THE IMPACTS OF CELL PHONE COVERAGE AREAS ON DISTRACTED DRIVING, TRAFFIC CRASHES, FATALITIES, AND INJURIES

Final Report

AGREEMENT NO. 30530 WORK ORDER NO. 23-10

by

Sal Hernandez, Ph.D., Associate Professor
Oregon State University
School of Civil and Construction Engineering
Corvallis, Oregon 97331

for

Oregon Department of Transportation
Department of Motor Vehicles
Transportation Safety Office
Kelly Kapri, Distracted Driving Program Manager

Dedicated to Alexxyss Therwhanger.
Appreciation to Shannon Moulton-Gilman.

September 2023

Technical Report Documentation Page

Report No	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle The Impact of Cell Phone Coverage Areas on Distracted Driving, Traffic Crashes, Fatalities, and Injuries	5. Report Date September 2023
	6. Performing Organization Code
7. Author(s) Salvador Hernandez	8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Section 555 13th Street NE, Suite 1 Salem, OR 97301	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Oregon Dept. of Transportation Research Section 555 13th Street NE, Suite 1 Salem, OR 97301 Federal Highway Admin. 1200 New Jersey Avenue SE Washington, DC 20590	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This study examined the prevalence of distracted driving-related crashes on Oregon's highways from 2017 to 2020, with a primary emphasis on crashes involving cell phone use. Notably, even in 2020, when there was a reduction in overall travel due to the pandemic, the rate of cell phone-related accidents remained high. Geospatial tools were employed to identify the locations of these crashes, revealing urban centers like Portland and Salem as significant hotspots. The research also highlighted factors influencing injury severity in these crashes, emphasizing the protective role of seatbelts. The findings indicate a pressing need for initiatives to address distracted driving in Oregon.

17. Key Words Distracted driving, Heatmaps, Injury severity	18. Distribution Statement Copies available from NTIS, and online at www.oregon.gov/ODOT/TD/TP_RES/

19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages XXX	22. Price

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	millimeters squared	mm^2	mm^2	millimeters squared	0.0016	square inches	in^2
ft^2	square feet	0.093	meters squared	m^2	m^2	meters squared	10.764	square feet	ft^2
yd^2	square yards	0.836	meters squared	m^2	m^2	meters squared	1.196	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	kilometers squared	km^2	km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	ml	ml	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C	°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

ACKNOWLEDGEMENTS

The authors would like to thank Kelly Kapri for her invaluable input throughout the project. Additionally, Oregon State University graduate students Namu Timilsina.

DISCLAIMER

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the view of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Technological advancements in communication, coupled with the growing popularity of social media platforms like Instagram, Meta (formerly Facebook), and TikTok, have accelerated the use of cellphones in motor vehicles. As of now, the United States boasts over 300 million smartphone users, a figure projected to reach 360 million by 2040 (Statista, 2023). While smartphones serve as beneficial technological aids, offering everything from mapping directions to real-time traffic alerts, they pose significant distractions to drivers.

According to the National Highway Traffic Safety Administration (NHTSA), "distraction" is a form of inattention that arises when drivers shift their focus from the task of driving to another activity. NHTSA (2021) highlighted that 9% of fatal crashes, 15% of injury-related crashes, and 15% of all police-reported vehicle crashes in the US in 2019 were attributed to distraction-affected crashes. Furthermore, 6% of drivers involved in fatal crashes that year were labeled as distracted. Alarmingly, drivers aged 15 to 20 constituted the highest percentage of distracted drivers during these fatal crashes. In Oregon, between 2016 and 2020, distracted driving was implicated in over 15,000 crashes, resulting in 186 deaths and approximately 24,000 injuries (ODOT, 2023). The trajectory of these numbers is concerning, especially as social media platforms grow more ingrained in our daily lives.

The central aim of this research was to investigate the statistical and spatial risks tied to cellphone usage and the resulting injury severity in vehicle crashes. Despite numerous studies on the subject, the connection between distracted driving, crash factors, crash severity, and geographical location remains unclear. One poignant example from Oregon is the tragic accident involving 19-year-old Alexxyss Therwhanger on February 19th, 2016. As she drove through the sparsely populated, patchily covered cellular regions of Eastern Oregon—frequented by residents and tourists alike—Alexxyss was occupied in her phone, eventually leading to a fatal crash. It was discerned by the Oregon State Police (OSP) that she began using her phone as she regained cellular coverage, engaging in texting, reading, and interacting on Meta. The uncertainty surrounding cellular reception zones in Oregon presents significant hurdles for safety experts in devising effective preventative strategies.

Hence, this research aspires to clarify the dangers inherent in the moments of initial reception loss and subsequent restoration in Oregon, employing a comprehensive statistical and spatial analytical approach. The study also aims to offer recommendations, informed by a spatial correlation between accident locations and cellphone reception areas, through the aforementioned analytical framework. To achieve this, this research incorporated crash data from the Oregon Department of Transportation (ODOT), data from the Federal Communications Commission (FCC), Geographic Information Systems (GIS), and other proprietary datasets previously employed by our research team. The insights derived from this research provides invaluable resources for stakeholders in transportation safety, law enforcement, public health, and emergency medical services, potentially informing the creation of focused interventions against distracted driving. Potential solutions might encompass pullouts, enhanced signage, heightened enforcement measures, and public awareness campaigns. To our team's knowledge, this pioneering study holds great promise in its novelty and potential impact.

This *Final Report* summarizes the research and is organized into 5 chapters. Chapter 1 presents the introduction. Chapter 2 summarizes data organization and formatting, Chapter 3 illustrates the data visualization, Followed by Chapter 4 which presents the safety analysis. Finally Chapters 5 and 6 contains references and appendices.

2.0 DATA ORGANIZATION AND FORMATTING

In the following section, Oregon's historical crash data is analyzed to discern trends associated with distracted driving crashes on state highways. Distracted driving crashes are categorized as those events related to cell phone use (either recorded on a Police Accident Report [PAR] or noted in use by the driver), cell phone usage observed by another participant, distractions due to navigation systems or GPS devices, distractions from other electronic devices, or texting. Figure 2.1 displays the distribution of these crashes from 2017 to 2020. This data has been collected by the Crash Analysis and Reporting Unit of Oregon's Department of Transportation (ODOT). Table 2.1 provides an overview of crashes during this four-year span, detailing the total number of crashes alongside those specifically attributed to distractions.

Table 2.1 Table Comparing Yearly Totals of All Crashes vs. Distracted-Related Crashes (2017-2020): Analyzing the Percentage Contribution of Distractions

Year	All Crashes	Total Distracted Related Crashes	% Of Total	Normalized Distracted Crashes
2017	57716	381	0.66%	0.39
2018	50092	421	0.84%	1.00
2019	50117	388	0.77%	0.54
2020	38124	311	0.82%	0.00

Further, Table 2.1 demonstrates that between 2017 and 2020, Oregon's crash data highlights varied patterns in overall and distracted driving crashes, for example, 2017 registered the highest total crashes at 57,716 but had a moderate proportion of distracted driving events at 0.66%. In contrast, 2018, despite a dip in overall crashes, experienced the peak of distracted driving with 421 crashes, accounting for 0.84% of total crashes, and also marked the peak of cell phone-related crashes at 255. When examined using normalized data, 2018's distracted crashes stand out starkly, with a value of 1 indicating the highest relative intensity. In 2020, possibly influenced by pandemic-induced reduced travel, noted the lowest overall crashes at 38,124, yet its percentage of distracted driving crashes remained notably high at 0.82%, with its normalized value underscoring the least relative intensity of distracted driving that year. This analysis emphasizes a noticeable issue: while total crash numbers varied, the consistent and significant risk posed by distracted driving, especially due to cell phone use, remained alarmingly stable, even when normalized to account for yearly variations.

Next, Figure 2.1 showcases the distribution of specific crash events under examination in the study. The examined events included: cell phone use (as documented on a Police Accident Report [PAR] or when a driver is observed in the act), cell phone usage as witnessed by another party, distractions stemming from navigation systems or GPS devices, distractions induced by other electronic devices, and texting incidents. Among these categories, the "cell phone use" (either recorded on a PAR or observed firsthand) experiened the highest number of unique crash_IDs throughout the four-year analysis span. On a year-by-year breakdown, these crashes represented an average of 58% in 2017, 61% in 2018, 64% in 2019, and a noticeable increase to 76% in 2020.

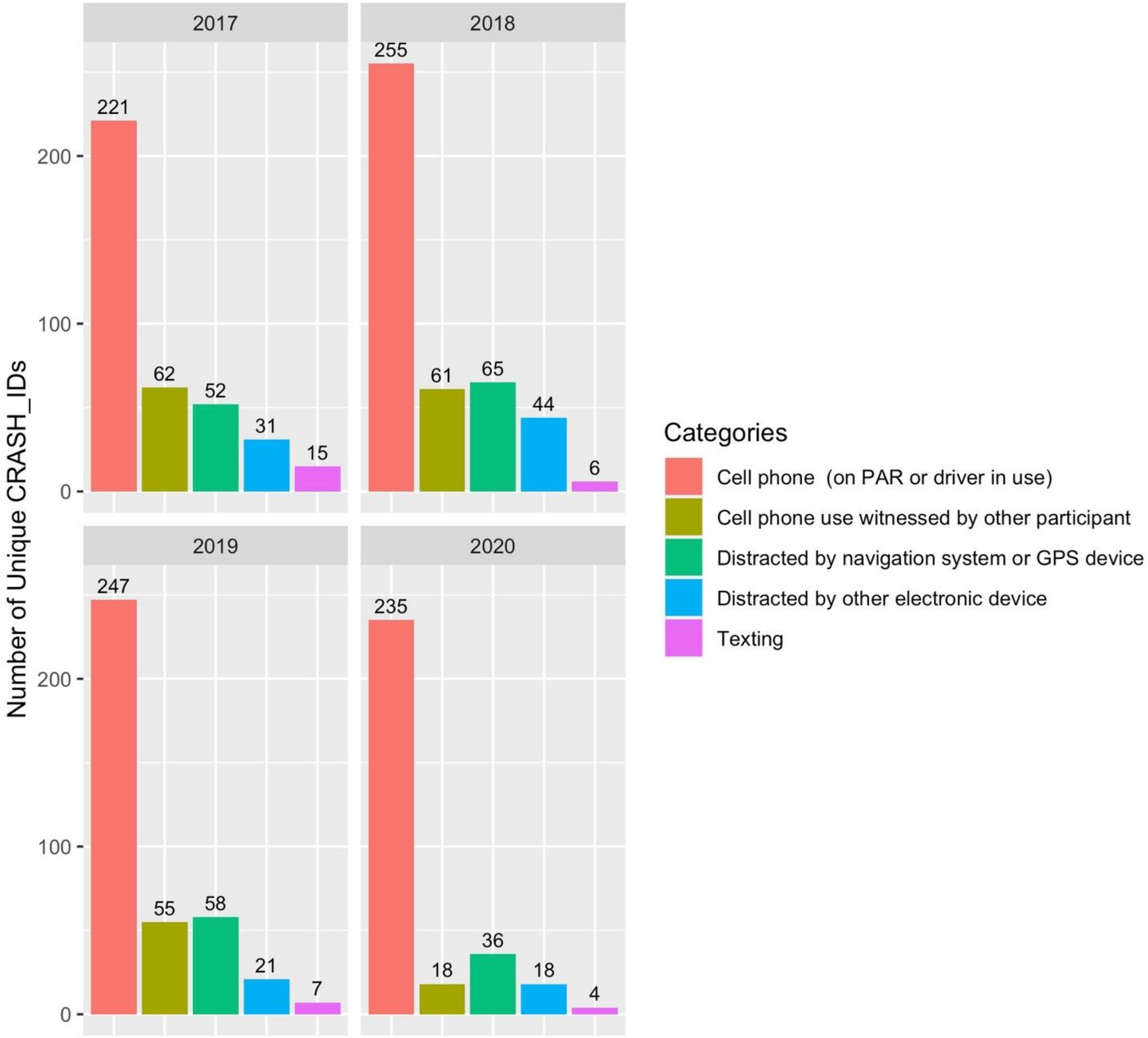

Figure 2.1 Breakdown per Year of Crash Events by Distraction Source: From Cell Phone Use to Texting

In the following analysis, driver injury severities were examined, as depicted in Figure 2.2. The figure reveals that the predominant injury severity over the span of four years was non-fatal. This indicates that injuries, while not fatal, were nonetheless significant, underscoring the seriousness of the situation. Interestingly, 2020 saw a relative rise in the percentage of fatalities compared to other years. As mentioned, to earlier, this uptick might be attributed to reduced traffic volumes paired with increased incidences of over-speeding during that timeframe. Furthermore, there's a discernible upward trend in fatalities from 2017 through 2020, emphasizing the growing concern over road safety in recent years.

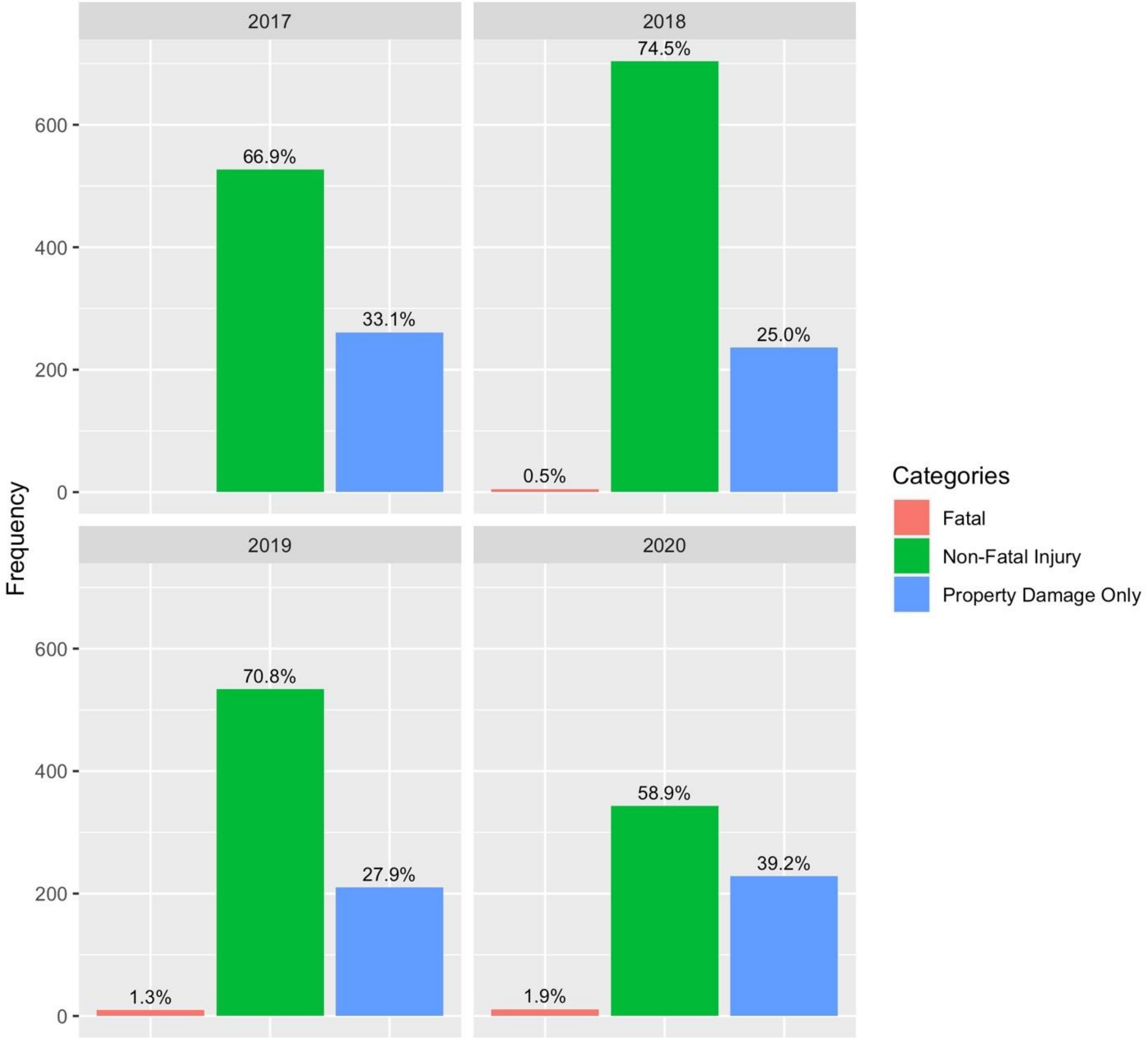

Figure 2.2 Histograms per Year Showcasing Injury Severity Across All Distraction Sources: From Cell Phone Use to Texting

In Figure 2.3, the dominant collision types associated with the designated categories of distraction are described. Noticeably, rear-end collisions stand out as the most common, trailed by fixed-object or other object collisions. Turning movements are also particularly frequent. This distribution implies that distractions mainly hinder a driver's capacity to uphold safe following distances and execute accurate turning maneuvers, possibly because of attentional lapses or tardy reactions while distracted. The recurrence of these collision types across various distractions highlights the global hazards of any form of inattention on the road.

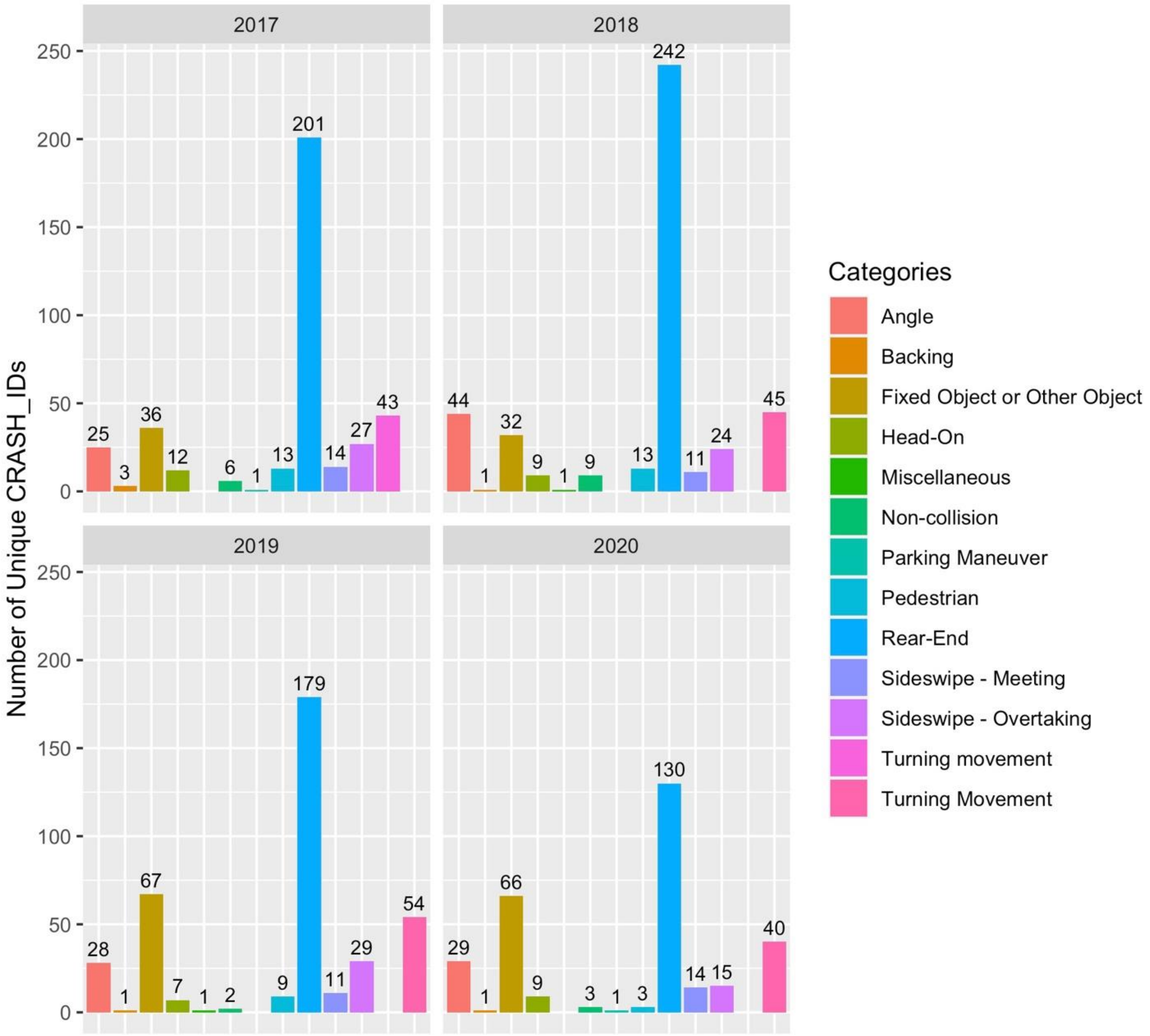

Figure 2.3 Yearly Histograms of Collision Types Resulting from Distractions: Analyzing Impacts of Distraction-Induced Crashes

In examining the locations of these crashes, Figure 2.4 describes consistent trends over the four-year study period. The data reveals that a significant portion of the crashes happen on straight roadway segments and at intersections. This observation aligns with expectations; straight roadways often lend themselves to higher speeds, and in the presence of distraction, they become hazardous. Similarly, intersections, with their inherent stop-and-go dynamics, can pose challenges for distracted drivers. The confluence of multiple vehicle paths and the need for timely reactions at intersections make them distinctly unsafe when drivers are not fully attentive.

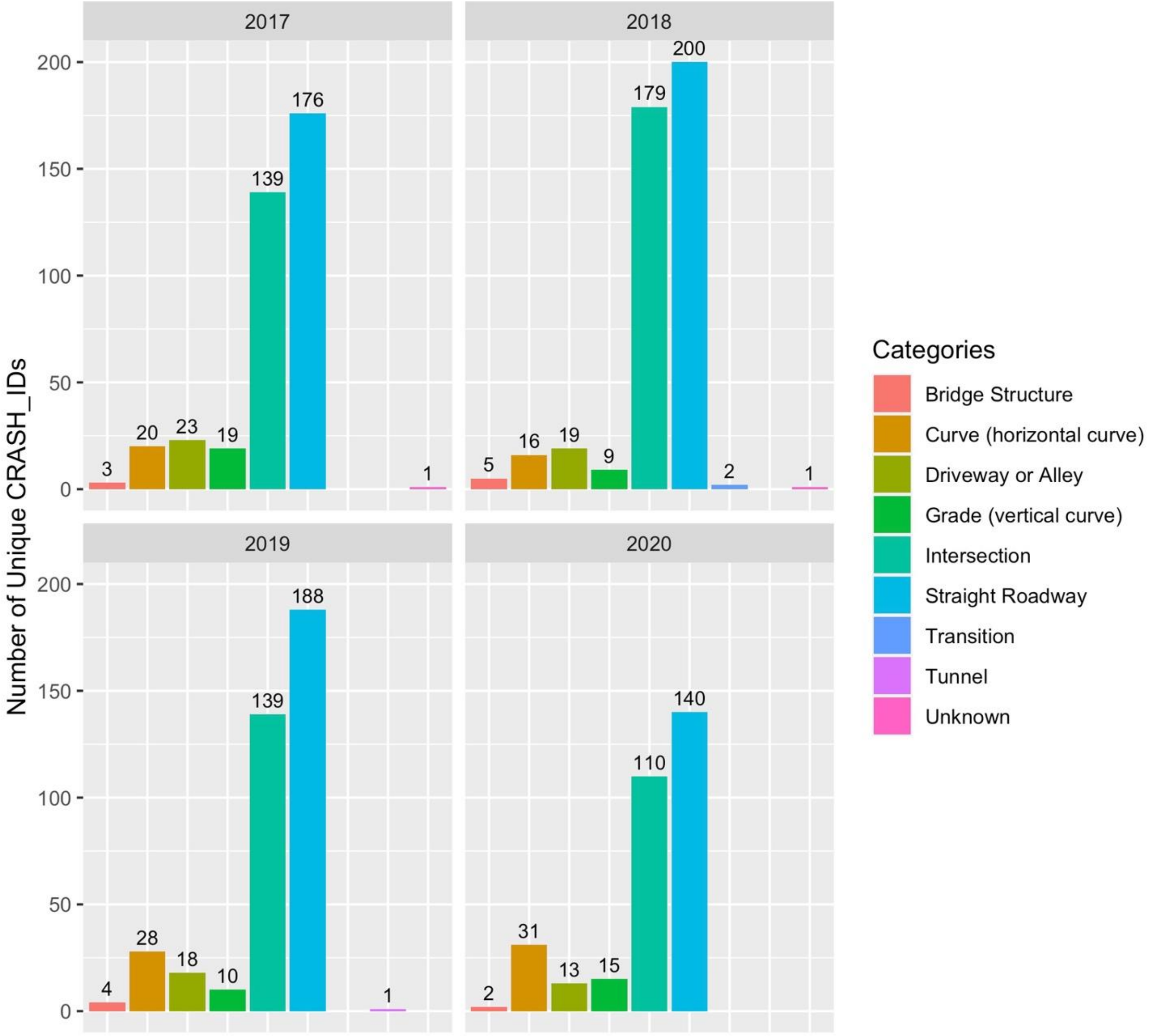

Figure 2.4 Yearly Histograms of Roadway Characteristics in Distraction-Related Crashes: Analyzing Environments of Distraction-Induced Crashes

Figure 2.5 sheds light on the ambient conditions during which most distracted-related crashes occur. The data suggests that daylight dominates as the prevalent lighting condition under which distracted driving crashes occur, particularly those stemming from cell phone usage or similar distractions. Situations of darkness with streetlights follow closely as the next significant category. This observation is logical, as some drivers might perceive better-lit conditions as a chance to glance at their phones, mistakenly assuming improved visibility equates to reduced risk. However, the attraction of mobile devices during these times underscores the persistent challenge of reducing distractions regardless of lighting conditions.

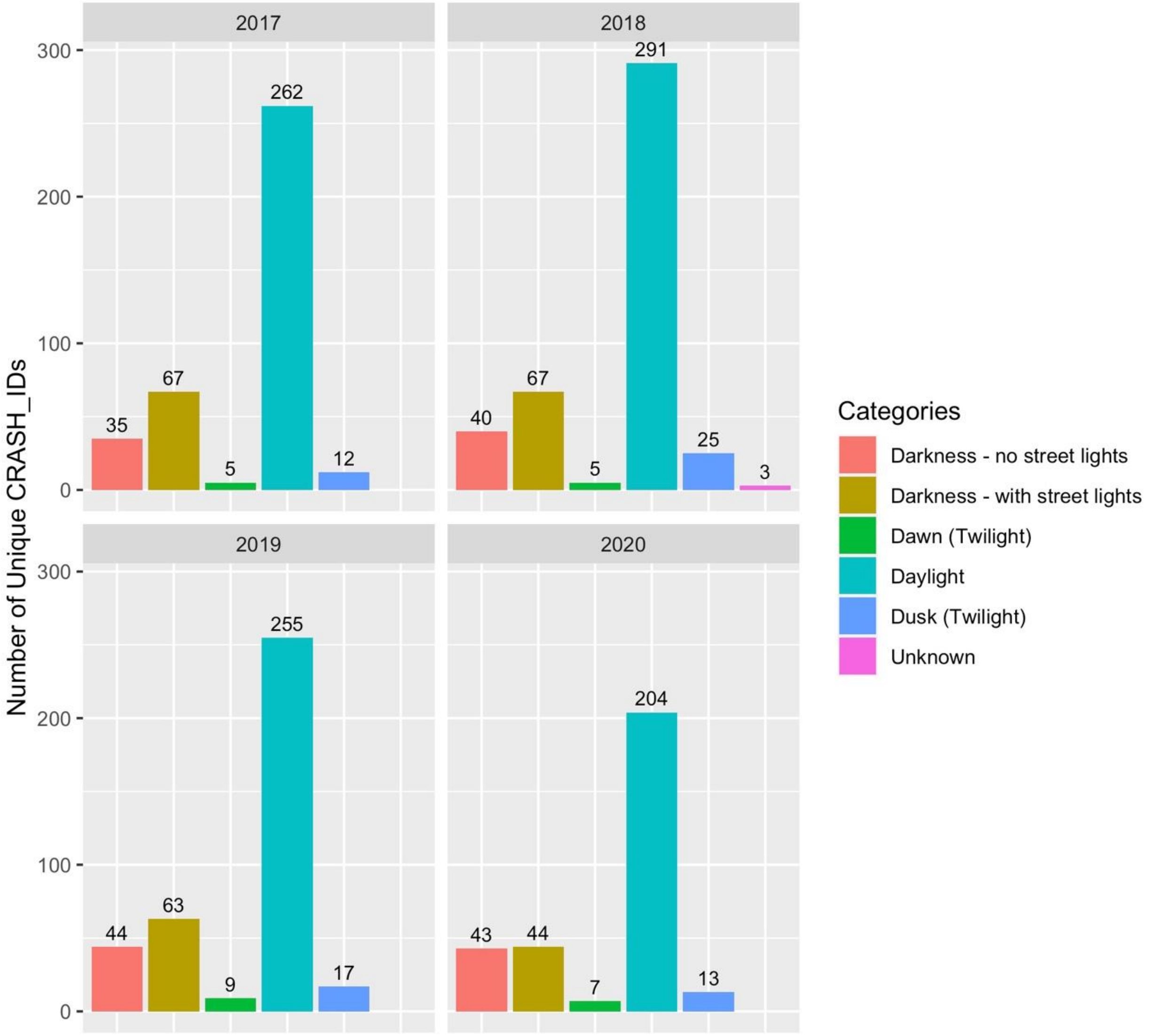

Figure 2.5 Yearly Histograms of Lighting Conditions in Distraction-Related Crashes: Shedding Light on Times of Distraction-Induced Crashes

Here, Figure 2.6 reveals the influence of weather conditions on drivers' tendencies to engage with electronic devices while driving. Predominantly, dry conditions are highlighted as the weather scenario under which most drivers succumb to the temptations of distracted driving. While cloudy and rainy conditions rank next in frequency for such events, they are noticeably less prevalent. The prominence of clear conditions aligns with a common perception: many drivers, feeling confident under seemingly safe conditions, might erroneously believe it's an favorable moment to check or use their mobile devices. This underscores the persistent misconception that favorable weather equates to safer multitasking on the road, emphasizing the need for continuous education on the dangers of distracted driving in all conditions.

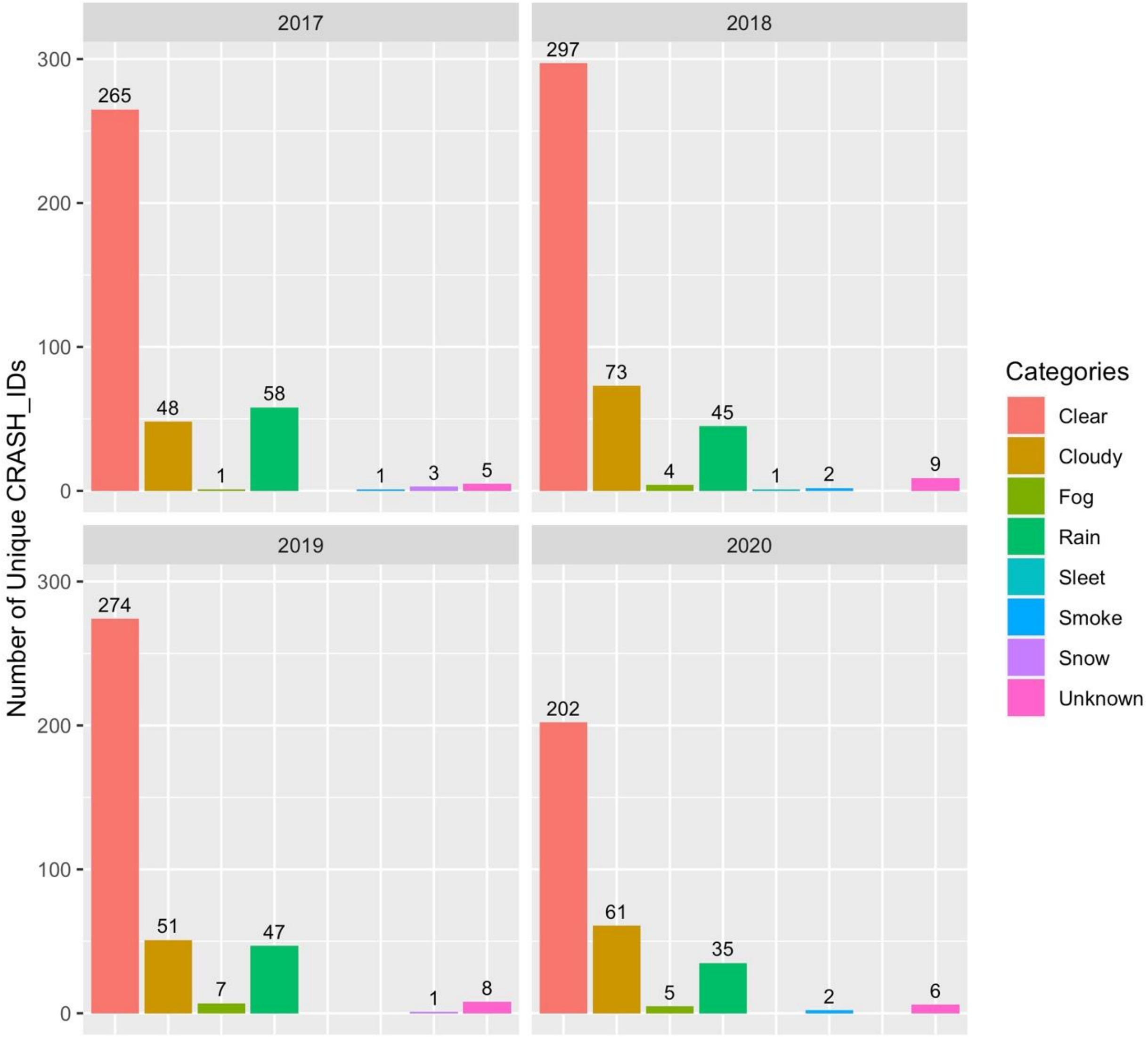

Figure 2.6 Yearly Histograms of Weather Conditions in Distraction-Related Crashes: Unveiling the Climate of Distraction-Induced Crashes

Similarly, to Figure 2.6, Figure 2.7 examines the perceived favorable road conditions that may unintentionally encourage drivers to engage in distracted driving. The data clearly points to dry road surfaces as the primary setting under which these incidents transpire over the study period. Such conditions often correlate with clear weather, leading to a deceptive sense of security. However, it's crucial to understand that even when road surfaces are dry, the risks of distracted driving remain. The consistent trend across both figures emphasizes the importance of constant vigilance and the need to challenge the misconception that seemingly safe road and weather conditions justify any form of distraction.

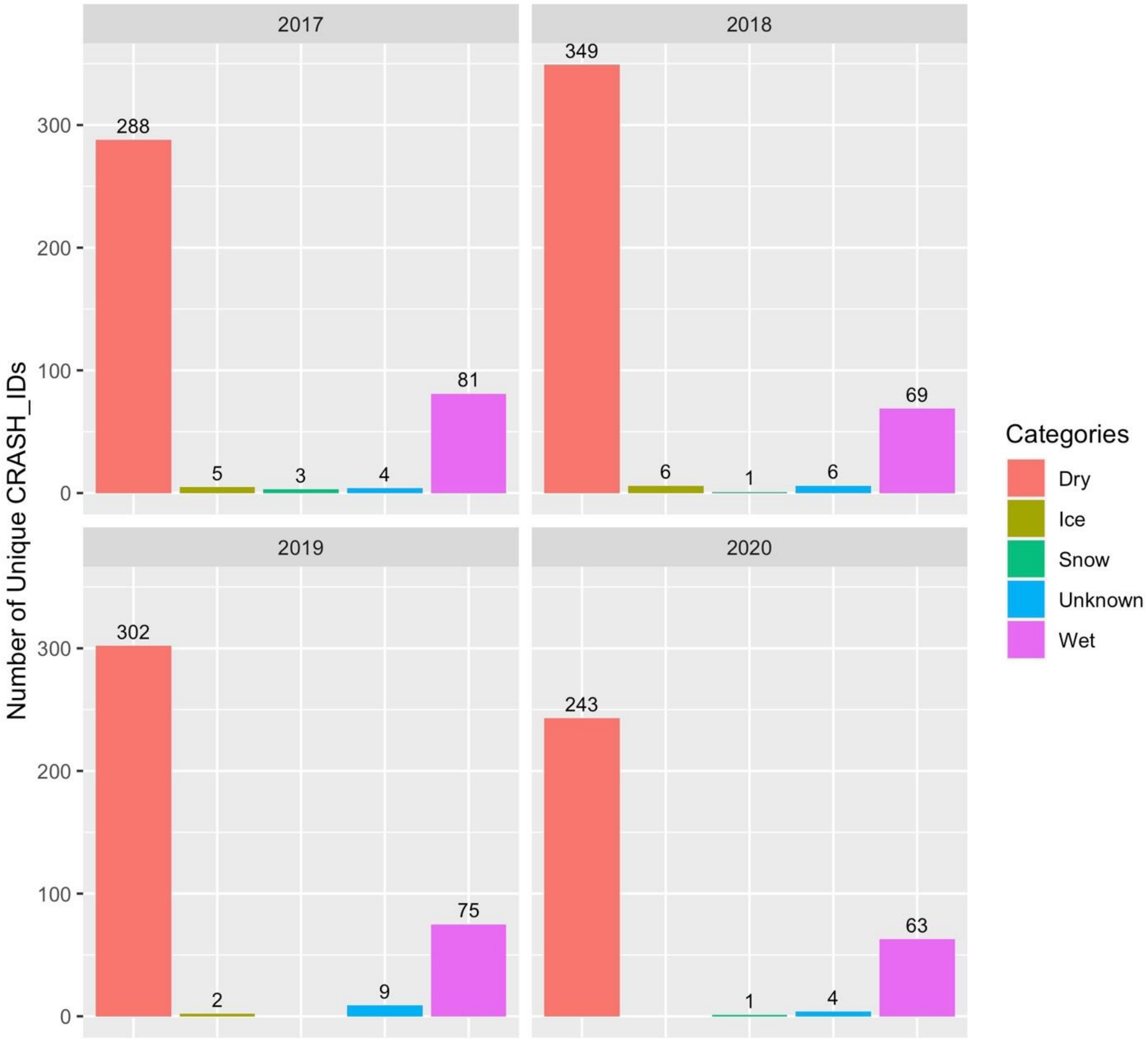

Figure 2.7 Yearly Histograms of Roadway Conditions: Distribution of Distraction-Related Crashes on Dry, Ice, Snow, and Wet Surfaces

2.1 SUMMARY

In analyzing Oregon's historical crash data, key trends associated with distracted driving on state highways emerged. Data spanning 2017 to 2020, as illustrated in Figure 2.1 and captured in Table 2.1, offered a comprehensive overview of these trends. Notably, the data consistently underscored the significant threat posed by distracted driving, particularly involving cell phone use. While total crash numbers fluctuated annually, the presence and risk of distraction remained a worrying constant, even after accounting for variations in annual crash totals. Specifically, 2020, a year marked by reduced travel due to the pandemic, reflected a concerning trend. While the total crashes decreased, the proportion of distracted driving incidents remained conspicuously high. This hints at an alarming pattern, suggesting that even under reduced traffic scenarios, distracted driving, especially cell phone use, continues to pose a substantial risk to road safety.

As the data analysis progressed, the specific characteristics of distracted driving crashes became increasingly evident. Figure 2.1 detailed the classification and distribution of such events over the four-year span, and among them, direct cell phone usage by drivers emerged as the predominant category. Injury patterns further elucidated the serious implications of distracted driving. Figure 2.2's description on driver injury severities over the same period revealed a consistent prevalence of non-fatal injuries. However, 2020 witnessed a spike in fatalities, potentially exacerbated by pandemic-induced traffic dynamics and behavioral shifts. Other figures in the analysis, such as Figure 2.3 and Figure 2.4, illuminated the recurring crash types and their frequent locations—further underscoring the universal dangers of any form of inattention while driving. Whether due to lighting conditions, as per Figure 2.5, or perceived safe weather and road conditions highlighted in Figures 2.6 and 2.7, the persistent risk of distracted driving remains evident. These insights collectively emphasize the central message that despite varying external conditions, the intrinsic danger of distracted driving is undeniable and warrants rigorous intervention and education measures.

3.0 DATA VISUALIZATION

The purpose of this section is to analyze Oregon's historical crash data, seeking to pinpoint trends, specifically the presence of hotspots, on Oregon's highways. The objective is also to discern the root causes of these crashes using visualization techniques grounded in Geographic Information Systems (GIS). Utilizing GIS to visualize and analyze cell phone-related distracted driving crashes can uncover patterns that might otherwise remain obscured. Alongside the Oregon historical crash data, this study incorporates the national FCC Mobile LTE Coverage Map. This map, developed by the Federal Communications Commission (FCC)[1], showcases the breadth and caliber of 4G LTE mobile broadband coverage across the U.S. It serves as a valuable tool for consumers, policymakers, and industry stakeholders, offering insights into areas well-served by LTE, as well as highlighting potential coverage gaps. The map aggregates data from a multitude of mobile carriers, including notable entities like Verizon and AT&T. For the purposes of this research, specific emphasis was placed on data from these two dominant carriers.

3.1 DATA AND ANALYSIS METHOD

The methodology for visualizing distracted driving crashes due to cell phone use in Oregon leaned heavily on the power of heatmaps within QGIS[2], a tool proficient at portraying spatial data distributions. Heatmaps, in this context, served as a potent visual aid to pinpoint regions with heightened instances of cell phone-induced distracted driving.

The foundation of this analysis was the geospatial point data layer for all crashes from the study period (2017-2020) representing specific instances of distracted driving attributed to cell phone usage across Oregon. Once this dataset was integrated into QGIS, the "Heatmap" feature from the "Raster" menu was invoked to transform these discrete data points into a continuous visual representation. Behind this transformation was the kernel density estimation (KDE) technique. Each incident of distracted driving was represented by a kernel—a smoothly tapered surface—reaching its peak at the exact location of the crash and gradually decreasing with increasing distance from the point. Bandwidth, a crucial parameter in this process, determined how much each crash influenced its surrounding area. While a broader bandwidth illuminated larger regions affected by distracted driving, a narrower one offered a more focused glimpse of high-risk zones.

For interpretative clarity, a color gradient was applied to the heatmap. Here, intense, or warmer colors like red and orange (Magna) pinpointed areas with a higher concentration of cell phone-related driving crashes, whereas cooler hues like blue or green indicated regions with fewer i crashes. Adjusting the output cell size ensured the heatmap displayed an optimal level of detail. The resultant heatmap, once generated, presented a compelling visual narrative, highlighting zones within Oregon where crashes related to cell phone usage while driving/other related distraction as

---

[1] See FCC at https://www.fcc.gov/BroadbandData/MobileMaps/mobile-map
[2] See QGIS at https://www.qgis.org/en/site/

emphasized in Section 2 was especially rampant, thus spotlighting areas necessitating heightened awareness campaigns or policy interventions.

The following figures illustrate the data utilized for this analysis.

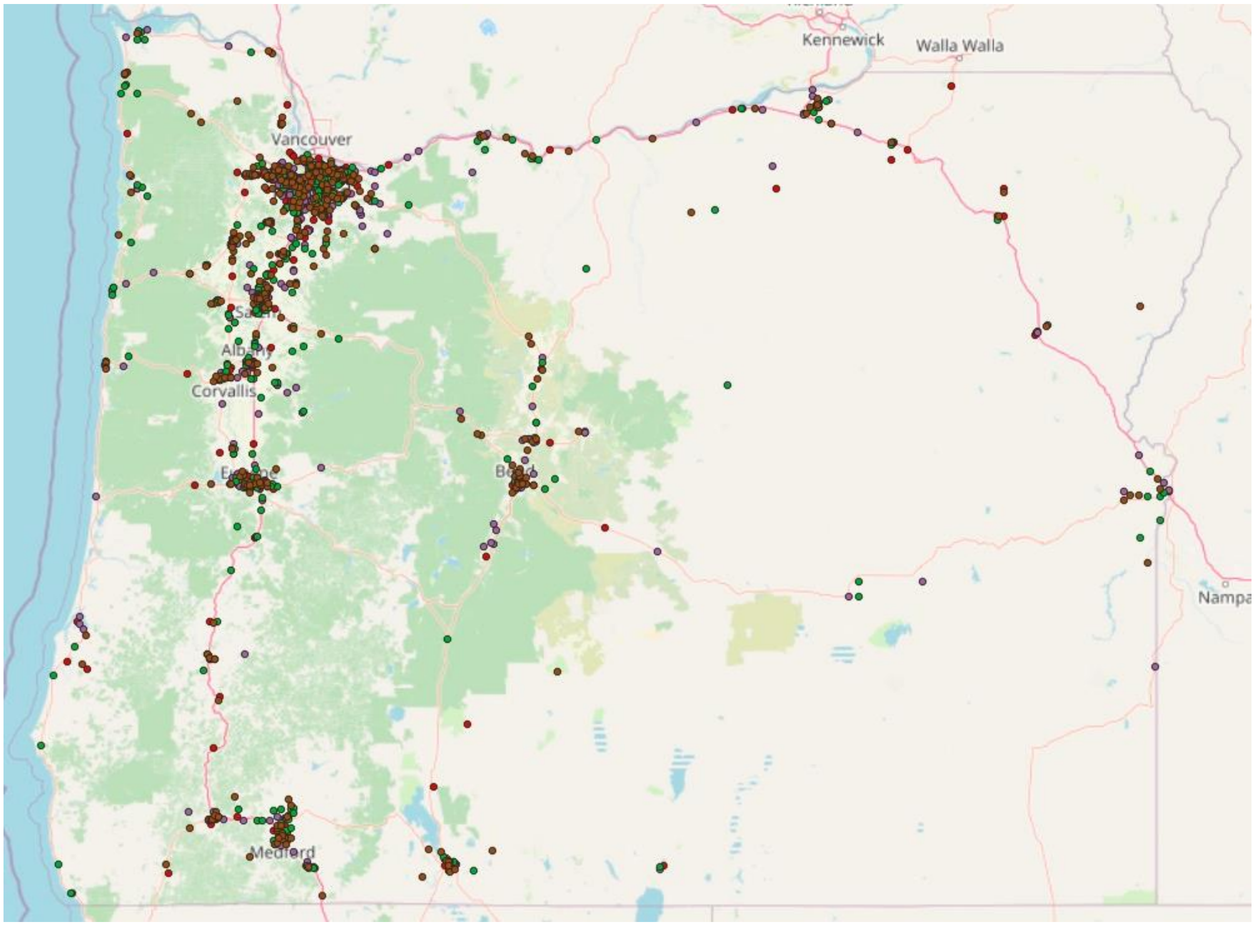

Figure 3.1 Spatial Distribution of Distracted Driving Crashes in Oregon (2017-2020): A GIS visualization highlighting the geolocations of reported incidents over the four-year study period.

Figure 3.1 displays the geospatial distribution of crash incidents spanning the period from 2017 to 2020, derived from the Oregon Historical crash dataset. To generate this focused map, a query was executed on the comprehensive dataset for each of the study years in QGIS. The criteria for selection encompassed a range of distracted driving events: those directly linked to cell phone use as documented on a Police Accident Report (PAR) or when a driver was visibly engaged with a phone, instances where another participant witnessed cell phone use, distractions arising from the utilization of navigation systems or GPS devices, distractions due to other electronic gadgets, and texting-related episodes. This spatial visualization provides a detailed landscape of the areas most affected by such distractions, offering valuable insights into patterns and potential zones of concern within Oregon. For individual year clusters see Appendix.

The following figures illustrate the impact of cell phone coverage on distracted driving crashes.

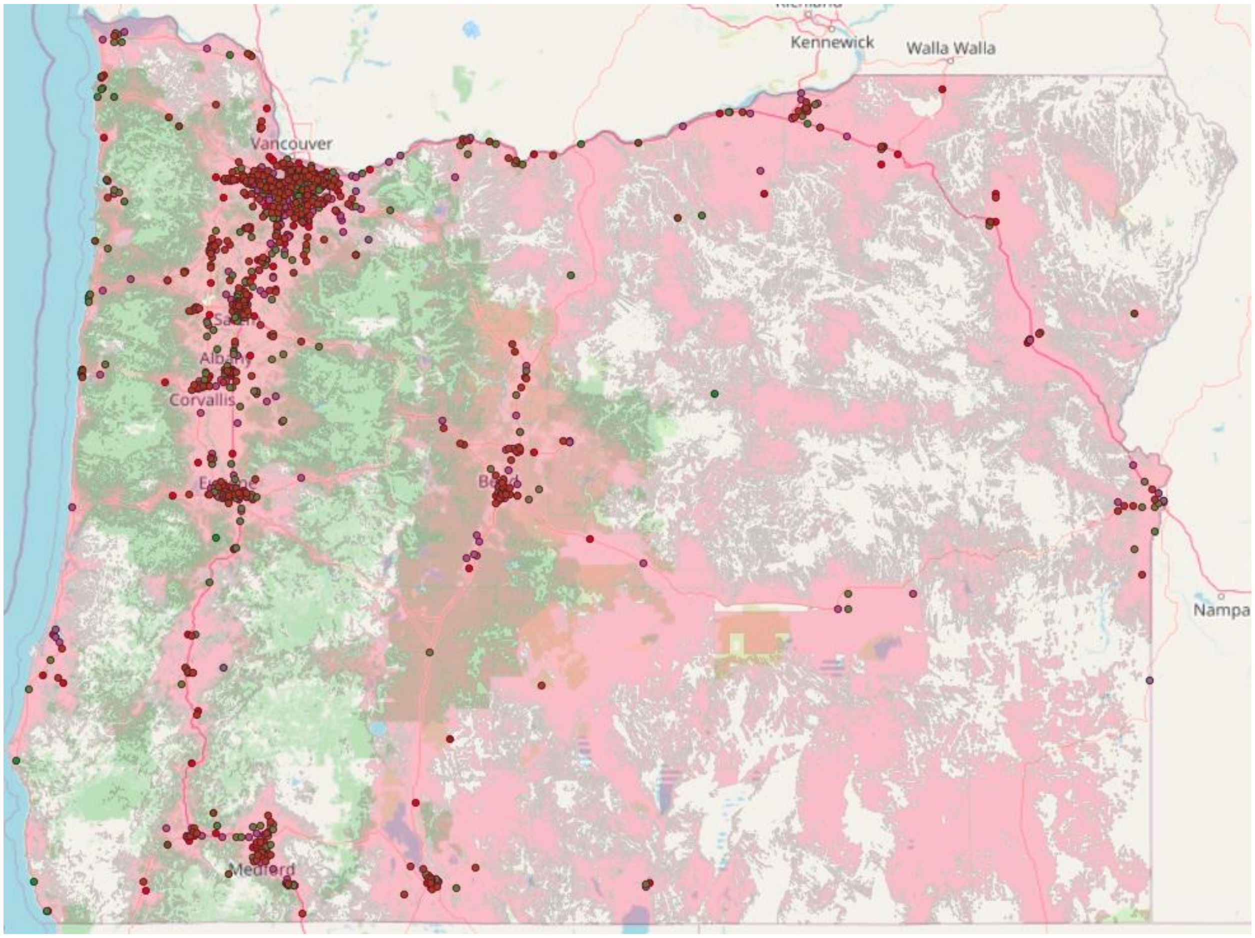

Figure 3.2 Verizon Mobile Cell Coverage Map Superimposed onto the Recorded Crash Sites from the Study Period (2017-2020)

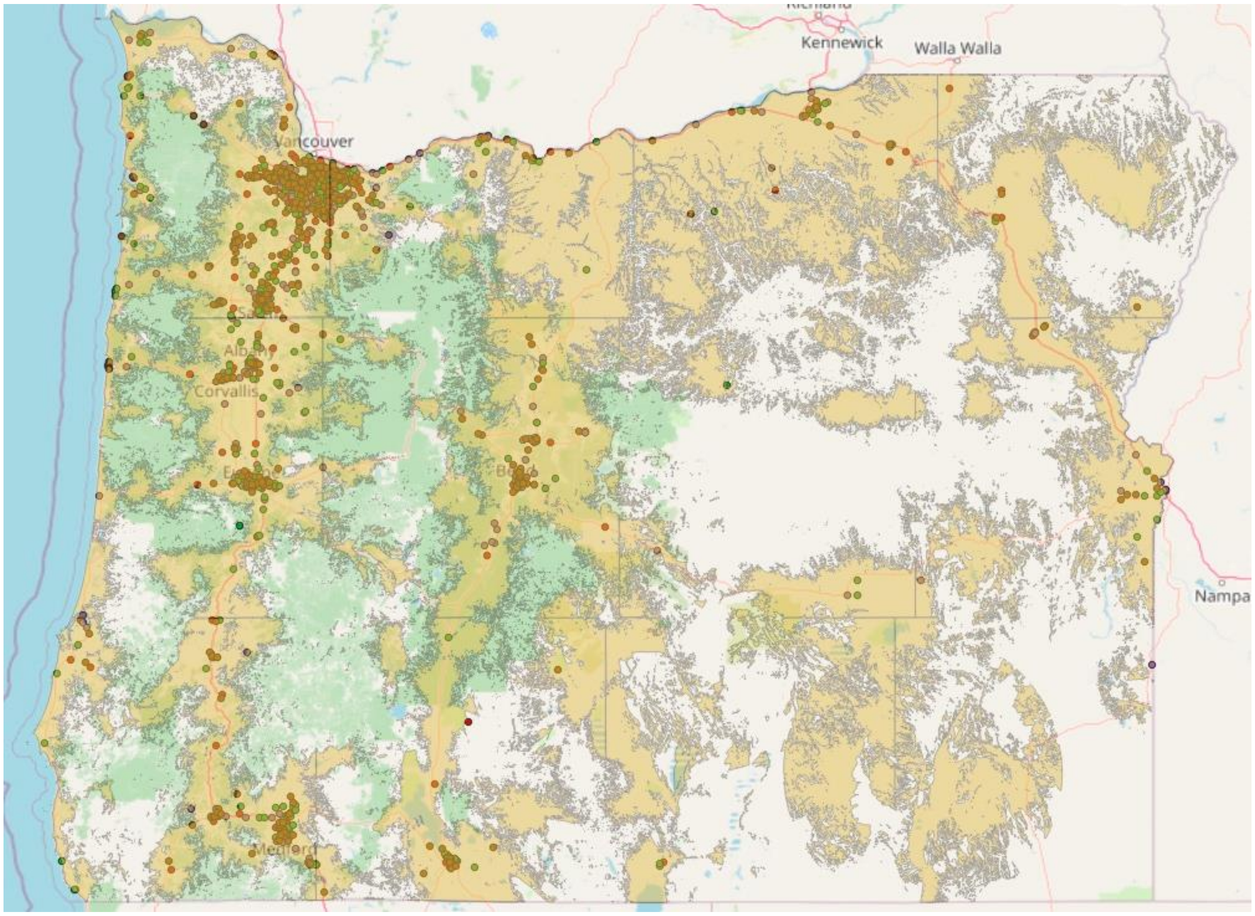

Figure 3.3 AT&T Mobile Coverage Map Superimposed onto the Recorded Crash Sites from the Study Period (2017-2020)

A pivotal aspect of this research aimed to ascertain whether cell phone coverage, or its absence, played a role in influencing the locations of distracted driving crash clusters. Figure 3.2 and Figure 3.3 present the mobile coverage maps for Verizon and AT&T, respectively, superimposed onto the recorded crash sites from the study period. The maps employ light-colored regions to depict areas devoid of coverage, while pink (in Figure 3.2 for Verizon) and yellow (for AT&T in Figure 3.3) shades signify areas with cellular service. Upon close examination, a notable pattern emerges: most crashes appear to be concentrated within the cell service zones for both carriers. This suggests a potential correlation between areas with active mobile service and the incidence of distracted driving crashes, underscoring the need for further investigation into the underlying factors and drivers' behaviors in these regions.

3.2 HEATMAPS

In Section 3.1, we introduced the application of heatmap analysis, a tool designed to reveal regions of high crash density by using a gradient of colors. In this context, areas with a higher concentration of crash incidents are represented with warmer hues such as red, signifying 'hot' zones of frequent occurrences. Conversely, regions with fewer recorded incidents adopt cooler tones, such as blue, indicating 'cold' zones with infrequent crash events. The subsequent figure provides a comprehensive visual of these crash clusters across Oregon. To offer a detailed perspective on urban areas known for high vehicular activity, specific illustrations for both the Portland and Salem regions are also included.

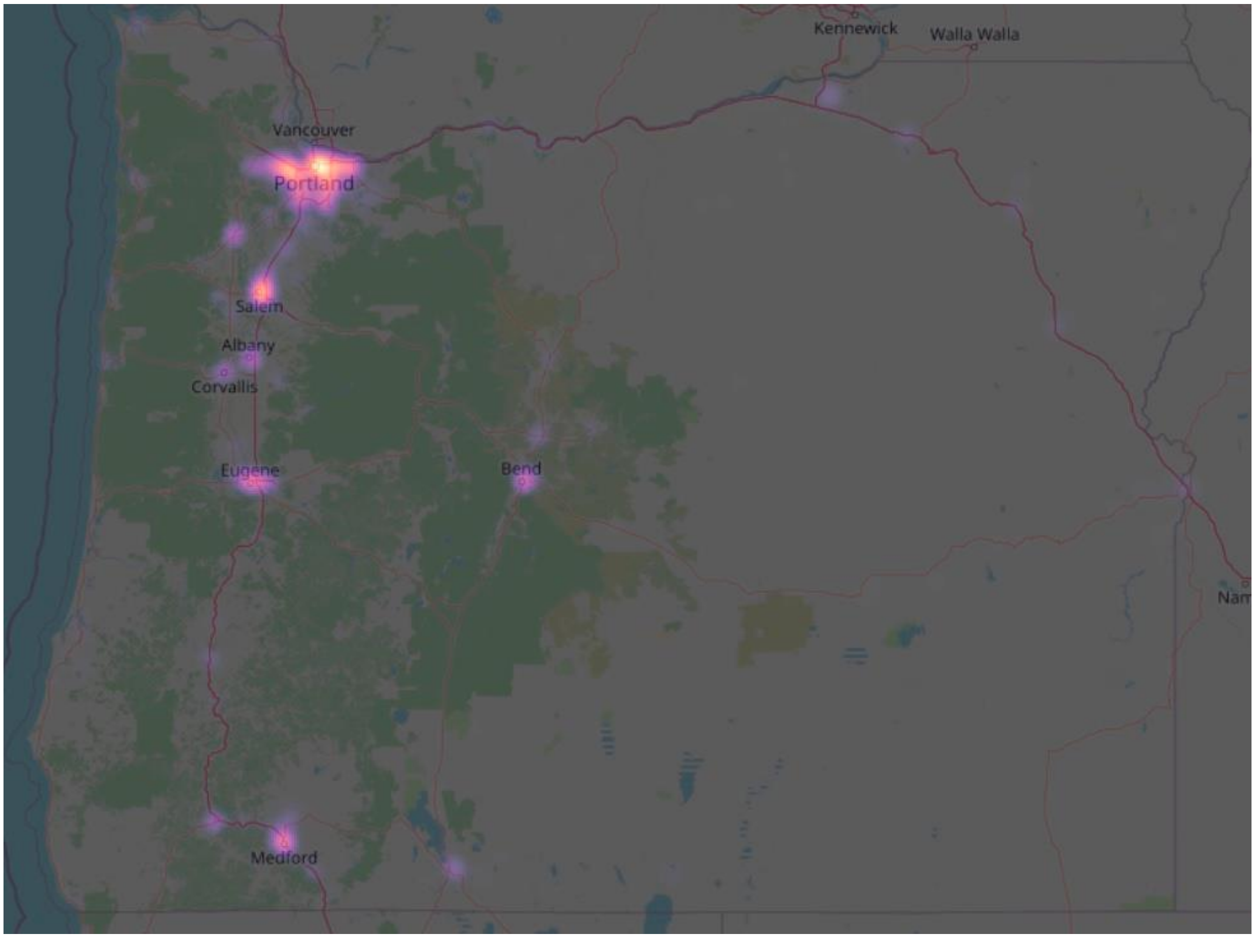

Figure 3.4 Heatmap of Oregon: Delineating Concentrations of Distracted Driving Crashes with Dominant Clusters in Major Urban Centers like Portland, Salem, Eugene, Medford, and Bend

Figure 3.4 distinctly showcases multiple crash clusters, with Portland emerging as the most prominent, illuminated with the brightest hue. This is succeeded by Salem, Eugene, Medford, and Bend, Oregon. It is not surprising to observe such a pronounced cluster in the Portland area, given that it is the most populous region in the state. This high population density naturally leads to a greater volume of vehicular traffic, and subsequently, a higher likelihood of crashes. Similarly, Salem, as the state capital and one of Oregon's larger urban centers, predictably records a heightened density of such incidents. The prominence of these clusters underscores the importance of implementing safety measures and awareness campaigns in these high-traffic regions in regards to cell phone use and distracted driving.

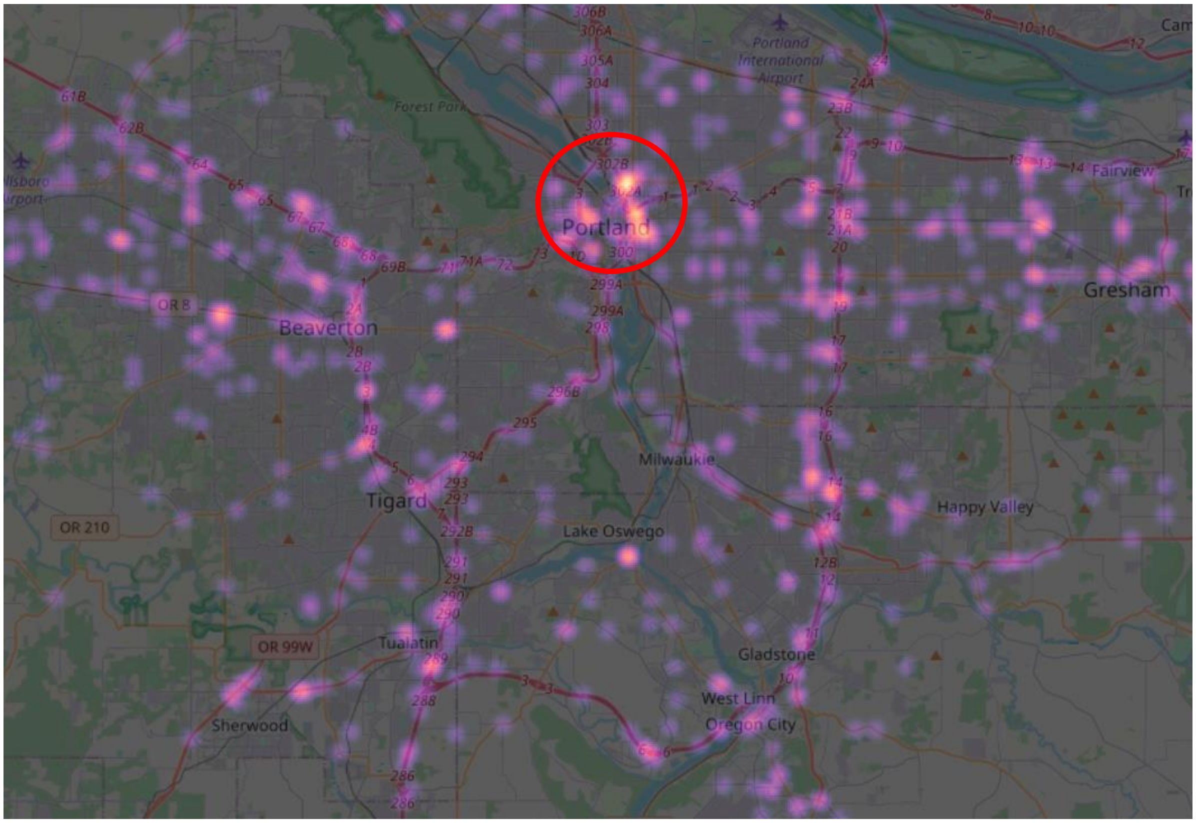

Figure 3.5 Heatmap of the Portland Area: Highlighting Concentrations of Distracted Driving Crashes with Intense Clusters in Downtown

Upon a more detailed examination of the Portland Area, the most intense clusters are predominantly located in the downtown region. This part of the city not only faces elevated traffic volumes but also contends with zones where cell signal drops are notably frequent. These signal interruptions can potentially lead to increased distractions as drivers might check their phones for connectivity or attempt to restart navigation. While downtown is undoubtedly a hotspot, it's imperative to note that other regions around Portland also register a significant uptick in occurrences of distracted driving crashes. Such widespread patterns emphasize the need for broader interventions and awareness campaigns across the entire metropolitan area.

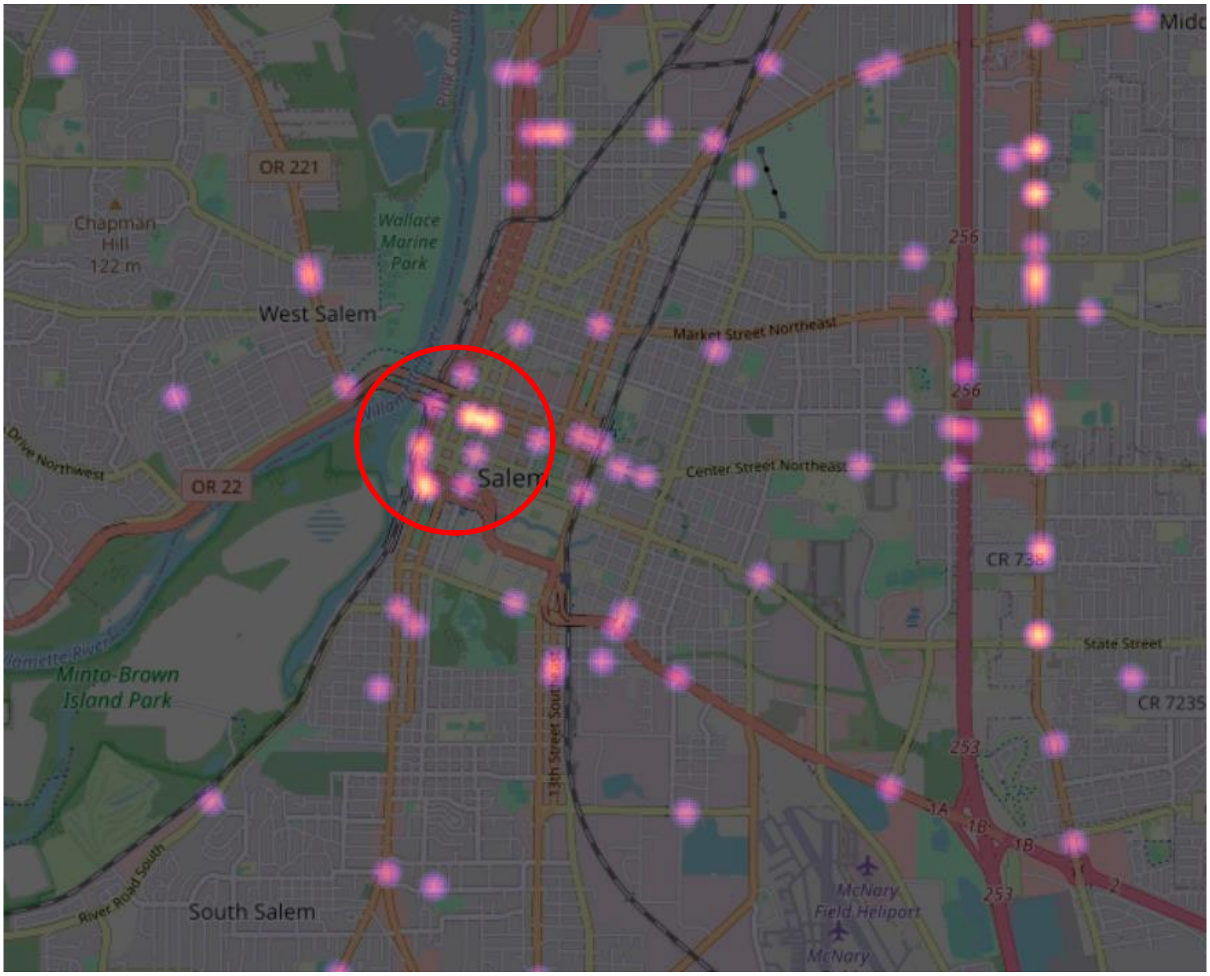

Figure 3.6 Heatmap of Salem Downtown: Highlighting Concentrations of Distracted Driving Crashes, with Intense Clusters Downtown

In Figure 3.6, a focused heatmap of Salem provides insights into the distribution of distracted driving crashes. The most pronounced clusters emerge in the downtown region, which aligns with expectations given the area's elevated traffic volumes. Interestingly, this central zone not only experiences heightened vehicular activity but also areas where cell signal disruptions are relatively frequent. Such signal drops could contribute to instances where drivers momentarily divert their attention to address connectivity issues, thereby increasing the potential for distracted driving crashes. Although the core downtown region is the epicenter of activity, peripheral areas around Salem also display significant occurrences of distracted driving crashes, underlining the pervasive nature of the issue across the cityscape.

3.3 SUMMARY

The motivation of this research revolved around a meticulous analysis of Oregon's historical crash data, predominantly focusing on identifying patterns and hotspots on the state's highways. By employing the advanced visualization capabilities of Geographic Information Systems (GIS), this study aimed to uncover the underlying causes of these road crashes. GIS visualization provided discernible patterns linked to cell phone-induced distracted driving, which might otherwise remain concealed. Complementing the Oregon crash data, this analysis also incorporated the national FCC Mobile LTE Coverage Map, an instrument crafted by the Federal Communications Commission (FCC) to portray the 4G LTE mobile broadband coverage spread across the nation. This map, collating data from leading mobile carriers like Verizon and AT&T, proved instrumental in delineating areas with robust LTE coverage and potential connectivity voids.

Central to our research methodology was the utilization of heatmaps within QGIS—a geospatial tool renowned for its adeptness at visualizing spatial data distributions. Through the heatmaps, our analysis transformed discrete data points into continuous visual narratives, delineating regions experiencing elevated instances of cell phone-induced/related crashes. The subsequent figures and illustrations, ranging from a holistic state-wide perspective to focused urban analyses of Portland and Salem, highlighted the distracted driving scenario in Oregon. As hypothesized, urban centers, with higher vehicular activity and sporadic cell signal disruptions, emerged as significant hotspots for distracted driving crashes. With Portland and Salem standing out in this regard, the findings suggest an urgent need for targeted awareness campaigns, policymaking, and safety measures, especially in densely populated or frequently trafficked regions.

In conclusion, the relationship between cell phone use, connectivity, and distracted driving crashes is both complicated and multifaceted. While regions with pronounced cell service witness a concentration of such crashes, sporadic connectivity zones present their own set of challenges, potentially diverting driver attention. As this study reveals the overarching patterns and hotspots in Oregon, it also underscores the importance of further research and strategic interventions to address this pressing concern.

4.0 SAFETY ANALYSIS

This section provides an in-depth analysis of the factors contributing to crashes associated with specific distraction-related events, using advanced econometric methods. The crash level events under study include cell phone use, as documented on a Police Accident Report (PAR) or observed in use by the driver, instances where another party witnessed the driver's cell phone usage, distractions stemming from the operation of navigation systems or GPS devices, distractions attributed to other electronic devices, and incidents related to texting while driving. Subsequent subsections provide a detailed overview of the empirical context, the applied methodology, a thorough discussion of the findings, and a summary of the results.

4.1 EMPIRICAL SETTING

This research relied on police-reported crash data sourced from ODOTs Crash Analysis and Reporting Unit, spanning the years 2017 to 2020. Emphasis was placed on crash-level events specifically related to drivers' distractions. These events are characterized by several forms of distractions including: cell phone use, as documented on a Police Accident Report (PAR) or observed in use by the driver, instances where another party witnessed the driver's cell phone usage, distractions stemming from the operation of navigation systems or GPS devices, distractions attributed to other electronic devices, and incidents related to texting while driving. From the comprehensive dataset, a subset of 2,690 observations were identified, each representing drivers involved in such distracted events. Each observation included information regarding driver, driver action, crash, roadway, temporal, environmental, and vehicle characteristics.

To assess the severity of the outcomes stemming from these distractions, the study employed a modified version of the traditional KABCO injury scale. This scale was condensed into three primary categories for clarity: severe injury (comprising fatal and incapacitating outcomes, labeled as K+A), minor injury (including non-incapacitating and potential injuries, denoted as B+C), and cases where there was no injury sustained by the driver, resulting solely in property damage (categorized as O). A closer examination of the 2,690 observations revealed a breakdown in injury outcomes: 32 crashes (or 1.19%) led to severe injuries; 960 cases (or 35.69%) ended in minor injuries; and the majority, accounting for 1,698 crasehs or 63.12%, documented instances where no injury, with damages limited to properties. The following table illustrates the descriptive statistics of the significant variables in each of the three injury severity models.

Table 4.1 Descriptive Statistics of Significant Variables by Injury Severity Category

Variable	Mean	Std Deviation
Mixed Logit Model		
Severe Injury		
Airbag (1 if the airbag deployed, 0 otherwise)	0.134572	0.341288
Collision Type (1 if rear-end, 0 otherwise)	0.562082	0.496162
High Speed (1 if was greater than 55 MPH, 0 otherwise)	0.178439	0.382905
Crash Month (1 if fall months, 0 otherwise)	0.289219	0.453428
Minor Injury		
Airbag (1 if the airbag deployed, 0 otherwise)	0.134572	0.341288
No Injury		
Safety Equipment (1 if seatbelt use, 0 otherwise)	0.549814	0.497543
Low Speed (1 if speed greater than 20 MPH but Less than 40 MPH, 0 otherwise)	0.302602	0.459413
Road Characteristic (1 if Horizontal Curve, 0 otherwise)	0.044238	0.205636
Driver Proximity to Residence (1 if within 25 Miles, 0 otherwise)	0.521933	0.49955
Age (1 if driver age is less than 25 years old)	0.526766	0.499314

4.2 MODELING APPROACH

In the present research, while the police-reported crash data offer an extensive array of insights, they do not capture certain details. Aspects such as the driver's physical characteristics (e.g., height, weight) or nuanced environmental conditions at the exact moment of the crash (e.g., subtle shifts in weather or lighting) remain unclear. Such factors can introduce unobserved variations across the dataset, termed as "unobserved heterogeneity". If not addressed, this heterogeneity can skew the model's estimations, potentially leading to biased outcomes, as highlighted by (Mannering et al., 2016).

To mitigate the impact of this heterogeneity, the current research employed the mixed logit model. This methodology stands as a cutting-edge statistical and econometric tool, with its application evident in a myriad of recent studies focused on injury severity. Further, this econometric modeling method treats injury severity outcomes as discrete choices, enabling insights into the probability of each injury severity outcome. Using this approach, the estimated parameters of the mixed logit model highlight statistically significant factors that either elevate or reduce the likelihood of specific injury severity outcomes.

The mixed logit model starts with a linear function. Each linear function corresponds to a particular injury severity resulting from a distracted driving crash and can be represented as:

$$\mathrm{U_{in}} = \boldsymbol{\beta_i X_{in}} + \varepsilon_{\mathrm{in}} \tag{1}$$

where U_{in} is a linear function for injury severity i and distracted driving crash n; i represents injury severities of no injury, minor injury and severe injury; $\boldsymbol{X_{in}}$ represents the vector of explanatory variables that lead to the discrete outcome of crash due to distracted driving n; $\boldsymbol{\beta}_i$ represents the vector of estimated parameters for injury severity i and ε_{in} is the error term that attempts to capture the unobserved factors within the model (Washington et al., 2011); but, ε_{in} is unable to capture all the unobserved factors. Police-reported crash data often lacks certain essential variables, and the variability within the available variables can lead to unobserved heterogeneity. If this heterogeneity is overlooked, it may produce biased estimates and lead to incorrect conclusions (Mannering et al., 2016). Therefore, the mixed logit model attempts to capture this heterogeneity by allowing parameters to vary. In addition, the mixed logit model (if variables are found to be random) eliminates the independence from irrelevant alternatives (IIA) property. In essence, by accounting for variables identified as random, unobserved factors are addressed, allowing for the categorization of injury severities into three distinct groups (Geedipally et al., 2011). The mixed logit model is then formulated as follows (McFadden and Train, 2000; Washington et al., 2011):

$$\mathrm{P_n}(\mathrm{i}|\varphi) = \int \frac{\mathrm{e}^{(\boldsymbol{\beta}_\mathbf{i}\mathbf{X}_\mathbf{in})}}{\sum_{\forall \mathrm{I}} \mathrm{e}^{(\boldsymbol{\beta}_\mathbf{i}\mathbf{X}_\mathbf{in})}} \mathrm{k}(\beta_\mathrm{i}|\varphi)\, \mathrm{d}\beta_\mathrm{i} \tag{2}$$

where $\mathrm{P_n}(\mathrm{i}|\varphi)$ is the weighted outcome probability of injury severity i conditional on $\mathrm{k}(\beta_\mathrm{i}|\varphi)$, where $\mathrm{k}(\beta_\mathrm{i}|\varphi)$ is the density function of $\boldsymbol{\beta}_\mathbf{i}$ and φ with distribution specified by the analyst—the density function is what allows the parameters to vary and is regularly specified to be normally distributed. All other variables have the same definition as the ordinary multinomial logit model (Washington et al., 2011).

4.3 MODEL AND RESULTS

In this study, nine unique variables were identified as significant across three injury severity categories (severe, minor, and no injury). Notably, the variable 'airbag deployment' was significant in both the 'No injury' and 'Minor injury' categories. Out of these nine variables, two were found to be random parameters, with statistically significant means and standard deviations. Specifically, as per Table 4.2, the random parameters were 'Airbag deployment' for the 'Minor Injury' category and 'Driver Proximity to Residence' (within 25 miles of their home) for the 'No Injury' category.

A random parameter, as previously discussed, means that a particular variable's effect is not consistent across all observations but varies, capturing the inherent differences within the dataset. To illustrate, the variable 'airbag deployment' in the 'Minor injury' category followed a normal distribution with a mean of 2.2208 and a standard deviation of 3.15704 (see Table 4.2). This indicates that in approximately 24.09% of the cases where airbags were activated during distracted driving events, the average effect of the parameter was negative. Conversely, for 75.91% of the cases, the average effect was positive. Therefore, for 24.09% of drivers, airbag deployment reduced the likelihood of incurring a minor injury during distracted driving incidents. However, for the remaining 75.91%, airbag deployment had the inverse effect.

In addition, the 'Driver Proximity to Residence' (within 25 miles of their home) for the 'No Injury' category was also found to be random and normally distributed with a mean of -1.38579 and a standard deviation of 5.05412.

Similarly, the variable 'Driver Proximity to Residence' (within 25 miles of their home) in the 'No Injury' category exhibited characteristics of a random parameter. It was found to be random and normally distributed with a mean of -1.38579 and a standard deviation of 5.05412. This distribution suggests that in cases where drivers were within 25 miles of their residence during distracted driving crashes, the average effect of the parameter was positive for a certain percentage of observations and negative for the rest. Specifically, for approximately 39.2% of such cases, being close to one's residence increased the likelihood of sustaining no injuries during distracted driving events. Conversely, for the remaining 60.8%, being near one's home had the opposite effect, suggesting these drivers were more prone to sustaining injuries (the negative sign).

As for the marginal effect values for the three injury severity categories, here they represent the change in the dependent variable for a one-unit change in an independent variable, holding all other variables constant. In simpler terms, they provide insight into the incremental impact of a particular explanatory variable on the outcome of interest. For instance, the marginal effects derived from the mixed logit model for the "Driver Proximity to Residence" variable offer insightful interpretations regarding the impact of a driver's closeness to their home on injury outcomes. Specifically, when a driver is within 25 miles of their residence, the probability of not sustaining any injury decreases by 1.67%. Conversely, the same proximity increases the likelihood of incurring a minor injury by 1.56%. Interestingly, there's also a slight rise of 0.11% in the chance of experiencing a severe injury. In essence, these findings suggest that drivers closer to their homes are marginally less likely to emerge unharmed from a crash, slightly more prone to minor injuries, and have an incrementally higher risk of severe injuries, holding other factors constant.

Table 4.2 Mixed logit Model Results and Marginal Effects for Severe, Minor and No Injury

Variable	Coefficient	T-Statistic	Severe	Minor	No Injury
Mixed Logit Model					
Severe Injury					
Constant	-7.24864	-11.95			
Airbag (1 if the airbag deployed, 0 otherwise)	2.19966	3.82	0.0099	-0.0066	-0.0033
Collision Type (1 if rear-end, 0 otherwise)	-1.34562	-2.74	-0.0041	0.0029	0.0012
High Speed (1 if speed was greater than 55 MPH, 0 otherwise)	2.50192	4.61	0.0122	-0.0084	-0.0038
Crash Month (1 if fall months, 0 otherwise)	0.8104	1.7	0.0028	-0.002	-0.0008
Minor Injury					
Constant	-2.32054	-7.76			
Airbag (1 if the airbag deployed, 0 otherwise) *(Standard Deviation of Parameter, Normally Distributed)*	2.2208 (3.15704)	3.56 (2.53)	0.0009	0.0113	-0.0122
No Injury					
Safety Equipment (1 if seatbelt use, 0 otherwise)	-2.74009	-9.3	0.0057	0.1304	-0.1361
Low Speed (1 if speed greater than 20 MPH but Less than 40 MPH, 0 otherwise)	0.75022	3.01	-0.0002	-0.0122	0.0124
Road Characteristic (1 if Horizontal Curve, 0 otherwise)	-0.97154	-1.96	0.0003	0.0022	-0.0025
Driver Proximity to Residence (1 if within 25 Miles, 0 otherwise) *(Standard Deviation of Parameter, Normally Distributed)*	-1.38579 (5.05412)	-5.15 (5.97)	0.0011	0.0156	-0.0167
Age (1 if driver age is less than 25 years old)	1.70131	6.65	-0.0012	-0.0313	0.0325
Model Statistics					
Number of Observations	2690				
Restricted Log-Likelihood	-2955.267				
Log-Likelihood at Convergence	-1285.449				
McFadden pseudo-*R*-squared (ρ^2)	0.565				

The following bullet points provide a detail discussion of the results from Table 4.2.

Severe Injury

- **Airbag Deployment**: The presence of an airbag deployment (Coefficient: 2.19966, T-Statistic: 3.82) is associated with an increased probability of severe injuries by 0.99%. However, it slightly reduces the odds of minor (-0.66%) and no injuries (-0.33%). In essence, when airbags deploy during distracted driving crashes, there's a greater likelihood of severe injuries.
- **Collision Type**: Rear-end collisions (Coefficient: -1.34562, T-Statistic: -2.74) decrease the chances of severe injuries by 0.41% but increase the odds for minor (0.29%) and no injuries

(0.12%). This suggests that rear-end collisions, while common, often result in less severe injuries.

- **High Speed**: Driving at speeds greater than 55 MPH (Coefficient: 2.50192, T-Statistic: 4.61) leads to a 1.22% higher probability of severe injuries while slightly decreasing the likelihood of minor (-0.84%) and no injuries (-0.38%). Unsurprisingly, higher speeds are correlated with more severe outcomes.
- **Crash Month**: Crashes during the fall months (Coefficient: 0.8104, T-Statistic: 1.7) elevate the odds of severe injuries by 0.28%, yet they marginally reduce the probability of minor (-0.2%) and no injuries (-0.08%).

Minor Injury

- **Airbag Deployment**: The deployment of an airbag (Coefficient: 2.2208, T-Statistic: 3.56) slightly raises the chances of minor injuries by 1.13% while correspondingly reducing the probability of no injuries (-1.22%). The normally distributed standard deviation of this parameter suggests significant heterogeneity in this effect across the observations.

No Injury

- **Safety Equipment**: Seatbelt use (Coefficient: -2.74009, T-Statistic: -9.3) significantly reduces the odds of not sustaining any injuries (-13.61%) but increases the likelihood of severe injuries (0.57%) and minor injuries (13.04%). This underscores the critical role of seatbelts in injury mitigation.
- **Low Speed**: Driving at speeds between 20 and 40 MPH (Coefficient: 0.75022, T-Statistic: 3.01) raises the probability of no injuries by 1.24% but decreases the chances for severe (-0.02%) and minor injuries (-1.22%).
- **Road Characteristic**: Horizontal curves (Coefficient: -0.97154, T-Statistic: -1.96) have a slight negative impact on the odds of not sustaining injuries (-0.25%) but marginally increase the likelihood for severe (0.03%) and minor injuries (0.22%).
- **Driver Proximity to Residence**: Being within 25 miles of one's residence (Coefficient: -1.38579, T-Statistic: -5.15) slightly diminishes the probability of no injuries (-1.67%), yet it increases the odds for minor (1.56%) and severe injuries (0.11%). The associated standard deviation again points to variability in this effect.
- **Age**: For drivers under 25 years old (Coefficient: 1.70131, T-Statistic: 6.65), the likelihood of not getting injured increases by 3.25%, while the chances of minor (-3.13%) and severe injuries (-0.12%) decrease.

These results, based on 2,690 observations, present a comprehensive understanding of the dynamics of distracted-related crashes across various significant parameters, with a strong model fit evidenced by a McFadden pseudo-R-squared value of 0.565.

4.4 SUMMARY

This study investigates the complex factors that contribute to crashes due to specific distraction-related events, using police-reported crash data from ODOTs Crash Analysis and Reporting Unit between 2017 to 2020. Notably, the data examines events characterized by distractions from cell phone use, navigation systems, other electronic devices, and texting while driving. Out of the vast dataset, 2,690 observations were pinpointed, denoting drivers involved in distracted driving crashes. These distractions were gauged for their impact on injury severity through a modified KABCO injury scale. It revealed that of the total crashes, 1.19% led to severe injuries, 35.69% to minor injuries, and a significant 63.12% resulted in no injuries, with only property damage.

However, certain caveats prevail. While the data is comprehensive, it doesn't encapsulate nuances like the driver's physical details or subtle environmental changes during the crash, leading to "unobserved heterogeneity." Addressing this heterogeneity, the study employed the mixed logit model, a robust statistical tool that discerns injury severity as discrete choices. Such an approach revealed significant factors that influence the probability of specific injury outcomes. For instance, the variable "airbag deployment" varied in its effect, indicating that in some cases it reduced the likelihood of minor injuries, while in others it increased it. Similarly, a driver's proximity to their residence had a mixed influence on injury outcomes.

The analysis shed light on several interesting findings. For example, airbag deployment during a distracted driving incident heightens the chance of severe injuries by 0.99%. Conversely, rear-end collisions, despite being frequent, often culminate in milder injuries. Safety equipment usage, particularly seatbelts, substantially mitigates injury, emphasizing their critical importance. Furthermore, younger drivers, those below 25 years, exhibited a higher likelihood of escaping injuries. Collectively, these insights, derived from a significant dataset and a robust econometric model with a McFadden pseudo-R-squared value of 0.565, provide a holistic understanding of distraction-induced crashes, serving as a foundation for targeted interventions.

5.0 CONCLUSIONS

The study of Oregon's highways between 2017 and 2020 has highlighted the urgent and widespread problem of distracted driving, a phenomenon further magnified by the widespread use of cell phones while driving. Although the overall number of crashes showed fluctuations, the constant threat posed by distractions remained alarmingly consistent. Particularly concerning is the data from 2020, a year with reduced travel owing to the pandemic, which indicated that even in periods of lesser traffic, the proportion of distraction-related incidents remained high. This clearly signals that the inherent risk of distracted driving is not purely a function of traffic volume but a reflection of deeply entrenched behavioral patterns among drivers.

A closer examination of the crash data uncovers the intricate details of these events. For instance, while a significant portion of these crashes resulted solely in property damage, a troubling percentage led to injuries, both minor and severe. The advanced econometric model used on the data aided in distinguishing the diverse elements affecting injury results. Airbag deployment, surprisingly, presented mixed outcomes – in certain cases, increasing the likelihood of severe injuries. Interestingly, rear-end collisions, although frequent, often resulted in less severe injuries. Notably, the use of safety equipment like seatbelts emerged as a vital preventive measure, substantially mitigating the severity of injuries.

The advanced visualization capabilities provided by the Geographic Information Systems (GIS) offered an invaluable layer of insight into the issue. GIS, in conjunction with the national FCC Mobile LTE Coverage Map, illuminated patterns correlating connectivity zones and distracted driving incidents. This comprehensive view helps in understanding the multi-dimensional aspects of the problem, such as areas with stable cell service witnessing higher incidents or the unique challenges sporadic connectivity zones introduce. Urban centers, characterized by Portland and Salem, are especially vulnerable, with increased vehicular activity and sporadic cell signal disruptions exacerbating the issue.

To effectively address this problem, a multi-faceted strategy is essential. Firstly, aggressive public awareness campaigns, particularly in densely populated urban regions, should be rolled out, focusing on the dire consequences of distractions, especially due to cell phones. Technology can play a pivotal role in mitigation – innovations such as applications that restrict phone functionalities when driving or enhance in-car safety features could be promoted. Infrastructure-wise, introducing features like designated texting zones or rest areas might deter drivers from resorting to their devices while driving. Strengthening the enforcement of existing road safety regulations, combined with community outreach and education, can further reinforce the message.

In conclusion, while modern technology, especially cell phones, offers myriad conveniences, it also presents grave challenges, particularly on the road. The information from Oregon acts as a stark alert to all involved parties, from decision-makers to regular drivers, emphasizing the immediate need for collective action against distracted driving. Balancing the allure of technology with the imperative of road safety is the way forward, ensuring that Oregon's highways remain safe for all users.

6.0 REFERENCES

Anderson, J., Hernandez, S., 2017. Heavy Vehicle Crash Rate Analysis: A Comparison of Heterogeneity Methods Using Idaho Crash Data. Transportation Research Record: Journal of the Transportation Research Board, No. 2637, pp. 56–66.

Geedipally, S., Turner, P., Patil, S., 2011. Analysis of Motorcycle Crashes in Texas with Multinomial Logit Model. Transportation Research Record 2265, 62–69

McFadden, D., Train, K., 2000. Mixed MNL Models for Discrete Response. Journal of Applied Econometrics 15, 447–470

Washington, S.P., Karlaftis, M.G., Mannering, F.L., 2011. Statistical and Econometric Methods for Transportation Data Analysis, 2nd ed. Taylor and Francis, Chapman & Hall/CRC Boca Raton, FL.

Statista. Statista Digital Market Insights, https://www.statista.com/statistics/201182/forecast-of-smartphone-users-in-the-us/ . Accessed 2023.

NHSTA (2021). Distracted Driving 2019

ODOT. Distracted Driving. https://www.oregon.gov/odot/safety/pages/distracted.aspx . Accessed 2023

APPENDIX A

The following figures represent the GIS layers for the derived crash data for crash level events from 2017 to 2020 for cell phone use, as documented on a Police Accident Report (PAR) or observed in use by the driver, instances where another party witnessed the driver's cell phone usage, distractions stemming from the operation of navigation systems or GPS devices, distractions attributed to other electronic devices, and incidents related to texting while driving.

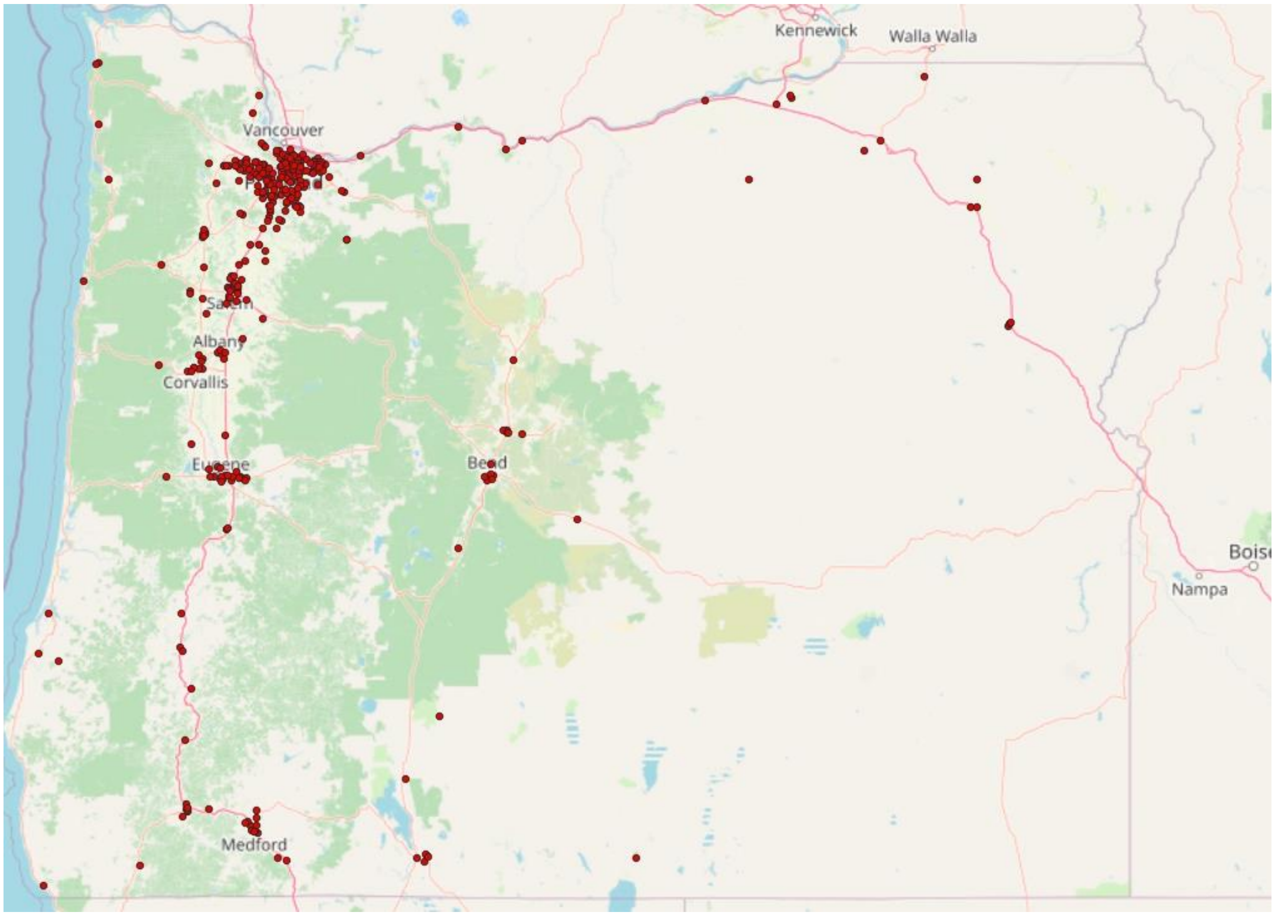

Figure A1 – Derived Crash data for 2017

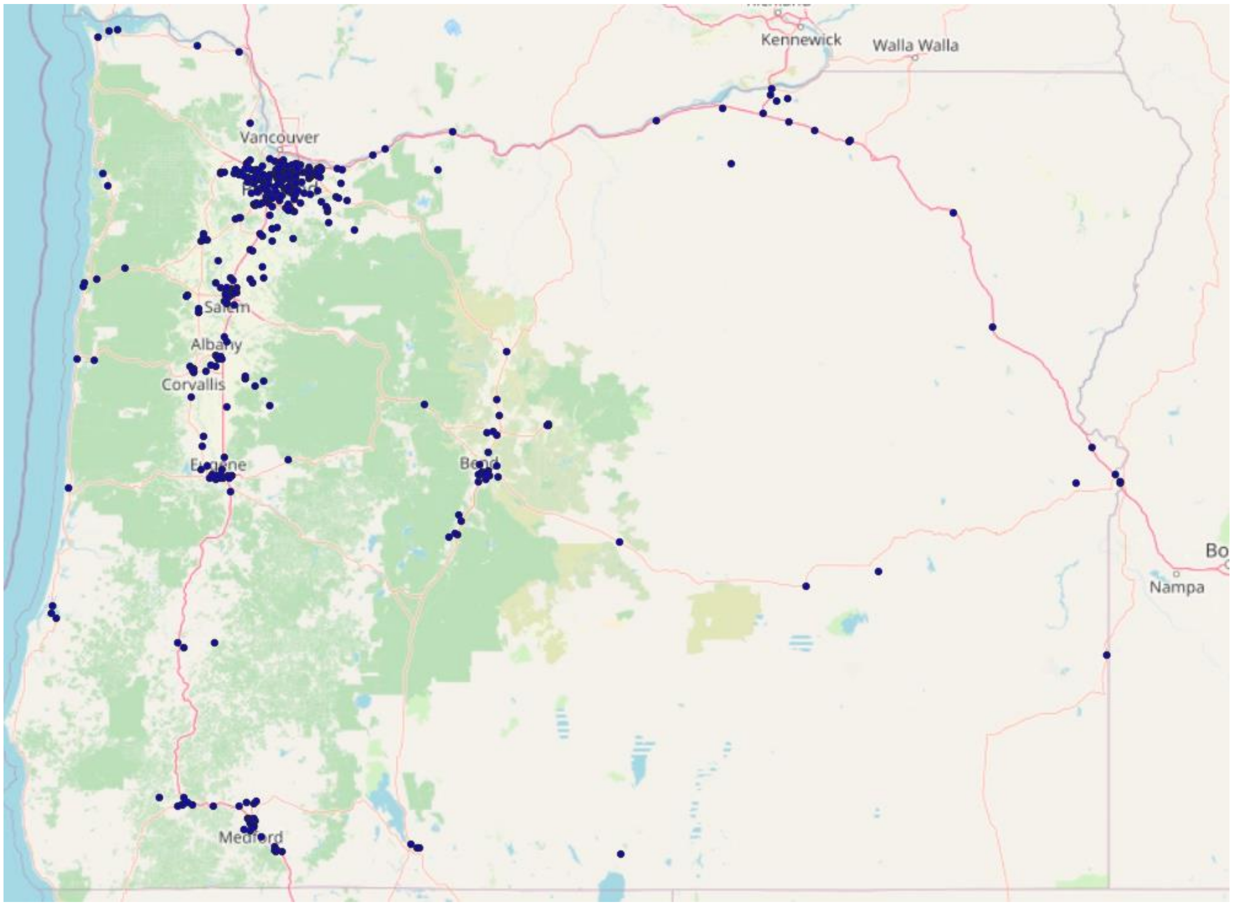

Figure A2 – Derived Crash data for 2018

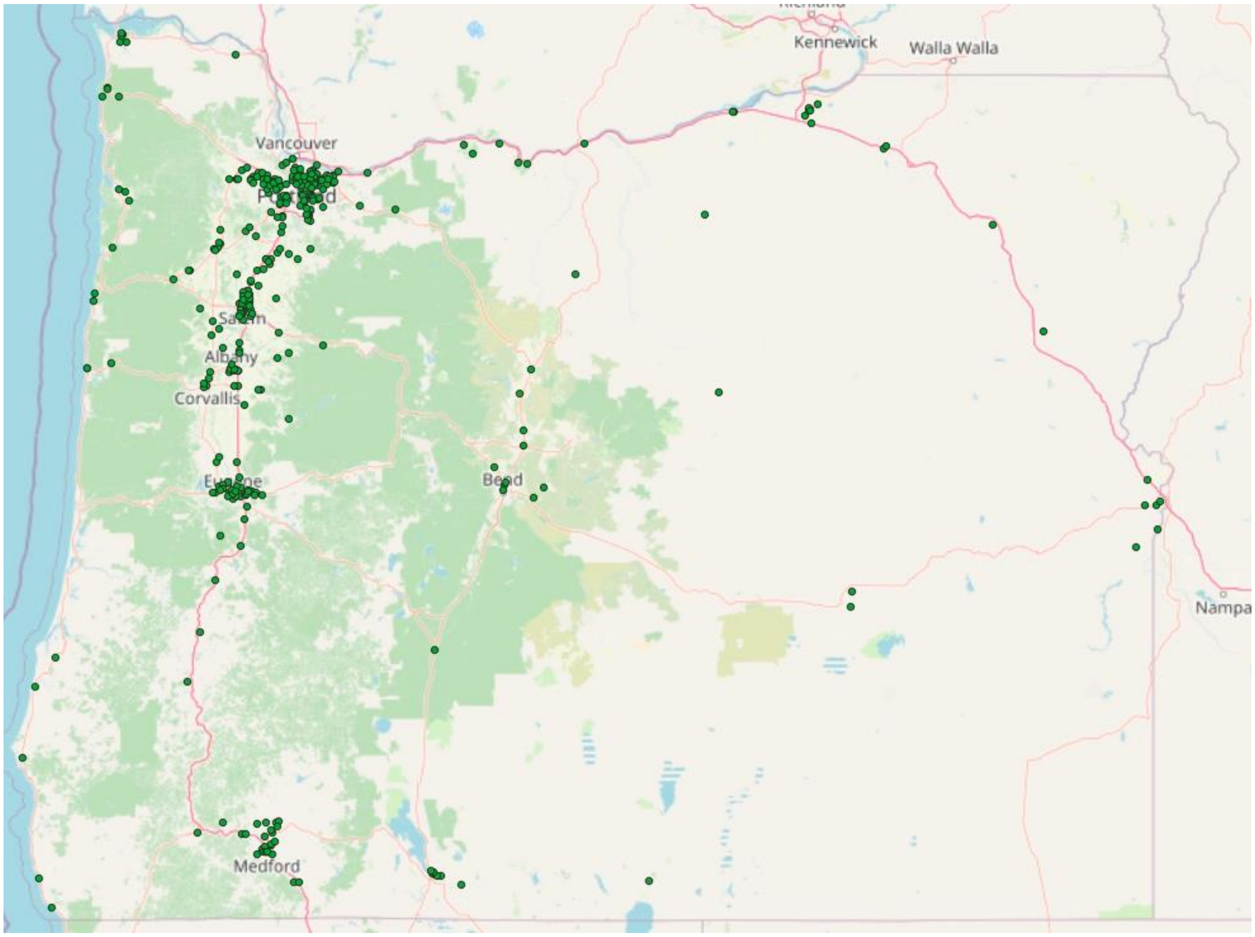

Figure A3 – Derived Crash data for 2019

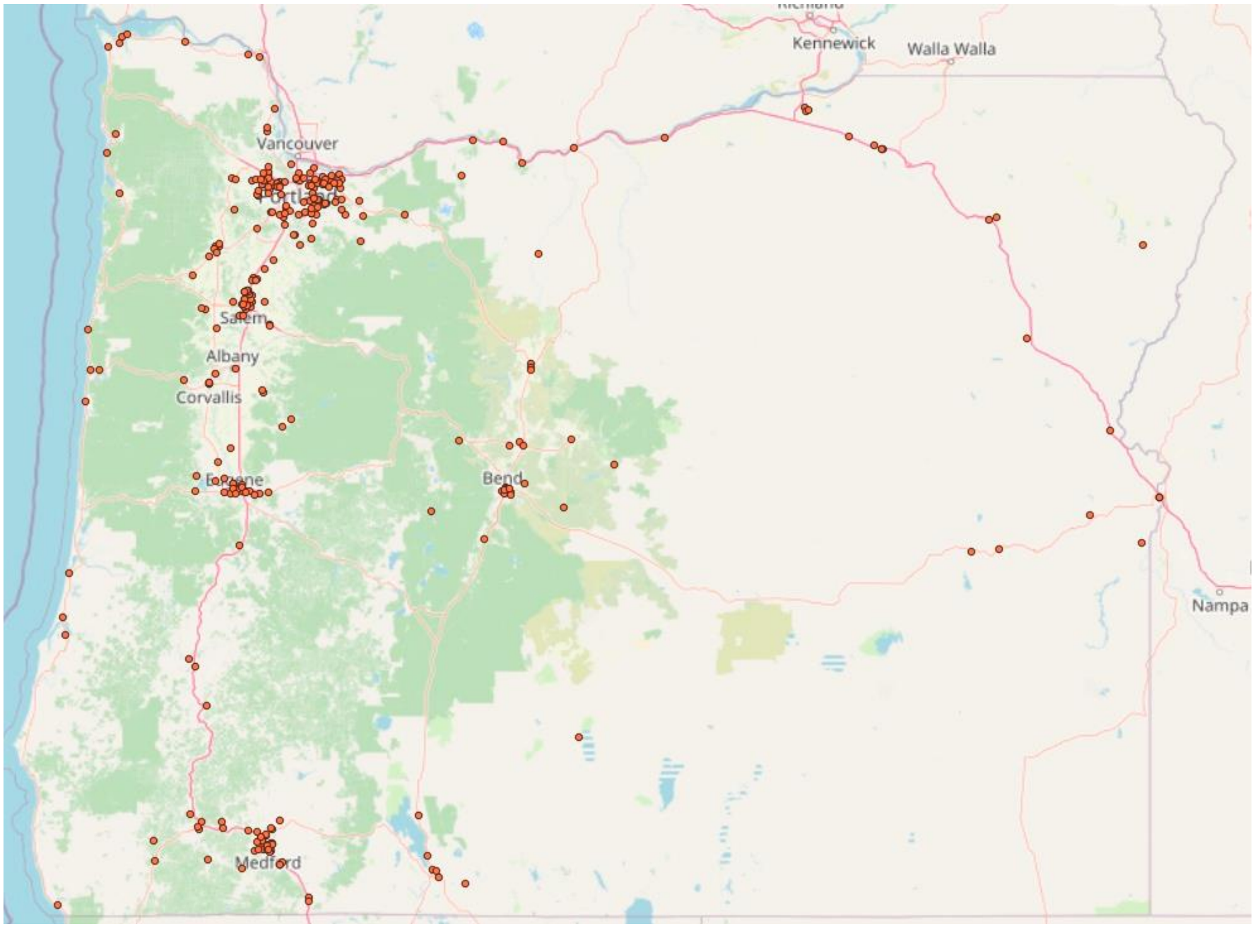

Figure A4 – Derived Crash data for 2020