Measuring Pedestrian-Friendly Attributes of Streets in Seattle: A Computational Approach

Steven Youn

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Urban Design and Planning

University of Washington

2023

Committee:

Daniel B. Abramson, Chair

Tomás Méndez Echenagucia

Program Authorized to Offer Degree:

Urban Design and Planning

University of Washington

Abstract

Measuring Pedestrian-Friendly Attributes of Streets in Seattle: A Computational Approach

Steven Youn

Chair of the Supervisory Committee:
Associate Professor Urban Design and Planning
Daniel B. Abramson

Department of Urban Design and Planning

This research project aims to enhance pedestrian-friendliness in Seattle by utilizing computational methods to analyze street elements' various measurements. Python, a programming language commonly used in geospatial data analysis, generates geographic visualizations (geo-visualizations) that provide insights into the current state of street infrastructure in Seattle. In order to establish the significance of this research objective, the paper begins by examining the existing plans and initiatives published by the City of Seattle and reviewing literature by renowned urban design theorists to emphasize the importance of pedestrian-friendly streets and street elements. The methodology of this paper is quantitative, involving the collection of numeric data from official websites, which serves as a reliable source for coding purposes. The ultimate goal of this

study is to assist the City of Seattle in managing street feature data and make computational methods more accessible to urban design students and researchers. This paper identifies potential avenues for future research by leveraging computational methods, showcasing the transformative capabilities of coding in manipulating urban design data. This approach empowers individuals to generate visualizations by crafting lines of code, opening up new possibilities for analyzing and understanding urban environments.

TABLE OF CONTENTS

LIST OF FIGURES

Chapter 1. INTRODUCTION

Seattle's rapid population growth has brought about heightened traffic congestion, highlighting the importance of investing in transportation infrastructure to enhance the city's sustainability, security, and overall livability. One crucial aspect of this infrastructure is the transportation infrastructure of pedestrians, which has become an increasingly important issue since the adoption of Seattle's Complete Streets policy through the passing of Ordinance 122836 by the City Council in 2007. This policy aims to design, plan, and construct transportation improvements that promote safe operations for all users while encouraging walking, bicycling, and transit use (City of Seattle, 2016). By adopting this policy, Seattle has been encouraged to invest more in transportation infrastructure for pedestrians, resulting in improvements that have made the city more pedestrian-friendly, sustainable, and livable.

Given Seattle's emphasis on developing pedestrian-friendly streets, this research project focuses on identifying opportunities for further enhancing the urban streets through the lens of urban design. While conventional urban design research typically entails examining and improving physical and social aspects within urban environments, this paper takes a more architectural approach, integrating numerical shape considerations into the analysis. By incorporating this approach, the study aims to provide a multi-factor understanding of Seattle's urban streetscape and propose innovative strategies for further enhancement.

Creating streets that are accommodating for all users still poses challenges. However, leveraging technology can enable the analysis of the physical environment, leading to more efficient and pedestrian-friendly streets. This study aims to examine the features of streets in Seattle and explore the effectiveness of computational methods. The study will review existing literature and conduct experiments using computational methods to develop an approach to urban design that can support the overall quality of city streets. The computational methods in this paper will use the programming language Python, along with the libraries GeoPandas and Plotly, to integrate Seattle's existing geospatial GIS data and generate geo-visualizations displaying a heat map based on key metrics related to the city's buildings, sidewalks, streets, and other elements such as crosswalks, light poles, and trees. These geo-visualizations will provide insights into the measurements of different street features in various areas of Seattle. Depending on the specific street feature being analyzed, the geo-visualizations will indicate which areas have higher or lower measurements.

Furthermore, the study will undertake a thorough literature review to establish the fundamental principles and requirements for designing pedestrian-friendly streets that prioritize the safety and needs of pedestrians. The review will also explore the potential of computational methods in improving street design by examining various research papers on computational methods. By integrating the findings of the literature review on traditional and emerging approaches, this study aims to provide a multi-factor approach to exploring the potential of computational methods in developing urban design projects, with a particular focus on enhancing pedestrian-friendly streets. The synthesis of these two areas of investigation will contribute to a better understanding of the relationship between pedestrian-friendly street design principles and computational methods, paving the way for developing more effective design strategies that promote the safety and accessibility of pedestrians in urban areas.

The primary objective of this study is to employ the computational approach to determine the measurements of street features present in Seattle. Moreover, to develop a computational approach to urban design to assist the City of Seattle in managing urban growth and improving pedestrian infrastructure.

Chapter 2. RESEARCH QUESTIONS

The central aim of this thesis is to explore the application of computational methods in the development of pedestrian-friendly streets in Seattle. The author argues that the design of such streets poses significant complexities; however, computational methods present a viable approach to addressing these intricate issues. By employing computational methods, this study seeks to tackle the challenges of improving pedestrian environments. In pursuit of this overarching objective, the paper formulates the following research question and specific aims.

2.1 Research Questions and Aims of Study

Research Question:

- What is the significance of pedestrian-friendliness in urban areas, and how does it contribute to promoting a sustainable and livable environment?
- How can urban design leverage computational methods to create pedestrian-friendly streets, and what are the implementation strategies for these methods?

Aims of Study:

- To conduct a literature review to identify principles and requirements necessary for designing pedestrian-friendly streets that prioritize the safety and needs of pedestrians and to explore the potential of computational methods in improving street analysis.
- To analyze the streets of Seattle to identify and propose improved suggestions that prioritize pedestrian needs and enhance the overall pedestrian experience.
- To introduce and explore the application of computational methods in urban design, explicitly utilizing Python, to facilitate the development of pedestrian-friendly streets.

- To provide insights and recommendations for future streetscape design in Seattle, prioritizing pedestrian-friendliness based on the findings of this study.

2.2 Audience and Scope:

This paper targets a diverse audience of professionals and academics interested in Urban Design, including urban designers, planners, policymakers, researchers, and students. This study's primary focus revolves around utilizing computational methods to facilitate the exploration of street features, with a specific emphasis on pedestrian-friendly streets in the context of Seattle. Additionally, this research holds relevance for individuals seeking to gain insights into the integration of Geographic Information Systems (GIS) data and digital mapping techniques within the realm of Urban Design.

This study significantly contributes to the ongoing discourse surrounding urban design practices by employing these quantitative methodologies. It highlights the potential of emerging technologies to serve as valuable tools for informing and enhancing the design of public spaces. By exploring computational methods and their application in the specific context of pedestrian-friendly street design in Seattle, this research provides valuable insights and guidance for professionals and academics striving to promote sustainable and livable urban environments.

2.3 Significance of the Research:

This research aims to address the significance of enhancing the quality of life for pedestrians in the streets by facilitating pedestrian-friendliness through computational methods. The design of urban streets encompasses various intricate steps, and therefore, computational methods offer a promising approach in this regard. These methods leverage computational insights to discern areas that necessitate improvement and enable a more systematic approach to urban design. By employing computational methods, it becomes feasible to analyze pedestrian spaces, considering factors such as accessibility, comfort, and security. Additionally, integrating geospatial data and Python programming facilitates the efficient collection, analysis, and visualization of urban data, thereby providing valuable information to inform the design process.

The City of Seattle has demonstrated a commendable effort in establishing well-structured data libraries websites such as Seattle GeoData (“Seattle GeoData”, n.d.) and Seattle Online Dashboard (City of Seattle, 2023), which exhibit a high level of organization and accessibility for users. These platforms serve as valuable repositories of urban data, offering insights into various aspects of the city's infrastructure and functioning. However, there is potential for further enhancement by incorporating diverse urban design-related data in this research.

The geo-visualizations generated through this study can provide additional value to the existing data library websites of the City of Seattle. By integrating these visual representations, the websites can expand their categories and offer new perspectives on the pedestrian-friendly street design process. Incorporating these geo-visualizations will enable users to access and comprehend information related to pedestrian infrastructure, walkability assessments, and potential design improvements more intuitively and visually appealingly.

This collaborative effort between the research conducted in this study and the City of Seattle's data library websites has the potential to foster a more systematic understanding of pedestrian-friendly streetscape design. By leveraging the computational methods employed in this research, the city can augment its existing data resources and provide valuable insights to urban planners, policymakers, and the general public. Ultimately, this collaboration can contribute to the city's ongoing efforts to create safer, more accessible, and pedestrian-friendly urban environments in Seattle.

2.4 Evaluation Criteria:

The research will be evaluated based on its ability to identify critical metrics related to street infrastructure that affect pedestrian friendliness and integrate Seattle's GIS data using computational methods. It will also be assessed for its effectiveness in testing proposed analysis factors to improve pedestrian friendliness, providing actionable recommendations for future urban design projects in Seattle, and contributing to improving the quality of life for pedestrians in urban environments. The outlined critical factors of the evaluation criteria are as follows:

- Identification of critical metrics: The research should identify and analyze the essential measurements that affect pedestrian friendliness in street infrastructure.
- Successful integration of Seattle's GIS data: The research should effectively use computational methods to integrate Seattle's GIS data and provide a systematic analysis of pedestrian friendliness in the city.
- Effectiveness of proposed analysis factors: The research should propose and test specific analysis factors that enhance pedestrian friendliness.
- Recommendations for future streetscape design projects: The research should provide actionable recommendations for streetscape design projects in Seattle based on the research findings.
- Contribution to the field of urban design: The research should significantly contribute to urban design by improving the quality of life for pedestrians through computational methods.

Chapter 3. BACKGROUNDS OF STUDY

3.1 Definition of Urban Design in the Context of this Study

Integrating computational methods into urban planning and design is a relatively unfamiliar territory due to the multitude of features and complexities inherent in this domain. Urban environments encompass many elements, including transportation, land use, infrastructure, and social dynamics. Consequently, applying the computational methods introduces a novel and unexplored avenue within urban planning and design practices.

The multifaceted nature of urban design necessitates a holistic approach that considers diverse stakeholder interests, environmental considerations, and the functionality of urban spaces. Computational methods offer a promising means to navigate this complexity by capitalizing on calculative insights, computational modeling, and simulation techniques. By employing these methods, urban planners and designers can adopt a systematic and quantitative approach to analyze various aspects of urban spaces, such as pedestrian flow, accessibility, safety, and aesthetic preferences.

Within the broader context of urban design and computational methods, this paper specifically focuses on investigating the quantitative features that are particularly relevant to the architectural aspects of urban design. By delving into the quantitative aspects, the research aims to contribute to a better understanding of how computational methods can be effectively employed to enhance the relationship between architecture and urban design. This research endeavor aims to achieve a deeper comprehension of the interplay between computational methods and urban architecture, enabling more informed decision-making processes and fostering the creation of sustainable, livable, and pedestrian-friendly urban environments.

Urban design is a multidisciplinary field that involves a deep understanding of the environment, people, and space. It encompasses various perspectives, including architecture, planning, landscape architecture, and other related disciplines. The primary objective of urban design is to translate planning objectives for space, settlement patterns, and resource allocation into physical strategies that can guide the work of architects, developers, and other implementers (Krieger, 2008, as cited in Larice M. & MacDonald E., 2012).

The tasks and specializations within urban design are diverse, and some are particularly relevant to architecture, providing quantitative support to guide building design and construction in their intended locations. Although urban designers are not typically involved in architectural design or engineering aspects, they play a critical role in creating a framework for architects and developers that can serve as the foundation and guideline for their projects. Consideration of numerous factors is necessary in urban areas, including restrictions on height or massing. As a pioneering zoning regulation, the 1916 landmark code in New York initially determined these restrictions based on measurable criteria, such as access to sunlight. These criteria can now introduce as commonly held good form-based values. (Krieger, 2008, as cited in Larice M. & MacDonald E., 2012) This highlights the importance of urban design in ensuring that physical structures complement the surrounding environment and meet the needs of their users.

This paper aims to provide quantitative support for Urban Design projects, a field closely related to Architecture and Construction. Through quantitative methods, this paper aims to enhance the effectiveness and efficiency of Urban Design projects by providing accurate data and analysis. Integrating quantitative approaches in Urban Design can provide a systematic and objective evaluation of various design options and outcomes, leading to informed decision-making and improved project outcomes. By emphasizing the importance of quantitative analysis in Urban

Design, this paper aims to advance and refine the field, benefiting all stakeholders involved in Architecture, Construction, and Urban Design.

3.2 Current Seattle's Plans and Initiatives for the Pedestrian-Friendly Streets

Seattle has demonstrated its commitment to developing a transportation system that is safe, equitable, and sustainable through various programs and initiatives. The Seattle 2035 Comprehensive Plan is an example of this commitment, as it acknowledges the significance of prioritizing walking and biking as the most sustainable modes of transportation. The plan emphasizes the importance of walking and biking as fundamental elements of a compact, complete, and connected city (City of Seattle, 2020). Notably, people recognize walking and biking as the most sustainable forms of transportation. In line with Seattle's commitment to sustainable transportation, the Pedestrian Master Plan seeks to improve the pedestrian environment in the city by enhancing walking conditions and safety, promoting connectivity, and ensuring accessibility for people of all ages and abilities. The plan emphasizes the need for Seattle's pedestrian infrastructure to design in a manner that is safe, inviting, comfortable, and accessible to create an environment that is welcoming to all individuals (City of Seattle, 2017).

Seattle's commitment to pedestrian safety is evident in its strategic transportation plan, Move Seattle. This plan prioritizes pedestrian safety by implementing Vision Zero, which aims to eliminate traffic fatalities and serious injuries. Additionally, the plan focuses on creating Safe Routes to School programs and designing Complete Streets that are safe and accessible for all users. Move Seattle also identifies the need to make 27% of the city without sidewalks more walkable by constructing up to 30 new blocks of sidewalks connecting to transit stops and community centers (Seattle Department of Transportation, 2015, p. 11). Furthermore, the plan aims to pilot new pedestrian-only streets in areas with high pedestrian and low vehicle demand (Seattle Department of Transportation, 2015, p. 19). In order to achieve these goals, the city is seeking new funding tools and partnerships to increase sidewalk construction.

It is crucial to recognize that the document "City Life at Street Level" emphasizes the importance of creating welcoming environments in public areas, particularly in urban settings. The study underscores the need to prioritize pedestrian safety, accessibility, and convenience in designing streets and public spaces. This approach aims to create an environment that promotes physical activity and enhances community livability. The study also highlights the relationship between buildings and public space, particularly regarding the influence on active people who use them for movement. By examining several buildings in Seattle, the case study identifies good practices that promote public life, such as Ground Level Setback and Height, Size of Commercial Spaces within the Building, Building Transparency, and Average Door Spacing. These metrics create a pedestrian-friendly environment that encourages public life and enhances community livability. (Seattle Department of Transportation, 2019)

Seattle has implemented various programs and plans to prioritize pedestrian safety and accessibility in the city's transportation system. The Seattle Right-of-way Improvements Manual (City of Seattle, 2017) provides detailed design standards and guidance for sidewalks, emphasizing pedestrian needs and accessibility. The manual ensures that sidewalks are safe, convenient, and accessible. The Seattle Department of Transportation (SDOT) aims to provide an interconnected pedestrian network that includes sidewalks, curb ramps, stairways, and convenient street crossing opportunities, facilitating walking as a safe, attractive, and viable travel mode. SDOT carefully reviews streetscape design elements to ensure that the materials, dimensions, and design elements meet local, state, and national safety and accessibility requirements.

In addition, the New Mobility Playbook highlights how the prioritization of cars in city planning has led to narrower sidewalks and hostile road environments for non-car travelers. The playbook acknowledges that new transportation technologies can shape a more livable, vibrant, and equitable city. However, it also emphasizes the importance of managing these services to ensure that they work for all residents of Seattle. The Seattle Department of Transportation prioritizes an accessible, reliable transportation system that provides residents with the options they need when they need them, including walking, biking, and public transportation. Furthermore, the playbook recognizes the importance of planning for demographic changes and technological advancements while maintaining excellent service quality today (Seattle Department of Transportation, 2017).

Seattle has demonstrated its commitment to developing a safe, equitable, and sustainable transportation system that prioritizes walking and biking as the most sustainable modes of transportation. This commitment is evident in various programs and initiatives, including the Seattle 2035 Comprehensive Plan, the Pedestrian Master Plan, and Move Seattle. Seattle also emphasizes the importance of creating welcoming environments in public areas, particularly in urban settings, through the City Life at Street Level study. The Seattle Right-of-way Improvements Manual provides design standards and guidance for sidewalks, emphasizing pedestrian needs and accessibility. Finally, the New Mobility Playbook acknowledges the significance of managing new technologies to ensure they work for all residents of Seattle while planning for demographic changes and technological advancements. Overall, Seattle's efforts to prioritize pedestrian-friendliness with safety and accessibility contribute to creating a more livable, vibrant, and equitable city for all.

In order to gain a deeper understanding of the significance of pedestrian-friendly environments, it is essential to consider the insights of experts in the field. Their perspectives offer valuable insights into the benefits of prioritizing pedestrian activity and safety in urban transportation systems and the challenges and opportunities involved in implementing such initiatives. By incorporating the viewpoints of experts, this research can provide an understanding of the importance of pedestrian-friendly environments in creating sustainable, safe, and equitable transportation systems. The recognition of walking as the most sustainable form of transportation is a critical factor in why the author focuses on improving pedestrian-friendliness in Seattle.

Chapter 4. LITERATURE REVIEW

Although the commitment of Seattle to prioritize pedestrian-friendly environments is clear through proactive measures aimed at enhancing pedestrian infrastructure, understanding the significance of pedestrian-friendliness in urban planning and design is essential, which necessitates a thorough exploration of insights provided by renowned experts in the field of urban design, as well as an examination of the fundamental reasons that underpin the indispensability of creating pedestrian-friendly environments.

By immersing ourselves in the perspectives of esteemed urban design professionals, this literature review endeavors to illuminate the criticality of pedestrian-friendliness in urban streets. Through a meticulous analysis of their viewpoints, valuable insights can glean regarding the underlying principles and rationales driving pedestrian-friendly urban environments' prioritization. Furthermore, synthesizing these perspectives will contribute to cultivating a robust understanding of the manifold benefits associated with pedestrian-oriented urban design.

Moreover, given the relatively unfamiliar terrain of computational methods in urban design, this review also presents compelling case studies demonstrating the potential of computational methods within urban design. These case studies serve as empirical evidence, shedding light on computational methods' practical applications and advantages. By showcasing these real-world examples, the review aims to foster greater familiarity and appreciation for computational methods in urban design, broadening the horizons of researchers, practitioners, and stakeholders alike.

Through this various exploration of expert perspectives and case studies, this literature review strives to consolidate existing knowledge, elucidate the importance of pedestrian-friendliness, and showcase the untapped potentials of computational methods in urban design. By enhancing our understanding in these areas, this review contributes to the ongoing discourse. It inspires further research, ultimately creating more livable, sustainable, and pedestrian-friendly urban environments.

4.1 Streets for People

In many cities in the United States, automobile-oriented design has taken precedence, with Seattle being no exception. This approach prioritizes the use of cars and often needs to pay more attention to the needs and well-being of pedestrians and cyclists. However, urban theorist and activist Jane Jacobs presented a contrasting vision for urban design in her book "Death and Life of Great American Cities." Jacobs proposed the creation of livable, interconnected neighborhoods that prioritize the safety and health of residents while placing a strong emphasis on pedestrian-friendly environments. Her ideas aimed to improve the quality of life for people in urban areas by prioritizing pedestrian-friendly environments to create vibrant and prosperous cities. Jacobs argued that designing cities with pedestrians in mind can promote safety, foster social interaction, and create a sense of community ownership over the urban environment.

One of the ways to achieve pedestrian-friendly environments is to create small blocks with frequent opportunities to turn corners, encouraging people to walk and engage with their surroundings. Jacobs emphasized the importance of mixing buildings that vary in age and condition, creating an economically diverse environment that can support many residents and businesses, fostering social interaction, and creating a sense of community ownership over the urban environment. Jacobs' ideas highlight the need for urban planners and designers to prioritize the needs and experiences of people in creating livable and enjoyable urban environments. By creating pedestrian-friendly environments that prioritize safety and social interaction, cities can become more vibrant, economically sustainable, and socially connected (Jacobs, 1961).

Additionally, Jacobs argued that sidewalks are essential to creating vibrant and active neighborhoods. She stated, "Lowly, unpurposeful, and random as they appear, sidewalk contacts are the small change from which a city's wealth of public life may grow" (Jacobs, 1961, p. 72). Jacobs emphasized the diverse range of activities on sidewalks, noting that they serve not only as a space for pedestrian movement but also as a venue for social interactions and community building. She criticized urban planning policies prioritizing vehicular traffic over pedestrian activity, which often results in barren and uninviting streetscapes.

Jacobs's ideas have gained significant attention and affected many urban planners and designers worldwide. Her emphasis on pedestrian-friendly environments and the importance of sidewalks has influenced urban design and transportation policies in many cities. As Seattle continues prioritizing pedestrian safety and activity in its transportation system, Jacobs' ideas provide a valuable framework for creating livable, enjoyable, and socially connected urban environments.

Moreover, creating pedestrian-friendly environments in urban areas is an essential aspect of urban planning and design. According to Jan Gehl's "Life Between Buildings," designing cities prioritizing safety, social interaction, and community ownership of the urban environment is critical (Gehl, 2010). Pedestrian-friendly environments foster social interaction and community cohesion by creating a space for diverse residents to meet and interact. Designing public spaces with a human scale in mind creates a more welcoming and comfortable environment for pedestrians. Gehl stresses the importance of walkability in creating thriving cities where public spaces facilitate walking, sitting, and socializing (Gehl, 2010). By prioritizing the needs and experiences of pedestrians, urban planners and designers can create livable and enjoyable urban environments. This approach promotes safety, fosters social interaction, and creates a sense of

community ownership over the urban environment. Ultimately, pedestrian-friendly environments are essential in making cities more vibrant, economically sustainable, and socially connected.
In "Cities for People," Gehl emphasizes prioritizing safety, social interaction, and community ownership in urban planning and design.

According to Gehl, designing public spaces with a human scale in mind can create a more welcoming and comfortable environment for pedestrians, which fosters social interaction and community cohesion, allowing diverse residents to meet and interact. By prioritizing the needs and experiences of pedestrians, pedestrian-friendly environments can promote safety, foster social interaction, and create a sense of community ownership over the urban environment. Gehl notes that inviting more people to walk, bike, and stay in city space can strengthen the potential for a lively city (Gehl, 2010, p. 6). Thus, prioritizing pedestrian activity can create livable and enjoyable urban environments vital to making cities more vibrant, economically sustainable, and socially connected.

4.2 Measurements of the Streets

As this thesis will use quantitative data and computational tools, it is crucial to identify the specific metrics that can demonstrate good pedestrian-friendly streets. In "Great Streets" by Allan B. Jacobs, he emphasizes the importance of street elements that contribute to creating great walking streets. Specifically, Jacobs highlights the significance of defining elements at the ends of a street, which may be vertical and horizontal. According to Jacobs, these defining elements are typically buildings, walls, trees, or a combination of these elements, all of which contribute to the visual and physical definition of the space. Additionally, Jacobs notes that the floor plays a critical role in creating a great walking street, as it can guide movement and enhance the pedestrian experience.

(Jacobs, 1993) By prioritizing the design of street elements that enhance the pedestrian experience, urban planners and designers can create a more enjoyable, accessible, and safe environment for pedestrians.

Allan B. Jacobs identifies the various elements that make a street great for walking and discusses the measurements of these elements that shape the streets. He notes that "All of the great streets have definition. In sections, their vertical-to-horizontal ratios range from 1.0: 4.0 in the case of Monument Avenue, a residential street, to 1.0: 0.40 in the case of the Via dei Giubbonari. Most of the great streets seem to fall within a range (vertical to horizontal) of from 1.0: 1.1 to 1.0: 2.5. For the widest streets where width is significantly greater than height, such as long the Champs-Elysees or the Paseo de Garcia, it is the intervening trees as much as or more than buildings that strengthen or provide definition." (Jacobs, 1993, p.279). He also notes other essential measurement details of street elements, such as the spacing of trees, the placement of street furniture, and the quality of lighting. By considering and implementing these measurement details, cities can create more pedestrian-friendly environments that promote walking, social interaction, and a sense of community ownership over urban spaces.

Urban design experts have long stressed streets' significant role in creating livable and safe environments. For example, Jane Jacobs and Jan Gehl have emphasized the importance of social interaction in street design, highlighting the need for careful consideration of the elements and dimensions of streets to ensure the safety and security of people. A vital aspect of this is the design of walking environments, including sidewalks, crosswalks, and other street features essential for creating appropriate pedestrian streets. Moreover, Allan B. Jacobs expressed his ideas on measuring street design by reviewing streets considered great. Incorporating the valuable insights of urban design experts, it is evident that the design of streets plays a critical role in influencing pedestrians' willingness to walk and engage with their environment. Therefore, accurately measuring and analyzing the different components of street design is crucial for improving the overall quality of the street. In this way, detailed measurements of each street element, such as the ratio of vertical to horizontal elements, the density of trees, street furniture, lighting, and more, are essential for understanding how these elements interact to create a pedestrian-friendly environment. Quantitative metrics and computational tools can assist in measuring these elements, providing valuable insights into what aspects of the street design can be improved to enhance pedestrian experiences and promote more walkable cities.

Urban planning is a complex process encompassing multiple facets of urban elements, and it greatly benefits from utilizing computational tools and data analysis. In this regard, Seattle has made significant strides by developing a systematic dataset that can effectively link urban design with computational methods. By integrating such data, designers can gain deeper insights into the needs and preferences of their communities, allowing them to create streets that are practical, safe, visually appealing, and conducive to social interaction.

Computational approaches to urban design help designers better understand the needs and behaviors of the community, resulting in tailored designs to specific needs. For example, using data on pedestrian's built environments, designers can determine the proper width of sidewalks, the placement of crosswalks, and the types of street furniture and amenities needed to create safe and comfortable walking environments. Integrating data into the pedestrians' built environment attributes can yield valuable insights and analysis to inform future work. By incorporating computational tools and data analysis into the urban design and planning process, designers can create functional and aesthetically pleasing streets while promoting safety and social interaction.

4.3 Case Studies of Computational Methods in Urban Design

While there have been many successful case studies on using computational tools for urban planning, there needs to be more research on applying these tools for physically reshaping and designing urban areas. More examples of successful implementation must be provided in a remarkably complex and challenging area. This section will highlight some case studies that demonstrate the use of computational methods in urban design, an area that may be unfamiliar to some readers.

Figure 1 Enabling Customizable Urban Design on Informal Area Site. (Miao et al., 2018)

In the case study "Computational urban design prototyping: Interactive planning synthesis methods—a case study in Cape Town" (Miao et al., 2018), computational methods were employed to address specific urban design and planning challenges. The paper highlights using computational tools such as GIS data, 3D modeling software, and parametric design tools in a public space project in Cape Town, South Africa.

One of the primary challenges addressed by the computational methods was the ability to generate and explore multiple spatial configurations based on predefined parameters and requirements. Traditionally, urban planners would manually create and revise design options, which could be time-consuming and limit the exploration of alternatives. By utilizing generative methods and the Customizable Urban Design Platform (CUDP), planners could automatically generate urban layouts based on specific parameters, allowing for interactive revisions, significantly increasing the planning process's efficiency, and expanding the design possibilities. Another challenge the computational methods aimed to address was considering residents' needs and preferences in a housing cluster design. The CUDP incorporated preference-based clustering methods, enabling urban designers to consider the requirements and desires of the community members. This approach facilitated a more participatory design process, ensuring that the resulting urban spaces would align with the resident's needs and enhance their overall satisfaction.

Additionally, the ability to visualize the generated results and make them accessible online played a crucial role in addressing stakeholder engagement and decision-making challenges. By providing stakeholders with visual representations of the proposed designs, the computational tools allowed for early-stage discussions and feedback, enabling more informed decision-making processes, which helped foster collaboration among various stakeholders, including urban planners, community members, and government officials, leading to more inclusive and transparent urban design outcomes. While the case study acknowledges some limitations, such as the need for further customization for specific design requirements and constraints, it showcases the potential of computational methods in overcoming challenges in urban planning. By leveraging GIS data, 3D modeling, and parametric design tools, the study demonstrates how computational approaches can improve planning efficiency, design quality, and stakeholder engagement in urban design projects.

Kohn Pedersen Fox (KPF), an architecture firm, also implemented computational methods in a successful case study in Toronto and documented its distinctive methodology as "How to

Generate a Thousand Master Plans: A Framework for Computational Urban Design" (Wilson et al., 2019) presents the CUrbD methodology as a way to provide an iterative and quantitative approach to master planning. One of the main challenges that computational methods aimed to address in this case study was the complexity of navigating numerous and seemingly contradictory constraints and stakeholder interests in the master planning process. Traditional master planning approaches often rely on manual methods, which can be time-consuming and limit the exploration of design possibilities. An ample design space of iterations could be generated and tested using the CUrbD methodology, which involves the procedural generation and parameterization of urban design variables. This approach allowed for the exploration of many design options, considering various constraints and stakeholder interests.

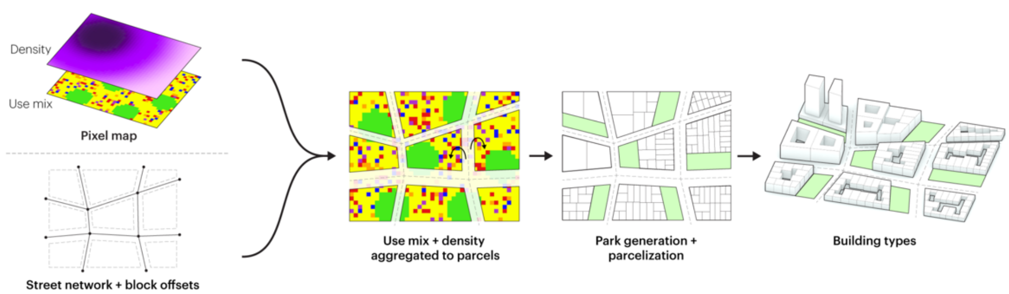

Figure 2 Inputs and procedural generation. (Wilson et al., 2019)

Another challenge that computational methods addressed was the need for an iterative and quantitative approach to urban design. With population growth and transportation demands, master planning requires the ability to analyze and evaluate multiple design scenarios in a systematic and data-driven manner. The CUrbD methodology provided a framework for generating a diverse range of master plans by varying inputs and generating a design space of 1,152 iterations. This iterative and quantitative approach enabled designers to assess the performance of different design configurations based on predefined metrics and objectives. The visualization capabilities of computational tools, such as Rhinoceros and Grasshopper, and the application of Python scripts for handling complex geometry and file management, also addressed the challenge of effectively communicating the resulting designs. Visualizations allowed stakeholders to understand better and evaluate the proposed master plans, facilitating discussions and decision-making processes. While the case study acknowledges that the place of computational urban design within the master planning process remains a question, it emphasizes the importance of incorporating iterative and quantitative approaches to address cities' increasing challenges. By leveraging computational methods, master planning projects can navigate complex constraints, balance stakeholder interests, and generate a wide range of design possibilities that can contribute to more informed and sustainable urban development over the long term.

The case study titled "Integrated Parametric Urban Design in Grasshopper/Rhinoceros 3D Demonstrated on a Master Plan in Vienna" (Fink and Koenig, 2019) demonstrates the practical application of integrated parametric urban design using Grasshopper and Rhinoceros 3D. The study focuses on a master plan developed for Vienna, highlighting the challenges that computational methods aimed to address in urban design. One of the key challenges addressed in this case study was the need for human-centered development that integrates future technologies with traditional approaches to create sustainable and livable environments while saving time and resources. When applied within an integrated parametric urban design framework, computational methods provide a means to capture and analyze complex urban layers efficiently, allowing designers to generate informed solutions that align with sustainability goals. The study emphasizes the importance of urban modeling and simulation tools in capturing the multifaceted aspects of a city. By utilizing the integrated parametric urban design process within Rhinoceros 3D and Grasshopper, designers could divide the urban design process into six steps, creating a structured workflow. These steps could be repeated in the form of feedback loops, enabling iterative refinement of the design solutions. The choice of software, Rhinoceros 3D and Grasshopper, as the immediate environment, along with using QGIS and Mapbox for data processing, addressed the challenge of handling and analyzing complex urban data. These digital tools provided the means to capture and represent the city's intricate layers, allowing designers to make informed decisions based on spatial analysis and simulation results.

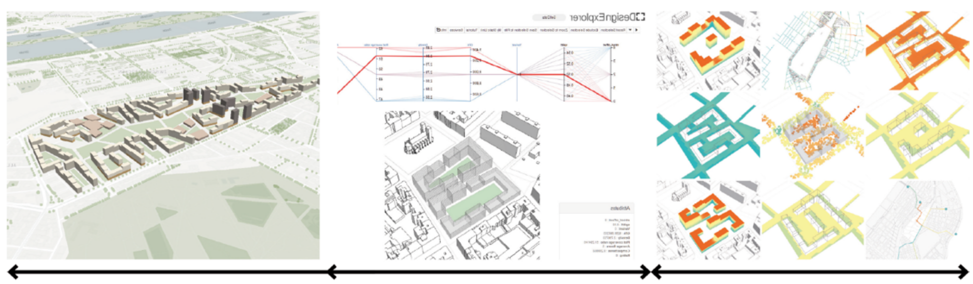

Figure 3 Methodology steps: Visual Integration. (Fink and Koenig, 2019)

Furthermore, integrating computational methods with the expertise of urban design professionals and executive planners facilitated the restoration of compromised ecosystems, supported informative decision-making, and enabled effective information exchange between stakeholders. By utilizing computational tools, designers could design the built environment and public realm with a focus on enhancing sustainability and quality of life.

The case study emphasizes that while computational methods have the potential to address these challenges, they should be employed in conjunction with human expertise and stakeholder input. Integrating technology and human-centered approaches is essential to ensure that computational methods effectively address the complexity of urban planning and design challenges. As technology advances and urban environments become increasingly complex, computational methods will play a crucial role in shaping the future of urban planning and design. They provide a means to generate and evaluate many design iterations, facilitate informed decision-making, and enable more sustainable and efficient urban development processes.

4.4 Review Conclusion

In conclusion, this literature review offers the significant role of pedestrian-friendliness in urban planning and design, drawing upon insights from renowned experts in the field. By exploring the works of influential figures such as Jane Jacobs and Jan Gehl, we have gained a profound understanding of the underlying principles and justifications that advocate for the prioritization of pedestrians in urban environments. Additionally, Allan B. Jacobs' research on recommended street proportions and measurements for pedestrians has provided subjective yet valuable insights from observing numerous exemplary streets worldwide. The collective works of these experts emphasize the crucial importance of designing cities that prioritize the safety and well-being of pedestrians, foster social interaction, and cultivate a sense of community ownership over public spaces. By placing pedestrians at the forefront of urban design considerations, cities can create vibrant, inclusive, and sustainable environments that enhance the quality of life for all residents.

Furthermore, this review has highlighted the potential of computational methodologies in urban planning and design. By examining relevant case studies, we have witnessed how computational methods, such as parametric design tools and data analysis, can significantly enhance the efficiency and quality of the design process. These advanced methodologies allow designers to generate and assess multiple design iterations, consider diverse parameters and requirements, and visualize potential outcomes. As a result, they enable more informed decision-making and the creation of improved urban environments. The integration of computational techniques offers promising avenues for designers to augment their tasks in urban design, providing valuable support and expanding the possibilities for innovative and practical design solutions.

By synthesizing expert perspectives and presenting practical examples, this literature review has contributed to a general understanding of the multifaceted benefits of pedestrian-oriented urban design and the untapped potential of computational methods in urban design. Moreover, it endeavors to stimulate further scholarly research and constructive dialogue within urban design, aiming to shape cities that embrace the needs and experiences of pedestrians, promote meaningful social interactions, and cultivate thriving and inclusive urban communities. By merging the expertise of urban design professionals with computational methods capabilities, we can catalyze the development of cities that prioritize pedestrian well-being and forge a path toward sustainable urban development.

Chapter 5. THESIS DESIGN

This chapter outlines the methodology employed in this paper, highlighting the key elements essential to creating pedestrian-friendly environments. These elements have been identified and emphasized in the literature review as crucial factors contributing to urban streets' sociability, safety, and overall friendliness. By incorporating these elements into the analysis, it becomes possible to assess the pedestrian-friendliness of specific areas within Seattle and identify opportunities for enhancing accessibility and security for pedestrians. The selected elements are based on quantitative measures, enabling a systematic evaluation of the pedestrian infrastructure. They serve as benchmarks for assessing the effectiveness of computational methods in urban design interventions and their effect on the pedestrian experience. The elements identified in this study include Building Height, Street Width, Sidewalk Width, and the availability of Trees, Furnishings, Crosswalks, and Street Lights.

5.1 Seven Significant Attributes

5.1.1 Building Heights

Building height is an essential element of urban environments, as it determines the vertical dimension of structures in a city. In densely populated areas like New York City, high-rise buildings are ordinary due to the need for increased space on narrow plots of land with solid foundations. Meanwhile, in cities like Copenhagen, Denmark, mid-rise buildings are prevalent, allowing for more comfortable views of the sky and surroundings, positively affecting the pedestrian experience. While buildings may seem like ordinary elements of typical city streets, their height can significantly affect the pedestrian environment. Therefore, building height is one of the key metrics in assessing the pedestrian-friendliness of urban areas, particularly in areas with a high concentration of buildings. By considering building height as a factor, we can analyze the influence of skyscrapers versus mid-rise buildings on the pedestrian experience and develop strategies to enhance the walkability and safety of urban environments.

5.1.2 Sidewalk Width

Sidewalk width is another crucial element to consider when evaluating urban pedestrian-friendliness. The width of sidewalks can significantly affect the ability of pedestrians to move comfortably and safely through the city. Narrow sidewalks can lead to overcrowding, making it difficult for pedestrians to pass each other or walk comfortably; that can be particularly problematic for individuals with mobility impairments or those using strollers or other wheeled devices. In contrast, wider sidewalks can provide more space for pedestrians to move freely and comfortably, contributing to a more enjoyable and safer walking experience. Additionally, wider sidewalks can accommodate amenities such as street furniture and trees, enhancing the pedestrian experience and providing a more attractive and welcoming environment. Therefore, when assessing the pedestrian-friendliness of urban areas, it is crucial to consider the width of sidewalks and their effect on pedestrian comfort and safety. By analyzing sidewalk width and its associated pedestrian experience, we can develop strategies to improve the walkability and safety of urban environments.

5.1.3 Street Width

Street width is another essential element in assessing the pedestrian-friendliness of urban environments. It refers to the width of the roadway available for pedestrians and is an important factor in determining the safety of the pedestrian experience. A lack of adequate street width can create an unsafe pedestrian environment in narrow streets with heavy traffic. On the other hand, wider streets can offer more space for pedestrians to navigate, increasing their safety and comfort. However, extensive streets can also negatively affect pedestrian safety, as they can lead to higher vehicle speeds and longer crossing distances for pedestrians. Therefore, street width must be carefully considered in urban design to ensure pedestrians' safety and comfort. We can develop strategies to enhance the balance between pedestrian safety and vehicular traffic flow by assessing the street width in different neighborhoods.

5.1.4 Crosswalks

Crosswalks play a vital role in evaluating the pedestrian-friendliness of urban areas. They serve as designated areas where pedestrians can safely cross streets and interact with vehicular traffic. Typically marked with painted lines or visual cues like crosswalk signals, they communicate to drivers the need to yield to pedestrians. When assessing urban pedestrian-friendliness, it is crucial to consider various aspects of crosswalks, including their availability, design, placement, and appropriate signage and signals. Crosswalks must ensure safety and accessibility for all individuals, including those with mobility impairments or disabilities. Strategic placement of crosswalks, such as at critical intersections or high pedestrian activity areas, helps facilitate pedestrian movement and minimize pedestrian-vehicle conflicts. By analyzing crosswalk availability and quality in urban environments, we can develop strategies to enhance public spaces' walkability and overall safety. These strategies involve introducing new crosswalks, improving existing ones, and placing them strategically to optimize pedestrian safety and movement.

5.1.5 Furnishings

Furnishing is an essential element to consider when evaluating the pedestrian-friendliness of urban areas. Excellent and well-designed furnishing can provide a range of benefits for pedestrians, including rest, social interaction, and observation. Furnishing can also create a sense of place and community as people gather and engage with each other in public spaces. When assessing the pedestrian-friendliness of urban areas, it is important to consider the availability of furnishing. Furnishing should be accessible to many users, including individuals with mobility impairments or other disabilities. In addition, furnishing should be strategically placed to take advantage of pedestrian activity and provide opportunities for social interaction and observation. Furnishing should also be in areas with appropriate levels of sun and shade, depending on the area's climate. By analyzing the availability of furnishing in urban environments, we can develop strategies to improve the walkability and overall quality of public spaces, which include adding new furnishing elements, improving existing furnishing elements, and strategically placing furnishing to enhance pedestrian activity and social interaction.

5.1.6 Street Lights

Light poles are crucial elements to consider when evaluating the pedestrian-friendliness of urban areas, especially during nighttime. They significantly enhance visibility and safety, enabling pedestrians to navigate public spaces more efficiently and reducing the risk of accidents or incidents. When assessing urban pedestrian-friendliness, evaluating the quality and coverage of light poles in public areas, including streets, parks, plazas, and other public spaces, is essential. The design of light poles should ensure even coverage, minimizing shadows or dark areas where criminal activity could occur. To provide optimal visibility for pedestrians, strategic placement of light poles is also essential, particularly at critical intersections, parking lots, and along pedestrian paths. Analyzing the availability and quality of light poles in urban environments allows us to develop strategies for improving the walkability and safety of public spaces for pedestrians, particularly during nighttime. These strategies involve installing new light poles, improving existing lighting infrastructure, and strategically placing light poles to enhance pedestrian visibility and safety.

5.1.7 Street Trees

Street trees are a vital element to consider when evaluating urban pedestrian-friendliness. Trees provide numerous benefits, including shade, visual interest, and improved air quality. In addition, street trees can also help to mitigate the effects of heat islands, which are urban areas that experience significantly higher temperatures than surrounding areas due to the concentration of buildings and pavement. Street trees can also create a more pleasant and welcoming pedestrian environment, as they provide a sense of natural beauty and help soften the built environment's hard edges. In addition, trees can provide a buffer between pedestrians and vehicular traffic, which can help to improve the sense of safety for pedestrians. When assessing the pedestrian-friendliness of urban areas, it is essential to consider the presence and quality of street trees. By analyzing the availability of street trees and their associated benefits, we can develop strategies to improve the walkability and overall quality of urban environments.

5.2 Two Primary Groups

Studying all seven elements of the street can be challenging due to their diversity and distinct features. Therefore, they broke into two groups for further analysis and examination. As Allan B.

Jacobs noted in his book "Great Streets," the proportion of the street's vertical to horizontal dimensions has a crucial effect on the pedestrians' experience. The **first group** comprises Building heights, Street widths, and Sidewalk widths, which are the fundamental elements that establish the entire dimension of the street. The **second group** includes street crosswalks, light poles, trees, and furnishings, which support highlighting the street as a more sociable, comfortable, and safe environment. Each group serves as a framework for assessing and evaluating the pedestrian-friendliness of streets in Seattle by coded geo-visualizations.

5.2.1 Street Proportions (Group I)

As discussed earlier, Allan B. Jacobs emphasized the significance of street proportions, particularly by examining the ratio between building heights and street widths. Through his analysis of exceptional streets worldwide, Jacobs concluded that a range of 1:1.1 to 1:2.5 is typically observed in great streets (Jacobs, 1993). In order to depict these proportions effectively, we will refer to a hand-coded map that illustrates the relationships between Building Heights and Street Widths.

Furthermore, Jacobs highlighted the importance of sidewalk widths as well. Considering the walking experience, the ratio between Building Heights and Sidewalk Widths will also be examined. This approach allows us to explore how the heights of buildings contribute to the overall pedestrian experience, considering the available space on the sidewalks.

Moreover, given that the width of sidewalks is crucial in determining the pedestrian experience, the hand-coded map will also incorporate the proportions of Street and Sidewalk widths. Wider sidewalks provide more walking space for pedestrians and can enhance the overall comfort and safety of the pedestrian environment. In contrast, shorter sidewalks can constrain pedestrian movement and negatively affect their freedom of movement. Therefore, including Sidewalk Width proportions in the coded map will assess the pedestrian-friendliness of Seattle streets.

In summary, the hand-coded map will provide an assessment of the pedestrian-friendliness of streets, incorporating the following proportions:

- A: Proportion of Building Heights and Street Widths
- B: Proportion of Building Heights and Sidewalk Widths
- C: Proportion of Sidewalk Widths and Street Widths

By incorporating these three different proportions, the hand-coded map will evaluate the pedestrian-friendliness of streets more. This approach will provide valuable insights into the physical proportions of each street, allowing us to generate ideas on how to create an environment conducive to pedestrians.

The group proposes calculating the proportions as averages within a grid system to visualize the data. Each grid cell represents the average building height divided by the average street width, expressed as a decimal number. This proportion is essential in influencing pedestrians' perception of their surroundings, encompassing both the constructed and natural elements. Notably, it influences factors such as the sky's visibility and other areas within the city that are observable between buildings. To delve into this proportion more thoroughly, we can examine the following equation in the following manner:

Average of Building Heights / Average of Street Widths = Proportion A

Average of Building Heights / Average of Sidewalk Widths = Proportion B

Average of Sidewalk Widths / Average of Street Widths = Proportion C

By analyzing these equations, we can evaluate the extent to which the relative heights of buildings compared to the width of the streets affect the pedestrian experience. This proportion is a useful quantitative measure to assess the spatial dynamics between buildings and streets and their influence on the pedestrian environment. By examining the relationships between these elements, we can gain insights into the design and planning of pedestrian-friendly streetscapes that prioritize safety, accessibility, and comfort.

5.2.2 Street Components (Group II)

Acknowledging that the ratio of buildings to streets is not the sole determining factor in creating pedestrian-friendly streets is essential. Other essential elements, such as crosswalks, light poles, furnishings, and trees, also play a significant role in establishing an inviting pedestrian environment. In order to evaluate pedestrian-friendliness in Seattle, a coded map can assess the presence of these elements across different areas of the city. In addition to analyzing the building height-to-street width ratios, the hand-coded map will consider the existence of crosswalks, light poles, furnishings, and trees in a single geo-visualization. This visualization will allow users to toggle the visibility of different elements, including crosswalks, light poles, furnishings, and trees. This inclusive information will provide a more holistic assessment of the pedestrian-friendliness of the city's streets and enable a better understanding of areas that are more accommodating to pedestrians in terms of these factors.

5.3 Computational Tools and Data

5.3.1 Python and Geospatial Data

The application of computational methods in urban design is becoming increasingly popular, and Seattle is an ideal location to explore the potential of this approach due to the availability of high-quality geospatial data accessible through the city's ArcGIS Online website, Seattle GeoData. Understanding the capabilities of this data is crucial for realizing its full potential.

Geospatial data plays a vital role in urban design and planning by providing valuable insights into cities' and towns' physical, social, and economic development. This data enables urban planners to analyze patterns and trends in urban areas, which helps inform decisions about infrastructure development, housing, transportation, and other public services. With the help of geospatial data, accurate and detailed maps of urban areas can be created, which allows planners to identify areas that require infrastructure development, such as roads, bridges, and public transportation systems. Zoning maps can also be developed using geospatial data, which identifies areas for residential, commercial, industrial, and other types of land use.

Apart from the significant role of geospatial data in urban planning, it can also facilitate the creation of pedestrian-friendly urban environments. Utilizing geospatial data, urban designers can prioritize the safety and convenience of pedestrians over cars and other vehicles. Specifically, designers or planners can analyze various components of streets, including quantitative data related to sidewalks, streets, building height and footprint, the number of crosswalks, furnishings, lighting, and trees, enabling designers to identify areas that require improvement to enhance pedestrian accessibility, safety, and comfort. Using geospatial data, urban designers can create computational, evidence-based plans to make urban areas more pedestrian-friendly, contributing to creating sustainable and livable cities.

Incorporating programming languages into their work can significantly benefit urban designers, in addition to utilizing geospatial data. Designers can streamline their workflow by writing code to manipulate geospatial data, efficiently analyze large datasets, and create automated mapping processes. They can extract relevant information and visualize it in innovative ways. Programming languages like Python are beneficial for analyzing and visualizing geospatial data due to their user-friendly nature and extensive library support. Python, known for its versatility, offers a wide range of data manipulation and processing tools that can be effectively used for various purposes. By leveraging these capabilities, designers can extract valuable insights related to pedestrian safety, including sidewalk dimensions, crosswalk locations, and densities. Python's ease of use has made it a popular choice among researchers and professionals in geospatial analysis, and its intuitive syntax and comprehensive documentation facilitate a smooth learning curve, allowing individuals to quickly grasp and apply the language's concepts in their analyses.

The growing popularity of Python as the preferred language for geospatial analysis is underscored by works such as "Geospatial Power Tools" (Mitchell, T., 2019), highlighting its simplicity, ease of use, and extensive data and geospatial analysis libraries. Moreover, "Mastering Geospatial Analysis with Python" (Toms S. et al., 2018) emphasizes Python's utility in developing tailored geospatial workflows to address specific research questions and data types. With tools like Plotly, urban planners can construct interactive visualizations that facilitate a deeper comprehension of pedestrian activity patterns, including identifying areas with high pedestrian density and frequently used walking paths. Integrating Python can potentially augment the design process in urban planning by enabling planners to adopt a more computational and evidence-based approach. Ultimately, Python proves to be an invaluable tool for developing pedestrian-friendly urban environments. Its extensive libraries and tools empower urban planners to analyze and interpret geospatial data related to pedestrian activity and infrastructure, providing valuable insights to help identify areas requiring improvements to create safer and more pedestrian-friendly environments.

In the field of urban design, the integration of programming languages such as Python has gained increasing importance in the analysis and manipulation of geospatial data. Python offers a rich selection of libraries specifically designed for geospatial analysis, making it an ideal language for creating digital maps with diverse applications, including developing pedestrian-friendly environments. Leveraging these libraries, urban designers can analyze data concerning pedestrian infrastructure and traffic patterns, enabling them to pinpoint areas that require improvements to enhance pedestrian-friendliness.

One notable library for geospatial analysis in Python is GeoPandas, which equips urban planners with powerful tools for working with geospatial data. Using GeoPandas, planners can perform spatial queries to identify areas with high pedestrian traffic and visualize this information on maps. These maps serve as a valuable resource for identifying areas needing enhancements, such as developing new sidewalks or crosswalks, thereby increasing pedestrian-friendliness.

Another valuable library for creating interactive visualizations of geospatial data in Python is Plotly. With Plotly, urban designers or planners can generate interactive maps that illustrate the geospatial data. These maps prove instrumental in identifying areas that require improvements and assist planners in making exquisite decisions. By harnessing the capabilities of Python libraries like GeoPandas and Plotly, urban planners can augment their understanding of pedestrian traffic patterns and infrastructure needs, ultimately contributing to creating more pedestrian-friendly environments.

5.3.2 Data Source and Type

As previously mentioned, this paper will use the GIS data available on the "Seattle GeoData" website (https://data-seattlecitygis.opendata.arcgis.com), which provides access to a comprehensive GIS library containing various geospatial data sets pertaining to Seattle. While this website contains data on six street elements, including Crosswalks, Lightings, Furnishings, Sidewalks, Streets, and Trees, the Building Height data will be extracted from a particular website titled "ArcGIS Online" (https://www.arcgis.com/index.html), which universally possesses GIS data. The Building Height data was created by Sean Breyer, who currently serves as a program manager at ESRI, a leading provider of GIS applications.

In this research, the author will focus on extracting specific data related to the widths of sidewalks and streets and the availability of each element from Group II. Additionally, the building heights data will be extracted solely for the Seattle area, separate from the original file that encompasses all data for the state of Washington. In order to accomplish this, the QGIS software ensured the analysis is concentrated on Seattle-specific data. Furthermore, to maintain consistency and establish a definitive location for collaboration, all data will adhere to the coordinate reference system WGS84, with an authority ID of EPSG:4326.

Among the various file types available within Geographic Information Systems, the GeoJSON file format is particularly suited to the purposes of this study, as it provides the necessary metrics for each element that will be used in the code for further analysis. Geojson is a popular format for encoding geographic data structures using JavaScript Object Notation (JSON) and is compatible with a wide range of software tools and programming languages. Using this file type allows for efficient processing and manipulation of the data, enabling more precise and detailed analysis of the pedestrian-friendliness of the streets in Seattle. The GeoJSON file presents each data name and number using a dictionary-style pattern, which includes colons, commas, curly brackets, and quotation marks to organize the data assets, making it easier for both humans and computers to recognize the order and find the data within it.

Despite the extensive exploration of file types used in this research, presenting them within the confines of this paper proves challenging due to the vast amount of data involved. Consequently, to enhance comprehension of each dataset, the following list provides directions to detailed data descriptions for each street element:

- Crosswalks (Seattle GeoData): Appendix A
- Light Poles (Seattle GeoData):
  https://gisdata.seattle.gov/server/rest/services/COS/SCL_Poles_Lines/MapServer/0
- Street Furnishings (Seattle GeoData):
  https://gisdata.seattle.gov/server/rest/services/SDOT/SDOT_Assets/MapServer/17
- Sidewalks (Seattle GeoData): Appendix B
- Streets (Seattle GeoData): Appendix C
- Trees (Seattle GeoData): Appendix D
- Building Heights (ArcGIS Online): https://github.com/Microsoft/USBuildingFootprints

All appendices above in Chapter 11 of this paper contain specific descriptions and attributes for the elements supported by official documentation from the Seattle Geodata website. For elements that do not have official documentation, their descriptions are in the respective web page addresses provided. Each address provided for the dataset descriptions is sourced from the Seattle GeoData website, except for the Building Heights data. As mentioned earlier, the Building Heights data are from the ArcGIS website, and detailed information about this dataset was from the author's GitHub website. This approach ensures that the data sources for each element are appropriately credited and easily accessible for further reference.

5.3.3 Libraries for Python

Python is a versatile programming language that can handle various data structures for various fields, including this research. Its flexibility and efficiency make it an ideal tool for analyzing and processing large amounts of data. As such, Python will be used in this study to extract and manipulate the geospatial data from Seattle GeoData and ArcGIS Online, enabling us to generate a systematic framework for evaluating the pedestrian-friendliness of the streets in Seattle. Python will facilitate the creation of maps and visualizations that will enhance the readability of the results and provide a more intuitive understanding of the findings. Utilizing this powerful programming language can streamline the analysis process and ultimately generate more insightful and accurate results.

Within the Python data structure, the language is constrained in its ability to manipulate data and scripts. As such, it may need help understanding certain data types that possess geometric features, such as GeoJSON data. To overcome this limitation, using an open-source computational framework called Compas can be highly effective. By integrating Compas with Python, the language gains a much deeper understanding of geometric data, enabling more efficient and precise data analysis.

Moreover, to improve the clarity and interpretability of the data analysis, we will use various techniques for data manipulation and visualization in the code. Specifically, we will employ Pandas, a Python library for data manipulation, to convert the geo data into a data frame, a two-dimensional tabular data structure. Subsequently, we will use Plotly, a visualization library, to create a scatter plot, which involves extracting each point's x and y coordinates from the data frame. At the same time, the geo data will determine the color of each point.

5.4 Flow Chart Diagram: Visualizing the Methodological Process

The following figure presents a simple flow chart diagram that helps visualize and understand the overall system of methodologies. This diagram illustrates the sequential progression and interconnection of different components, visually representing the various steps involved in the process.

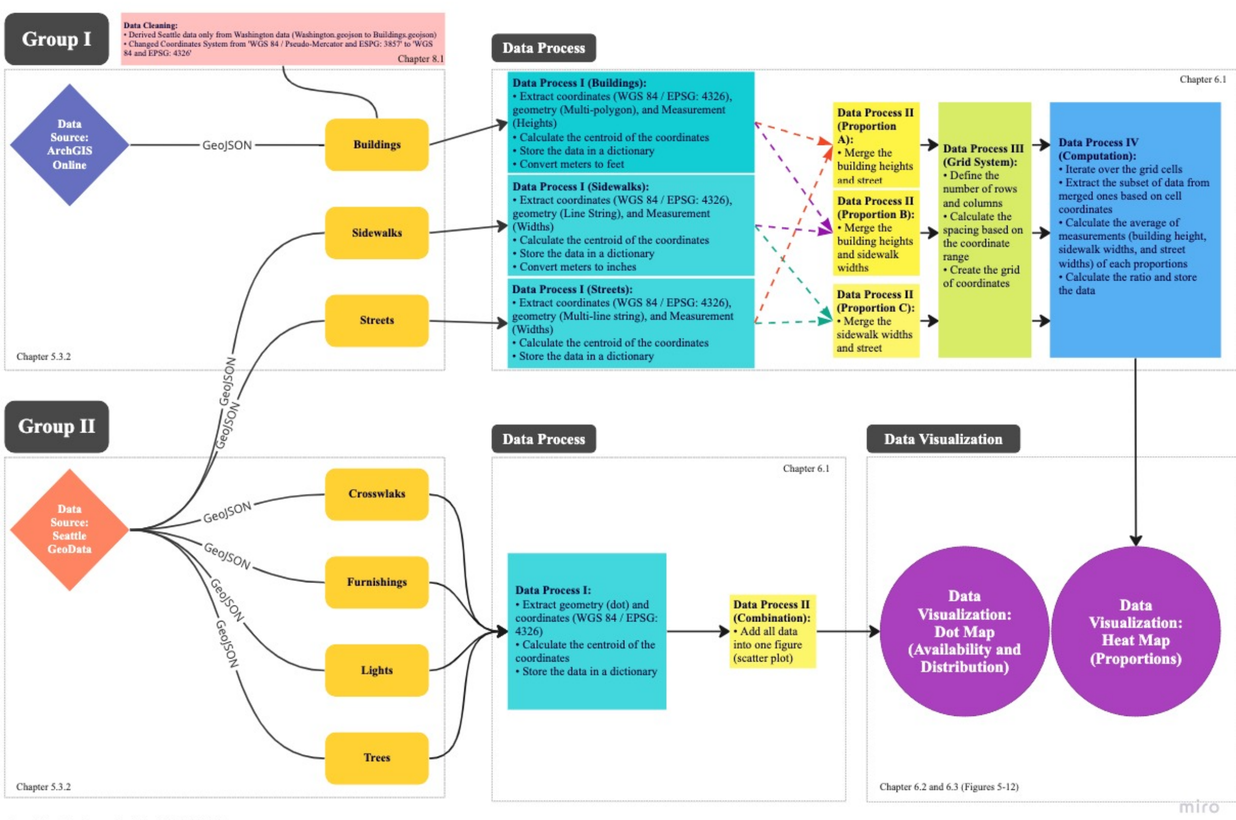

Figure 4 Flow Chart Diagram: Visualizing the Methodological Process (2023)

Chapter 6. FINDINGS

This chapter presents the research results that use computational methods to investigate the measurements between different urban street elements, explicitly focusing on enhancing pedestrian-friendliness. Using coding, the research successfully produced noteworthy findings highlighting the incorporation of coding within the urban design process. Hand-coded scripts facilitated the generation of geo-visualizations, which provided valuable insights into the measurements of street elements. These insights hold great potential for fostering the development of pedestrian-friendly environments.

The upcoming sub-chapters will present the analytic visual outcomes on three key aspects: Ratios of Building Heights to Sidewalk and Street Widths, Sidewalk Widths to Street Widths, and the interactive availability between Crosswalks, Furnishings, Lights, and Trees. These visualizations were generated using geospatial data from various websites, as mentioned in the previous chapter (5.3.2). While the geospatial data may have varying dates, they represent the most up-to-date information accessible through the specified websites.

Additionally, the primary objective of the analysis is to assess the framework's effectiveness in conducting a comparative analysis between different districts within Seattle. Given the numerous districts in Seattle, this study focuses on examining specific urban centers and villages that the city administration has officially recognized. These selected areas serve as representative examples for the analysis and are extensively discussed in the findings chapter to explain the research outcomes. For more visual information, see Appendix E, a map showing the locations of the urban centers and villages.

6.1 Workflow and Script

This section is based on Python script flow as the primary programming language for generating geo-visualizations. Python's versatility and extensive capabilities are a solid basis for the following content. Building upon a thorough understanding and practical implementation of Python, the following section introduces an entire Python script. These scripts offer a robust solution for generating heat map and dot distribution map visualizations, which are powerful analytic tools for highlighting the pivotal relationship between ratios and availability among street elements. These visualizations contribute to urban planning, architectural studies, and urban design research by effectively capturing this relationship.

The overall structure of the two main groups involves importing essential libraries, including Plotly, Pandas, and Compas, which establish the foundation for subsequent data processing and visualization tasks. The first group begins by loading the relevant measurement data, including heights and widths, as well as geometry data written in formats such as "LineString," "MultiPolygon," and "MultiLineString" from corresponding GeoJSON files. The second group loads the available geometry data ``Point" in the study area in a separate script from the corresponding GeoJSON files. Simultaneously, both codes carefully process and merge the datasets based on shared geographical coordinates. This accurate data processing and merging procedure ensures the seamless integration of the datasets, enabling further analysis and visualization.

To establish a coherent spatial representation, the script for the first group employs a systematic grid system, allowing for structured analysis. Grid dimensions denote the number of rows and columns, and the spacing between individual grid cells is calculated precisely. By leveraging these parameters, the script generates a grid by systematically generating coordinate pairs for each cell. Meanwhile, the second group presents a constructed framework representing the available elements as dots with toggle functionality. This framework enables the visualization of these elements, which can be selectively turned on or off. By providing the option to toggle the visibility of elements, the framework offers a dynamic representation of their presence and availability.

The script's first group's core functionality is computing the ratio of building heights to street and sidewalk widths and sidewalk widths to street widths for every grid cell. This computation entails aggregating the relevant data within each cell, subsequently calculating the average of all measurements. The resulting ratio values are meticulously stored, encapsulating the fundamental information required for subsequent heatmap generation.

With the computed data at hand, the scripts effectively use the capabilities of the Plotly library to generate visually engaging visualizations, including heatmap and dot distribution maps. The heatmap adeptly communicates spatial patterns and fluctuations in the ratio values across the entire area through skillful mapping of the calculated ratio values to their corresponding coordinates within the grid. Additionally, meticulous attention is given to defining the layout of the dot distribution map to ensure an accurate spatial representation. The scaling of the x-axis and y-axis is appropriately adjusted to maintain equal proportions, offering an unbiased depiction of the spatial relationships among the urban features. Moreover, including a legend in the visualizations allows for precise identification of each urban feature, enhancing the interpretability of the maps.

Furthermore, the script allows the author ample flexibility to configure the layout and presentation of the heatmap and dot distribution map figure. Crucial elements such as the title, axis labels, and other aesthetic properties can be fine-tuned to match the research requirements. The resulting heatmap and dot distribution map visualization can be seamlessly embedded within this research paper, effectively enhancing the reader's understanding and facilitating insights into the intricate relationship between all street elements within the studied area.

6.2. Group I

The presence of buildings and streets primarily defines urban environments, and the interplay between their physical measurements significantly affects the pedestrian experience. The dimensions of buildings, sidewalks, and streets collectively shape urban spaces' overall atmosphere and functionality. The wider streets and taller buildings can often create a sense of intimidation among pedestrians, leading to potential barriers in their movement and navigation. Such conditions can impede the pedestrian's comfort and sense of safety. In contrast, narrower streets and lower buildings have the potential to establish a more human-scale environment, fostering a pedestrian-friendly atmosphere that encourages more effortless movement and facilitates social interactions.

Additionally, the relationship between building height and sidewalk width also plays a crucial role in determining the pedestrian-friendliness of an area. Adequate sidewalk widths in proportion to building heights allow for comfortable pedestrian circulation, ensuring sufficient space for individuals to walk, interact, and access various amenities alongside the street.

Furthermore, by establishing this precise measurement of 16,743.28 square feet for each cell in the grid pattern, we enable ourselves to make accurate estimations and interpretations while examining the visualizations. This information empowers us to navigate the data with confidence, ensuring a comprehensive understanding of the displayed heat map.

6.2.1 Building Heights to Street Widths

The forthcoming image comprehensively represents the complete range of proportions of building heights to street widths within Seattle. This geo-visualization offers valuable insights into the spatial distribution of the building height-to-street width ratio and its influence on the pedestrian experience. The visualization enables the identification of areas that exhibit a balanced proportion between building heights and street widths, as well as those that may require modifications to enhance pedestrian accessibility and comfort.

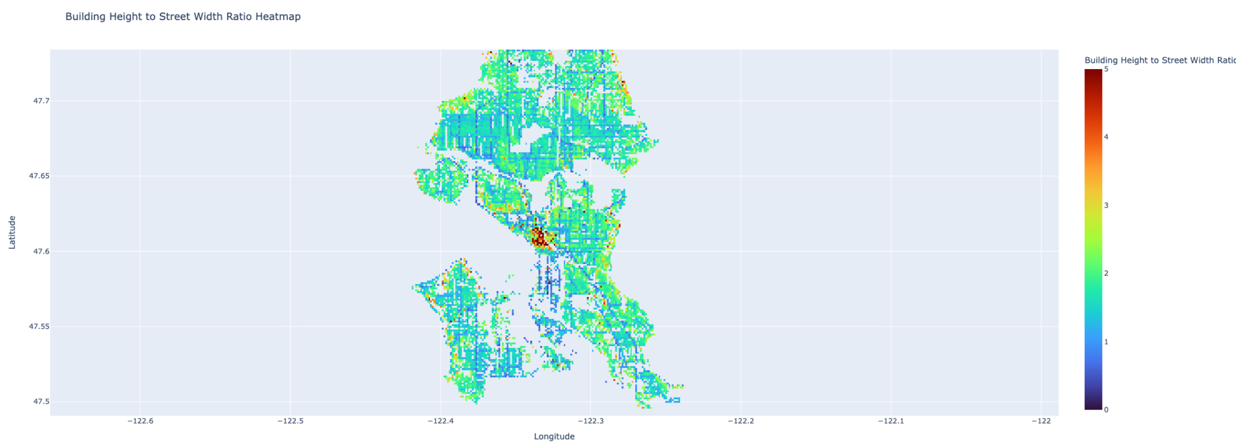

Figure 5 Visualizing Building Height-to-Street Width Ratio through a Coded Map (2023)

The geo-visualization presented above reveals that the proportion of building height to street width in most areas of Seattle falls within the range of 0.00 to 2.00. This finding aligns with Jacobs' proportions of great streets, which typically range from a ratio of 1.00: 1.10 to 1.25. In the context of the specific geo-visualization, this translates to a range of 0.91 to 0.80, as indicated by the scale bar in the visualization's results. This observation suggests that the building height-to-street width ratios in Seattle's areas conform to the principles advocated by Jacobs for creating vibrant and pedestrian-friendly urban streets. Meanwhile, the visualization also reveals that the downtown area stands out with a stand-out color, indicating a significantly higher proportion of the calculated ratio compared to other areas in Seattle, as they are above 10.00. This observation highlights a significant difference only in the downtown area of Seattle, where pedestrian traffic is the highest.

6.2.2 Building Heights to Sidewalk Widths

The following image presents a heatmap depicting the ratio of building heights to sidewalk widths, which is another crucial proportion to examine as it directly relates to the pedestrian's perspective. This ratio offers insights into the relationship between the vertical scale of buildings and the available space for pedestrians along the sidewalks. Visualizing this ratio through the heatmap makes it possible to identify areas where the balance between building heights and sidewalk widths may contribute positively or negatively to the pedestrian experience. This analysis aids in understanding how the urban environment can be enhanced to improve the viewpoint and comfort of pedestrians within the given context.

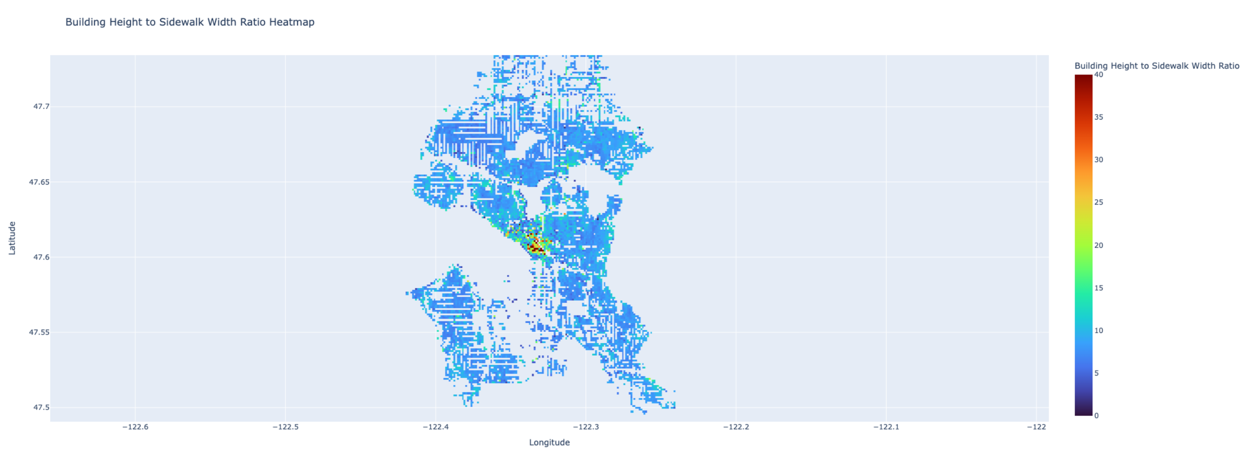

Figure 6 Visualizing Building Height-to-Sidewalk Width Ratio through a Coded Map (2023)

Similarly, to the first geo-visualization, the heatmap depicting the ratio of building heights to sidewalk widths reveals that the downtown area stands out prominently compared to other neighborhoods. The colors in the downtown area indicate higher ratios, suggesting a potential disparity between building heights and available sidewalk widths. However, it is worth noting that this visualization exhibits more empty cells than the first. This observation indicates that many streets within specific neighborhoods, such as Bitter Lake Village, Lake City, Crown Hill, and Aurora Licton Springs, lack sidewalks. This insight highlights areas where pedestrian infrastructure, specifically sidewalks, may need to be improved or present. Understanding these gaps is essential for urban planners and policymakers to prioritize improvements in pedestrian infrastructure and ensure a more pedestrian-friendly environment throughout the city.

6.2.3 Sidewalk Widths and Street Widths

The availability of sidewalks is widely regarded as a crucial factor in promoting pedestrian-friendly streetscapes. However, the surge in automobile use has led to a paradigm shift in street design towards prioritizing vehicular traffic over pedestrian needs, resulting in narrow and insufficient sidewalks. From the perspective of pedestrian preference, a wider sidewalk can be more favorable than a vehicular way as it can minimize conflicts between pedestrian and vehicular traffic and provide a more comfortable walking experience. The presented geo-visualization below displays the ratio of Sidewalk Widths to Street Widths across different areas in Seattle, providing insights into the variation in the sidewalk and street width ratios across the city.

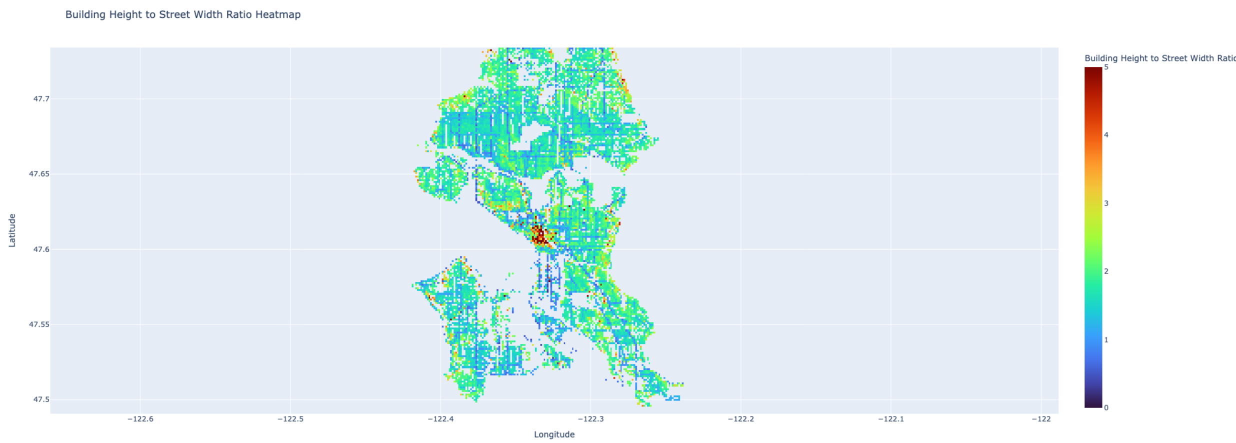

Figure 7 Visualizing Sidewalk Width-to-Street Width Ratio through a Coded Map (2023)

The geo-visualization presented above illustrates a range of calculated ratios that represent the proportion of sidewalk widths to street widths across different areas of Seattle. The visualization suggests that most ratios fall within the range of 0 to 0.4, indicating that sidewalks tend to be narrower than the adjacent streets. Additionally, specific residential neighborhoods such as Ballard, Wallingford, Madrona, and Queen Anne display a slightly broader range of ratios, reaching between 0.4 to 0.5. This finding suggests that sidewalks in these areas are relatively wider compared to other neighborhoods in Seattle. In contrast, areas like Downtown, Uptown, and the University District exhibit narrower sidewalks, indicating a potential constraint on pedestrian space in those locations.

Understanding these variations in sidewalk widths across different neighborhoods provides valuable insights into the pedestrian experience and highlights areas where infrastructure improvements may be necessary. By recognizing the differing characteristics of sidewalk proportions in various neighborhoods, urban planners can tailor interventions and prioritize enhancements to create more inclusive and pedestrian-friendly environments throughout the city. Moreover, this observation underscores the need for greater emphasis on creating pedestrian-friendly streetscapes that prioritize the provision of wider sidewalks to accommodate pedestrian traffic.

6.3 Group II (Availability and Distribution)

The subsequent findings present dot distribution maps showcasing the locations of crosswalks, furnishings, lights, and trees. Due to the large amount of data, only a sample of 1000 data points is visualized to enable a comparative analysis between the different elements. By representing the distribution of these urban features as dots on the map, it becomes possible to observe their spatial patterns and assess their availability across the city. This visual representation allows for quick comparison and identification of the relative density and distribution of crosswalks, furnishings, lights, and trees in different areas. Although the sample size is limited to 1000 data points, these dot distribution maps provide valuable insights into the presence and concentration of these elements, aiding in assessing the pedestrian-friendly characteristics and urban quality within specific neighborhoods or regions of the city.

6.3.1 Crosswalks

Crosswalks are a critical component in creating pedestrian-friendly environments as they enable the safe crossing of streets for pedestrians through various features such as pavement markings, signage, and flashing lights. The presented geo-visualization below offers valuable insights into the distribution and availability of crosswalks in different areas of Seattle. By analyzing the data presented in the visualization, we can better understand the extent to which crosswalks have been implemented in the city and in which areas they are most prevalent.

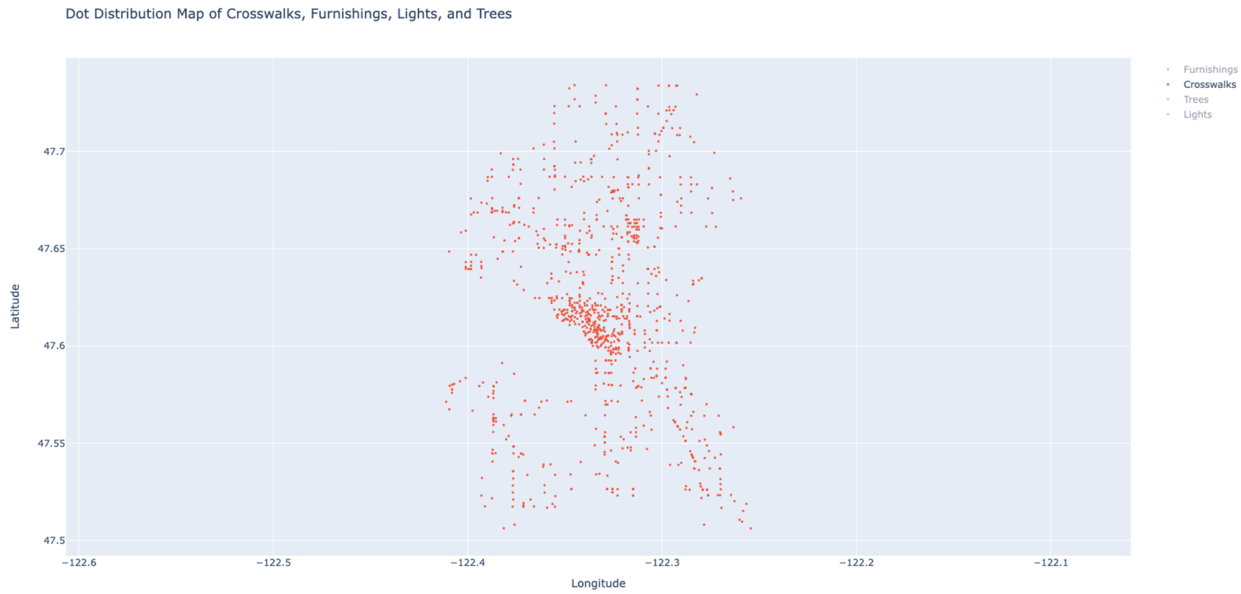

Figure 8 Mapping the Availability and Distribution of Coded Dots for Crosswalks (2023)

As depicted in the geo-visualization above, the downtown area of Seattle and a small part of the University District display a relatively high concentration of crosswalks. Conversely, West Seattle, South Seattle, Lake City, and other peripheral regions appear to exhibit a relatively low density of crosswalks compared to other areas within Seattle. Such findings suggest that there may be a need to enhance the distribution of crosswalks in certain parts of the city to improve pedestrian safety and promote walkability.

6.3.2 Furnishings

Street furnishings, such as benches, tables, rails, and clocks, play a crucial role in enhancing the pedestrian experience by providing a sense of comfort and utility. They can serve as rest areas for pedestrians after a long walk or even as social spaces for people to interact with one another. The presented geo-visualization below provides insights into the availability and distribution of furnishings on the streets of Seattle.

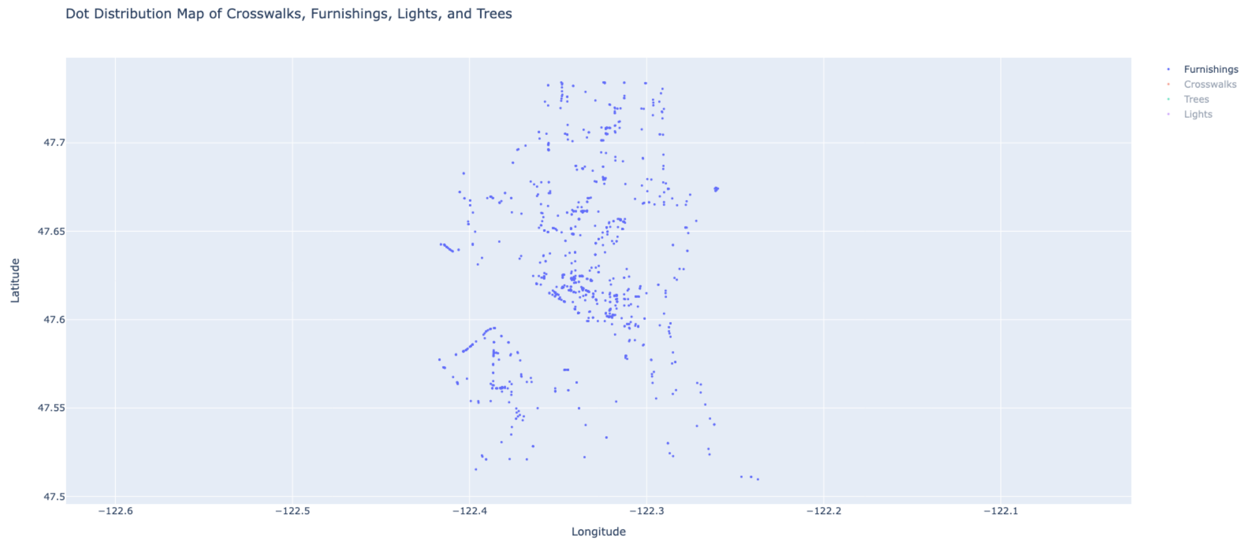

Figure 9 Mapping the Availability and Distribution of Coded Dots for Furnishings (2023)

Based on the presented geo-visualization, it can be observed that furnishings are generally not adequately available throughout the city of Seattle. While the downtown area appears to have the highest concentration of furnishings, the availability in other areas varies. Specifically, the areas spanning from the Central District to Queen Anne exhibit some consistent availability of furnishings, while others exhibit a need for more.

6.3.3 Lights

The provision of light poles is considered critical in promoting safe streets, particularly during the night when pedestrian activity tends to decrease. Light poles enhance visibility and deter crime, creating a sense of pedestrian security. The geo-visualization below depicts the availability and distribution of light poles in Seattle.

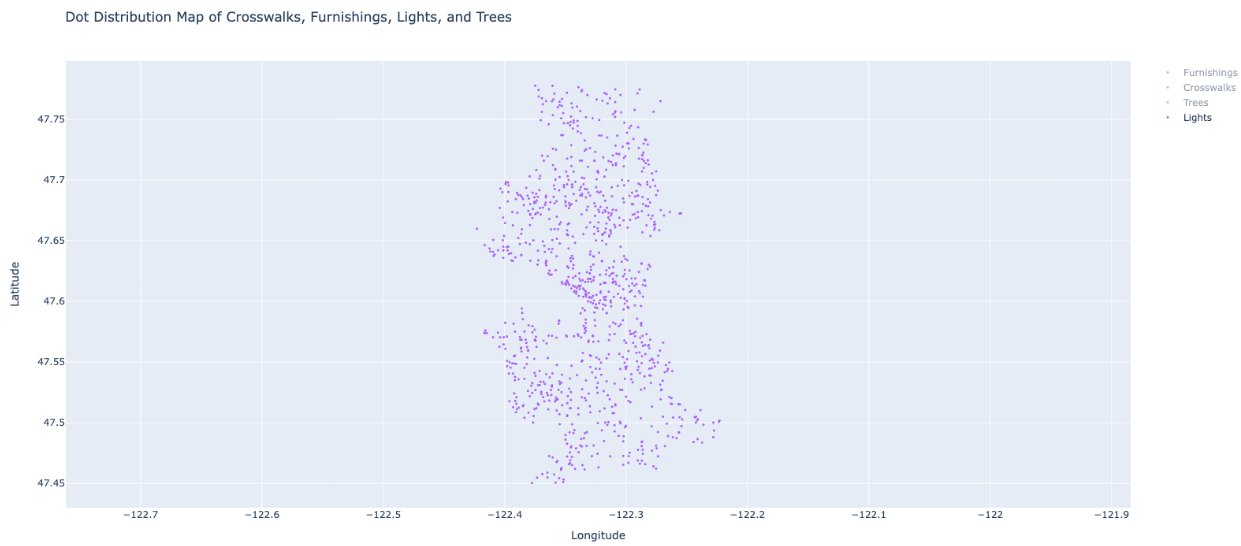

Figure 10 Mapping the Availability and Distribution of Coded Dots for Light Poles (2023)

The presented geo-visualization depicts the distribution of light poles in various areas of Seattle. Light poles are widely distributed throughout the city. However, the downtown area has the highest concentration of light poles. Notably, as one moves toward the city edges or ends of the South and North areas, the availability of light poles decreases.

6.3.4 Trees

Trees are widely recognized as essential in creating comfortable walking environments for pedestrians. Trees provide a sense of freshness and separation between walking and driving paths, enhancing safety. Additionally, trees offer shade during summer, adding to the pedestrians' comfort. The geo-visualization presented below displays the availability and distribution of trees across Seattle.

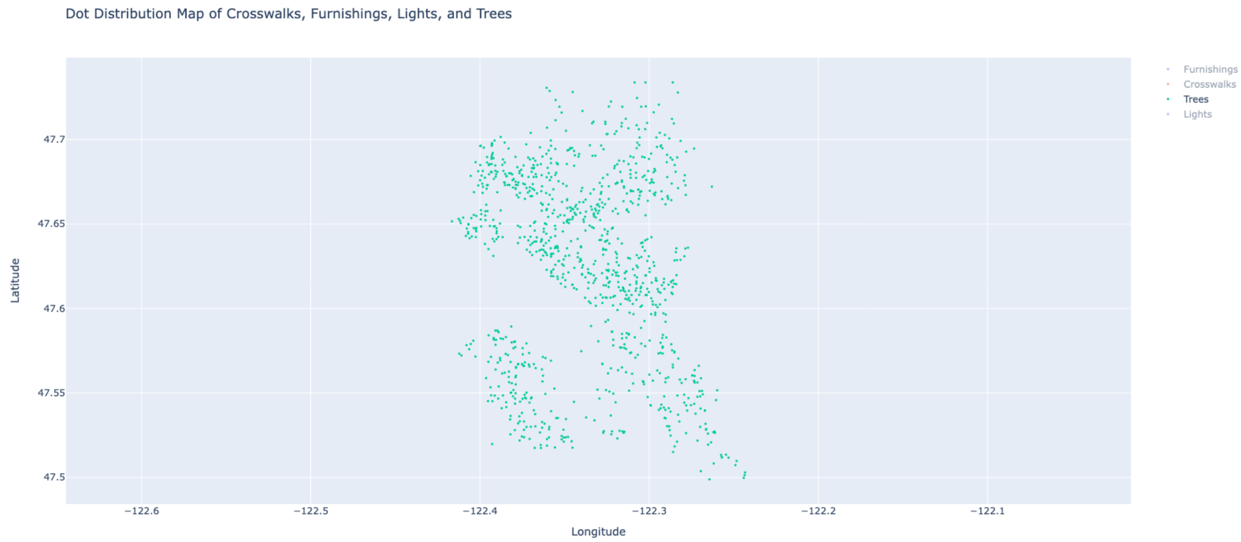

Figure 11. Mapping the Availability and Distribution of Coded Dots for Trees (2023)

The geo-visualization showcases the varying availability and distribution of trees across different areas of Seattle. While the downtown area does exhibit a substantial number of trees, neighborhoods such as Ballard, Fremont, Wallingford, University District, First Hill, Capitol Hill, and Central District have a higher concentration of trees. It is worth noting that these neighborhoods are situated in the city's central region. On the other hand, the tree availability in the southern and northern areas of Seattle shows a significant decrease compared to the neighborhoods.

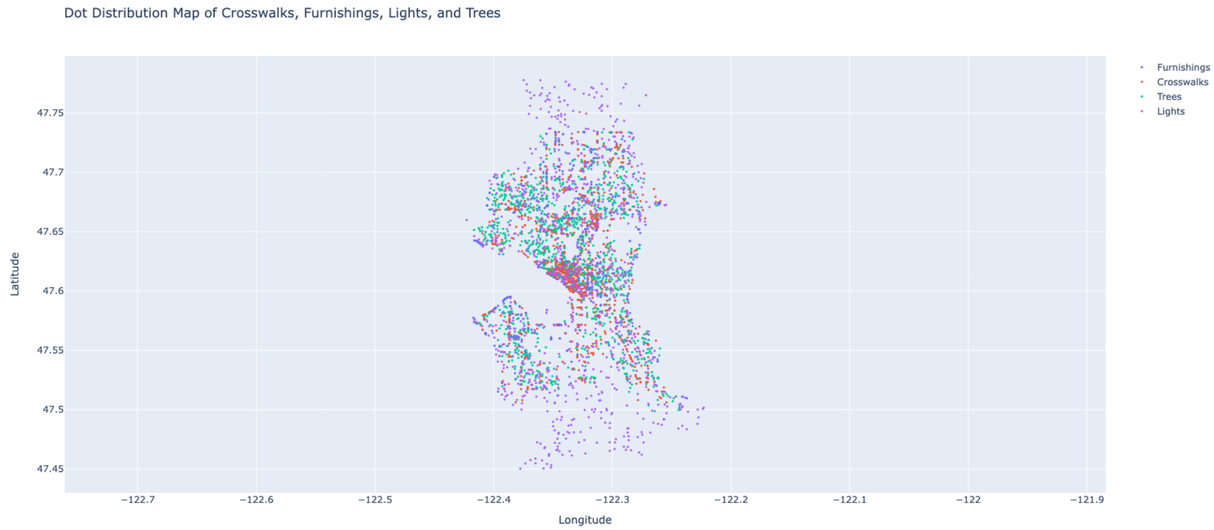

Figure 12 Mapping the Availability and Distribution of Coded Dots for Group II (2023)

By consolidating all the element maps into a single comprehensive geo-visualization, users can toggle specific elements on or off, facilitating an in-depth analysis of the availability and distribution of various street features. This geo-visualization (Figure 12) allows individuals to compare different elements according to their preferences, enabling a thorough examination of the street environment.

Chapter 7. DISCUSSION

The primary objective of this research is to investigate the potential of computational methods in urban design, with a particular focus on creating pedestrian-friendly streets. The findings chapter presents the results obtained through the use of these methods. The observations indicate that computational methods can be a valuable tool in urban design practices by providing accurate visual representations and calculations of various urban design elements, including building heights, street widths, sidewalk widths, and the number of crosswalks, furnishings, light poles, and trees. The geo-visualizations generated through computational methods enabled the author to identify patterns and variations in the distribution of these elements across different neighborhoods in Seattle.

The findings from the first group of analyses reveal a lack of unexpected outcomes, thus corroborating the initial assumptions. The examination of the ratio between building heights and street widths on various urban streets shows general suitability in most cases, with no pronounced effect on pedestrian-friendliness. Intriguingly, even in areas characterized by towering structures, such as downtown, the pedestrian experience remains favorable.

Nonetheless, this research holds inherent value by offering valuable insights by identifying and delineating specific geographic locations and their corresponding ratios. Such insights prove invaluable for professionals actively engaged in the painstaking task of streetscape design. The understanding of existing conditions, as provided by this study, aids in formulating effective strategies for potential enhancements across diverse neighborhoods within Seattle.

Furthermore, using coding techniques as an integral component of this research underscores the potential inherent in computational methodologies. This study successfully manipulates and interprets the intricate numerical data associated with various street elements by harnessing algorithms and computational analysis. This computational prowess holds vast promise, extending beyond the confines of this research, and can revolutionize urban design by facilitating computational methods. Consequently, this innovative approach enhances urban design projects' efficiency, effectiveness, and accuracy, providing a solid foundation for informed decision-making and improved urban planning practices.

The dot distribution maps provide a comprehensive overview of the distribution of crucial street elements across the entire city of Seattle, including crosswalks, furnishings, lights, and trees. While these elements can be found throughout the city, there is an apparent concentration of these features in the central areas such as Ballard, Downtown, First Hill/Capitol Hill, Fremont, South Lake Union, Uptown, University District, and Wallingford.

This concentration suggests that these central areas exhibit a higher level of pedestrian-friendliness compared to the city's outer areas. More street elements in these neighborhoods indicate a stronger focus on pedestrian infrastructure, amenities, and urban design principles to create walkable and pedestrian-oriented environments. These areas will likely offer better pedestrian experiences and foster more vibrant street life.

However, these findings also highlight the need to prioritize and enhance pedestrian infrastructure in other areas, particularly those on the city's periphery. These areas may need more street elements, potentially resulting in a less pedestrian-friendly environment. By adopting a more equitable approach to the distribution and availability of street elements, urban planners and policymakers can create a more balanced and inclusive urban environment that prioritizes the needs and experiences of pedestrians throughout the city.

Moreover, the fact that these findings were derived through hand-coded analysis underscores the significance of using computational methods and spatial analysis techniques in urban planning and design research. The ability to generate insights and visualize data through coding enables researchers, urban planners, and policymakers to make informed decisions and implement evidence-based interventions to enhance the pedestrian experience and create more livable cities for all residents, irrespective of their geographical location.

Chapter 8. LIMITATIONS AND FUTURE RESEARCH

8.1 Limitations

While coding proved a valuable technique for conducting this urban design research, the author encountered several limitations that provided opportunities for further development. One of the primary limitations was the presence of missing data within the files used for analysis. Dealing with missing data is a complex task as it requires additional time and effort to address the gaps in the dataset. The absence of data poses challenges in accurately representing the complete picture and may affect the reliability of the research findings.

Furthermore, as the building heights data was sourced separately from the other elements, the author faced the challenge of working with a different coordinate reference system and authority ID. Specifically, the building heights data used the WGS 84 / Pseudo-Mercator coordinate reference system with an authority ID of EPSG:3857, while the other elements adhered to the WGS 84 system with an authority ID of EPSG:4326. This difference presented a significant obstacle, highlighting the importance of establishing consistency and ensuring data cleanliness before proceeding with the coding project.

Through careful attention to detail, the author recognized the need to harmonize the coordinate reference systems and authority IDs across all datasets. By addressing this issue and converting the building heights data to WGS 84 with EPSG:4326, the author achieved a cohesive and reliable dataset for analysis. This experience was a valuable lesson, emphasizing the significance of maintaining uniformity and accuracy in data preparation to facilitate smooth and accurate coding projects.

Moreover, it is crucial to highlight that the measurements of each element in the first group differed in terms of units. For instance, the sidewalk data was recorded in inches, building heights in meters, and streets in feet. This unit variation added an extra layer of complexity during the data analysis process. However, the bright side of utilizing coding techniques became evident in resolving this issue. Coding provides the flexibility to handle such discrepancies efficiently. The data can be standardized to a consistent unit system through appropriate conversions and transformations, enabling seamless analysis and visualization. The ability of coding to address unit conversions and ensure uniformity across different measurements proved invaluable in this research. It exemplified the power and effectiveness of coding in handling diverse data formats and facilitating data analysis tasks. By leveraging the coding capabilities, the author could streamline the data processing workflow, mitigate the challenges posed by varying units, and enhance the accuracy and reliability of their analyses.

To achieve more sophisticated results, allocating additional resources and time to effectively handle missing data and enhance the quality and detail of the geo-visualizations is one of the crucial future tasks. By investing in further development and refinement of the coding techniques employed in this research, future studies can overcome the limitations experienced and attain more detailed outcomes. Improving data quality involves actively addressing missing or incomplete data points and ensuring consistency and accuracy throughout the dataset, which may require implementing data imputation techniques or seeking additional sources to fill in the gaps. By taking these steps, researchers can strengthen the reliability and robustness of their analysis.

Moreover, dedicating effort to refining the coding techniques used for visualization can yield more visually appealing and informative results, which may involve exploring advanced visualization libraries or employing creative design and decoration techniques to enhance the visual outputs. By investing in developing and refining these coding techniques, researchers can generate geo-visualizations that effectively communicate complex information and insights. These improvements contribute to a deeper understanding of the urban environment and support more informed decision-making processes in urban design projects. By producing more reliable, accurate, and visually compelling findings, future studies can drive urban planning and design advancements, facilitating sustainable and efficient urban development.

8.2 Future Research

For future practical research or potential implementation, it is essential to question the effectiveness of these geo-visualizations in contributing to the urban design and planning fields, which is particularly important given that Seattle has provided inclusive information regarding its urban design and planning practices through its website. One such resource is Performance Seattle, which features a range of categories that provide residents with multipurpose data to inform them of various urban planning and design aspects. Given the availability of these resources, it is essential to consider how the geo-visualizations presented in this research can be effectively used to enhance the existing data and contribute to the ongoing efforts to improve pedestrian-friendly streets in Seattle.

One possible strategy to use the geo-visualizations generated in this research is to integrate them into an online dashboard (Figure 13) that exhibits digital maps and graphics presenting a diverse range of urban design and planning-related records and performance metrics. Since the geo-visualizations were generated using code with a GeoJSON file which is interactable with the web, it would be relatively easy to incorporate them into the dashboard. This digital platform could complement the existing Performance Seattle website by providing a more visually engaging way of presenting information to residents and other stakeholders. This approach could enhance accessibility to urban design information for a wider audience and promote greater involvement with urban design and planning practices. Furthermore, geo-visualizations could be used to monitor changes in urban design and planning patterns over time, enabling more informed decision-making and assessment of the effectiveness of different strategies.

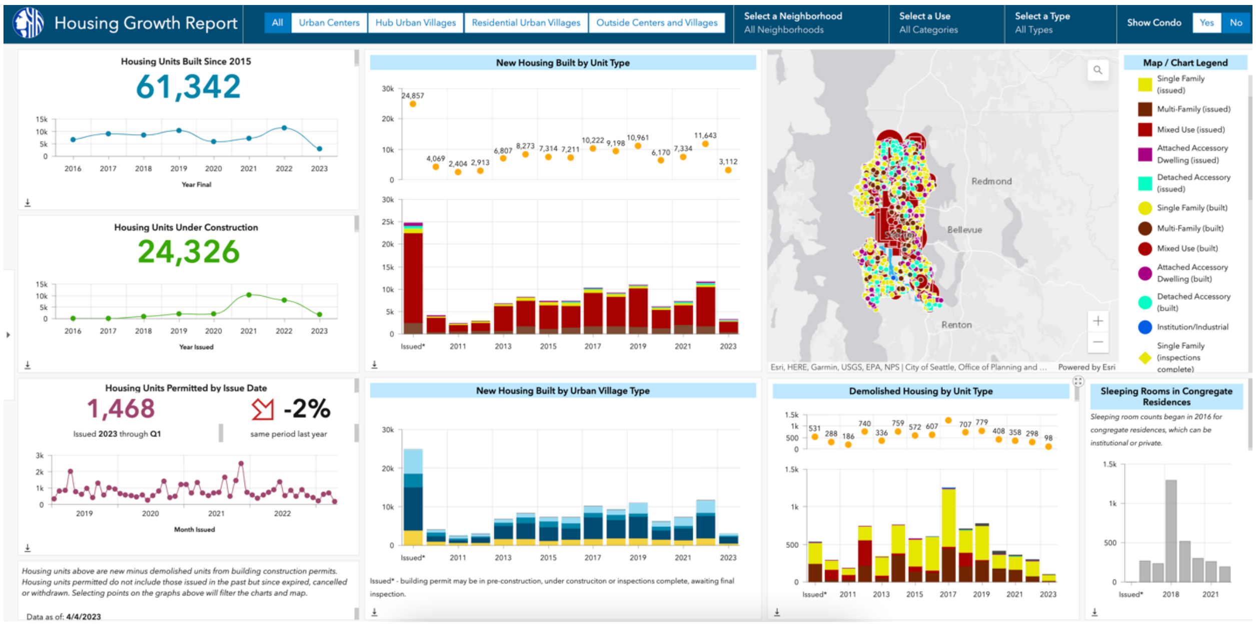

Figure 13 Seattle Housing Growth: Online Dashboard for Insights (City of Seattle, 2023)

In addition, this research has the potential to contribute to further studies on walkability in urban design and planning. Walkability digital maps, such as the well-known Walk Score, have already been developed to assess walkability based on the distances to various urban features, such as parks, schools, grocery stores, and public transit. These maps have become increasingly popular, especially in the real estate industry, as walkability is essential when choosing new locations.

Future research could investigate how the geo-visualizations produced in this study could be incorporated into existing walkability digital maps to enhance their accuracy and comprehensiveness. For example, the information provided by the geo-visualizations on the distribution of street elements, such as crosswalks, furnishings, light poles, and trees, could be integrated into walkability assessments. This would provide a more detailed and nuanced understanding of walkability and help urban planners and designers create more pedestrian-friendly and sustainable urban environments.

A geographer and public health researcher at the Institute for Health Metrics and Evaluation, University of Washington, Nat Henry, produced an interactive map that showcases the potential of color-coded heat maps in displaying walking times from every block in Seattle to a variety of amenities, including parks, libraries, supermarkets, restaurants, coffee shops, schools, light-rail stations, and bus stops with direct access to downtown. (Figure 14) This example highlights how coding can be effectively used to present valuable visualized information in urban design and planning. Moreover, it provides evidence that computational methods are flexible and valuable methods that can be easily incorporated into websites to provide accessible and easily consumable information for the public without requiring significant data storage.

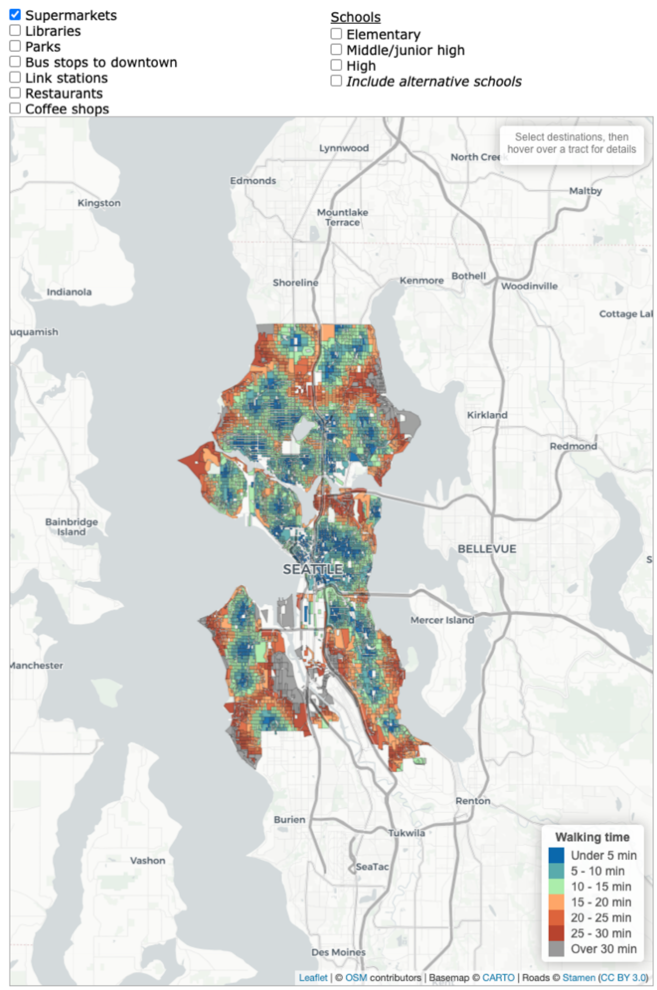

Figure 14 Nat Henry's Coded Heat Map: Walkability in Seattle Visualization (Henry N., 2023)

Chapter 9. CONCLUSION

In recent years, there has been a significant increase in the attention given to pedestrian-friendly urban design, driven by the recognition of its role in reducing emissions and fostering sustainable urban environments. However, the growing population in cities like Seattle has introduced complexities to urban design and planning processes. In order to address this challenge, computational methods have emerged as a promising tool for mitigating these complexities. These methods provide professionals with efficient and explicit capabilities to analyze and visualize complex urban data, facilitating informed decision-making and the creation of pedestrian-friendly urban environments that cater to the needs of all residents.

This research specifically focuses on the role of computational methods in enhancing pedestrian-friendly streets in Seattle, employing Python with geospatial data to demonstrate these computational tools' practical utility and efficacy. The findings underscore the importance of carefully considering and integrating various elements, including crosswalks, furnishings, light poles, trees, sidewalks, streets, and buildings, to create a harmonious and functional urban environment for pedestrians. Leveraging computational methods enables quantitative analysis of these elements, enabling more precise decision-making.

Moreover, as this research exemplifies, computational methods have made visually impactful results, such as heat maps with ratios of building heights to sidewalk and street widths and sidewalk widths to street widths, increasingly accessible for observation and analysis. These methods provide interactive approaches through coding, allowing users to engage with the data and analysis dynamically. This approach offers a heightened level of intuitive comprehension regarding the relationships between various urban elements by allowing users to input relevant data and parameters into the code, process calculations for desired ratios and metrics, and visualize the outcomes through interactive graphics. Furthermore, this method enables more detailed analysis, such as focusing on a specific area within Seattle with a particular intention to increase the number of sidewalks. The accessibility of these interactive methods and coding empowers professionals, researchers, urban enthusiasts, and community members to participate actively in urban design and planning analyses. It promotes transparency and inclusivity by providing a platform for different stakeholders to contribute their perspectives and insights to the decision-making process.

Furthermore, the inherent complexity of urban environments, with numerous factors to consider, necessitates adopting a holistic approach to create a cohesive and well-structured urban fabric that is aesthetically pleasing and organized for all residents. Computational methods play a vital role in managing this complexity by providing valuable support in understanding the overall urban fabric and assisting in decision-making. The benefits of employing these methods include their ability to rapidly process and store vast amounts of information, enabling the development of accurate representations of urban streets. By considering the city as a whole and examining the interrelationships among different street elements using computational methods, urban designers and planners can create functional and harmonious urban environments that explicitly and rapidly address the needs of all residents. Therefore, incorporating computational methods in urban design and planning represents a promising direction for advancing the field, offering new opportunities to address complex problems and enhance the quality of life for all residents.

In conclusion, this research underscores the significance of computational methods in enhancing pedestrian-friendly urban environments. By leveraging these methods, professionals can efficiently analyze and visualize urban data, enabling more informed decision-making. The accessibility and interactivity of computational methods facilitate engagement from various stakeholders, promoting transparency and inclusivity in the urban design and planning processes. Moving forward, integrating computational methods into urban design and planning endeavors holds great promise for addressing complexities, improving the quality of life for residents, and fostering sustainable and vibrant cities.

BIBLIOGRAPHY

City of Seattle (2016). *City of Seattle Council Bill 115861.* http://clerk.ci.seattle.wa.us/search/results?d=CBOR&s1=115861.cbn.&Sect6=HITOFF&l=20&p=1&u=/%7Epublic/cbor2.htm&r=1&f=G

City of Seattle (2020). *Seattle 2035 Comprehensive Plan: Managing Growth to Become an Equitable and Sustainable City 2015-2035.*

Seattle Department of Transportation. (2017). Pedestrian Master Plan. https://www.seattle.gov/documents/Departments/SDOT/About/DocumentLibrary/SeattlePedestrianMasterPlan.pdf

Seattle Department of Transportation. (2019). City life at street level. https://dailyplanit.seattle.gov/wp-content/uploads/2020/01/City-Life-At-Street-Level-email-version.pdf

City of Seattle. (2017). Seattle Right-of-way Improvements Manual Sidewalk Design Standards. Streets Illustrated. Retrieved from https://streetsillustrated.seattle.gov/design-standards/sidewalks/

Seattle Department of Transportation. (2017). New Mobility Playbook. Retrieved from https://www.seattle.gov/Documents/Departments/SDOT/NewMobilityProgram/NewMobility_Playbook_9.2017.pdf

Seattle Department of Transportation. (2015). Move Seattle: A Strategic Plan for Transportation. Retrieved from https://www.seattle.gov/documents/Departments/SDOT/About/DocumentLibrary/MoveSeatte-FinalDraft-2-25-Online.pdf

Krieger A. (2008). Where and How Does Urban Design Happen? from Urban Design In Larice, M., & MacDonald, E. (Eds.). (2012). The urban design reader. Taylor & Francis Group.

Gehl, J. (2010). Cities for people. Island Press.

Jacobs, J. (1961). The death and life of great American cities. Vintage.

Jacobs, A. B. (1993). Great Streets. The MIT Press.

Fink, T., & Koenig, R. (2019). Integrated Parametric Urban Design in Grasshopper / Rhinoceros 3D Demonstrated on a Master Plan in Vienna. *Blucher Design Proceedings*. https://www.proceedings.blucher.com.br/article-details/34369

Wilson, L., Danforth, J., Davila, C. C., & Harvey, D. (2019). *How to Generate a Thousand Master Plans: A Framework for Computational Urban Design*.

Miao, Y., Koenig, R., Knecht, K., Konieva, K., Buš, P., & Chang, M.-C. (2018). Computational urban design prototyping: Interactive planning synthesis methods—a case study in Cape Town. International Journal of Architectural Computing, 16(3), 212-226. doi:10.1177/1478077118798395

Mitchell, T. (2019). Geospatial power tools. O'Reilly Media, Inc.

Toms, S., Crickard, P., & van Rees, E. (2018). Mastering geospatial analysis with Python. Packt Publishing.

GeoPandas 0.12.2. GeoPandas. (n.d.). Retrieved from https://geopandas.org/en/stable/gallery/plotting_basemap_background.html

Low-Code Data Apps. Plotly. Retrieved from https://plotly.com/

COMPAS 1.0 Affine Anchor. (n.d.). Retrieved from https://compas.dev/

Seattle GeoData. (n.d.). Retrieved from https://data-seattlecitygis.opendata.arcgis.com/

City of Seattle. Monitoring Programs. (2023). Retrieved from https://population-and-demographics-seattlecitygis.hub.arcgis.com/pages/indicator-projects

Henry, N. *Is Seattle a 15-minute city?* (2023). *It depends on where you want to walk*. Retrieved from https://nathenry.com/writing/2023-02-07-seattle-walkability.html

APPENDIX A

Crosswalks' Attributes and Details

Data Set Summary

Data Set Basics	
Title	*Marked Crosswalks*
Abstract	*Marked Crosswalks in the City of Seattle.*
Description	*To show the location and display some attributes of marked crosswalks in the City of Seattle using the GIS for cartographic, analysis and tracking purposes.*
Supplemental Information	*A route event created using data from Hansen table HANSEN_RPT.MVW_GIS_XWK.*
Update Frequency	*Weekly*
Keyword(s)	*SDOT, Seattle, Transportation, Marked Crosswalk, Pedestrian, Street*
Contact Information	
Contact Organization	*SDOT Traffic Management, Traffic Operations Group*
Contact Person	*SDOT GIS Analyst*
Contact Email	*DOT_IT_GIS@seattle.gov*

Attribute Information

Attribute	*Data type, length*	*Description*
OBJECTID	*ObjectID*	*ESRI unique identifier*
UNITID	*Text, 20*	*Alpha-numeric Hansen unique identifier. XWK- followed by a sequential number*
UNITDESC	*Text, 255*	*Structured description of the Marked Crosswalk location*
CONDITION	*Text, 10*	*Marked Crosswalk condition:* *GOOD = "as new" or requires only routine maintenance to keep it in service FAIR = requires major rehabilitation to keep it in service* *POOR = should be replaced*

Attribute	*Data type, length*	*Description*
CONDITION_ASSESSMENT_DATE	*Date*	*Date/time Marked Crosswalk condition was last assessed*
OWNERSHIP	*Text, 10*	*The organization that owns the Marked Crosswalk*
CURRENT_STATUS	*Text, 10*	*Current Marked Crosswalk status:* *INSVC= In service* *PLND= Planned*

PRIMARYDISTRICTCD	*Text, 10*	*The code for the primary council district in which this Marked Crosswalk is located.*
SECONDARYDISTRICTCD	*Text, 10*	*The code for the secondary council district in which this Marked Crosswalk is located if applicable.*
OVERRIDEYN	*Text, 1*	*Council District override flag*
COMPTYPE	*Short*	*Asset type code assigned by the Hansen asset management system*
SEGKEY	*Long*	*Foreign key to the primary key (compkey) of the associated street segment asset*
UNITTYPE	*Text, 10*	*Marked Crosswalk category, enhanced for the City of Seattle. Always = XWK.*
OLD_ID	*Text, 20*	*OLD Marked Crosswalk identification number*
APPROACH	*Text, 3*	*Geographic location of the crosswalk in the intersection. Does not apply to segments for mid-block crosswalks.* *N = north S = south E = east W = west* *NE = northeast* *NW = northwest* *SE = southeast* *SW = southwest*

MARKING_TYPE	*Text, 10*	*Description of the marking type: LADER = Ladder, PARSL = Parallel Solid LInes, BRICK = Brick, OTHER = Other*
SCHOOL	*Text, 1*	*Whether the crosswalk is in a school area (Y/N)*

Attribute	*Data type, length*	*Description*
MIDBLOCK_CROSSWALK	*Text, 1*	*Whether the crosswalk is located mid-block (Y/N)*
INSTALL_DATE	*Date*	*Date/time the Marked Crosswalk was identified by the Crew Chief or Engineer as complete*
COLOR	*Text, 10*	*Marked Crosswalk Color GRY = Gray, RED = Red, WHT = White*
COMMENTS	*Text*	*Asset comments, contains WILS number*
CATEGORY	*Text, 10*	*Marked Crosswalk category: RASED = Raised PAINT = Paint TRDWN = Torch Down THRPL = Thermoplastic OTHER = Other*
OWNERSHIP_DATE	*Date*	*Date/time ownership took effect*
CURRENT_STATUS_DATE	*Date*	*Date/time Marked Crosswalk current status last updated*

MAINTAINED_BY	*Text, 10*	*Organization maintaining Marked Crosswalk*
MAINTENANCE_AGREEMENT	*Text, 150*	*Nature of maintenance responsibility / agreement*
CURBSPACEID	*Text, 11*	*Curb space number (if provided)*
MAINT_DISTRICT	*Text, 10*	*Marked Crosswalk location by maintenance district* *NORTH* *SOUTH* *CENTRAL*
OVERRIDECOMMENT	*Text, 255*	*Council District override comment*
SHAPE_LNG	*Double*	*Longitude of the Marked Crosswalk*
SHAPE_LAT	*Double*	*Latitude of the Marked Crosswalk*
CROSSWALK_CONTROL	*Text, 10*	*Feature controlling traffic at Marked Crosswalk* *SIGNAL= Traffic Signal* *STOPSIGN= Stop sign*
DISTANCE		*Recorded distance in feet from beginning point of blockface element to location of the Marked Crosswalk* *(distance to low)*
WIDTH		*Distance (perpendicular) of blockface element from street segment (+/- 4).*

Attribute	*Data type, length*	*Description*

		Distance +/- in feet (usually <null> for crosswalks)
CITY_SECTOR		*Marked Crosswalk location by city sector: E = East, NE = Northeast, NW = Northwest, SE = Southest, SW = Southwest, W = West*
NBRHOOD_DISTRICT		*Marked Crosswalk location by neighborhood district: BLRD = Ballard, BLRD-NW = Shared- Ballard & Northwest, CNTRL = Central, CNTRL-E = Shared-Central & East, DLRD = Delridge, DWTN = Downtown, E = East, GRDWM = Greater Duwamish, GRDWM- DLRD = Shared-Greater Duwamish & Delridge, LKUN = Lake Union, LKUN-BLRD = Shared-Lake Union & Ballard, LKUN- NW = Shared-Lake Union & Northwest, MGNL-QA = Magnolia/Queen Anne, N = North, N-NW = Shared-Norht & Northwest, NE = Northeast, NW = Northwest, SE = Southeast, SW = Southwest*

APPENDIX B

Sidewalks' Attributes and Details

Data Set Summary

Data Set Basics	
Title	*Sidewalks*
Abstract	*Sidewalks in the City of Seattle.*
Description	*The sidewalk inventory was developed to assist staff in planning walkway development and to prioritize sidewalk improvements and maintenance. Sidewalk locations will be based on the locations of the assets on either side of the street segments. Expired assets are excluded. The sidewalk system consists of paved walkways (concrete, asphalt, and pavers), a few soft-surface pathways.*
Supplemental Information	• *Sidewalk locations will be based on the locations of the assets on either side of the street segments.* • *The Sidewalk start point will coincide with the Blockface element start point and the end point will be calculated by the start point plus length (STPOINT + LEN).* • *The view will be linear referenced to create a Route Event using TRANSPO.GEOBASID_ROUTE as the route reference. The route key field is TRANSPO.GEOBASID_ROUTE.COMPKEY and the table (event) key field is SEGKEY.* • *There can be multiple attachments for each Sidewalk. The attachment names and paths will be concatenated.* • *Expired assets are excluded.* • *The Level 1 sidewalk asset record is excluded.* • *WIDTH should be calculated based on the segment element record (+/-) 7.5 feet*
Update Frequency	*Weekly*
Keyword(s)	*SDOT, Seattle, Transportation, Curb, Planting Strip, Ramp, Sidewalk*
Contact Information	

Contact Organization	*SDOT GIS Team*
Contact Person	*SDOT GIS Analyst*
Contact Email	*DOT_IT_GIS@seattle.gov*

Attribute Information

Attribute	*Data type, length*	*Description*
OBJECTID	*ObjectID*	*ESRI unique identifier*
COMPKEY	*Long*	*Primary key of the Sidewalk asset table, assigned by the Hansen asset management system.*
COMPTYPE	*Short*	*Asset type code assigned by the Hansen asset management system. (Hardcoded as 97)*
SEGKEY	*Long*	*Foreign key to the primary key (compkey) of the associated street segment asset.*
UNITID	*Text, 20*	*Alpha-numeric Hansen unique identifier*
UNITTYPE	*Text, 3*	*Sidewalk category, enhanced for the City of Seattle.*
UNITDESC	*Text, 255*	*Structured description of the Sidewalk location*

ADDBY	*Text, 30*	*User who added the record to Hansen*
ADDDTTM	*Date*	*Date/time record was added to Hansen*
ASBLT	*Text, 10*	*As built plan number*
CONDITION	*Text, 10*	*Sidewalk condition (Fair, Good, Poor)*
CONDITION_ASSESSMENT_DATE	*Date*	*Date/time Sidewalk condition was last assessed*
CURBTYPE	*Text, 10*	*Sidewalk curb type: (410A - 410A-Free Standing; 410B - 410B-Curb & Gutter; 410C - 410C-Doweled Curb; AR - Armored Free Standing; EX - Extruded Concrete; G - Granite; MONO - Monolithic; NONE - NONE; OTH - OTHER; ROLLCB - Rolled Curb; TEAC - Thicknd Edge Asphalt; TEPCC - Thicknd Edge Concrete; UND – Undetermined)*
CURRENT_STATUS	*Text, 10*	*Current sidewalk location status: (INSHOP - In the Shop; INSVC - In Service; OUTSVC - Out of Service; PLANNED - Planned; REMOVED - Removed; TEMPOUTSVC - Temporarily Out of Service;*

Attribute	*Data type, length*	*Description*
		UNDERCONS - Under Construction)
CURRENT_STATUS_DATE	*Date*	*Date/time Sidewalk status last assessed*
FILLERTYPE	*Text, 10*	*Configuration of the filler / planting strip, the area between the curb and the Sidewalk, according to the following codes:* *(AC - Asphalt Concrete;* *BR - Stone BLK/BRICK/PAVER;* *GRAVEL - Gravel;* *LSCP - Landscpe Continuous;* *NONE - None;* *OTH - Other;* *PCC - Portland Cement Concrete; PV/OTHER - Pervious + Other Type(s); PVAS - Pervious Asphalt;* *PVCC - Pervious Concrete;* *SWALE - Swale;* *TR/AC - TR Pit/Plntr + Asphalt;* *TR/BR - TR Pit/Plntr + BLK/BRICK/PAVER;* *TR/O - TR Pit/Plntr + Other;* *TR/PCC - TR Pit/Plntr + Concrete)*
FILLERWID	*Double*	*Sidewalk filler width in inches*
INSTALL_DATE	*Date*	*Date/time Sidewalk was installed*
HANSEN_RPT_MVW_GIS_SDW_LEN	*Double*	*Length*
LENUOM	*Text, 10*	*Length unit of measure* *(AC - ACRE(S);* *DEGREES - DEGREES; FT - FEET;* *FTSQ - SQARE FEET;* *INCH - INCH(ES);*

		PCT – PERCENT)
SW_WIDTH	*Double*	*Sidewalk width from structural tab in inches*
MAINTAINED_BY	*Text, 10*	*The organization responsible for sidewalk maintenance (see ownership table below)*
MATL	*Text, 10*	*Sidewalk built material (BLK - Black Asphalt; CLR - Colored Asphalt; CON - Concrete; OTH - Other; PAV - Pavers; TXT - Textured Concrete)*
MODBY	*Text, 30*	*User who last modified record in Hansen*

Attribute	*Data type, length*	*Description*
MODDTTM	*Date*	*Date/time record was last updated in Hansen*
OWNERSHIP	*Text, 10*	*The organization that owns the sidewalk (see ownership table below)*

SIDE	*Text, 3*	*Sidewalk street side* *(N – North;* *NW –* *Northwest; NE –* *Northeast; S –* *South;* *SW – Southwest;* *SE – Southeast;* *E – East;* *W – West)*
SURFTYPE	*Text, 10*	*Sidewalk surface type* *(see surface type table below)*
BUILDERCD	*Text, 10*	*Builder Code* *(CIP-OTH - CIP- Other Department;* *CIP-SDOT - CIP-SDOT;* *NSF-CRF - NSF-CRF;* *PRIDEV - Private Development;* *SDOTPED - SDOT Pedestrian Programs)*
INVALIDSWRECORDYN	*Text, 1*	*Whether sidewalk has an invalid record (Y/N)*
MAINTBYRDWYSTRUCTYN	*Text, 1*	*Whether sidewalk is maintained by roadway structures (Y/N)*
NOTSWCANDIDATEYN	*Text, 1*	*Whether feature is a sidewalk candidate (Y/N)*
SWINCOMPLETEYN	*Text, 1*	*Whether the sidewalk is incomplete (Y/N)*
INCSTPOINTLOWEND	*Double*	*Start point from the low address end of a segment* *(incomplete sidewalks only)*
INCSTPOINTUNKNOWN	*Text, 1*	*Whether the start point is unknown for an incomplete sidewalk (Y/N)*
MULTIPLESURFACEYN	*Text, 1*	*Whether the sidewalk contains multiple surface (Y/N)*

GSITYPECD	*Text, 10*	*Green Stormwater Infrastructure Type (FACILITY; SURFACE)*
DATE_MVW_LAST_UPDATED	*Date*	*Date/time Sidewalk Minimum Variable Width was last updated*
PRIMARYDISTRICTCD	*Text, 10*	*The code for the primary council district in which this sidewalk is located.*
SECONDARYDISTRICTCD	*Text, 10*	*The code for the secondary council district in which this sidewalk is located if applicable.*

Attribute	*Data type, length*	*Description*
OVERRIDEYN	*Text, 1*	*Council District Override Flag*
OVERRIDECOMMENT	*Text, 255*	*Council District Override Comment*
CURBRAMPHIGHYN	*Text, 1*	*Whether there is a curb ramp at the high address street end (Y/N)*
CURBRAMPMIDYN	*Text, 1*	*Whether there is a curb ramp at the center of the street (Y/N)*
CURBRAMPLOWYN	*Text, 1*	*Whether there is a curb ramp at the low address street end (Y/N)*
SRTS_SIDEWALK_RANK	*Long*	*Safe Routes to School Ranking*
PRIMARYCROSSSLOPE	*Double*	*Sidewalk Primary Cross Slope (percentage)*
MINIMUMVARIABLEWIDTH	*Double*	*Sidewalk Minimum Variable Width (inches)*

SHAPE_Length	*Double*	*ESRI field that stores information about a feature's length in GIS*

Ownership Code Table

Code	*Description*
CJOTS	*City Jurisdiction Other Than Seattle*
CNTY	*County*
CONTRCTR	*Contractor*
DON	*Department of Neighborhoods*
FED	*Federal*
FFD	*Fleets & Facilities Department*
METRO	*Metro Transit*
METRO-JNT	*Metro Joint Use*
OTHER	*Other Maintains*
PARK	*Parks Department*
PIKEPLMKT	*Pike Place Market Preservation & Development Authority*
POS	*Port of Seattle*
PRIV	*Private*
SCL	*Seattle City Light*

SDOT	*Seattle Departmentt of Transportation*
SEAC	*Seattle Center*
SNDTR	*Sound Transit*
SPH	*Seattle Public Housing*
SPS	*Seattle Public Schools*
SPU	*Seattle Public Utilities*
VOLUNTEER	*Volunteer Maintains*

Code	*Description*
WSDOT	*Washington State Department of Transportation*

Surface Type Code Table:

Code	*Description*
AC	*Asphalt Conc/Flex Base*
AC/AC	*Asphalt Conc Overlay/Flex Base*
AC/PCC	*Asphalt Conc/Rigid Base*
BR	*Stone Block, Brick Paver*
GRAVEL	*Gravel*
OTHER	*Other*
PCC	*Portland Cement Concrete*

PCC-PAD	*Portland Cement Concrete Pad*
PVAS	*Pervious Asphalt*
PVCC	*Pervious Concrete*
ST	*Bituminous Surface Treatment*
UIMPRV	*Unimproved*
UND	*Undetermined*

APPENDIX C

Streets' Attributes and Details

Data Set Summary

Data Set Basics	
Title	*Seattle Streets*
Abstract	*Streets in the City of Seattle*
Description	*The Streets Layer is a representation of the City's Street Network Database (SND) showing drivable public streets within the Seattle City limits, symbolized by arterial classification.*
Supplemental Information	
Update Frequency	*Weekly*
Keyword(s)	*SDOT, Seattle, Transportation, Streets*
Contact Information	
Contact Organization	*SDOT*
Contact Person	*SDOT GIS Analyst*
Contact Email	*DOT_IT_GIS@seattle.gov*

Attribute Information

Attribute	*Data type, length*	*Description*
OBJECTID	*ObjectID*	*ESRI unique identifier*
ARTCLASS	*Long*	*Arterial classification code:* · *5 - Interstate Freeway* · *4 - State Highway* · *3 - Collector Arterial* · *2 - Minor Arterial* · *1 - Principal Arterial* *0 - Not Designated (not an arterial)*
COMPKEY	*Long*	*Primary key of the Street asset table, assigned by the Hansen asset management system.*
UNITIDSORT	*Text, 30*	*Alpha-numeric Hansen unique identifier*

Attribute	*Data type, length*	*Description*
UNITDESC	*Text, 100*	*Structured description of the Street location*
STNAME_ORD	*Text, 40*	*Street segment name*
XSTRLO	*Text, 60*	*Cross street at low end of segment*
XSTRHI	*Text, 60*	*Cross street at high end of segment*
ARTDESCRIPT	*Text, 60*	*Arterial class code description*
OWNER	*Text, 10*	*The organization that owns the street, if not the city*

STATUS	*Text, 10*	*Current street status:* *INSVC = in service*
BLOVKNBR	*Long*	*Identification number of block street runs adjacent to*
SPEEDLIMIT	*Long*	*Street speed limit in MPH*
SEGDIR	*Text, 3*	*Street segment direction*
ONEWAY	*Text, 1*	*One Way Street (Y/N)*
ONEWAYDIR	*Text, 3*	*One Way Street traffic flow direction*
FLOW	*Text, 1*	*One Way Street traffic flow classification*
SEGLENGTH	*Double*	*Street segment length in feet*
SURFACEWIDTH	*Double*	*Street segment width in feet*
SURFACETYPE_1	*Text, 10*	*Primary pavement used on Street surface AC = Asphalt Concrete* *PCC = Rigid Pavement* *AC/PCC = Composite AC and PCC ST = Bituminous Surface Treatment*
SURFACETYPE_2	*Text, 10*	*Secondary pavement used on Street surface*
INTRLO	*Text, 80*	*Description of the intersection location with cross street at high address end of segment*
DIRLO	*Text, 3*	*Relative direction of low address end of segment*
INTKEYLO	*Long*	*Intersection key at low address end of segment*

INTRHI	*Text, 80*	*Description of the intersection location with cross street at high address end of segment*
DIRHI	*Text, 2*	*Direction of high address end of segment*
NATIONHWYSYS	*Text, 1*	*Whether the street is part of the National Highway System (Y/N)*
STREETTYPE	*Text, 50*	*Street type classification (from Seattle Right of Way Improvements Manual)*
PVMTCONDINDX1	*Double*	*Primary pavement condition, out of 100*
PVMTCONDINDX2	*Double*	*Secondary pavement condition, out of 100*

Attribute	*Data type, length*	*Description*
TRANCLASS	*Long*	*Street transit classification*
TRANDESCRIPT	*Text, 60*	*Transit class description*
SLOPE_PCT	*Long*	*Street grade in slope percentage*
SHAPE_Length	*Double*	*ESRI field that stores information about the length of a feature in GIS*

APPENDIX D

Trees' Attributes and Details

Data Set Summary

Data Set Basics	
Title	*Trees*
Abstract	*Tree locations in the public right of way of the City of Seattle.*
Description	*Listing of both publicly and privately maintained trees in the public right of way, with information on the condition, location, size, species and maintenance responsibility. Data was collected with the intent to predict maintenance needs, as well as to show the level of diversification within the street tree population.*
Supplemental Information	
Update Frequency	*Weekly*
Keyword(s)	*SDOT, Seattle, Transportation, Trees, Street Trees, Heritage Trees, Tree Inventory, Urban Forestry*
Contact Information	
Contact Organization	*SDOT, Urban Forestry*
Contact Person	*SDOT GIS Analyst*
Contact Email	*dot_it_gis@seattle.gov*

Attribute Information

Attribute	***Data type, length***	***Description***
OBJECTID	*ObjectID*	*ESRI unique identifier*
COMPKEY	*Long*	*Primary key of the tree asset table, assigned by the Hansen asset management system.*
UNITID	*Text, 20*	*Alpha-numeric Hansen unique identifier. Begins with TRE- followed by 7 or fewer digits. Seven digit numbers provided by contractor, less than seven digits from SDOT*

Attribute	***Data type, length***	***Description***
UNITDESC	*Text, 255*	*Structured description of the tree location as provided by contractor. Not validated*
CONDITION	*Text, 10*	*Tree condition*
CONDITION_ASSESSMENT_DATE	*Date*	*Date/time tree condition last assessed*
CURRENT_STATUS	*Text, 10*	*Current tree status. Indicates if the tree is "in service" or actively growing on site.*
PRIMARYDISTRICTCD	*Text, 10*	*The code for the primary council district in which this tree is located.*

SECONDARYDISTRICTCD	*Text, 10*	*The code for the secondary council district in which this tree is located if applicable.*
OVERRIDYN	*Text, 1*	*Council District override flag*
COMPTYPE	*Short*	*Asset type code assigned by the Hansen asset management system.*
SEGKEY	*Long*	*Foreign key to the primary key (compkey) of the associated street segment asset.*
UNITTYPE	*Text, 3*	*Tree category, enhanced for the City of Seattle*
OWNERSHIP	*Text, 10*	*The organization that owns the tree*
CURRENT_STATUS_DATE	*Date*	*Date/time current status last assessed*
LAST_VERIFY_DATE	*Date*	*Date/time tree information last verified*
PLANTED_DATE	*Date*	*Date/time tree was planted*
BOTANICAL_NAME	*Text, 10*	*Coded value for botanical name. TREE_BOTNAME contains corresponding common and scientific names.*
SCIENTIFIC_NAME	*Text, 30*	*Tree scientific name (binomial nomenclature)*
HERITAGE	*Text, 1*	*Whether tree has been designated a Heritage tree in SDOT/Plant Amnesty program (Y/N)*

EXCEPTIONAL	*Text, 1*	*Whether tree is classified as exceptional trees per DPD's rules (Y/N)*
CODEREQ	*Text, 1*	*Whether tree is required by DPD building code (Y/N)*
GSI	*Text, 1*	*Whether tree is included in the Green Streets Initiative (Y/N)*
GREEN_FACTOR	*Text, 1*	*Whether tree is part of a Green Factor project (Y/N)*

Attribute	***Data type, length***	***Description***
WIRES	*Text, 1*	*Whether tree may interfere with overhead wires (Y/N)*
CABLED	*Text, 1*	*Whether tree is cabled (Y/N)*
CLEARANCE_PROBLEM	*Text, 1*	*Whether tree has an associated clearance problem (Y/N)*
SPACETYPE	*Text, 10*	*Surface treatment of the planting pit or strip.*
SITETYPE	*Text, 10*	*Tree site description*
GROWSPACE	*Double*	*Width of the planting pit or strip (from curb to sidewalk)*
DIAM	*Double*	*Trunk diameter in inches (at 4.5 feet from ground level)*
CONDITION_RATING	*Text, 10*	*Tree condition rating out of 5*

FUNDING_SOURCE	*Text, 10*	*Tree maintenance funding source*
WATER_THROUGH_YR1	*Long*	*First year after planting tree must be watered*
WATER_THROUGH_YR2	*Long*	*Second year after planting tree must be watered*
WATER_THROUGH_YR3	*Long*	*Third year after planting tree must be watered*
OWNERDIAM	*Text, 5*	*Code combining tree owner and diameter category*
EXPDATE	*Date*	*Date/time tree was removed or taken out of the inventory*
COMMON_NAME	*Text, 300*	*Tree common name*
TREEHEIGHT	*Double*	*Tree height in feet*
ASBUILTPLANNO	*Text, 10*	*As built plan number*
LANDSCAPEAREAASSOC	*Long*	*Associated landscape area*
COMMENTS	*Text, 255*	*Additional comments*
OVERRIDECOMMENT	*Text, 255*	*Council District override comment*
SHAPE_LNG	*Double*	*Longitude of the tree*
SHAPE_LAT	*Double*	*Latitude of the tree*
IRRIGATESYSYN	*Text, 1*	*Whether the tree is served by an irrigation system (Y/N)*

ASSETGROUPID	*Text, 10*	*Asset group identification number*
ASSETGROUPDESC	*Text, 255*	*Asset group description*
MODDATE	*Date*	*Date/time record was last updated in Hansen*
MODBY	*Text, 30*	*User who last modified record in Hansen*

Attribute	***Data type, length***	***Description***
TOTAL_RANK	*Long*	*Genus ranking by total number of observed individuals*
TOTAL_COUNT	*Long*	*Total count of observed trees within a genus*
GENUS	*Text, 50*	*Tree genus name*

APPENDIX E

Map of Urban Centers and Villages