

Child Walkability Across Seattle Census Tracts:
Comparing Child-Friendliness Through Geospatial Analysis and an Equity Lens

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Abstract

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Seattle, Washington, has faced massive economic and population growth over the past decade. And as a result, there have been concerns of continued racial inequity and displacement. One topic less studied has been on the child-friendliness of the city. Despite the benefits of child-friendly planning seen in the literature review, Seattle is often colloquially discussed as being unfriendly for children yet friendly for pets. However, fewer studies have examined such statements empirically. This thesis asks then, “how amenable are Seattle census tracts for child walkability?” And as a sub-question, “does the child-friendliness of walkability correlate with racial demographic composition of the tract?” To address such questions, a walkability index was created to assess the walkability for children ages 5-9 across Seattle census tracts. The index used indicators to assess factors that enable or hinder walkability in the built environment, safety,

and environmental hazards. These variables included, but were not limited to, variables such as sidewalk quality, public realm amenities densities, and crime, and air quality. The index was aggregated using standardized Z-scores and then compared against socioeconomic and demographic variables from the 2019 American Community Survey. Pearson's correlations coefficients and Local Bivariate Relationship tests in GIS were used to assess statistical significance. The results showed insignificant statistical results in assessing correlation between the total index, race, and the density of children ages 5-9 across census tracts. However, both future qualitative study and index analysis at the block level could further understanding. Regardless of statistical significance, this thesis finds that policy that incorporates child-centric considerations is needed—the benefits of planning for children can support the long-term livability of a city through more walkable neighborhoods.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
AAWT	Annual Average Weekday Traffic
ACS	American Community Survey
BIPOC	Black, Indigenous, People of Color
CDC	Center for Disease Control
CFCI	Child-Friendly Cities Initiative
EPA	Environmental Protection Agency
GIS	Geographic Information System
GUIC	Growing Up In Cities
HCM	Highway Capacity Manual
HH	Household
ITDP	Institute for Transportation and Development Policy
LOS	Level of Service
LQ	Location Quotient
MPH	Miles Per Hour
OLS	Ordinary Least Squares
OPCD	Office of Planning and Community Development
PM 2.5	Particulate Matter 2.5
PSRC	Puget Sound Regional Council
SDG	Sustainable Development Goals
SDOT	Seattle Department of Transportation
SODO	South of the (King) Dome / Downtown
SPD	Seattle Police Department
SPU	Seattle Pacific Utilities
SRTS	Safe Routes to School
TRAP	Transportation Related Air Pollution
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNICEF	United Nations International Children’s Emergency Fund
WSDOT	Washington State Department of Transportation

Chapter 1. INTRODUCTION

Seattle, Washington, is known for its high-growth, hot real estate market and its commercial entities like Boeing and Amazon. One aspect the city is not famous for is having a high population of children. Greenblatt (2015) writes, “The downtown [Seattle] amenities that attract young professionals and empty nesters—the bars, restaurants and nightlife options—aren’t what families need. The result is that Americans, already used to segregation by income and race, are seeing another type of geographic separation, with people living apart according to their stages of life.” It may come as no surprise, then, that many Seattleites joke that Seattle is more friendly to dogs than it is to youth and children (Balk 2013, 2019).

Gentrification and the real estate market have only hastened such trends; while construction of multifamily dwellings may increase the overall housing supply in an already undersupplied market, many of the new buildings are small units that are not amenable to families or children, causing many Seattle families to move out of the city by the time their child is five-years-old (Greenblatt 2015). Furthermore, the Puget Sound Regional Council’s (PSRC) reported that through their 2019 household travel survey, they “found that all People of Color households with children had a greater rate of displacement than white households with children” (PSRC 2020b, 3). The survey also found that 16% of White respondents reported better schools as a deciding motivator for relocation, compared to only 2% of People of Color. When it came to displacement factors, 19% of recent People of Color movers reported housing cost to be a factor in relocation among those displaced, compared to only 11% for White respondents (PSRC 2020a).

Seattle is not alone in such issues of including children. Globally and nationally, there have been calls for child-friendly city initiatives and for including children in policy processes and considerations. However, such calls have faced challenges. Ro writes (2019), “Some city officials argue that it makes more economic sense to prioritise citizens without children, who bring a net economic gain to a city, over families, who bring a net loss.” Some residents may also favor child-free city designs. Ro describes:

Some residents also *want* to keep things adult-only. Amy Beins, 32, and her husband, who both left Seattle recently, love child-free spaces. Beins is not anti-kids, and also wants safe streets, parks and nice homes just like families do. But she says she “would likely pay extra to live in a child-free apartment community than one with children.” (Ro 2019)

These challenges are only amplified considering that children are underrepresented from both planning and policy discussions (Gillespie 2013). Indeed, the impact of their historic exclusion and disempowerment has been felt both nationally in poverty statistics and in the American built environments. In 2019, the official poverty rate for youth under 18 years of age was nearly 5 percentage points higher than working age and elderly adults (Semega et al. 2020). Such disparity is not new, however. While elderly populations have continued to see drops in poverty, child poverty rates have remained higher than other age groups since the 1980s (Gormley 2012). In 2017, Balk (2019) reported that as much as 40% of Seattle single-mom households were in poverty, with one in eight Seattle children living in households below the poverty threshold. Furthermore, Balk continues, “Kids in Seattle are a significantly more diverse group than the rest of us. A slight majority (54 percent) of the under-18 population is white, compared with two-thirds of adult Seattleites.” Despite such challenges, many Seattle children also come from affluent families, a testament to the Seattle’s economic growth and lack of

affordability for middle to lower class incomes: households with children had a median income of over \$125,000 in 2017 (Balk 2019).

In cities and towns across the United States, children's exclusion from policy processes and planning has hindered their ability to walk or bike in their neighborhoods, resulting in fewer accessible play spaces and streets to navigate (Riazi and Faulkner 2018; Villanueva et al. 2016). It is no surprise, then, that rates of children being driven to school rather than walking have increased over 400% since the 1970s (Larouche 2018; McDonald and Aalborg 2009). Encouraging such increasing rates has been the changing American built environment to better accommodate car travel. Since the passage of the Federal Interstate Highway Act in 1956, driving convenience over other modes has only increased. Such convenience has encouraged vast suburbanization and urban sprawl across American cities (Baum-Snow 2007; Duranton and Turner 2012). And with distance to school and convenience being determining factors behind a parent's decision to drive their child to school, the prioritization of auto-centric infrastructure development can have a profound impact on disincentivizing active modes to school (McDonald and Aalborg 2009; McDonald 2007).

Such disparities can be compounded along lines of race and ethnicity. Children of Color in the United States often have higher rates of negative health outcomes compared to their white counterparts. For example, in their state-by-state analysis, Matthews, Ely, and Driscoll (2018) found that non-Hispanic Black women experience infant mortality rates between 8-14%, compared to 3-7% for White women and 4-9% for the overall national rate. Furthermore, when considering pedestrian-related accidents as a whole, Hamann, Peek-Asa, and Butcher (2020) find that from pedestrian-related accidents, mortality was 50% higher for Blacks and 21% higher for

Hispanics compared to the rate for Whites. Hospitalization rates for Blacks were also 18% higher than the rate for Whites (Hamann, Peek-Asa, and Butcher 2020, 3).

In response, there have been calls for child-friendly cities, amidst rises in child obesity, many planners and health experts have renewed efforts to promoting active transportation as a public health strategy through programs like Safe Routes to School (SRTS) (McDonald and Aalborg 2009). Furthermore, not only does active transportation, particularly walking, play an integral role in public health, it is also important for child development and play. Walking, and in some cases rolling, is one of the most universal and accessible vectors for children to access both play spaces and socializing with one another (Horton et al. 2014; Kyttä 2004; ITDP 2018).

Internationally there have also been calls to address children and youth's exclusion from urban policy and planning. The UN's Convention on the Rights of a Child and Sustainable Development Goals (SDG) have seeded a global movement to include children in planning processes (Aerts 2018; Derr et al. 2013; Derr and Kovács 2017; Malone 2006). UNICEF also has its own Child Friendly Cities Initiative (CFCI), which builds international networks and tools for cities to build more child-friendly cities (Malone 2006). However, as described by Malone (2006), much of the CFCI efforts have been in building a global movement of resources and networks to build child-friendly cities. Perhaps, such approach is at the detriment to building accountability and reporting mechanisms towards establishing meaningful global progress. Villanueva et al. (2016) write, "Although current global policy agendas advocate the need for child-friendly, livable cities and for place-based initiatives, these agendas currently lack the evidence and data needed to leverage policy change for healthier child development" (16).

In my literature review, I have found that while there have been many studies internationally on child-friendly planning (Hanssen 2019; Kyttä 2004; Larouche 2018), there

have been fewer studies that map child mobility locally in Seattle neighborhoods (SDOT 2019a; Sarmiento and Duarte 2019). The purpose of my research will be to fill this gap in the literature on Seattle child friendliness. Specifically, I ask, *how amenable are Seattle census tracts for child walkability?* And as a sub-question, *does the child-friendliness of walkability correlate with racial demographic composition of the tract?* This thesis examines children ages 5 through 9. Children in this age group are starting school, but are largely still reliant on their parents for transportation and mobility decisions (McDonald and Aalborg 2009).

To address this question, I first provide a literature review, in Chapter 2, on both previous studies on child mobility and walkability. Walking as a key measure is important because, as the Institute for Transportation and Development Policy (ITDP) states in their (2018) *Pedestrians First* toolkit, “all trips require walking at some point” (9). Furthermore, the act of walking alone has been shown to be beneficial for child socialization and development (Horton et al. 2014). Indeed, active transportation modes, such as bicycling and walking, increase child health and physical well-being, such as reduced risk of childhood obesity, cardio-vascular disease, and type II diabetes (Mitra 2013). Lastly, walking generally does not require a vehicle or money, making it one of the most accessible means of mobility and transportation.

In Chapter 3, I discuss how I measured the child friendliness and walkability of Seattle census tracts using four dimensions, or categories, to create an index for child-friendliness and walkability. The key subpopulation examined are children 5-9 years of age and Black, Indigenous, People of Color (BIPOC), identified through the US American Community Survey (ACS). While still being dependent on parents for mobility decisions, children between these ages are becoming more involved in the built environment, both through school and other public realms (McDonald and Aalborg 2009; Leander, Phillips, and Taylor 2010). This thesis uses a

Geographic Information System (GIS) to compile, quantify, analyze each of the indices. The data used was publicly available datasets from King County, the City of Seattle, Washington State Department of Transportation (WSDOT), the US Census' 2019 ACS, and the Center for Disease Control (CDC).

The four main categories of analysis to quantify the child friendliness of walkability are (1) built environment form factors, (2) safety; (3) environmental hazards, and (4) socioeconomic and demographic factors. Built environment form included measures such as sidewalk quality and access to public realm amenities such as parks. Safety includes indices of crime, lighting, and traffic collisions. Environmental hazards include traffic and pollution factors. Lastly, socioeconomic factors included income, race, and age demographics. The socioeconomic and demographic factors were used to compare and analyze whether certain indices correlated across key factors such as race, income, and relative density of children ages 5-9. By combining the socioeconomic and demographic variables into an additional index I called the vulnerability index, I was able to better identify tracts that are more sensitive to the walkability indicators. For example, tracts that had high concentrations of children ages 5-9, Black Indigenous, and People of Color (BIPOC), and had lower incomes.

Ultimately, in Chapter 4, this thesis finds that there were statistically insignificant and inconclusive relationships between the index measures and key demographic and socioeconomic variables measured at the tract-by-tract level through geospatial analysis. This thesis did find strong linear relationships between tracts with high percentages of car-free households and built environment form and safety dimensions ($\alpha = 0.05$). The thesis concludes with Chapter 5 and Chapter 6, a discussion of the results, limitations, and policy implications of this research, arguing that there is still a case to be made to consider intergenerational and racial equity lenses

in planning policies. Finally, the Appendices include a description of the data collection and cleaning process and the full Pearson's correlation results for all the variables in the thesis.

Chapter 2. LITERATURE REVIEW

2.1 THE CONTEXT OF CHILD-FOCUSED PLANNING

Children and urban environments have been discussed and studied for decades. Sipe, Buchanan, and Dodson (2006) aid our understanding of this history by identifying three main eras of child-friendly planning research: pre-1960s, 1970-1990, and post-1990. For the first era, much of the research and literature focused on creating parks and provision of urban environments that facilitated child play and social development. In the 1960s-70s era, research aimed to gain a deeper understanding of children's interactions with urban environments. In the most recent era, post-1990s, literature has moved away from the relationships and has focused more on child obesity and planning as a policy intervention to mitigate through promoting active transportation.

However, I would argue that Sipe, Buchanan, and Dodson (2006) miss an additional element, or era, in the context of child-friendly planning: the establishment of human-rights based frameworks to argue for transformative change, and specifically, the role of the UN's sustainable development goals and frameworks. Malone's (2006) article addresses this gap by discussing the history and role of the UN in advocating and providing tool-kits for child-friendly urban development and cities. Such work largely took off with the launch the UNESCO Growing Up In Cities (GUIC) project in 1996 and the Child Friendly Cities Initiative (CFCI) in the early 2000s. Malone argues that the convergence of child rights and involvement in governance decisions and sustainable development goals has provided the UN the unique position of being

both a resource and providing a needed framework for child-friendly planning and urban policy.

Malone describes the CFCI:

There is no single definition of what a child friendly city is or ought to be. In fact the documents go to great length to say that cities can never achieve child friendly status because they will always be transforming and responding to the changing local and global context. In some cities, especially in high-income nations, emphasis tends to be on environmental and physical issues such as improving recreational spaces and green spaces, alienation and controlling traffic to make streets safe for young citizens. In low-income nations, the focus is frequently on increasing access to basic services for the poor. (2006, 21)

It is no surprise that because of such the adaptability of this approach, as Malone describes, that many recent studies focusing on transformational change for child-friendly cities adopt the UN's frameworks and lenses in their research, especially in focusing on child participation (Aerts 2018; Derr et al. 2013; Malone 2006). The following section discusses this topic in detail.

2.2 ENGAGING CHILD VOICES AND EFFECTIVE PARTICIPATION

Much of the literature that adopts human-rights based frameworks focus on the importance of effectively involving children in participatory planning practice. Derr et al. (2013) use the UN's human-rights based frameworks on a project in Boulder, Colorado, that engaged marginalized children and youth to elevate their voices in planning and design. The authors argue that planners cannot expect youth to effectively participate without both meeting them where they feel safe and through mediums that take their voices seriously. One such medium to facilitate youth and child engagement with planning is through technology. De Andrade, Poplin, and de Sena (2020) use Minecraft as a vector of child participation in urban design and planning in Tirol, Brazil. They found that using the game as a tool could bridge the gap between the way younger and older generations participate in the urban planning process (de Andrade, Poplin, and de Sena 2020).

However, some may argue that children are not involved in planning and policy processes for good reason: they do not have the capacity to contribute in a meaningful way. Speak (2000) addresses such an argument through interviews with 24 children to get their views and opinions on the Park Community Development Trust in the UK. The article concludes that contrary to their treatment by adults as unknowledgeable and unable to contribute, “the [interviewed] children showed a firm belief that they had something worth saying, and that all people had a right to be consulted and listened to” (Speak 2000, 38). Gillespie’s (2013) work furthers Speak’s assertion in relation to planning theory. The field of planning wields a large amount of power and influence on child wellbeing. Yet, childhood is given little thought in planning theory. Gillespie writes, “Writing children into planning theory requires examining how children can be more fully respected in their own right, and actively involved in shaping our cities—without judging them against ‘adult’ forms of communication and participation” (77). To address such a gap between “adult” forms and “child” forms of engagement, Horelli (1997) argues that a combination of theories is essential: children learn in different ways and contexts, and the theories implemented should reflect that.

In short, there is strong support in the literature that the UN’s and UNICEF’s goals for inclusion of children in policy and planning processes should not just be aspirational values, but practical solutions to the gap in child and youth considerations in planning projects and processes (Derr and Kovács 2017; Gillespie 2013; Speak 2000). Indeed, child and youth involvement in planning can not only be beneficial for child-friendly planning initiatives, but also for more inclusive processes that benefit all (Wilks and Rudner 2013). The next section examines children and youth’s relationships with the built environment, and how such relationships matter for future research.

2.3 CHILDREN, PLACE, AND THE BUILT ENVIRONMENT

A large body of research focuses on how children and youth interact with places and what makes such places inclusive for children's play and socialization. One such example is Loukaitou-Sideris and Sideris' (2010) examination of the factors that hinder child-use of the parks. Using regression models to measure the different variables that influence children's use of the inner-city and suburban parks, they found children differed in their park preferences across race and gender. Talen and Coffindaffer (1999) had consistent findings stating, "children [as a whole] favor neighborhood environments that are diverse, stimulating, and socially engaging" (330). Such findings are often in contrast to reality: standardization of park materials result in exclusion of different child interests and activities across age, gender, and racial groups (Loukaitou-Sideris and Sideris 2010). Ultimately, these findings indicate that researchers cannot merely assume the importance of parks for children and youth without considering demographic differences among children and the design and upkeep of the respective parks.

Other studies popularly use mapping and Geographic Information Systems (GIS) to better understand children and youth's relationship to places. Christensen, Mygind, and Bentsen (2015) use place mapping in a suburban Copenhagen neighborhood with a group of fifth graders. The authors categorize three reasons children avoid specific places: bad social experiences, unfamiliarity, and contested spaces (Christensen, Mygind, and Bentsen 2015). Contested spaces were defined as spaces that certain children might avoid but others may love. For example, some children may have experiences with racism in such spaces where others may navigate the places without discrimination. Christensen, Mygind, and Bentsen's results emphasize that despite commonalities among children in their mapping exercises, not all children are alike, and should not be treated as homogenous through research.

Wridt (2010) implemented a qualitative, participatory GIS mapping exercise with 10 and 11 year-old children to better understand the children's usage and perceptions of their neighborhood space outside of school. Using a set of criteria and line of questioning, the researchers developed a series of maps that inform planners about what the children value and care about in their physical environments. Much like the arguments for participatory planning, Wridt's article highlights the importance of qualitative, inclusive, planning processes to best understand children and youth's values and relationships between physical spaces.

An important consideration in such mapping research and place-focused research alike is the fallacy of confining research considerations to the public realm such as streets, schools, and parks. When in fact, such an assumption is not always the case. Wridt (2010) found that many children valued the play area in McDonalds restaurant, which would have been ignored had the study only looked at schools, streets, and home. There is multi-disciplinary evidence that highlights this issue, finding that many studies are confined to the institutions in which children live, play, and learn (Kraftl, Horton, and Tucker 1978; Leander, Phillips, and Taylor 2010). Specifically, from the field of education, Leander, Phillips, and Taylor (2010) argue, child and youth learning happens everywhere, not just the classroom/institution of learning. Kraftl, Horton, and Tucker (1978) take a similar standpoint in their study on children in built environments: "Very often—partly as a result of disciplinary boundaries—research in children's geographies stays within children's geographies, and its usefulness remains defined in a narrow and constricted way" (401). As a result, the understanding of children's interactions outside of these institutions is limited. Gershoff, Mistry, and Crosby (2013) further expand this picture, arguing children not only learn and grow based on their family and school circles, but also from the

cultural contexts of the places in which they live; poverty, schools, culture, and policy all influence how children learn and gain access to society.

A common theme across all the research on children's relationships to places is that children should not be treated as a homogenous group: their experiences differ based on race, gender, age, and preferences. From an adult perspective, it may be second nature for us to look across the similarities of children and their experiences. However, the literature paints a different picture. One means for future study to better understand the complicated relationships between children, places, and their lived experiences is through ecological theory (Gershoff, Mistry, and Crosby 2013). By viewing children's respective interactions with place through ecological lenses and not subscribing to assumptions of what types of land uses are important to children, we can better understand what makes such places friendly or unfriendly to children (Gershoff, Mistry, and Crosby 2013; Kraftl, Horton, and Tucker 1978; Leander, Phillips, and Taylor 2010). The following section addresses child mobility throughout such spaces.

2.4 TRANSPORTATION AND MOBILITY

Much of the literature surrounding child mobility and transportation is related to their commute to school. Since the 1960s, rates of students walking to school have been on the decline in favor of being driven instead (Riazi and Faulkner 2018; Mitra 2013). Increasing distances to school (Larouche 2018), concerns of safety (Larouche 2018; McDonald and Aalborg 2009), and societal stigmas (Riazi and Faulkner 2018) all foster the declining rates of walking to school. This decline coupled with concerns of child and youth obesity have increased the calls from planners and public health experts for increasing child active transportation (Sipe, Buchanan, and

Dodson 2006). Such calls have resulted in programs like Safe Routes to School (SRTS), which generally are used to fund pedestrian and bicycle infrastructure (McDonald and Aalborg 2009).

However, investing in infrastructure often ignores the sociological variables that influence the declines in children walking to school (McDonald and Aalborg 2009; Riazi and Faulkner 2018). McDonald and Aalborg (2009) examine the reasons why the rates of children walking to school has declined in the San Francisco Bay Area. Surveying parents that live within walking distance to schools, the authors found that parents do not want to spend the time walking with their children to school and do not allow their children to walk unsupervised. The authors urge consideration of non-infrastructure initiatives to address dropping rates of walking to school, like designated adult walk supervisors to and from school and creating multi-modal connections with school buses.

Considering child independent mobility in general and not specifically in relation to the trip to school, one important factor is the child's ability, or "license," to travel independently (Kytta 2004; Riazi and Faulkner 2018). In other words, do the child's parents or guardians allow them to cross certain streets? How far can they go without adult supervision? Riazi and Faulkner's (2018) literature review of child independent mobility in Canada highlights that despite the benefits of independent child mobility for child health and development, their "licenses" to travel independently have been reduced over time. The authors identify individual elements that influence such licenses, like child age and gender as well as societal and family factors, stigma of "bad parenting" for letting children travel independently and "stranger danger" (Riazi and Faulkner 2018).

However, as seen in Kytta's (2004) article based in Finland and Belarus, children do not necessarily follow such licenses in their entirety. The article measures child friendliness of the

built environment based on the ability for children to independently move around to different environments and the different types of activities that they can do in such environments (running, playing catch, etc.). The author conducted case studies to measure both the *allowed* mobility by parents and the children's *actual* mobility patterns. Kytä then compared such ability and travel with the activities the children could do in the places they reached, ultimately finding a correlation between increased licenses and children's ability to engage a diversity of play and activities.

Licenses are not the only factor important to youth mobility. In Sarmiento and Duarte's (2019) qualitative study in Madison, Wisconsin, on access and mobility to public services and libraries, they found that distance is one of the most influential variables for child independent mobility. Furthermore, distance was also a key indicator of racial segregation and marginalization across different communities, with students of color having to travel further by bus than their White counterparts. They write, "While a path and safe route to the library could increase youth's accessibility to the public space, it does not resolve why the majority of youth of color needs to travel so far to access these public services that are essential to their development" (Sarmiento and Duarte 2019, 11).

Unsurprisingly, safety was a key consideration in whether parents would grant licenses to their children to be independently mobile. However, the literature shows that perceived safety can vary depending on key factors like demographics and age. Olvera et al. (2012) examined perceived safety by Hispanic children and their mothers, finding that, unsurprisingly, mothers perceived greater unsafety than their children did in the neighborhood. Lack of crosswalks were identified as a key barrier to child physical ability (walking) by mothers, and relatedly traffic concerns. Interestingly, traffic was viewed more seriously than crime by the mothers in the

study. In other cases, “stranger danger” was a more explicit concern for parents. McDonald and Aalborg (2009) found that fear of strangers far outpaced any other concerns for allowing their children to walk to school.

In addition to safety considerations and licenses, walking as a mode is not a choice for some families, raising equity concerns over who *must* walk. In their study, Su et al. (2013) found that despite facing greater environmental and safety concerns, such as traffic and noise, students from low-income communities were more likely to walk, likely out of necessity. McDonald (2008) had a similar finding: many low-income and minority students often used active travel modes more frequently than their White and higher-income counterparts to get to school. Such findings indicate the need for equity lenses and critical theories to address child-friendly walkability in pedestrian and SRTS programs.

The last consideration is that walking and mobility are not just utilitarian acts for children, but activities that facilitate social capital for youth and children. Horton et al. (2014) argue that much of the research on child mobility, licenses, and walksheds miss a critical component, the act and value of the walk itself as an activity for children:

We note that many studies... ostensibly deal with walking, but rarely focus on practices of walking itself. Although countless studies have produced metrics of distances walked and maps of spatial ranges, these analyses have rarely qualitatively explored the actual practices of walking—what happens during those distances walked and within those mapped ranges—and how such practices matter. (96)

Sarmiento and Duarte (2019) had similar findings on the social value of travel for children:

“students often traveled together—for example, taking the bus or riding bikes together.... The bus stop served as an important node, or key junction where youth clustered. It was a part of their everyday experience as they started their travel every morning” (8). Professional planners can fail to recognize this important social element for youth mobility, viewing mobility in its purpose

to getting people from point A to point B—routes to work, school, and so forth. Horton et al.’s (2014) piece shows that research must not ignore the importance of considering in the value of walking for walking’s sake for children and their development.

2.5 MEASURING WALKABILITY FACTORS

If there is one lesson learned from this literature, it is to use caution when researching children, the built environment, and their mobility. Far too often, researchers can fall victim to the same trap that they are arguing against—they ignore important child perspectives in their research processes. For example, they might acknowledge that children are important to consider in planning but fail to address their lives outside of school and playgrounds (Kraftl, Horton, and Tucker 1978; Villanueva et al. 2016). Or, the research measures children’s ability to travel from point A to point B independently but underestimates the social and developmental value of the walking trip itself (Horton et al. 2014). Such examples show that researchers can miss key considerations of understanding child interactions with built environments if they fail to recognize the nuanced, qualitative differences across the child populations themselves.

On the other hand, there is a case to be made for more universal walkability and “child-friendliness” measures. While broad indicators may ignore the micro and social elements that influence child walkability and mobility in a given neighborhood—“big kids” or scary dogs for example—a broader measure of walkability allows researchers and policy makers to track progress towards goals. Villanueva et al. (2016) explain:

Although current global policy agendas advocate the need for child-friendly, livable cities and for place-based initiatives, these agendas currently lack the evidence and data needed to leverage policy change for healthier child development. The development of indicators (and therefore measurement and data) is one way to augment and accelerate the policy debate. Evidence-based indicators are valuable tools in the policy environment to benchmark, measure, and monitor community progress (success or otherwise failure), providing more promising leverage points for policy change. (16)

In other words, in order to set and measure progress towards policy objectives, generalizable indicators can be useful, even if they do not capture all the qualitative nuances of child mobility.

In addition to the policy and organizational role quantifying child friendliness plays, there is also precedent for effective measurement of walkability and the friendliness of walkable neighborhoods. Frank et al. (2010) implemented a geospatial application of a walkability index in King County, Washington and Baltimore-Washington, DC, to better separate how sociodemographic and urban form elements affect walkability. Their study primarily focuses on indices of land uses—such as retail versus residential—which is perhaps less applicable for measuring child-friendly walkability who are more vulnerable to environmental and built environment factors (Su et al. 2013). However, after measuring walkability using their criteria of land use and intersection density, the authors corroborated their findings by comparing against mode and travel pattern data. They found that the travel patterns did indeed support the validity of walkability indices, showing that it is possible to estimate walkability without qualitative measures, even if they did not get the “fine grained” understanding of walkability at the micro, neighborhood scale. In the Wridt (2010) case, such fine-grained understanding involved identifying places of scary dogs and bullies.

Lo (Lo 2009) provides some guidance for measuring walkability by reviewing different literature, and professional standards on pedestrian level of service (LOS). Through this review, Lo identified common themes and criteria for quality of pedestrian environments. Such factors include street trees and landscaping, separation from traffic, and quality of sidewalk infrastructure to name a few. However, Lo acknowledges that there are conflicting ideas across such literature as well. For example Lo (Lo 2009) writes, “the Highway Capacity Manual (HCM) pedestrian level of service (LOS) criteria contradict almost every other planning and research

source on pedestrian quality of service. Under the HCM, an implicit bias toward lower volumes of pedestrians—and, by inference, lower density land-use contexts—conflicts directly with urbanist values for both accessibility and security” (163). Lo concludes by noting the importance of how multidisciplinary walking as an act is, which has hindered widespread, interdisciplinary consensus on walkability standards.

Considering such physical infrastructure characteristics that may hinder walkability, Kelly et al. (2007) provides evidence that walkability, namely sidewalk quality, differs across areas, dependent on race. In their multilevel logistic regression, they found that, “block groups that were predominantly African-American were 26.69 times more likely to have street segments with a lot of unevenness” controlling for poverty and “15.05 times more likely to have [obstructed] street segments” (Kelly et al. 2007, 980). Such differences should therefore be controlled for when measuring walkability across different neighborhoods.

More relevant to child mobility, the Institute for Transportation and Development Policy (ITDP) has developed its own tool for walkability. ITDP (2018) use babies and caretakers as key baseline for establishing their walkability criteria. Furthermore, their tool acknowledges the importance of qualitative considerations as well as including wide-spread metrics by identifying three scales at which to measure using different criteria: city, neighborhood, and street level scales. However, while the ITDP provides tools for measurement, the only mapped index of walkability that they have completed is their city-level metrics, due to data availability. Instead, they provide the local-based tools for community use and implementation.

Ultimately, there are various means in to create indicators for walkability in general, let alone for youth and children. In the end, however, ITDP’s toolkit shows promise in both its simplicity and generalizability. Despite the primarily qualitative method of assessing child

walkability at the block and neighborhood scale, the measure is both simple enough to be accessible for all readers while still being founded in previous research and measures (ITDP 2018).

Chapter 3. METHODS

3.1 OVERVIEW

To test for walkability across Seattle census tracts, this thesis created an index measuring: (1) factors from the built environment; (2) safety; (3) environmental hazards; and (4) socioeconomic and demographics. Children in the 5-9 age group were selected as the key demographic under consideration. There are two primary reasons behind this selection. First, children ages 5-9 are interacting more with public realm resources, such as elementary schools. Second, despite such interactions with public resources, they are still vulnerable and reliant on their parents for transportation and life choices; previous literature indicates that children after the age of 10 begin to travel more independently (M. H. Matthews 1992; McDonald and Aalborg 2009). This chapter discusses how the index was created. Sections 3.2 and 3.3 discuss the data and methods used to quantify child-friendly walkability. Sections 3.4 and 3.5 discuss statistical tests and analysis scenarios.

3.2 DATA GATHERING, PREPARATION, AND CODING INDICES

This thesis compiled data from publicly available geospatial datasets from the City of Seattle, US Census Bureau, King County, WSDOT, and the CDC. These datasets were cleaned and processed using ArcGIS Pro so that the boundaries matched census tract boundaries and missing and unneeded variables were excluded (See Appendix A for a complete description of

data compilation, cleaning process, and data inventory sources). Through processing these datasets, I coded the indices into four key dimensions of analysis and indexing based on the themes and categories of child-friendly walkability in previous literature:

1. Built Environment Form
2. Safety
3. Environmental Hazards
4. Socioeconomic and Demographic factors

From these dimensions, I built indices of analysis to compare the census tracts against one another (See Table 1: Child-friendly walkability criteria).

The target year for the data used was 2019, based on the ACS variables used. While ideally, I would have been able to use one year for all the indices for consistency, there were several cases that I decided to use differing years depending on data availability and outlying events. For example, 2018 traffic study data from the Seattle Department of Transportation (SDOT) and WSDOT were used to avoid any unusual traffic patterns from the 2019 “Seattle Squeeze” (Fesler 2018). For consistency, the decision rules for each and any deviation from selecting 2019 data was based on two criteria: (1) 2019 data was unavailable and (2) the 2019 data available did not reflect a “typical year” for that unit of analysis.

3.3 WALKABILITY INDICES AND FOUR DIMENSIONS

Each of the indices that fall under the four dimensions were drawn from previous literature. While there are various studies to draw from to base the criteria on, deciding factors on which to choose were largely dependent on data availability, analysis feasibility, and whether it satisfied the overall *intent* of the dimension at hand. For example, traffic is used as a proxy for noise pollution. And instead of measuring small blocks as provided by the Institute for

Transportation and Development Policy (ITDP) methods, I measured the average length of blockfaces across the tracts. Ultimately, the overarching question of how child-friendly Seattle tracts are to walkability can fall into several questions:

- How convenient is the built environment for walking (McDonald and Aalborg 2009; ITDP 2018)?
- How safe is the neighborhood for walkability, both in perceived safety and actualized safety (McDonald and Aalborg 2009; Olvera et al. 2012)?
- What environmental hazards do families and children face when walking that would lessen the experience (Su et al. 2013)?

From the literature and these overarching questions, this study isolated a set of criteria under the four categories described in the next subsections. Table 1 displays the entire list of criteria, the literature justification and background research, and the equation used to quantify.

Table 1: Child-friendly walkability criteria

Dimension	Indicator	Lit. Source / Justification	Measurement per census tract	Data Source
Built Environment Form	Public realm opportunity	(Sarmiento and Duarte 2019)	(Libraries + elementary schools + park features) / (Sq. miles)	City of Seattle
	Arterial sidewalk quality	(ITDB 2018)	% Poor or very-poor quality arterial sidewalks	SDOT
	Bus stop density	(Sarmiento and Duarte 2019)	Bus stops / (Sq. mile)	King County
	Bus stop shelter	(Sarmiento and Duarte 2019)	% Bus stops that have shelters	King County
	Crossing availability	(Lo 2009)	(Intersections) / (Sq. mi)	SDOT
	Slope	(Meeder, Aebi, and Weidmann 2017)	Average tract street slope	SDOT
	Blockface Length	(ITDB 2018)	Average blockface length	Block density
	Tree canopy	(ITDB 2018)	Percentage of tract covered by tree canopy	City of Seattle
Safety	Collisions	(Partnership for a Walkable America et al. n.d.)	(Collision accidents) / (Sq. miles)	SDOT
	Crime	(Lo 2009)	(Violent crimes) / (Sq. mile)	SPD
	Lighting	(Lo 2009; ITDB 2018)	(Light posts) / (Sq. mile)	Seattle City Light
Environmental Hazards	Trash	(Partnership for a Walkable America et al. n.d.)	(Adopt-a-Street length) / (Sq. mile)	City of Seattle
	Car speed limits	(Lo 2009)	Mean MPH within tract	SDOT Streets
	Heavy traffic flows	(Partnership for a Walkable America et al. n.d.)	(Avg. Annual Weekday Traffic)	SDOT
	Air quality	(Bae and Sinha 2016)	Annual Avg. PM2.5	CDC / EPA (2016)
Socioeconomic and Demographic Comparison Variables	Vehicle access		Percentage of households with no vehicle	2019 ACS
	Income		Median household income	2019 ACS
	BIPOC		Percentage of tract not "White alone"	2019 ACS
	LQ for ages 5-9		Location quotient for children ages 5-9	2019 ACS

3.3.1 *Built Environment Form*

The built environment form dimension largely pertains to both convenience and access through walking. In general, it includes the factors that influence walkability: Is the sidewalk adequate (Lo 2009)? How direct are the walking routes to destinations (ITDP 2018)? Considering the rather nuanced influences of different built environment forms and infrastructure towards walkability, this dimension has the most criteria of the four.

Public realm opportunity measured the sum of different public realm amenities—including libraries, schools, different park features—divided by square mile. The measure includes the variety of park features, creating bins for different amenities to consider the importance of diversity and variety of amenities for child-friendliness (Kytä 2004), including park water features, sports, and others (See Appendix A for a description of the complete data collection and cleaning process).

For transportation amenities, updated sidewalk quality data was unfortunately limited, so only arterials were used. Arterial sidewalk quality data was to assess path quality, measured by and obtained from the City of Seattle’s Open Data Portal. Transit access is an important consideration for walkability for school aged children and families (Sarmiento and Duarte 2019). Bus stop density per square mile and the percentage of stops that had shelter were used to assess transit access and quality of the stops as potential nodes. Intersections were measured as densities as well, to account for distance factors.

In assessing the physical environment’s ability to facilitate pleasant and direct paths, slope was also added to this list. While not a common theme found in the literature, slope is a concern for a hilly city like Seattle (Meeder, Aebi, and Weidmann 2017). To assess directness of paths—smaller blocks facilitate more paths and greater walkability as discussed by ITDB

(2018)—average blockface lengths by tract were measured using Seattle Department of Transportation (SDOT) data. Lastly, tree canopy was used to assess the pleasantness of the built environment for child-friendly walkability, measured as a percent coverage of the entire tract.

3.3.2 *Safety*

Safety is an important factor in encouraging walkability. However, it is also contentiously measured. For example, fear of police might supersede fear of criminal activity for some parents depending upon race and immigration status (Wridt 2010). On the other hand, crime could correlate with more policing, resulting in fears of racial discrimination in policing in such neighborhoods (Weisburd and Majmundar 2018). In a qualitative study with young Black men, Brunson’s (2007) finds, “Involuntary police/citizen encounters are more apt to occur in disadvantaged neighborhood contexts where aggressive policing strategies are disproportionately used” (95). Therefore, this thesis includes crime rates as a measure considering these two related factors: safety concerns out of fear of unsafe criminal activities and fear of racial discrimination from policing. Additionally, when it comes to *perceived* safety, Hipp (2013) found that violent crime was the most significant type of crime for perceived safety concerns. Considering such factors, this thesis measures violent crimes per square mile to assess such safety concerns.

Lighting and traffic collisions also play a role in perceived physical safety for pedestrians, be it children or adult (Olvera et al. 2012; Lo 2009). All collisions in 2019 were used to measure traffic safety, dividing by square mile. Isolating pedestrian collisions only resulted in small sample errors, so all collisions were used. Seattle Public Utility (SPU) light poles per square mile were used to assess lighting.

3.3.3 *Environmental Hazards*

Environmental hazards influence walkability and have equity implications for subpopulations that have no alternative transportation, whether from lack of vehicle ownership or income—many from vulnerable populations have no choice but to walk and face environmental hazards (Su et al. 2013). The environmental hazards measured in this study are trash (litter), vehicle speeds and traffic, and air quality.

There was not any data on trash and litter, unfortunately, clean paths being important to child-friendly walking paths (Partnership for a Walkable America et al., n.d.). The length of Adopt-A-Street programs per square mile were used instead as a proxy. The Adopt-A-Street Program allows individuals or organizations to volunteer to keep a certain street segment clean and enhances community engagement in the city. In return, the volunteer hours can be recorded, and the city provides supplies for the efforts (Seattle Public Utilities n.d.; Shobe and Conklin 2018).

Average vehicle speed limits and traffic were used to assess noise and barriers to walkability and child-friendliness (Lo 2009; Partnership for a Walkable America et al., n.d.). Data from SDOT was used to measure average speed limits by tract. For traffic, data was cleaned and blended from WSDOT and SDOT to include both city and state managed traffic. Average Annual Weekday Traffic (AAWT) was measured by census tract.

Poor air quality can affect both walkability and child-friendliness (Bae and Sinha 2016). This thesis used annual average Particulate Matter (PM) 2.5 data to assess Transportation-Related Air Pollution (TRAP). Air quality data at the census tract boundary level proved somewhat challenging to obtain. While the Puget Sound Clean Air Agency does actively collect PM 2.5, using their test site point-source data would have required geospatial modeling to

estimate pollution levels at the census tract level. Instead, Center for Disease Control modelled 2016 EPA PM 2.5 data at the tract level for this study (See Chapter 5 for data limitations starting on p. 33) (CDC National Environmental Public Health Tracking Network 2020).

3.3.4 *Socioeconomic and Demographic Comparison Variables*

The socioeconomic and demographic data was used largely to obtain a more fine-grained understanding of the walkability measures. For example, a tract may not be very friendly to child walkability, but it may not necessarily need to be if its land use is primarily industrial over residential and has very few children. So, by measuring the age characteristics, income, race, and vehicle ownership, the study can compare each of the other dimensions across such factors to understand the tract- and city-wide level factors for friendliness of child walkability. Race was measured as the percentage of those who did not answer “White alone” on the 2019 ACS. While such an approach ignores some of the inter-racial differences across Black, Indigenous, People of Color (BIPOC) communities, it does provide a better understanding of the racial equity implications for child walkability. Lastly, to account for relative concentration of densities of children, a location quotient (LQ) was measured for each of the tracts using the following formula:

$$\text{Location Quotient (LQ)} = \frac{\frac{\text{Number of Children between 5 and 9 years old per track}}{\text{Number of Children less than 18 years old per track}}}{\frac{\text{Total Number of Children between 5 and 9 years old in Seattle}}{\text{Total Number of Children less than 18 years old in Seattle}}}$$

This thesis employs two methods for evaluating these indices against the walkability dimensions. First, Pearson’s correlations (r coefficients) were implemented against each of the socioeconomic and demographic variables (See Table 3, p. 35. and Table 4, p. 37). Second, the

socioeconomic variables were aggregated into a vulnerability score to measure the means across the vulnerability measures (See Figure 10, p. 45).

3.4 STANDARD SCORING AND STATISTICAL ANALYSIS

This thesis does not implement an ordinary least squares (OLS) regression research model, because many of the variable indices could be deeply related to one another. Rather, this thesis examined each of the index dimensions to establish correlation factors between the built environment form, safety, and environmental hazard dimensions against the socioeconomic and demographic factors to gain a deeper understanding. Indeed, the intent of this approach was not to determine causality, but the trends and associations between elements that enable or hinder walkability against socioeconomic and demographic characteristics of the tracts. Z-scores were used to standardize each of the indices. For some variables, the absolute values were taken of these scores to account for the nature of the variable. For example, a higher positive z-score for bus stop density benefits walking and mobility, while a higher positive z-score for collisions per square mile does not. The indices that absolute values were taken for z-scores were:

- Percentage of poor arterial sidewalks
- Average slope percentage
- Average blockface length
- Collisions per square mile
- Violent crime incidents per square mile
- Average speed limit
- Average annual daily traffic
- Average annual daily PM 2.5 by census tract

3.5 INDEX SCENARIO MODELS

To better control for variations across population demographics in comparing and analyzing the index, I created analysis scenarios:

- *Unweighted Child-Friendly Walkability Index*. Measuring and ranking tracts based on the sum of the unweighted child-friendly walkability index
- *Parental Walkability Perception Index*. Measuring and ranking tracts based on a weighted child-friendly walkability, based on parental concerns and reasons for driving versus walking their children to school (McDonald and Aalborg 2009).
- *Comparing Child-Friendly Walkability Index Scores by Socioeconomic Vulnerability*. Seattle census tracts all have different economic and demographic compositions. This thesis created a Socioeconomic Vulnerability Index to identify the most and least

This Section discusses each in more detail.

3.5.1 *The Unweighted Child-Friendly Walkability Index Scenario*

The unweighted scenario totals up each of the indicators by dimension discussed in Section 3.3. Each of the indicators are unweighted, meaning crime is considered just as important as lighting considerations in the model. The Z-scores are summed by dimension, and the dimension subtotals were then summed to create the total score.

3.5.2 *The Parental Walkability Perception Scenario*

The unweighted model scenario assumes that each of the indicators discussed in Section 3.3 carry equal importance towards enabling or hindering child-friendly walkability. However, this is often not the case. Culture, family background, economic status, preference, and demographic factors all influence different households' perceptions of what is walkable or unwalkable, resulting in differing weights to each of the indicators (Kytta 2004; Olvera et al. 2012; McDonald and Aalborg 2009). For example, while safety is indeed deemed very important in most studies evaluating parents' reasons to allow, or accompany their children on trips the school, the individual motivations and emotion behind what makes a safe, walkable trip for parents and children varies. McDonald and Aalborg (2009) found that "stranger danger" ranked among one of the top concerns for parents. Olvera et al.'s (2012) study found that traffic was viewed more seriously than crime by mothers. Indeed, cultural and community aspects of the neighborhood may very well influence the overall reasons for allowing or forbidding children to walk.

Despite differences in the literature, I selected McDonald and Aalborg's (2009) qualitative study to create weights for my model for two reasons. First, it was conducted in San Francisco, which, in terms of city comparisons, is a west coast city with similar economic characteristics. Second, their survey methods covered a variety of family members, while Olvera et al. (2012) focused primarily on Hispanic parents. McDonald and Aalborg categorize parents' unwillingness to walk their children to school under two categories.

- *Convenience.* 66% of respondents in the study reported lack of convenience as a reason for driving versus walking their child to school.

- *Safety concerns.* 34% of McDonald and Aalborg’s respondents reported safety as a motivating factor to drive over walk their child to school.

Using this framework, I coded these themes as weights across the indicators, which are summarized in Table 2. Largely, convenience factors were coded into built environment form features, while safety was coded into the safety and environmental hazards dimensions.¹ Crime was given a 2.5 percentage point boost compared to other safety indicators due to the study finding “stranger danger” as the most common safety concern among parents and guardians (McDonald and Aalborg 2009). The bus stop indicators were halved in percentage points as to not over-value them compared to the other indicators in the built environment form dimension.

Table 2: Weights for the parental walkability perception index

Dimension	Indicator	Weighting Factor	Individual Weight
Built Environment Form	Public realm opportunity	Convenience: 66%	9.4%
	Arterial sidewalk quality		9.4%
	Bus stop density		4.5%
	Bus stop shelter		4.5%
	Crossing availability		9.4%
	Slope		9.4%
	Blockface Length		9.4%
	Tree canopy		9.4%
Safety	Collisions	Safety: 34%	4.5%
	Crime		7.0%
	Lighting		4.5%
Environmental Hazards	Trash	Safety: 34%	4.5%
	Car speed limits		4.5%
	Heavy traffic flows		4.5%
	Air Quality		4.5%

¹ It must be noted that the coded convenience themes in the McDonald and Aalborg (2009) study largely pertained to time and distance concerns among parents, which do not directly relate to physical design and infrastructure. However, built environment factors can influence convenience through design. For more accurate weighting matrices, future research could replicate such a study using qualitative research to better understand the reasons behind walking or driving for Seattle parents.

3.5.3 *The Socioeconomic Vulnerability Scenario*

The City of Seattle has a Racial and Social Equity (RSE) Index to prioritize projects and funding to historically disadvantaged and marginalized communities (OPCD 2020). This thesis created a Socioeconomic Vulnerability index for a similar purpose: there may be tracts that *need* more child-friendliness and walkability but score lower in the walkability index scenarios. To create this second index, the socioeconomic and demographic dimension variables were standardized using Z-score and summed, weighted by LQ to show higher overall vulnerability depending on concentration of children ages 5-9. After creating this variable, quartiles were identified and created to compare index means across each vulnerability score. See Figure 10 in Section 4.7 starting on page 43 for its results.

Socioeconomic Vulnerability Index

$$= (Z_{Vehicle\ Access} + (Z_{Median\ HH\ income} * -1) + Z_{\%BIPOC}) * LQ_{Ages\ 5-9}$$

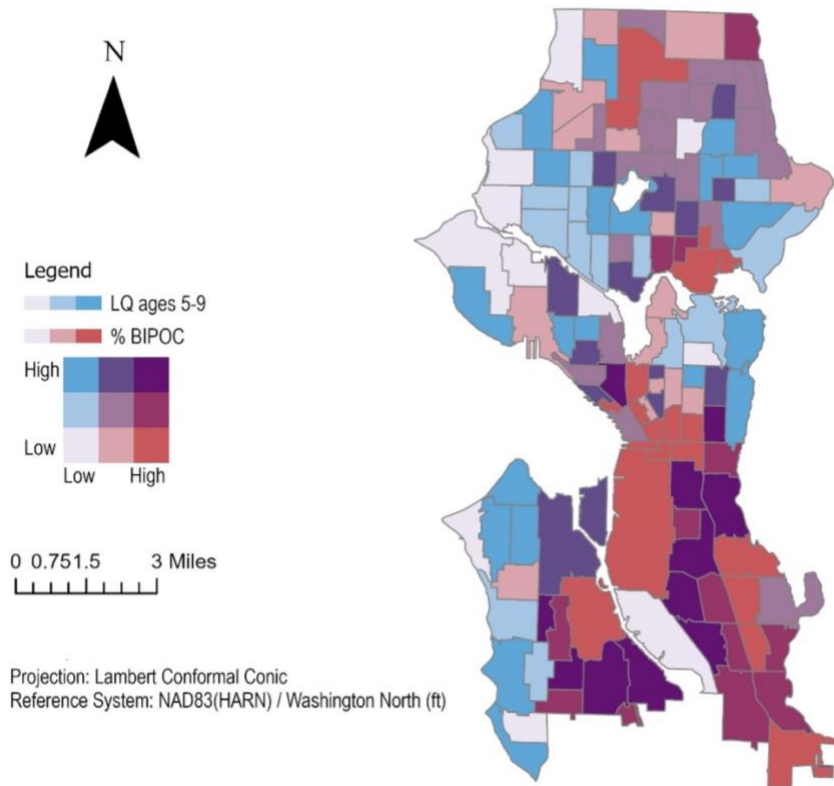
Chapter 4. RESULTS

4.1 POPULATION CHARACTERISTICS

Overall, the population demographics were consistent with previous data on race and income. Tracts in South Park and South Lake Union had the highest concentrations of children ages 5-9 and Black, Indigenous, and People of Color (BIPOC) based on the LQ measures and 2019 ACS figures. However, such concentrations were not statistically significant at 95% confidence based on ArcGIS's Local Bivariate Relationship test. Higher concentrations of both White populations and children ages 5-9 were found to be in tracts located in West Seattle, Madrona, Ballard/Crown Hill neighborhoods, and Northgate/ Laurelhurst neighborhoods. In

Figure 1, we see the tracts with both higher rates of BIPOC individuals and concentrations of children ages 5-9 depicted in deep purple, with tracts with both White individuals and higher concentrations of children depicted in turquoise blue.

Figure 1: Bivariate comparison of children ages 5-9 and percentage BIPOC



4.2 OVERVIEW OF SEATTLE WALKABILITY VARIABLES

Before standard scoring, this thesis used Pearson’s correlation coefficient to understand the city-wide effects of each of these variables across all Seattle census tracts (See Appendix B). For socioeconomic and demographic figures, comparing the location quotient to median income and vehicle ownership yielded statistically significant correlations, meaning that census tracts with higher concentrations of children 5-9 are more likely to have higher incomes and own a

vehicle (both $p = 0.001$).² With the percentage BIPOC and lack of vehicle ownership variables, there was a statistically significant positive correlation, indicating that Seattle Tracts with higher proportions of BIPOC individuals were more likely to have higher proportions of car-free households (See Appendix B, Table 6: Socioeconomic and demographics variables).

For the built environment form variables, bus stop density was negatively correlated with the location quotient variable. However, figures across the dimensions that have higher concentrations in the downtown area, such as lighting and crime, tend to negatively across the variables, indicating the geographic density of downtown, coupled with fewer children residing in downtown neighborhoods. Perhaps more interesting was the tree canopy coverage variable. Tree canopy was moderately positively correlated with median household income ($r = 0.4$ with $p = 0$) and negatively correlated with crossing density ($r = -0.4$ with $p = 0$), showing both income and built environment factors into tree canopy. The public realm amenities variable only appeared to slightly correlate with bus stop density ($r = 0.3$ with $p < 0.01$), with the others yielding insignificant results. The strongest linear relationship was between bus stop density and the percentage of households without a vehicle ($r = 0.8$ with $p = 0$). For the full list of coefficients, see Appendix B, Table 7: Built Environment Form variables.

For Safety, the variables with higher concentrations of instances in the downtown tracts tended to bias the correlations. For example, violent crime, light poles, and percentage of vehicle free households all significantly correlate with one another, indicating some selection bias across the variables due to the measures' design (See Appendix B, Table 8: Safety variables). Lastly, for the Environmental Hazard variables, the air pollution, measured as annual daily average PM 2.5, was unexpectedly negatively correlated with the variable representing higher concentrations

² All correlation statistics evaluated at 95% confidence ($\alpha=0.05$).

of BIPOC individuals ($p = 0$), which is somewhat contradictory to studies that have found higher exposure to pollution among BIPOC groups (Su et al. 2013). However, this could very well be due to the data source for PM 2.5—the Center for Disease Control (CDC) and Environmental Protection Agency (EPA)—modeled the pollution at a macrolevel (CDC National Environmental Public Health Tracking Network 2020). The implications of this limitation are further discussed in Chapter 5, on page 33. Perhaps more in line with expectations, rates of PM 2.5 were negatively correlated with percentage of households without a vehicle ($p = 0$) and greater presence of Adopt-a-Streets ($p = 0.024$).

4.3 UNWEIGHTED CHILD-FRIENDLY WALKABILITY INDEX

With the unweighted child-friendly walkability index scenario, described in Section 3.5 on page 28, the built environment form indicators, as predicted by the Pearson's correlations, did indeed show greater walkability scores in downtown neighborhoods when aggregated (See Figure 4 on p. 39). However, such bias was largely eliminated upon totaling the index, as environmental and safety factors scored more highly in non-downtown tracts, discussed further in Section 4.5.

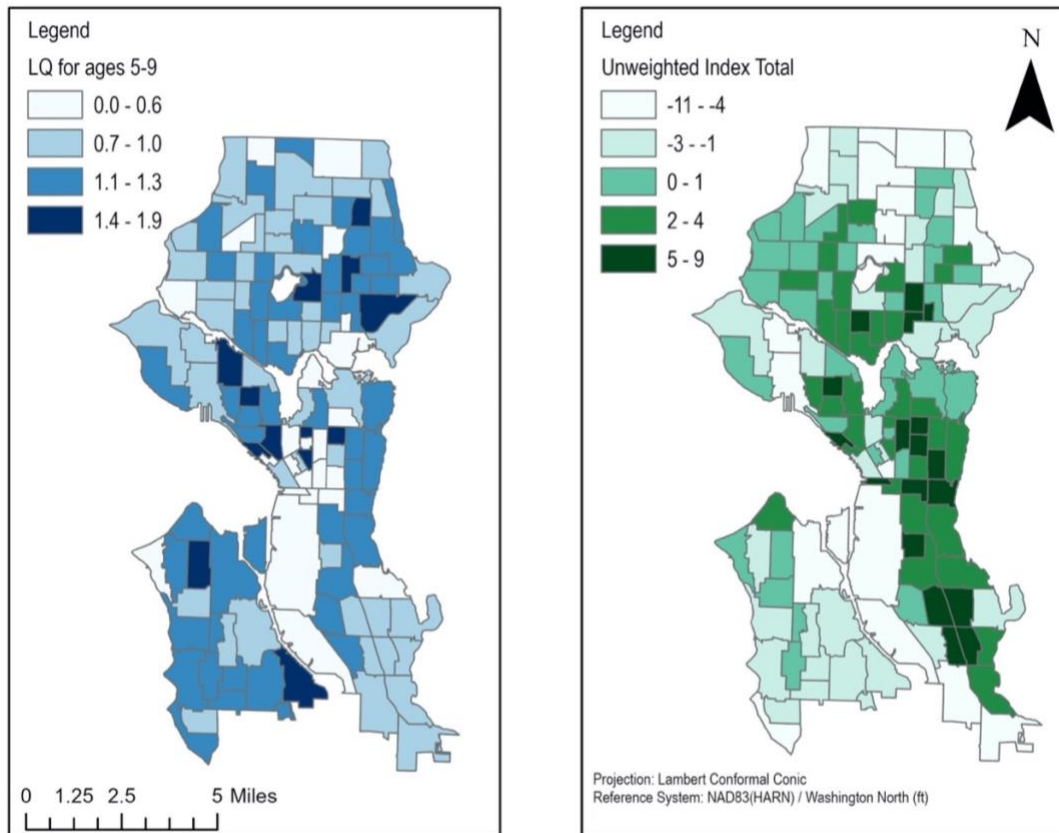
Testing across all tracts using Pearson's correlation coefficient, higher densities of children ages 5-9 were positively correlated with greater index values (See Table 3). Race was found to be statistically insignificant measuring against the total index, but slightly negatively correlated with safety and positively correlated with environmental hazards ($\alpha = 0.05$). The strongest linear relationship—defined as $r < -0.5$ for negative relationships and $r > 0.5$ for positive relationships—was between car-free households and the built environment form and safety dimensions. In other words, there was an relationship between tracts with higher percentages of car-free households and higher built environment factors that enable child-friendly walkability.

Table 3: Unweighted index Pearson's correlation coefficients

	Built Environment Form	Safety	Environmental Hazards	Total
LQ for ages 5-9	-0.0333	0.2854*	0.0565	0.1054
	<i>0.7043</i>	<i>0.0008</i>	<i>0.5151</i>	<i>0.2290</i>
% BIPOC	0.1001	-0.2444*	0.1986*	0.1466
	<i>0.2536</i>	<i>0.0043</i>	<i>0.0209</i>	<i>0.0934</i>
% Households without a vehicle	0.5257*	-0.5867*	0.1196	0.2701*
	<i>0</i>	<i>0</i>	<i>0.1672</i>	<i>0.0017</i>
Median HH income	-0.2424*	0.4118*	-0.0157	-0.0856
	<i>0.0051</i>	<i>0</i>	<i>0.8561</i>	<i>0.3293</i>
P-values in italics. Asterisks denote statistical significance at 95% confidence.				

When it came to the overall ranking of census tracts, tracts in the Beacon Hill and Queen Anne/South Lake Union neighborhoods scored the highest, and downtown and SODO neighborhoods scoring the least friendly for walkability. Testing the total index against the socioeconomic and demographic variables—race, vehicle access, LQ, and income—no significant relationships were found at 95% confidence. In comparing the index to LQ visually in Figure 2, higher walkability scores are seen in Capitol Hill, Beacon Hill, University District, and Queen Anne. Lower scores are seen in North and Southwestern tracts of Seattle and the Industrial, Duwamish Valley area.

Figure 2: Total unweighted index map compared to LQ



4.4 PARENTAL WALKABILITY PERCEPTION SCENARIO

The weighted parental walkability perception scenario did not prove to be vastly different than the initial, unweighted model (See Figure 3). In comparing Pearson's correlation coefficients in the new weighted scenario (Table 4), we find that there is neither direction nor large statistical significance changes across the index and socioeconomic and demographic variables. The only significant change was the percentage of the BIPOC population in correlation to the total index. In the unweighted model, there was a significant positive correlation between the walkability index and the proportion of the tract that is BIPOC ($p = 0.093$). In the parental walkability perception scenario, the significance is decreased ($p = 0.315$). The strongest linear relationship was the negative correlation between the percentage of households without a vehicle

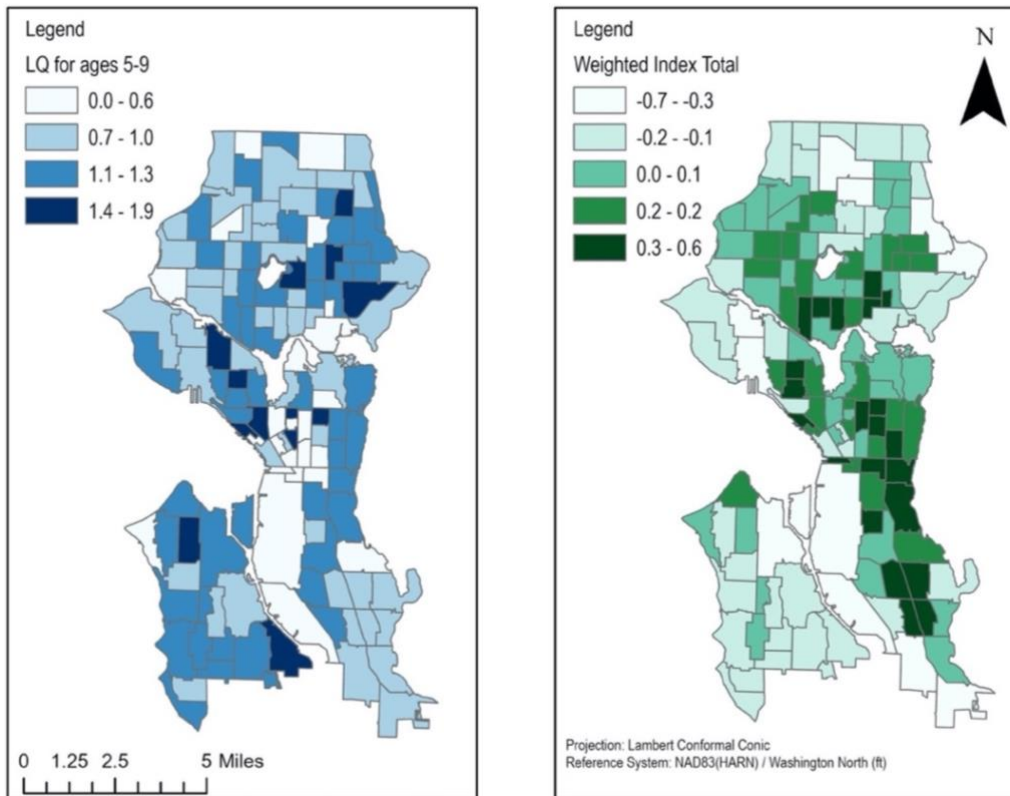
and the safety indicator ($r = 0.7$ with $p = 0$). The implications of these statistical relationships are discussed in Chapter 5, starting on page 49.

Table 4: Parental walkability perception index Pearson's correlation coefficients

	Built Environment Form	Safety	Environmental Hazards	Total
LQ for ages 5-9	0.0037	0.2844*	0.0565	0.1246
	<i>0.9667</i>	<i>0.0008</i>	<i>0.5151</i>	<i>0.1547</i>
% BIPOC	0.0561	-0.2301*	0.1986*	0.0881
	<i>0.523</i>	<i>0.0072</i>	<i>0.0209</i>	<i>0.3151</i>
% Households without a vehicle	0.4481*	-0.6649*	0.1196	0.2208*
	<i>0</i>	<i>0</i>	<i>0.1672</i>	<i>0.0109</i>
Median HH Income	-0.1829*	0.4126*	-0.0157	-0.0515
	<i>0.0358</i>	<i>0</i>	<i>0.8561</i>	<i>0.5577</i>

P-values in italics. Asterisks denote statistical significance at 95% confidence

Figure 3: Total parental walkability perception index map compared to LQ



4.5 COMPARING THE UNWEIGHTED AND PARENTAL WALKABILITY PERCEPTION INDICES

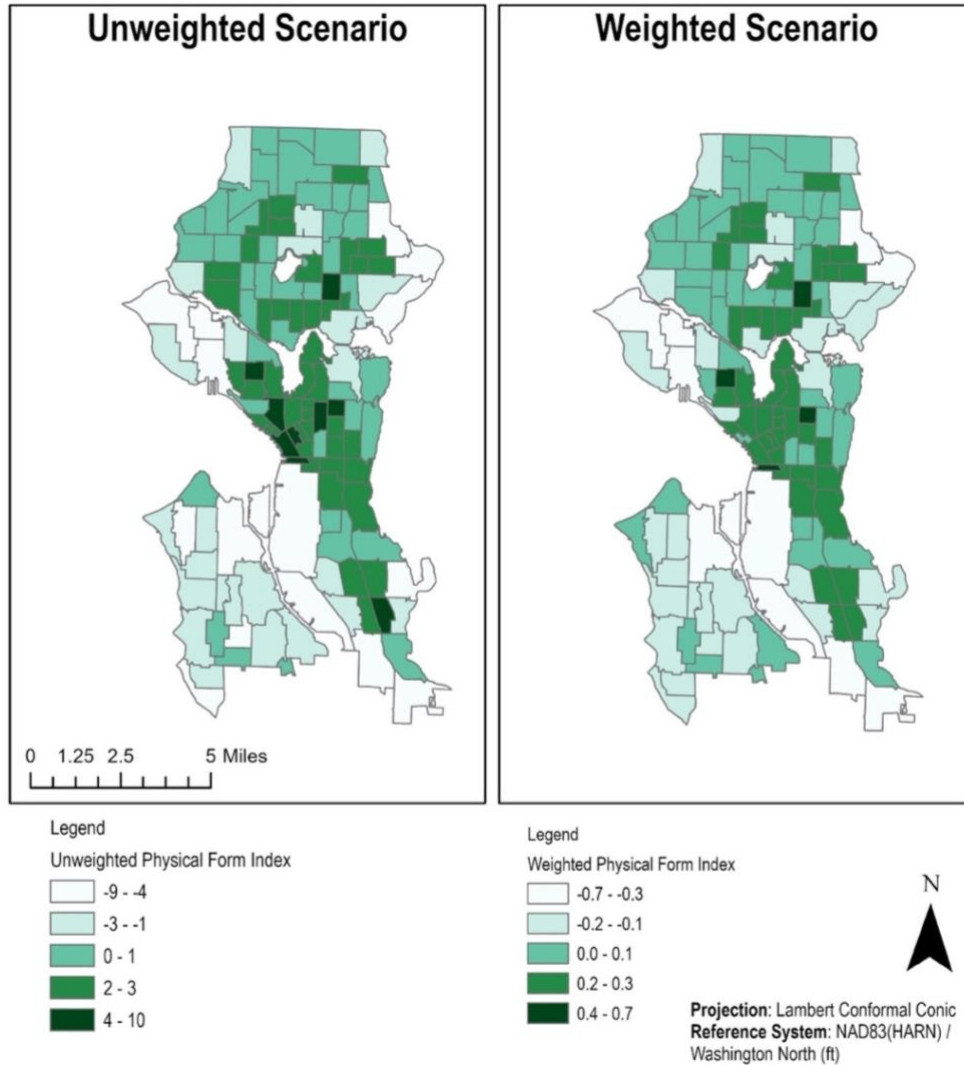
Although the weighting did not significantly alter the comparative rankings of each of the tracts as depicted in the map, it did alter some of the top ranked census tracts, though general neighborhoods remained similar across the two scenarios (See Table 5).

Table 5: Highest walking index tract comparison

Rank	Unweighted Index		Parental Walkability Perception Index	
	Tract	Neighborhood	Tract	Neighborhood
1	Census Tract 53.01	University District	Census Tract 76	Broadway
2	Census Tract 76	Broadway	Census Tract 44	Ravenna
3	Census Tract 103	Mid-Beacon Hill	Census Tract 53.01	University District
4	Census Tract 44	Ravenna	Census Tract 111.01	Mid-Beacon Hill
5	Census Tract 80.01	Lower Queen Anne	Census Tract 103	Mid-Beacon Hill

Some of the reasons behind the differences can be seen by examining the resulting maps of each of the dimensions. First, for built environment form, we see in Figure 4 that the unweighted, standard scenario index had more walkability elements than in the parental walkability perception scenario. Yet, the general score levels remain somewhat consistent across neighborhoods—Beacon Hill, located in the southeastern portion of the city had slightly higher values. Tracts along the Duwamish River remained less walkable in both scenarios. The downtown tracts scores, which scored high due to its relatively higher density of built environment indicators—such as bus stops, small blocks, and sidewalk quality (discussed in Section 3.3 starting on p. 20)—were more balanced in the parental walkability perception scenario from the weights.

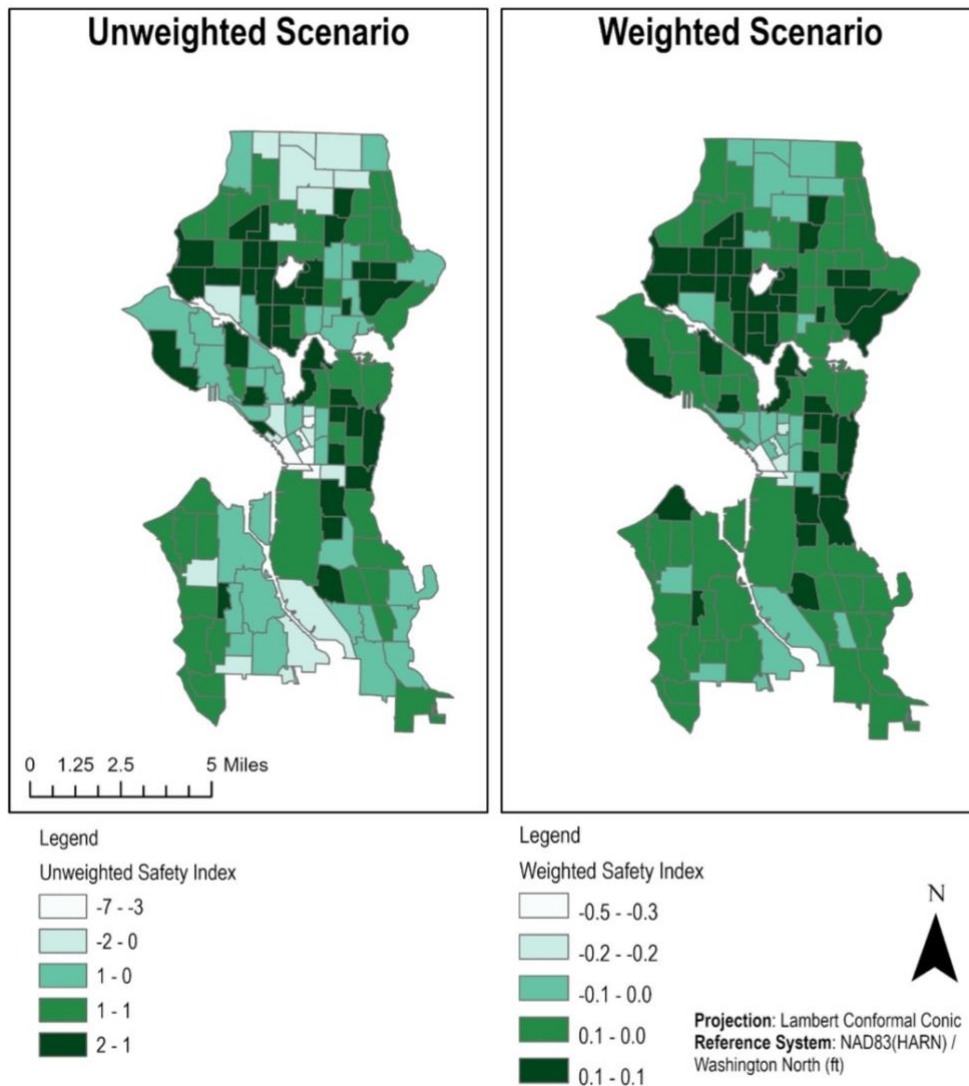
Figure 4: Built Environment Form dimension index for the unweighted and weighted parental walkability perception scenarios



There was a more obvious gap across the tracts regarding downtown versus the rest of the city when it came to the safety dimension. As seen in Figure 5, in both the unweighted and weighted parental walkability perception scenario, downtown tracts scored lower than the rest of the city. Violent crime and collisions are more heavily concentrated in downtown tracts,

resulting in this gap. Interestingly, lighting was more heavily concentrated in downtown tracts, but it was not enough to out measure the effects of crime and collisions.

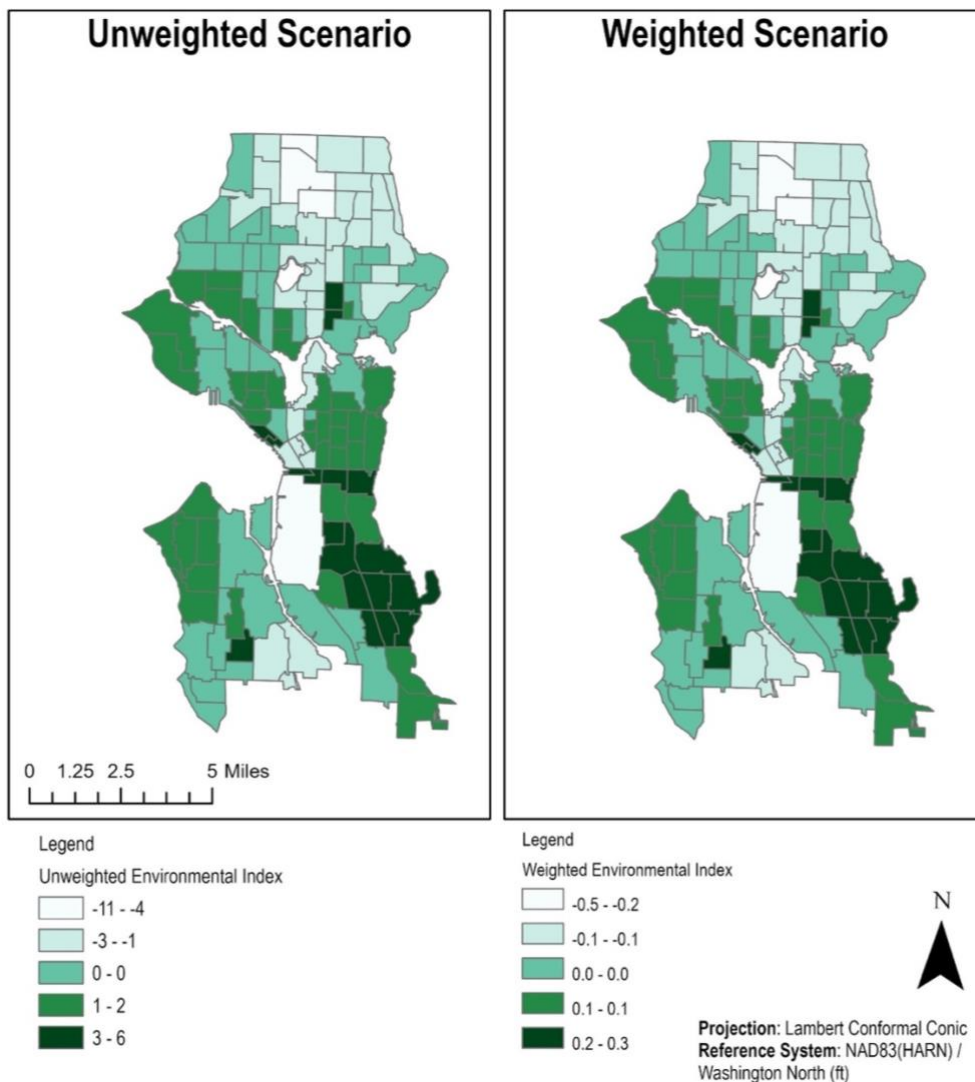
Figure 5: Safety dimension index for the unweighted and weighted parental walkability perception scenarios



Viewed as a scaled rank, the weighted parental walkability perception index was not discernably different than the raw, unweighted index, as seen in Figure 6. Some of the reasons

for the neighborhoods surrounding Beacon Hill and the southwestern tracts of Seattle can be seen through this dimension, with strong scores for fewer environmental hazards. Greater environmental hazards were found in the SODO tract, the large tract located in the center of the map depicted white. Such low scores are likely due to land use, since the tract has high traffic volumes from its industrial uses.

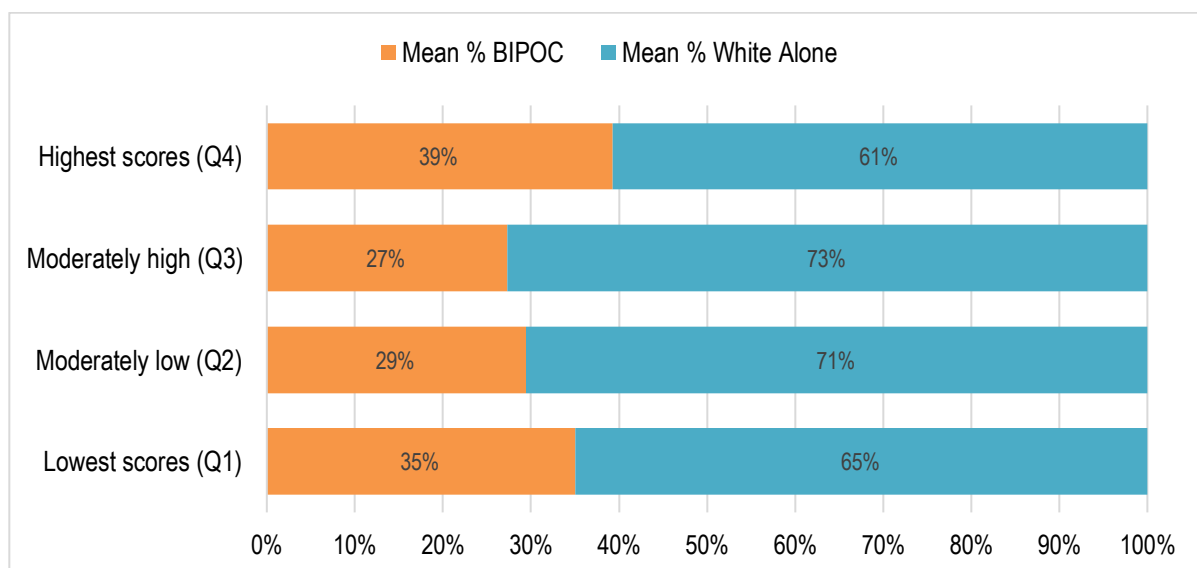
Figure 6: Environmental Hazards dimension index for the unweighted and weighted parental walkability perception scenarios



4.6 COMPARING WALKABILITY INDEX MODELS AGAINST SOCIOECONOMIC AND DEMOGRAPHIC VARIABLES

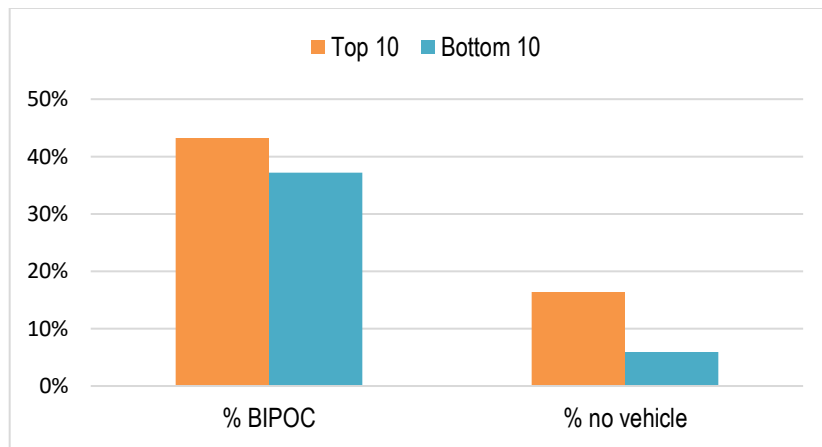
Using the Local Bivariate Relationship tool in ArcGIS, none of the Socioeconomic and Demographic indicators had statistically significant relationships with both index scenarios (95% confidence). In comparing the top and lowest 10 ranked census tracts in the weighted index scenario, taking average values for the socioeconomic and demographic variables, there does not appear to be a large difference at a summary level. Figure 7 shows that the highest quartile of tracts—or most walkable—comprised of 39% BIPOC, slightly higher than the next two quartiles, comprising 27% and 29% BIPOC on average respectively. Interestingly, the most and least walkable neighborhoods, defined by the top and bottom quartiles, had somewhat similar compositions, 39% BIPOC for the highest scoring and 35% for the lowest.

Figure 7: Average percent BIPOC by parental walkability perception index quartile



Median income was even higher on average for the least walkable tracts, \$90,354 compared to \$75,025. The one gap identified, however, was vehicle ownership. As seen in Figure 8: Mean vehicle ownership and racial characteristics compared across the top and bottom 10 ranking tracts from . The top 10 ranked tracts in the parental walkability perception index model had, on average, 10 percentage points fewer households that owned any personal vehicle.

Figure 8: Mean vehicle ownership and racial characteristics compared across the top and bottom 10 ranking tracts from the parental walkability perception index

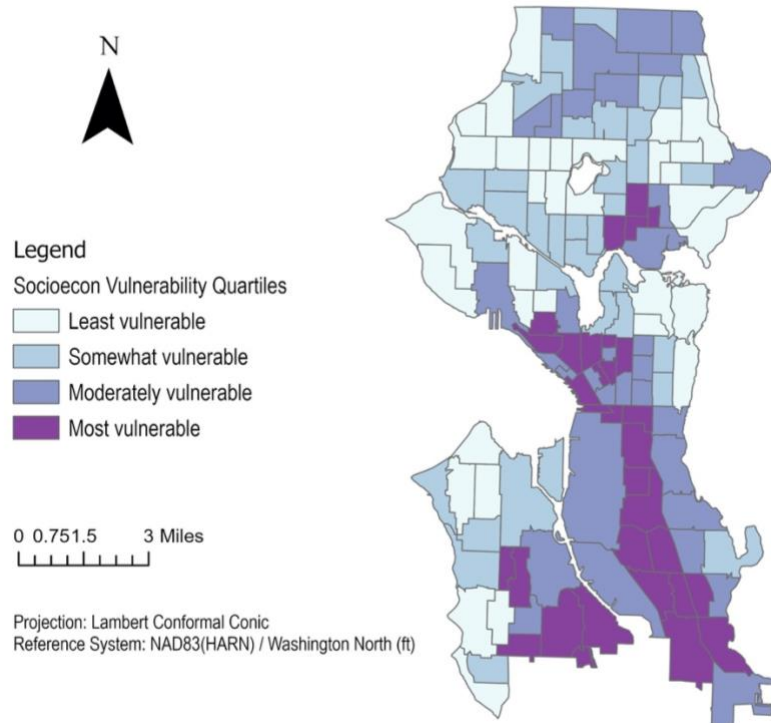


4.7 THE SOCIOECONOMIC VULNERABILITY INDEX MODEL

In addition to comparing the parental walkability perception and unweighted walkability indexes against each of the socioeconomic and demographic variables, I quantified and identified more vulnerable and sensitive census tracts by creating an index from the Socioeconomic and Demographic measures. As seen in Figure 9, the most vulnerable Tracts are in South Seattle, Center City and Commercial Core tracts, and in South Park with higher vulnerability index scores. However, like the previous index models, running ArcGIS Pro’s Local Bivariate Relationship tool yielded insignificant statistical relationships across all census tracts at 95% confidence. The high socioeconomic vulnerability in the Commercial Core is likely to be a result

of the higher concentrations of car-free households, which is discussed more in Chapter 5, page 49.

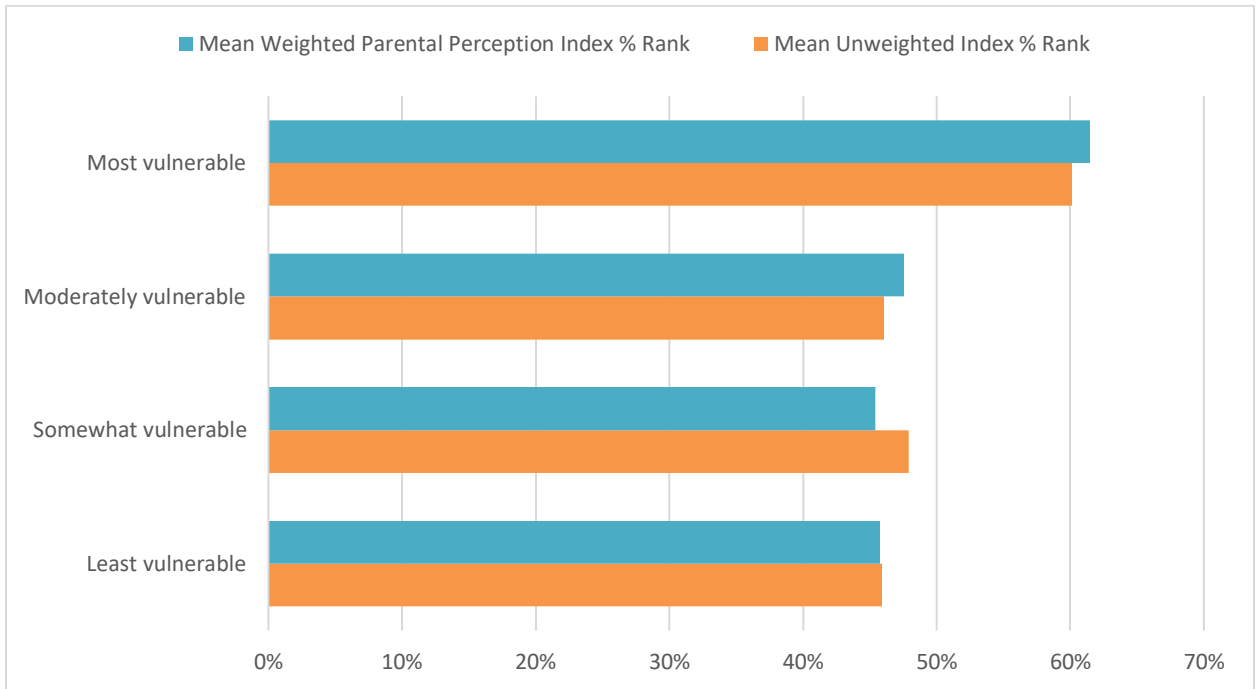
Figure 9: Socioeconomic vulnerability index map by quartile



The vulnerability index scores were then divided by quartiles to examine the child-friendliness scores across the vulnerability bins. By dividing by quartile, we are better able to assess the walkability scores across vulnerability. For example, are the more vulnerable tracts—those with greater BIPOC, lower incomes, and more children ages 5-9—less “walkable” according to the indices than less vulnerable tracts? For comparing walkability across socioeconomic vulnerability, both unweighted and parental walkability perception indices were converted to percentage rankings for greater comparability. Interestingly, as seen in Figure 10, when comparing the average percent rank index scores across the most and least vulnerable tracts to walkability factors, the most vulnerable tracts had, on average, scored more than 10

percentage points higher in both the parental walkability perception and unweighted walkability index models. Such score differences are likely due to the high socioeconomic vulnerability of the Beacon Hill area neighborhoods, coupled with high walkability scores.

Figure 10: Average walkability rank compared across socioeconomic vulnerability quartile and index scenarios



Chapter 5. DISCUSSION

This thesis used indicators to address the question and subsequent questions: *how amenable are Seattle census tracts for child walkability?* And as a sub-question, *does the child-friendliness of walkability correlate with racial demographic composition of the tract?* To answer this question, I created the walkability index. The results of the aggregated index proved to be statistically inconclusive and insignificant when looking at most of the racial demographics and socioeconomic characteristics on a tract-by-tract basis using ArcGIS Local Bivariate

Relationship tool. Indeed, in looking at the top and bottom ranked tract summary statistics, there was no discernible racial gap across the index and comparison variables. In examining vulnerability to walkability factors, the results indicated slightly higher rankings of walkability for the most vulnerable tracts. Such results were contrary to my hypothesis that more vulnerable tracts were less walkable due to factors of racial exclusion, income, and lack of access to transportation. This section first discusses the findings of each of the results sections—the unweighted and weighted parental walkability perception index models and the vulnerability scoring—in greater detail. Then, this thesis’ limitations are discussed, followed by the policy implications of walkability indices.

First, in examining both the weighted parental walkability perception and unweighted child-friendly walkability index dimensions—Built Environment Form, Safety, and Environmental Hazards—across the Socioeconomic and Demographic variables, there were several statistically significant findings through the initial Pearson’s correlation coefficient examination ($\alpha = 0.05$).

Seattle tracts with higher concentrations of ages 5-9 had higher levels of safety. LQ for ages 5-9 was positively correlated with the safety dimension in both the parental walkability perception and unweighted models ($p < 0.01$). Such statistical significance indicates that census tracts with higher LQs are slightly safer in terms of crime rates, lighting, and collisions, a plus for Seattle’s child-friendliness. However, the coefficients indicate only a slight weak linear relationship ($r = 0.3$).

Tracts with more BIPOC also had lower safety scores. The percentage BIPOC was slightly negatively correlated with safety ($r = -0.2$ in both weight scenarios), indicating, on average, a slight relationship between crime, collisions, and streetlight access for BIPOC

compared to Whites ($p < 0.01$). Such a relationship is consistent with the trends of displacement in Seattle and the history of redlining and concentrations of poverty across the United States (Taylor 2019; PSRC 2019; Greenblatt 2015).

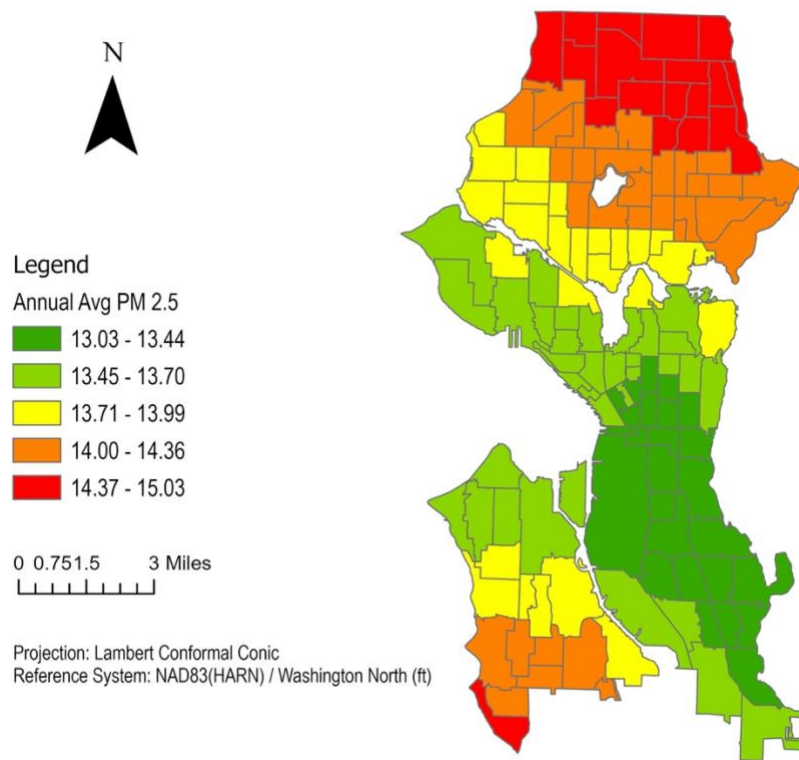
Tracts with higher median household also had higher levels of safety. Higher median household incomes were moderately positively associated with greater safety scores ($p < 0.01$ for unweighted and $p = 0.04$ for the parental walkability perception index). Given that income and race were also significantly correlated, this is unsurprising. The coefficient of 0.4 indicates that such a relationship is moderately linear and is one of the stronger ones in comparison to other coefficients.

Tracts with higher incomes scored slightly lower in walkability across the city. Higher household incomes were also slightly negatively correlated with the built environment form walkability dimension ($r = 0.2$ and $p = 0.01$ for the unweighted scenario and $p = 0.03$ for the parental walkability perception scenario), indicating less amenable built environment form factors for walkability. This could potentially be a result of newer, more auto-centric tracts being more expensive compared to older, more walkable neighborhoods (Lo 2009; Baum-Snow 2007).

Contrary to previous study—and likely due to data limitations—tracts with higher concentrations BIPOC were associated with fewer environmental hazards. Conversely to safety, the percentage BIPOC was weakly positively correlated with better scores of Environmental Hazards in both index models ($p = 0.02$). This contrasts with other studies, which found greater environmental hazard risk for BIPOC (Su et al. 2013). Looking at the hazard variables, this correlation stems from significant correlations from greater average Adopt-a-Street miles ($p = 0$) and lower Average PM 2.5 levels ($p = 0$) in BIPOC Tracts (See Appendix B, Table 9: Environmental Hazard variables for full list). As seen in Figure 11, the air quality

dataset was from a broad modeled source from the CDC and may ignore some of the fine-grained PM 2.5 levels at the street level (CDC National Environmental Public Health Tracking Network 2020). However, it provided air quality at the tract level, where the Puget Sound Clean Air Agency data did not, requiring additional modelling. Future policy and data collection efforts should be made to fill such a gap; while high-level air quality is still important, it does not enable greater understanding of the interaction between environmental hazards at the street-level and inequitable health outcomes for BIPOC.

Figure 11: CDC air quality data in Seattle by census tract



In addition, the Adopt-a-Street variable was in proxy for lack of trash or litter datasets. Because of such data limitations and the smaller coefficient values ($r = 0.2$), I hesitate to make any solid conclusions from this correlation.

Car-free households had the strongest statistical relationship with safety and built environment. There were higher concentrations of car-free households in less safe tracts and in tracts that have better walkability in terms of the built environment, such as central city tracts. The percentage of households without vehicles proved to show the strongest linear relationships across the socioeconomic and demographic dimension. Safety was negatively correlated with higher rates of car-free households, having a coefficient of -0.6 ($p < 0.01$) for the unweighted model and a coefficient of -0.7 ($p = 0$) for the parental walkability perception model. Built environment form on the other hand, showed a positive linear correlation with car-free households ($p = 0$). This result may be due to land uses—older, more centrally located neighborhoods are more walkable and denser compared to newer, suburban style housing (Lo 2009). Future study could examine Seattle’s land uses in conjunction with such car-free households to better understand this correlation. These two correlations might be attributed to the concentration of car-free households in downtown, coupled with higher crime rates and collisions and greater access to built environment amenities. The parental walkability perception index model compensated for some of this strong effect in the built environment form, reducing the correlation coefficient from 0.5 to 0.4, the linear relationship was still significant.

In examining the aggregated total indices, the gap between car ownership between the top and bottom ranked tracts does seem promising for encouraging non-driving modes—by fostering and prioritizing walkability more Seattle residents *may* be able to opt out of car ownership.³ However, another consideration is that many households may not have a choice—the expense of owning a car may be cost prohibitive. As seen in the Seattle Congestion Pricing Study (SDOT 2019b), the average Seattle household spends 15% of its budget on transportation. And for low-

³ Examining the individual variables, the strong linear correlation between car-free households and bus stop density scores likely drives much of this overall index correlation ($r = 0.8$ with $p = 0$).

income households, transportation can cost around 30% of their total income. The study estimated that 89% of these transportation costs came from auto ownership and maintenance expenses. Such a correlation is an opportunity for future research. This thesis did not consider household expenses and housing affordability directly through its variables. Future study could examine the equity implications of costs of living—housing and transportation—in tracts that are more walkable versus those that are less walkable. Economic conditions may very well be the case for South Park tract's 17% of households that do not own a car, which also has higher concentrations of children ages 5-9 (LQ = 1.6), and lower median incomes than the rest of Seattle (\$53,807 compared to \$92,263).

As such analysis is simply a bivariate correlation, there could be a level of self-selection bias—households without cars choosing transit-dense neighborhoods to live. Examining the correlation between LQ and the households that are car-free and bus stop density, we find slight negative correlations. In other words, Seattle census tracts that have higher proportions of car-free households are also moderately less likely to have higher concentrations of children ages 5-9 ($r = -0.3$ with $p < 0.01$). As seen in Figure 12, center city tracts showed significant correlations between income and car-free households, shown in green; as median incomes rise, car ownership diminishes. Considering that bus stop density is also slightly negatively correlated with LQ for ages 5-9 ($r = -0.2$ with $p = 0.03$), there is therefore some evidence that census tracts with greater proportions of children ages 5-9 have less transit access and fewer car-free households.

Figure 12: Bivariate relationship between income and percentage of households without a vehicle (95% significance)

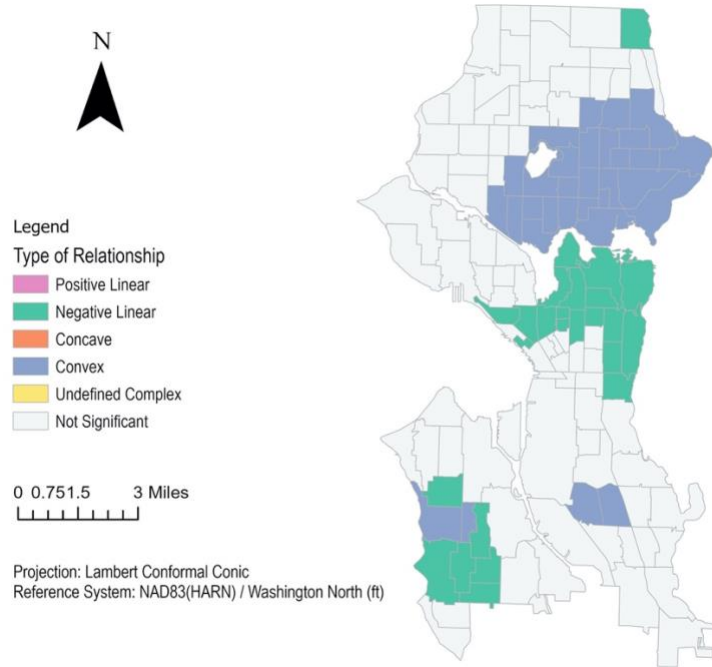
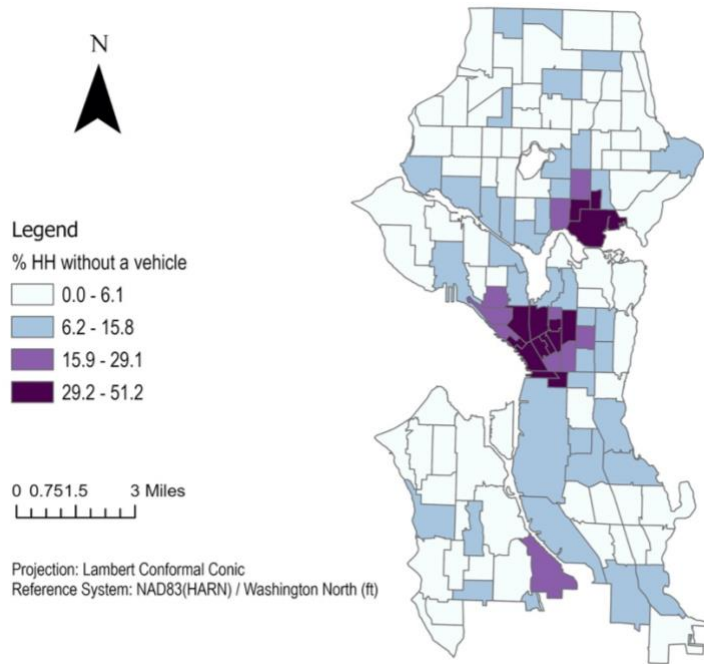
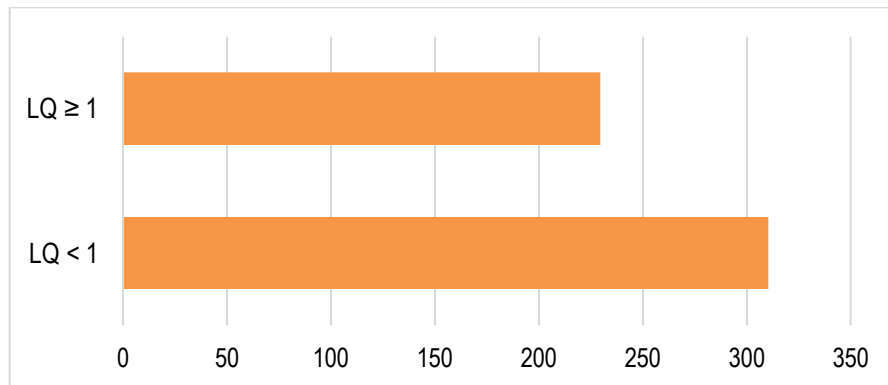


Figure 13: Percentage of households without a vehicle



While the strong correlations between the percentage of car-free households and dimensions such as bus stop density is likely biased by the downtown effect (See Figure 13), it is indicative of a larger issue and discussion of transit priorities. Sarmiento and Duarte (2019) discuss how important riding the bus is and the social nodes that bus stops provide for youth. However, Seattle’s high downtown density of transit, compared to the rest of the census tracts, implies a strong priority for work and commute travel rather than towards orienting transit towards children and youth use; at the summary statistic level, tracts higher concentrations of children ages 5-9 had, on average, fewer bus stops per square mile than tracts with lower concentrations of the age group (See Figure 14). Future qualitative research similar to Sarmiento and Duarte’s (2019) study could examine this theme further through travel journals and participatory mapping.

Figure 14: Average bus stop density by LQ



For the vulnerability index, the higher average scoring for walkability and child-friendliness for the most vulnerable tracts—defined as the top quartile based on the index—may indicate a level of selection bias among families with children. Since the vulnerability index model was weighted by LQ for children ages 5-9, there may be a certain level of families

choosing neighborhoods that are amenable to raising a family. Parents and guardians want the best for their children and may—if they are financially able—choose to live in neighborhoods that are more favorable for children. Furthermore, neighborhood selection in relation to school availability plays a key consideration for prospective and current parents alike (Sander and Testa 2015).

5.1 LIMITATIONS AND VALIDITY CONSIDERATIONS

As with any study, this thesis is not without its limitations. The COVID-19 pandemic hindered the ability to validate or obtain qualitative data on child walkability. As much of the literature indicated, what children and youth value in terms of the built environment—the aspects that make their neighborhoods walkable—often vary across gender, race, age, and other cultural nuances (Wridt 2010). Ideally, my thesis would have been able to validate some of the findings through focus groups. Or, better yet, the index would have been generated not from literature review and data availability, but through a mixed-method approach of child travel surveys or qualitative data collection in conjunction with geospatial analyses. Without such methods and child origin and destination data, this study was unable to accurately model distances of travel and route characteristics, some of the more important factors for walkability (Su et al. 2013). However, due to COVID-19, such qualitative methods were deemed unfeasible for the scope of this project. Future studies could elaborate and further such analysis by honing the index considering such a gap.

Lastly, this study used point-in-time data sources to create the index. As a result, it largely ignores the trends of displacement from the city. BIPOC communities are priced out and displaced through the effects of gentrification (PSRC 2019). Parents may choose to move out of the city and have longer commutes to afford more space for the children (Greenblatt 2015).

Future research could examine child-friendliness specifically when it comes to displacement. Such studies could use a longitudinal lens or qualitative methodology to better understand the stories of those who have moved or been displaced.

5.2 POLICY IMPLICATIONS

While the relationship between the walkability index and socioeconomic and demographic factors may not have overall, strong statistical correlations, creating walkability indicators could provide a policy tool for planners and policy analysts at the city; the literature review exemplifies a history of both misunderstanding child mobility needs and underrepresenting child and youth considerations in policy (Speak 2000). So, what can city planners and local governments prioritize to bring children and youth considerations into the built environment and local policymaking? The literature provides three key lessons: (1) engage youth and children in participatory processes; (2) enhance data-driven strategies for child-friendly city planning; and (3) embrace the intersections of school, play places, and neighborhood life.

5.2.1 *Engagement and participation*

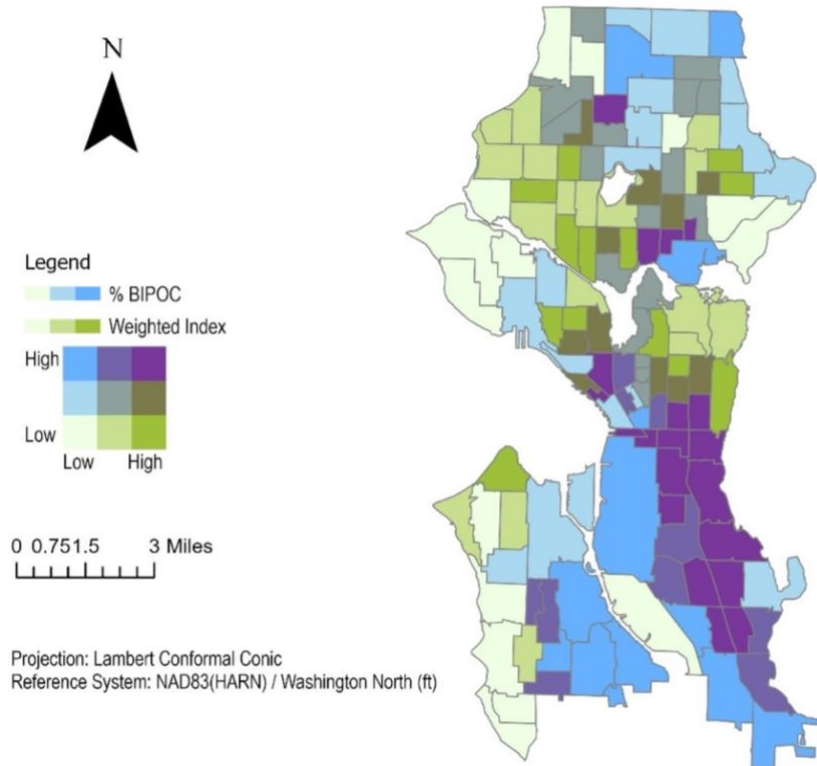
Children and youth can effectively contribute to public discourse on planning (Derr and Kovács 2017). UNICEF provides frameworks and tools to further engage children and youth in planning policy and decisions. The City of Seattle employs Community Liaisons for engaging diverse communities and could strengthen existing and expand partnerships with children and youth groups.

5.2.2 *Effective data-driven policymaking*

Engagement and participation are ineffective if it is not tied with accountability and the means to make data-driven decisions and to attain goals. While planners and policymakers have made attempts at indexing displacement risk and inequitable consequences of the displacement of BIPOC households, there has been less of an attempt to index child-friendliness (OPCD 2020). Indeed, the measuring and studying of child-friendliness and -walkability is often limited in scope to specific programs, such as Safe Routes to School (SRTS), rather than examining the holistic factors across neighborhoods (SDOT 2019a). The literature review shows strong evidence that examining only one geography or dimension of child mobility, such as school trips, ignores the other factors that make walking as a mode enjoyable and meaningful for a child (Kraftl, Horton, and Tucker 1978; Horton et al. 2014; Villanueva et al. 2016). Integrating child-walkability and child-friendliness measures into the existing mapping tools would enable better identification of and targeting planning interventions to make Seattle more child-friendly.

This thesis' index provides an attempt at such a tool. And while strong correlations were unclear in its findings, consistently through the walkability and vulnerability indices, higher risk tracts can be identified. Visualizing the index scenarios using the bivariate visualization tool within ArcGIS provides further insight concerning locational aspects of socioeconomic and demographic variables (See Figure 15). Particularly, census tracts in the South-central portion of Seattle along the Duwamish both have higher proportion BIPOC and have lower walkability scores.

Figure 15: Bivariate comparison across race and the weighted parental walkability perception index



5.2.3 Diversity of the public realm environment

Planning policy tends to divide geographies through a portfolio of programs, whether it be for commuters getting to work or children getting to school. However, such geographies are one and the same for households with children. I believe that the high scoring for physical factors downtown is indicative of such urban planning and policy frameworks: a focus on the downtown, commuter base rather than that of livable neighborhoods and 15-minute cities (Pozoukidou and Chatziyiannaki 2021). With COVID-19 drastically altering the way people work, shop, and live, I would argue that urban planning and policy should reflect some of the lessons of this thesis and other studies about creating livable cities. Indeed, a return to the status

quo of prioritizing commerce over livability would be a missed policy window toward embedding themes of walkable neighborhoods throughout the city. As much of the previous literature suggests, centering children in such planning and policy paradigms would benefit more than just families and children and would create more accessible and livable cities (Speak 2000).

Chapter 6. CONCLUSION

This thesis created a child-friendliness index to assess the walkability of Seattle census tracts. In creating such an index, this study also sought to assess whether child-friendliness of walkability correlates with racial demographic composition of the tract. The results of the index showed insignificant statistical results in assessing correlation between the index, race, and the density of children ages 5-9 across census tracts.

This thesis hopes to contribute to the wider study of child-friendliness, equity, and furthering livability in cities. Trends of displacement, the child-unfriendliness of cities, and the continued impact of racial inequities will continue across all cities. When I began this research, there was a noticeable gap between pragmatic studies focusing on specific programs, such as McDonald and Aalborg's (2009) study on Safe Routes to School (SRTS), and those that sought transformational change in planning and policy theory to include children in youth in planning decisions, such as Derr's (2013) study on including marginalized youth in planning processes.

Indeed, to better understand the threats to livable cities and child-friendliness, in both Seattle and in other American cities, qualitative research is needed to understand if and how racial discrimination and institutional racism may play a role in walkability and child-friendliness. In addition, case study comparisons and analyses at the census block level could further our understanding of how race, age, and other socioeconomic factors interact with

walkability across the built, environmental, and social environments that we interact with.

Ultimately, policy that incorporates child-centric considerations into both policy analysis and planning decision-making is needed—the benefits of planning for children can support livability as a whole through safe built environments and greater access to active transportation infrastructure (Villanueva et al. 2016).

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APPENDIX A SHAPEFILE DATA CLEANING, ASSUMPTIONS, AND PROCESSES

Sidewalk Data

- i) Sidewalk data from the Seattle Department of Transportation was used for deriving sidewalk quality as an indicator under form. While condition data covered much of the city, 25% of the sidewalks lacked maintenance condition data, especially in non-arterial, residential areas. To systematically exclude sidewalks with missing values, I chose to only measure sidewalk quality of arterials. While there were still missing values for sidewalk quality among this data, it was much smaller. I then created a dummy variable for sidewalk quality, coding 1 for values of “Poor” or “Very-Poor,” and 0 for anything else. From this dummy variable, I was able to find the proportion of sidewalks that were designated poor when I performed a spatial join by calculating the mean.

Public Realm Sites

For access to public realm sites, I chose to focus on public schools and excluded private ones. While private schools may potentially provide information regarding wealth concentrations and access, the goal of the indicator was to measure access without a financial barrier to children and families.

To clean the parks data, it was important to capture the diversity of activities that children could engage in at the locations. So, I used Seattle Parks feature data accessed through Seattle Open Data. I created categories for the different feature types. These bins were:

- sports (i.e., soccer, baseball, etc.)
- water features (i.e., swimming, beaches, and fountains)
- skate and bike (i.e., BMX trails, skateparks)

- nature (i.e., trails, woods, views)
- community and historic (community/environmental centers and historic sites)
- recreation (fishing, picnic areas, and firepits)
- facilities (bathrooms, rental facilities)
- garden & greenspace (P-Patches, green spaces, etc.)
- dog areas
- paths

I excluded features such as adult exercise equipment, boating, pickleball courts, wedding venues, and Scuba Diving sites.

Tree canopy

The City of Seattle maintains tree canopy shapefiles. The dataset used in this thesis was mapped in 2016 with LiDAR. Tree canopy area was quantified as a percentage of the entire census tract using a Spatial Join, matching by contains.

Blocks and blockface data

Blockface data was obtained from the City of Seattle’s Open Data Portal (City of Seattle n.d.). The raw dataset includes all blockfaces adjacent to street, including interstate and non-walkable blocks. So, to obtain city blockfaces, I isolated the data by selecting “neighborhood” street type classifications and excluded trails. I then used the spatial join tool to determine the average length of these blockfaces by tract.

Transit

King County bus stop data was obtained using King County’s open GIS portal (King County n.d.). There were two primary measures I was interested in: density and quality of transit stops. I created a new dummy variable field for the transit stops and coded stops with shelters with 1, and those without 0. I then implemented a spatial join to find the proportion of stops that had transit shelters. For transit stop density, I divided the total count of transit stops by track over the tracts’ respective area in square miles.

Crossings / Intersections

There were many potential ways in which to measure crossings. Ultimately, I decided to replicate Frank et al.’s (2010) approach of intersection density. In my preliminary data examination, many of the marked crosswalks across Seattle are along streets that may not be considered “walkable”, such as arterials. So, while intersection density may not account for truly “safe” crossings considering it does not always account for accessibility and marked crosswalks, it does account for the many unmarked, calm residential streets and route directness.

SAFETY

Collisions

Collision data was obtained from the Seattle Department of Transportation, and limited to reported collisions during the year 2019. Isolating the points by time provides a more accurate picture and maintains consistency across our socioeconomic data, which pulls from the 2019 ACS survey. While I could have chosen to isolate collisions to pedestrian-related collisions, the result would have been a small sample of data considering the point-in-time isolation. Furthermore, any type of collision can affect the overall safety of the right of way.

Crime

Crime data was obtained from the Seattle Police Department using 2018 data. Crimes were limited to those that would influence parents' concern or unwillingness to allow their children to walk freely in the neighborhood. The data was isolated by offense parent group, excluding crimes that were non-violent or unrelated to child mobility. Specifically, crimes excluded from the data were:

- Animal cruelty
- Curfew/Loitering/Vagrancy (excluded for subjectiveness of the offense)
- Peeping tom
- Pornography / obscene material
- Prostitution offenses
- Trespassing

Filtering out these categories involved assuming that these crimes were not as pressing as the others included in considering child mobility. For example, while animal cruelty may be a heinous act, it likely does not impact a parent's decision to allow their child to walk outside like violent or weapon related offenses in the areas might. The crimes included in the data are:

- Sex offenses
- Family/domestic offenses
- Drug and alcohol related offenses
- Kidnapping and human trafficking
- Violent and weapon related offenses

The crimes were then quantified over the census tracts, taking the sum of the filtered offenses over square miles of the respective tract.

Lighting

Seattle City Light provides shapefile data for their light poles. From this data, Light poles were isolated and quantified by tract, dividing the sum of light poles over square miles.

ENVIRONMENTAL HAZARDS

Trash

While I could not obtain data on litter and trash directly, the City of Seattle does have an inventory of Adopt-a-Streets, which is a program designed to enable community groups and organizations to clean-up litter along designated streets. Many of these streets crossed many of the Census tract boundaries. So, for analysis, I first split the shapefile lines by Tract boundary using ArcGIS Pro's Intersect tool. Then, to quantify the number of streets controlling for size of the tract, I divided the sum of each Tract's length of Adopt-a-Streets by the Tract's area in square miles.

Transportation-Related Noise and Air Pollution

I decided to use 2018 SDOT and WSDOT traffic volume data as a proxy for both traffic-related noise and air pollution. While there is data for air pollution, measurement is conducted at a regional level. As a result, there were little to no observed differences across Census tracts. Furthermore, I chose 2018 traffic data over 2019 flows because it exemplifies a more "normal" year of traffic—in 2019, Seattle closed the viaduct and there was a period of realigning the

highway with the new SR-99 tunnel. As a result, traffic flows and commuting patterns were altered (Daniels 2018). To quantify an index from the SDOT traffic flow data, I used ArcGIS Pro's Intersect tool to split the street geometries to align with Census Tract boundaries. For the WSDOT traffic data, I first clipped the 2018 traffic sections to just Seattle and then used the intersect geoprocessing tool to split the road segments to tract boundaries. The last step before merging the data was to delete any duplicated segments of street from the SDOT data, namely any state routes (SRs) that were counted both in the WSDOT and SDOT data. Then, I merged the SDOT and WSDOT traffic data into one shapefile.

Vehicle Speeds

Vehicle speed data was obtained from SDOT's Street GIS data on the City of Seattle's Open Data Portal. To get an unbiased dataset for showing hazards for pedestrians from high-speed traffic, I excluded state routes and interstate highways. This assumes that many do not have direct routes to cross these roads, and therefore they do not pose a direct hazard in terms of speed. However, highways do interfere with walkability through a connected network, which is captured in the Built Environment Form dimension. I also excluded streets that appeared to have missing values for speed limits. I then used a Spatial Join to obtain the mean speed limit across Census tracts.

SOCIOECONOMIC

Many of the socioeconomic variables from the 2019 ACS were minimally transformed and adjusted (US Census Bureau 2019). To find the percentage of the tract that was Black, Indigenous, or People of Color (BIPOC), I subtracted 1 from the proportion of the population

that identifies as Non-Hispanic, White alone on the 2019 ACS. Median incomes were used for that tracts. I found the percentage of households, by tract, that did not have any personal vehicles. I generated the relative location quotient for the children ages 5-9 to better control for city effects and density with the following formula:

$$Location\ Quotient = \frac{\frac{N\ Tract\ Children\ 5 - 9}{N\ Tract\ Children < 18}}{\frac{Seattle\ Children\ 5 - 9}{Seattle\ Children < 18}}$$

APPENDIX B PEARSON'S CORRELATION FOR INDEX VARIABLES

Table 6: Socioeconomic and demographics variables

	LQ	Median HH Income	Percentage BIPOC	Percentage of HH without a vehicle
LQ	1			
Median HH Income	0.2799*	1		
<i>p-value</i>	0.001			
Percentage BIPOC	-0.1362	-0.6258*	1	
<i>p-value</i>	0.1151	0		
Percentage of HH without a vehicle	-0.3000*	-0.4804*	0.2042*	1
<i>p-value</i>	0.0004	0	0.0175	

Table 7: Built Environment Form variables

	LQ	Median HH Income	% BIPOC	% No vehicle	Avg. Blockface Length	Avg. Slope %	Bus Stop Density	Crossing Density	% Tree canopy	% sidewalks poor quality	% Bus stops with shelter	Public Realm Amenities
LQ	1											
Median HH Income	0.2799*	1										
<i>p-value</i>	0.001											
% BIPOC	-0.1362	-0.6258*	1									
<i>p-value</i>	0.1151	0										
% No vehicle	-0.3000*	-0.4804*	0.2042*	1								
<i>p-value</i>	0.0004	0	0.0175									
Avg. Blockface Length	-0.0059	0.2435*	-0.1072	-0.3179*	1							
<i>p-value</i>	0.9456	0.0044	0.216	0.0002								
Avg. Slope %	-0.0153	0.3144*	-0.1743*	-0.0721	-0.0406	1						
<i>p-value</i>	0.8602	0.0002	0.0432	0.4057	0.6403							
Bus Stop Density	-0.1854*	-0.2697*	0.117	0.7794*	-0.2844*	0.0168	1					
<i>p-value</i>	0.0314	0.0016	0.1767	0	0.0008	0.8464						
Crossing Density	0.0097	0.0651	-0.0932	0.3982*	-0.4066*	0.3188*	0.4833*	1				
<i>p-value</i>	0.9114	0.4529	0.2826	0	0	0.0002	0					
% Tree canopy	0.1605	0.4235*	-0.2104*	-0.5459*	0.1543	0.2675*	-0.5399*	-0.3807*	1			
<i>p-value</i>	0.0629	0	0.0143	0	0.074	0.0017	0	0				

	LQ	Median HH Income	% BIPOC	% No vehicle	Avg. Blockface Length	Avg. Slope %	Bus Stop Density	Crossing Density	% Tree canopy	% sidewalks poor quality	% Bus stops with shelter	Public Realm Amenities
% sidewalks poor quality	0.0317	0.1622	-0.0476	-0.1938*	0.0005	0.1793*	-0.0714	0.0703	0.0907	1		
p-value	0.717	0.0621	0.5861	0.0254	0.9959	0.0389	0.4139	0.4211	0.2991			
% Bus stops with shelter	-0.0445	-0.2972*	0.1904*	0.1796*	-0.3739*	-0.2193*	-0.0102	0.1467	-0.2244*	0.0045	1	
p-value	0.6108	0.0005	0.0282	0.0386	0	0.0112	0.9075	0.092	0.0094	0.9587		
Public Realm Amenities	-0.0013	0.0019	0.1056	0.1338	-0.1365	-0.021	0.2677*	0.1193	0.1219	-0.0232	0.0006	1
p-value	0.9879	0.9822	0.2231	0.1218	0.1144	0.8086	0.0017	0.1681	0.1591	0.7908	0.995	

Table 8: Safety variables

	LQ	Median HH Income	% BIPOC	% No Vehicle	Collision Density	Violent Crime Density	Light pole density
LQ	1						
Median HH Income	0.2799*	1					
<i>p-value</i>	0.001						
% BIPOC	-0.1362	-0.6258*	1				
<i>p-value</i>	0.1151	0					
% No Vehicle	-0.3000*	-0.4804*	0.2042*	1			
<i>p-value</i>	0.0004	0	0.0175				
Collision Density	-0.3033*	-0.3260*	0.2261*	0.6290*	1		
<i>p-value</i>	0.0003	0.0001	0.0084	0			
Violent Crime Density	-0.2390*	-0.3525*	0.1559	0.7822*	0.7497*	1	
<i>p-value</i>	0.0052	0	0.071	0	0		
Light pole density	-0.2251*	-0.2206*	0.1103	0.7589*	0.7706*	0.8612*	1
<i>p-value</i>	0.0087	0.0101	0.2029	0	0	0	

Table 9: Environmental Hazard variables

	LQ	Median HH Income	% BIPOC	% of HH without a vehicle	Adopt-a-Street (Trash)	Annual Avg Daily Traffic	Speed Limit	Avg. PM 2.5
LQ	1							
Median HH Income	0.2799*	1						
<i>p-value</i>	0.001							
% BIPOC	-0.1362	-0.6258*	1					
<i>p-value</i>	0.1151	0						
% of HH without a vehicle	-0.3000*	-0.4804*	0.2042*	1				
<i>p-value</i>	0.0004	0	0.0175					
Adopt-a-Street (Trash)	-0.0506	-0.4022*	0.3953*	0.4097*	1			
<i>p-value</i>	0.5597	0	0	0				
Annual Avg Daily Traffic	-0.1748*	-0.1855*	0.1472	0.3514*	0.1324	1		
<i>p-value</i>	0.0426	0.0313	0.0885	0	0.1258			
Speed Limit	-0.0952	-0.2560*	0.1677	0.1403	-0.0203	0.2265*	1	
<i>p-value</i>	0.2721	0.0027	0.0519	0.1046	0.8155	0.0083		
Avg. PM 2.5	0.0982	0.073	-0.3456*	-0.3384*	-0.1947*	-0.1277	0.119	1
<i>p-value</i>	0.2572	0.3998	0	0.0001	0.0237	0.14	0.1693	