Spatial Inequity in Accessibility for Non-Drivers in Seattle: A Spatial Urban Metabolism approach

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Abstract

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This paper examines how auto-dominant transportation planning contributes to accessibility inequities for non-drivers in the United States. Using an urban metabolism framework, the study conceptualizes mobility as a set of interconnected flows shaped by street networks, land use, infrastructure, and policy. A GIS-based analysis evaluates how urban form, land use history, and transportation infrastructure shape access for people who cannot or do not drive. The findings suggest that spatial patterns inherited from past planning decisions continue to constrain mobility and reinforce inequitable access. By linking urban metabolism with an urban complexity perspective, the paper shows how transportation inequity emerges from interactions among street networks, land use, and policy decisions rather than from isolated infrastructure conditions. The study also provides a replicable GIS workflow using the ArcGIS Online Portal Network Dataset, offering a method that can be adapted to analyze accessibility inequities in other urban regions.

Foreword

When I was a young teenager, I became a victim of poor transportation planning as a pedestrian. In that moment- a soothed petrichor afternoon- the kind where the world feels washed clean, changed my life in an instant. Shaped by a collision of three things I care about deeply- education, public transit, and pedestrianization- this was an incredibly redefining moment for me. It exposed me to the very force I founded this thesis on: auto-domination, unsafe street design, and the consequences of planning that fails to account for the full spectrum of human experience. For years, this event lived in the background of my life as something taken from me. Writing this thesis was part of my decision to transform it into something that fueled my resilience, curiosity, and passion to change it into something that *gives* to me.

As I prepared to write this work, I encountered concepts I had never heard *named* before. *Messy Cities* (2025) introduced me to the idea that urban chaos, spontaneity, and "desire lines," informal paths people carve through the world, are all expressions of human need, and they are failures of past planning practice. Jason Thorne's argument that "we should always be questioning and challenging our rules and regulations to ensure that they are serving a clear purpose and not get in the way of fostering the kind of vibrant [places] we all want to see" (2025) resonated deeply with me. Although this book focuses on urban planning, its lessons apply across all types of neighborhoods and communities and *every* municipality should account for this. The challenge for planners is not to eliminate messiness, but to design conditions where urbanism, messy cities- messy human behavior can thrive safely and equitably.

While this thesis may read as a critique of engineering, its sole purpose is to urge planners to move beyond rigid, outdated standards and the black-and-white thinking that has shaped so much of our built environment. Lives are complex. Mobility is complex. So why do we continue to implement rational, linear transportation plans that fail to account for everyone who uses our streets? If organizations want to claim equity as a value, they must practice it; not only in rhetoric but in design, policy, and everyday decision-making. This paper is my contribution to that ongoing effort: **a call for transportation planning that acknowledges lived experience, embraces complexity, and prioritizes safety and dignity for all.** **Hannah xx**

Executive Summary

Mobility in the United States has been shaped by transportation systems that have historically prioritized automobile efficiency over safety, equity, and accessibility. Scholars such as Marshall (2024) and Davis (2023) argue that these traditional design choices systematically disadvantage non-drivers, including people who cannot or do not drive because of cost, disability, age, preference, or structural barriers. Seattle reflects these inequities. Mid-twentieth-century highway construction reshaped neighborhoods around auto-oriented infrastructure, despite the city's earlier reliance on pedestrian movement, non-motorized transportation, and transit mobility (Seattle Municipal Archives, n.d.).

This thesis examines how contemporary urban development patterns perpetuate or challenge these inequities by comparing two Seattle neighborhoods: South Lake Union (SLU), a rapidly redeveloped technology district, and First Hill, a historically dense neighborhood. These Neighborhoods proximity qualifies them for an exploratory analysis. In this paper, legacy refers to the old, firm and long standing structure. Using an urban metabolism framework, the study conceptualizes each neighborhood as a system composed of interconnected flows, including flows of people, resources, and accessibility. Accessibility is examined through walkability, transit adjacency, and the permeability of neighborhood entrances. This framework is grounded in urban complexity theory and is used to analyze how interconnected activities and spatial structures shape mobility outcomes. The literature review highlights three key insights:

- **Transportation equity** is shaped by interdependent flows that can produce "accessibility poverty" when non-drivers cannot reach essential destinations.

- **Urban** metabolism provides a useful lens for understanding how mobility, investment, and spatial form reinforce or disrupt inequitable patterns.
- **Walkability and transit** function as **core** mobility pathways because they shape access to public spaces, opportunities, and essential services.

To evaluate these dynamics, the study applies GIS-based methods using ArcGIS Pro 3.5, including Spatial Analysis, Network Analyst, and origin-destination matrix travel-time modeling. ArcPy is used to calculate normalized composite accessibility scores that measure 10-minute walkability and pedestrian access from neighborhood entrances to key destinations. This spatial approach aligns with research showing that GIS can reveal inequities that may remain invisible in traditional planning analyses (Leslie et al., 2007).

Findings indicate that SLU's flatter topography, grid-based street network, and multiple entrances from major arterials create more continuous pedestrian flows and higher walkability scores. In contrast, First Hill's steep slopes, freeway edges, and limited entrance points constrain pedestrian movement and reduce accessibility for non-drivers. These differences reflect broader patterns in transportation equity research: newly redeveloped districts may benefit from upgraded infrastructure, while older neighborhoods can retain *structural* barriers that limit mobility.

Overall, this thesis argues that equitable mobility depends on more than infrastructure performance. It requires understanding how spatial form, network permeability, and systemic flows shape access for non-drivers. By integrating urban metabolism with GIS-based accessibility modeling, the thesis offers a neighborhood-scale framework for analyzing mobility inequities and provides insights for planners seeking to create safer, more inclusive, walkable, and accessible urban environments.

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1. Introduction

In the United States, streets reveal how mobility is distributed unequally. As Wes Marshall argues in *Killed by a Traffic Engineer* (2024), the laws and engineering standards that shape the transportation system are “often outdated [and sometimes arbitrary], producing a built environment that prioritizes driver efficiency over safety, equity, and accessibility for everyone. These design choices are not merely technical decisions; they shape everyday mobility conditions and systematically disadvantage non-drivers.

Auto-oriented street design is often treated as the natural order of American (and many other countries) streets, yet it is a relatively recent historical development. Large-scale highway construction accelerated in the mid-twentieth century, reshaping cities around automobile movement. In Seattle, the focus of this thesis, the construction of Interstate 5 in the late 1950s tore through neighborhoods and reorganized spatial and political priorities around the needs of drivers (Wilma 2002). This shift marked a major departure from earlier patterns of movement. In the late nineteenth century, bicycles and transit played a significant role in Seattle’s mobility system (Cipalla 2019). By the time I-5 arrived, auto-dominance had become deeply embedded in the city’s infrastructure and planning priorities- to some in my profession, a moment like a grey cloud. Even today, it is illegal to build a home without a parking space in much of the United States. This is a fact that doubles as a metaphor for the nation’s deep structural commitment to cars (Grabar 2023).

Contemporary planning literature offers alternative visions. In *Messy Cities* (2025), Dylan Reid’s essay “Flexible Streets” describes how streets once functioned as shared public spaces before pedestrians were increasingly confined to sidewalks as cars became dominant. Reid documents new and reinforced efforts to reimagine streets as “hybrid, flexible, shared” spaces that support more equitable mobility (p. 134). His example of Daniella, a non-driver with a visual disability navigating Scott Street in Toronto, illustrates both the potential and the limitations of flexible street design for pedestrians with different mobility needs.

Reid traces these ideas to Dutch innovations such as the *woonerf*, or “living street,” where cars move slowly through a pedestrian-oriented environment (p. 127), and Hans Monderman’s “naked street,” which reduces signage and hard boundaries to encourage more attentive movement by all street users (p. 127). Both models challenge the assumption that safety depends primarily on separating users through rigid traffic controls. Instead, they suggest that streets can become safer and more welcoming when designed as shared spaces. Evidence from the Netherlands indicates that these approaches can reduce collisions where they have been implemented.

This thesis examines how these ideas translate, or fail to translate, within the United States. Seattle provides a useful case. Some neighborhoods are celebrated as rapidly developed,” (Seattle Municipal Archives, n.d) yet rapid development does not necessarily produce safer, more equitable, or more accessible streets. South Lake Union (SLU), for example, has been identified by Seattle’s Office of Community Planning and Development as an area that has “seen more change in the last 20 years than any other area of our city” (South Lake Union Regional Center Planning, n.d.). The neighborhood traded factories and warehouses into a high-rise landscape of technology campuses and mixed-use development. It is often presented as a model of contemporary urbanism. But does rapid redevelopment actually produce safer, more equitable, or more flexible streets for non-drivers?

To address this question, this thesis compares First Hill with SLU. First Hill is a similarly sized historic neighborhood, built out in 1852 (Dorpat, 2001) that has stood the test of time. Their geographic proximity allows for an exploratory comparison of how urban form, development history, and street design shape accessibility for non-drivers. This question matters because everyone deserves a safe, reliable, and equitable way to move through space. After all, it it is of utmost importance to understand that mobility is a basic condition of urban life. Street design helps determine who has access to that right.

2. Literature Review

2.1 Transportation Equity and Metabolic Flows

Transportation equity begins with the principle that, as Davis argues in *Inclusive Transportation*, "*everyone deserves safe, reliable, and affordable transportation options"*, establishing the normative foundation for evaluating mobility systems (Davis, 2023, p8). This equity lens highlights how U.S. transportation networks continue to produce uneven patterns of access, particularly for people who do not or cannot drive. Ferrero and Fernández similarly argue this by emphasizing that access to transportation infrastructure shapes broader flows of energy, goods, and opportunity, and that understanding these relationships is essential for allocating resources more equitably. Together, these perspectives point toward the need for a systems-based framework capable of revealing how mobility advantages and disadvantages circulate through the urban environment. An urban metabolism approach provides that analytical structure by conceptualizing the city as a set of interconnected flows, one of people, resources, and access, that collectively determine who can move through space with ease and who encounters structural barriers (Trancity Valiz, 2023. p13).

Transportation equity challenges are deeply embedded in the spatial and systemic dynamics of cities. Non-drivers often face uneven access to public spaces, amenities, and mobility options, especially in rapidly redeveloped neighborhoods such as South Lake Union (SLU) and in older, legacy, urban networks such as First Hill. Traditional transportation planning methods, which are often auto-oriented, can overlook these inequities because they focus primarily on infrastructure performance and efficiency" rather than on the flows, relationships, and interdependencies that shape lived mobility experiences.

Mobility justice scholars extend this critique by showing that transportation systems are shaped by unequal power relations. Sheller argues that mobility justice requires rethinking how people move and live across local, urban, national, and global scales. Her work emphasizes that mobility is not only a technical problem but also a question of justice, access, and shared responsibility. This perspective is especially important for examining how planning decisions affect people who do not drive, including those excluded by income, disability, age, race, gender, or infrastructure design.

An urban metabolism framework offers one way to analyze these inequities. It conceptualizes the city as a system of interconnected flows, including the movement of people, resources, energy, and opportunities. Within this framework, walkability and transit can be understood as core mobility pathways that shape how residents move through and access the city. Applied to SLU and First Hill, this approach helps reveal how urban form, transportation infrastructure, and development history produce different conditions of accessibility for non-drivers.

2.1.2 Defining Non-Drivers

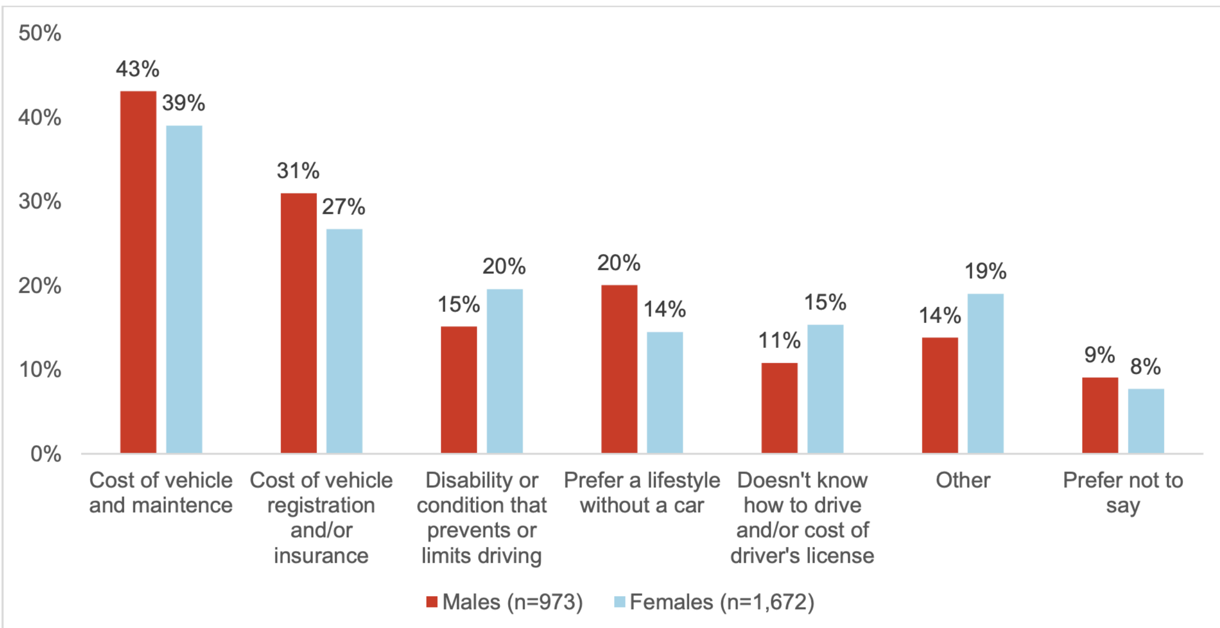


Figure 1 : Reasons for Not Driving, Washington State Non Driver Study (2023)

This study focuses on non-car users, who are referred to in this study as non-drivers. The *Washington State Non Driver Study (2023)* reinforces the national inequity to a state level, stating that Washington is a place where non-drivers face disproportionate barriers to accessing essential services, *public spaces*, and daily needs. The report concludes that in general, transportation systems in Washington are not designed for non-drivers. This is a trend in rural and even urban areas throughout the US (Speck, 2023). The Non Driver study, conducted by

Cascadia Consulting Group, and Strategic Research Associates, helped define the study group of selection (Figure 1). Non-Drivers consist of many types of people, and is similarly applied in this paper to define non-drivers.

As noted in Figure 1, there are many different reasons for not driving. It is expensive, registration and insurance is a burden, disability or conditions that limit a person to operate a vehicle, preference, not knowledgeable enough, or other factors. This is the scope defining the control group in the study.

2.1.3 Defining Urban Metabolism

To introduce the core concept of urban metabolism, this study draws on *The City as a System* by Trancity Valiz (2023). Urban metabolism has been defined in multiple ways across the literature, from organic metaphors that describe the city as a living body to systems-based interpretations that emphasize feedback, regulation, and interdependence. Trancity Valiz (2023) traces this conceptual evolution, noting that some scholars describe cities through biological analogies of lungs, organs, and circulatory systems, while others, such as Howard T. Odum frames urban metabolism as a systemic process governed by feedback loops. Odum argues that "the city as a system means that each of its different components can self-regulate" (Odum, as cited in *The City as a System*, 2023, p. 209). Yet self-regulation does not necessarily produce equity. In urban systems, flows of people, resources, and investment can stabilize around existing patterns of accessibility, reinforcing disparities in mobility and opportunity unless planning interventions intentionally redirect them.

Daniel Ibañez offers a choice definition that combines organic and systemic perspectives. Drawing on biological analogy, he argues that organisms must sustain their metabolism in order to survive, and strengthen its metabolic capacity. In the same way, surplus investment, density, and demand for transit in cities: “Any organism looking to survive must sustain its own metabolism. This applies as much to cells as to cities” (Ibañez, as cited in *The City as a System*, 2023, p. 214). Ibañez describes cities as systems of “interdependencies” that regulate and circulate flows (p. 205). He explains how conceptualization shapes intervention, and that to understand the world, one must shape how planners and researchers interpret urban problems and identify possible interventions. This is especially relevant for GIS exploration, and is vital to understand the system in which a city works. Relating back to Sheller’s mobility-justice framework, surplus flows expand mobility options, while low ridership, disinvestment, or weak connectivity can trigger a form of urban “autophagy” (page 224), the body's natural cellular recycling and housekeeping process, where the variables selected for measurement reflect an underlying theory of how the city works.

In this thesis, urban metabolism provides a framework for examining how mobility flows, infrastructure investment, and spatial form shape accessibility for non-drivers. Linking this framework to Sheller’s mobility justice perspective, the study asks how surplus flows of investment, density, and transit access may expand mobility options in some neighborhoods, while disinvestment, weak connectivity, or low ridership may reduce accessibility in others. In this sense, urban metabolism helps analyze not only how movement occurs, but how mobility capacity is produced, unevenly distributed, and sometimes diminished over time..

2.1.4 Wicked Problem and Systems Thinking

Trancity Valiz describes urban metabolism as a "different [way of] look[ing] at the city," one that is especially useful for understanding wicked problems because urban flows are non-linear and interdependent (2023, p. 11). The "wickedness" of transportation planning emerges from these interdependencies. Much of the dominant transportation system in the United States relies on automobiles. We already know that this is not accessible to everyone. Research has linked limited transportation access to broader social disadvantage and exclusion (Currie, 2009). Transportation plays a "pivotal role in facilitating access" to out-of-home activities, including work, services, social life, and other daily needs (Karner et al., 2024). Karner et al. describe this condition as "accessibility poverty," which occurs when people cannot meet daily needs or live a "dignified and fulfilling life" because of limited access to services and opportunities.

As Trancity Valiz argues, urban problems become wicked when interventions in one part of the system generate consequences elsewhere. Ibañez's notion of compromise, described through: "every time you are constructing a landscape, you are destroying another landscape elsewhere" captures the tradeoffs embedded in mobility decisions (Ibañez, as cited in Trancity Valiz, 2023, p. 207). Applied to transportation planning, investment in auto-supportive infrastructure can reduce the possibility of creating safer and more accessible landscapes for pedestrians, cyclists, transit riders, and other non-drivers. The International Transport Forum (2021) similarly describes transportation networks as uncertain and interdependent systems, emphasizing the need for systemic resilience in planning. This system's perspective aligns with the goal of this thesis: to use spatial data to examine how transportation flows, street networks, and urban form shape accessibility for non-drivers in SLU and First Hill.

2.1.5 Metabolic Flows Through Transit and Walkability to Public Spaces

Walkability is a foundational component of equitable urban mobility and a critical pathway within an urban metabolism framework. Pedestrian movement connects residents to public spaces, services, amenities, and transit. Research consistently shows that walkable environments support health, sustainability, and social equity by reducing travel burdens and expanding access for non-drivers. Ewing and Cervero's (2010) analysis demonstrates that built-environment factors, including street design, destination accessibility, and land use mix, strongly influence walking behavior and travel choices. In this thesis, walkability is treated as a measurable condition that shapes mobility flows and determines how easily non-drivers can access public spaces and essential destinations.

3. Methods

This study asks two related research questions:

1. How do transportation flows, modeled through pedestrian accessibility, reflect inequitable access to public spaces for non-drivers in South Lake Union and First Hill?
2. How can pedestrian accessibility, conceptualized through an urban metabolism framework, help identify spatial inequalities in access to public space for non-drivers?

The study answers these questions through an exploratory GIS-based methodology.

Introduction

I wanted to have a concept of whether more recent planning methods are more equitable and sustainable than older neighborhoods. I chose South Lake Union and First hill for exploratory analysis. Because they are both located in Seattle, they both represent a similar demographic, which is important for my research as both neighborhoods are diverse and the representation is not limited. (US Census Bureau, 2023.)

Pedestrian accessibility is a foundational component of equitable urban mobility, yet it varies across neighborhoods because of differences in street networks, land use patterns, topography, and physical barriers. The central research question guiding this analysis is: **How does pedestrian accessibility differ between (older) and newly redeveloped neighborhoods, and what spatial factors contribute to these differences?** Conceptualizing neighborhoods as systems of flows in which people move through defined "entrances" and along pedestrian networks. This systems-based perspective highlights how boundary conditions, connectivity, and network permeability influence walkability.

This thesis conceptualizes neighborhoods as systems of movement in which people enter through defined access points and travel along pedestrian networks to reach public spaces and other destinations. This systems-based perspective highlights how boundary conditions, connectivity, and network permeability shape walkability and accessibility for non-drivers.

Using ArcGIS Pro, Network Analyst, and ArcPy, the analysis measures 10-minute walkability, travel times between neighborhood entrances and key destinations, and composite accessibility scores for each neighborhood. The 10-minute walkability metric is commonly used in planning practice to assess access to public spaces. The City of Seattle uses these standards in their own documentation, and 10-minute walkability guidelines in its Parks and Recreation Open Space Plan (2024), including:

- a 5-minute walkability guideline within Urban Center boundaries; and
- a 10-minute walkability guideline outside Urban Center boundaries.

By comparing First Hill and South Lake Union through a consistent spatial workflow, this project identifies where pedestrian access is strongest, where gaps persist, and how urban form shapes these patterns. The findings provide planners and decision-makers with insights for improving pedestrian connectivity and reducing accessibility inequities across Seattle's urban core.

3.1.2 Methodology

This exploratory analysis compares pedestrian accessibility in two Seattle neighborhoods with contrasting urban forms: First Hill and South Lake Union. Using GIS-based network analysis in ArcGIS Pro and ArcPy, the study evaluates accessibility from neighborhood entrance points to housing and parks. An urban metabolism framework treats the city as a system of inputs, outputs, and flows. Applied to transportation planning, this framework shifts the question from simply asking where people walk to examining how mobility systems distribute access to resources, destinations, and public spaces. Both neighborhoods are located in Seattle and have established pedestrian networks represented in the ArcGIS Online Portal Network Dataset. This dataset provides a replicable source for conducting network-based accessibility analysis. The comparison examines First Hill as an older, historically dense neighborhood and South Lake Union as a rapidly redeveloped neighborhood. The workflow moves from data preparation in ArcGIS online. This is a replicable and authoritative source of GIS data. By choosing these two neighborhoods, I compared a legacy pedestrian network (First Hill) and a rapidly developed network analysis and ArcPy-based calculation and visualization.

Origins and destinations were selected to represent likely pedestrian access points and key neighborhood destinations. Four entrance points were identified for each neighborhood based on major pedestrian approaches from (arterial codes 4 and 5: Minor Collector and Major Arterial) (Seattle Department of Transportation, n.d.). Then I chose the most likely points of entry for pedestrians to the neighborhood (Seattle Department of Transportation, 2024).

3.1.3 Study Areas: First Hill and South Lake Union

The study areas are two similarly sized urban neighborhoods designated by the City of Seattle as Urban Villages, a classification used in relation to the city's growth management planning under the Washington State Growth Management Act (Seattle Office of Planning & Community Development, 2023). The purpose of selecting these neighborhoods was to compare pedestrian accessibility in an older (legacy) with a newer development: First Hill being an older development-historically dense neighborhood, with a rapidly redeveloped neighborhood, South Lake Union- rapidly developed newer neighborhood which is said to have seen more change in the last decade than any other area in Seattle. (Seattle Office of Planning & Community Development, 2023). The boundaries were drawn from the Neighborhood Boundaries layer. After uploading the relevant layers onto the base map, the analysis organized the project into four neighborhood group layers: First Hill base layer, South Lake Union base layer, First Hill network analysis, and South Lake Union network analysis.

Figure 2: South Lake Union Entrances

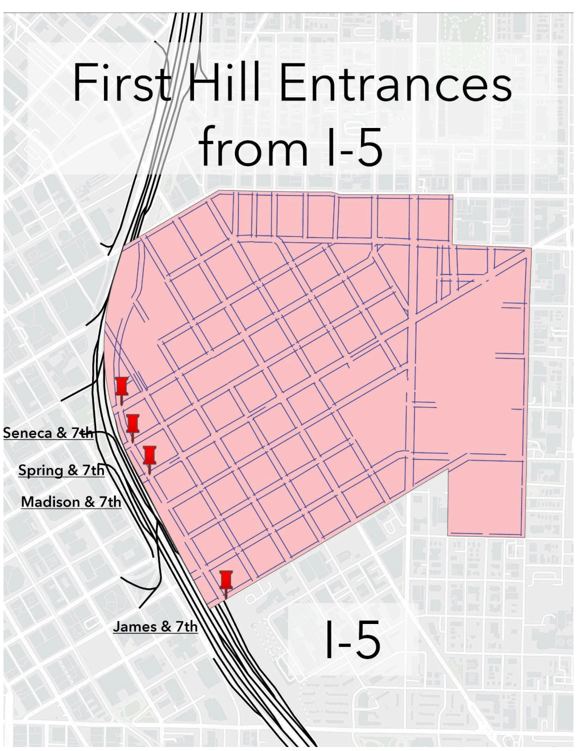
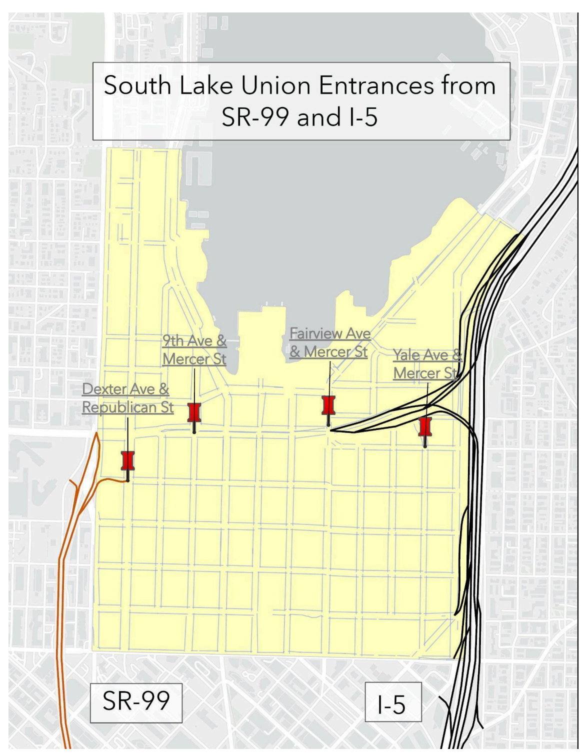


Figure 3: First Hill Entrances



Parks were selected as representative public spaces because they are vital destinations in everyday urban life. Housing was included to connect accessibility to where people live and to holistically illustrate the urban metabolism framework, which examines relationships among movement, residence, and public space, for neighborhood activity. A 10-minute walking threshold was used because local planning agencies commonly use this measure to assess walkable access to public space.

This structure was used to organize the spatial workflow. Eight total features were then created to represent pedestrian access points across the two neighborhoods, with four entrance points for each neighborhood. Entrances are important for accessibility modeling, because it ensures the network represents the flows in and out of the neighborhood; enabling network permeability and defined boundaries. It is also intentional for operationalization of edges. They were based to reference entrances from the main road, which v were symbolized as Arterial Code 4 and 5 (Minor Arterial; and Major Collectors [WSDOT; 2023]). For South Lake Union, pedestrian entrances consisted of: Dexter Ave & Republican St, and 9th ave and Mercer Street (SR-99 Entrances), and Yale & Mercer St, as well as Fairview & Mercer Street (I-5 Entrances) (Figure 3**).** For First Hill, because there is only one major road connecting it, I-5, all the entrances are on 7th: 7th and Seneca, Spring & 7th, Madison & 7th, and James & 7th. (Figure 2**).** By creating entrances, based on SDOT's literature, we can use verifiable expectations of the most likely used edges on the pedestrian network. Entrances from the major roads are a vital step to connect the analysis to Urban Metabolism. Many studies referencing Urban Metabolism explain how flows are modeled (Tuffaha. Sallay. 2025) from major roads which facilitate transportation. These features operationalize the flows of pedestrians into and out of the districts.

3.1.4 Data Sources and Preprocessing

To create this thesis, my methodology consisted primarily by using ArcGIS Pro 3.5, through a student-use license, enabled with extensions. The preliminary analysis was conducted using the Network Analyst extension. Using authoritative sources to provide points, lines and polygons to represent my variables, I created a conceptual framework to display the base of my project (Figure 4**)** I uploaded my variables onto the project, which consisted of the following (respective data sources in parenthesis):

- **Parks** (clipped from the Seattle Parks and Recreation Parks layer) - represent public spaces and green spaces within each neighborhood.
- **Proximity Parks** (1000-ft buffers around neighborhood boundaries) - represent nearby parks within typical walking tolerance.
- **Seattle Street Network** (with Major Arterials [Codes 4 and 5] highlighted) - represents the primary connectivity routes into each neighborhood.
- **Neighborhood Boundaries** (from the Seattle Neighborhoods layer) - define the spatial extents of First Hill and South Lake Union.
- **Housing Nodes** (derived from King County parcel centroids) -represent residential destinations for accessibility modeling.
- **Sidewalk Layer** (Visualization reference only; not part of the network dataset or network) pedestrian-focused context of the study area.
- **ArcGIS Online Portal Network Database** (.ND)- This was via my Student Use License from Esri.
- **Neighborhood Entrances** that are to represent transit and pedestrian entry points into each neighborhood.

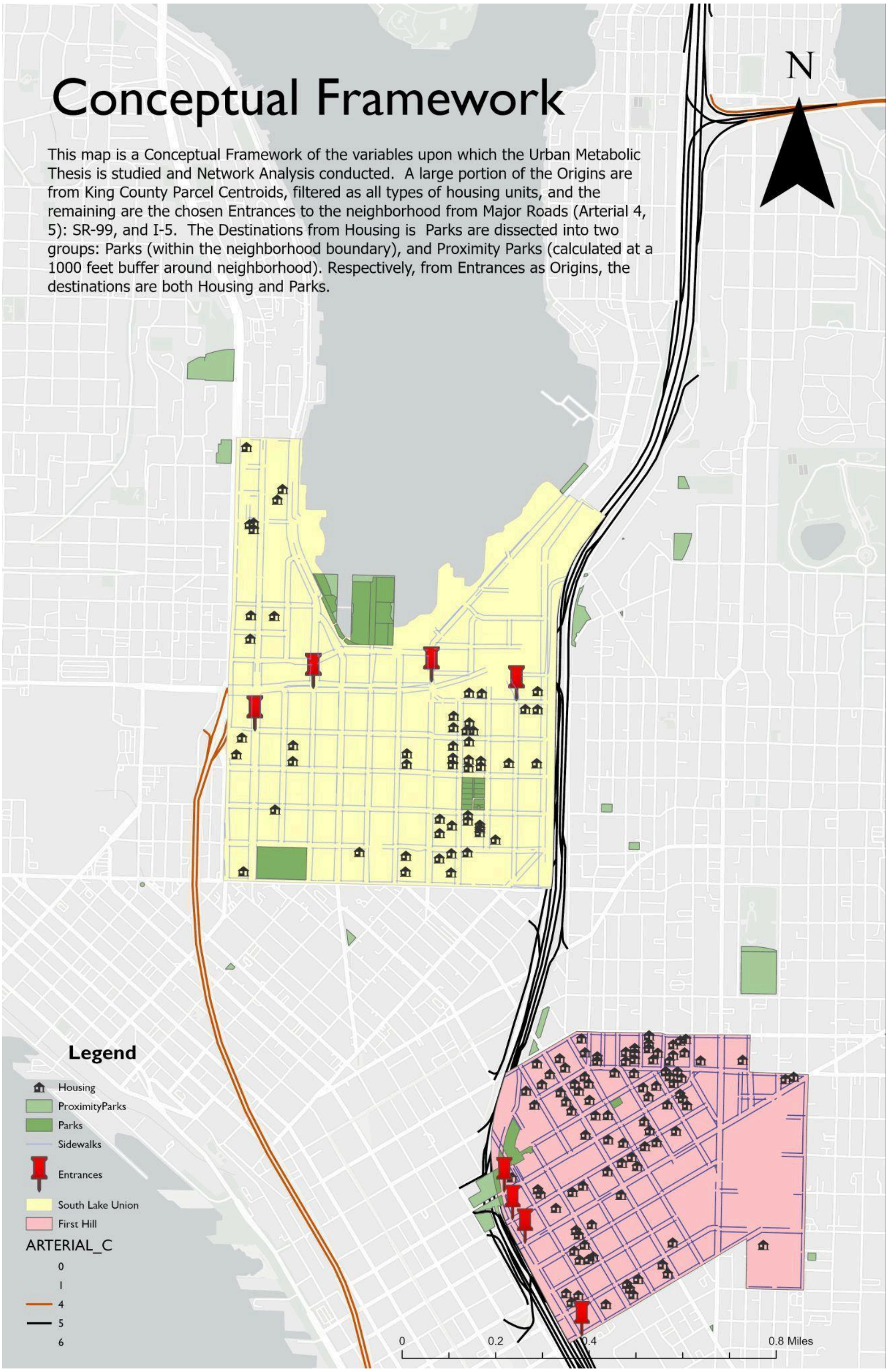

Conceptual Framework
This map is a Conceptual Framework of the variables upon which the Urban Metabolic Thesis is studied and Network Analysis conducted. A large portion of the Origins are from King County Parcel Centroids, filtered as all types of housing units, and the remaining are the chosen Entrances to the neighborhood from Major Roads (Arterial 4, 5): SR-99, and I-5. The Destinations from Housing is Parks are dissected into two groups: Parks (within the neighborhood boundary), and Proximity Parks (calculated at a 1000 feet buffer around neighborhood). Respectively, from Entrances as Origins, the destinations are both Housing and Parks.
N
Legend
Housing
ProximityParks
Parks
Sidewalks
Entrances
South Lake Union
First Hill
ARTERIAL_C
0
1
4
5
6
0
0.2
0.4
0.8 Miles

Figure 4: *Conceptual Frame, with Study Area Boundaries in Yellow and Pink, with a housing layer, a parks layer, an Arterial Code layer with 4 and 5 highlighted to represent major roads. The chosen entrances along 7th Avenue and Mercer Street are symbolized in red pins.*

3.1.5 Network Analyst Procedures

When conducting the network analyst layers I used Service Area to identify the extent of walkable access from each neighborhood entrance. **(**Appendix #5**)** A 10-minute walking threshold was selected based on widely used public-health and planning standards, and is

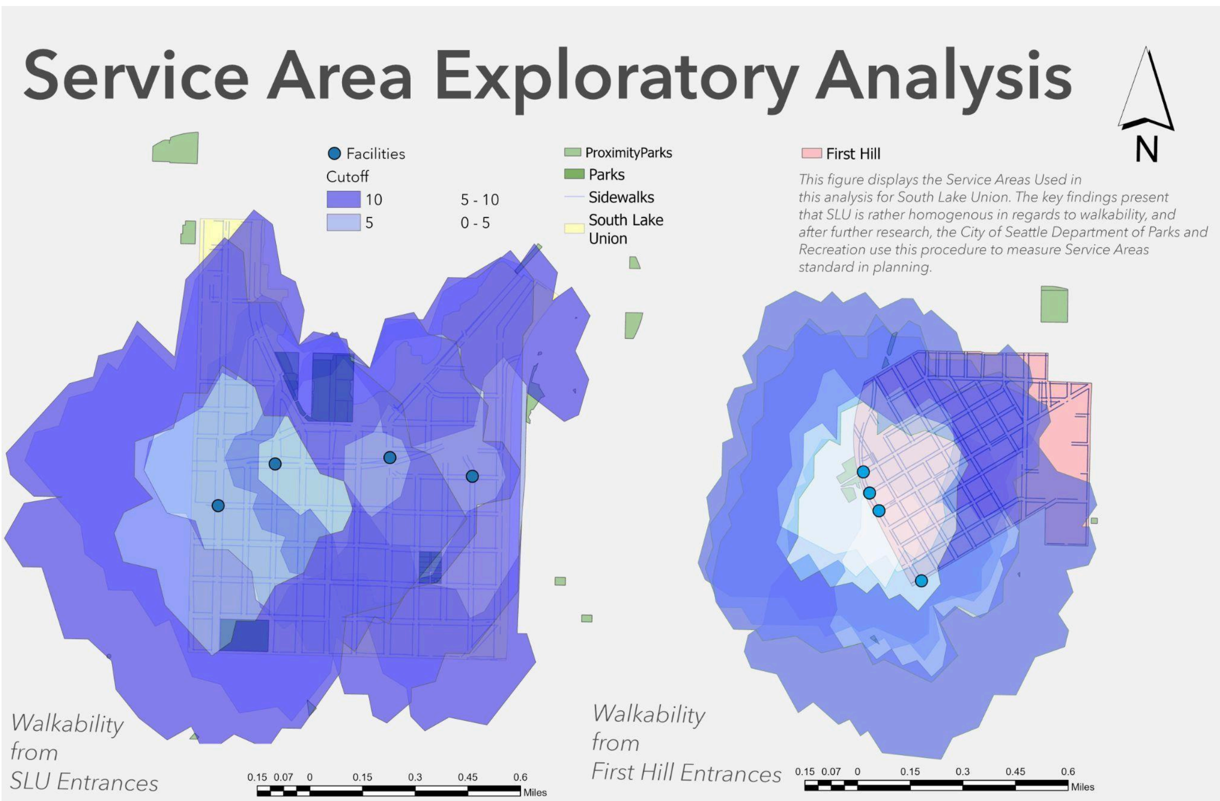


Figure 5*: Service Area Map. Represented are South Lake Union and First Hill Service area with the origin points held at entrances. Cutoff for walkability in 10 minutes, conducted on ArcGIS Pro using the Portal Network Dataset.*

consistent with the metric employed by Seattle Parks & Recreation in their accessibility mapping. Using this threshold, the tool generated polygons representing areas reachable within a 10-minute walk along the pedestrian network from selected entrances (Figure 3 and Figure 4). Housing nodes falling outside these polygons were classified as lacking walkable access to the neighborhood's primary entry points. This step provided a preliminary understanding of spatial inequities in access and established a baseline for

comparing the relative walkability of First Hill and South Lake Union.to conduct preliminary analysis on housing units that fell outside the 10-minute walkability framework from Entrances.

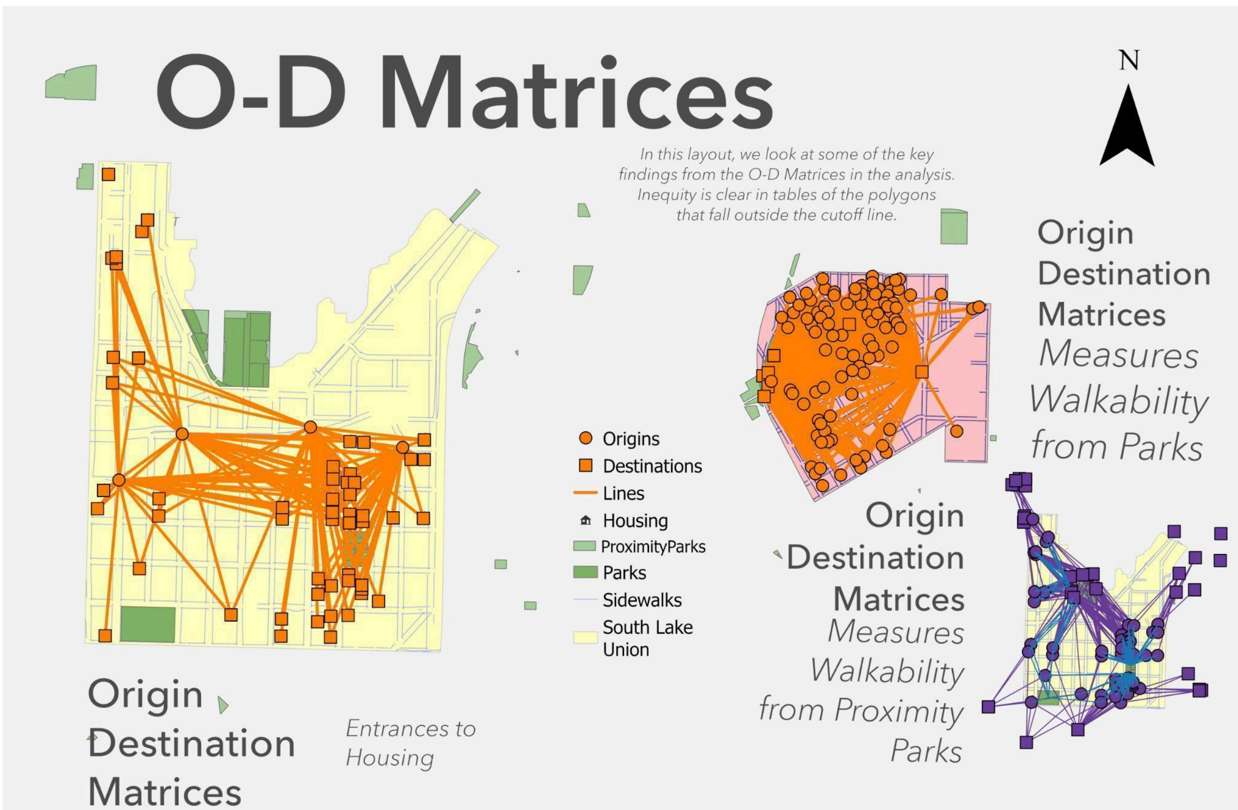


Figure 6*: OD Matrix Network Analyst tool with lines as output to represent distances that are deemed walkable within 10 minutes by the Portal Network Dataset. These lines are then exported to be used in Section 3.1.6.*

The central and most important Network Analysis I created was OD Cost Matrix (Figure 6) to calculate network-based travel times between entrances (origins) and key destinations, including housing nodes, parks, and proximity parks. This tool computes the shortest travel time along the pedestrian network for each origin–destination pair, producing a table of impedance values that quantify accessibility across the neighborhood. These outputs were exported as CSV files for further processing in ArcPy, where they were normalized and combined into composite accessibility scores. The OD‑Matrix results form the analytical backbone of the study, enabling direct comparison of how each entrance connects to residential areas and green spaces.

Finally, the Location‑Allocation tool was employed (Figure 7) to identify the most accessible potential intervention areas within each neighborhood based on the 10‑minute walkability threshold. Entrances were modeled as demand points and parks as facilities; an appropriate configuration because the analysis intended to understand how residents enter the neighborhood network and move toward fixed park destinations. By modeling entrances as origins we capture the neighborhood's edge conditions, while treating parks as facilities reflects their role as essential endpoints in the pedestrian network.

The model identified three optimal locations per neighborhood, defined not as *new* park sites but as the *existing park edges or entrances* that minimize travel time from the set of demand points without encountering polygon barriers. These optimal sites show distinct spatial patterns across the two neighborhoods that are key to the findings. In South Lake Union, the selected sites cluster along the more permeable portions of the grid, where shorter blocks and multiple access points allow flows to converge efficiently. In First Hill, by contrast, the optimal sites are pulled toward the few entrances not constrained by I‑5 boundaries or steep slopes. Both of these points together underscore and reinforce the findings from Service Area and OD-Matrices.

Together, these patterns show where accessibility is inherently strongest and where it is structurally constrained. The results also inform the recommendations section by highlighting specific edges where targeted improvements, such as crossings, sidewalk upgrades, or micro‑infrastructure that support non-drivers (and really everyone) could extend walkability to underserved areas. Although exploratory, this analysis adds a strategic dimension to the study by linking modeled accessibility patterns to actionable planning interventions.

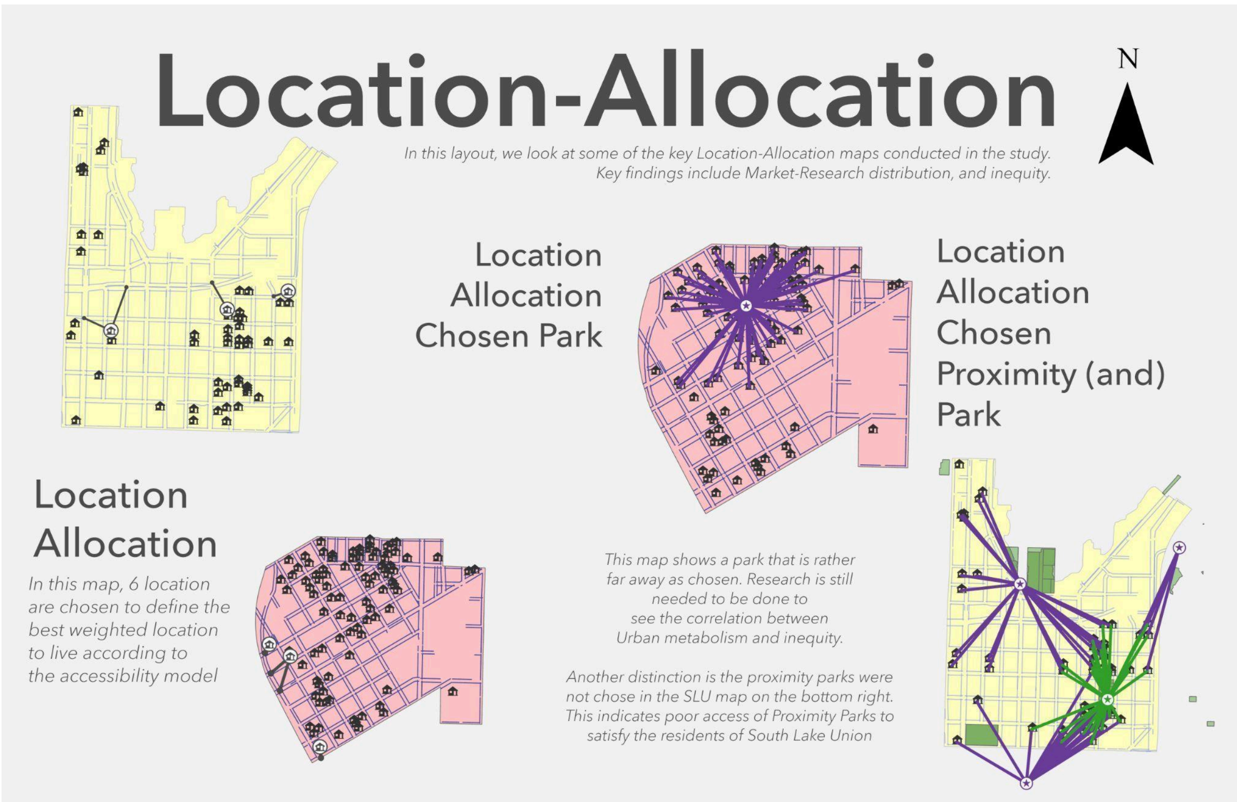


***Figure** 7: Location-allocation results illustrating the mismatch between geographic proximity and functional accessibility. Despite several parks being physically close to dense residential areas, the model selects further facilities, revealing barriers in walkability, transit integration, and urban form that leave portions of South Lake Union and First Hill underserved.*

3.1.6 Arcpy: Composite Score Calculation

To supplement a holistic neighborhood study, I needed to create a model of supply and demand (Liu, 2023). This study operationalizes that model by measuring distances from neighborhood entrances to housing and from housing to public spaces, generating a holistic (realistic and full) set of "flows" that *define access*. Because the analysis combines two distinct measures to supplement holistically: entrance-to-housing access and entrance-to-park access, I normalized both variables using min-to-max scaling to place them on a comparable 0-1 range (best-worst). This allowed me to create a composite accessibility score that averaged the two normalized components with equal weighting. Normalization was important as both elements capture a different, but parallel, dimension of neighborhood accessibility. Entrance-to-housing accessibility reflects access to the internal residential network, while entrance-to-park accessibility reflects access to public and proximity parks. The entrances also represent modelled transit entrances, therefore it stands as a precursor to an outside transit study. I chose to apply the same weight to both as an exploratory assumption, because it provides a neutral baseline that treats both forms of access as conceptually equivalent without imposing a hierarchy.

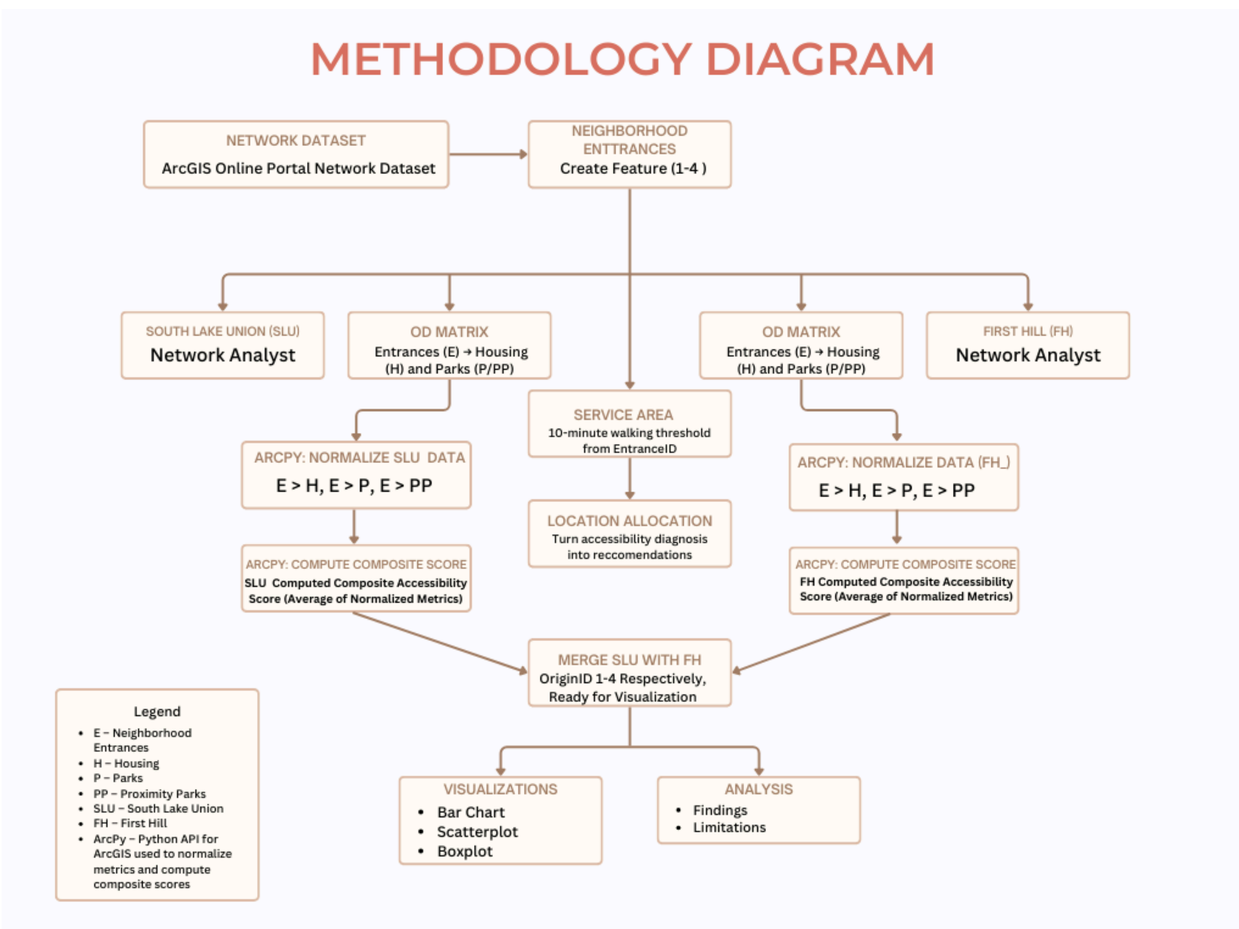


Figure 8. *Workflow diagram illustrating the full methodological process used to evaluate pedestrian accessibility in South Lake Union and First Hill. The chart shows the progression from GIS data preparation, Network Analyst service-area and OD-Matrix modeling, through ArcPy-based normalization and composite score calculation, to the final merging and visualization of accessibility results. Parallel processing streams for each neighborhood highlight the consistent analytical structure applied across both study areas.*

Running in python (Appendix #1) to calculate the composite score was important for my process because a verifiable baseline is essential for basing the findings and recommendations. The process I followed in python followed the charts (Figure 9; Figure 10; Figure 11) shown below; starting with the OD-Matrix outputs, I exported to CSV files, so that the API could read them. In Python Notebooks, I normalized the data, respectively. After normalization, I joined the Entrance to Proximity Parks to the Entrance to Parks tables so that all park distances were counted the same. After this, I computed composite scores using the following equation for both neighborhoods:

$$Composite_{Neighborhood} = \frac{(Entrance\ to\ Housing) + (Entrance\ to\ Parks)}{2}$$

Figure 9 *Equation for Composite Accessibility Scores . Entrance to Housing and Entrance to Parks are joined to create a holistic view of the flows. 0 represents best accessibility and 1 represents worst accessibility.*

Entrance (OriginID)	SLU Composite Score	First Hill Composite Score
1	0.209445	0.739447
2	0.399684	0.396546
3	0.862753	0.405758
4	0.500000	0.344820

Figure 10 *Composite accessibility scores (0 = best, 1 = worst) for South Lake Union and First Hill, calculated from normalized OD-Matrix travel times between neighborhood entrances, housing units, and parks. The table shows how accessibility varies by entrance within each neighborhood and highlights differences in relative walkability between the two districts.*

During calculation of composite score (Figure 9), results will display a 0-1 scale of best accessibility to worst; 0 represents the best weighted accessibility, and 1 represents the worst weighted accessibility. Both are combined to create a holistic accessibility metric reflecting supply and demand.

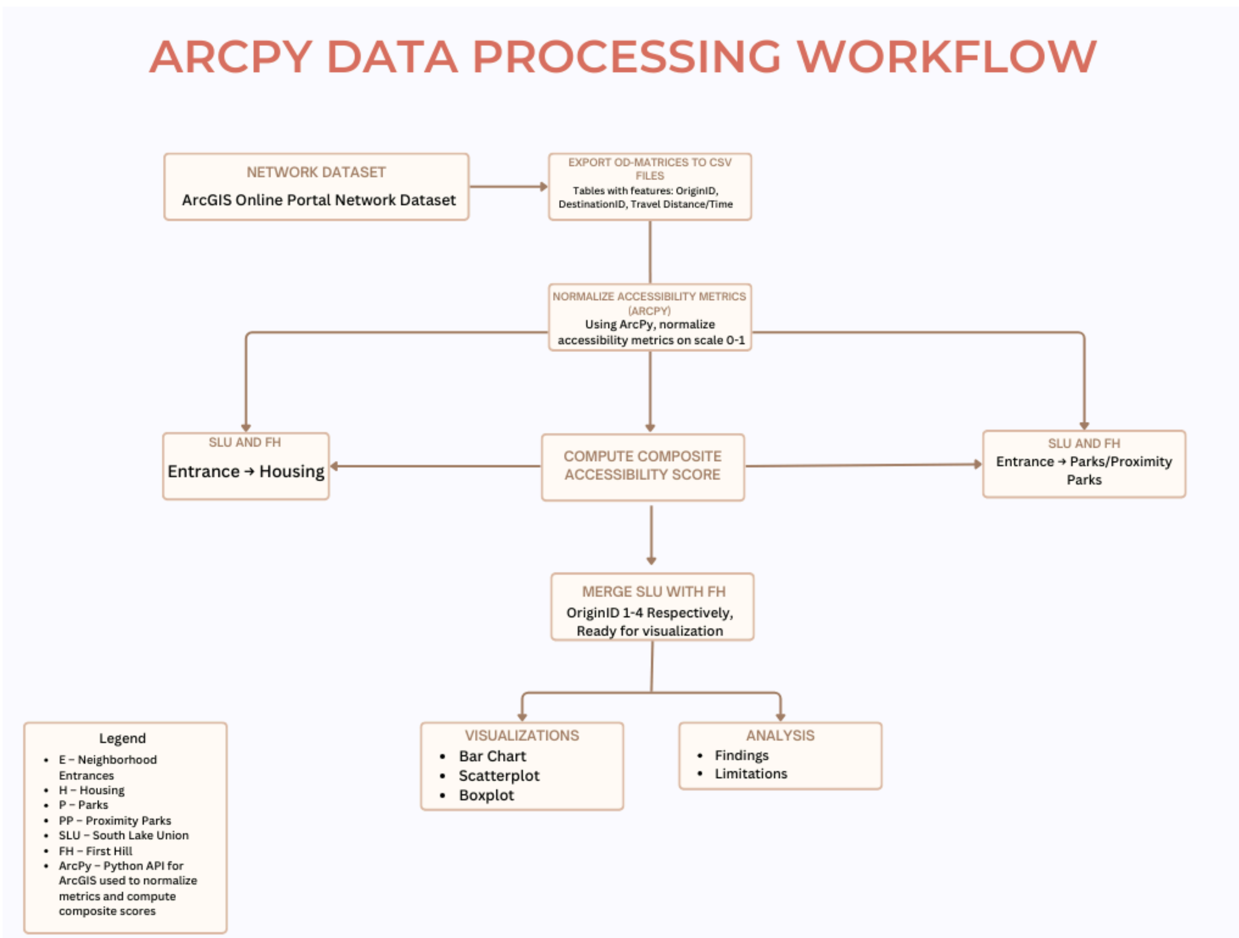


Figure 11. *ArcPy workflow used to normalize OD-Matrix outputs and compute composite accessibility scores. The diagram illustrates the sequence from CSV export, data cleaning, and min-max normalization through table joins and final composite-score calculation for each neighborhood entrance.*

After merging, I had an input appropriate to compare visually. I created a bar chart, scatterplot, and boxplot. See Figure 12, Figure 13, and Figure 14 for the visual diagrams. Bar charts compare composite scores across entrances; Scatterplots show relationships between housing and park accessibility; and Boxplots summarize distributional differences between neighborhoods.

3.2.1 Limitations

Several methodological limitations should be brought to light to understand and contextualize the findings of the analysis. First, the analysis relies on the Portal Dataset, which ensures replicability, is very standard and does not inherently represent pedestrian experience on the network. It may not fully capture the small nuances such as sidewalk obstructions, construction, desired pedestrian paths, and crosswalk quality. This indicates that it may not fully represent actual pedestrian experience.

Secondly, the creation of neighborhood entrances, which although are supported by SDOT and surrounding literature, remains a modeled abstraction in the analysis. Entrances operationalize the likely pedestrian paths that enter the neighborhood- but could produce significantly different results if modeled in different locations (IE Denny way for South Lake Union, or 9th Avenue near the hospital in First Hill). They do not provide Empirical pedestrian counts or observed movement patterns. This creates uncertainty in the accuracy that these "edges" reflect real-world behaviour.

Similarly, the Service Area and OD-Matrix assume a constituency in walking speeds and a perfect unobstructed network. This does not reflect the diversity of needs in mobility differences, signal timing, slope differences in neighborhoods, and does not consider safety. These are factors which greatly influence the walkability in practice. The 10-minute threshold is used in planning and public-health research commonly, but is a normative standard rather than universal. The Location-Allocation tool results identify optimal sites based on these modeled quantitative results, but do not consider qualitative factors, such as park amenities, perception of safety or user preferences. These factors would most likely influence actual park usage and accessibility that is not necessarily modeled in the model.

Finally, the composite accessibility score is dependent on normalization choices and weighting decisions. It is an exploratory-analysis limitation of this study. Although min-max normalization (0-1) allows for comparability across datasets, it's sensitive to outliers and anomalies. It is important to understand that the weighting scheme reflects analytical judgement rather than empirically validated hierarchy of importance. Different normalization or weighting approaches could produce alternative interpretations; ie, the different weights could change the rank of entrances or neighborhoods.

Together, these limitations do not undermine the value of the exploratory analysis,but highlight the need to interpret results as modeled approximations of pedestrian accessibility rather than precise representation of lived experience.

3.2.2 Methodological Rigor

Despite the limitations I stated, several elements of this study contribute to its methodological rigor and strengthen transparency, consistency, and replicability. The analysis follows a consistent and replicable workflow across both neighborhoods. Identical data structures, processes in entrance creation, network analyst tools, and ArcPy processing steps were followed in both neighborhoods. This ensured that the differences in outcomes were comparable and reflected the underlying spatial conditions needed for the analysis, rather than inconsistencies in analytical treatment.

All of my datasets were sourced from authoritative public agencies, such as Seattle Parks and Recreation, Seattle Department of Transportation, King County GIS and the Washington State Department of Transportation. These agencies maintain regularly updated geoportals and good Quality-Control procedures that provide a reliable foundation for network modeling, and spatial analysis. These data sources are appropriate and credible, however they may not fully capture real-world pedestrian conditions.

Similarly, the use of ArcGIS Online Network Dataset enhances analytical precision and optimized workflow timeline. It incorporates detailed routing details, such as turn restrictions, pedestrian pathways, and network impedance values. Although it is generalized, the dataset is widely used in professional planning practices and supports reproducible, standards based network analysis. The reliance on a standardized network dataset also ensures that results can be replicated by other researchers with access to the same service.

Fourth, the decision to normalize the O-D Matrix outputs using min-max scaling and to apply a transparent weighting scheme in the composite score calculation contributes to analytical clarity. Each of the steps in the scoring process taken is documented, reproducible, and grounded in established accessibility-measurement practices. The formula was applied uniformly for all of the entrances in both neighborhoods, enabling a direct comparison.

Finally, the workflow integrates multiple analytical perspectives, including service-area modeling, OD Matrix Travel Times, Location-Allocation, and composite scoring through Arcpy. This provides a triangulated understanding of pedestrian accessibility in these neighborhoods. This approach reduces reliance on any single metric, and strengthens the interpretation validity of results. Together, all of these elements demonstrate a rigorous methodological framework that supports the transparency, reliability and replicability of study's findings.

My hypothesis tests these questions directly:

H1: South Lake Union, as a more recently redeveloped neighborhood, will show higher modeled pedestrian accessibility than First Hill, an older and historically dense neighborhood.

H2: Newer redevelopment patterns will be associated with more even spatial access to public spaces for non-drivers than older urban forms.

4. Analysis

As a reminder, this project defines accessibility as modeled pedestrian travel time from chosen neighborhood entrances to two key destination types: housing and parks. These measures, derived from OD‑Matrix results, represent entrance‑to‑housing accessibility and entrance‑to‑park accessibility, which together operationalize walkability as a set of mobility flows rather than static proximity metrics. Within this study, the urban metabolism framework is applied as a focused operationalization of pedestrian movement, conceptualizing accessibility as the flow of people through network entry points toward essential destinations. When running the analysis, the findings both confirmed and challenged the initial hypothesis. To interpret the results, the analysis is organized into four thematic areas: the role of urban form, the specific patterns observed in South Lake Union, the patterns observed in First Hill, and the comparative insights generated through the composite accessibility score produced in the Python notebooks/

4.1 Urban Form

The service‑area analysis revealed an important and initially unanticipated insight about urban form. When symbolized consistently, resulting polygons showed that First Hill's service areas were noticeably more fragmented and spatially constrained, while South Lake Union's appeared more continuous and expansive. This indicated a "polygon barrier." This difference was not an indication of symbology but a reflection of the underlying network structure: in First Hill, steep slopes, disjointed connections, and the single major arterial roads creating abrupt breaks in the service-area symbology catchments. These fragmented service areas illustrate how topography and constrained street geometry limit the outward expansion of walkable catchments. In contrast, South Lake Union's flatter terrain and more permeable grid produce service areas that extend more evenly across the neighborhood, forming a continuous pattern of *reachable* streets. Together, these patterns demonstrate that urban form directly shapes modeled walking accessibility, with First Hill's physical constraints restricting service-area growth and SLU's network supporting broader, more uniform coverage.

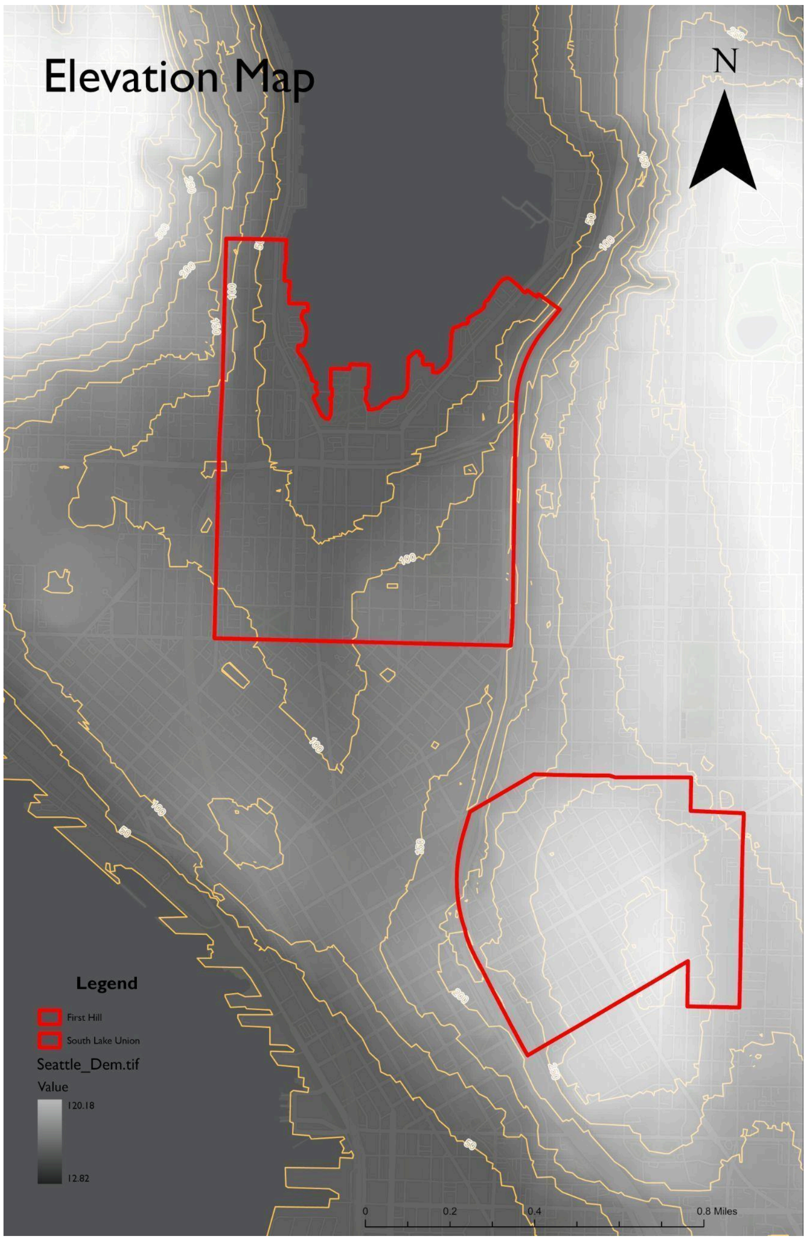


Figure 15: Elevation Map using a DEM from City of Seattle GeoDatabase.

When urban form became an implication, I created a topography elevation map (Figure 15) using a USGS DEM, pictured to the right. The first hill neighborhood falls in the highest elevation ranges up to 120.18, where SLU ranges around the lowest elevation values of 12.82. This implies that the lack of pedestrian-targeted infrastructure updates (ie. at-grade crossings, Rectangular Rapid Flashing Beacons) between streets. SLU's flat topography and grid based network (of sidewalks) create short, redundant routes and consistent accessibility. First Hill's steep slopes and fragmented street network create longer, more variable routes, producing uneven accessibility outcomes. These differences are structural, not resultant, and the results suggest that topography and street-network structure contribute to uneven accessibility.

It confirms the difference in slopes, which is also a lived experience when visiting First Hill vs South Lake Union. Geography and geographic features, in this case the topography in First Hill, are a little bit more of an obstacle which are not as easily fixed, and must be preserved. However, there are ways to accommodate non-drivers on the first hill and make it more walkable. See my recommendations for my suggestions.

4.2.1 South Lake Union

When I ran the South Lake Union tests first, I was surprised to see the rather homogenous results. All of my parks, and proximity parks were covered within a 10-minute walking radius. In South Lake Union, all housing units and objects in the park layers were covered which suggested that the composite scores would fare better than the first hill. It was developed more recently, so I wasn't as surprised to find this. However, my OD matrices had multiple housing as destinations unreached within the accessibility framework, which indicated that accessibility does not equal reachability. The composite scores were also more uneven in this neighborhood.

4.2.2 First Hill

In First Hill, the findings were almost the inverse of those in South Lake Union. The service-area polygons did not reach all housing units from the modeled entrances, reflecting how steep slopes, discontinuous connections, and major arterials constrain walkable catchments. In contrast, the park layer fully fell within the 10-minute layer. This explains why the park-access service areas appeared lighter and more spatially constrained than those in South Lake Union, even though the destinations themselves were still within range. The overall coverage for the service- area was only about 3% lower than in South Lake Union, but the entrance-to-housing accessibility results revealed more pronounced fragmentation. It is important to understand the distinction: the service areas failed to reach all housing destinations, but they did reach all park destinations. Although the difference is numerically modest, it has meaningful implications for less-dense or topographically complex neighborhoods in Seattle, where urban form can sharply limit the spatial extent of walkable housing access.

4.3.1 Composite Scores

To put the differences into concrete quantitative results, I used python notebooks (via ArcGIS Pro) to generate differences in Composite Scores from the OD-Matrices lines (Figure 11). The lower the composite score, the better the access; and I chose to do this on a 0-1 scale, with 0 equaling the best accessibility and 1 equaling the worst accessibility.

$$\text{Entrance} \rightarrow (\text{Housing} \cap \text{Parks}) \rightarrow \text{Composite}$$

Calculating a composite score is important for this project due to the multivariate analysis, as shown above. Throughout this process (as mentioned in the methodology section of this paper) I successfully imported OD Matrix travel Times and after Data preparation and metric construction computed and presented the composite score for comparison and analysis (Appendix #1; Figure 12, Figure 13, and Figure 14**)**.

I articulated the Composite scores to articulate the relationship between the Entrances to Housing, and Housing to Parks.What struck me was the graphs generated on python to display the relationship between the Housing to Parks. After reruns and tests, I noticed that one of the parks counted for both districts is shared; Freeway Park is considered in both of their parks. I decided to exclude because my intention was focusing on how the parks differed. This did raise a limitation of geographic proximity but the shared park count was marginal so I didn't let it affect my analysis.

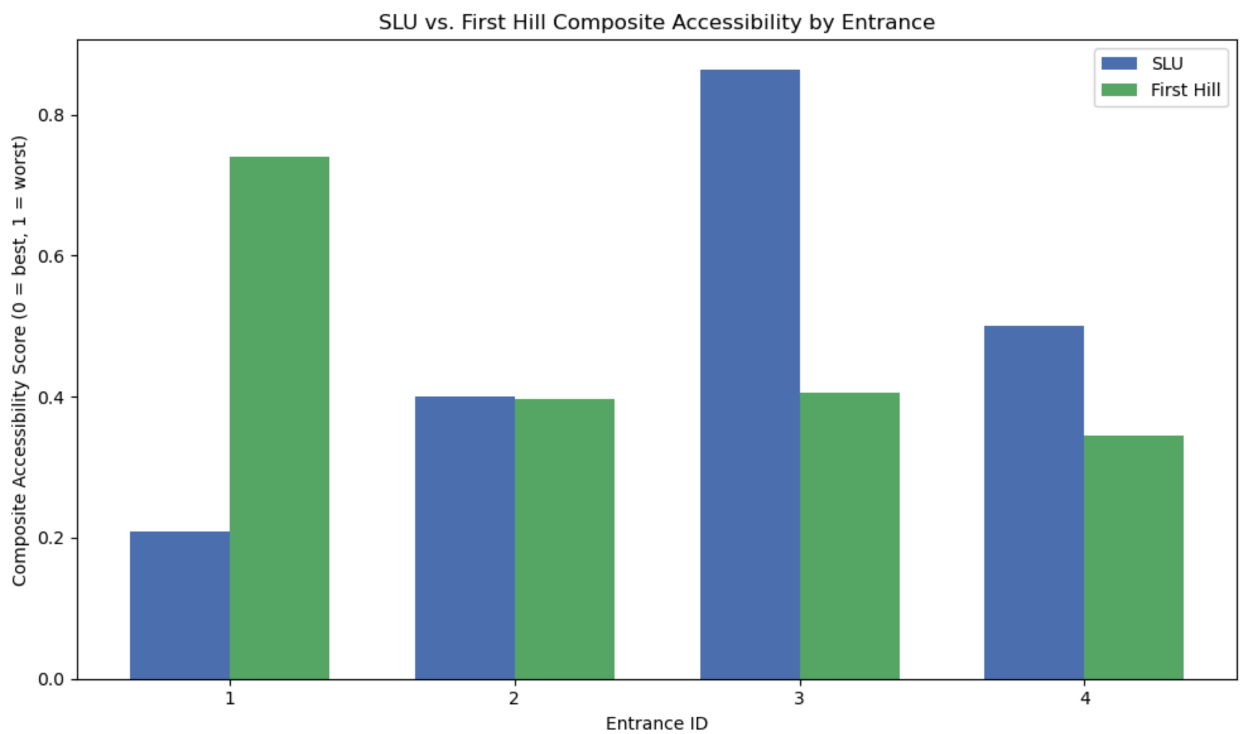


Figure 12 *Composite accessibility scores for South Lake Union (SLU) and First Hill, plotted for the same set of entrance origins. The figure shows paired composite values for each OriginID, representing normalized (0 = best, 1 = worst) accessibility derived from OD Cost Matrix travel times between entrances to housing and parks synthesized. SLU and First Hill values are shown side-by-side to allow direct comparison of relative accessibility at each entrance. The underlying comparison table was constructed by merging SLU and First Hill composite datasets on shared OriginIDs, ensuring a one-to-one alignment across neighborhoods. This visualization highlights variation in entrance-level park accessibility and illustrates where one neighborhood outperforms the other.)*

I focused on analyzing the distance relationship between entrances, to parks and housing together, where the composite score varied a lot. To start, I calculated the baseline Composite of Walkability from entrances as a flow to housing and entrances (respective to both neighborhoods), I used python to generate composites (see methodology for a more detailed explanation of the process.).

OD-Matrices used here were the calculation of Parks, Proximity Parks, and Housing. When calculating the total Composite - Entrances to Housing and Housing to Parks, this is what matplotlib generated on python notebooks in ArcGIS. These results are based on everything at the starting point of entrance ID 1, 2, 3 and 4 from respective neighborhoods. This indicates variance in composite score based on the Entrance_ID.

Figure 12 provides a quantitative view of how this study's flows shape and perpetuate inequitable access, using a composite accessibility score calculated by averaging the normalized OD‑Matrix travel times from entrances to housing and parks. Because the composite score represents *normalized* travel times, the paired values for each entrance (1–4) each illustrate how walkability varies across the pedestrian network via each entrance. The consistent differences between South Lake Union and First Hill, at each respective origin point, showed where the network facilitates or restricts movement for non‑drivers, revealing micro‑inequalities that traditional planning metrics do not capture.

This directly tested my first hypothesis about whether a newer neighborhood (South Lake Union) offers better walkability than First Hill (legacy network). Some entrances in SLU do perform better than their First Hill counterparts, but others perform worse, SLU captures both the best *and* worst scores. First Hill has a more consistent mid-level output range. This demonstrates that SLU's newer development does not consistently translate into superior walkability or more equitable access. Instead, the findings suggest that urban metabolic advantages are spatially uneven and non-drivers in both neighborhoods experience varying levels of accessibility depending on their location and entrance point within the network.

These results are sensitive to entrance placement, which in this study followed a west-to-east alignment in South Lake Union and a north-to-south alignment in First Hill. While the specific pairings would shift if entrances were ordered differently, the overall pattern of uneven accessibility across both neighborhoods would remain.

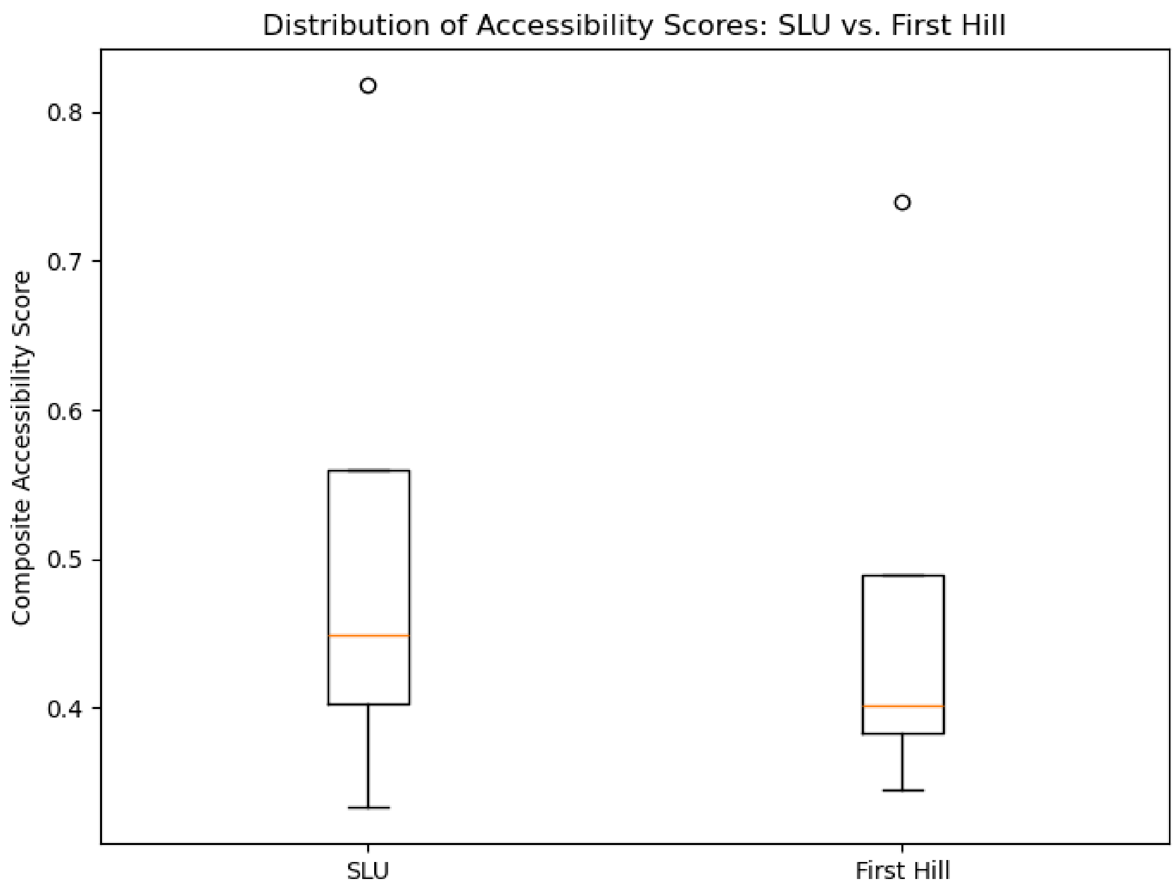


Figure 13. *Boxplot comparing the distribution of composite accessibility scores (0 = best, 1 = worst) for South Lake Union (SLU) and First Hill.* Each box shows the median (horizontal line), interquartile range (box), and variability across entrances within each neighborhood. Lower values indicate better accessibility to parks under the OD Cost Matrix–derived composite. First Hill displays a slightly lower median score and a narrower spread, suggesting more consistent access across entrances, while SLU exhibits greater variability and higher outliers, indicating more uneven accessibility conditions.

Figure 13 deepens this analysis by showing how a walkability-flows framework reveals spatial patterns of accessibility that traditional transportation planning would miss. This boxplot distributional view shows the internal variability within respective neighborhoods. We can begin to understand how the pedestrian flows circulate on the urban fabric and urban form. First Hill's lower and tighter IQR indicate a more equitable distribution of walkable access across entrances, while South Lake Union's wider speed and height outliers point to localized barriers that disproportionately affect certain origins. These findings challenge the 2nd hypothesis that new neighborhoods display more equitable spatial patterns. Instead of demonstrating uniform accessibility, South Lake Union's distribution suggests that recent development has produced fragmented walkability conditions, whereas First Hill's older finer-grained street network (translated to pedestrian network) supports more access for non-drivers. The boxplot shows how an urban metabolic perspective- one focused on urban flows, uncovers inequities that traditional planning framework overlooks.

The accessibility‑relationship scatterplot in Figure 14 provides an additional lens for understanding how entrance‑level walkability differs between the two neighborhoods. By plotting normalized entrance‑to‑housing accessibility against entrance‑to‑park accessibility, the figure reveals how these two components of the composite score interact. South Lake Union's entrances cluster tightly in the lower‑left portion of the plot, indicating that its network supports consistently short travel times to both residential areas and parks. First Hill's points, by contrast, are more widely dispersed and trend toward higher values on both axes, reflecting the uneven accessibility created by steep slopes, freeway edges, and a more constrained set of entrance

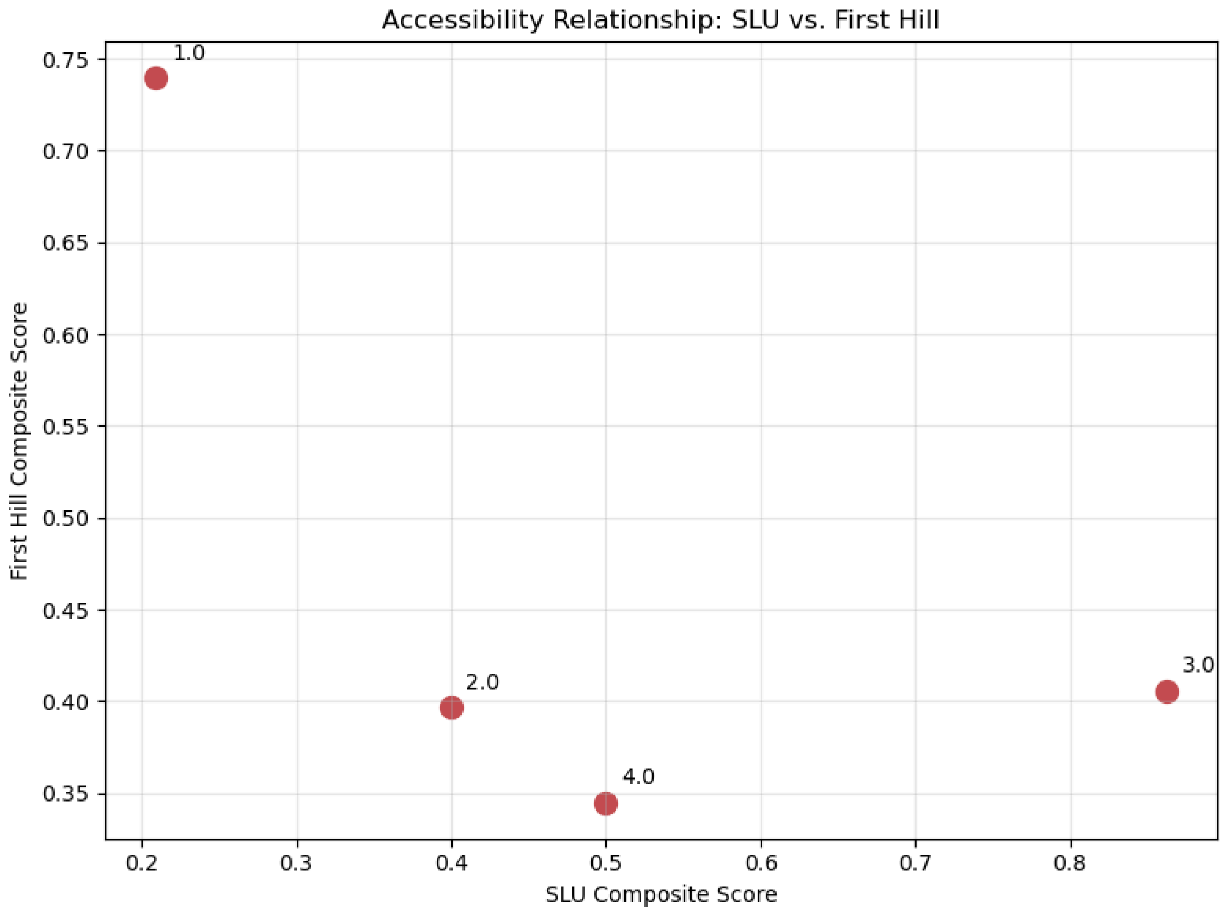


Figure 14. *Scatterplot illustrating the relationship between entrance-to-housing accessibility and entrance-to-park accessibility for South Lake Union (SLU) and First Hill. Each point represents a neighborhood entrance, plotted using normalized (0 = best, 1 = worst) OD-Matrix travel times. The figure shows that SLU's entrances cluster tightly in the lower-left portion of the plot, indicating consistently short travel times to both residential areas and parks. First Hill's points are more widely dispersed and trend toward higher values on both axes, reflecting the uneven accessibility created by steep slopes, freeway edges, and a more constrained set of entrance locations. This relationship highlights how SLU's pedestrian network performs more uniformly across destination types, while First Hill's accessibility varies substantially depending on entrance location and surrounding spatial barriers.*

locations. This divergence illustrates that SLU's pedestrian network performs more uniformly across multiple destination types, while First Hill's accessibility varies substantially depending on the specific entrance and the spatial barriers surrounding it.

4.3.2 Location-Allocation Results

The location-allocation outputs (Figure 7) add nuance to the accessibility results by showing how the model identifies the optimal service locations based on the impedance between demand points and service points. In this configuration, the entrances serve as demand points, and the park layer and housing node function as candidate facilities. The model therefore selects the optimal sites that minimize total network-based travel time for the greatest number of residents.

In South Lake Union, selected sites cluster along the neighborhood's most permeable grid connections, including several parks *outside* the boundary that are reached more efficiently than internal options. This pattern reflects SLU's relatively open, high-connectivity street network, which channels residents toward nearby external parks through direct, low impedance routes.

In First Hill, the model repeatedly selects parks located immediately adjacent to the neighborhood's limited set of corridors, and not further along the network. These choices display the structural barriers imposed by steep slopes, and a smaller spread of viable entrances. Because the model optimizes for travel impedance rather than park size or capacity, the selection of First Hill Park, despite its very small footprint, demonstrates how topography and freeway edges shape the service area.

Across both neighborhoods, the resulting eight chosen locations represent the optimal service network for in-neighborhood housing and highlights a mismatch between geographic public space placement and actual accessibility. These findings reinforce the broader argument that spatial inequities emerge, not only from park distribution, but from the metabolic structure of the urban network itself.

4.4 Synthesis

Together, Figures 12 and 13 show that walkability flows have a complex and uneven landscape of accessibility. Findings challenge standard assumptions about neighborhood age, design, and equity. Figure 12 shows us that accessibility is not a uniform neighborhood attribute but a spatially patterned experience; with entrance-level disparities showing how the pedestrian network advantages some origins while burdening others. Figure 13 shows how differences aggregate into broader distributional patterns, revealing that SLU's newer characteristic produces greater variability with more outliers, while First Hill's older network supports more consistent access.

Figure 14 extends this analysis by displaying the components of the composites: entrance-to-housing and entrance-to-park accessibility. These results do not follow the pattern previously anticipated; that newer neighborhoods with recent development are consistently better. While SLU has the highest extreme (or lowest composite score), it also has the lowest extreme (or highest composite score). SLU's composite scores cluster at *higher combined* impedance values, reflecting how its long block structure, superblocks, and landscape history constrain pedestrian movement despite the highest and worst range of entrances. First Hill, by contrast, forms a tighter, lower-impedance cluster. Its finer-grained street network, shorter blocks, and more consistent topographic conditions produce more even and more efficient access across public space and housing destinations. This relational-system perspective underscores that accessibility outcomes emerge from the interaction of network granularity, block morphology, and urban terrain, which are factors collectively shaping performance more than any single improvement.

Across the three figures, the urban metabolic framework helps reveal modeled accessibility differences, bottlenecks, and uneven access patterns that may be missed by simpler measures in traditional transportation planning. This combination of evidence indicates equitable access for non-drivers depends less on neighborhood age or topography, and more on the underlying spatial logic of the pedestrian network, including block structure, pedestrian targeted infrastructure, connectivity, and the distribution of entrances relative to public spaces.

4.5 Limitations

The most notable limitation in this study comes from the origins, or entrances, used in the analysis. I created these features as part of the Urban Metabolic Framework (Tuffaha. Sallay. 2025) to represent 4 locations where pedestrians may enter the neighborhood street network, respectively. While the entrances were modeled assumptions, they were selected after researching the major roads connected to each neighborhood so they would represent "realistic" access points throughout the areas being studied (Seattle Department of Transportation, 2024). If different entrance locations had been chosen, the underlying spatial data (i.e. slopes, block structure, network geometry) would remain unchanged. However, the *accessibility scores themselves* could shift substantially because the model's outputs depend on the specific origins used to calculate impedance. Changing entrance locations would not alter the input layers, but it could meaningfully alter the resulting composite scores by re-ordering entrance IDs or producing different relative relationships among them. Effectively, the modeled accessibility outcomes are sensitive to how origins are defined. Therefore, the results from the selected entrances should be interpreted as representative rather than exhaustive of all possible pedestrian access points.

Another limitation relates to differences between the neighborhoods themselves. First Hill is only connected to Interstate 5, while South Lake Union connects to two major routes, State Route 99 and Interstate 5 (Figure 4). This difference may influence how entrances connect to the surrounding transportation network and may affect accessibility patterns observed in the analysis. There are also limitations related to the network dataset used for the OD Cost Matrix analysis. The model assumes consistent walking speeds and standardized travel conditions across the network. In reality, pedestrian accessibility may be influenced by additional factors such as external conditions, unforeseen sidewalk conditions, and intersection safety, which were not explicitly modeled in this study. The goal was to establish a baseline for comparing accessibility across the two neighborhoods.

Another simplification in the analysis is the composite accessibility score used in the study. The composite combines multiple variables, including entrance-to-housing and entrance-to-park accessibility, into a single normalized metric. While this allows for easier comparison between neighborhoods, it may obscure differences between individual accessibility components Additionally, Freeway Park was excluded from the analysis because it is accessible from both neighborhoods. While this simplified the comparison, it may influence the resulting accessibility scores.

The network dataset used in this project comes from the ArcGIS Online Portal provided through Esri's Network Analysis services. While this dataset provides a comprehensive representation of the street network, the routing assumptions within the dataset, like standardized pedestrian walking speeds, may not fully capture real-world pedestrian conditions.

Finally, this analysis represents a static snapshot of accessibility conditions at the time the network data were accessed. Changes in pedestrian infrastructure or land use over time may alter accessibility patterns. This study is also limited in geographic scope, focusing only on two neighborhoods in Seattle that are located close to one another.

5 Discussion

In this exploratory analysis, the findings demonstrate that pedestrian accessibility in Seattle's urban core is shaped less by a neighborhood's age and more by the spatial logic of its pedestrian network, boundary conditions, and urban form. By applying an Urban Metabolic framework, the study reveals how flows of movement into and through First Hill and South Lake Union vary according to entrance locations, network permeability, and topographic constraints. The results show that while South Lake Union's newer, master-planned development offers more distributed access and generally stronger entrance-level performance, these advantages are absolutely not uniform. First Hill, despite its older and more constrained form, exhibits pockets of strong accessibility alongside areas where steep slopes and freeway edges limit walkability.

Across both neighborhoods, the combination of service-area modeling, OD-Matrix travel times, and composite scoring highlights micro-scale inequities that traditional transportation planning tools often overlook. These findings underscore that equitable access for non-drivers depends on the quality and configuration of the pedestrian network (entrances, connectivity, and barriers) rather than on assumptions about neighborhood age or density. While the analysis is modeled and subject to the limitations of generalized network data, it provides a replicable, transparent framework for diagnosing accessibility gaps and identifying where targeted improvements could meaningfully expand walkable access.

Ultimately, this study reinforces the importance of designing pedestrian networks in planning and how they should support continuous, safe, and permeable flows. As Seattle continues to grow, planners can use these insights to prioritize investments that reduce structural barriers, enhance entrance connectivity, and promote more equitable access to parks, housing, and essential destinations. By centering non-driver mobility within an Urban Metabolic perspective, the analysis contributes to a broader understanding of how urban form and infrastructure shape everyday movement, and how intentional planning can support healthier, more connected, and more equitable (walkable) neighborhoods

5.1 Reconnecting to the Research Questions

Thinking back to our research questions, there are immediate answers that appear from the figures provided in the analysis (Figure 5, Figure 6 and Figure 7). Specifically, **these figures** displays that our issue is not resolved in a single direction- implying that entrance-specific measures must occur. In figure 12, composite scores results higher in SLU, and other times First Hill- suggesting that it doesn't matter whether the pedestrian network has aged, or is new. The transportation flows are differing and results suggest outside factors.

When running Service Area analysis (Figure 5), we can *visually* identify how urban metabolism is not spatially distributed. In both of the maps displayed on the layout, the coverage areas are split into 2 distinct bounds covering 5-10 minute radii, for walkability. (Walkability from SLU Entrances; Walkability from First Hill Entrances) In SLU, we see that pretty much the whole neighborhood is surrounded by bounds- suggesting South Lake Union is walkable from the entrances- at least in terms of distance. In First Hill, the service area indicates two different challenges- it is not all walkable from the entrance and a polygon barrier changes the output. I concluded that it is most likely the topography in the area, which is useful for planners to consider when tackling this challenge (Figure 15). For South Lake Union, it would be beneficial to begin to look at safety measures when planning.

5.2 Interpretation of Key Findings

This analysis suggests that urban form impacts and shapes walkability and mobility access in both South Lake Union and First Hill, but the mechanisms vary between the two neighborhoods. Moreover, the results speak to land-use history. In South Lake Union, walkability is constrained primarily by the structure of the street network: long blocks, and irregular connections inherited from its industrial, auto‑oriented past. These findings imply that features create fragmented pedestrian environments and produce highly uneven composite scores (Figure 12). Although SLU contains one entrance with the strongest accessibility score, it also contains the single worst‑performing entrance in the dataset, illustrating how the built environment and urban form channels spatial mobility.

In contrast, First Hill's accessibility patterns reflect the logic of its pre‑automobile streetcar‑era grid. Looking at First Hill early modernity in "First Hill - Thumbnail History," we understand how pre-automobile patterns shaped the neighborhood, previously having 3 streetcars to aid mobility (Dorpat, 2001). First Hill's tight, block structure supports more consistent pedestrian movement, with a well-aged sidewalk grid. Even though steep slopes and infrastructure gaps prevent some service areas from reaching every entrance, and display a polygon barrier, it still results in a lower composite score. The entrances that were reachable nonetheless produced moderate and stable composite scores, reinforcing the literature's argument that fine‑grained grids provide a resilient foundation for walkability. South Lake Union's land-use history, dubbed as a "funnel" in the 1960s (HistoryLink.org , n.d) for Seattle's "growth and expansion," we understand that maybe it was always meant to follow the pattern of reinforced industry. It started as a tribal land, home to the Duwamish, who began bartering and building mills and factories on the land in the 19th Century (Tesfazion, N.D) Ultimately, SLU's inherited superblocks, from the warehouse era, depress walkability in specific locations, while First Hill's grid structure provides a more consistent baseline despite topographic challenges.

These results directly reflect the theoretical frameworks outlined in the literature review. Cervero, Ewing, Speck, and Gehl emphasize that block length, intersection density, and connectivity are foundational determinants of walkability. What furthers this point is removing 2 out of the 3 streetcar lines that run through First Hill. Kwan's critique of aggregated spatial metrics is also evident here: the entrance‑level variation uncovered in this study reveals inequities that would be invisible at the neighborhood scale. The contrast between SLU and First Hill illustrates how historical planning decisions; whether industrial and auto-oriented design or streetcar-era grid development, continue to shape present‑day mobility opportunities. In this sense, the composite scores operationalize the mobility justice literature, showing how structural conditions embedded in the built environment determine who can move easily and who encounters barriers.

Furthermore, the conclusion that First Hill outperforms South Lake Union within the parameters of this method is both empirically supported and theoretically grounded. It challenges the common assumption that SLU is inherently more accessible due to its density and recent investment, demonstrating instead that accessibility is a product of spatial logic, historical form, and micro-scale variation - not simply development age or intensity.

5.2.1 Urban Form as a Determinant of Accessibility

Essentially, this study shows how urban form is a primary determinant of walkability and accessibility. In South Lake Union, the long blocks, superblocks, and irregular street connections inherited from its industrial, auto-oriented past create fragmented pedestrian environments. The structural features align with the critiques raised by Speck, and Ewing and Cervero, who argue that block length, spatial frequency of intersections, and street connectivity are foundational to walkability and cannot be compensated for by density alone. The uneven composite scores observed in SLU reflect these constraints: entrances located along shorter blocks or near newer pedestrian improvements perform well in access to the public parks, while those embedded within larger industrial parcels perform, with visible updates to cater the car (Parking Lots, large Highway Off-Ramps) poorly (King County, KCGIS Parcel Viewer, 1932; 2023). In contrast, First Hill's pre-automobile streetcar-era sidewalk grid provides a more consistent baseline for pedestrian movement. Even though the hill slopes and infrastructure gaps limit accessibility in certain locations, the underlying grid supports more predictable and equitable mobility flows.

This pattern aligns with Gehl's emphasis on fine-grained street networks as essential for human-scaled movement and with Marshall's argument that historical street patterns exert lasting influence on contemporary mobility. For non-drivers, these structural differences translate into meaningful disparities in how easily they can navigate each neighborhood.

5.2.2 Entrance-Level Inequities and Micro-Spatial Variation

Because this study area scale is exploratory, one of the most important takeaways is that accessibility varies at the entrance level, to represent inconsistency at the neighborhood scale. This is exactly what Kwan warns about when she critiques aggregated metrics, because they smooth over inequities that matter most for lived-experience mobility. In both SLU and First Hill, the entrance-level results show that mobility is patterned by micro-scale conditions. It is also very important to note that a single block, a slope, or a missing connection can completely change how someone experiences the neighborhood! This is another area where mobility justice literature becomes relevant. Sheller and Davis emphasized that mobility is *not just about movement* but about *who gets access to movement.* The metabolic flows in these neighborhoods are uneven, and the entrance-level analysis makes that visible. In SLU, the fragmentation and uneven topography creates sharp differences from one entrance to the next. In First Hill, slope and infrastructure gaps create localized barriers, displayed through the polygon barrier. These are the kinds of disparities that matter for non-drivers navigating the city on foot.

5.2.3 Comparing Legacy vs. New Development Patterns

The comparison between SLU and First Hill challenges the assumption that newer development automatically produces better accessibility, which is exactly what the first hypothesis predicts. SLU is newer, denser, and has a heavy transit investment, but its inherited industrial grid still shapes how people move. The “rapid” redevelopment didn’t fundamentally change the wide warehouse block structure, and the results reflect that. First Hill, despite being older and more topographically challenged, performs more consistently because its streetcar-“populated” -era grid was designed for walking in the first place. It supports the argument that historical street patterns have long-lasting effects on mobility. In other words, “new” does not necessarily mean “more walkable,” “more accessible,” and “old” does not automatically mean “outdated,” “inaccessible,” and “auto-dependent.” In fact, it only reinforces the idea that the world is and has been turning more to an auto-oriented place. This underlying spatial logic matters more than the age of the neighborhood and buildings inside it.

5.2.4 Composite Scores and What They Reveal

The composite scores (Figure 12, Figure 13, and Figure 14) help clarify what is actually happening at the ground level. While the service area maps (Figure 5) show that SLU is overwhelmingly reachable within a 5- or 10-minute walk, the composite scores reveal that reachability does not equal the accessibility by this study’s model. SLU’s scores swing from very strong to very weak, which reflect the inconsistency of its street network. First Hill’s scores cluster more tightly, which matches the stability of its grid (see Figure 14). This is why composite scoring is useful: it captures the multidimensional and metabolic nature of walkability and exposes patterns that single metrics would miss. In this way, the metabolic nature is identified. The variance, clustering, and the outliers all tell a story about how mobility is structured in each neighborhood. The results reinforce the importance of distance-based tools to understand accessibility in planning.

5.3 Evaluating the Hypotheses

The entrance-level differences identified in this study have implications for mobility justice. Non-drivers do not experience neighborhoods uniformly; their mobility is shaped by the specific entrances they use and the spatial conditions around them.

The first hypothesis assumed that South Lake Union would demonstrate stronger modeled pedestrian accessibility because of its density, investment, and more recent redevelopment pattern. The results only partially support this hypothesis. SLU has one entrance with a strong composite score, but its overall pattern is inconsistent. The neighborhood also contains the worst-performing entrance in the dataset, which challenges the assumption that newer redevelopment automatically produces better walkability. The underlying street network still shapes how people move, and SLU's inherited industrial block structure continues to affect accessibility in ways that density and investment cannot fully resolve.

The second hypothesis assumed that newer neighborhoods would show more equitable spatial access. This hypothesis was not supported. First Hill's legacy network, despite being older and more topographically complex, produced more stable accessibility outcomes across entrances. These findings suggest that walkability is not simply a function of neighborhood age or recent investment; it is shaped by spatial structure, network connectivity, block size, and topography.

5.4 Implications for Transportation Planning

5.4.1 Mobility Justice

The findings have implications for mobility justice because they show that non-drivers who rely on walking do not experience neighborhoods uniformly. Their mobility is shaped by the specific entrance they use, the surrounding street network, and local spatial conditions. This aligns with transportation equity literature showing that access is unevenly distributed across urban streets. The study suggests that the built environment can create uneven mobility opportunities, and that these differences matter for non-drivers.

5.4.2 Urban Metabolism as an Analytical Lens

Using urban metabolism as a framework helps reveal how pedestrian movement flows through each neighborhood. The service-area maps, OD-Matrix lines, and ArcPy-based analysis show that these flows are not evenly distributed. Some entrances provide stronger access than others, as reflected in the composite scores. An urban metabolism approach does not replace traditional planning tools; rather, it complements them by emphasizing movement, connectivity, and spatial relationships instead of treating accessibility as a static condition. It also highlights how historical and spatial conditions shape contemporary mobility patterns.

5.4.3 Implications for Public Space Access

This study shows that walkability affects who can reach public spaces, and that flow-based planning is imperative. The disparities observed in both neighborhoods suggest that access to parks and other public amenities is uneven. This finding aligns with scholarship that frames public space access as an equity issue, and one of high importance to fix. If certain entrances consistently underperform, then some non-drivers **will** face greater barriers to reaching public amenities. Improving entrance-level accessibility is therefore essential for supporting more equitable public space access.

5.5 Implications for Planning Practice

5.5.1 Entrance-Based Planning

The results suggest that planners should evaluate pedestrian access at the entrance level, not only at the neighborhood scale. A single entrance can shape a person's mobility experience. Designing for permeability" is especially important for non-drivers in areas with fragmented street networks, freeway edges, or limited access points.

5.5.2 Designing for Topography

In neighborhoods like First Hill, slope is not only a physical condition; it can also shape accessibility. Interventions such as improved crossings, curb ramps, rectangular rapid flashing beacons, shaded routes, pedestrian refuges, and other small-scale infrastructure improvements can help reduce barriers created by grade and difficult crossings. These interventions cannot eliminate topographic constraints, but they can improve pedestrian comfort, safety, and accessibility. This is especially important for otherly-abled individuals; such as wheelchair users, elderly, and parents with strollers, and others for whom steep slopes and difficult crossings can create significant barriers. It is important to note that these are a only a few of who these improvements.

5.5.3 Rethinking Walkability Metrics by Normalization

The limitations of the GIS analysis highlight the need for more nuanced accessibility tools. Distance-based measures alone do not fully capture the reality of pedestrian movement. Combining OD-Matrix modeling with normalized composite scores provides a more detailed picture of relative accessibility, especially in neighborhoods with complex spatial conditions such as steep terrain, freeway barriers, large blocks, or uneven pedestrian connectivity. However, these modeled scores should be interpreted alongside qualitative and field-based evidence, including sidewalk conditions, crossing safety, slope, disability access, and pedestrian experience.

5.5.4 Implications for SLU and First Hill

This analysis helps identify location-specific priorities for transportation planning. South Lake Union needs targeted interventions that address connectivity gaps and pedestrian safety within its inherited industrial grid. These may include breaking up long blocks where feasible, adding pedestrian crossings and safety measures, improving sidewalk continuity, and strengthening access to transit.

First Hill needs improvements that address slope-related barriers and strengthen entrance-level access. Because the district is constrained by its existing street network and freeway edges, adding major new roads would be inefficient and disruptive. Instead, planning should focus on improving pedestrian access within the existing network, strengthening transit connections, and reducing barriers at key entrances. Overall, both neighborhoods would benefit from planning approaches that prioritize non-drivers and recognize the micro-scale nature of accessibility.

5.6 Methodological Contributions

This study contributes to accessibility analysis by focusing on walkability from neighborhood entrances rather than relying only on generalized neighborhood boundaries. The entrance-based modeling approach reveals micro-scale variation that broader neighborhood-level measures may overlook. The composite scoring method adds a multidimensional measure of relative accessibility, while the integration of urban metabolism with GIS provides a replicable workflow for analyzing pedestrian mobility in other neighborhoods or urban contexts. Together, these methods can help planners better understand how accessibility is produced and unevenly distributed.

This analysis treats walkability not as a fixed neighborhood characteristic but as a condition shaped by movement through the built environment. The urban metabolism framework helps show that accessibility is produced by the relationships among people, paths, destinations, and connections circulate through space, not by whether a neighborhood is simply deemed "walkable" on paper. The service-area maps and OD-Matrix results show how pedestrian movement can branch, narrow, or break depending on block structure, slope, and entrance conditions. In South Lake Union, these flows are disrupted by long blocks and fragmented connections. In First Hill, they are shaped more by topography and infrastructure gaps, although the underlying grid supports more consistent movement. Modeling accessibility as a flow helps identify where mobility is supported, constrained, and unevenly distributed for non-drivers. Using the ArcGIS Online Portal Network Dataset also supports replicability because the workflow can be adapted to other cities where comparable network data are available. However, this strengthens consistency and transferability of the method, not necessarily the accuracy of every modeled result.

This analysis also encourages planners to think more critically about the assumptions and spatial units used in accessibility analysis.

5.7 Limitations - Interpretive

The interpretations from this analysis have several limitations. First, the project is exploratory in scale and the magnitude of data is lacking in depth to be a full study. This exploratory analysis is meant to be suggestive for a larger study on Metabolic Planning. The interpretative limitation is its direct impact on findings outside of Seattle. The analysis is intended to suggest a framework for future research on urban metabolism and accessibility, rather than to provide definitive conclusions. Because the findings are shaped by specific urban forms, historical land-use patterns, and neighborhood conditions in South Lake Union and First Hill, they should not be generalized directly to other geographies.

Second, the GIS analysis models walkability and pedestrian access, but modeled walkability is not the same as lived experience. A systems-based approach can reveal spatial patterns, but it cannot fully capture how people experience safety, comfort, disability access, slope, weather, construction, or intersection conditions. As Allmendinger argues, “aggregate human behaviour is not always reducible to a simple formula” (Allmendinger, 2007).

Third, the entrance points used in the analysis are modeled abstractions. Although they were selected to represent likely pedestrian and transit-related access points, other street edges could also be justified. Different entrance choices could produce different accessibility scores. Future analysis could strengthen this approach by testing alternative entrance points and incorporating transit lines, stops, and observed pedestrian movement.

Finally, the composite accessibility score is only one way to summarize multiple measures. The weighting choices are transparent and useful for exploratory comparison, but they are still analytical assumptions rather than direct measures of lived accessibility. Future work should combine modeled accessibility with field observations, qualitative evidence, and user experience data. For methodological limitations, see Chapter 3.

5.8 Future Research

This study sets a baseline for future research. One obvious next step could be linking transit level measures- such as transit stop-level accessibility (GTFS data), and routing equity. One thing that could specifically further this study is to add the raw data of first-mile and last-mile modeling, specifically furthering the discussion of the entrances.

Other contributions based on the entrances is to model accessibility under different entrance configurations. By removing this vital piece of the study, specifically “most-likely” pedestrian entrances, would change the scope of the study. Perhaps a finer urban fabric would suit the accessibility model better, but for different reasons.

Other future research could include qualitative measures *and* quantitative measures: for example, adding pedestrian counts, while asking about experience. By doing this, we would have a more holistic view and feedback of the perception of the neighborhood's urban metabolic accessibility.

Finally, further research would replicate itself to be modeled in other cities- with different transit, geography, urban form and land use history. This is a very important next step in metabolic planning.

5.9 Conclusion of the Discussion

From this discussion, we have learned that walkability is not a neighborhood attribute but a spatially patterned flow. This verifies this thesis and demonstrates why planners must move toward integrating neighborhood scale indicators with entrance-level, flow-based approaches which reveal where accessibility is supported, and where interventions would matter most. Urban metabolism reveals inequities traditional planning misses, and we see this in the GIS analysis conducted.

SLU and First Hill both show uneven accessibility for non‑drivers, and for different reasons. It doesn't matter who is older, or who is newer and supposedly with improved infrastructure. By looking even closer than general neighborhood-scale size, we can understand even more about flows and spatial patterns. This study shows that entrance‑level analysis is *essential* for equitable mobility planning- this study highlighted urban form, slope, and network relationships.

Composite scoring verifies the thesis by showing that reachability (distance) and accessibility (quality of movement) are not one in the same, this is also supported by literature. SLU and First Hill differ not in overall proximity but in structural access. South Lake Union's block structure (influenced by its history) produces sharp disparities in entrance performance. First Hill's grid structure has a more even accessibility score, even with topography. This reinforces the network's permeability shaping walkability. To operationalize the findings of this study, Location-Allocation highlights where targeted interventions would most effectively model accessibility and restore metabolic flows, by highlighting case study examples of housing and parks to shape recommendations.

Overall, my study shows that aggregated neighborhood indicators are insufficient for equitable planning, because they smooth over the very disparities that shape lived mobility. Rather, analysis based on entrance-level metabolic methods offer planners a more precise and just way that's clear and intervenes in accessibility, specifically for non-drivers navigating the city on foot.

6. Conclusion

This thesis investigated whether more recently redeveloped neighborhoods produce stronger modeled pedestrian accessibility for non-drivers than older neighborhoods. It also examined whether spatial accessibility patterns appear more evenly distributed in newer development contexts. These questions were motivated by a broader concern with transportation equity for non-drivers and by the potential of metabolic planning to analyze accessibility through a systems perspective. By modeling the metabolic flows of pedestrian access in ArcGIS, the study aimed to identify spatial inequities that traditional transportation planning metrics may overlook.

The findings were more complex than a simple confirmation or rejection of the hypotheses. Entrance-level data on walkability and access to housing and parks produced composite scores that highlighted the importance of urban form and land-use history. Rather than showing that newer development automatically produces better access, the results suggest that accessibility is shaped by the interaction of entrance locations, street-network structure, block size, topography, and destination distribution.

A central finding is that walkability should not be treated only as a neighborhood attribute. Accessibility varies across fine-grained networks and cannot be summarized adequately at the neighborhood scale alone. This study shows that access emerges from micro-scale spatial conditions, including network permeability, urban form, and entrance configuration.

South Lake Union is more recently redeveloped, but its accessibility is still shaped by inherited industrial superblocks that create uneven pedestrian conditions. First Hill is older and topographically steep, yet its finer-grained grid supports more consistent modeled accessibility in some locations. The entrance-level analysis, using network modeling and composite scoring, shows that reachability does not necessarily equal accessibility. Even if a destination is within a 10-minute walk, that measure alone does not explain how direct, safe, comfortable, or equitable the walking experience is, or for whom. Composite scoring revealed patterns that were not visible in the service-area analysis alone.

These findings suggest that accessibility is not a static number on which to base planning decisions. Through an urban metabolism framework, this study conceptualizes accessibility as a spatial flow: uneven, patterned, and shaped by structural conditions. Walkability emerges from interactions among multiple spatial factors, rather than from any single variable. This supports the argument that planning must pay closer attention to micro-scale complexity. The study also contributes to mobility justice literature by showing how non-drivers may experience the same neighborhood differently depending on the entrance used and the spatial barriers encountered. Methodologically, this thesis demonstrates the value of entrance-based modeling as an alternative to neighborhood-scale accessibility metrics. The integration of service-area analysis, OD-Matrix modeling, composite scoring, and location-allocation in ArcGIS Pro. By using this software, this study demonstrates replicability and efficiency of using ArcPy. This overall shows how to operationalize metabolic flows in GIS.

6.1 Recommendations for Planning Practice.

6.1.2 Transit Planning

Planning for non-drivers requires attention to multiple scales of access. This study supports entrance-level planning: pedestrian and transit access should be evaluated at neighborhood edges and key access points, not only within neighborhood boundaries. In transit planning, stop placement and access routes should be evaluated by how well each entrance performs, not simply by whether a neighborhood has transit service. The variation in the composite scores suggests that agencies should identify weak entrance nodes where pedestrian access breaks down. This can help planners address micro-scale barriers such as long blocks, slopes, difficult crossings, and poor sidewalk connectivity.

6.1.3 Designing for Urban Form and Topography

Neighborhood planning should work with existing urban form while identifying targeted interventions that improve connectivity for non-drivers. In South Lake Union, planners should focus on pedestrian connectivity and safety within the inherited industrial grid. In First Hill, planners should prioritize slope mitigation, safer crossings, curb ramps, resting points, and other micro-infrastructure improvements that support people with different mobility needs.

6.2 Limitations

This study provides a useful exploratory foundation, but it has several limitations. Modeled walkability does not fully reflect lived pedestrian experience. Entrance points are analytical abstractions, and different entrance selections could produce different results. The normalization and weighting choices influence the composite scores, and the network data provide a static representation of accessibility conditions. The analysis also does not fully model transit access, multimodal travel, sidewalk quality, crossing safety, disability access, or observed pedestrian behavior. These limits mean the findings should be interpreted as modeled accessibility patterns, not as a complete measure of transportation equity.

6.3 Future Research

Future research could extend this work by integrating transit stop-level accessibility using GTFS data and by modeling first- and last-mile connections. The framework could also be expanded to include multimodal mobility flows, including biking, micromobility, wheelchair access, and other forms of rolling mobility. Adding qualitative data, field observations, and user experience research would also strengthen the analysis by connecting modeled accessibility to lived experience. Applying the workflow to additional neighborhoods or cities would help test how well the urban metabolism framework supports comparative accessibility analysis across different urban contexts.

6.5 Concluding Thoughts

Access is a spatially patterned flow. This thesis shows that entrance-level analysis, interpreted through an urban metabolism framework, can reveal accessibility differences that traditional neighborhood-scale measures may overlook. This approach offers a more precise way to examine pedestrian access for non-drivers and provides a foundation for future equity-focused planning research.

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Appendix

Appendix #1: Python Code

Analysis .py Code:

```
access.head()
```

	OriginID	E_P_mean	E_P_norm	E_H_mean	E_H_norm	Composite	E_PP_norm
0	1	6.313890	0.418889	5.072701	0.000000	0.209445	1.000000
1	2	6.154146	0.366540	6.176938	0.432828	0.399684	0.478299
2	3	8.087143	1.000000	6.923622	0.725506	0.862753	0.727149
3	4	5.035653	0.000000	7.623915	1.000000	0.500000	0.000000

```
comparison = pd.merge(
    access[["OriginID", "Composite"]].rename(columns={"Composite": "SLU_Composite"}),
    FH_access[["OriginID", "FH_Composite"]],
    on="OriginID",
    how="outer"
)

comparison
```

	OriginID	SLU_Composite	FH_Composite
0	1	0.209445	0.739447
1	2	0.399684	0.396546
2	3	0.862753	0.405758

3	4	0.500000	0.344820

```
comparison = pd.DataFrame({
    "OriginID": [1, 2, 3, 4],
    "SLU_Composite": [0.209445, 0.399684, 0.862753, 0.500000],
    "FH_Composite": [0.739447, 0.396546, 0.405758, 0.344820]
})
import pandas as pd

comparison = pd.DataFrame({
    "OriginID": [1, 2, 3, 4],
    "SLU_Composite": [0.209445, 0.399684, 0.862753, 0.500000],
    "FH_Composite": [0.739447, 0.396546, 0.405758, 0.344820]
})

comparison
import pandas as pd

comparison = pd.DataFrame({
    "OriginID": [1, 2, 3, 4],
    "SLU_Composite": [0.209445, 0.399684, 0.862753, 0.500000],
    "FH_Composite": [0.739447, 0.396546, 0.405758, 0.344820]
})

comparison
```

	OriginID	SLU_Composite	FH_Composite
0	1	0.209445	0.739447
1	2	0.399684	0.396546
2	3	0.862753	0.405758
3	4	0.500000	0.344820

```
import matplotlib.pyplot as plt
import numpy as np

x = np.arange(len(comparison["OriginID"]))
width = 0.35
```

```
plt.figure(figsize=(10,6))
plt.bar(x - width/2, comparison["SLU_Composite"], width, label="SLU", color="#4C72B0")
plt.bar(x + width/2, comparison["FH_Composite"], width, label="First Hill", color="#55A868")

plt.xticks(x, comparison["OriginID"])
plt.xlabel("Entrance ID")
plt.ylabel("Composite Accessibility Score (0 = best, 1 = worst)")
plt.title("SLU vs. First Hill Composite Accessibility by Entrance")
plt.legend()
plt.tight_layout()
plt.show()

plt.figure(figsize=(8,6))
plt.scatter(comparison["SLU_Composite"], comparison["FH_Composite"], s=100, color="#C44E52")

plt.xlabel("SLU Composite Score")
plt.ylabel("First Hill Composite Score")
plt.title("Accessibility Relationship: SLU vs. First Hill")

for i, row in comparison.iterrows():
    plt.text(row["SLU_Composite"] + 0.01, row["FH_Composite"] + 0.01, str(row["OriginID"]))

plt.grid(alpha=0.3)
plt.tight_layout()
plt.show()



plt.figure(figsize=(8,6))
plt.boxplot([comparison["SLU_Composite"], comparison["FH_Composite"]],
            labels=["SLU", "First Hill"])
plt.ylabel("Composite Accessibility Score")
plt.title("Distribution of Accessibility Scores: SLU vs. First Hill")
plt.show()
```