

Influence of Street Trees on Frequency of Vehicle Collisions in Seattle

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A thesis

submitted in partial fulfilment of the  
requirements for the degree of

Master of Urban Planning

University of Washington

2023

Committee

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Program Authorized to Offer Degree:

Urban Design and Planning

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**Abstract**

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This thesis explores the correlation between street trees and motor vehicle crash frequency in Seattle, WA, focusing on the implications for livability and safety. While previous literature initially suggests a potential negative relationship between trees and crashes, the present study finds no significant correlation in the case study area of Seattle. Additionally, the study highlights the complexity of the relationship between trees and crash frequency at the census block level. It is likely that factors like tree placement, density, and proximity to roadways play a significant role in influencing this relationship. Therefore, it is recommended that to better understand this observation, other factors such as driver behavior, road design, and traffic patterns must also be considered, as they may overshadow the influence of street trees. A comprehensive analysis incorporating these variables is necessary for more definitive conclusions.

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## Chapter 1. INTRODUCTION

The built environment and the natural world are not often spoken of as having much in common, instead many imagine cities as hardscaped places wholly separate from nature. While this sentiment may be accurate for some cities, others on the other hand proudly boast about the extent of greenery throughout their urban neighborhoods – Chicago, nicknamed “The City in a Garden” due to its extensive public park system, and Atlanta, known as “The City in a Forest” due to its nearly 50% tree coverage, serve as excellent examples of places which have famously integrated urban development with their natural environment and market themselves as such. These municipalities know that it was dreams of leafy streets and green gardens that contributed to the desire of millions of American homebuyers to relocate to the suburbs over the course of the twentieth century. Ebenezer Howard, founding father of the Garden City movement, precursor to said era of suburbanization, postulated that urbanites could be liberated from the blight of the nineteenth century’s industrial cities through relocation to new towns developed along expansive rural belts of forest and agricultural land ringing pre-existing cities. The point being that integration of the natural realm with the urban realm has historically been an ambition of urbanists and city boosters to elevate a place’s perception of livability; a notion put to the test in a 2003 study that surveyed a population representative of American racial and class demographics, finding that images of tree-lined roadways were judged more favorable than roadways devoid of trees (Wolf, 2003).

The urban tree canopy contributes to a city’s livability for a variety of reasons. It has been shown to reduce the urban heat island effect, contribute to local biodiversity, mitigate the impacts of storm water runoff, increase property values, provide mental health benefits, and add

aesthetic qualities to the public realm (Wolf et al., 2020; Kadir & Othman, 2012). Municipal leaders of Seattle, WA, “The Emerald City,” have acknowledged as much and have committed to increasing the city’s tree cover to 30% by 2037 (Office of Sustainability & Environment, 2023). Unfortunately, the city has found this to be a challenge difficult to overcome despite the plethora of motivating benefits that would be realized by growing the urban tree canopy, and instead it has shrunk each year between 2019 and 2022. Perhaps Seattle could begin to find success in increasing the urban tree canopy if it were tied to another of the city’s explicit policy goals – to eliminate traffic-related injuries and fatalities from city streets by 2030.

## 1.1 RESEARCH INTENT, HYPOTHESIS, AND QUESTIONS

This thesis will investigate the influence of street trees on traffic safety outcomes, review the efforts of the City of Seattle to increase Seattle’s urban tree canopy and reduce the frequency of traffic-related fatalities and injury on city streets. Doing so will rely on vehicle collision reports provided by the Washington State Patrol (WSP) and Seattle Department of Transportation (SDOT), and urban tree inventory provided by the City of Seattle. Using this data, the research will identify and analyze the relationship between multiple variables related to traffic safety outcomes in order to uncover correlations and relationships between the frequency of vehicle collisions and the extent of the urban tree canopy in Seattle.

The inspiration for this research comes from the notion of “visual friction,” an urban design concept that refers to the intentional placement of elements in the public right of way that produce visual cues that result in a slowing of vehicle traffic and an increase in safety while likewise contributing to a more enjoyable public realm. Trees themselves are a form of visual friction, but published research on design techniques to influence traffic safety primarily examine broader urban design strategies that feature numerous contributing elements such as

textured and colored paving, raised pedestrian crossings, and other varieties of street furniture and design elements, rather than analyze the effectiveness of any one design element, therefore the goal of this research will be to identify the effectiveness of street trees by themselves as a design intervention to improve traffic safety, thereby contributing insights that may support local planning efforts to grow Seattle's urban tree canopy and eliminate annual traffic-related death and injury. Of course, there are numerous additional variables which likely have a relationship with the frequency of collisions, one of which being the population density since a higher populations are going to coincide with more trips being generated and more potential for collisions to occur. As such, this thesis will also determine if population density has an effect on the presence of a relationship between street trees and collisions.

- *Research Question 1:* Is there a relationship between the presence of street trees and traffic safety?
- *Hypothesis 1:* There is a negative relationship between the presence of street trees and the frequency of vehicle collisions.
- *Research Question 2:* Does population density affect possible relationships between street trees and vehicle collisions?
- *Hypothesis 2:* Population density has a negative relationship with the density of street trees and a positive relationship with collisions, therefore it is confounding the relationship between street trees and vehicle collisions.

## Chapter 2. LITERATURE REVIEW

### 2.1 URBAN DESIGN AND VISION ZERO

It can never be ethically acceptable that people are killed or seriously injured when moving within the roadway transport system. This is the guiding principle of Vision Zero, the initiative to entirely eliminate traffic-related death and injury. First officially adopted by the Swedish Parliament in 1997, dozens of national and subnational public decision-making bodies have since followed suit as the number of annual traffic-related deaths has grown to 1.35 million globally, emerging as the leading cause of death for people ages 5 to 29 (World Health Organization, 2018). Meanwhile, In the United States, the National Highway Traffic Safety Administration estimated that 42,915 Americans died in motor vehicle traffic crashes in 2021, the deadliest year on record since 2005 (NHTSA, 2022). In Washington State, 745 people were killed in motor vehicle traffic crashes in 2022, the highest number since 1990, while Seattle led Washington cities with 36 traffic-related deaths that year, contributing to an overall upward trend in traffic related deaths in the city since SDOT's official launch of its Vision Zero program in 2015 (Fry, 2023). Despite these bleak statistics, the silver lining is that each and every one of these traffic-related deaths are entirely preventable, but prevention may require alterations to the design approach of the public right of way to prioritize road safety over vehicle speed and throughput.

Though traffic-related fatalities have grown to crisis levels globally, the variation in their distribution is significant. Nearly 90% of traffic-related fatalities occur in low- and middle-income countries, few of which have adopted a policy of Vision Zero and where the development of road transport infrastructure has often prioritized facilitating economic growth over addressing safety concerns (Wegman, 2017). Researchers examining the Nairobi-Thika

Road in Kenya found that improvements to this highway linking Nairobi to Somalia enabling driving speeds of 100 kilometers per hour has enabled greater regional trade but has resulted in speeding and careless driving emerging as the leading cause of crashes (Gichaga, 2017). In developed economies however, particularly those of Northern Europe which are host to matured urban environments and diversified systems of mobility, successful implementation of Vision Zero has been achieved. Oslo, Norway's capitol and a city of comparable population and geography to Seattle, committed to Vision Zero in 2015, the same year that Seattle did, but unlike Seattle, Oslo has consistently seen years in which zero traffic-related deaths were recorded while Seattle cannot say the same. Among the strategies Oslo adopted to reach its traffic safety goals were changes to traffic enforcement, investment into more frequent transit service, reduction of speed limits, but most importantly, made changes to the design of the public right of way (Hartmann & Abel, 2020).

The City of Oslo has now joined a cohort of national and subnational governments who have likewise achieved Vision Zero through a strategy of adapting the design of roadways to accommodate the inherent capabilities and limitations of human beings, attributing the primary cause of crashes to the design characteristics of the roadway which a crash has occurred on rather than attributing the cause of crashes to risky driving behavior or simply 'bad luck', as has historically been the case (Hagenzieker et al., 2014) Oslo, and other cities seeing zero annual traffic deaths, redesigned their streets in such a way that portions of the city now completely exclude cars all together, and where cars do remain allowed, general purpose travel lanes have been thinned and reduced, sidewalks widened, and multi-modal travel facilities introduced (Hartmann & Abel, 2020). Overall, these strategies are indicative of a broader sea change from

understanding the right of way as a place to facilitate vehicle travel to one in which people can simply exist.

With that said, what has been the Seattle approach to Vision Zero, and where is it finding its successes and failures? Though the city has been proactive in enacting changes to its approach to traffic enforcement, reduced speed limits citywide, and contributed funding to expand local transit service just like Oslo did, the ambitious design changes of the variety that led to quick Vision Zero success elsewhere have only been implemented in a handful of corridors in Seattle. Until more roads and arterials in Seattle can be brought up to Vision Zero design standards, the majority of Seattle's streets, like those of many American cities, will continue to feature the same design philosophies born from the 1966 Congressional road safety hearings that were standardized in the American Association of State Highway Officials' roads and highways design guidelines, and adhering to which are preventing Seattle from reaching Vision Zero; more on this in the next section. This is all to say that the right of way design, more so than any other factor, has the greatest effect on roadway safety outcomes, as was elucidated by Dr. Eric Dumbaugh in his piece, *Safe Streets, Livable Streets* (2005). Dumbaugh explains, "[positive design] recognizes that drivers use the total information provided by their environment – not just posted speed limits – and strives to take advantage of these opportunities to provide drivers with the information they need to operate their vehicles safely and appropriately". In other words, roadways that successfully signal to drivers to engage in safe driving behavior that is appropriate for the urban context they find themselves in will heavily feature safety-based design elements. While the definition of "livability" may be subjective, safe design can be considered as such because it prevents traffic-related death and injury, while just so happening to enable perceptions of comfort among pedestrians.

## 2.2 AASHTO'S GREEN BOOK

The American Association of State Highway and Transportation Officials, formerly just the American Association of State Highway Officials, is a non-governmental, transportation research and standards setting organization that publishes protocols, guidelines, and specifications that contribute guidance on the design of roads and highways throughout the United States. Despite being a non-governmental organization, its voting membership consists of the department of transportation for every U.S. state, and its roads and highways design standards publication, *A Policy on Geometric Design of Highways and Streets*, also known as “The Green Book,” is a highly influential guide for the coordination of the standard design of transportation infrastructure among each of the U.S. states.

In 1966 the United States Congress held a series of hearings in regard to roadway safety, which contributed to much of the enduring roadway design philosophy that has continued to be published in AASHTO's most recent edition of the green book, which was published in 2018. These hearings featured the influential testimony of, among others, General Motors engineers. Said testimony was characterized by three recommendations to improve road safety in the United States: access management, one-way traffic, and reduced roadside obstacles. The value of this third recommendation, reduced roadside obstacles, is what this thesis will be investigating. These recommendations were devised based on the observations made at the GM Proving Ground, an expansive vehicle test track facility characterized by limited-access, freeway-like test tracks. One engineer's testimony reading that, “This is the real transportation problem that remains to be approached. What we must do is to operate the 90% or more of our surface streets just as we do our freeways... [converting] the surface highway and street network to freeway and Proving Ground road and roadside conditions” (Marshall et al., 2018). These hearings, and the testimony

therein, directly led to the inception of the “clear zone” concept, the area of the roadside in which fixed-object hazards, such as street trees, are explicitly minimized, or eliminated when possible. The exact design of clear zones is situational and project-specific, but a common trait of clear zones is they serve as an unobstructed area along the roadside that can safely accommodate a parked vehicle with its doors open. The function of a clear zone is to allow a drifting vehicle adequate room to maneuver back to the driving lane or to safely come to a complete stop.

### 2.3 CLEAR ZONES

Less than 1% of vehicle crashes in the United States that occur on urban streets involve a tree, but trees are nevertheless categorized as “fixed roadside hazards”(Bratton & Wolf, 2005). Trees are considered traffic hazards by AASHTO because they are “fixed” roadside objects that provide little or no cushioning effect to colliding vehicles and therefore have the potential to increase the severity of crashes should they occur. In an urban context however, under the absence of street trees, what would these vehicles have collided with instead? Perhaps pedestrians who would have otherwise been shielded by street trees and structures that would similarly be unable to provide a cushioning effect to colliding vehicles, and therefore lead to similar outcomes as that of a collision with a street tree but now with the added possibility of pedestrian death and injury and greater property damage. Street trees, in this way, act much like bollards do, and just as bollards are not typically regarded as the cause of a collision, perhaps neither should trees be.

The clear zone concept has stood as a commonplace design element of road safety programs in the United States for more than half a century, but mounting scholarship is beginning to cast doubts on to the concept’s purported improved safety outcomes and its appropriateness in urban contexts. The intent behind the clear zone is that it will broaden sight lines for drivers and

therefore improve drivers' understanding of their surroundings and anticipate oncoming hazards. However, this may in fact be having the opposite effect; by expanding driver sightlines, clear zones may in fact be giving drivers a false sense of security, leading to an increase in risky driving behaviors, such as speeding, and thereby increasing crash risk (Wolf, 2006). This would be a similar effect to that seen by the variation of widths of driving lanes between those of local roads and controlled-access highways; where controlled-access highways feature wide lanes meant to encourage fast driving speeds and local roads often feature narrow lanes meant to discourage speeding. Just as the variation of lane widths effect driver behavior by playing on driver comfort levels, so to do trees.

## 2.4 VISUAL FRICTION

While the clear zone concept is predicated on the notion that enhanced sightlines should lead to positive traffic safety outcomes, its antithesis, visual friction, instead serves as the suggestion that diminished sightlines should have a stifling effect on unsafe driving behavior because right of way design that emphasizes elements of visual friction tends to imbue drivers with a sense of discomfort, resulting in slower speeds and positive safety outcomes. A 2020 study on the effect of built environment characteristics on driver attention appears to confirm as much, "Trees that are aligned along the roadway in a linear fashion, creating a visual wall or barrier on the side of the roadway ... elicited increased driver attention" (Tice et al., 2020). The study would also go on to identify that elements such as on-street parking, narrow lane widths and the presence of driveways all resulted in drivers slowing their driving speeds, and the researchers recommended that municipalities introduce these elements, but to do so in a strategic way, such as placing trees in a linear fashion, so it creates a wall of sorts that makes the street feel enclosed from a driver's perspective.

## 2.5 STREET TREES AND DRIVER SAFETY

While street trees fail to provide a cushioning effect that would reduce the severity of vehicle collisions, they are able to reduce the severity of vehicle collisions through other means. The arching tree canopy of a tree lined street has been shown to have a traffic calming effect similar to that of visual friction, thereby reducing higher speed driving and improving driver awareness (Wolf, 2006). Of course, street trees do present obstructions to sightlines for drivers that may present challenges at intersections, but Ewing and Dumbaugh note that this may not be the case for all roadways and that the value of clear zones is different for slow-speed urban streets compared to high-speed rural roads (Ewing & Dumbaugh, 2009). In fact, Chen et al. argues that when trees are deemed the cause of vehicle crashes, it is the fault of poor tree maintenance rather than the presence of trees themselves (Chen et al., 2016).

## 2.6 STREET TREES AND PEDESTRIAN AND BICYCLIST SAFETY

The presence of street trees can provide shading to sidewalks, reduce stress levels, and accommodate urban wildlife like birds and squirrels; therefore, it should come as no surprise that tree-lined streets generate greater amounts of pedestrian travel than streets without street trees because they are generally perceived to be more enjoyable places to be (Nehme et al., 2016). The density of the urban tree canopy has also been positively associated with pedestrian travel because the presence of street trees contributes to an increased perception of safety among pedestrians, in addition to outright increases to safety outcomes (Chester et al., 2015) A study that examined the relationship between street trees and pedestrian safety in the central business district of Melbourne, Australia uncovered a negative association between street trees and pedestrian safety (Zhu et al.,

2016). This has similarly been found to be the case with bicycle route preference, with street trees been found to be positively associated with bicycle route preference; but this association, however, should not be regarded as being as strong as that of the association between pedestrian route preference and street trees because commuters who commute to work by bike value route efficiency over the comfort provided by street trees, unlike leisure cyclists and cyclists overall. Likewise, cycle routes that prominently featured street trees whose tree maintenance was lacking, and therefore overgrown branches and roots presented obstructions to bicycle travel, tend to be avoided (Nawrath et al., 2019).

## 2.7 SEATTLE VISION ZERO TOP TO BOTTOM REVIEW

As noted previously, the incidence of death and serious injury on Seattle's roads has trended upward in recent years, meaning that overall, the interventions by the SDOT, the agency charged with carrying out the city's vision zero program, have generally failed to achieve the city's safety goals. In September of 2022, the newly appointed SDOT director, Gregg Spotts, ordered a review of the agency's vision zero efforts to uncover why the agency's safety interventions and programs have failed to reduce the number of injurious and deadly crashes in Seattle.

The report expressed that given the trends of previous years, SDOT projects that fatalities among motor vehicle drivers will reduce slightly over time, but overall fatalities will noticeably rise to 35 deaths per year by 2030, with cyclist deaths rising slightly and pedestrian deaths accounting for the majority of traffic-related fatalities (Seattle Department of Transportation, 2023). This poses an existential crisis for the city's efforts to cultivate walkable places that people arrive to by other means than private vehicle; but this also follows national trends, particularly since the beginning of the CoVid-19 pandemic, in which incidence of death and

injury have diverged between people inside vehicles and people outside them. The report goes on to note that the United States is something of an outlier in this regard. Of the 31 wealthy countries examined, 27 saw traffic-related deaths decrease since the beginning of the pandemic, 1 experienced no significant change, while deaths rose by 2% in Ireland, 5% in Switzerland, and 5% in the United States. While bucking national trends may be a challenging undertaking, some American cities have seen Vision Zero success, nonetheless, indicating that municipalities can still devise methods to improve safety despite challenges at the national level.

SDOT anchors its approach to vision zero through three guiding frameworks. Through community input and collaboration from historically underrepresented and marginalized groups, SDOT created the Transportation Equity Framework, a guide to ensure that SDOT's vision zero work addresses historic inequities.

Likewise, SDOT looks to the Safe System Approach to develop vision zero projects and programs. The Safe System Approach echoes many of the principles of vision zero: that humans are vulnerable and prone to mistakes, that safety is paramount in all pieces of the overall transportation system, safety improvements must be proactive rather than reactive, and that the onus of responsibility falls to stakeholders to the transportation system. Implementation of the Safe System Approach, as recommended by the US Department of Transportation, should be guided by the following principles: Safer behavior, from both drivers, as well as non-drivers, safer vehicles, safer speeds, safer roads, and enhanced post-crash care. SDOT is not able to affect all of these principles, for example, regulation of the design of vehicles falls to the federal government, therefore 'safer vehicles' is not within the purview of SDOT, and enhanced post-crash care is largely the domain of emergency rooms and trauma centers, but SDOT and the city can contribute work on safer roads, speeds, and people through various means.

Finally, SDOT looks to the Center for Disease Control's Hierarchy of Controls, noting that traffic-related fatalities are a public health threat. While SDOT recognizes that vehicles serve important, or sometimes essential roles for many people as well as our region's broader economy, under the Hierarchy of Controls, SDOT likewise recognizes that vehicles pose an inherent safety risk to non-drivers and that the most effective means by which to reduce that safety risk is to eliminate vehicles all together and provide mobility substitutions. SDOT, however, has taken the stance that elimination of hazard and introduction of travel substitutions is not within their authority, and instead focus primarily on lower tier strategies within the hierarchy of controls: engineering controls – street design, and administrative controls – speed limits and enforcement. With the knowledge that Oslo found safety success by eliminating personal vehicles from the city's urban core and introduced travel substitutions in the form of more frequent and reliable public transit and safer bike lanes, SDOT's approach may not be able to ever prevent deadly and injurious outcomes.

While the frameworks that guide SDOT's work present a mixed bag, the agency's analysis of the city's existing conditions and the policies, projects, and programs it's developed under these conditions provides a closer look into why safety continues to elude Seattle. SDOT's dedicated vision zero team is appropriately located in the agency's Project Development Division, the division dedicated to developing conceptual designs based on the projects prioritized by the city's various modal master plans, but while the Project Development Division may house the vision zero team, the Vision Zero Top to Bottom Review makes clear that vision zero is an inter-divisional value and is typically carried out via coordination between various teams and workgroups. The report also goes on to list some of the actions SDOT has taken

toward vision zero, some effective, such as restricting right turns during red lights at various intersections, and others less effective, such as posting reduce speed limit signage across the city.

Important statistics of note laid out by the Vision Zero Review Report include the finding that between 2015 and 2022 93% of pedestrian fatalities occur on arterial roadways and that 80% of said fatalities occurred on multi-lane, bi-directional arterials. Furthermore, SDOT has also determined that during that same time period, 80% of killed cyclists were killed where no cycling-supportive facilities exist (Seattle Department of Transportation, 2023). These findings are consistent with the prevailing body of literature on transportation safety, that high-speed roadways, particularly ones devoid of multi-modal supportive facilities, produce almost all traffic-related death and injury (Ziakopoulos & Yannis, 2020). With this in mind, SDOT was able to map out a high-Injury network (HIN) in order to determine the locations of priority investments, a tactic the Vision Zero Network, a U.S.-based non-profit committed to advancing vision zero, advocates for. The HIN SDOT developed identifies the Rainier Valley, home to historically under-invested-in BIPOC communities, North Seattle, historically a more recent area to be developed and annexed into the city of Seattle and where much of which has yet to receive investment into sidewalks, and Downtown Seattle, the area with the region's highest vehicle counts and incidence of reported crashes. In developing the HIN that SDOT uses to prioritize investments, SDOT relies on data provided by the Seattle Department of Police, which leaves out an unknown number of unreported crashes, and therefore the data SDOT relies on serves as a presumed undercount of actual fatal and injurious incidences.

In addition to identifying corridors of prioritized investment, SDOT uses data to uncover the demographics that are most at risk of being the victims of deadly or injurious traffic crashes. The demographics SDOT is prioritizing investment toward are the unhoused population of

Seattle, who in 2021 made up 27% of people killed in traffic related accidents, up from 13% in 2016, as well as people walking, biking, and rolling, who were involved in 7% of total collisions but comprise 61% of fatalities (Seattle Department of Transportation, 2023). The Vision Zero Top to Bottom Review goes on to note that historically disadvantaged communities, children, seniors and people with disabilities are all uniquely vulnerable users of the right of way and are therefore inform priority safety investment by SDOT.

SDOT's vision zero review concludes with a series of recommendations SDOT should consider in order to reverse the concerning upward trends in traffic-related death and injury in Seattle. Despite the expressed prioritization of safety outlined throughout the vision zero review, the recommendations section speaks to what SDOT has yet to include in its approach to safety, indicating that significant safety blind spots exist in SDOT's project development and delivery. The review recommends a greater adherence to safety as a priority across all projects, clearer safety guidance, and acceleration of planning for safety enhancement projects at the system-wide level. Furthermore, the review recommends strengthening internal support for vision zero and for SDOT to serve as a stronger advocate for safety in the agency's partnerships with other local institutional stakeholders. These recommendations imply that, as it stands, vision zero is not central to project design and delivery in practice and may provide evidence as to why SDOT investments have failed to diminish or eliminate traffic related death and injury in Seattle.

## 2.8 CITY OF SEATTLE TREE CANOPY ASSESSMENT 2021

As previously noted, street trees have been proven to calm traffic and produce greater safety outcomes in addition to their many quality of life benefits their presence contributes to communities. Acknowledging these many beneficial characteristics of the city of Seattle has been tracking the extent of the coverage of Seattle's urban tree canopy in order to better

comprehend the prevailing context of trees in Seattle. Just as traffic-related deaths and injury in Seattle have continued to grow, Seattle has likewise witnessed a diminishment of the city's urban canopy despite an expressed policy of growing the city's tree canopy. In 2023 the city released its assessment of Seattle's tree canopy in 2021, outlining the city's vision for Seattle's urban forest, identifying the extent and health of the urban canopy, determining why the canopy has failed to grow, and providing recommendations for reversing this trend.

The assessment outlines that in 2021 Seattle's tree canopy cover was 28.1%, a loss of .5% from 28.6% in 2016, or a net loss of 255 acres of canopy since 2016. This loss, while not immediately alarming on its face, is not occurring equally across Seattle. Similarly, to the increase in traffic deaths and injuries, tree canopy loss occurred at a greater rate in areas of Seattle that have been historically under-invested in and whose residents have historically faced marginalization (Office of Sustainability & Environment, 2023). Furthermore, the assessment team also uncovered that since 2016, Seattle lost 1,790 acres of tree cover but also gained 1,534 acres of tree coverage, this is of concern because the variable loss and gain in trees frustrates Seattle's broader vision of growing into a more equitable city saturated with nature.

Seattle's goal is to equitably grow its tree canopy to cover 30% of the city by 2037, but challenges lay ahead to achieve that vision. Climate change is already resulting in hotter and drier summers, increasing canopy maintenance costs and stressing the health of the existing canopy, while Seattle's population is projected to continue to grow at staggering rates, resulting in the removal of trees to make room for housing and infrastructure. According to the assessment, the lost 255 acres of canopy could have stored hundreds of thousands of pounds of carbon while simultaneously store millions of gallons of water and trap thousands of pounds of pollutants. The assessment also acknowledges that the public right of way alone constitutes 27%

of Seattle's land area, adding credence to the notion that tree planting efforts associated with safer road design may represent an untapped opportunity to grow the urban tree canopy while likewise reducing vehicle collisions.

According to the city's urban forestry staff, one of the most effective methods to grow the urban tree canopy is through protection and maintenance of maturing trees because this enables trees to naturally densify and spread over time. Unfortunately, municipal legislation in Seattle requires the replacement or replanting of uprooted trees but the regulatory landscape has yet to introduce mandates for the ongoing maintenance and protection of trees, which has been pointed to as one of the reasons why the urban tree canopy continues to diminish in Seattle (Office of Sustainability & Environment, 2023). Canopy losses, on the other hand, can be attributed to heat and drought driven stress, particularly in the face of climate change induced warming summers, non-native deciduous second-growth trees planted to replace the native old growth forest that was clear cut in the 1800's and which are now reaching the end of their natural lifespans, and ongoing tree removal to make space for infrastructure and housing development necessitated by Seattle's population and business growth.

The diminishment of Seattle's urban tree canopy, like the rise in traffic death and injury, is felt particularly acutely by communities facing historic and ongoing inequity. Areas of the city that have been subject to inequity are categorized by Seattle's Office of Sustainability and Environment as Environmental Justice Priority Areas; these areas are prioritized for investment in tree maintenance and planting efforts. Perhaps unsurprisingly, these areas also overlap with much of the HIN roadways identified by SDOT. In 2021 Environmental Justice Areas had 27% less urban canopy cover than the most advantaged areas of Seattle, with 25.3% and 33.2%

canopy cover respectively and witnessed a relative urban canopy reduction of -3.5% from 2016 to 2021 (Office of Sustainability & Environment, 2023).

The decline in the urban canopy may be the result of deficiencies in Seattle's integrated canopy management approach. In Seattle, there is no one department or agency in charge of growing and maintaining the city's tree canopy, instead stewardship is disseminated between a number of stakeholders, both public and private, but in the case of street trees, which contribute approximately a quarter (23%) of Seattle's urban canopy and the loss of which has accounted for 4% of city-wide losses between 2016 and 2021, they are the concurrent responsibility of the property owners nearest to them, SDOT, and Seattle Parks and Recreation.

Finally, the urban canopy assessment concludes with a number of recommendations to more successfully grow the city's tree canopy. Recommendations include the establishment of a dedicated canopy stewardship program, increase planting in publicly owned properties and the right of way, focus on planting trees uniquely suitable for Seattle's climate and conditions, align development needs with the needs of the urban canopy and increase funding for canopy maintenance effort.

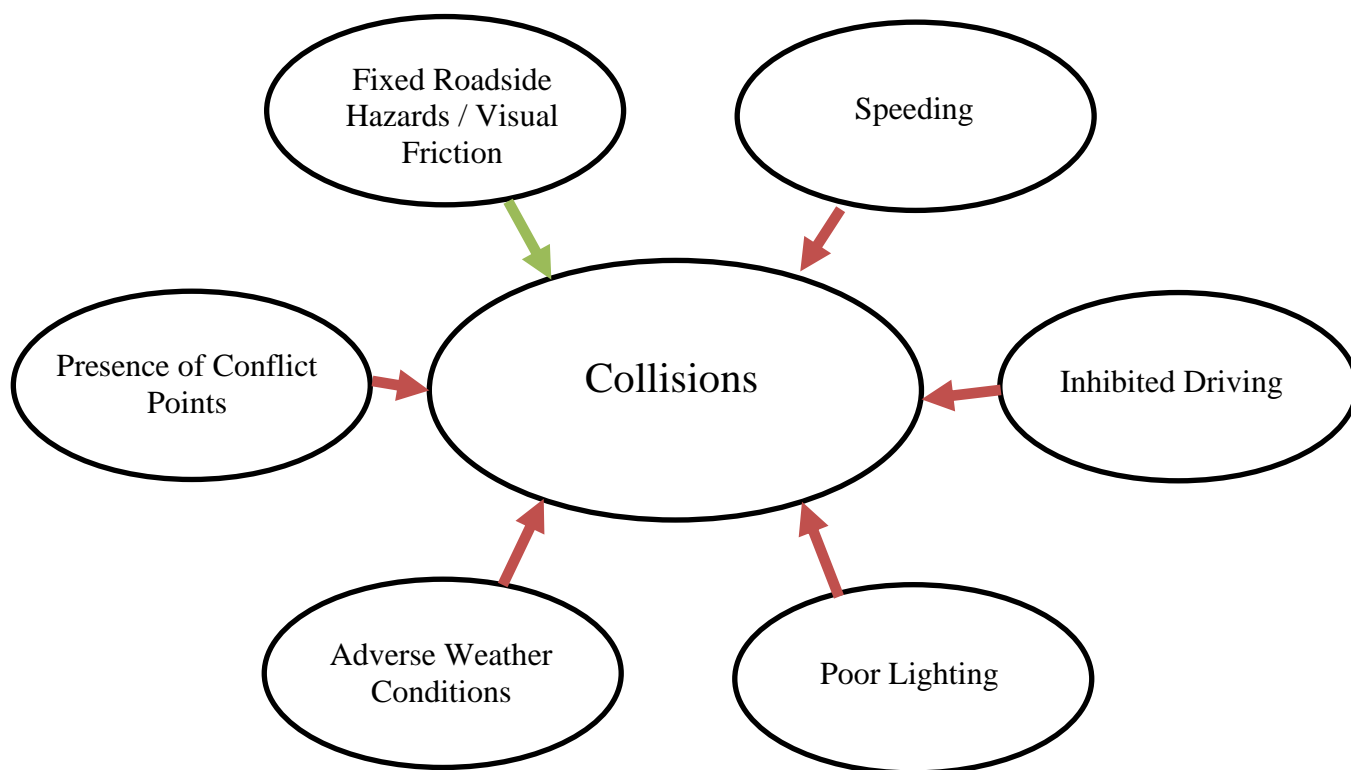
## Chapter 3. METHODS

This study will examine the relationship between street tree density and crash frequency in Seattle, Washington. Collision reports are a required element of this analysis because they are necessary in order to determine the location of collision incidences in relation to street trees. This data is available in varying detail from SDOT. Of course, another critical component to this thesis study is data on Seattle's urban tree canopy. There are various sources of data on this material, but the City of Seattle has commissioned several analyses of its urban tree canopy over various time periods, so municipal data from 2003 and 2016, two tracking periods from which the city has made data publicly available, were selected for this study. As reviewed previously, the City of Seattle has also published an assessment on the extent and health of Seattle's urban tree canopy, but at the time of writing has yet to publish the data on the 2021 urban tree canopy, therefore this study will only rely on urban street tree data for the years from which necessary data is available: 2003 and 2016. Furthermore, the years from which collision data was selected were 2004 and 2016. SDOT and WSP have a 20-year data retention period, and therefore collision data for 2003 is no longer publicly available. For the purposes of this study, it is assumed that the variation in the urban tree canopy between 2003 and 2004 experienced negligible variation, so 2003 urban tree canopy data has been associated with 2004 collision data.

One final note; in Washington State, under Revised Code of Washington (RCW) 46.52.030 all vehicle collisions that result in death, injury, or property damage in excess of \$1000 must be reported to the municipality or county in which the collision occurred. This study relies on data from SDOT, which obtained its data from WSP, the agency charged with recording such reports, and therefore the collision dataset utilized is the most comprehensive available. That said, it should

be acknowledged that it's entirely possible that an unknown number of collisions go unreported every year.

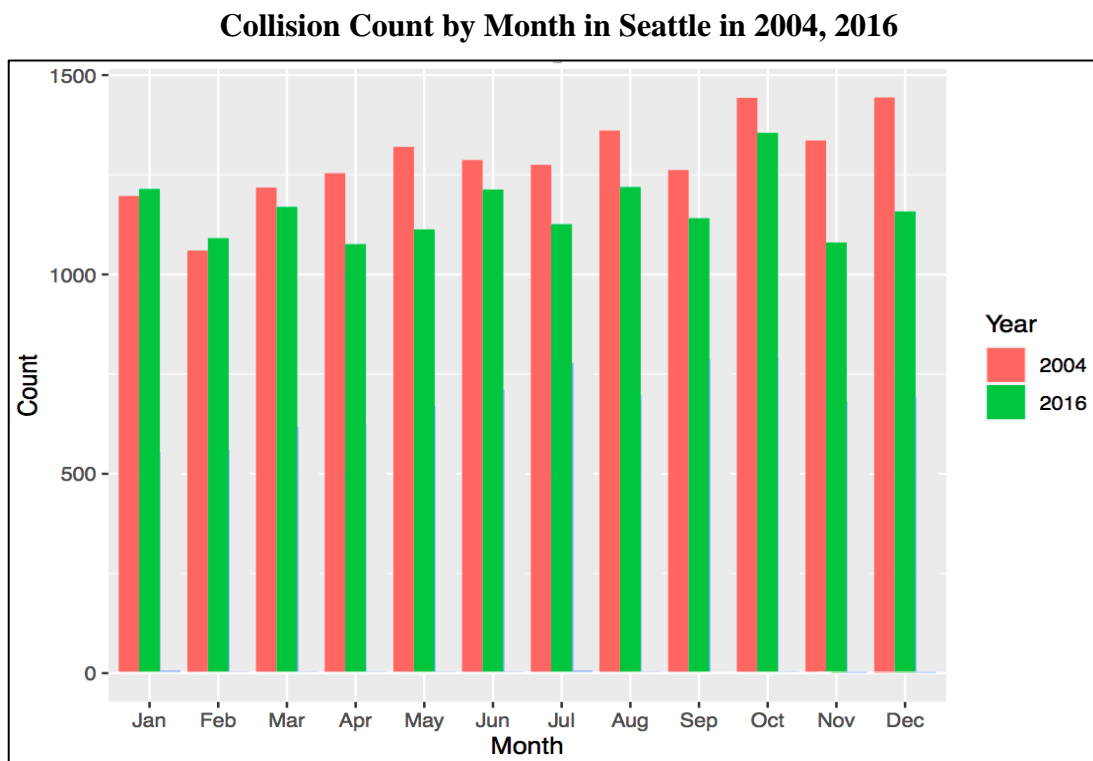
Please note that this thesis is examining the relationship between collisions and one of many possible contributing variables. The conceptual diagram below should help readers understand other possible variables which can play a role in causing collisions to occur. In the below diagram, street trees, as they relate to collisions, are examples of fixed roadside hazards and visual friction.



### 3.1 STUDY AREA AND DATA

Seattle, Washington was selected as the study area due to the availability of collision and canopy data, and for the relevance of this kind of study to ongoing municipal efforts to develop a safer, greener city. The unit of analysis is the boundaries of Seattle's census tracts used in the 2020 census. Urban tree canopy coverage for the years 2003 and 2016 were restricted to coverage only within the public right of way in order to isolate the effects of street trees from the overall urban canopy, which were then mapped and analyzed.

Initial Seattle collision analysis reveals a relatively uniform distribution of city-wide collision frequency over the twelve-month periods from 2004 and 2016, with the greatest number of crashes occurring in December for 2004 and October for 2016 (Figure 1). Due to the uniform distribution of collisions, seasonal influences will not be included in this analysis. Furthermore, keep in mind that while overall city-wide *collisions* diminished between each of the study years, the number of traffic-related *fatalities and injuries* increased between each study year, indicating that while total reported crashes may have fallen, those that do continue to occur have become more severe. Finally, traffic counts were not included in this study due to limitations in data availability

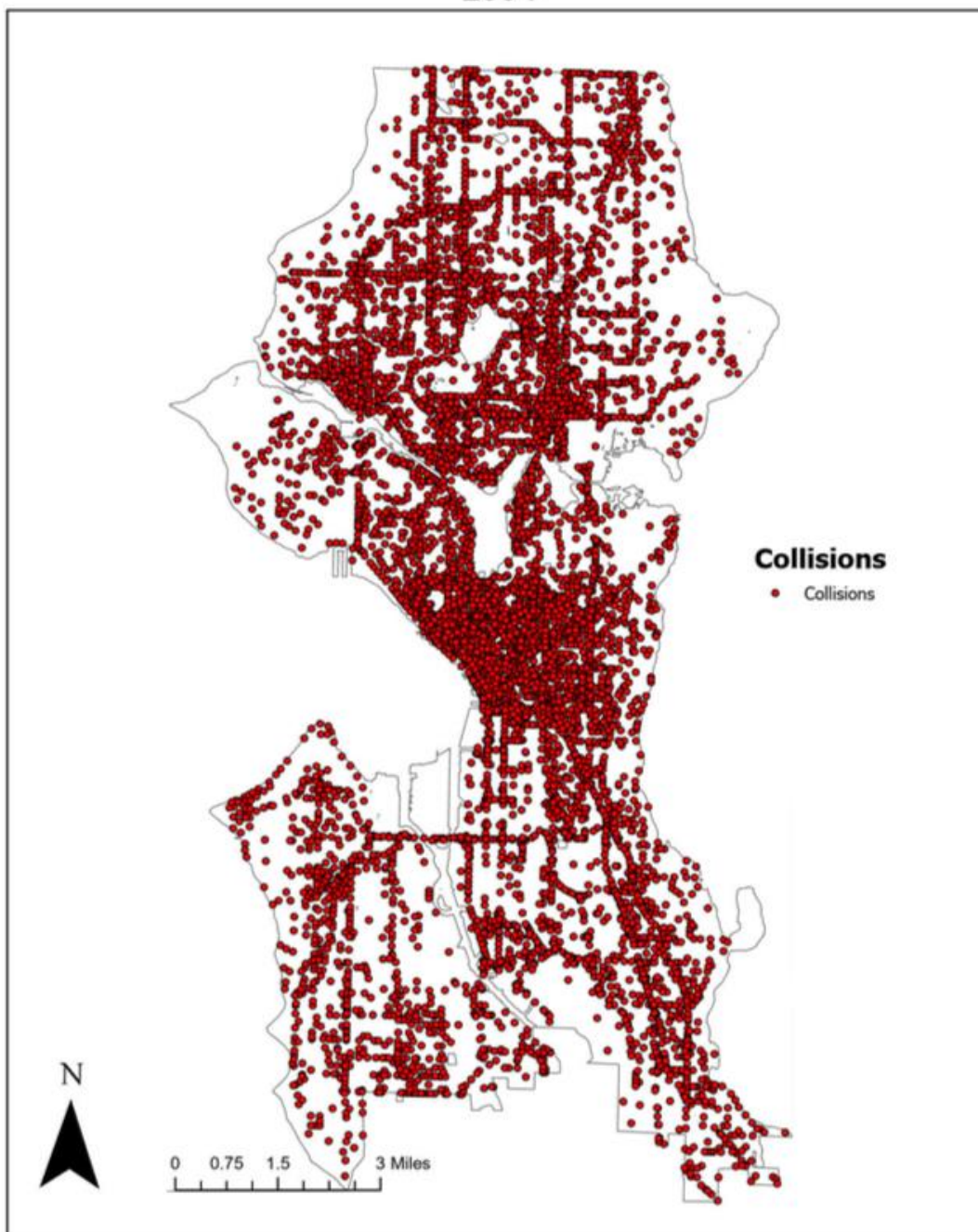


*Figure 1 Collision Count by Month in Seattle in 2004, 2016*

While the temporal distribution of collisions in Seattle may be uniform, the spatial distribution is anything but. For each of the study years, the areas of Seattle which experienced the greatest number of collisions were the tracts that comprise the neighborhoods of Downtown Seattle and Capitol Hill as well as other notable neighborhoods like the University District, Ballard, and Fremont. These are areas of Seattle characterized by significant amounts of employment and multi-family residential and mixed-use structures and therefore have higher population densities than the rest of the city. Likewise, the tracts which experienced the least number of collisions are those that comprise the areas of Magnolia, Sodo, and areas of West Seattle such as Delridge. These are areas of Seattle whose urban fabric generally constitute single-family detached residences and are not near regional job centers and are therefore low density. This spatial distribution of collisions initially indicates that higher density areas are

associated with greater frequency in collisions. Figures 2 and 3 depict the distribution of collisions for each study year.

### Distribution of Motor Vehicle Collisions in Seattle 2004



*Figure 2 Distribution of Motor Vehicle Collisions in Seattle - 2004*

## Distribution of Street Trees in Seattle 2016



*Figure 3 Distribution of Motor Vehicle Collisions in Seattle - 2016*

The distribution of the street tree canopy meanwhile varies notably between each of the study years. Across each study year notable gaps in coverage persisted in Sodo, Interbay, and the Aurora Village area, but canopy growth appears to have occurred in Downtown, Ballard, and

Capitol Hill. Between 2004 and 2016 the overall street tree inventory shrunk by 1.6%. Figures 4 and 5 depict the distribution of Street Trees in Seattle in 2004 and 2016.

### Distribution of Street Trees in Seattle 2004

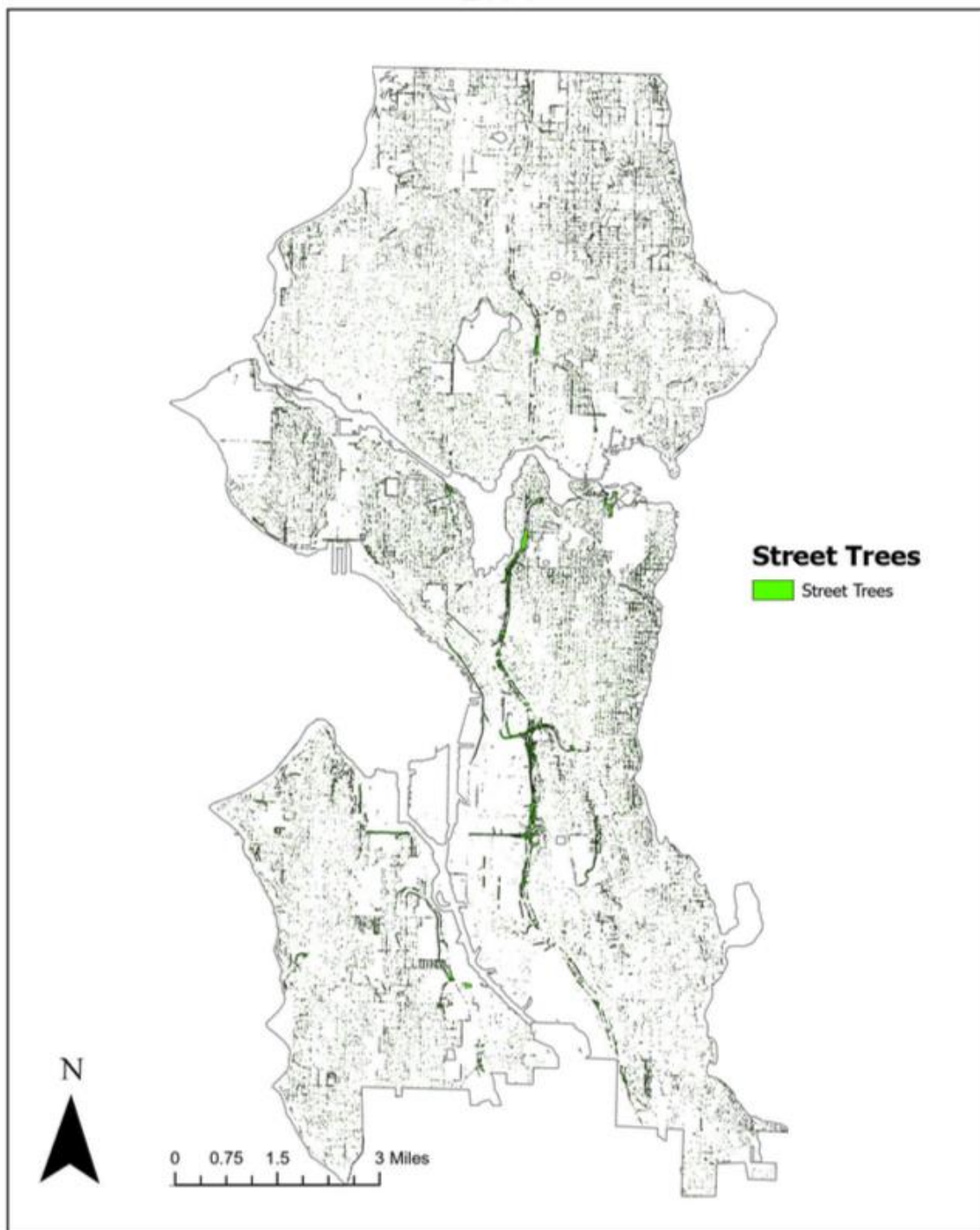


Figure 4 Distribution of Street Trees in Seattle - 2016

### Distribution of Street Trees in Seattle 2016

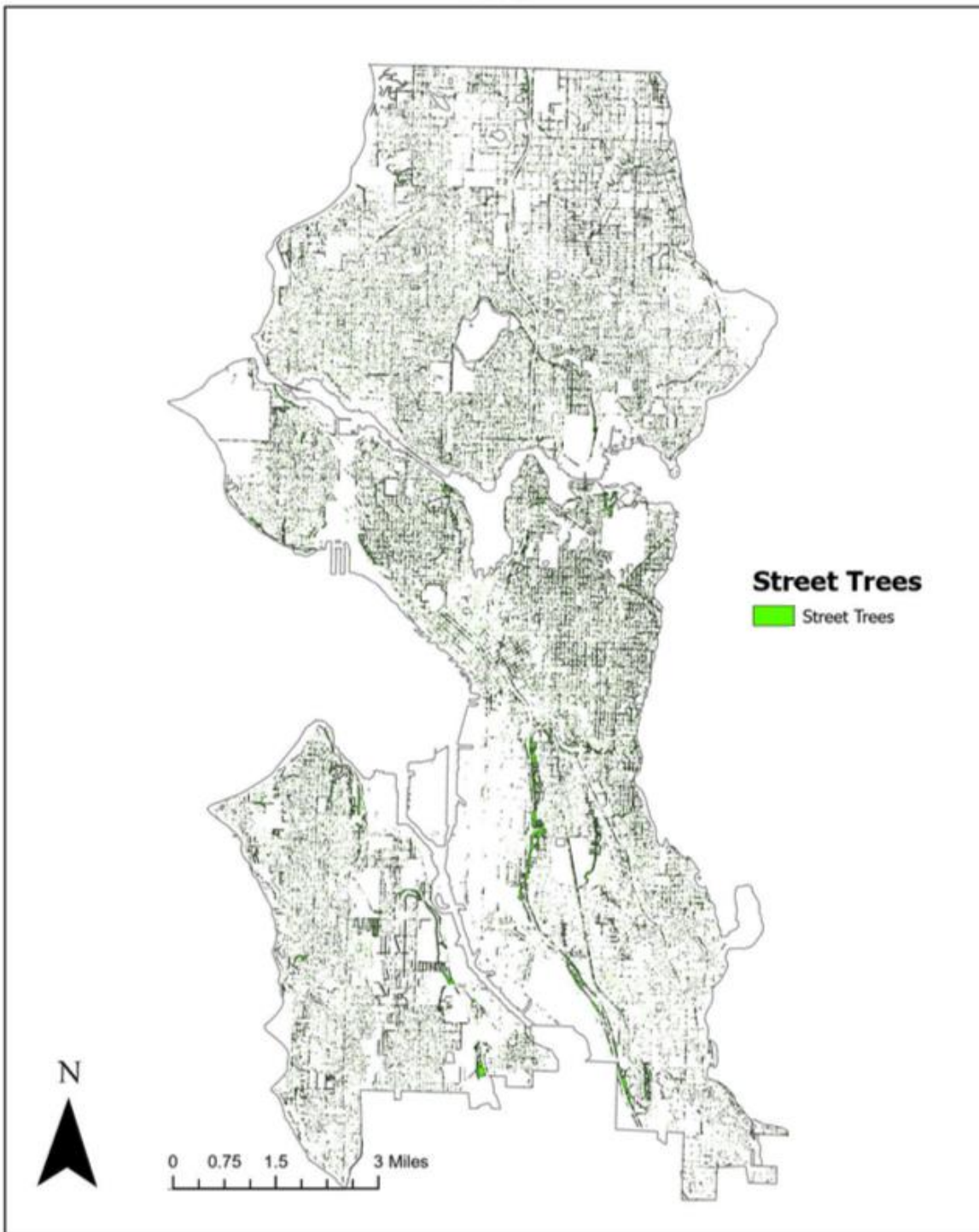


Figure 5 Distribution of Street Trees in Seattle - 2016

### 3.1 SPATIAL AND STATISTICAL ANALYSIS

Vehicle collision data and urban tree canopy data for the years of 2004 and 2016 was input into ArcGIS® using a World Geodetic System 1984 coordinate system to address the hypothesis that there is a negative relationship between the presence of street trees and the frequency of vehicle collisions. ArcGIS® was used to spatially visualize collision data, representing each collision with a red dot symbology and urban tree canopy data for each of the study years was displayed as green polygons which were developed from separate lidar surveys commissioned by the City of Seattle in separate assessments of the Seattle's urban tree canopy. The Seattle shoreline, census tracts, and municipal boundaries are denoted using a black polygon outline. The 'Intersect' tool in ArcGIS® was used on the urban tree canopy data and spatial data of the public right of way of Seattle, which was provided by the Washington State Geospatial Data Archive, to isolate trees in the public right of way from Seattle's overall urban tree canopy in order to account for only street tree influences in the statistical and spatial analysis of this study. This street tree layer was depicted in green polygons.

On initial inspection it appears that there may indeed be a relationship between the variables. The geographic clusters with the greatest density of collision occurrences in each of the study years – Downtown Seattle, The University District, and along Rainier Avenue in South Seattle – coincide with areas which also appear to have lower street tree cover relative to the rest of Seattle. The square footage in street tree coverage and collision counts for each year were tallied for each census tract in which they occurred/existed, but because this study is being conducted across two time periods, determining the change in each variable between each study year was also necessary. The unit of analysis of this study is the census tract level, but because the tracts vary both in land area and urban form characteristics the variables attributed to each

tract would need to be normalized based on aspects of each census tract. The square footage of street tree coverage per tract was divided by the overall land area of each tract in order to determine the percent of each tract covered by the street tree canopy while the collisions that occurred in each tract were divided by right of way mile in each tract in order to determine collisions per mile of each tract. Each tract was categorized by population density as a method by which to determine how “urban” each tract is. This was one method by which to determine if the relationship between street trees and vehicle collisions may also be impacted by the degree to which each tract is considered urban. Because the population density of each tract between the study years was subject to change, tracts were categorized by the change in density.

Finally, a local bivariate relationship analysis was conducted to identify a possible relationship between the count of collisions per right of way mile per census tract and the percent street tree cover per tract for each of the separate study years of 2004 and 2016 as well as for the change between the variables between each year. These analyses were conducted using ArcGIS® Pro’s “Local Bivariate Relationship” tool with a 90% level of confidence set as the confidence level. The dependent variable was set as the collisions per right of way mile per tract while the explanatory variable was set as the percent of each tract covered by street trees for the analyses of the 2004 and 2016 study years. An additional local bivariate relationship analysis was conducted to determine if the change in collisions per right of way mile per tract is related to the change in street tree coverage per tract, where the change in collisions per mile was set as the dependent variable and the change in street tree coverage was set as the explanatory variable

## Chapter 4. RESULTS AND DISCUSSION

Figure 6 depicts the type of relationship identified for each local neighborhood by the local bivariate relationship analysis for the year of 2004. While 22 out of 177 tracts in Seattle were shown to support the hypothesis that there is a negative relationship between street trees and collisions, the majority of Seattle's census tracts either supported the null hypothesis that there is no relationship between the variables or that the relationship between the variables is actually positive.

The tracts which were identified as having a positive relationship between the street tree canopy and vehicle collisions in 2004 were all located in West Seattle and Sodo, and each of these tracts had a population density below 20 people per acre. The tracts which had a negative relationship between street trees and collisions, on the other hand, were distributed across the city. They comprised much of the Central District, South Lake Union, and many of the southern portions of West Seattle. These Tracts, save for 2 of the 22 total whose bivariate relationship was negative, were also under a population density of 20 people per acre.

While the local bivariate relationship analysis that focused on only the study year of 2004 returned results which indicate a varied distribution of unique relationships between street trees and vehicle collisions across Seattle's census tracts, the local bivariate relationship analysis specific to the study year of 2016 identified no significant relationship between the variables across almost all of Seattle's census tracts, save for a few exceptions such as the tracts that comprise the Wallingford area and five tracts in the western portion of Capitol Hill – each of these areas indicating a negative linear relationship between the prevalence of street trees and the frequency of collisions. As was the case for the analysis specific to 2004, the majority of tracts with a negative relationship between the variables likewise had a population density below 20 people per acre.

Overall, though, 166 of Seattle's 177 census tracts demonstrated no significant relationship between street trees and vehicle collisions whatsoever in 2016.

### Type of Relationship Between Street Trees and Motor Vehicle Collisions - 2004

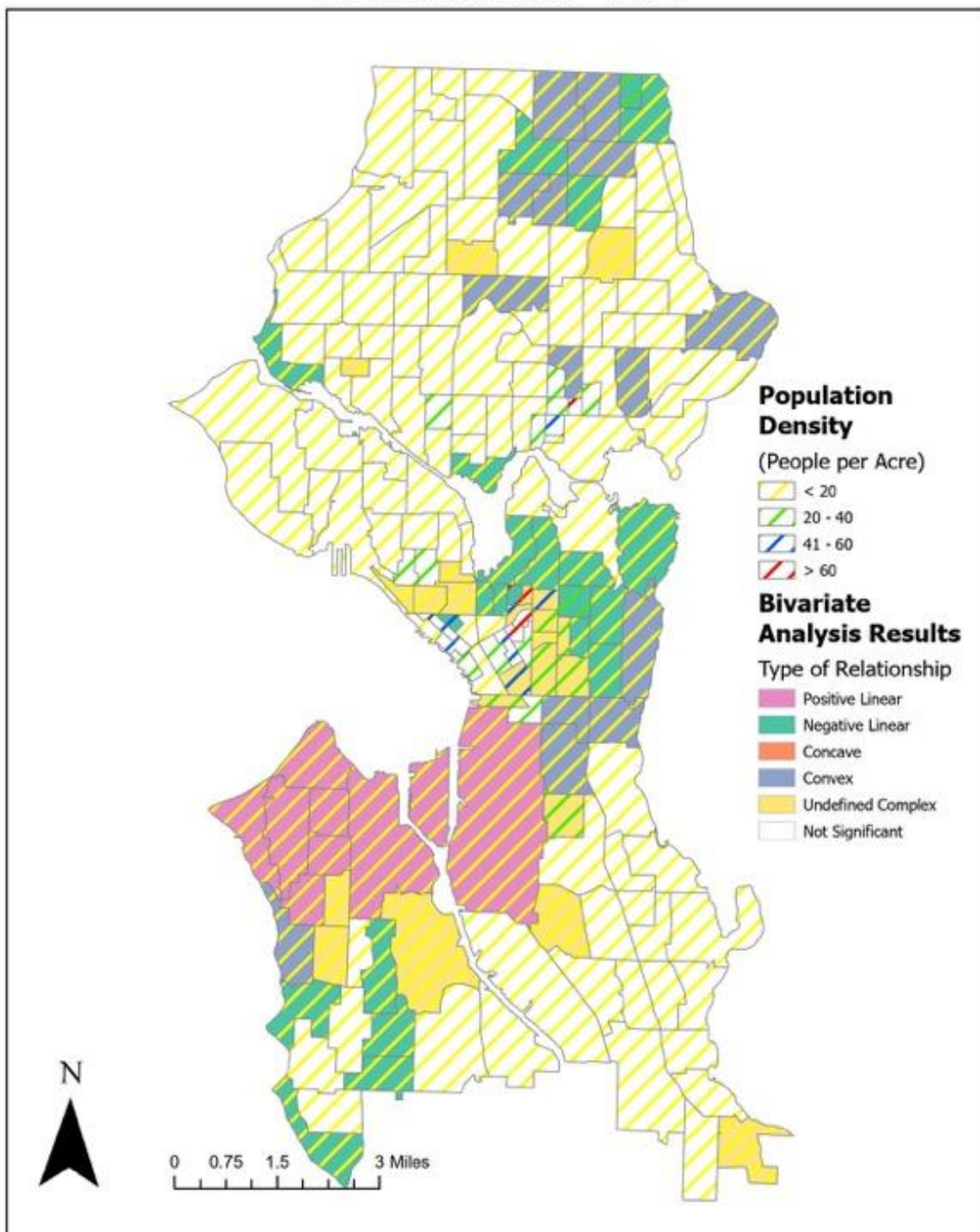


Figure 6 Type of Relationship Between Street Trees and Motor Vehicle Collisions - 2004

## Type of Relationship Between Street Trees and Motor Vehicle Collisions - 2016

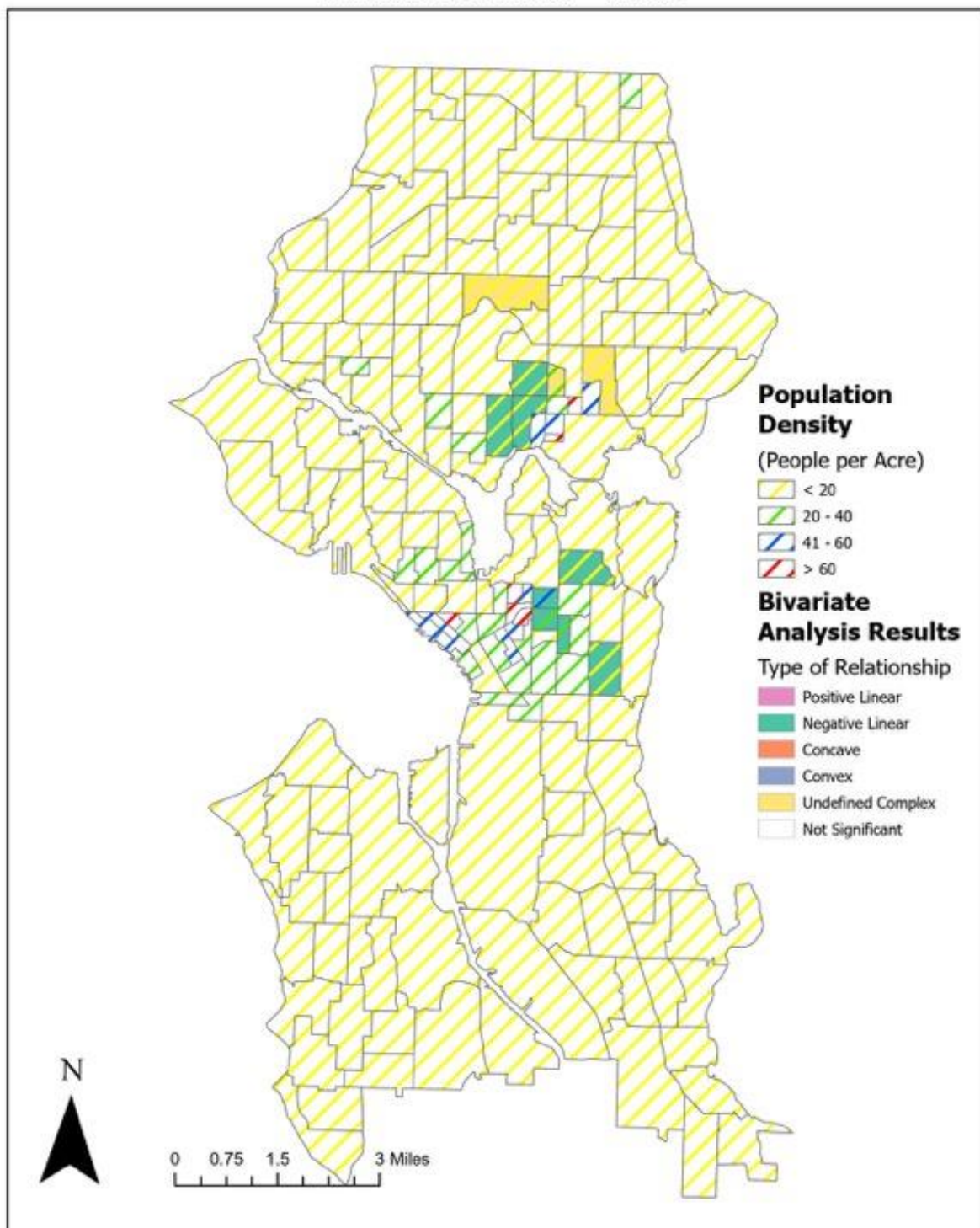


Figure 7 Type of Relationship between Street Trees and Motor Vehicle Collisions - 2016

Finally, figure 8 depicts the local bivariate relationship analysis which examined the change in street tree cover and collisions per tract between 2004 and 2016. While the majority of Seattle's census tracts were shown to have no significant relationship of any type between the change in street trees and the change in vehicle collisions, 14 tracts were shown to have an undefined, complex relationship between the variables, while 12 were shown to have a negative linear relationship. The tracts that comprise East Queen Anne and much of the Rainer Valley revealed an undefined, complex bivariate relationship while the tracts that comprise the largely residential neighborhoods surrounding Magnuson Park demonstrated a negative linear relationship between the change in street tree canopy and the frequency of vehicle collisions. However, of the tracts which returned a negative linear relationship between the variables, while the majority did see reductions in collisions between 2004 and 2016 many of these tracts also either shrank in population density or grew by less than 2 people per acre, indicating that the reduction/minimal population growth may be contributing to the reduction in collisions.

## Type of Relationship Between Change in Street Trees and Change in Motor Vehicle Collisions - 2004 - 2016

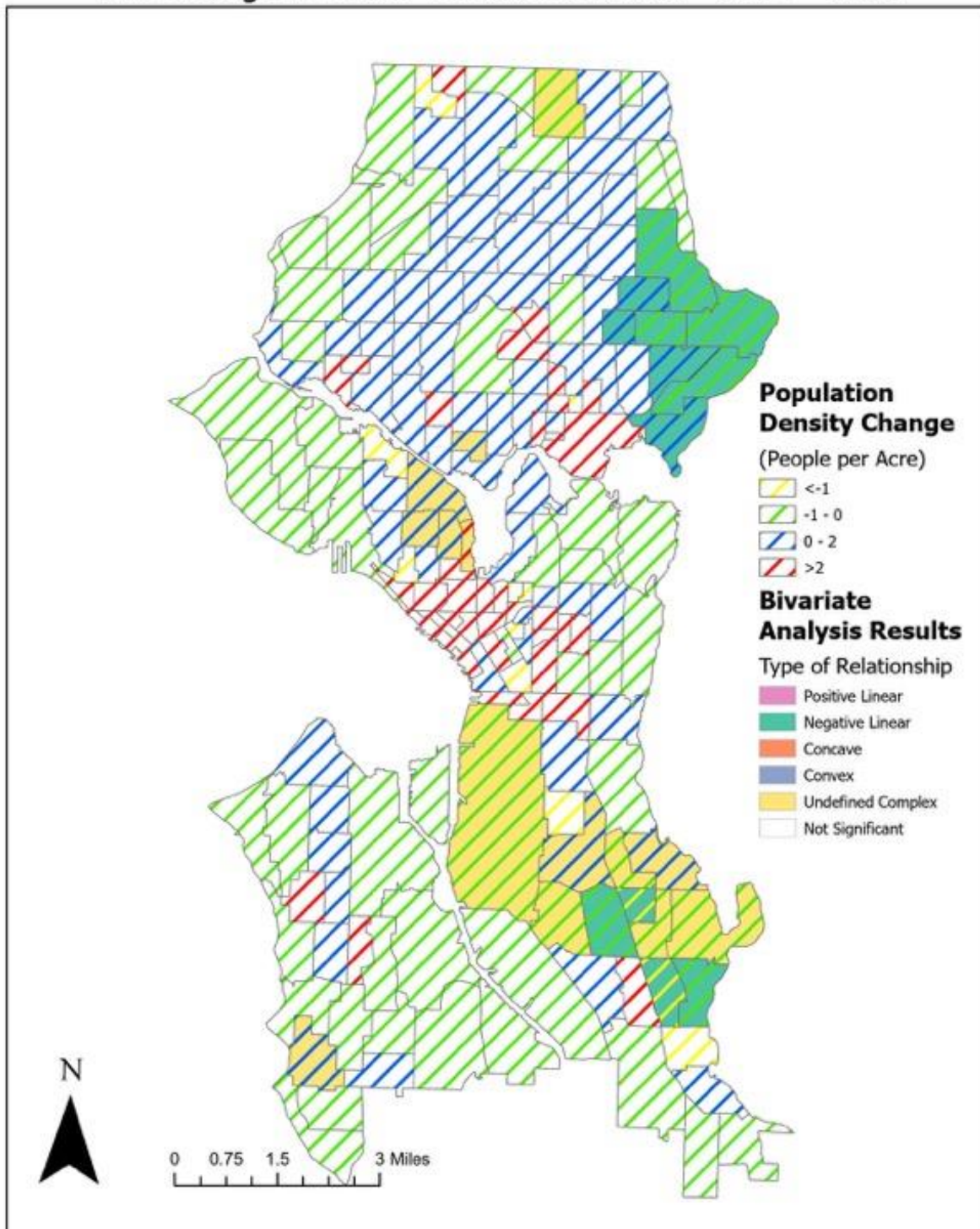


Figure 8 Type of Relationship Between Change in Street Trees and Change in Motor Vehicle Collisions, 2004 - 2016

## Chapter 5. CONCLUSION

In comparing the change in street tree canopy cover in Seattle between 2004 and 2016 and the change in the frequency of vehicle collisions in each of Seattle's census blocks across that same time period, this thesis research sought to answer the question, "is there a relationship between the presence of street trees and traffic safety", by either supporting or failing to support the hypothesis that there is a negative relationship between street trees and vehicle collisions.

If humans were incapable of making errors while driving, drivers would never drive above the speed limit, road signs would always be obeyed, and conflicts in the road would hypothetically never occur. Driverless driving technology may have the potential to eliminate such errors that lead to death and injury on the road, but it remains unclear how long, if ever, it will take for such technology to enter the consumer market. Meanwhile innovation in vehicle safety features is ever evolving, but the widening discrepancy between driver death and injury and non-driver death and injury appears to indicate that achieving vision zero cannot rely on vehicle safety technology alone and must be paired with comprehensive ROW design interventions, particularly if cities wish to encourage more active mobility and transit use, which Seattle has indicated it intends to do. As planners strive to reduce risk of serious crash incidences in Seattle, determining the influences of street trees on traffic safety will be an important component of making streets safer.

In the United States, historic planning and urban design policy which have prioritized vehicle speed and throughput, as outlined in the literature review, have led to the production of wider sight lines, shoulders, and general-purpose lanes, resulting in frequent speeding due to their tendency to imbue drivers with a false sense of security, leading many drivers to allow themselves to make riskier driving decisions, ultimately making roads more dangerous (Tice et

al., 2020). When vehicles move at higher speeds, the risk of severe collision increases, especially on roads with roadside fixed object hazards like street trees. When a vehicle collides with a tree, the collision is more likely to be fatal because trees are unable to provide any degree of cushioning on impact (Wolf, 2003). Therefore, it's easy to conclude that roads can be made safer by removing street trees, but this conclusion may in fact be erroneous, as there is evidence to support the notion that the presence of street trees actually leads to safer driving behavior and therefore positive safety outcomes (Eisenman et al., 2021). Furthermore, the results of this research indicate that the presence of street trees has no clear relationship with collisions, neither contributing to their occurrence nor acting to prevent them, indicating that the removal of fixed roadside hazards, such as street trees, may be unnecessary, therefore the concept of the clear zone design policy may not be serving much value as a preventative measure against collisions.

Of course, the findings of this thesis research indicate that the presence of street trees alone does not account for the frequency of vehicle collisions that occurred in each of Seattle's census tracts. The local bivariate relationship analysis used to test the hypothesis ultimately uncovered few statistically significant negative relationships between the presence of street trees and collision frequency in the majority of Seattle's census tracts, failing to support the hypothesis that there is a negative relationship between street trees and vehicle collisions. As Seattle continues to search for solutions to reverse the upward trend of traffic-related fatalities and injuries, it appears that solely growing the city's tree canopy may not be a method to do so. Countries and municipalities that successfully achieved vision zero did so through multi-faceted efforts that included driver safety education campaigns, changes to traffic enforcement, and widespread redesign of the ROW of the kind that would include, but is not limited to, street tree

planting and the introduction of multi-modal travel facilities such as protected bike lanes and widened sidewalks (Hartmann & Abel, 2020).

## 5.1 RESEARCH LIMITATIONS

When studying spatial vehicle collision data there are a number of limitations to research. The factors that contribute to collisions are extremely complex and involve an unknowable number of external variables. A critical aspect of determining the effects of street trees on the frequency of vehicle collisions is identifying if trees were the direct cause of crashes analyzed in this study but doing so is outside of the scope of this study. Furthermore, the method of aggregation of the dependent and explanatory variables differed; while collisions were aggregated linearly, the aggregation of the street tree canopy per tract was not, therefore the relationships, or lack thereof, between these two variables which were identified by this research may be skewed.

Another limitation to this study is the use of the census tract as the unit of analysis. Relationships can exhibit different patterns at different scales and the census tract scale may not fully capture scale-dependent phenomena, which can limit the ability to generalize findings across different spatial extents. In the context of this study, this may mean that while across the scale of a census tract the presence of street trees may have negligible impacts on the frequency of vehicle collisions, but at a smaller scale like the street-level, the introduction or elimination of street trees may indeed result in statistically significant changes in vehicle collision frequency.

Additional methods of analysis were considered as part of this research as well, but none yielded noteworthy results worth discussing. These included examining only the relationship between *fatal/injurious* collisions and street trees, running a geographically weighted regression analysis between the variables rather than a bivariate relationship analysis, and determining hot

and cold spots of collisions which occurred within 10 meters of a tree throughout the city. With each analysis, the prevailing conclusion returned was that a significant relationship between street trees and vehicle collisions may not exist.

Finally, the methods to develop urban canopy cover assessments like the ones used to support this thesis are quite varied and subject to uncertainty. The datasets of Seattle's urban tree canopy cover for 2003 and 2016 were each developed under a categorical raster-based measure methodology, which relies on random points within aerial imagery being categorized, in this case categorized to identify trees from everything else, but categorization can be challenging, as well as subject to bias, therefore the tree canopy assessments used in this study, like all tree canopy assessments, should be understood as being subject to uncertainty and reflect an estimation of Seattle's urban tree canopy rather than a perfect inventory of it (Richardson, 2014).

## 5.2 FUTURE RESEARCH POTENTIAL

Considering that this study only examined the years of 2004 and 2016, it's logical that should the City of Seattle ever publish the urban tree canopy data collected for its 2021 Urban Tree Canopy assessment, that a future study of similar nature could also include analysis of the relationship between street trees and vehicle collisions in 2021. This would be of particular note because it might also reveal whether the shifting traffic patterns which resulted from the CoVid-19 Pandemic may have affected a relationship between collisions and street trees.

In the future, a study like this could also be broadened to analyze the relationship between street trees and collisions across a range of other cities or at a larger scale such as at the county level. Conversely a similar study could be conducted at an even smaller scale, perhaps comparing the frequency of vehicle collisions along a complete street – a street which prioritizes accessibility for all users, and which commonly features street trees – and a segment of roadway

which features the kind of design elements which have been historically implemented, like wider lanes and the presence of clear zones. Any future study may also benefit from the analysis of additional variables that contribute to vehicle collisions, but which were omitted from this study, like driving speeds, driving behavior, or other built environment elements.

As for this study's professional applications, this study adds to the body of knowledge of design interventions oriented toward improving safety. This research should be used by planners as an indication that street beautification efforts, like those that would heavily rely on roadside tree planting and landscaping, are not enough to produce positive safety outcomes. Indeed, this research indicates that holistic approaches to redesigning the right of way to force safer behavior are potentially much more likely to result in greater safety outcomes. Likewise, this research may also serve as a foundation from which to build off of as Seattle continues to track the extent and health of its urban tree canopy. As more tree canopy assessments are released, more data points and study years can be input into this study, resulting in a greater degree of confidence when determining the relationship between street trees and vehicle collisions.

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