4. Analysis and Results.....	50
4.1 Preliminary Visualization of the Data.....	50



## TABLE OF CONTENTS (CONTINUED)

	<u>Page</u>
4.1.1 Pedestrian Distraction Proportions .....	55
4.2 Chi Squared Test.....	57
4.3 Normality .....	60
4.4 Full Linear Regression Model .....	61
4.4.1 Model Diagnostic Tests .....	65
4.4.2 Diagnostic Summary.....	71
4.4.3 Extra Sum of Squared Tests for Model Comparisons .....	72
4.5 Final Model.....	74
5. Conclusion .....	79
5.1 Discussion of Results.....	79
5.2 Limitations and Errors .....	82
5.3 Future Work .....	83
6. Bibliography .....	85

## LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
FIGURE 1. GRAPH OF A DRIVER’S COMPETING DEMANDS AND HOW THE COMBINATION OF THE DEMANDS CAN EXCEED THE DRIVER’S CAPACITY TO RESPOND (ADAPTED FROM REGAN ET AL., 2009). .....	8
FIGURE 2. HUMAN WALKING SPEED CATEGORIES OUTLINED (NOVACHECK, 1998)..	9
FIGURE 3. HUMAN WALKING SPEED CATEGORIES OUTLINED BY VAUGHAN (VAUGHAN, 1984).....	10
FIGURE 4. IMAGE OF THE VIRTUAL ENVIRONMENT USED IN THE RESEARCH CONDUCTED BY STAVRINOS ET AL. (STAVRINOS ET AL., 2009). .....	28
FIGURE 5. IMAGE OF PEDESTRIAN WALKING PATH USED IN EXPERIMENT CONDUCTED BY LAMBERG AND MURATORI (LAMBERG ET AL., 2012). .....	29
FIGURE 6. FIGURE OF THE RESPECTIVE LOCATIONS OF ALL THREE CITIES (ARCMAP 10.2.2). .....	40
FIGURE 7. CORVALLIS DATA COLLECTION LOCATIONS (ARCMAP 10.2.2). .....	41
FIGURE 8. ALBANY DATA COLLECTION LOCATIONS (ARCMAP 10.2.2).....	41
FIGURE 9. EUGENE DATA COLLECTION LOCATIONS (ARCMAP 10.2.2). .....	42
FIGURE 10. PEDESTRIAN ENTERING (TOP IMAGE) AND EXITING (BOTTOM IMAGE) CROSSING IN WINDOWS LIVE MOVIE MAKER. ....	43
FIGURE 11. FIRST LANE SPEED BOXPLOT FOR MAIN CATEGORIES. ....	51
FIGURE 12. ISLAND SPEED BOXPLOT FOR MAIN CATEGORIES. ....	52
FIGURE 13. SECOND LANE SPEED BOXPLOT FOR MAIN CATEGORIES. ....	53
FIGURE 14. OVERALL SPEED BOXPLOT FOR MAIN CATEGORIES.....	54

## LIST OF FIGURES (CONTINUED)

<u>Figure</u>	<u>Page</u>
FIGURE 15. EUGENE PIE CHART FOR MAIN DISTRACTION CATEGORIES. ....	56
FIGURE 16. CORVALLIS PIE CHART FOR MAIN DISTRACTION CATEGORIES. ....	56
FIGURE 17. ALBANY PIE CHART FOR MAIN DISTRACTION CATEGORIES.....	57
FIGURE 18. OVERALL SPEED HISTOGRAM FOR RAW DATA.....	60
FIGURE 19. OVERALL SPEED HISTOGRAM FOR LOG TRANSFORMED DATA.....	61
FIGURE 20. NORMAL Q-Q PLOT FOR FULL MODEL.....	66
FIGURE 21. RESIDUALS VS FITTED VALUES PLOT FOR FULL MODEL. ....	67
FIGURE 22. STUDENTIZED RESIDUALS PLOT FOR FULL MODEL. ....	68
FIGURE 23. COOK'S DISTANCE FOR FULL MODEL. ....	69

## LIST OF TABLES

<u>Figure</u>	<u>Page</u>
TABLE 1. COMMON ELEMENTS OF DISTRACTION DEFINITIONS AND EXAMPLES OF EACH ELEMENT (ADAPTED FROM NHTSA, 2010). ....	5
TABLE 2. COMPARISON BETWEEN DRIVING AND WALKING TASKS (ADAPTED FROM FHWA, 2014).....	7
TABLE 3. VARIANCE INFLATION FACTORS FOR FULL MODEL. ....	71
TABLE 4. EXTRA SUM OF SQUARES TESTS RESULTS.....	73
TABLE 5. EXTRA SUM OF SQUARES F-TEST FOR DISTRACTION SUM VARIABLE. ...	74
TABLE 6. CONFIDENCE INTERVAL, ESTIMATE, AND STANDARD ERROR FOR LOGARITHMIC FULL MODEL (RSTUDIO, 2015). ....	75
TABLE 7. CONFIDENCE INTERVAL, ESTIMATE, AND STANDARD ERROR FOR NON-LOGARITHMIC FULL MODEL (RSTUDIO, 2015). ....	76
TABLE 8. CONFIDENCE INTERVAL, ESTIMATE, AND STANDARD ERROR FOR LOGARITHMIC FINAL MODEL (RSTUDIO, 2015).....	77
TABLE 9. CONFIDENCE INTERVAL, ESTIMATE, AND STANDARD ERROR FOR NON-LOGARITHMIC FINAL MODEL (RSTUDIO, 2015).....	78

## LIST OF APPENDICES

	<u>Page</u>
7. Appendices.....	90
7.1 Location Images.....	90
7.1.1 Corvallis.....	90
7.1.2 Albany.....	94
7.1.3 Eugene.....	98
7.2 Tables of Field Data Collected .....	101
7.3 Geometric Layouts.....	105
7.4 Pie Charts for Other Types of Distractions.....	108

## LIST OF APPENDIX FIGURES

<u>Figure</u>	<u>Page</u>
FIGURE 24. CROSSING NORTH OF SW 14 <sup>TH</sup> ST & SW JEFFERSON WAY (WINDOWS MEDIA PLAYER, 2015).....	90
FIGURE 25. CROSSING WEST OF SW 15 <sup>TH</sup> ST & SW JEFFERSON WAY (WINDOWS MEDIA PLAYER, 2015).....	90
FIGURE 26. CROSSING NORTH OF SW 30 <sup>TH</sup> ST & SW JEFFERSON WAY (WINDOWS MEDIA PLAYER, 2015).....	91
FIGURE 27. CROSSING NORTH OF SW 35 <sup>TH</sup> ST & SW KNOLLBROOK AVE (WINDOWS MEDIA PLAYER, 2015).....	91
FIGURE 28. CROSSING SOUTH OF NW 9 <sup>TH</sup> ST & NW SPRUCE AVE (WINDOWS MEDIA PLAYER, 2015).....	91
FIGURE 29. CROSSING SOUTH OF SW 3 <sup>RD</sup> ST & SE MAYBERRY AVE (WINDOWS MEDIA PLAYER, 2015).....	92
FIGURE 30. CROSSING SOUTH OF SW 3 <sup>RD</sup> ST & SW TUNISON AVE (WINDOWS MEDIA PLAYER, 2015).....	92
FIGURE 31. CROSSING WEST OF SW BIRDSONG DR & SW HOLLYHOCK CIR (WINDOWS MEDIA PLAYER, 2015). ....	92
FIGURE 32. CROSSING EAST OF SW COUNTRY CLUB DR & SW 47 <sup>TH</sup> PL (WINDOWS MEDIA PLAYER, 2015).....	93
FIGURE 33. CROSSING SOUTH OF NE CIRCLE BLVD & NE WALNUT BLVD (GOOGLE MAPS, 2015). ....	93
FIGURE 34. CROSSING EAST OF MEADOW PL SE & 21ST AVE SE (WINDOWS MEDIA PLAYER, 2015).....	94

## LIST OF APPENDIX FIGURES (CONTINUED)

<u>Figure</u>	<u>Page</u>
FIGURE 35. CROSSING EAST OF SW 3 <sup>RD</sup> AVE & SE LYON ST (WINDOWS MEDIA PLAYER, 2015).....	94
FIGURE 36. CROSSING NORTH OF BROOKSIDE AVE SE & WAVERLY DR SE (WINDOWS MEDIA PLAYER, 2015). ....	95
FIGURE 37. CROSSING SOUTH OF 12 <sup>TH</sup> AVE SE & SE GEARY ST (WINDOWS MEDIA PLAYER, 2015).....	95
FIGURE 38. CROSSING SOUTH OF SE 11 <sup>TH</sup> AVE & OAK ST SE (WINDOWS MEDIA PLAYER, 2015).....	95
FIGURE 39. CROSSING WEST OF SE 31 <sup>ST</sup> AVE & PINE ST SE (WINDOWS MEDIA PLAYER, 2015).....	96
FIGURE 40. CROSSING WEST OF SANTIAM HWY SE & BAIN ST SE (WINDOWS MEDIA PLAYER, 2015).....	96
FIGURE 41. CROSSING WEST OF SANTIAM HWY SE & BAIN ST SE (GOOGLE MAPS, 2015). ....	96
FIGURE 42. CROSSING NORTH OF PRICE RD SE & BLUE OX DR SE (GOOGLE MAPS, 2015). ....	97
FIGURE 43. CROSSING EAST OF LAWNRIIDGE ST SW & SW 12 <sup>TH</sup> AVE (WINDOWS MEDIA PLAYER, 2015).....	97
FIGURE 44. CROSSING SOUTH OF W 11 <sup>TH</sup> AVE & CITY VIEW ST (WINDOWS MEDIA PLAYER, 2015).....	98
FIGURE 45. CROSSING NORTH OF W 14 <sup>TH</sup> AVE & CITY VIEW ST (WINDOWS MEDIA PLAYER, 2015).....	98

## LIST OF APPENDIX FIGURES (CONTINUED)

<u>Figure</u>	<u>Page</u>
FIGURE 46. CROSSING EAST OF WILLAMETTE ST & E BROADWAY (WINDOWS MEDIA PLAYER, 2015).....	98
FIGURE 47. CROSSING WEST OF WILLAMETTE ST & W BROADWAY (WINDOWS MEDIA PLAYER, 2015).....	99
FIGURE 48. CROSSING NORTH OF RIVER RD & HAMILTON AVE (WINDOWS MEDIA PLAYER, 2015).....	99
FIGURE 49. CROSSING WEST OF SILVER LN & RIVER RD (WINDOWS MEDIA PLAYER, 2015).....	99
FIGURE 50. CROSSING WEST OF HARLOW RD & SWEET GUM LN (WINDOWS MEDIA PLAYER, 2015).....	100
FIGURE 51. CROSSING NORTH OF RIVER RD & KNOOP LN (WINDOWS MEDIA PLAYER, 2015).....	100
FIGURE 52. CROSSING SOUTH OF RIVER RD & OWOSSO DR (GOOGLE MAPS, 2015). .....	100
FIGURE 53. GEOMETRIC LAYOUT 1 (AUTOCAD, 2015).....	105
FIGURE 54. GEOMETRIC LAYOUT 2 (AUTOCAD, 2015).....	105
FIGURE 55. GEOMETRIC LAYOUT 3 (AUTOCAD, 2015).....	106
FIGURE 56. GEOMETRIC LAYOUT 4 (AUTOCAD, 2015).....	106
FIGURE 57. GEOMETRIC LAYOUT 5 (AUTOCAD, 2015).....	107
FIGURE 58. GEOMETRIC LAYOUT 6 (AUTOCAD, 2015).....	107
FIGURE 59. PIE CHART OF OTHER TYPES OF DISTRACTIONS FOR CORVALLIS.....	108



## LIST OF APPENDIX FIGURES (CONTINUED)

<u>Figure</u>	<u>Page</u>
FIGURE 60. PIE CHART OF OTHER TYPES OF DISTRACTIONS FOR ALBANY. ....	109
FIGURE 61. PIE CHART OF OTHER TYPES OF DISTRACTIONS FOR EUGENE. ....	110

## LIST OF APPENDIX TABLES

<u>Figure</u>	<u>Page</u>
TABLE 10. TOTAL PEDESTRIAN COUNTS PER CROSSWALK SITE WITH AND WITHOUT WALKING SPEEDS (2014).....	101
TABLE 11. COUNTS OF PEDESTRIANS WITH WALKING SPEEDS PER CROSSING.....	103

## **1. Introduction**

This research focused on the influence of pedestrian distraction at midblock crossings characterized by the geometry of the crossings, pavement markings, and the environmental surroundings. Based on pedestrian data collected by the National Highway Traffic Safety Administration (NHTSA), 4,280 pedestrian fatalities occurred in 2010 (NHTSA, 2012). NHTSA found that almost three-fourths (73%) of pedestrian fatalities occurred in urban areas, and almost four-fifths (79%) of those fatalities occurred at non-intersection locations (NHTSA, 2012). Based on the National Pedestrian Crash Report by NHTSA, about 79.7% of pedestrian fatalities were on a roadway, 21.1% of pedestrian fatalities were on a roadway with a crosswalk, 41.8% of pedestrian fatalities were on roadway a without a crosswalk, and 8.8% of pedestrian fatalities were at a crosswalk (NHTSA, 2008). The report found that, for the year 2006, 47 pedestrian fatalities occurred at non-intersection crosswalk locations and 1,255 pedestrian fatalities occurred at a non-intersection roadway with a crosswalk available (NHTSA, 2008). These values are lower than the 2005 values (63 and 1,373 respectively), but are higher than the 2004 values (44 and 1,088 respectively) (NHTSA, 2008).

The primary behaviors that NHTSA related to pedestrian fatalities were improper crossing (27.3%), walking against the traffic (25.4%), failing to yield (13.9%), darting or running (12.1%), not being visible (9.8%), being inattentive (2.6%), and failing to obey the traffic control (1.5%) (NHTSA, 2008). From these

statistics, the issue of pedestrian safety is of significant concern. An improved understanding of the factors contributing to pedestrian fatalities could contribute to safer roadway designs.

This research focused on how pedestrian distraction at midblock crossings affects a pedestrian's walking speed. Inattention was among the main categories listed by NHTSA as a reason for pedestrian fatalities. Compliance rates, such as the use of pedestrian push buttons and jaywalking, will also be included in the study. This document begins with a Literature Review section that discusses the previous studies on pedestrian distraction and related topics. The Materials and Methods section then discusses what types of data were collected, where the data was collected, and how the data was collected. This section also describes the data transcription and analysis process. Then, the Analysis and Results section, shows the steps of the analysis and the results obtained from statistical testing and modeling. The Conclusion section discusses the results of the analysis, detail the limitations of the study, and describes possible future studies.

## **2. Literature Review**

Several important concepts related to pedestrian distraction at midblock crossings are considered in detail. Terminology related to the study of pedestrian distraction is defined, and the results of previous research are described and evaluated. It is important to examine the results of previous studies in order to identify existing gaps in knowledge and to consider how the field of transportation engineering may be advanced by resolving those gaps.

### **2.1 Driver Distraction**

According to Regan et al., distraction for a person operating a vehicle is defined as “when a driver is delayed in the recognition of information needed to safely accomplish the driving task because some event, activity, object, or person within or outside the vehicle compelled or tended to induce the driver’s shifting attention away from the driving task,” (2009). According to the National Highway Traffic Safety Administration (NHTSA), driving distraction is divided into three categories: visual distraction, manual distraction and cognitive distraction (NHTSA, 2010). Visual distraction is defined as “tasks that require the driver to look away from the roadway to visually obtain information,” (NHTSA, 2010). An example of visual distraction would be the driver glancing at the vehicle’s clock, which would take the driver’s eyes off of the road. Manual distraction is defined as “tasks that require the driver to take a hand off the steering wheel and

manipulate a device,” (NHTSA, 2010). An example of this would be the driver grabbing an item, such as a wallet, without taking their eyes off of the road. Cognitive distraction is defined as “tasks that are defined as the mental workload associated with a task that involves thinking about something other than driving,” (NHTSA, 2010). An example of this would be the driver being engaged in a conversation with a passenger. It is important to note that there are instances when the driver is influenced by multiple types of distractions simultaneously, such as texting a message on their cell phone, where the driver is glancing away from the road, has one hand removed from the steering wheel, and must think about the message they are typing. Table 1, adopted from *Driver Distraction*, shows the different sources that distraction can come from, and includes the outcomes of these distraction sources.

**Table 1. Common Elements of Distraction Definitions and Examples of Each Element (adapted from NHTSA, 2010).**

Source	Location of Source	Intentionality	Process	Outcome
Object	Internal activity (e.g., daydreaming)	Compelled by source	Disturbance of control	Delayed response
Person	Inside vehicle	Driver's choice	Diversion of attention	Degraded longitudinal and lateral control
Event	Outside vehicle		Misallocation of attention	Diminished situation awareness
Activity				Degraded decision making Increased crash risk

## 2.2 Pedestrian Distraction

Pedestrian distraction is distinctly different, however, from driving distraction.

While the aforementioned definition of distraction (section 2.1) works well for drivers, pedestrian distraction is different as the person is not operating a vehicle and therefore less complex control, guidance, and navigation functions occur. In relation to the three types of distraction, a visual distraction would result in a pedestrian looking away from their forward path, conflicting traffic (vehicle, bicyclist, or pedestrian) or other fixed objects in close proximity; manual distraction occurs when a pedestrian is engaged in a task that requires the pedestrian to manipulate an object carried by the pedestrian; and cognitive

distraction involves a pedestrian thinking about something other than safely maneuvering across the built environment (such as a conversation with another pedestrian).

### **2.3 Driving and Walking Task Comparison**

There are similarities and difference between the driving and walking task.

According to the Federal Highway Administration (FHWA), the driver is “continuously balancing three main tasks: control, guidance, and navigation” (FHWA, 2014). Control is defined as when a driver interacts with the vehicle through activities, such as obtaining information from the vehicle and from the roadway, maintaining the vehicle’s speed, and keeping the vehicle on the roadway (FHWA, 2014). Guidance is how the driver interacts with the surrounding environment, such as other vehicles, the roadway, and the surrounding environment, in order to guide the vehicle along the route (FHWA, 2014). Navigation is “how the driver is going to get from their origin to their destination,” which requires pre-trip and in-trip decisions (USDOT FHWA, 2014). In terms of walking, control is how the pedestrian interacts with elements of the built environment, such as crosswalks, pedestrian push buttons, curbs, and islands. Guidance is how the pedestrian reacts to external stimuli, such as the surrounding environment, other pedestrians, vehicles, and distractions, in order to maintain a safe path on the sidewalk or crosswalk. The navigation task is how the



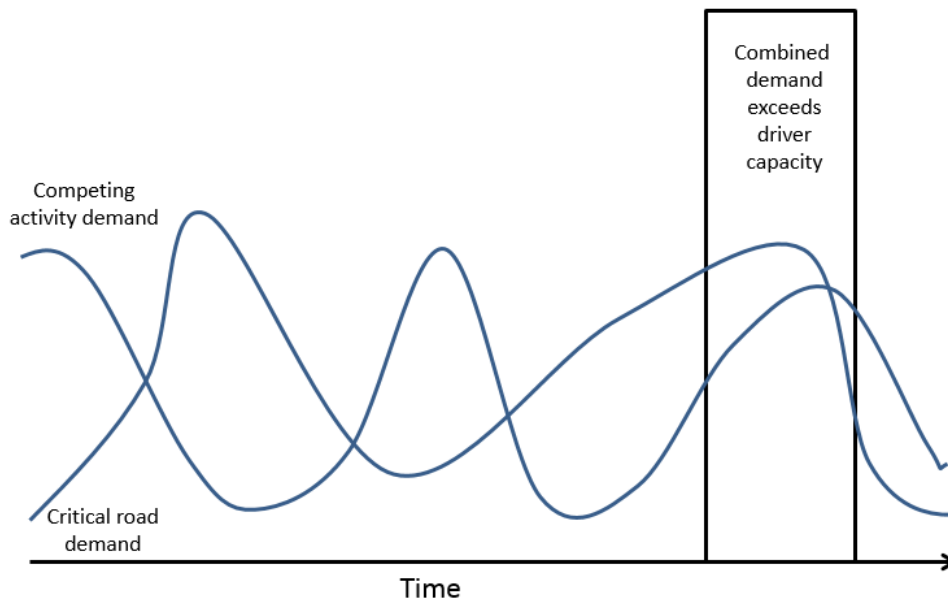
pedestrian intends to select and follow a particular route from one location to another. Table 2 compares pedestrian and driving distraction in relation to control, guidance, and navigation to emphasize their similarities and differences.

**Table 2. Comparison between driving and walking tasks (adapted from FHWA, 2014)**

<b>Mode of Transportation</b>	<b>Control</b>	<b>Guidance</b>	<b>Navigation</b>
Driving	All activities requiring direct interaction with the vehicle, i.e. steering, acceleration, etc.	How driver interacts with external factors to guide the vehicle down the roadway	How the driver will get from an origin to a destination
Walking	All activities requiring direct interaction with the built environment, i.e. placement of feet on sidewalk, ped button activation, etc.	How the pedestrian interacts with external factors to reach the other side of the crossing	How the pedestrian will get from an origin to a destination

Distraction is an important concept to study as it is directly related to safety. A person has less awareness of their surrounding environment when they are distracted. Figure 1 adapted from *Driver Distraction* shows that a person who is distracted has competing demands from both the roadway environment and the

distraction, which can lead to mishaps when the two demands exceed the individual's capabilities.



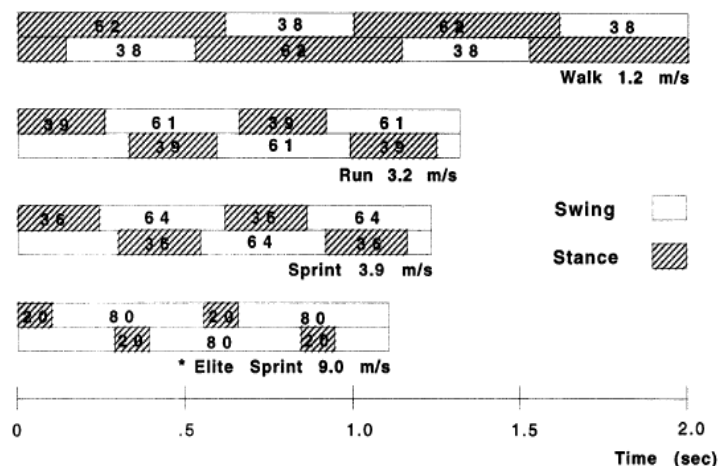
**Figure 1. Graph of a driver's competing demands and how the combination of the demands can exceed the driver's capacity to respond (adapted from Regan et al., 2009).**

In this study, pedestrian distraction is defined as any secondary task performed while walking. These secondary tasks may cause a pedestrian crossing the street to not pay attention to the roadway environment (such as oncoming vehicles).

## **2.4 Walking Speed**

Walking speed is a parameter that directly related to the design of pedestrian infrastructure and associated traffic control. It is also a pedestrian performance measure that may be influenced by distraction. According to Novacheck in "The

biomechanics of running,” there are upper and lower bounds to walking speeds (Figure 2).

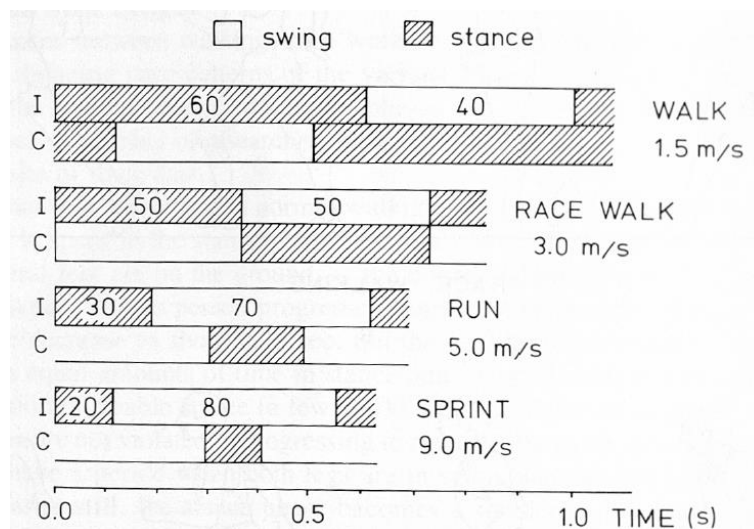


**Figure 2. Human walking speed categories outlined (Novacheck, 1998).**

As this study is focused on the walking speeds of distracted and non-distracted pedestrians, understanding the range at which the pedestrians are determined as walking is important in explaining the results of the study. Novacheck suggests that walking speeds are up to 1.2 m/s (3.9 ft/s), and that speeds between 1.2 m/s to 3.2 m/s (10.5 ft/s) should be classified as running (Novacheck, 1998). He also defines the highest category, the elite sprint, as between 3.9 m/s (12.8 ft/s) to 9 m/s (29.5 ft/s), suggesting that the pedestrian speeds obtained in the field should not exceed 29.5 ft/s (Novacheck, 1998). These thresholds are based on data obtained from the Motion Analysis Lab at Gillette

Children's Specialty Healthcare and from "Biomechanics of running gait" by Vaughan.

Figure 3 figure displays a higher walking speed, 1.5 m/s (4.9 ft/s), and defines the categories differently from Figure 2 (Vaughan, 1984). Race walk, is defined as between 1.5 m/s and 3.0 m/s (9.8 ft/s), and running is defined as between 3.0 m/s and 5.0 m/s (16.4 ft/s). The sprint speed, which is between 5.0 m/s and 9.0 m/s, is the highest category and appears to be similar to the "Elite Sprint" mentioned in Figure 2 (Vaughan, 1984).



**Figure 3. Human walking speed categories outlined by Vaughan (Vaughan, 1984).**

Figure 3 is a compilation of data that the author obtained from three other sources: "Biomechanics of walking, running and sprinting" by Mann and Hagy,

“Kinematic and electromyographic patterns of Olympic race walkers” by Murray et al., and “The transition from walking to running – a comparison of muscle activity and movement patterns” by Nilsson and Thorstensson. Mann and Hagy (1980) included 13 total participants, 2 male sprinters, 5 experienced joggers (2 females and 3 males), and 6 elite long-distance runners (3 males and 3 females) who routinely run races that have distances greater than 1,500 meters (Mann and Hagy, 1980). The study was conducted at the Gait Analysis Laboratory for Crippled Children in San Francisco in a 150 foot long runway (Mann and Hagy, 1980). Murray et al. (1983) studied two male subjects, 23 and 24 years old, who were World Class Race Walkers that had qualified for Olympic trials (Murray et al., 1983). The subjects were photographed and filmed in a laboratory while they conducted tests while moving at free-speed, fast, and race walking paces (Murray et al., 1983). The data obtained by the researchers analyzed the body positions and movements of the athletes, while recording the athletes’ speeds (Murray et al., 1983). The research conducted by Nilsson and Thorstensson could not be obtained.

While the article by Vaughan did not include field data, the researcher used data obtained from observing a national-caliber female distance runner to explain the results obtained (Vaughan, 1984). The female runner was analyzed at three speeds: jogging at 3.8 m/s (12.5 ft/s), racing pace at 5.6 m/s (18.4 ft/s), and

sprinting at 7.5 m/s (24.6 ft/s) (Vaughan, 1984). The data was used to analyze the body movements and strains on the muscles for the female runner.

In a study by Coffin and Morrall (1995), it was found that elderly pedestrian speeds at midblock crossings and signalized intersections tend to be around 1.0 to 1.2 m/s (3.3 to 3.9 ft/s). As it is expected that some of the pedestrians in the study will be elderly persons, this information is important for the analysis of our data as it shows that elderly persons tend to move at speeds slower than younger pedestrians.

## **2.4 Midblock Crossing**

According to the definition provided by the FHWA, midblock crossings are “locations between intersections where a marked crosswalk has been provided” (2014). According to Granié et al. (2014), pedestrian crossing decisions are significantly affected by the surrounding environment. Seventy-seven pedestrians were presented with 20 photos of urban built environments and asked if they would chose to cross the street or not based solely on the information provided in the photographs (Granié et al., 2014). Granié et al. found that participants’ crossing decisions were affected by visually perceived differences in the environments. Participants preferred crossing in city centers which were assumed as safe and pleasant to cross, with the other locations having lower scores for safety and pleasantness for crossing. The participants’ primary safety concern was

vehicle speed. Data was collected through interviews facilitated with static photographs, as such the results may be inaccurate.

Zhuang and Wu (2011) conducted a field study using two synchronized cameras to capture the behaviors of 254 pedestrians that crossed at an unmarked crossing in China which was known to have high numbers of pedestrians (2011). The authors found that the majority of pedestrians did not look at traffic before crossing, though all pedestrians looked at the vehicles while crossing, and that pedestrians preferred to cross aggressively as soon as an appropriate gap occurred. It was also found that more pedestrians ran rather than stepped back when interacting with vehicles, that pedestrians who ran started to run at the borderline, or border between the curb and the street, that pedestrians prefer safer paths to shorter paths, that pedestrians crossed the second half of the roadway with greater speed, and that middle-aged pedestrians, pedestrians in a group, and pedestrians who looked before crossing were safer than other types of pedestrians (Zhuang and Wu, 2011). The authors postulate that pedestrian behaviors may be a result of difference in the geometric layout of the crossing (Zhuang and Wu, 2011).

Coffin and Morrall (1995) conducted two types of studies, an indoor data and an in-field data collection. The indoor data collection had 184 participants over 60 years old, and required participants to walk at both a normal and a fast speed down a 13 meter corridor. The in-field study consisted of six different

crosswalks, two of which were actuated midblock crossings, two were signalized intersection crossings, and two were unsignalized intersection crossings, in which 15 elderly pedestrians were timed walking in each direction and 30 elderly pedestrians were interviewed at each crossing in order to determine elderly walking speeds. The study reported that walking speeds for the elderly vary depending on functional classification, gender, and intersection type, and that the design speeds should be approximately 1.0 to 1.2 m/s (3.3 to 3.9 ft/s). It was also found that the elderly had issues in the usability of the crossings in terms of the geometric design, such as negotiating curbs, fear of turning vehicles, inability to determine vehicle speeds, discourteous drivers, and confusion with the pedestrian signal indications.

## **2.5 Compliance**

Pedestrian compliance to traffic laws and regulations is a critical element in maintaining the safety of surface transportation systems. In many instances municipal codes define what acceptable pedestrian behavior is. For Corvallis, the municipal code does not include required pedestrian behavior while crossing the roadway area for the traffic section of the code (City of Corvallis, Oregon, 2015). It should be noted that Ray Thomas (2008) developed a guide for pedestrian rights in Oregon which defines the different crossing behaviors allowed for multiple counties in Oregon. While the guide included Albany and Eugene in the



City Ordinances Relating to Pedestrians, Corvallis was not included. For Albany and Eugene, the municipal codes do state required pedestrian actions. In Albany, pedestrians are allowed to jaywalk, except in business districts, so long as they cross the street in the shortest possible route (City of Albany, 2015). Eugene requires pedestrians to cross the street at right angles, unless they are crossing within a crosswalk (Eugene, 2015). The pedestrians are therefore allowed to jaywalk in all areas of Eugene, unlike in Albany where they must not jaywalk in business districts. While no mention of the recommended use of pedestrian signals at midblock crossings could be found in the Corvallis, Albany, and Eugene municipal codes, it was stated that pedestrians must obey traffic control devices pertaining to pedestrian movements in the Oregon pedestrian guide by Ray Thomas (Thomas, 2008). Pedestrians, therefore, are considered compliant if they use the traffic control devices for signalized midblock crossings, and wait to cross until the light is green.

Several studies noted pedestrian compliance rates at crossings. Brewer et al. (2014) studied pedestrian compliance rates for rectangular rapid-flashing beacons (RRFBs) and pedestrian hybrid beacons. The in-field study of four sites with the RRFBs and one site with a pedestrian hybrid beacon (Brewer et al., 2014). Staged crossing, where the researcher posed as a pedestrian crossing the street in order to determine if the vehicle would yield, and non-staged crossings

where actual pedestrians were observed. A total of 203 non-staged pedestrians were observed in the study. Brewer et al. found that 94% of non-staged pedestrians activated the beacons, that there was an increase in the number of non-staged pedestrian crossings after the beacons were installed, and that when no crossing guard was present the pedestrian searched more actively for conflicting vehicles with 90% looking in at least one direction and 68% looking in both directions at least once. It was noted, however, that there was a 4% increase in the number of pedestrians who did not look before entering after the beacon was installed (Brewer et al., 2014).

Hatfield et al. (2007) conducted a field study of 2,854 pedestrians at a signal-controlled intersection to observe pedestrians' attention to traffic for different pedestrian and traffic signal combinations. Hatfield et al. also conducted interviews with 574 participants where the participants answered questions from the perspective of either a pedestrian or a driver for a wide-range of pedestrian right-of-way situations at different crossing types (2007). Measures of pedestrian compliance were used with the walk indication or jaywalking when comparing distracted and non-distracted pedestrians. The study results suggest that pedestrians have misunderstandings of the right-of-way rules (Hatfield et al., 2007). While this study was concerned with an intersection crosswalk, it suggests that pedestrian compliance at crossings is an important consideration.

## **2.6 Pedestrian**

FHWA defines a pedestrian as “any person afoot” (2014). FHWA noted that definitions of a pedestrian have been known to vary by city, but as an example, Chicago, Los Angeles, New York City, and Phoenix generally agreed that a pedestrian is any person travelling afoot (Kar and Gajula, 2008).

## **2.7 Previous Research on Pedestrian Distraction**

The previous studies on pedestrian distraction can be categorized into three experimental approaches: 1) dataset analyses and questionnaires, 2) laboratory testing involving virtually built environmental simulators, or participants walking a specified distance in a controlled environment, and 3) empirical field observations. Several of the previous research studies consisted of multiple experimental approaches, such as obtaining direct observations and conducting questionnaires, or doing laboratory testing and empirical field observations.

### **2.7.1 Dataset Data and Questionnaires**

Dataset data collected by a third party can have large amounts of information, but may not have information related to distraction. However, several previous studies using phone surveys, the National Electronic Injury Surveillance System (NEISS) database, and questionnaires were able to obtain information on the subject. Several of the studies used databases to determine the safety implications of distraction. Madden and Rainie (2010) obtained phone survey data (2,252 US

participants) and concluded that about 17% bumped into another person or object due to distraction. The self-reported survey results of this study found that millennials are the most likely age group to bump into something (33%), that only 15% of Generation X cell users bump into objects, that only 8% of Baby Boomers bump into objects, and only 3% of those over age 65 bump into objects (Madden and Rainie, 2010). These results indicate that the younger pedestrians are more likely to bump into objects than older pedestrians. It was also noted that pedestrians who live in urban areas are more likely to bump into other people or objects while using a cell phone than pedestrians in rural areas, with 20% and 13% respectively, and that pedestrians with college degrees are more likely to be distracted by cell phones than pedestrians with high school degrees, with 20% and 14% respectively (Madden and Rainie, 2010). This study indicates that distraction affects a person's ability to focus on the walking task, and that age, education, and the surrounding environment may affect a pedestrian's level of awareness.

A study by Smith et al. (2013) used the NEISS dataset (5,754 cases from years 2000-2011, 68% female, 49% white, 16% African American, 5% other ethnicity, 30% no ethnicity recorded) in order to conclude that the majority of patients (78%) were talking on their cell phone when they fell, though there are limitations to this study due to underreported and non-reported incidences. Smith et al. noted the danger of distractions by stating that cell phones increase the

opportunities for an injury in the home, even though they allowed for more mobility (2013). Therefore, as in (Madden and Rainie, 2010), the researchers found that distraction causes a person to lose their focus on the walking task, which is a safety concern. It should be noted, however, that these articles only focused on cell phone distraction, and did not cover other types of distractions.

Nasar and Troyer (2013) also leveraged records in the NEISS from 2004 through 2010 to confirm that there is a risk of injury for pedestrians who use mobile phones. The NEISS dataset confirmed that men are more likely than women to obtain pedestrian injuries, though the authors were not able to conclusively determine why. Again, Nasar and Troyer only considered cell phone distractions.

Some studies have used questionnaires as a secondary study to supplement field or laboratory experiments. Hyman Jr et al. (2010) conducted a field study of pedestrian behavior at a large 59,210 square foot square plaza, in which one of the two studies consisted of questioning 151 pedestrians (84 females, 139 college age, 10 older than college age, and 2 with ages unknown) on whether they saw a unicycling clown in the middle of a plaza (Hyman Jr et al., 2010). The results of the study determined that cell phone users exhibited inattention or blindness of their surroundings, with only 25% of the cell phone users noticing the clown, and that they tended to walk more slowly, weave, and fail to acknowledge others in

the study area (Hyman Jr et al., 2010). The participants who walked in pairs, however, were the most likely group to notice the clown, and it was noted that more than half of the other types of distractions apart from cell phone users also noticed the clown (Hyman Jr et al., 2010). This study not only reinforces the idea that distractions cause safety issues, but also shows that different types of distractions have varying degrees of inattention to the surrounding environment.

Nasar et al. (2008) selected 60 participants at an entrance to a large urban land-grant university, and then questioned the participants after they had walked a prescribed 100 yard route either alone or in a group in which half were distracted due to a conversation on their cell phone and the other half were not distracted. Post-walk subjects were surveyed on if they had observed a series of objects, some of which were and some of which were not along the route. To reduce bias, participants were not told the true reason for the study until after they had participated. The study concluded that cell phone distraction reduces a pedestrians' situational awareness, which is similar to the results of other previous studies on cell phone distraction (Nasar et al., 2008).

Safe Kids Worldwide (2013) conducted interviews of 2,441 students in conjunction with field observations to determine the thoughts of the teenage pedestrians. It was determined that most teenagers perceive that other age groups are more at risk than their age group, that 40% of teenagers listen to music while

walking, and that about half of the interviewed teenagers use cell phones to text or talk while they are walking (Safe Kids Worldwide, 2013). State crash data (ages 12-19, years 2007-2011, all 50 US States) was used to determine which states had the greatest number of child pedestrian fatalities (California), and the greatest number of fatalities per 100,000 children (South Dakota) (Safe Kids Worldwide, 2013). This data concluded that most teenage pedestrian fatalities occur in urban rather than rural settings, with two-thirds on urban roads and one-third on rural roads (Safe Kids Worldwide, 2013). This study shows that the location of the crossing matters in terms of the safety of the pedestrians, though it does not link the occurrence of pedestrian fatalities to distractions.

There are several main results identified from the dataset and questionnaire studies. It was found that distractions increase the likelihood of pedestrians bumping into other objects and reduce a pedestrian's awareness of surroundings, raising safety concerns, and that different types of distractions affect a pedestrian in different ways. It was also determined that age, gender, education level, and the surrounding environment or location affect pedestrian behavior. While the dataset data and questionnaire studies are able to provide conclusive results for the data obtained, not all of the data is related to pedestrian distraction. Therefore, it is necessary to study the results of laboratory and field experiments.

### **2.7.2 Laboratory Testing**

Most previously conducted studies regarding pedestrian distraction at midblock crossings have been performed in the laboratory. Schwebel et al. (2009) conducted a study using one virtual midblock crossing with traffic moving in both directions (245 participants, 62% female, average age = 21) in which the participants' were ranked based on their level of attentional control, or how easily distracted a person is, and their level of high intensity pleasure, or their intention to "seek and enjoy high-stimulus, exciting, novel, and diverse experiences and stimuli" (Schwebel et al., 2009). The results of the study determined that higher attentional control correlated with waiting longer and choosing longer gaps before crossing, and that high intensity pleasure correlated with higher hits by oncoming vehicles (Schwebel et al., 2009). This study underlines that the level of attention to surroundings affects a pedestrians' decisions, and that a pedestrians' general behavior, which is based on their level of high intensity pleasure, also affects a pedestrians' decisions before and during crossing.

Stavrinos et al. (2011) conducted two experiments using a virtual environment crosswalk. The first experiment included 108 university participants (58% female, average age = 21), in which participants conducted six distracted and six non-distracted trials. After using questionnaires to obtain the experience level and capacity of the participants, the participants were asked to walk down a



15 foot hallway four times to obtain their walking speeds. This study considered four variables: time left to spare, missed opportunities, attention to traffic, and hits or close calls. The second study (59 participants, 55% female, ages 18-35) had participants conduct 12 simulated crossings (2 non-distracted, 1 for answering a cell phone, 9 for either a cell phone conversation, answering questions regarding item locations, or counting backwards). The experiments determined that all students are influenced by distraction, conversation content does not significantly affect pedestrians, though attention is greatly affected by some types of cognitively demanding conversations, distracted pedestrians miss more opportunities and have more close calls or hits with oncoming vehicles, cell phone conversation distractions compromise a pedestrians' safety, and there were no significant associations between demographic factors and the susceptibility to distraction (Stavrinos et al., 2011).

Schwebel et al. (2012) used a virtual crosswalk with 138 participants (64% female, ages 17-45), in which participants completed 12 crossings in the virtual environment, in which four conditions were randomly assigned (non-distracted, listening to music, talking on the phone, or texting on the phone). The results indicate that listening to music or texting increased the potential of being hit by a vehicle when compared to non-distracted pedestrians, that all distracted pedestrians looked away from the street while waiting to cross, and that distracted

pedestrians did not miss more safe opportunities to cross when compared to the non-distracted group (Schwebel et al., 2012).

Stavrinos et al. (2009) studied a midblock crossing in a virtual simulator (77 participants, 48% female, ages 10-11) in which participants conducted 12 crossings (6 non-distracted and 6 distracted by a cell phone conversation). Surrogates for safe crossing included: average start delay, average safety time, hits or close calls, and attention to traffic. It was found that cell phones distract children and increase risky behavior, and that children are more likely to be hit or have close calls when distracted and during their first time in the virtual environment. The authors did note, however, that using cell phones are not necessarily hazardous for children, but that the use of cell phones should be limited while crossing the street (Stavrinos et al., 2009).

Byington et al. (2013) studied one virtual crossing (92 participants, 74% female ages 17-25) in which participants performed 10 crossings (5 non-distracted and 5 using their cell phone to access the internet). The researchers used six dependent variables: hits or close calls, start delay, wait time, missed opportunities, looking at traffic, and eyes off of the road. It was seen that distracted pedestrians displayed riskier behaviors (waiting longer to cross, missing more safe opportunities, taking longer to cross when a safe gap was available, glancing less often, spending more time looking away from the road, and being

more likely to be hit or almost hit by an oncoming vehicle) when compared to the non-distracted pedestrians (Byington et al., 2013). It was also noted that experience in using the internet on a mobile phone did not increase pedestrian safety as all of the participants were distracted by their cell phone (Byington et al., 2013).

Neider et al. (2010) studied a virtual crossing in an urban environment on a two-way (one-lane per direction) roadway with no median refuge island (36 participants, 53% female, ages 18-30). Adjacent buildings occluded conflicting vehicles until the pedestrians were about to enter the roadway. The participants were told to walk, not run, while crossing for three conditions (not distracted, listening to music with headphones, and conversing on a hands free cell phone). Pedestrians conversing on a cell phone made more unsafe decisions and tended to walk slower than non-distracted pedestrians and pedestrians listening to an ipod device (Neider et al., 2010). The authors concluded that conversing on a cell phone impacts a pedestrian's ability to successfully navigate a street crossing when compared to non-distracted crossings (Neider et al., 2010).

Murray et al. (2006) conducted four experiments on pedestrian distraction in which pedestrians crossed a virtual environment consisting of two lanes of traffic separated by a broken white line. The first study (55 participants, 28 female, ages 18-24) had participants walk at normal or rushed walking speeds and

focused on the conversation condition, or conversing with a researcher on a cell phone, and the initial distance between vehicles in terms of dependent variables of the measures of safety, potential components of safety, and measures of caution (Murray et al., 2006). The second experiment (19 participants, 12 female, aged 18-27, and 16 participants, 11 female, aged 50-67) had participants cross at normal and rushed walking speeds, and focused on the conversation condition, the initial distance, and the age group in terms of the same dependent variables of the first experiment with the added variable of postural stability (Murray et al., 2006). The third experiment (20 participants, 11 females, aged 18-24) had participants conduct 40 trials similar to the second experiment, but in which the layout was altered and the instruction to start was altered by dropping the instruction to turn left (Murray et al., 2006). The fourth experiment (12 participants, 7 females, aged 20-41) had participants conduct 20 trials (10 in the actual environment with a Head-Mounted Display and 10 in the virtual environment for distracted and non-distracted conditions) and focused on the environment and the conversation conditions in terms of walking speed (Murray et al., 2006). The results of the studies concluded that conversing on a cellular phone reduces safe behavior, that pedestrians walk slower when conversing, that pedestrians who converse tend to walk at shorter gaps between vehicles, that distances between vehicles affect

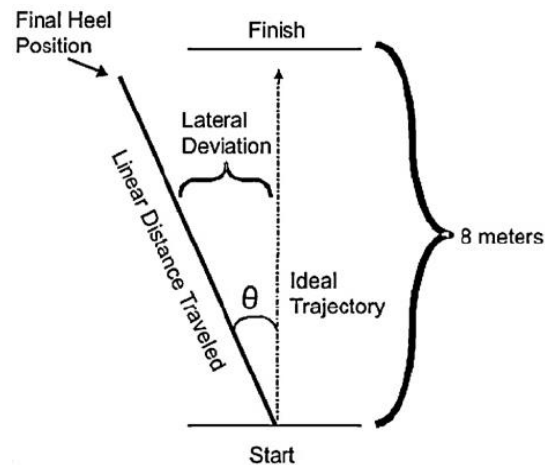
pedestrian behavior, that older pedestrians walk faster than younger pedestrians, and that pedestrians are affected by the environment (Murray et al., 2006).

Neider et al. (2011) conducted a virtual simulation study of one mid-block crossing with 2 age groups (18 aged 18-26, 50% female, and 18 aged 59-81, 39% female), in which the participants crossed the street in 60 experimental trials. The conditions for the participants were non-distracted, listening to music on an iPod Nano, and engaging in a hands-free cell phone conversation. Results indicated that the difficulty of the task and the task load are important factors, that the performance of older adults suffers more than younger adults when engaged in two tasks concurrently, that older adults were less likely to complete their crossing when conversing on a cell phone compared to the other conditions, and that older adults took more time than younger adults to initiate their crossing (Neider et al., 2011). It was also noted that the older adults had higher walking speeds than younger participants, and that the younger participants walked slower in the cell phone condition when compared to the other conditions (Neider et al., 2011). This indicates that age and distraction type are important determinants of pedestrian performance.



**Figure 4. Image of the virtual environment used in the research conducted by Stavrinos et al. (Stavrinos et al., 2009).**

Another type of laboratory experiment for pedestrian distraction involved participants walking in a controlled environment rather than in the virtual reality environment. Lamberg et al. (2012) conducted an experiment (33 participants, 70% female), that had participants walk an 8 meter distance for one of three randomly assigned conditions: walking, walking while talking on a cell phone, or walking while texting. The results determined that walking while texting or talking on a cell phone impacts functionality and working memory and leads to gait disruptions, with texting having a more significant effect, and that texting causes greater path deviations when compared to talking (Lamberg et al., 2012).



**Figure 5. Image of pedestrian walking path used in experiment conducted by Lamberg and Muratori (Lamberg et al., 2012).**

Schabrun et al. (2014) conducted an experiment (26 participants, 73% female ages 18-40) in a controlled 8.5 meter long hallway to determine the safety implications of texting while walking. There were three conditions: walking at a comfortable pace, walking at a comfortable pace while reading on a mobile phone, and walking at a comfortable pace while texting. Participants had slower walking speeds, greater deviations from a straight path, and had reduced relative motion for walking while reading text or texting on a mobile phone as compared to normal walking. It was also found that subjects who wrote text had reduced walking speed and greater deviations from a straight path when compared to reading text (Schabrun et al., 2014).

There were several key findings obtained from the laboratory tests. It was determined that distraction increases risky pedestrian behaviors, that pedestrians conversing on cell phones walk slower than non-distracted pedestrians, that different types of distractions affect a pedestrian differently, that pedestrian behavior and the environment affect pedestrian decisions, that experience in the use of a cell phone does not increase pedestrian safety as the pedestrian is still distracted, and that walking speeds and the ability to complete tasks vary between different age groups, though pedestrian demographics do not determine a pedestrian's susceptibility to distraction. Other findings were that certain types of conversation material can greatly affect a pedestrian, and that the distances between vehicles can affect pedestrian behavior. The laboratory tests compared distracted pedestrian behaviors with non-distracted pedestrian behaviors, but there are limitations to the fidelity of the virtual environments and the simulated walking tasks. While the laboratory experiments allow for complete control of all experimental variables, the participants are aware that they are being observed which may affect the results. There are also low numbers of pedestrians in the laboratory tests (12 to 245 participants) compared to the database archives (minimum of 310 participants) or field observations (26 to over 1000 participants).



### **2.7.3 Direct Observations**

The majority of the direct observation studies were conducted at intersections. Bungum et al. (2005) considered a T-intersection near a large university campus in Las Vegas, NV, with a seven-lane approach width and a 30 mph posted speed (866 pedestrians, 332 females, age range from teens to 70s). The researchers observed the pedestrian's glance patterns and compliance to signalization, and included distractions of whether the pedestrian was seen eating or drinking or smoking, and had headphones or a cellphone. Researchers concluded that only 13.5% of the pedestrians were observed looking left and right while crossing and waiting on the curb until the light turned green, that males and females had no significant difference in cautionary behaviors, and that distraction had significant effects on cautionary behavior (Bungum et al., 2005). Approximately 20% of the pedestrians were distracted, some pedestrians crossed multiple times, and the behavior of the pedestrians could have been affected by recent articles on pedestrian safety and law enforcement intervention (Bungum et al., 2005).

Cooper et al. (2012) conducted a field study of pedestrian, bicyclist, and vehicle behaviors at intersections near 12 Bay Area transit stations (1,144 pedestrians, 557 bicyclists, 2,267 drivers). Field observations included pedestrian compliance to signalization, glance patterns, behavior, and the use of a cell phone or other communication device. It was determined that men were more likely than

women to cross against a red light, that pedestrians on their own crossed during the red and used mobile phones more than pedestrians in groups of two or more, and that females and younger pedestrians were more likely to use mobile phones than other groups (Cooper et al., 2012).

Hatfield and Murphy (2007) conducted field observations of 546 pedestrians at three signalized and three unsignalized intersections in three Sydney suburbs. The gender, age, distraction type (not talking on phone, hand-held phone, hands-free phone, text messaging, phone in hand, number of companions with pedestrian, if pedestrian was carrying anything), interaction with traffic, and interaction with traffic control devices were all recorded. Mobile phone usage resulted in unsafe gender specific behaviors, with females crossing more slowly and less likely to look at traffic before or during crossing or to wait for traffic to stop, and with males crossing more slowly at unsignalized intersections (Hatfield et al., 2007).

Thompson et al. (2013) observed the behavior, age, and gender of 1102 pedestrians in the crosswalks of 20 intersections. Observed distractions included: non-distracted, using a handheld phone, using a hands-free phone, text messaging, listening to music, and other types of distractions. Observed pedestrian behavior included walking alone or with others, talking or not talking, crossing at the crosswalk, obeying the lights, and looking right and left before crossing. It was

determined that distraction from mobile devices reduced crossing time, that texting is extremely risky for pedestrians with an 18% increase in crossing times and failure to exhibit safe behaviors, that distracted behavior continued while crossing in the intersection, that music listeners crossed faster but were less likely to look both ways before crossing compared to pedestrians who were not distracted, that females displayed less optimal behavior than males, and that younger pedestrians displayed more compulsive behavior around mobile device use (Thompson et al., 2013).

Zeedyk et al. (2002) collected video data of 56 children (45% female, ages 5-6) at two crossings located at a T-intersection in a local technology park in order to observe children's crossing. The children were distracted by searching for letters during a treasure trail activity that required the children to conduct two road crossings. The children displayed a variety of unsafe behavior, such as failing to stop at the curb before proceeding or not looking at on-coming vehicles while crossing a road, and their attention was dangerously inadequate and unfocused when distracted (Zeedyk et al., 2002).

Nasar et al. (2008) conducted field observations at three crosswalks on a university campus (127 pedestrians). The observers recorded the pedestrians' gender, if the pedestrian was using a cell or mobile phone, i-pod, or no technology, pedestrian behavior, if the action taken by the pedestrian was

observed as safe or unsafe, and if the pedestrians forced a car, pedestrian, or group to evade them. Of the pedestrians recorded, 19% used a mobile phone, 24.2% used an i-pod, and 55.9% did not use a device (Nasar et al., 2008). It was determined that mobile phone users had unsafe behaviors, that ipod users stopped more than others in conditions when no on-coming vehicles were present, that most cell phone users walked when an approaching vehicle was present and stopped when a stopped vehicle was present, that mobile phone users were less safe than either the ipod or not distracted groups, and that the group that exhibited the safest behavior in terms of the various walking conditions was the non-distracted group (Nasar et al., 2008).

While most of the distracted pedestrian studies were conducted at intersections, Walker et al. (2012) had observed pedestrian distraction at two midblock crossings, a two-lane zebra striped crossing and a two-lane painted crossing, at the University of British Columbia's Vancouver campus (264 pedestrians, 49% female, 58 listening to personal music device). The pedestrian's gender, the presence or absence of a personal music device, any other distractions (eating, drinking, on a cell phone, or selecting a song on their personal music device), the presence or absence of an approaching vehicle, and if the pedestrian displayed cautionary behavior were all recorded. Personal music devices were found to either increase or not affect a pedestrian's cautionary behavior,

supporting the idea that personal music affects pedestrians differently than cell phones, and gender differences in behavior were observed, such as how the males showed more cautionary behavior when using the music devices while the females showed no change in behavior (Walker et al., 2012).

Not all of the field studies were conducted at intersections or midblock crossings. Hyman Jr et al. (2010) conducted field observations in a large plaza (196 pedestrians, 52% female), in which 43 of the observed pedestrians walked alone without electronics, 47 used cell phones, 54 used music players, and 52 walked in pairs. The time, the weather, the presence of additional activities, the duration of crossing, pedestrian behavior, if the pedestrian was involved in a collision, and if the pedestrian acknowledged other pedestrians were recorded. The study concluded that people talking on cell phones and walking in pairs crossed more slowly than persons without electronics and using music players, gender had no effect on walking speed, and that cell phone users were more likely to change direction, weave, and acknowledge others than other conditions (Hyman Jr et al., 2010).

A study was conducted by Safe Kids Worldwide (2013) which determined from field observations (14,930 observations at 20 high schools and 19,395 observations at 48 middle schools) that 20% of high school students and one-eighth of middle school students cross a street while distracted, that students most

often text or use headphones when distracted, that there is a 26% higher chance of being distracted if there is a traffic light present, and that girls are 1.2 times more likely than boys to walk while distracted (Safe Kids Worldwide, 2013).

There were several main findings obtained from the direct field observations. It was found that distraction reduces cautionary behavior and affects crossing speed, that different types of distractions cause different types of pedestrian behaviors, age and gender may affect a pedestrian's behavior and crossing speed, and that the number of persons that the pedestrian crosses with affects behavior. It was also noted that the design of the crossing, such as if the crossing has signalization, may be correlated with the amount of pedestrian distraction observed. The above studies were conducted under a variety of conditions and should be considered in conjunction with their limitations. However, as summarized below, the studies give important insight into several concepts related to the influence of distraction on pedestrian behavior at midblock crossings.

## **2.8 Literature Review Summary**

While there were many different types of studies included in the literature review, there were several key results directly relevant to this research. The first is that distraction affects a pedestrian's walking speed. As the studies have varying types of locations, geometric designs, surrounding environments, and numbers of

participants, it is difficult to ascertain the exact effect that distraction has on walking speed, but the authors tend to conclude that walking speed is decreased due to distractions. One key result is that the adjacent built environment, such as residential or urban land uses, may also affect a pedestrian. Another important point made is that different types of distractions affect a pedestrian in different ways. It was noted that, for cell phones users, those who texted while walking had different levels of distraction when compared to those who talked while walking, even though the same device was used. Another key point noted was that pedestrian demographics, such as age and gender, may influence how the pedestrian is affected by the distraction and walking speed. Compliance rates were also noted to be influenced by pedestrian demographics in several of the studies.

These studies utilized several different experimental techniques and had varying degrees of limitations that influence the interpretation of the results, such as the sample sizes, the effect of bias in terms of the level of interaction between the researchers and participants (especially in the tests conducted in the laboratory setting and questionnaires), and the type and amount of data obtained. It is also important to note that it is very difficult to determine gender, age, and ethnicity accurately during manual or video based field observations as researchers must

guess. While the researchers used statistical analysis in order to account for these limitations, they must still be noted.

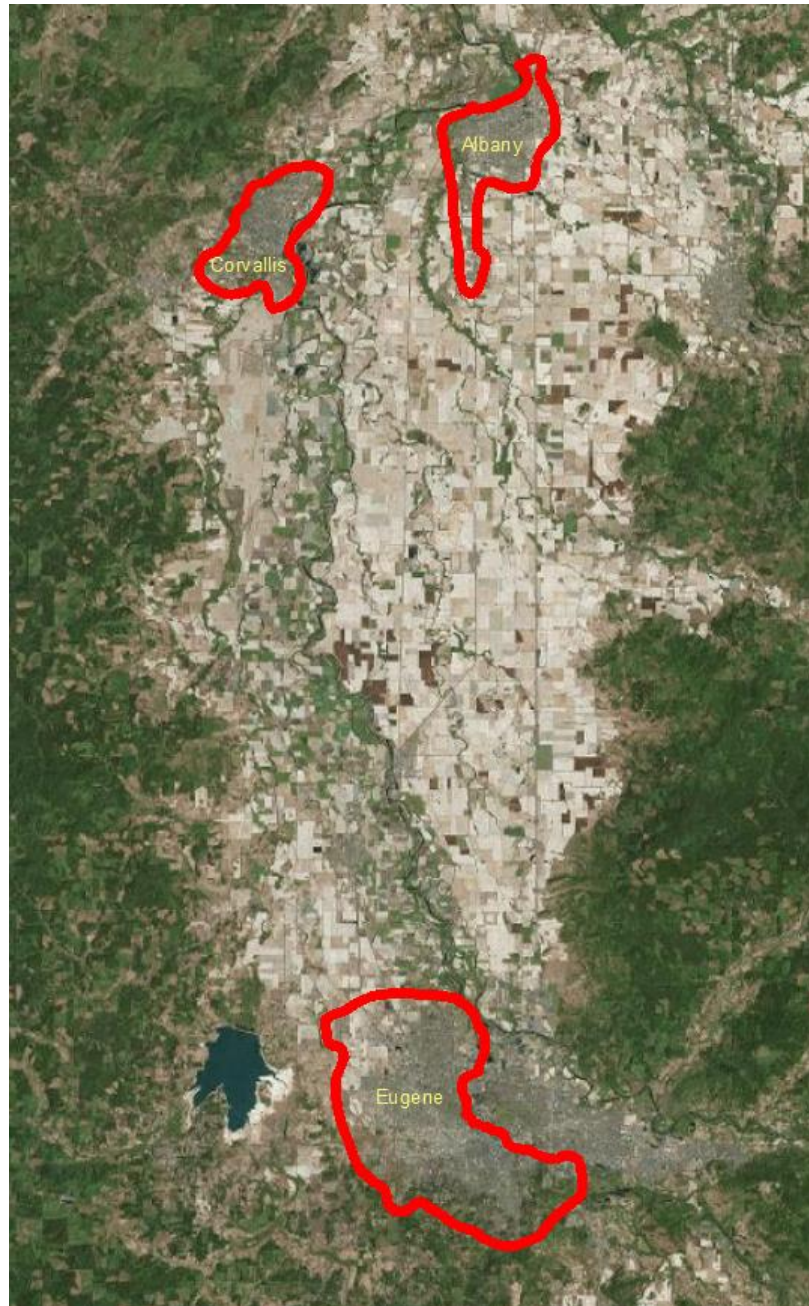


### **3. Materials and Methods**

A field study of pedestrians at midblock crossings with different geometric layouts was conducted. The following sections describe the methods used in obtaining and reducing the field observations of pedestrian behavior.

#### **3.1 Location Selection**

Three cities were included in the study: Corvallis, Albany, and Eugene, Oregon (Figure 6). A total of 24 midblock crossings were considered, though only 23 of the crossings were used for the analysis. The midblock crossings were selected based on their relative proximity to the OSU campus, geometric layout, and traffic control device location. Figures 7, 8, and 9 identify the locations of all 24 midblock crosswalks included in the study.



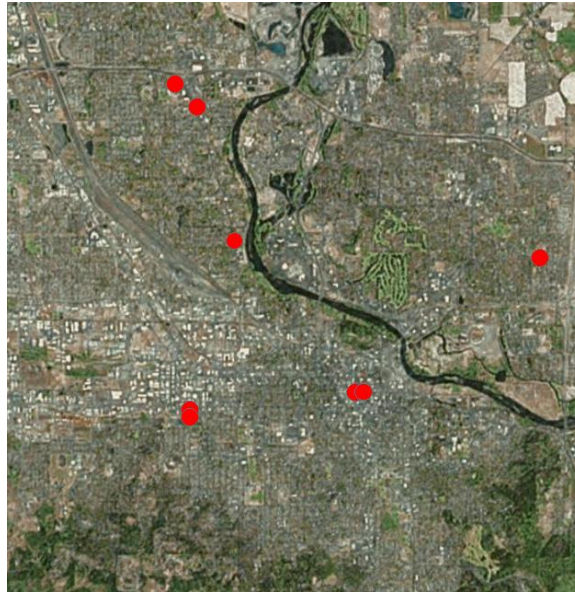
**Figure 6. Figure of the Respective Locations of All Three Cities (ArcMap 10.2.2).**



**Figure 7. Corvallis Data Collection Locations (ArcMap 10.2.2).**



**Figure 8. Albany Data Collection Locations (ArcMap 10.2.2).**



**Figure 9. Eugene Data Collection Locations (ArcMap 10.2.2).**

### **3.2 Data Acquisition**

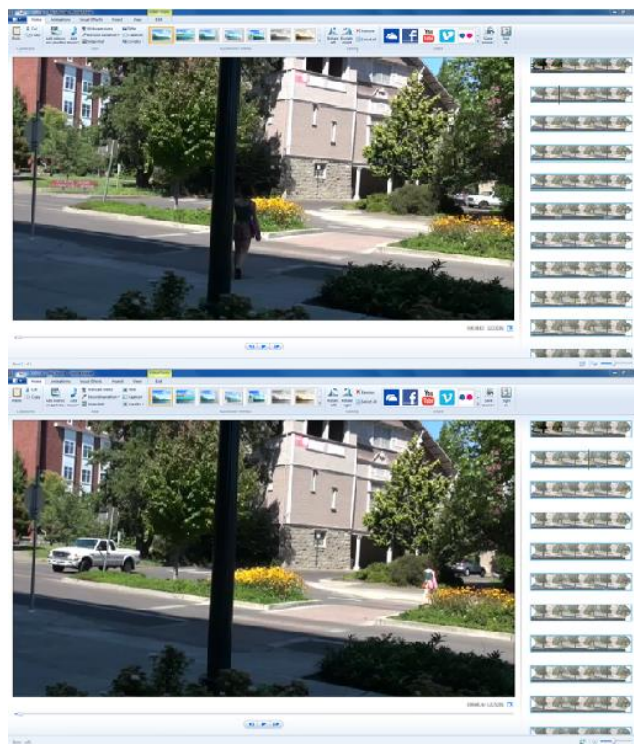
Researchers used field notes, measuring wheels, and SONY video cameras to collect the field data. Cameras were used to record the entirety of the interaction between pedestrians and conflicting vehicles at the midblock crosswalks. Field notes were used to determine if and how each pedestrian observed was distracted. A summary table of the data collected at each site is included in Appendix 7.2. The primary categories of distraction included: no distraction, looking at a handheld device, talking on a cell phone, wearing headphones, walking in a pair, walking in a group, and other. The length of the crossing and islands at each location were collected from Google Earth imagery and verified with a measuring wheel in the field.



### 3.3 Data Reduction

Walking speeds were determined directly from the video footage with the use of Windows Live Movie Maker (2012). The software displays the time interval with an accuracy of one hundredth of a second and can advance the video frame by frame (0.02 to 0.05 second intervals), which increases the accuracy of the transcribed data when compared with other methods.

A time stamp was recorded the moment the pedestrian entered and exited roadway the roadway (Figure 11).



**Figure 10. Pedestrian entering (top image) and exiting (bottom image) crossing in Windows Live Movie Maker.**

### **3.3.1 Limitations**

While the use of the software programs allowed for precise time stamps identifying pedestrian location in the crosswalk, the method of transcription used allows for errors.

There is potential error regarding the walking speeds of jaywalking pedestrians. Due to the difficulty associated with determining the exact distance that the pedestrian jaywalked, their walking speeds are typically over estimated.

Another potential error occurred when pedestrians stop while crossing the street, as only the times of when they entered/exited the section of the street were recorded, not the time that they stood still. It was not noted if the pedestrian stopped while crossing the street in the dataset.

### **3.4 Analysis**

After transcribing, the data was analyzed using the RStudio software program. The first step of the analysis was to visualize the gathered data. Pie charts of the main distraction categories and other categories, as well as boxplots of the walking speeds for the main types of distraction categories, were created using Excel and RStudio for the purpose of visual inspection. Next, a Chi Squared test was conducted to determine if the data of all three cities, Corvallis, Albany, and Eugene could be combined. More specifically, two Chi Squared tests were conducted, one in which the main distraction proportions were compared, and one

in which the distracted and not distracted proportions were compared. As the walking speeds are necessary for the pedestrians being analyzed, the pedestrians who had no walking speeds were eliminated from the Chi Squared Test. The same two tests were conducted for the distracted versus not distracted pedestrians, bringing the total to four Chi Squared tests.

Once the Chi Squared tests were completed, statistical modeling was performed. The full model (a multivariate linear regression equation) was analyzed in RStudio in order to determine the final model. The first step was to determine if the data should be log transformed using histograms of the walking speeds. Histograms of the raw data were created, and then compared to the histograms of the log transformed data for each of the four types of walking speed conditions (overall speed, first lane speed, island speed, and second lane speed).

Overall Speed is the total distance of the crossing divided by the total time that a pedestrian is within the street area. This is therefore the walking speed for the entire time interval that a pedestrian is in the roadway environment. First Lane Speed is the distance of the first lane divided by the time that the pedestrian is in the first lane. The first lane is all of the lanes for the first direction of traffic that the pedestrian encounters. The first lane therefore may have more than one lane, as the first direction of traffic may have two lanes in the case of a four lane crossing. In the event of there being an island, the first lane is the distance from

the entering curb to the island. Island Speed is the length of the island divided by the time that the pedestrian is in the island area. Second Lane Speed is the distance of the second lane divided by the total time that the pedestrian is in the second lane. The second lane is the all of the lanes for the second direction of traffic that the pedestrian encounters. Similar to the first lane, the second lane may also have more than one lane as the direction of traffic may have more than two lanes as in the case of a four lane crossing. In the event of there being an island, the second lane is the distance from the island to the exiting curb. Only the overall speed was considered for the full and final models as it is the pedestrian's average speed for the entire crossing area.

It should be noted that the variables (or indicator variables) are factors, and therefore are not log transformed (Ramsey & Schafer, 2013). The only value that is log transformed is the walking speed which is considered the output variable.

A combination several diagnostic tests (the Variance Inflation Factor, Normal Q-Q plots, and Residuals versus Fitted Plots) and a case-influence statistics (Cook's Distance and Studentized Residuals) were used to verify the full model (Marnell, 2013). Case-influence statistics are measures used to examine the individual influence of each observation (Ramsey & Schafer, 2013). The Residuals versus the Fitted values plot shows the curvature and the spread of the



data, showing if the data has signs of nonlinearity, nonconsistent variance, and the presence of outliers (Ramsey & Schafer, 2013). The Normal Q-Q plot is a plot used to assess the normality of the data. In general, data is robust to the normality assumption, meaning that there are small consequences if this assumption is violated (Ramsey & Schafer, 2013). Therefore, only if there is a small sample size and/or there are long tails (specifying outliers) is there a normality issue (Ramsey & Schafer, 2013). The Variance Inflation Factor is a technique used to determine if there is multicollinearity in the model (Ramsey & Schafer, 2013).

Multicollinearity is when too many variables are used to explain the explanatory variables (Ramsey & Schafer, 2013). The Studentized Residuals plot is a residual divided by its estimated standard deviation in order to determine the variation of the data (Ramsey & Schafer, 2013). Cook's Distance is a technique used to measure the overall influence of specific points (Ramsey & Schafer, 2013).

A series of Extra Sum of Squares F-Tests were then used in order to determine which variables are necessary for the model (Hurwitz et al., 2013). The Extra Sum of Squares F-Test is used to compare a full model to a reduced model in order to determine which variables are necessary (Ramsey & Schafer, 2013). The equation for the ESS F-Test is shown below (Fuentes, 2014) (Ramsey & Schafer, 2013):

$$F - \text{Statistic} = \frac{\left( \frac{RSS_{additive} - RSS_{nonadditive}}{df_{additive}(Res) - df_{nonadditive}(Res)} \right)}{RMS_{nonadditive}} \quad (1)$$

where:

$RSS_{additive}$  = the residual sum of squares obtained in the Anova test for the reduced model

$RSS_{nonadditive}$  = the residual sum of squares obtained in the Anova test for the full model

$df_{additive}(Res)$  = the residual degrees of freedom for the reduced model obtained in the Anova test

$df_{nonadditive}(Res)$  = the residual degrees of freedom for the full model obtained in the Anova test

$RMS_{nonadditive}$  = the residual of the mean square for the full model obtained in the Anova test

The p-value for comparison is obtained using the F-Statistic, the difference in the degrees of freedom, and the degrees of freedom for the full model. The p-value was used to determine if the full model or the reduced model should be used.

It should be noted that the model for this analysis does not include interaction terms. Interaction terms are terms in which two or more variables are multiplied in the model (Ramsey & Schafer, 2013). Interaction terms should only

be included in a model when one of three conditions are met: “when a question of interest pertains to the interaction,” “when good reason exists to suspect an interaction,” or “when interactions are proposed as a more general model for the purpose of examining the goodness of fit of the model without the interaction” (Ramsey & Schafer, 2013). It was determined that an interaction term is not necessary for answering the question of what affects a pedestrian’s walking speed or if distraction affects a pedestrian. Therefore, no interaction terms were included in the model.

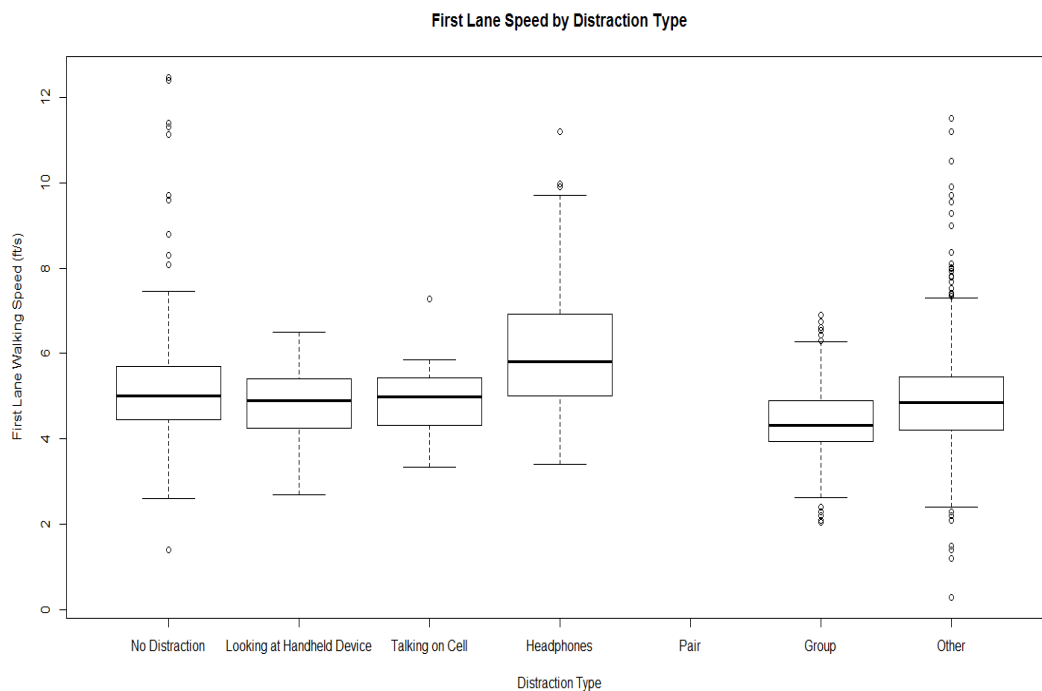
#### **4. Analysis and Results**

This section described the statistical analysis of the data collected at the pedestrian midblock crossings. First, the entire data set was visualized for the first lane speed, the island speed, the second lane speed, and the overall speed. The next step assessed the normality of the data to determine if a log transformation was necessary. Since only the overall pedestrian walking speed was considered for the analysis, the normality of only the overall walking speed was plotted. Once normality was determined, a Chi Squared test was performed to determine if the three cities should be included in the model. After the Chi Square test, the full model for the overall speed was developed using several diagnostic tests (the Variance Inflation Factor, Normal Q-Q plots, and Residuals versus Fitted Plots). The outlying points in the full model were assessed using case-influence statistics (Studentized Residuals and Cook's Distance). Finally, after using the diagnostic tests to determine the full model, the variables of the model were tested using the Extra Sums of Squares F-Test in order to verify the necessity of each of the variables in the full model.

##### **4.1 Preliminary Visualization of the Data**

The data obtained from the videos and the field notes was recorded into Microsoft Excel spreadsheets. The data was then converted into a Comma Separated Variable file (.CSV) in order to be imported into RStudio for analysis. RStudio

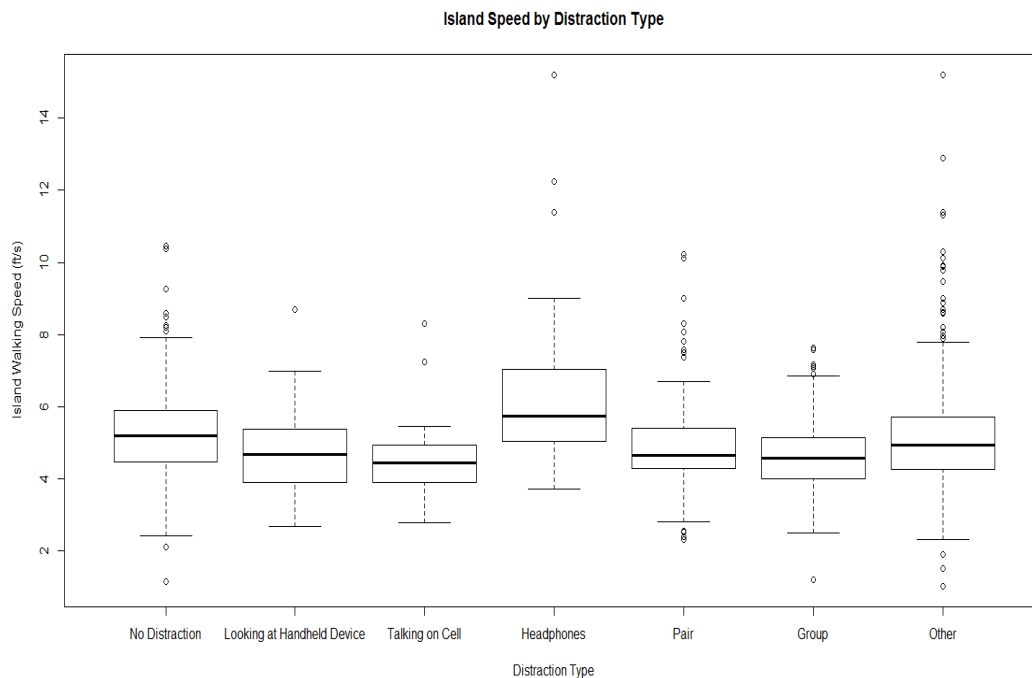
was used to create boxplots of the entire dataset's walking speeds for the main distraction categories. These were split into four graphs, shown below, for the first lane, island, second lane, and overall or entire crossing areas.



**Figure 11. First Lane Speed Boxplot for Main Categories.**

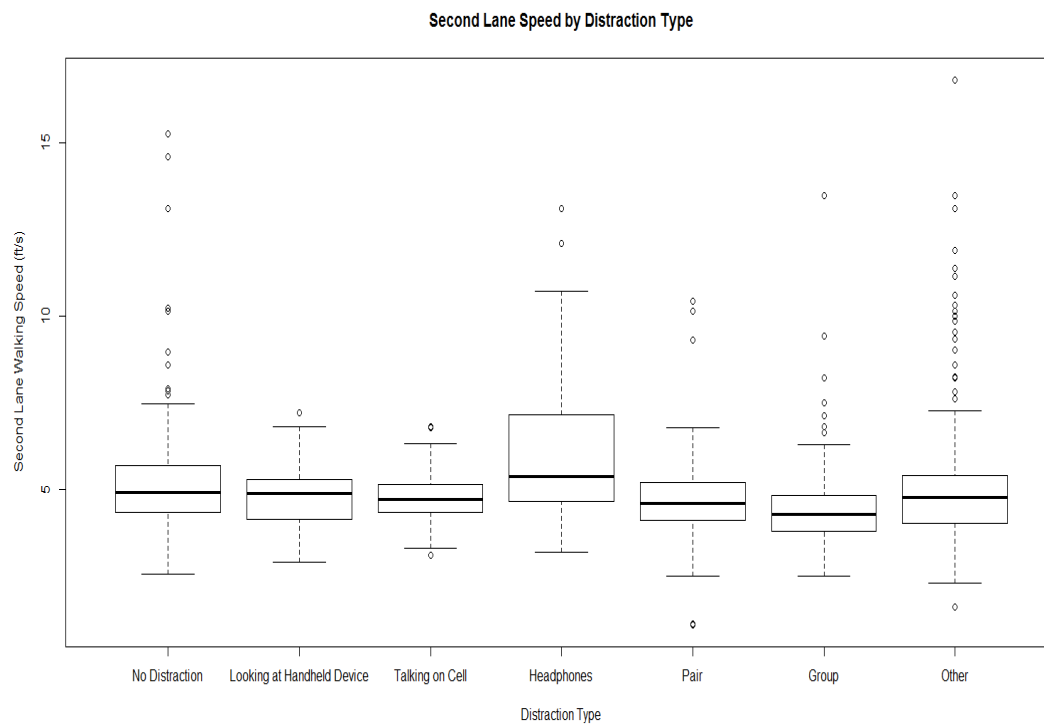
As can be seen in Figure 11, the average walking speeds for each category are approximately 4 to 6 ft/s. The “Pair” distraction category does not have a boxplot because there were no recorded walking speeds for pairs in the first lane. From the data, the “No Distraction” category has the highest walking speed values, but the “Headphone” category has the highest average walking speed. The “Other”

category has the lowest walking speed value, but the “Group” category has the lowest average walking speed.



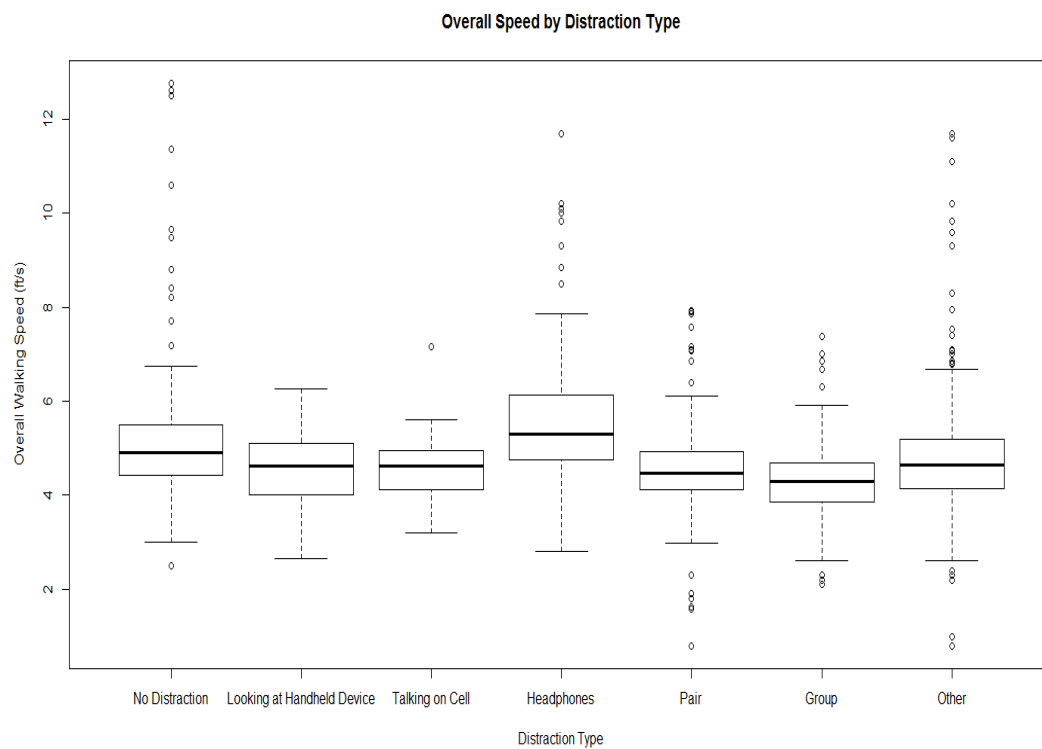
**Figure 12. Island Speed Boxplot for Main Categories.**

From the Figure 12, the average walking speeds for each category approximately 4 to 6 ft/s. The averages of the distraction categories are similar, but the “Headphones” category appears to have the highest walking speed average. From the data, the “Headphones” and “Other” categories both have the highest values for walking speed. The “Other” and “No Distraction” categories both have the lowest values for walking speed.



**Figure 13. Second Lane Speed Boxplot for Main Categories.**

From Figure 13, the average walking speeds for each category are approximately 5 ft/s. From the data, the “Other” category has the highest value for walking speed. The “Pair” category has the lowest value for walking speed.



**Figure 14. Overall Speed Boxplot for Main Categories.**

From Figure 14, the average walking speeds for each category are approximately 4 to 6 ft/s. The averages of the distraction categories are similar, but the “Headphones” category appears to have the highest walking speed average and the “Group” category appears to have the lowest walking speed average. From the data, the “No Distraction” category has the highest value for walking speed. The “Pair” and “Other” categories both have the lowest values for walking speed. It

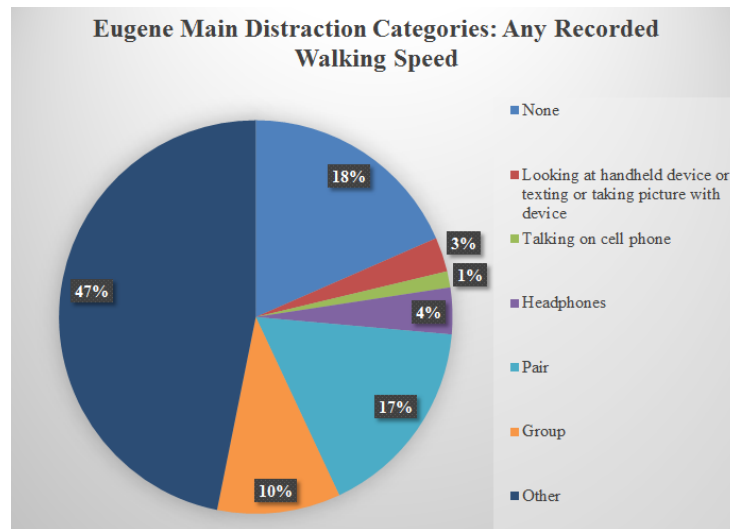


should be noted that of the 1261 observed pedestrians who have walking speeds, only 1045 pedestrians have overall walking speeds.

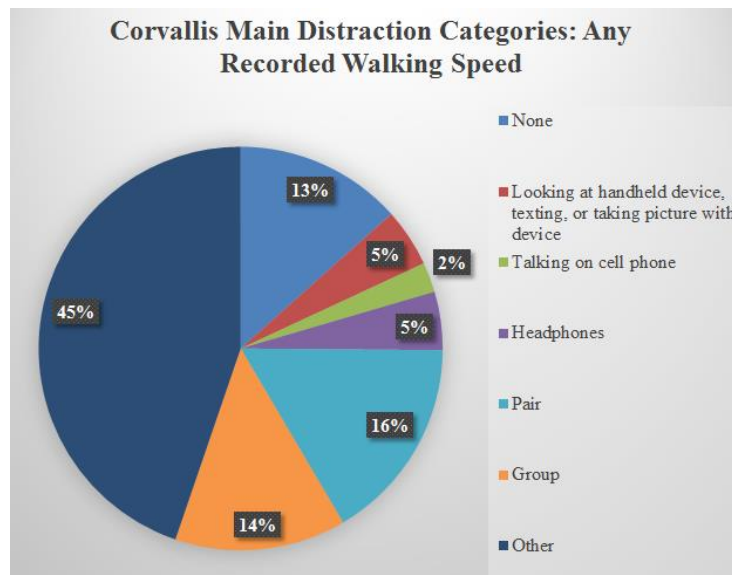
In general, the walking speeds are on average between 4 ft/s and 6 ft/s. There are also outlying points in the data set, with a large spread of values between 0 ft/s and 20 ft/s. This is still within the walking speed categories outlined in previous work (Novacheck, 1998; Vaughan, 1984). Therefore, the analysis' diagnostic tests are expected to remove outlying points from the dataset.

#### **4.1.1 Pedestrian Distraction Proportions**

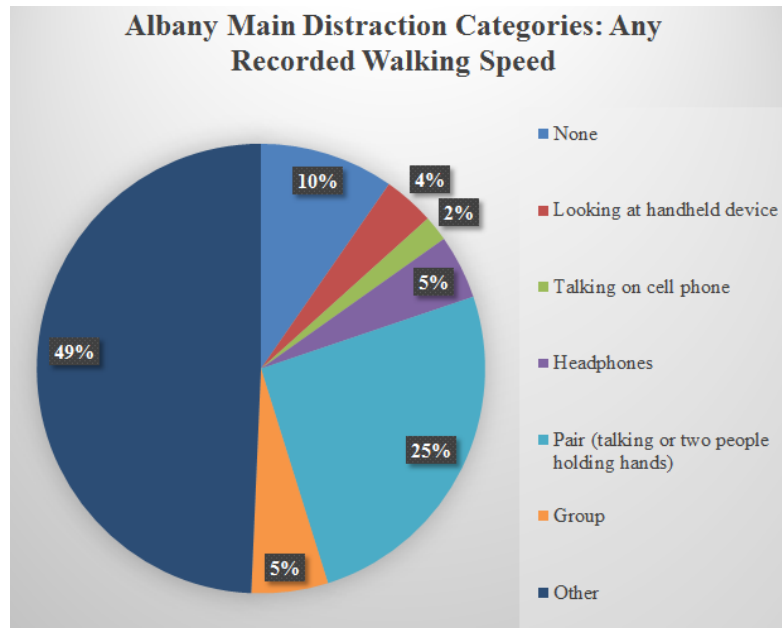
Pie Charts for each city were created in Excel in terms of the distraction proportions for each type of distraction recorded in the field. The pie charts below are for the main categories of distraction, the pie charts for the other types of distractions are in Appendix section 7.4. It was decided to only include the distractions of the pedestrians in which walking speeds were obtained. These proportions are based on the sums of the categories, they do not consider when a pedestrian has multiple distractions.



**Figure 15. Eugene Pie Chart for Main Distraction Categories.**



**Figure 16. Corvallis Pie Chart for Main Distraction Categories.**



**Figure 17. Albany Pie Chart for Main Distraction Categories.**

#### **4.2 Chi Squared Test**

Two Chi tests were conducted, one in which the main distraction proportions were compared, and one in which the distracted and not distracted proportions were compared. The Pair and Group distractions were summed together for the test and the “other” categories of distractions were summed together. As the walking speeds are necessary for the pedestrians being analyzed, the pedestrians who had no walking speeds were eliminated from the Chi Squared Test. Some pedestrians exhibited multiple distractions while walking. When summing up the columns, therefore, the total number of distractions did not equal the total number of pedestrians. In order to account for this, two tests were conducted. The first test

summed up the columns of the distraction categories, regardless of whether the pedestrians had multiple types of distractions.

The proportion test found no evidence ( $p\text{-value} = 0.52$ ) to reject the null hypothesis ( $H_0$ : All three cities have the same true proportions) indicating that the three cities have the same proportions of distracted pedestrians. It should be noted that the  $p$ -values between two cities for all three cases were significantly small (Corvallis and Albany  $p\text{-value} = 0.01$ , Corvallis and Eugene  $p\text{-value} < 0.001$ , and Eugene and Albany  $p\text{-value} = 0.001$ ).

The second test separated the pedestrians who had only one type of distraction from pedestrians who had multiply distractions. This was done by placing the pedestrians with multiple distractions (or a distraction sum greater than 1) in the “other” category. Only pedestrians who showed only that main type of distraction were included in the main type of distraction category. Afterward, the sums of the not distracted pedestrians and the main distraction categories were subtracted from the total number of pedestrians whose walking speeds were recorded.

The proportion test found no evidence ( $p\text{-value} = 0.99$ ) to reject the null hypothesis ( $H_0$ : All three cities have the same true proportions) indicating that the three cities have the same proportions of distracted pedestrians. It should be noted that the  $p$ -values between two cities for all three cases were significantly small

(Corvallis and Albany p-value  $< 0.001$ , Corvallis and Eugene p-value  $< 0.001$ , and Eugene and Albany p-value  $< 0.001$ ).

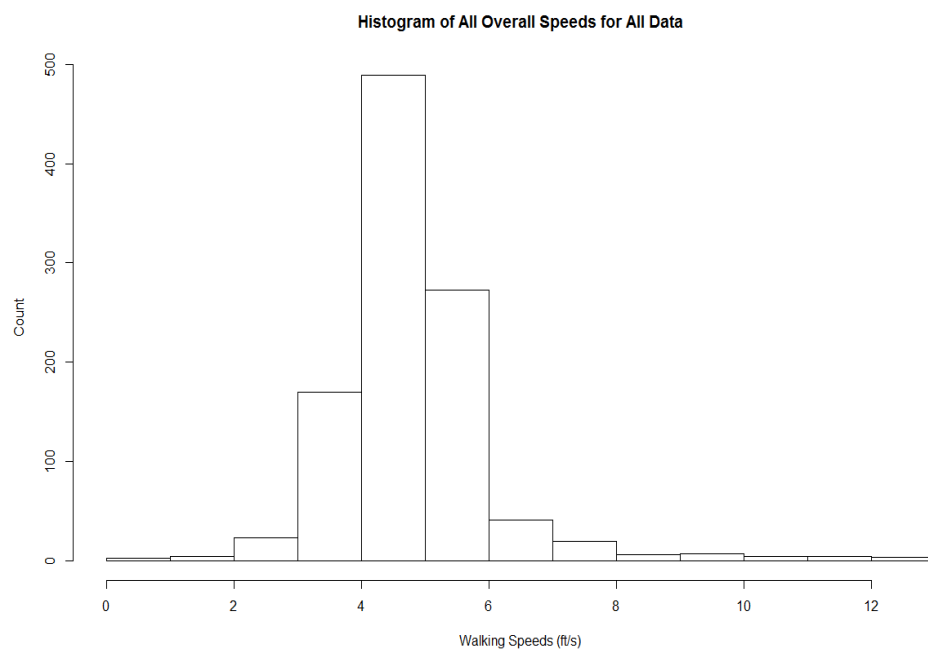
Chi-squared tests were also conducted between distracted pedestrians and not distracted pedestrians. The results of the first test (in which the columns were summed up) determined that the overall p-value was 0.002. The p-values for comparison between two cities (Corvallis and Albany p-value = 0.137, Corvallis and Eugene p-value = 0.007, and Eugene and Albany p-value = 0.003), were inconclusive as two were significantly small and one was large enough to be insignificant. The second test (in which the pedestrian population was accounted for) the overall p-value was 0.004. The p-values for comparison between two cities (Corvallis and Albany p-value = 0.142, Corvallis and Eugene p-value = 0.012, and Eugene and Albany p-value = 0.004), were also inconclusive with two being significantly small and one being insignificantly large.

The results show that the comparison of the distracted conditions between the three cities for both tests indicates that the cities have similar distraction proportions, but the comparison between the distracted and non-distracted pedestrians indicate that there is significant evidence that at least one city has a different proportion. Based on this result, it was determined that further analysis will be needed. Equal Sum of Squares F-tests were conducted on the multivariate

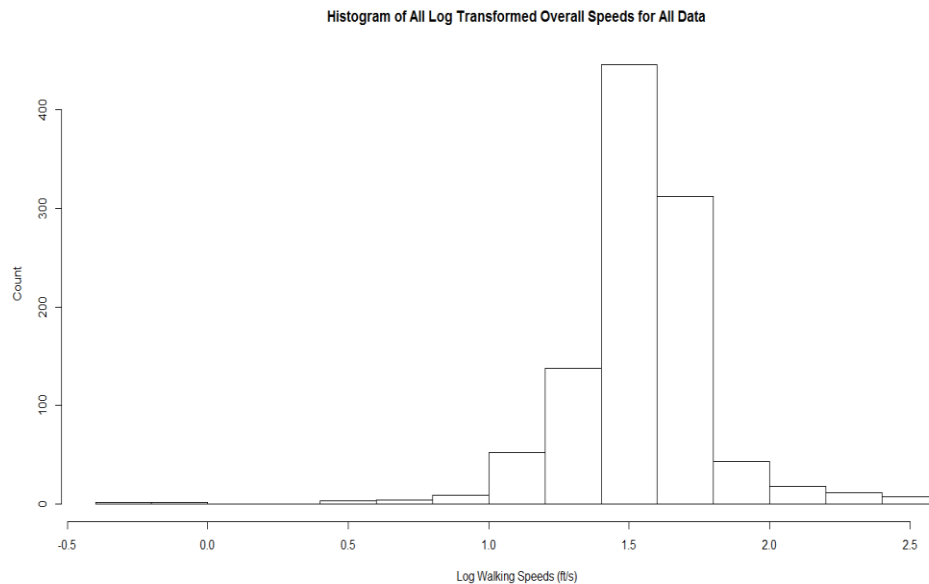
linear regression model in order to determine if the cities should be included in the models.

### 4.3 Normality

As the overall model is what the analysis will consider, only the normality of the histogram for the overall speed was considered.



**Figure 18. Overall Speed Histogram for Raw Data.**



**Figure 19. Overall Speed Histogram for Log Transformed Data.**

In comparing the histograms for the overall speed model, the right tail end of the non-log transformed histogram looks slightly more skewed when compared to the log transformed histogram. The right skewness of the non-log transformed histogram is likely due to the outlying values in the data obtained. Based on this result, it was determined that the analysis will use the log transformed model.

#### **4.4 Full Linear Regression Model**

The literature review revealed several key influences on pedestrian distraction and pedestrian walking speeds. Age, gender, adjacent land use, and the geometry of the crossing may affect the pedestrians walking speed. Based on the data collected several other variables were included as well. The full model, shown below,

includes all on the variables that were considered in the analysis. Many other types of distractions and other types of descriptive variables were identified in the data collection. However, having too many variables in the model risks overfitting the data. Overfitting the data causes outliers to be explained by complex and meaningless structural relationships (Ramsey & Schafer, 2013). Therefore, the model was simplified by combining all of the other types of distractions into one category and removing descriptive variables that were determined as unnecessary for the analysis. It should be noted that the variables (or indicator variables) are factors, and therefore are not log transformed (Ramsey & Schafer, 2013). The only value that is log transformed is the walking speed which is considered the output variable.

The full model for the overall speed before analysis, therefore, is:

Equation (2):

$$\mu(\text{Log}(\text{overall speed})) = \beta_0 + \beta_1 * \text{City} + \beta_2 * \text{geometriclayout} + \beta_3 * \text{crossingtype} + \beta_4 * \text{adjacent}_{\text{landuse}} + \beta_5 * \text{pedbutton}_{\text{use}} + \beta_6 * \text{onstreet}_{\text{parking}} + \beta_7 * \text{gender} + \beta_8 * \text{child}_{\text{yorn}} + \beta_9 * \text{glancebefore} + \beta_{10} * \text{glanceduring} + \beta_{11} * \text{no}_{\text{distraction}} + \beta_{12} * \text{looking}_{\text{at handheld device}} + \beta_{13} * \text{talking}_{\text{on cell}} + \beta_{14} * \text{headphones} + \beta_{15} * \text{pair} + \beta_{16} * \text{group} + \beta_{17} * \text{other} + \beta_{18} * \text{distractionsum} + \beta_{19} * \text{jaywalking}$$

The variables in the full model are defined as follows:

*City*: For the cities, defined as being 1 for Albany, 2 for Corvallis, and 3 for Eugene.



*geometriclayout*: Combination of the number of through lanes per direction, extra lanes (such as a bus or turning lane) apart from the through lanes, the number of bike lanes, and the number of islands. The type of layout for each number for this variable is shown in Appendix 7.3.

*crossingtype*: For the different types of crossings, defined as being 1 for painted crossings, 2 for striped or zebra crossings, 3 for outlined crossings, and 4 for unmarked crossings.

*adjacent\_landuse*: For the different types of adjacent land uses, defined as being 1 for a city center or business area, 2 for a residential area, and 3 for a college area.

*onstreet\_parking*: This variable is 1 for if there are parked cars on the street near the crossing area. This variable was kept as it may have an influence on the number of jaywalkers as pedestrians walk to their cars.

*pedbutton\_use*: For signalized crossings, if there is no signalization the variable has a value of “N/A”, and if there is signalization, then the variable has a value of either 1 (if the pedestrian used the signal), or a value of 0 (if the pedestrian did not use the signal). Cases in which the pedestrian only used the signal partially, such as not pushing the button until reaching the island, are still counted as 1.

*gender*: For gender, this is 1 if the pedestrian is a male, and 2 if they are female.

*glancebefore*: For glance patterns before crossing, if pedestrian only glanced in one direction (left or right) has a value of 1, has a value of 2 if glance in both directions, and a value of 0 if they did not glance.

*glanceduring*: For glance patterns during crossing, if pedestrian only glanced in one direction (left or right) has a value of 1, has a value of 2 if glance in both directions, and a value of 0 if they did not glance.

*jaywalking*: This variable accounted for all of the jaywalking activity, or when a pedestrian is outside of the crossing area at any time while crossing the street, regardless of the distance that the pedestrian jaywalked. If the pedestrian jaywalked then the value is 1, if not the value is 0, and if the pedestrian was blocked from view while entering or exiting the crossing then it was given a value of “N/A” as it could not be determined.

*child\_yorn*: If the pedestrian is a child (a small child around 12 years or younger) this has a value of 1, if they are an adult it is 0.

*distractions**sum*: This variable included the total number of distractions that the pedestrian exhibited. If the pedestrian had no distractions this value was 0. If the pedestrian was distracted, then the value is equal to the total sum of the number of distractions.

*other*: This variable is for all of the distractions observed that are not among the main types of distractions.

*no\_distraction*: If the pedestrian is not distracted the value is 1, and if the pedestrian is distracted then the value is 0.

*looking\_at\_handheld\_device*: This variable is for if a pedestrian was observed looking at a handheld device while crossing, such as a cell phone. Pedestrians who were observed as texting were also included in this variable.

*talking\_on\_cell*: This variable is for if the pedestrian was observed talking on their cell phone while crossing.

*headphones:* This variable is for if the pedestrian was observed wearing headphones while crossing.

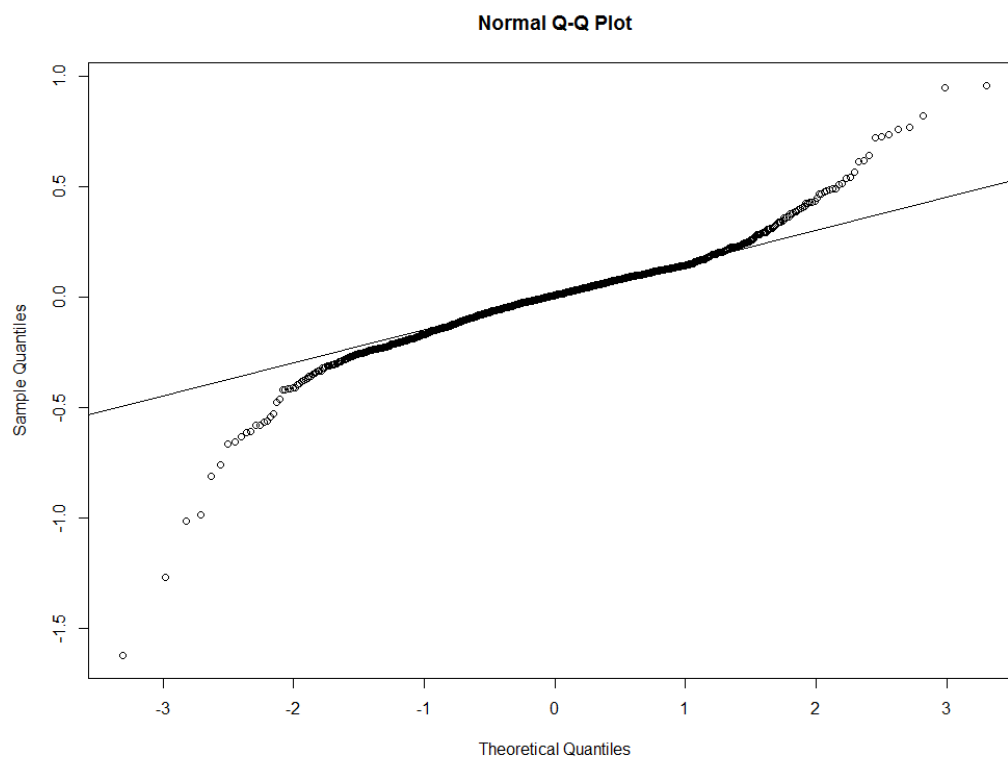
*pair:* This variable is for if the pedestrian was walking and either talking to or glancing at one other person while crossing the street. Some of the pedestrians in the videos were too far from the observer to determine if they were talking, so head movements or general proximity to the other pedestrian (such as walking together) were used in such cases.

*group:* This variable is for if the pedestrian was walking and either talking to or glancing at more than one other person while crossing the street.

For all variables analyzed, if a value could not be determined, than a value of “N/A” or Not Available was recorded.

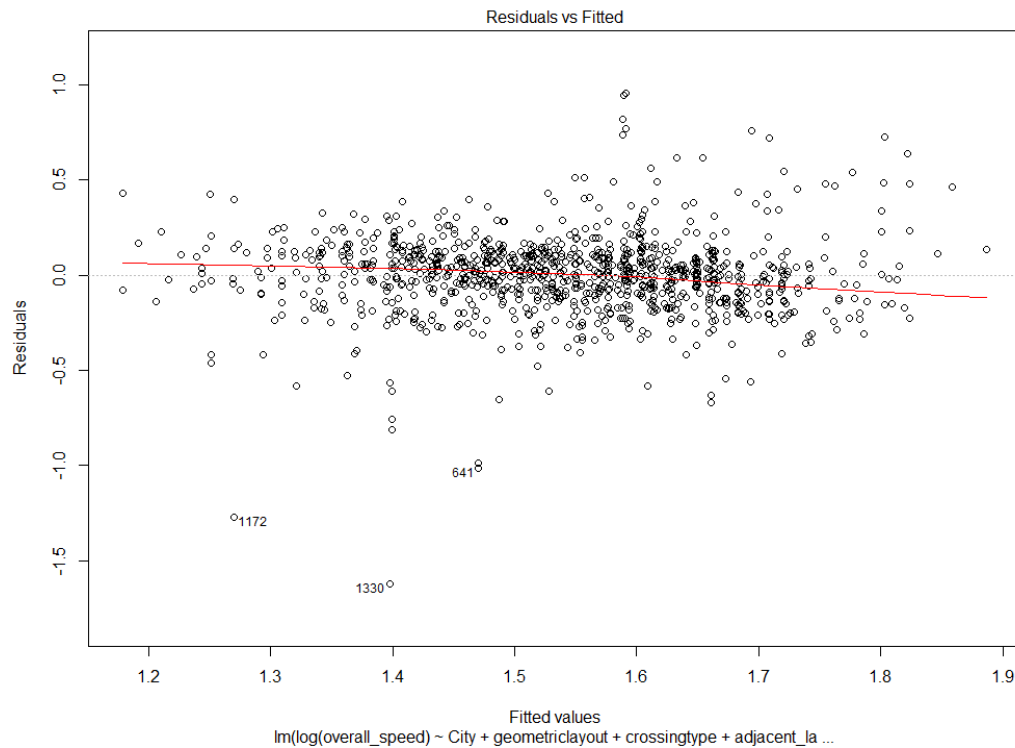
#### **4.4.1 Model Diagnostic Tests**

The following four plots are for the full model for all of the “overall” walking speeds collected in the field.



**Figure 20. Normal Q-Q Plot for Full Model.**

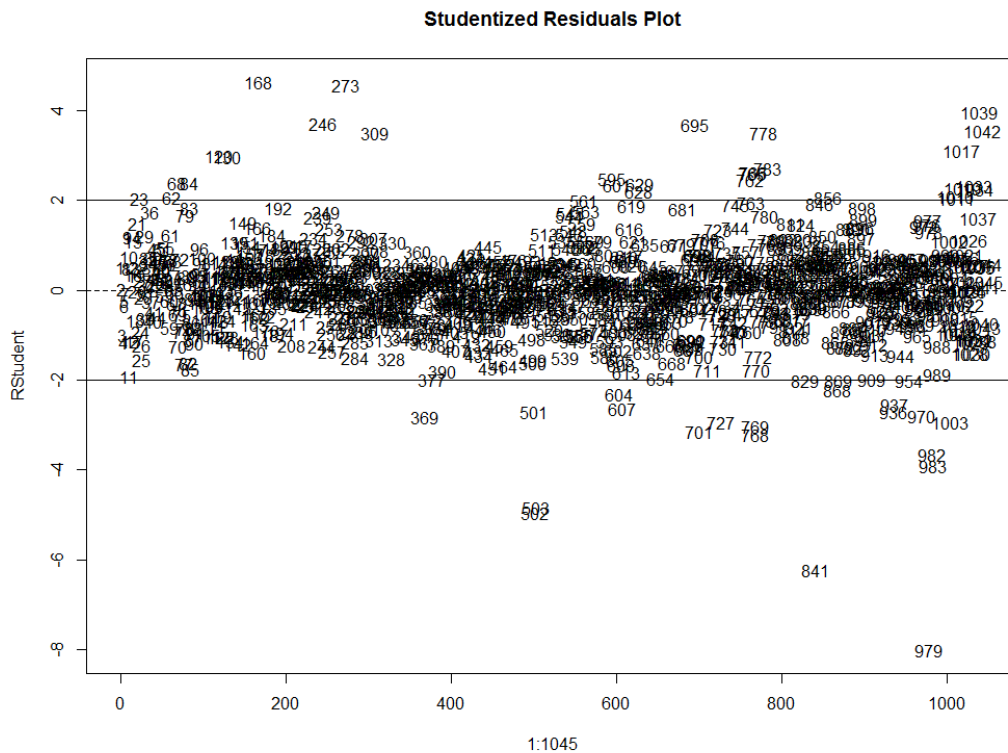
The Q-Q plot shows that the data is generally along the straight line, with a few outlying points at the tail ends.



**Figure 21. Residuals vs Fitted Values Plot for Full Model.**

The residuals versus fitted graph of the entire raw data shows that the line of the residuals versus fitted values is generally straight and close to the zero line, though the line does have a downward trend. There are apparently several outliers in the dataset, likely due to the method of data transcription. Therefore, the outlying values need to be analyzed using case-influence statistics in order to determine if they should be removed from the dataset. The Studentized Residual

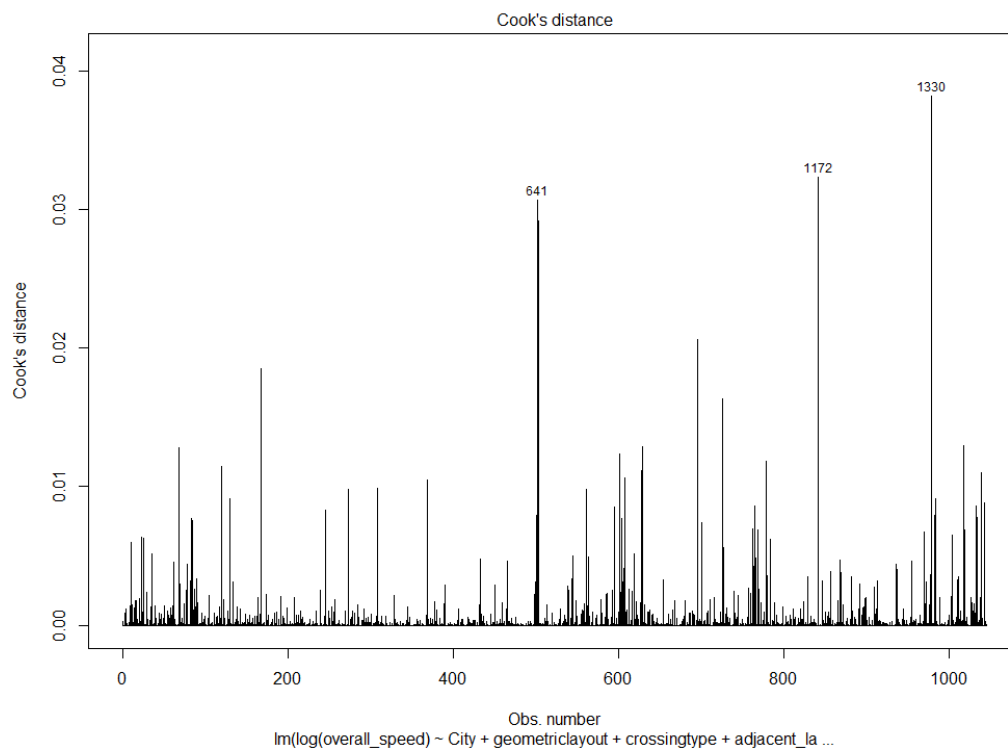
plot is a residual divided by its estimated standard deviation in order to determine if there are points that have high levels of variation (Ramsey & Schafer, 2013).



**Figure 22. Studentized Residuals Plot for Full Model.**

The Studentized Residual plot shows that the majority of the data is within the 2 and -2 lines, or two standard deviations. According to Ramsey and Schafer, roughly 95% of the data should be within two standard deviations, with approximately 5% outside of the lines (Ramsey & Schafer, 2013). Of the 1045 points, the majority of the points are within the 2 standard deviations range. There

does appear to be outlying points, with point 979 in particular being far from the rest of the dataset. However, it is difficult to determine from this graph alone if the outliers should be removed. Therefore, Cook's Distance is required to further analyze the data. Cook's Distance is a measure that examines the overall influence that the individual points have on the entire data set (Ramsey & Schafer, 2013).



**Figure 23. Cook's Distance for Full Model.**

As can be seen by the Cook's Distance plot of the entire raw data, there are several points that are far from the general set of data. However, none of these points are past the Cook's distance value of 1, which is the general rule of thumb for determining if a point is influential (Ramsey & Schafer, 2013). The highest value appears to be approximately 0.04 for point 1330, which is far below the value of 1. Therefore, none of the outlying values has an overall influence on the data. Based on the results of the Studentized Residuals Plot and Cook's Distance, it was determined that none of the data points need to be removed.

The variance inflation factor (VIF) was used to test the multicollinearity of the model. VIF values of five or greater are considered a sign of multicollinearity (Marnell, 2013). After using the `vif()` function from the `car` package in RStudio, the "distractionsum" variable was removed from the model for having a GVIF value of 7.96, far above the value of 5. GVIF, or the Generalized Variance Inflation Factor, is interpreted similarly to the VIF (Statistical Consulting Group San Diego University). After removing the distractionsum variable, the GVIF values of the remaining variables were less than 5. The GVIF values for the new full model are:



**Table 3. Variance Inflation Factors for Full Model.**

<b>Variable</b>	<b>GVIF</b>
City	1.954
geometriclayout	1.189
crossingtype	1.667
adjacent_landuse	2.979
pedbutton_use	2.623
glancebefore	1.067
glanceduring	1.117
gender	1.044
child_yorn	1.174
onstreet_parking	4.623
no_distraction	2.462
looking_at_handheld_device	1.078
talking_on_cell	1.080
headphones	1.278
pair	1.498
group	1.298
other	1.935
jaywalking	1.164

#### 4.4.2 Diagnostic Summary

The diagnostic summary has confirmed that the data has outlying points. The Residuals versus Fitted graph and the Studentized Residuals plot highlighted the possibility of influential points, but the Cook's Distance plot determined that the points are not influential enough to be removed from the dataset. The VIF test determined that the distractionsum variable should be removed from the full model, resulting in the final full model of:

Equation (3):

$$\begin{aligned} \mu(\text{Log}(\text{overall speed})) = & \beta_0 + \beta_1 * \text{City} + \beta_2 * \text{geometriclayout} + \beta_3 * \\ & \text{crossingtype} + \beta_4 * \text{adjacent}_{\text{landuse}} + \beta_5 * \text{pedbutton}_{\text{use}} + \beta_6 * \\ & \text{onstreet}_{\text{parking}} + \beta_7 * \text{gender} + \beta_8 * \text{child}_{\text{yorn}} + \beta_9 * \text{glancebefore} + \beta_{10} * \\ & \text{glanceduring} + \beta_{11} * \text{no}_{\text{distraction}} + \beta_{12} * \text{looking}_{\text{athandheld}_{\text{device}}} + \beta_{13} * \\ & \text{talking}_{\text{oncell}} + \beta_{14} * \text{headphones} + \beta_{15} * \text{pair} + \beta_{16} * \text{group} + \beta_{17} * \text{other} + \\ & \beta_{19} * \text{jaywalking} \end{aligned}$$

#### 4.4.3 Extra Sum of Squared Tests for Model Comparisons

The following sections highlight several reduced models obtained by removing one or more of the variables at a time. These reduced models were compared to the full model obtained from the diagnostic tests in order to determine which variables are necessary for understanding a pedestrian's overall walking speed. The table below summarizes the results of each F-test.

**Table 4. Extra Sum of Squares Tests Results.**

<b>Variable(s) Tested</b>	<b>Null Hypothesis Tested</b>	<b>p-value</b>	<b>Reject Null?</b>
Crossing Type	$\beta_3 = 0$	0	Yes
All Distraction Types	$\beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = \beta_{15} = \beta_{16} = \beta_{17} = 0$	0	Yes
City	$\beta_1 = 0$	0.043	Yes
Adjacent Land Use	$\beta_4 = 0$	0.004	Yes
Geometry of Crossing	$\beta_2 = 0$	0.004	Yes
Pedestrian Push Button	$\beta_5 = 0$	0.219	No
On Street Parking	$\beta_6 = 0$	0	Yes
Jaywalking	$\beta_{19} = 0$	0.001	Yes
Glance Patterns	$\beta_{10} = 0$	0	Yes
	$\beta_9 = 0$	1	No
Gender	$\beta_7 = 0$	0.013	Yes
Child	$\beta_8 = 0$	0.209	No
Distraction: Other	$\beta_{17} = 0$	0.589	No
Distraction: Looking at Handheld Device	$\beta_{12} = 0$	0.001	Yes
Distraction: Talking on Cell	$\beta_{13} = 0$	0.191	No
Distraction: Headphones	$\beta_{14} = 0$	<0.001	Yes
Distraction: Pair	$\beta_{15} = 0$	<0.001	Yes
Distraction: Group	$\beta_{16} = 0$	0	Yes

After obtaining the initial final model from the series of F-tests, it was noted that only 13 variables remained in the model. As the variance inflation factor is not an

issue with the low number of variables, an Extra Sum of Squares F-test was used to verify the results of the VIF test in removing the “distractionsun” variable. This F-test compared the initial final equation to the initial final equation with the “distractionsun” variable included.

**Table 5. Extra Sum of Squares F-Test for Distraction Sum Variable.**

Variable(s) Tested	Null Hypothesis Tested	p-value	Reject Null?
Distraction Sum	$\beta_{18} = 0$	0.103	No

Based on the results of the F-test, the “distractionsun” variable should not be included in the final equation.

#### 4.5 Final Model

From the series of F-tests, the final model was determined to be:

Equation (4):

$$\mu(\text{Log}(\text{overall speed})) = \beta_0 + \beta_1 * \text{City} + \beta_2 * \text{geometriclayout} + \beta_3 * \text{crossingtype} + \beta_4 * \text{adjacent}_{\text{landuse}} + \beta_6 * \text{onstreet}_{\text{parking}} + \beta_7 * \text{gender} + \beta_{10} * \text{glanceduring} + \beta_{11} * \text{no}_{\text{distraction}} + \beta_{12} * \text{looking}_{\text{at handheld device}} + \beta_{14} * \text{headphones} + \beta_{15} * \text{pair} + \beta_{16} * \text{group} + \beta_{19} * \text{jaywalking}$$

In order to compare the final model to the initial full model, the tables of the confidence intervals and the estimate values below were developed using the output from the RStudio commands of `summary()` and `confint()`. The standard errors for the variables were also included for further interpretation. As the model

was log transformed for the analysis, the confidence of the beta coefficients and the confidence intervals were exponentiated ( $e^{\beta}$ ,  $e^{SE}$ ,  $e^{CI}$ ) to be interpreted more accurately. For the initial full model and the final model, the tables are:

**Table 6. Confidence Interval, Estimate, and Standard Error for Logarithmic Full Model (RStudio, 2015).**

Variables	Estimate (log)	Confidence Interval (log)		Standard Error (log)
		2.50%	97.50%	
Intercept	1.443	1.310	1.576	0.068
City	0.028	0.001	0.055	0.014
geometriclayout	0.014	0.005	0.024	0.005
crossingtype	0.079	0.055	0.103	0.012
adjacent_landuse	0.037	0.012	0.062	0.013
pedbutton_use1	-0.018	-0.102	0.067	0.043
pedbutton_useN/A	-0.056	-0.138	0.026	0.042
onstreet_parking	-0.097	-0.153	-0.042	0.028
gender2	-0.035	-0.061	-0.009	0.013
child_yorn1	0.028	-0.034	0.091	0.032
glancebefore	0.000	-0.022	0.021	0.011
glanceduring	-0.059	-0.079	-0.040	0.010
no_distraction	0.046	-0.004	0.096	0.025
looking_at_handheld_device1	-0.026	-0.096	0.045	0.036
talking_on_cell1	0.018	-0.071	0.107	0.045
headphones1	0.204	0.134	0.275	0.036
pair1	-0.002	-0.056	0.052	0.028
group1	-0.055	-0.114	0.004	0.030
other	0.089	0.029	0.148	0.030
distractionsum	-0.066	-0.107	-0.024	0.021
jaywalking1	-0.073	-0.106	-0.040	0.017
jaywalkingN/A	-0.132	-0.547	0.283	0.212

**Table 7. Confidence Interval, Estimate, and Standard Error for Non-Logarithmic Full Model (RStudio, 2015).**

Variables	Estimate	Confidence Interval		Standard Error
		2.50%	97.50%	
Intercept	4.233	3.706	4.836	1.070
City	1.028	1.001	1.057	1.014
geometriclayout	1.014	1.005	1.024	1.005
crossingtype	1.082	1.057	1.108	1.012
adjacent_landuse	1.038	1.012	1.064	1.013
pedbutton_use1	0.982	0.903	1.069	1.044
pedbutton_useN/A	0.946	0.871	1.026	1.043
onstreet_parking	0.908	0.858	0.959	1.028
gender2	0.966	0.941	0.991	1.013
child_yorn1	1.028	0.967	1.095	1.033
glancebefore	1.000	0.978	1.021	1.011
glanceduring	0.943	0.924	0.961	1.010
no_distraction	1.047	0.996	1.101	1.025
looking_at_handheld_device1	0.974	0.908	1.046	1.037
talking_on_cell1	1.018	0.931	1.113	1.046
headphones1	1.226	1.143	1.317	1.037
pair1	0.998	0.946	1.053	1.028
group1	0.946	0.892	1.004	1.030
other	1.093	1.029	1.160	1.030
distractionsum	0.936	0.899	0.976	1.021

jaywalking1	0.930	0.899	0.961	1.017
jaywalkingN/A	0.876	0.579	1.327	1.236

**Table 8. Confidence Interval, Estimate, and Standard Error for Logarithmic Final Model (RStudio, 2015).**

Variables	Estimate (log)	Confidence Interval (log)		Standard Error (log)
		2.50%	97.50%	
Intercept	1.422	1.326	1.518	0.049
City	0.036	0.010	0.061	0.013
geometriclayout	0.014	0.004	0.023	0.005
crossingtype	0.088	0.066	0.110	0.011
adjacent_landuse	0.023	0.003	0.042	0.010
onstreet_parking	-0.134	-0.173	-0.095	0.020
glanceduring	-0.064	-0.084	-0.045	0.010
gender2	-0.034	-0.060	-0.008	0.013
no_distraction	0.039	0.002	0.075	0.019
looking_at_handheld_device1	-0.097	-0.154	-0.040	0.029
headphones1	0.139	0.084	0.194	0.028
pair1	-0.068	-0.100	-0.035	0.017
group1	-0.120	-0.158	-0.081	0.020
jaywalking1	-0.072	-0.104	-0.039	0.017
jaywalkingN/A	-0.128	-0.544	0.287	0.212

**Table 9. Confidence Interval, Estimate, and Standard Error for Non-Logarithmic Final Model (RStudio, 2015).**

Variables	Confidence Interval			Standard Error
	Estimate	2.50%	97.50%	
Intercept	4.145	3.766	4.563	1.050
City	1.037	1.010	1.063	1.013
geometriclayout	1.014	1.004	1.023	1.005
crossingtype	1.092	1.068	1.116	1.011
adjacent_landuse	1.023	1.003	1.043	1.010
onstreet_parking	0.875	0.841	0.909	1.020
glanceduring	0.938	0.919	0.956	1.010
gender2	0.967	0.942	0.992	1.013
no_distraction	1.040	1.002	1.078	1.019
looking_at_handheld_device1	0.908	0.857	0.961	1.029
headphones1	1.149	1.088	1.214	1.028
pair1	0.934	0.905	0.966	1.017
group1	0.887	0.854	0.922	1.020
jaywalking1	0.931	0.901	0.962	1.017
jaywalkingN/A	0.880	0.580	1.332	1.236



## **5. Conclusion**

Pedestrian distraction is a likely contributing factor for pedestrian fatalities at crossing locations. As such it is important to gain a better understanding of pedestrian distraction in order to develop more effective designs of crossing locations. The results of this work increased the general knowledge of pedestrian distraction and its influence on walking speed.

### **5.1 Discussion of Results**

The resulting model from the analysis suggests that the location, the geometric layout and markings of the crossing, the adjacent land use, nearby parking, gender, glance patterns while crossing, jaywalking, and distraction affect a pedestrian's overall walking speed. It is conclusive from the Extra Sum of Squares F-test that distraction does affect pedestrians, however not all of the distraction types were found to be statistically significant. The literature review suggested that while pedestrians are affected by distraction, different types of distractions affect a pedestrian differently (Neider et al., 2010). Therefore, each of the distractions were individually compared using the Extra Sum of Squares F-tests. It was surprising that cell phone use was found to have no effect on overall walking speed, as this has been suggested by previous literature (Neider et al., 2010). This may be due to the low number of cell phone users in the sample (only 30 out of 1045) that were observed. More data is required in order to confirm this

result. The use of headphones was found to increase walking speed ( $\beta$  (the estimate) = 1.149). This may be due to the number of pedestrians observed who wore headphones that were joggers (or 7.4% of headphone users in the data analyzed had speeds equal to or exceeding 9.8 ft/s). Two other types of distractions, looking at a handheld device and walking with one or more other pedestrians, were found to decrease the overall walking speed ( $\beta < 1$ ).

According to the literature review (Cooper et al., 2012), pedestrian demographics were found to be an important factor in terms of pedestrian behavior. This study found that gender had an effect on the overall walking speed ( $\beta = 0.967$  for females), but as this value is close to 1, this factor had a small effect. It was also found that being a child or an adult did not affect overall walking speed. As this variable is subjective to the observation skill of researcher, this result may not be accurate. There was also a small sample of small children in the analysis (5.2% of the 1045 pedestrians were counted as children). More data is desirable to confirm this result.

Pedestrian compliance was considered for the model as it may affect a pedestrian's behavior. It is unsurprising, based on the method of obtaining walking speeds, that jaywalking was found to have an effect on the overall walking speed. It was expected that jaywalking would reduce the speed of the pedestrian due to the method of obtaining the walking speeds, and the results of

the estimate and confidence interval ( $\beta = 0.931$ , 5% CI = [0.901, 0.962]) confirm this. The estimate, or multiplying factor, for cases in which jaywalking occurs is less than 1, meaning that jaywalking reduces a pedestrians overall walking speed.

It was also found that glance patterns while crossing affect a pedestrian's overall walking speed. This is a justified result as pedestrians who are looking for oncoming vehicles are expected to have different behavioral patterns than pedestrians who are not looking at vehicles. Glancing before entering, however, was found to not affect a pedestrian's overall walking speed. It should be noted that the fourth variable used for measuring pedestrian compliance, the use of pedestrian push buttons, did not affect a pedestrian's overall walking speed. This may be due to the low number of pedestrians observed at signalized crossings (200 pedestrians, 84.5% of which used a pedestrian push button).

The remaining variables considered were related to the design and location of the crossing. The inclusion of the City variable in the final model suggests that a pedestrian's overall walking speed in Corvallis differs from a pedestrian's overall walking speed in either Albany or Eugene. This was also suggested by comparing the distracted to the non-distracted pedestrian proportions in the Chi Squared test. Adjacent land use was also found to affect pedestrian walking speed. This result is sensible as pedestrians in the downtown areas will have more factors to pay attention to as opposed to pedestrians in residential areas where there are

fewer vehicles on the roadway. Another variable found to affect overall walking speed was nearby parking. Nearby parking is similar to the adjacent land use variable, as it is associated with the environment adjacent to the crossing area. The geometric layout of the crossing and the type of markings for the crossing were found to affect the pedestrian. This suggests that the design of the crossing can influence a pedestrian's behavior. It was also suggested in the literature that the geometry of the crossing may affect pedestrian behavior. More study will need to be conducted in order to determine what types of designs have more influence on pedestrian behavior.

## **5.2 Limitations and Errors**

From Table 8, the standard errors for the majority of the variables in the final equation are within 3%. However standard error for N/A jaywalking variable was 23.6%. This is most likely due to the fact that the equation was developed for overall walking speed. The standard error values for the full equation before analysis were mostly within 5%, with the exception being the N/A jaywalking variable which had a 23.6% standard error. The intercept in for the final equation had a standard error of 5%, lower than the 7% standard error from the full equation. Therefore, the final model (equation 4) has a lower standard error than the full model (equation 2).

The selection of an observational field study has several inherent limitations. The first limitation was that the actual number of distractions recorded is likely an underestimate. Only distractions that could be detected with a visual cue were identified. Cognitive distractions or line of sight obstructions may have resulted in distractions not having been recorded. For the analysis, only pedestrians who had recorded walking speeds for traversing the entire length of the roadway were included. From the initial number of 1407, the final count of pedestrians used for the analysis was 1045. Another limitation of the study was that not all of the pedestrians walked in a straight line tangent to the edge of the road. This introduces the potential for error in the walking speeds in some instances due to the variation in the distance that the pedestrians actually walked. It should also be noted that not all of the pedestrians walked at a continuous pace while crossing. There were pedestrians who stopped while they crossed the roadway, which reduced their walking speeds.

### **5.3 Future Work**

While this study increases the current knowledge regarding what factors influence a pedestrian's walking speed, future studies will need to be conducted to further the results from this research. There are several important future studies that should be conducted. The most important required future work would be to obtain more information at midblock crossings. It is important to gather more pedestrian

data for the different types of crossings in order to verify the resulting equation. There were several variables in which more data is required in order to justify the results, such cell phone. Another important step for future research would be to develop an automated technique for measuring pedestrian walking speeds. It is difficult, if not impossible, to determine age and gender from a field study in which the pedestrians were not questioned. Acquiring more demographic information would increase the accuracy of the research; therefore a more detailed demographic survey of the pedestrians is needed for future work. It was also noted in the field that there were many bicyclists that used the midblock crossings studied. A possible follow-up study would be to consider the interaction between bicyclists and pedestrians in midblock crossings.

## 6. Bibliography

Brewer, M.A., Fitzpatrick, K., & Avelar, R. (2014). Pedestrian and Driver Behavior Before and After Installation of Rectangular Rapid Flashing Beacons or Pedestrian Hybrid Beacons. TRB 2015 Annual Meeting, 1-18.

Bungum, T.J., Day, C., & Henry, L.J. (2005). The Association of Distraction and Caution Displayed by Pedestrians at a Lighted Crosswalk. *Journal of Community Health*, 30(4), 269-279.

Byington, K.W., & Schwebel, D.C. (2013). Effects of mobile Internet use on college student pedestrian injury risk. *Accident Analysis and Prevention*, 51, 78-83.

City of Albany (2015). Albany, CA Municipal Code & Charter. Available at: <http://www.albanyca.org/index.aspx?page=79>. Accessed January 29, 2015.

City of Corvallis, Oregon (2015). Municipal Code and Ordinances. Available at: <http://www.corvallisoregon.gov/index.aspx?page=428>. Accessed January 29, 2015.

Coffin, A., & Morrall, J. (1995). Walking Speeds of Elderly Pedestrians at Crosswalks. *Transportation Research Record*, (1487), 63-67.

Cooper, J.F., Schneider, R.J., Ryan, S., & Co, S. (2012). Documenting Targeted Behaviors Associated with Pedestrian Safety. *Transportation Research Record*, 2299, 1-10.

Eugene (2015). City of Eugene Code Information. Available at: <http://www.eugene-or.gov/codeinfo>. Accessed January 29, 2015.

Fuentes, C. (2014). ST 415/515 – Methods of Data Analysis II Two-Way Analysis of Variance, 1-15. Available at: [https://my.oregonstate.edu/webapps/portal/frameset.jsp?tab\\_tab\\_group\\_id=\\_2\\_1&url=%2Fwebapps%2Fblackboard%2Fexecute%2Flauncher%3Ftype%3DCourse%26id%3D378728%26url%3D%3E](https://my.oregonstate.edu/webapps/portal/frameset.jsp?tab_tab_group_id=_2_1&url=%2Fwebapps%2Fblackboard%2Fexecute%2Flauncher%3Ftype%3DCourse%26id%3D378728%26url%3D%3E). Accessed June 1, 2014.

Granié, M.A., Brenac, T., Montel, M.C., Millot, M., & Coquelet, C. (2014). Influence of built environment on pedestrian's crossing decision. *Accident Analysis and Prevention*, 67, 75-85.

Hatfield, J., & Murphy, S. (2007). The effects of mobile phone use on pedestrian crossing behaviour at signalised and unsignalised intersections. *Accident Analysis and Prevention*, 39, 197-205.

Hatfield, J., Ralston Fernandes, R., Job, R.F.S., & Smith, K. (2007). Misunderstanding of right-of-way rules at various pedestrian crossing types: Observational study and survey. *Accident Analysis and Prevention*, 39, 833-842.

Hurwitz, D.S., Heaslip, K.P., Schrock, S.D., Swake, J., Marnell, P., Tuss, H., & Fitzsimmons, E. (2013). Implications of Distracted Driving on Start-Up Lost Time for Dual Left-Turn Lanes. *American Society of Civil Engineering: Journal of Transportation Engineering*, 139, 923-930.

Hyman Jr, I.E., Boss, S.M., Wise, B.M., McKenzie, K.E., & Caggiano, J.M. (2010). Did You See the Unicycling Clown? Inattention Blindness while Walking and Talking on a Cell Phone. *Applied Cognitive Psychology*, 24, 597-607.

Kar, K., & Gajula, S. (2008). Focusing on Pedestrian Safety. U.S. Department of Transportation Federal Highway Administration, 71(6). Available at: <https://www.fhwa.dot.gov/publications/publicroads/08may/04.cfm>. Accessed January 18, 2015.

Lamberg, E.M., & Muratori, L.M. (2012). Cell phones change the way we walk. *Gait and Posture*, 35, 688-690.

Madden, M., & Rainie, L. (2010). Adults and Cell Phone Distractions. Pew Internet & American Life Project, 1-12.

Mann, R.A., & Hagy, J. (1980). Biomechanics of walking, running, and sprinting. *The American Journal of Sports Medicine*, 8(5), 345-350.

Marnell, P.S. (2013). Implications of Distracted Driving on Driver Behavior in the Standing Queue of Dual Left-Turn Lanes: An Empirical Study, 1-79.



Murray, M.P., Guten, G.N., Mollinger, L.A., & Gardner, G.M. (1983). Kinematic and electromyographic patterns of Olympic race walkers. *American Journal of Sports Medicine*, 11(2), 68-74.

Murray, S.J., Chen, Z., & Owen, D.H. (2006). The Effects of Simulated Cellular Phone Conversation on Road-Crossing Safety. University of Canterbury, 1-223.

Nasar, J., Hecht, P., & Wener, R. (2008). Mobile telephones, distracted attention, and pedestrian safety. *Accident Analysis and Prevention*, 40, 69-75.

Nasar, J.L., & Troyer, D. (2013). Pedestrian injuries due to mobile phone use in public places. *Accident Analysis and Prevention*, 57, 91-95.

National Highway Traffic Safety Administration (NHTSA) (2010). Overview of the National Highway Traffic Safety Administration's Driver Distraction Program. DOT-HS-811-299.

Neider, M.B., Gaspar, J.G., McCarley, J.S., Crowell, J.A., Kaczmariski, H., & Kramer, A.F. (2011). Walking and Talking: Dual-Task Effects on Street Crossing Behavior in Older Adults. *Psychology and Aging*, 26(2), 260-268.

Neider, M.B., McCarley, J.S., Crowell, J.A., Kaczmariski, H., & Kramer, A.F. (2010). Pedestrians, vehicles, and cell phones. *Accident Analysis and Prevention*, 42, 589-594.

Novacheck, T.F (1998). Review Paper: The biomechanics of running. *Gait and Posture*, 7, 77-95.

Portland State University. (2015). Annual Oregon Population Report. Available at: <<http://www.pdx.edu/prc/annual-oregon-population-report>>. Accessed 3 March, 2015.

Ramsey, F.L., & Schafer, D.W. (2013). *The Statistical Sleuth*, 3<sup>rd</sup> ed., Brooks/Cole Cengage Learning, Boston, MA.

Regan, M.A., Lee, J.D., & Young, K.L. (2009). *Driver Distraction: Theory, Effects, and Mitigation*. Taylor & Francis Group, LLC, Boca Raton.

Safe Kids Worldwide (2013). Teens and Distraction: An In-Depth Look at Teens' Walking Behaviors. 1-15.

Schabrun, S.M., van den Hoorn, W., Moorcroft, A., Greenland, C., & Hodges, P.W. (2014). Texting and Walking: Strategies for Postural Control and Implications for Safety. *PLOS ONE*, 9(1), 1-8.

Schwebel, D.C., Stavrinos, D., Byington, K.W., Davis, T., O'Neal, E.E., & de Jong, D. (2012). Distraction and pedestrian safety: How talking on the phone, texting, and listening to music impact crossing the street. *Accident Analysis and Prevention*, 45, 266-271.

Schwebel, D.C., Stavrinos, D., & Kongable, E.M. (2009). Attentional control, high intensity pleasure, and risky pedestrian behavior in college students. *Accident Analysis and Prevention*, 41, 658-661.

Smith, D.C., Schreiber, K.M., Saltos, A., Lichenstein, S.B., & Lichenstein, R. (2013). Ambulatory cell phone injuries in the United States: An emerging national concern. *Journal of Safety Research*, 47, 19-23.

Social Science Statistics (2014). Chi-Square Calculator. Available at: <<http://www.socscistatistics.com/tests/chisquare2/Default2.aspx>>. Accessed February 22, 2015.

Statistical Consulting Group San Diego University. Logistic Regression (R). Available at: <[http://scg.sdsu.edu/logit\\_r/](http://scg.sdsu.edu/logit_r/)>. Accessed March 1, 2015.

Stavrinos, D., Byington, K.W., & Schwebel, D.C. (2011). Distracted walking: Cell phones increase injury risk for college pedestrians. *Journal of Safety Research*, 42, 101-107.

Stavrinos, D., Byington, K.W., & Schwebel, D.C. (2009). Effect of Cell Phone Distraction on Pediatric Pedestrian Injury Risk. *PEDIATRICS*, 123(2), 179-185.

Thomas, R (2008). Oregon Pedestrian Rights: A Legal Guide for Persons on Foot. 1-147. Available at: [http://www.stc-law.com/pdf/OPRlegal\\_guide.pdf](http://www.stc-law.com/pdf/OPRlegal_guide.pdf). Accessed January 29, 2015.

- Thompson, L.L., Rivara, F.P., Ayyagari, R.C., & Ebel, B.E. (2013). Impact of social and technological distraction on pedestrian crossing behaviour: an observational study. *Injury Prevention*, 19, 232-237.
- U.S. Department of Transportation Federal Highway Administration (USDOT FHWA) (2014). *Bicycle & Pedestrian: Designing Sidewalks and Trails for Access*. Available at: [http://www.fhwa.dot.gov/environment/bicycle\\_pedestrian/publications/sidewalk2/sidewalks208.cfm](http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/sidewalks208.cfm). Accessed January 18, 2015.
- U.S. Department of Transportation Federal Highway Administration (2014). *Safety: Chapter 2. Driver, Vehicle, and Roadway Characteristics Related to Driving in Wet Weather*. (15 October 2014). Available at: [http://safety.fhwa.dot.gov/speedmgt/ref\\_mats/fhwasa12022/chap\\_2.cfm](http://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12022/chap_2.cfm). Accessed January 18, 2015.
- U.S. Department of Transportation Federal Highway Administration (2014). *Safety: Intersection Safety*. Available at: <http://safety.fhwa.dot.gov/intersection/>. Accessed January 18, 2015.
- U.S. Department of Transportation National Highway Traffic Safety Administration (2012). *Traffic Safety Facts 2010 Data: Pedestrians*. Available at: <http://www-nrd.nhtsa.dot.gov/Pubs/811625.pdf>. Accessed March 5, 2015.
- U.S. Department of Transportation National Highway Traffic Safety Administration (2008). *National Pedestrian Crash Report*. Available at: <http://www-nrd.nhtsa.dot.gov/Pubs/810968.pdf>. Accessed March 5, 2015.
- Vaughan, C.L. (1984). Biomechanics of running gait. *Critical Reviews in Biomedical Engineering*, 12(1), 1-48.
- Walker, E.J., Lanthier, S.N., Risko, E.F., & Kingstone, A. (2012). The effects of personal music devices on pedestrian behaviour. *Safety Science*, 50, 123-128.
- Zeedyk, M.S., Wallace, L., & Spry, L. (2002). Stop, look, listen, and think? What young children really do when crossing the road. *Accident Analysis and Prevention*, 34, 43-50.
- Zhuang, X., & Wu, C. (2011). Pedestrians' crossing behaviors and safety at unmarked roadway in China. *Accident Analysis and Prevention*, 43, 1927-1936.

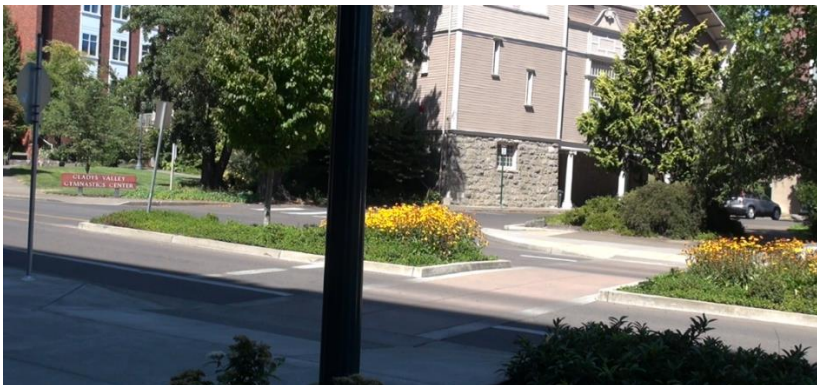
## 7. Appendices

### 7.1 Location Images

#### 7.1.1 Corvallis



**Figure 24. Crossing North of SW 14<sup>th</sup> St & SW Jefferson Way (Windows Media Player, 2015).**



**Figure 25. Crossing West of SW 15<sup>th</sup> St & SW Jefferson Way (Windows Media Player, 2015).**



**Figure 26. Crossing North of SW 30<sup>th</sup> St & SW Jefferson Way (Windows Media Player, 2015).**



**Figure 27. Crossing North of SW 35<sup>th</sup> St & SW Knollbrook Ave (Windows Media Player, 2015).**



**Figure 28. Crossing South of NW 9<sup>th</sup> St & NW Spruce Ave (Windows Media Player, 2015).**



**Figure 29. Crossing South of SW 3<sup>rd</sup> St & SE Mayberry Ave (Windows Media Player, 2015).**



**Figure 30. Crossing South of SW 3<sup>rd</sup> St & SW Tunison Ave (Windows Media Player, 2015).**



**Figure 31. Crossing West of SW Birdsong Dr & SW Hollyhock Cir (Windows Media Player, 2015).**





**Figure 32. Crossing East of SW Country Club Dr & SW 47<sup>th</sup> Pl (Windows Media Player, 2015).**



**Figure 33. Crossing South of NE Circle Blvd & NE Walnut Blvd (Google Maps, 2015).**

### 7.1.2 Albany



**Figure 34. Crossing East of Meadow Pl SE & 21st Ave SE (Windows Media Player, 2015).**



**Figure 35. Crossing East of SW 3<sup>rd</sup> Ave & SE Lyon St (Windows Media Player, 2015).**





**Figure 36. Crossing North of Brookside Ave SE & Waverly Dr SE (Windows Media Player, 2015).**



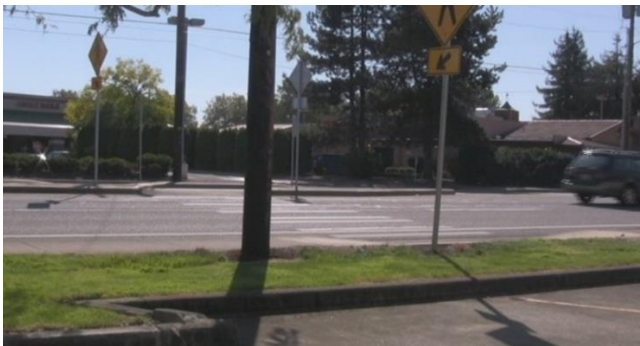
**Figure 37. Crossing South of 12<sup>th</sup> Ave SE & SE Geary St (Windows Media Player, 2015).**



**Figure 38. Crossing South of SE 11<sup>th</sup> Ave & Oak St SE (Windows Media Player, 2015).**



**Figure 39. Crossing West of SE 31<sup>st</sup> Ave & Pine St SE (Windows Media Player, 2015).**



**Figure 40. Crossing West of Santiam Hwy SE & Bain St SE (Windows Media Player, 2015).**



**Figure 41. Crossing West of Santiam Hwy SE & Bain St SE (Google Maps, 2015).**



**Figure 42. Crossing North of Price Rd SE & Blue Ox Dr SE (Google Maps, 2015).**



**Figure 43. Crossing East of Lawnridge St SW & SW 12<sup>th</sup> Ave (Windows Media Player, 2015).**

### 7.1.3 Eugene



**Figure 44. Crossing South of W 11<sup>th</sup> Ave & City View St (Windows Media Player, 2015).**



**Figure 45. Crossing North of W 14<sup>th</sup> Ave & City View St (Windows Media Player, 2015).**



**Figure 46. Crossing East of Willamette St & E Broadway (Windows Media Player, 2015).**





**Figure 47. Crossing West of Willamette St & W Broadway (Windows Media Player, 2015).**



**Figure 48. Crossing North of River Rd & Hamilton Ave (Windows Media Player, 2015).**



**Figure 49. Crossing West of Silver Ln & River Rd (Windows Media Player, 2015).**



**Figure 50. Crossing West of Harlow Rd & Sweet Gum Ln (Windows Media Player, 2015).**



**Figure 51. Crossing North of River Rd & Knoop Ln (Windows Media Player, 2015).**



**Figure 52. Crossing South of River Rd & Owosso Dr (Google Maps, 2015).**

## 7.2 Tables of Field Data Collected

The total video footage collected was approximately 95 hours. The table below summarizes the total number of observed pedestrian counts collected at each site in which data was collected.

**Table 10. Total Pedestrian Counts per Crosswalk Site with and without Walking Speeds (2014).**

City, State	Midblock Crossing	Distracted Pedestrians	Undistracted Pedestrians
Corvallis, Oregon	West of SW Jefferson Way and SW 15 <sup>th</sup> St	150	34
	North of SW Jefferson Way and SW 14 <sup>th</sup> St	85	38
	North of SW Jefferson Way and SW 30 <sup>th</sup> St	140	23
	West of SW Hollyhock Cir and SW Birdsong Dr	5	0
	South of SW 3 <sup>rd</sup> St and SE Mayberry Ave	46	5
	South of SW 3 <sup>rd</sup> Ave and SW Tunison Ave	41	9
	North of SW 35 <sup>th</sup> St and SW Knollbrook Ave	47	5
	South of NW Spruce Ave and NW 9 <sup>th</sup> St	39	16
	East of SW Country Club Dr and SW 47 <sup>th</sup> Pl	8	1
Albany, Oregon	East of SW 3 <sup>rd</sup> Ave and SE Lyon St	57	6
	South of 12 <sup>th</sup> Ave SE and SE Geary St	34	4

Eugene, Oregon	South of SE 11 <sup>th</sup> Ave and Oak St SE	6	2
	East of Meadow Pl SE and 21 <sup>st</sup> Ave SE	31	5
	West of SE 31 <sup>st</sup> Ave and SE Pine St	2	1
	North of Waverly Dr SE and Brookside Ave SE	2	3
	West of Bain St SE and Santiam Hwy SE	10	4
	West of Harlow Rd and Sweet Gum Ln	2	1
	West of River Rd and Silver Ln	144	63
	North of River Rd and Knoop Ln	6	0
	North of City View St and W 14 <sup>th</sup> Ave	19	16
	South of City View St and W 11 <sup>th</sup> Ave	27	12
	North of River Rd and Hamilton Ave	3	0
	West of Willamette St and W Broadway	99	17
	East of Willamette St and E Broadway	109	30
<b>TOTALS:</b>		<b>1112</b>	<b>295</b>



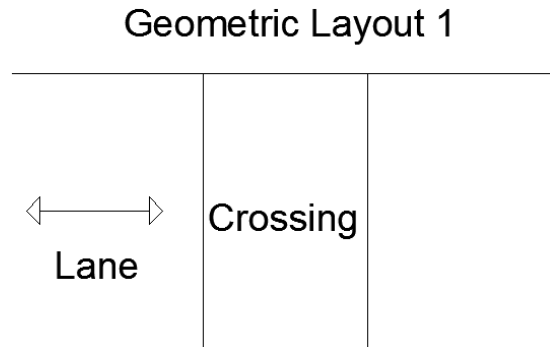
**Table 11. Counts of Pedestrians with Walking Speeds per Crossing.**

City, State	Midblock Crossing	Pedestrian Observations With:	
		Overall Walking Speeds	Any Walking Speeds
Corvallis, Oregon	West of SW Jefferson Way and SW 15 <sup>th</sup> St	115	179
	North of SW Jefferson Way and SW 14 <sup>th</sup> St	120	120
	North of SW Jefferson Way and SW 30 <sup>th</sup> St	124	155
	West of SW Hollyhock Cir and SW Birdsong Dr	5	5
	South of SW 3 <sup>rd</sup> St and SE Mayberry Ave	30	51
	South of SW 3 <sup>rd</sup> Ave and SW Tunison Ave	45	50
	North of SW 35 <sup>th</sup> St and SW Knollbrook Ave	51	51
	South of NW Spruce Ave and NW 9 <sup>th</sup> St	54	55
	East of SW Country Club Dr and SW 47 <sup>th</sup> Pl	9	9
Albany, Oregon	East of SW 3 <sup>rd</sup> Ave and SE Lyon St	50	50
	South of 12 <sup>th</sup> Ave SE and SE Geary St	32	36
	South of SE 11 <sup>th</sup> Ave and Oak St SE	8	8
	East of Meadow Pl SE and 21 <sup>st</sup> Ave SE	33	35
	West of SE 31 <sup>st</sup> Ave and SE Pine St	3	3
	North of Waverly Dr SE and Brookside Ave SE	0	5

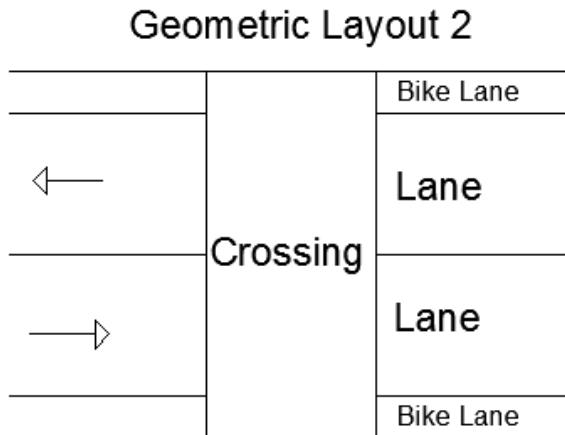
Eugene, Oregon	West of Bain St SE and Santiam Hwy SE	13	13
	West of Harlow Rd and Sweet Gum Ln	3	3
	West of River Rd and Silver Ln	60	127
	North of River Rd and Knoop Ln	6	6
	North of City View St and W 14 <sup>th</sup> Ave	31	35
	South of City View St and W 11 <sup>th</sup> Ave	33	36
	North of River Rd and Hamilton Ave	3	3
	West of Willamette St and W Broadway	106	115
	East of Willamette St and E Broadway	111	111
	<b>TOTALS:</b>	<b>1045</b>	<b>1261</b>

### 7.3 Geometric Layouts

The following images, created in Autodesk AutoCAD 2014, show the general geometric layouts of the pedestrian crossings in this study.



**Figure 53. Geometric Layout 1 (AutoCAD, 2015).**



**Figure 54. Geometric Layout 2 (AutoCAD, 2015).**

Geometric Layout 3

Bike Lane	Crossing	
Lane		←
Island		Island
Lane		→
Bike Lane		

Figure 55. Geometric Layout 3 (AutoCAD, 2015).

Geometric Layout 4

		Bike Lane
←		Lane
←		Lane
		Island
→		Lane
→		Lane
		Bike Lane

Figure 56. Geometric Layout 4 (AutoCAD, 2015).

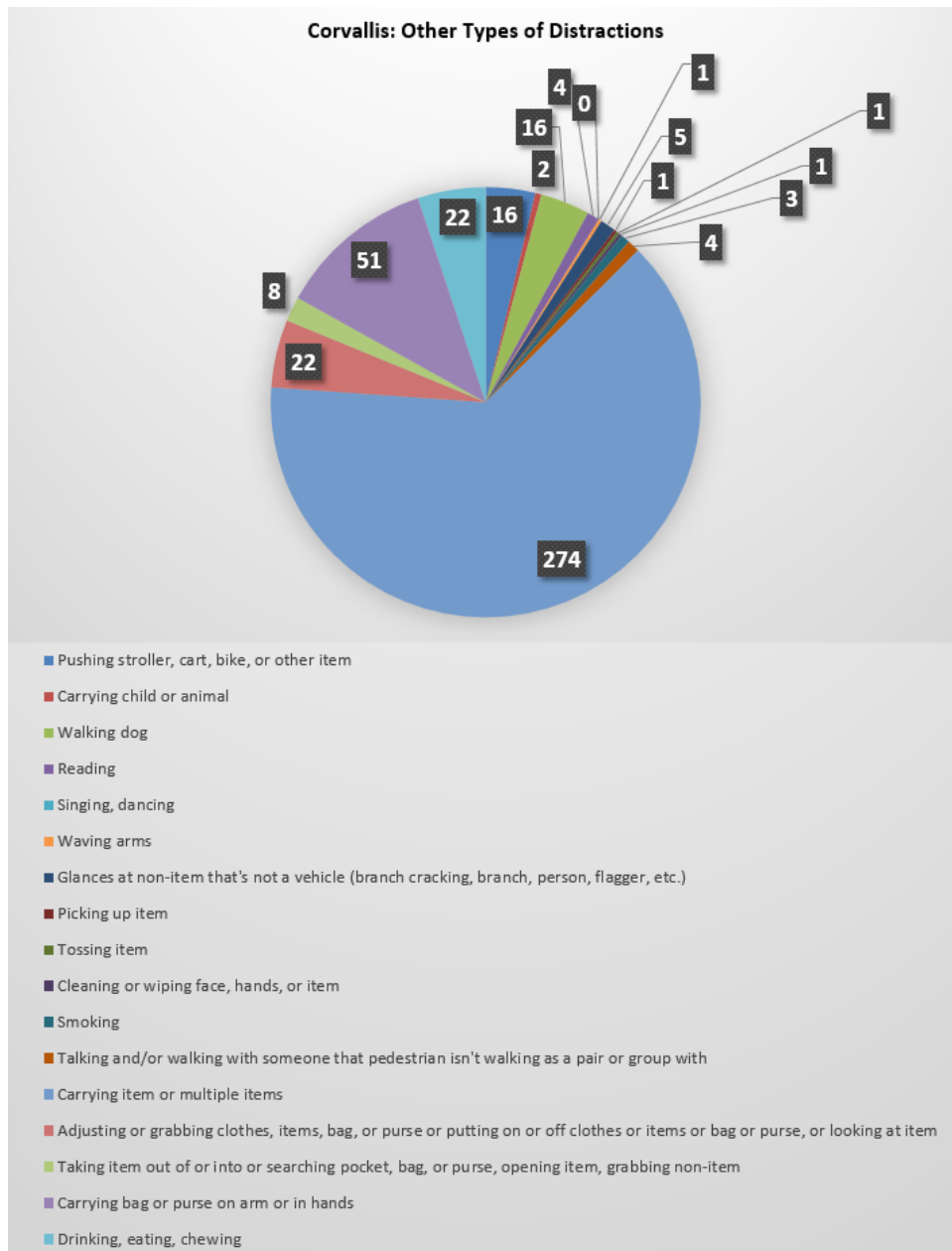
Geometric Layout 5		
Lane	Crossing	←
Island		Island
Lane		→

**Figure 57. Geometric Layout 5 (AutoCAD, 2015).**

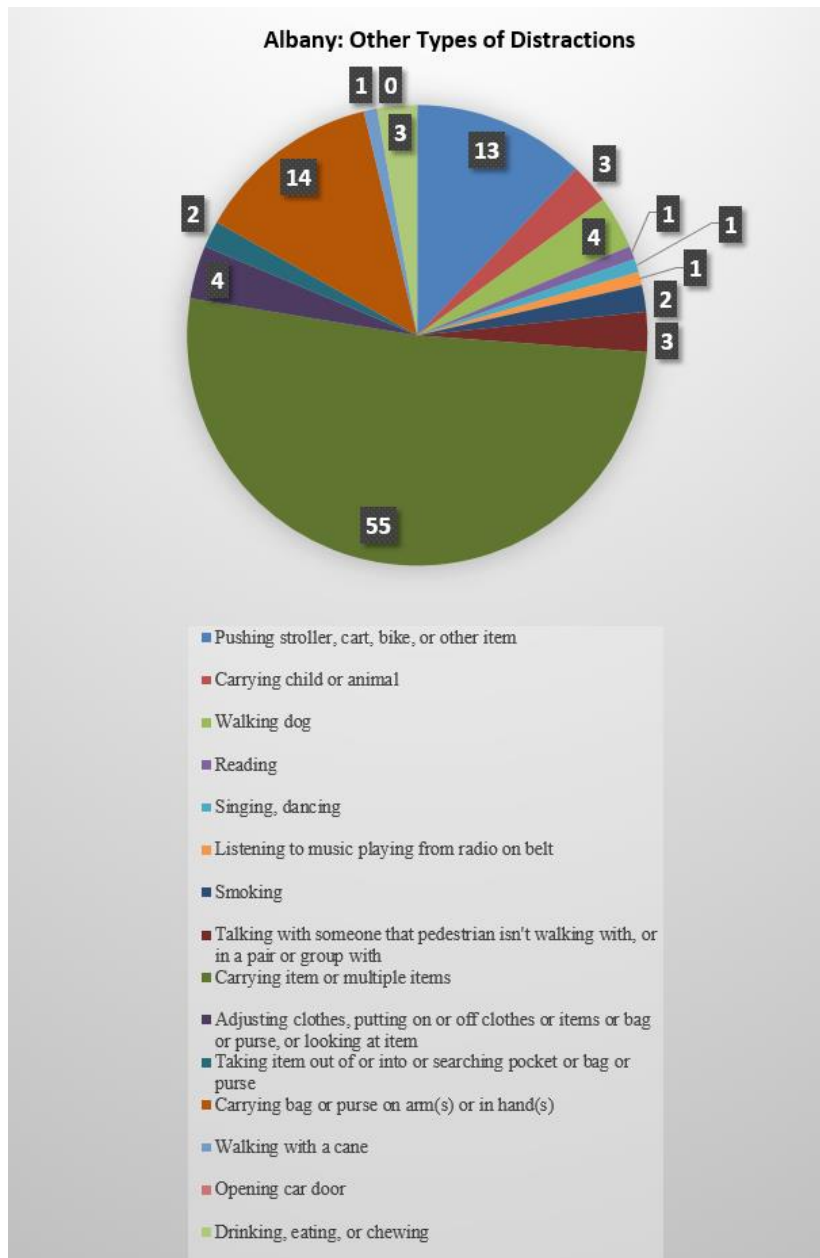
Geometric Layout 6		
Bike Lane	Crossing	
Lane		←
Island		Island
Lane		→
Bike Lane		
Lane		→

**Figure 58. Geometric Layout 6 (AutoCAD, 2015).**

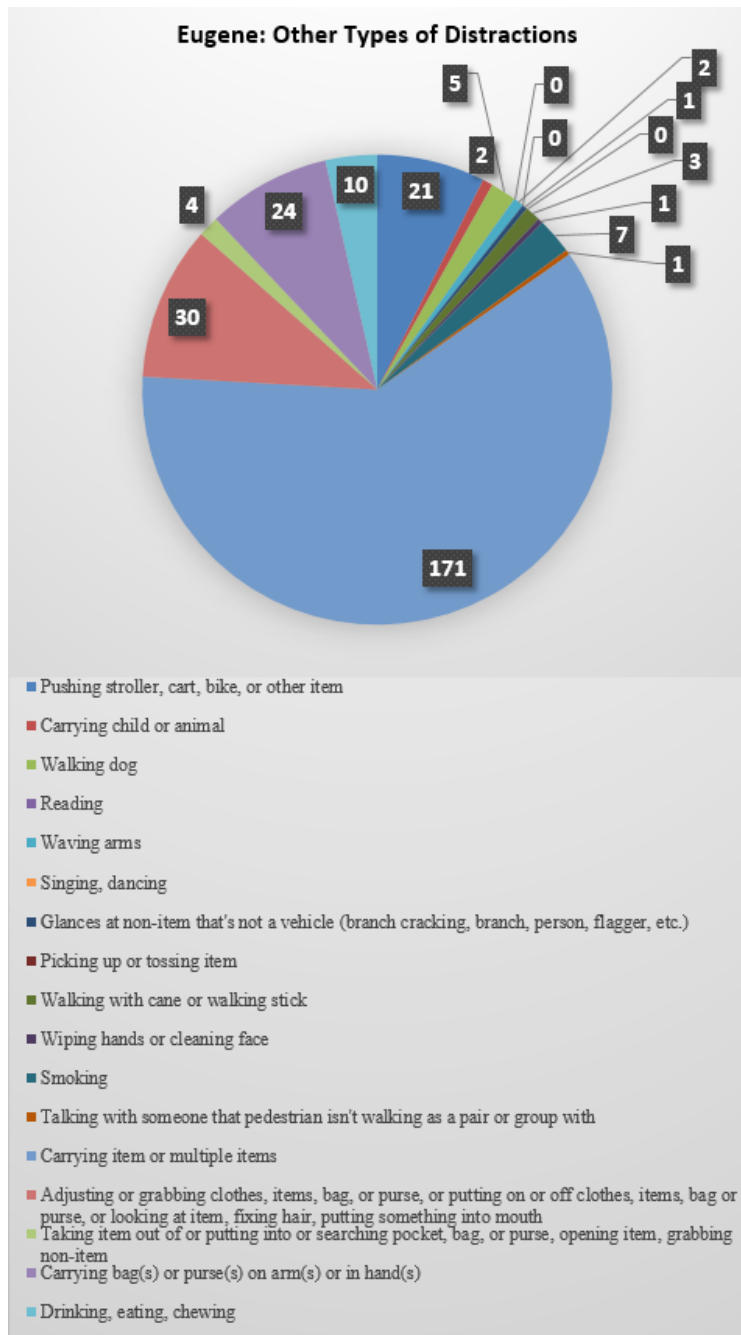
#### 7.4 Pie Charts for Other Types of Distractions



**Figure 59. Pie Chart of Other Types of Distractions for Corvallis.**



**Figure 60. Pie Chart of Other Types of Distractions for Albany.**



**Figure 61. Pie Chart of Other Types of Distractions for Eugene.**