Making Connections: Understanding Pedestrian Indices in Squamish, British Columbia

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Jordan Booth

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Declaration of Committee

Name:	**Jordan Booth**
Degree:	**Master of Urban Studies**
Title:	**Making Connections: Understanding Pedestrian Indices in Squamish, British Columbia**
Committee:	**Chair:** **Annika Airas** Lecturer, Urban Studies
	Peter V. Hall Supervisor Professor, Urban Studies
	Yushu Zhu Committee member Assistant Professor, Urban Studies and Public Policy
	Don Luymes Examiner General Manager, Planning & Development City of Surrey

Abstract

This research study explores the uses of both macrolevel and streetscape pedestrian environmental indices in Squamish, British Columbia. The introduction of several large-scale residential communities has been a recent occurrence in Squamish as a means to accommodate growing populations. Such residential communities also attempt to create a more pedestrian friendly environment, in a historically auto centric town. In this respect, Squamish is like other small town, sub- and ex-urban communities on the edge of major urban centres. The purpose of this analysis is to identify, using both indices, neighbourhood features that most impact pedestrian friendliness by comparing four case study neighbourhoods (dissemination areas) with contrasting geographies and characteristics. The takeaways from this research provide insight on the application and value of such indices, especially as they pertain to the pedestrian-oriented planning goals set by District of Squamish. While such indices have been created and studied for their effectiveness in population dense urban areas, their use in smaller edge cities have yet to be widely addressed in academic studies.

Keywords: pedestrian environmental index; microscale audits of pedestrian streetscapes; pedestrian environments; walkability; Squamish development; master planned communities; New Urbanism

For my dearest friend, Ainslie O'Neil.

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List of Acronyms

CCAP	Community Climate Action Plan
CDI	Commercial Density Index
CMA	Census Metropolitan Area
CNU	Congress of New Urbanism
DA	Dissemination Area
GFA	Gross Floor Area
GIS	Geographic Information Systems
GMB	Growth Management Boundary
ICC	Intraclass Correlation Coefficients
IDI	Intersection Density Index
LDI	Land Use Density Index
MAPS	Microscale Audit of Pedestrian Streetscapes
MAUP	Modifiable Aerial Unit Problem
MPC	Master Planned Community
OCP	Official Community Plan
PDI	Population Density Index
PEI	Pedestrian Environmental Index
PGE	Pacific Great Eastern Railway

Chapter 1. Introduction

Large-scale, residential developments have become a recent trend in exurban areas, with growing populations accommodated on available land. These residential communities in outlying municipalities have been promoted as a way to absorb growing populations of major cities. Municipal governments and developers often construct these communities applying New Urbanist principles, especially focusing on building mixed-use developments with both local-serving commercial and amenable residential spaces (Ewing et al., 2001). They market the benefits of such communities as being an alternative to urban sprawl, allowing for growing populations, smaller home sizes, healthier walkable neighborhoods, with nearby amenities (Ewing et al., 2001; Tilt & Cerveny, 2013). However, the typical location of such developments on the periphery of metropolitan regions raises important questions about mobility. While there seems to be some consideration given to how these large-scale communities will integrate with the existing adjacent landscapes, much of the evidence of connectivity as well as increased walkability seem to come from developers or real estate organizations (Shen & Wu, 2012). In reality, the large-scale residential communities are complicated. They have significant spatial demands, many have awkward physical configuration because of phased development, and in the case of Squamish are often located in geographically complex landscapes such as a steep hillside or between rail tracks. All of which make integration and connections with the current built and social environments challenging.

This has certainly been the case in Squamish, British Columbia, an exurban community of roughly 20,000 people located about 65 km north of downtown Vancouver. For example, in an article in The Squamish Chief from 2016, the mayor of Squamish mentioned apprehension about pedestrian connectivity in the new phase of development in the Eaglewind residential community. She is quoted saying:

> I generally think it is not a bad project, but I don't think it meets our expectation in regard to pedestrian access throughout the development, I don't think the proposal does a good job at all of creating pedestrian access into and throughout the development (Thuncher, 2016).

The new phase was approved, even given her and other council members hesitation with the development, specifically her concern about the lack of linkages to rest of the city. Pedestrian connectivity of the district continues to be a major hurdle for council and

the community despite the fact that Squamish has created strategic plans for creating and promoting more pedestrian friendly environments and networks. This includes the District of Squamish Active Transportation Plan (District of Squamish & Urban Systems, 2016), the 2031 Multi-Modal Transportation Plan (Lew & Rocchi, 2011) and Trails Master Plan (The District of Squamish, 2010) as well as active transportation as a key goal of the Official Community Plan (District of Squamish, 2018). However, in the 2018 mayoral elections, when councillor and mayoral candidate Susan Chappelle was asked her top three priorities if elected, she listed improving transportation and connectivity of the district first. She went on to say, “there have always been strategic plans for everything imaginable, but they have not been funded nor resourced appropriately. We have no neighborhood plans, and have densified residential without sidewalks, connectivity, or funding for our infrastructure…” (Thuncher, 2018). Despite, the acknowledgement of such challenges expressed by community leaders, there are no records that the district is currently using any tools or metrics for measuring pedestrian environments and connectivity in Squamish. The purpose of this research is to help identify if pedestrian environmental models, often used in urban areas to evaluate walkability features of the landscape, are an appropriate tool that could also be used in smaller, edge cities like Squamish. This thesis dissects two different types of walkability analysis tools, the Pedestrian Environmental Index (PEI) and Microscale Audit of Pedestrian Streetscapes (MAPS) to understand the neighbourhood features that most impact pedestrian friendliness by comparing four case study neighbourhoods (dissemination areas) in Squamish that have contrasting geographies and characteristics.

Squamish was selected as a case study for this research project because the culmination of described development patterns, its quickly growing population, and transitioning economy has formed a critical moment for evaluating its pedestrian networks. It shares similarities with rapidly growing communities located in the foothills of the Eastern Townships outside Montreal and Rockies outside Calgary, along the Niagara Escarpment outside Toronto, and on the coast outside the cities of Atlantic Canada. Squamish brands itself for its unique ocean and mountain community that has attracted residents due to the vast opportunities for outdoor activity. However, while it is known for its well-established recreation, it is also engrained in a culture of driving due to

past economic systems, land use patterns, as well as challenges presented by its fragmented geographic layout.

1.1. Context

The District Municipality of Squamish is located halfway in between downtown Vancouver and the resort town of Whistler, British Columbia. It is situated at the convergence of a river valley and estuary located at the northern point of the Howe Sound and covers 104.87 square kilometers of land.

Squamish was primarily a resource town until the early 1990s, with a substantial portion of the population employed in logging, pulp production, or sawmilling. This meant that early street layouts were practically laid out near the railroad. Later, the street network was built to accommodate large logging trucks hauling lumber from the Squamish valley to the mill, and then to the port. Further auto dependence was engrained in the community with the increase of personal automobile ownership following World War II, as well as the construction of Highway 99 from Vancouver to Squamish (McLane, 2000; Raad, 1998). Since then, planning in Squamish has continued to favor and enable automobile use through sprawling land use patterns and few options for alternative and sustainable mobility. Most recently, economic development has focused on expanding tourism in the region. This has put pressure on increasing and enhancing road infrastructure (Reed & Gill, 1997). For example, the B.C. Ministry of Highways and Transportation report concluded that the updates and road improvements to Highway 99 for the 2010 Winter Olympics would greatly improve “access to developable land” (Gutstein, 2007).

Continual highway and road updates have entrenched and exacerbated levels of auto dependence in Squamish. As referenced in Table 1.1 there has been only a relatively small modal shift in Squamish the last 20 years of those who walk or bike to commute to work rather than commute by car, truck, or van. According to Statistics Canada's 2016 National Household Survey, about 76% of Squamish residents are using a personal vehicle for transportation to and from work. Only about 3% use public transit, about 6% walk, and 4% cycle (Statistics Canada, 2016). The share is about 2% more for people commuting by walking or biking than in 1996 and about 3% less for people commuting by driving or as a passenger. Squamish’s combined active transportation

mode of travel to work is 10.6% in 2016. This is in comparison to equivalent areas previously noted like Canmore, Alberta in the Rockies where in 2016, 19% of population used active modes of travel to commute to work or Squamish's neighboring town to the north, Whistler, British Columbia where 28.6% of the population commuted by walking or biking in the same year. In another similar town on the opposite coast of the country Wolfville, Nova Scotia, about an hour drive outside Halifax, 23.2% of residents walk or bike to work according to the 2016 census. Other towns in Canada with similar geographic and demographic characteristics had rates of active transportation closer to Squamish; Collingwood, Ontario on the Niagara Escarpment was 12.3% in 2016, and Sutton, Quebec was 10.8%. The city of Vancouver, combined bike and walk to work was 19.8% in 2016. However, with a much more robust public transportation system, a significantly higher percent of residents traveled by bus or train to work than any of the other previously mentioned towns. If the larger metropolitan area of Vancouver is considered instead for the same year, active modes is only 9% of those traveling to work, however travel by public transportation remains high (Statistics Canada, 2016).

Table 1.1 Commute Mode in Squamish Overtime by Percent

Mode of Travel to Work in Squamish (by Percent)	1996	2001	2006	2011	2016
By car, truck, or van as driver	74.3	76.8	75.1	76.9	76.4
By car, truck, or van as passenger	13.4	14.2	13.2	9.4	8.7
Using public transit	1.7	2.0	2.7	3.7	2.9
Walking or biking	8.3	6.1	7.1	8.7	10.6

While walking and biking rates have remained low for commuters, it is lesser known if non-commuting active transportation coincide to the low rates for commuters. Squamish has considerable number of residents who commute for work. More Squamish residents than the average in British Columbia, commute outside of their census division (Statistics Canada, 2016). In the case of Squamish, a resident commuting to Vancouver would be recorded as working outside the census division. This could be a factor leading to higher commute rates by single occupancy vehicles in Squamish. Despite this, the District of Squamish is certainly aware of challenges around low active commute rates

and is attempting to promote the use of active transportation for both non-commuting and commuting. The district's website encourages active forms of travel on many pages of its website. For example, under their Active Transportation page they have a "Did You Know?!" heading which reads, "Transportation incorporates physical activity into your daily routine, increases mobility and social equity while improving community livability and safety by getting people out of their cars, and interacting in their community" (District of Squamish, 2019). Furthermore, they have been dedicated to creating initiatives and plans to encourage pedestrian travel including the Active Transportation Plan (District of Squamish & Urban Systems, 2016), the 2031 Multi-Modal Transportation Plan (Lew & Rocchi, 2011) and Trails Master Plan (The District of Squamish, 2010).

However, mobility concerns are complicated by the fact that the district is growing rapidly due in part to unaffordability in Vancouver. Between the 2006 and 2016 census years, the population increased substantially from 14,949 to 19,512. This population growth of 30.5%, is more than double the provincial and national rates in the same time period of 13% and 11% respectively (Statistics Canada, 2006, 2016). There is no anticipation that this expansion of population and development will subside in the near term. Construction has begun on the Squamish Oceanfront development which, according to the developer, will bring an additional 6,500 residents and employment for 2,300 (Newport Beach Development LP, 2018). Additionally, Bosa Properties is building a master planned community with 900 two- and three-bedroom townhouse and apartments as well as other amenities adjacent to the downtown (Blue Sky Properties, 2019). Finally, a major development project has been proposed just outside of Squamish. The Garibaldi at Squamish, a massive, proposed four season resort could add up to 1,500 hotel rooms and 2,000 residential units (Findlay, 2016).

Despite challenges presented by Squamish's geographic location, neighborhood sprawl, and recent population boom, Squamish has begun to reimagine the lay out of the region by developing a Growth Management Strategy (District of Squamish, 2005) that restricts development outside the containment zone as well as emphasizes the need for pedestrian-friendly areas and development, especially in the "downtown core". Prior to this, residential neighborhoods were even more scattered, and a sizable portion of the downtown area was underdeveloped. These new objectives combined with many other economic and social forces has allowed a considerable number of mostly residential development projects in recent years. The degree of success of such developments in

creating pedestrian connections through the built environment are examined in detail as part of this research project.

1.2. Research Question

The research question guiding this project is embedded in Squamish's history of development and current pedestrian connections as well as its vision to create more walkable, mixed-use, high-density communities. This research attempts to answer the question of whether recent large-scale neighborhood developments in Squamish have created more pedestrian friendly environments by asking, ***what neighborhood features relate to higher results on the Pedestrian Environmental Index (a measure of pedestrian friendliness) calculated at a neighborhood level in Squamish, British Columbia?*** It also asks, **how well do measures such as PEI align with active transportation strategies outlined by the District of Squamish?**

The first objective of this project is to evaluate the current built environment using two walkability indices to understand how different features impact on pedestrian friendliness in Squamish. Building off this initial analysis, the second aspect of this study aims to provide understanding into the usefulness of such indices, specifically within the Squamish edge city context. It will help to establish if and to what degree indices like PEI and MAPS (Microscale Audit of Pedestrian Streetscapes) are valuable tools for smaller municipalities to measure and develop pedestrian oriented best practices or goals. This includes the indices' ability to highlight complexities and failures within existing pedestrian networks and within specific local development context. It is important to note, that "pedestrian friendliness" is a subjective term. It can refer to the to many environmental features or conditions of making traversable surroundings. It can also refer to outcomes or performance of walkable environments for example making streets lively, sociable, or accessible (Forsyth, 2015). The abstract nature of the term is another reason to critically examine the differing ways that pedestrian environments are measured within the field. This analysis will add to researchers and practitioners understanding of the performance such indices in another context. For the purposes of this research, pedestrian friendliness was defined as the extent to which the built environment is passable, compact, safe, and physically enticing with nearby access to businesses and services. Two indices were used, MAPS that considers micro scale features of the environment for example the conditions and fluidity of sidewalks. The

other, PEI uses macroscale features like the performance of street network and access to a wide range of land uses. This research speaks to the broader topics of the measurement and planning of transportation infrastructure, land use, and development by taking an in-depth look at an examples of current neighborhood development trends in Squamish.

This research paper started by setting the broad context for this research both from a geographic and circumstantial perspective. Chapter 4 develops these themes further by diving into the history that has led to the current environment. It also lays out the pedestrian-oriented framework set out by the Municipality of Squamish as well as the existing status of the pedestrian environment throughout Squamish. This is followed by an introduction of each case study neighbourhood as well as comprehensive comparison of the neighbourhood results organized by PEI sub index features. Chapter 4 provides a comprehensive assessment of the background and circumstance related to the pedestrian environment and social context around walkability in Squamish. Some readers may wish to pass over this section. Chapter 5 reveals the overall PEI and the MAPS- Mini microscale scores for the case study neighbourhoods. Before this, Chapter 2 positions this research amongst the overall theoretical published works in this subject area in the Literature Review and Chapter 3 details the methodology that guided this research project. Finally, in Chapter 6, the major themes and findings of this project are addressed.

As hypothesized, neighborhoods closer to core of the town scored higher on both the PEI, the macroscale test and MAPS, the microscale index. There were not clear results in terms of the role MPCs have in determining pedestrian friendliness, although both neighborhoods with MPCs present did score higher on land use density index (LDI), a measure of entropy. In other words, these neighbourhoods have a greater ratio of differing land use types versus the amount of land they occupied. This section also highlights the benefits of the index in its ability to be used as standard baseline or audit tool for measuring pedestrian environments due to its relative ease of use. It also stresses the limitations and challenges of using both indices in the theoretical and practical realms. The paper concludes with the limitations of the research project and discussion of future research in Chapter 7.

Chapter 2. Literature Review

This literature review is separated into three sections that will synthesize the themes structuring the following research question**;** *What neighborhood features relate to higher results on the Pedestrian Environmental Index (a measure of pedestrian friendliness) calculated at a neighbor level in Squamish, British Columbia? Also, how well do measures such as PEI align with active transportation strategies outlined by the District of Squamish?* Density, diversity, and design are common neighborhood characteristics that have been recognized in the literature (Cervero & Kockelman, 1997) to influence pedestrian travel. Thus, the first part of this scholarly review will help establish how these factors are understood to be an appropriate means of measuring pedestrian environments. The next body of literature discussed will both define and establish the pillars of New Urbanism as a design form that is seen as method to solve urban sprawl through creating more walkable communities. I will also discuss the critiques and challenges of implementing and meeting New Urbanist designs and objectives. Finally, I will conclude by reviewing pedestrian indices and evaluate how such indices are understood in the planning context.

2.1. Neighborhood characteristics that influence pedestrian travel

A number of studies over the years have found a relationship between travel behavior and differing neighborhood forms. These studies examined travel outcomes using various neighborhood features including density, land use, population, employment distribution, and transportation infrastructure (Cervero & Radisch, 1996; Handy, 1992; Levinson & Wynn, 1963; Newman & Kenworthy, 1989). Of particular interest for this research, however, are studies that focus on the link between neighborhood characteristics and pedestrian travel.

Research has shown that neighborhood environments do affect the frequency with which people walk within and outside their neighborhoods. For example, (Kitamura, Mokhtarian, & Laidet, 1997) found that neighborhoods with continuous sidewalks and street crossings had higher levels of pedestrian travel. Route directness and connectivity were also found to influence pedestrian travel positively. (Cervero & Duncan, 2003;

Gordon & Peers, 1991; Handy, 1992; Saelens & Handy, 2008) Route directness is a measure of how uninterrupted the pedestrian path is between the origin and destination. Connectivity relates to “how well a pedestrian network connects land use parcels or activity location within an area” (Moudon et al., 1997). Connectivity is a function of route directness and the completeness of pedestrian facilities (Moudon, Hess, Snyder, & Stanilov, 1997). Also related to the idea of route directness and connectivity, Steiner (1997) identified distance as the strongest indicator in determining the decision to walk to a store.

Land use diversity is also associated with greater pedestrian travel in the literature (Cervero & Duncan, 2003; Handy, 1992). A mix of land uses generally includes residential, commercial, institutional, light industrial, as well as entertainment. This diversity of land use means destinations and amenities are within closer proximity to the starting point (Saelens & Handy, 2008). In an ideal situation this places shops, services, housing types, civic centers, and employment nearby, allowing residents to meet most of their daily needs by foot. Finally, research has shown that neighborhoods with higher land use density also have higher pedestrian mode share (Cervero & Duncan, 2003; Kitamura et al., 1997; Saelens & Handy, 2008). In other words, factors which influence pedestrian behavior have been referred to in literature as the three d’s: density, diversity, and design (Cervero & Kockelman, 1997).

Many of the conclusions from prior research as well as more recent evidence show consistent associations between walking for transportation purposes and population density, land use mix, and proximity services and amenities. These characteristics also each relate to the four components of neighborhood pedestrian reliability measured in the Pedestrian Environmental Index (PEI). This is the index chosen as a benchmark for pedestrian ease in this research. The four sub-indices that represent neighborhood characteristics in PEI are land use diversity, population density, commercial density, and intersection density. These four indices have been widely used in other models and have been shown to capture relevant neighborhood characteristics for walkability (Peiravian, Derrible, & Ijaz, 2014).

2.2. Defining New Urbanism in theory and in practice

The concept of neo-traditional development, now a part of the larger movement called New Urbanism is grounded in traditional pre-World War II neighborhood design which contained a mixed-use town center within walking distance for most residents. In broad terms, New Urbanist design encourages compact developments that aim to be pedestrian oriented by using an integration of residential and commercial areas, a grid-like street pattern, narrower streets, shorter setbacks, small lots, alleys, front porches, as well as variations in housing types, design, and materials (Cervero & Radisch, 1996; Congress of New Urbanism, 2000; Handy, 1992; Rodríguez et al., 2006). Another way New Urbanist designs and developments attempt to be conducive to walking is by abandoning the curvilinear streets and cul-de sacs of post-War suburban form. (Cervero & Radisch, 1996).

To further guide implementation of design guidelines, the Congress for the New Urbanism (CNU) has produced a charter of principles. These goals are meant to be flexible and can be achieved in many different ways. In a recent iteration of the charter one of the neighborhood principles states that

> Neighborhoods should be compact, pedestrian friendly, and mixed-use. Districts generally emphasize a special single use and should follow the principles of neighborhood design when possible. Corridors are regional connectors of neighborhoods and districts; they range from boulevards and rail lines to rivers and parkways (Congress of New Urbanism, 2000)

These principles have become increasingly popular in planning theory and practice, especially as they relate to reducing sprawl through design that promotes pedestrian travel. There is considerable evidence that New Urbanist street patterns and land-use mixtures offer many advantages, especially for pedestrians. For example, a study that analysed sets of paired neo-traditional and suburban developments in the San Francisco Bay Area and Los Angeles – Orange County region found that New Urbanist style neighborhoods averaged more pedestrian travel than their suburban counterpart (Cervero & Gorham, 1995). Furthermore, both Handy (1992) and Cerveo & Radisch (1996) found that those living in New Urbanist style neighborhoods made more active

transportation trips for leisure and non-work related trips than those living in auto-oriented areas.

In Canada, many cities have also adopted plans that encourage these principles as well, yet in a case study of three Canadian suburbs attempting to implement these design standards, Grant (2009) finds that many of these design ideals may have limited impact in practice. Grant found even where there was political will and strong commitment from both interdisciplinary planning staff as well as the municipal council to implement these innovative ideas, that market demands, and consumer preferences, for example parking and privacy, often led to compromises or modifications to plans from councilors or planners. There were also institutional barriers to conducting these visions. For instance, a council had recently become supportive of Smart Growth solutions but organizational issues within the administration led to disagreement between engineers and planners. Finally, implementation can prove to be difficult for planners when they lack the intuitional tools to act because of limited support from their council. This obstruction often stems from the fact that many councilors in these municipalities have previous experience working in the development industry. Furthermore, the pressure from private sector comes from the outside as well. Developers argue the high land prices make condominium developments the most plausible within planning guidelines. However, these such projects often facilitate private enclaves and undermine affordability and result in limited connectivity (Grant, 2009).

2.3. Pedestrian Indices

While there has been an emphasis placed on pedestrian accessibility in urban form, there is clearly a gap between theory and practice. Walkability is often incorporated into analysis of neighborhood design in professional practice through visual qualitative approaches, intuition, or traditional patterns of development. However, this process is highly subjective or requires staff that are expertly trained. The level of ambiguity that results from the current method used in planning practice could potentially be reduced by adding a quantitative means of measuring connectivity.

In a review of existing pedestrian indices in the literature, (Maghelal & Capp, 2017) suggest that there are two ways assessment tools can be classified, depending on the results. The first such tools calculate the number of objective features within the built

environment quantifying the suitability of walking into a numeric output. These tools use methods such as scales, levels of service, or indices. More recent analysis of this type has used GIS or similar systems where variables can be standardized as well as visually conceptualized based on their spatial characteristic. The second type uses checklists and surveys to measure the amount of objective and subjective built environment features that either support or hinder walking in neighborhoods (Maghelal & Capp, 2017). Below is a review of a few of the existing pedestrian tools that use objective measures for quantifying the built environment. Certainly, such models are complex and challenging to build but they offer planners and city officials the ability to measure pedestrian connectivity and friendliness over larger scales with decreased costs and time commitments of administering surveys as well as reduced need for multiple field visits.

Walk Score is a free publicly available web-based tool used to measure the built environment as well as promote walkable neighborhoods. Walk Score is now owned by a private company, Redfin but was originally created by a multidisciplinary advisory board based on three components of the built environment that influence pedestrian behavior. These are (1) the distance to a group of destinations and amenities; (2) population density, and (3) block length and intersection density of a given address. The data for this tool comes from various free online mapping databases, including Google, Open Street Map, as well as supplementary data added by the Walk Score user community. (Lo et al., 2019)

In general, Walk Score's output is for an individual address and cannot be computed at a neighborhood level. However, some researchers in Canada and the United States have measured the validity of Walk Scores to estimate a neighborhood's walkability (Cubukcu, Hepguzel, Onder, & Tumer, 2015; Lo et al., 2019). Cubukcu et al. (2015) were able to validate Walk Score using GIS indicators of neighborhood walkability at each of the neighborhood levels chosen in their study. This demonstrates that Walk Score can be an effective measure for estimating neighborhood pedestrian environments for multiple spatial scales. Furthermore, the authors suggest because Walk Score is free, quick, and easy to use, it could be a useful tool for crafting policy and plans for neighborhoods,

> Public health researchers, practitioners and policymakers, regardless of their level of technical experience in geospatial technologies, can easily utilize the Walk Score website. For example, researchers can easily assess the walkability of a person's neighborhood. Practitioners and policymakers can identify and intervene in areas with limited neighborhood resources (Cubukcu et al., 2015).

However, the authors in this study were able to use an additional tool that automatically retrieved mass Walk Score data quickly. Without this tool evaluating Walk Score at a neighborhood level would take considerably more time, cost, as well as may introduce keystroke error. (Cubukcu et al., 2015)

The Leadership for Energy and Environmental Design for Neighborhood Development (LEED-ND) is another rating system that is perhaps the most ubiquitously cited sustainability tool within the literature that is also being used in professional planning. LEED-ND is rating system that integrates aspects of New Urbanism and Smart Growth into a system for rating neighborhood projects on the sustainability of their plans (Boeing, Church, Hubbard, Mickens, & Rudis, 2014). LEED-ND was developed in order to broaden the certification of sustainability beyond green buildings to the scale of neighborhoods. LEED-ND employs many metrics that are similar to the Walk Score and PEI including density, land-use diversity, and accessibility. LEED-ND considers connectivity one of the most essential metrics, where the focus is on increasing the number of passable links through an area (Talen et al., 2013).While promoting walkability is not the only focus of this measurement tool it is a major aspect (Boeing et al., 2014). LEED-ND also has criteria for other social, environmental, and economic sustainability principles. However, due to significant costs as well as time and expertise involved in certifying projects, very few projects have been certified to date (Talen et al., 2013). Also, the use of LEED-ND for mapping development suitability for an entire municipality is infrequent thus far but has been done by a few cities in the United States (Talen et al., 2013). Finally, some literature on LEED-ND has considered its approach as a "one size-fits -all," where developers and city governments must ascribe to very particular and prescriptive design criteria in order to become certified (Boeing et al., 2014; Talen et al., 2013).

The Pedestrian Environmental Index (PEI), the index used in this research, is a relatively new method of calculating pedestrian friendliness of neighborhoods. Like other

models, it uses four components of the built environment that influence pedestrian environments to calculate the PEI. They are land-use diversity, population density, commercial density, and intersection density. The data for these components comes from commonly available GIS data. The results of this measurement tool are region specific and are only comparable between the sectors of the given study area. The authors of this method validated this model using a case study of Chicago. The final outputs of this case study matched with prior expectation of walkable areas in Chicago. Unlike the Walk Score, PEI can be easily calculated at a neighborhood or area level as opposed to a specific point. Additionally, PEI also differs from LEED-ND, in that it is a simpler and more straightforward means to compute pedestrian friendliness for specific environments. These two factors make this model especially suited for planners and municipal organizations. Furthermore, PEI could be used to compare already built environments while also identifying where further investments and funding may be useful to improve existing pedestrian environments (Peiravian et al., 2014).

Finally, the Microscale Audit of Pedestrian Streetscapes (MAPS) differs from the other indices in this section as it measures microscale neighborhood features. For instance, it considers more detailed aspects of a neighbourhood such as streets, sidewalks, and design and social characteristics. This information is typically completed through in person audits however, analysis using online imagery has also shown to be effective (Millstein et al., 2013; Fox et al., 2021). This index is similar to the previously noted indices in that it uses a scoring system. This scoring system was developed by categorizing theoretical streetscape elements of walkability into a tiered classification system. Most variables were coded dichotomously for simplicity and for frequency-based questions they were trichotomized. Statistical analysis was used to assess the inter-rater reliability. Within each subscale (destinations and land use, streetscape, and aesthetics and socials) items were aggregated into either a positive, negative, or positive-negative valence scores. Items such as presences of schools, public parks, drinking fountains, public art, landscaping, and pedestrian signage were thought to positively influence walking. Variables that were combined into the negative scores were thought to prevent walking. For example, high speed limits, adverse land use type, driveways intersecting sidewalks and non-barrier curbs were all grouped into the negative valence scores. The sub scores for each of these items ranged from moderate to excellent reliability scores. When the subsection scores were combined, the overall score had good/excellent

reliability. The scoring system in this tool is an advancement over other microscale audits that do not include the same level or any detailed numerical grade. Furthermore, many of them do not evaluate or report on the reliability of variables (Millstein et al., 2013) The easily interpretable scores of MAPS make the index more useable for policy makers, planners, and city officials however, the expense and time of data collection of microscale audits has hindered the use of such tools in practice. Lastly, while MAPS is expected to be generalized to metro areas in North America its uses in more rural environments have not been tested and published. It is hypothesized that some results would be applicable in such settings, deeper understanding and development of the tool is needed in this context.

2.4. Summary

This literature review has provided insight into how the built environment influences pedestrian behaviours as well as the various methods and variables used by researchers to measure the objectives for walkable neighborhoods. This body of knowledge provided me a baseline for understanding the factors and features that are influencing pedestrian environments in Squamish and the multitude of ways these could be measured. The academic literature regarding the concepts and design of New Urbanist principles developed by the CNU helped shape my understanding of how developers and municipal officials may be approaching new development practices taking place in Squamish. However, previous studies have also made clear that less is known about outputs or outcomes of these theoretical design principles, especially in municipal development practice. The literature reveals that there is a demand for new measurement tools and guidelines that can help direct future projects and neighborhood plans.

I found a similar necessity for such tool within Squamish when reviewing the pedestrian travel related goals in the planning documents. While the district has clearly stated objectives for achieving better walkability there is lack of a measurement or tracking tool that could visually and numerically highlight critical areas. This is outlined in Chapter 4 and expanded upon in Chapter 6 - Finding 4. The last section of this chapter reviewed the use of existing quantitative pedestrian tools in literature and practice. Scholarly research is beginning to analyze how pedestrian environment measurement tools may function beyond research and be adapted for use by government agency or

planning consultants. There are clear gaps, specifically in the understanding of how pedestrian indices may function at the planning level and how results are perceived and experienced. This is especially true in the context of a periphery city or non-population dense municipality like Squamish which have been the subject of even fewer academic studies in this field. In summary, this literature guided me in subsequent aspects of this research. The large body of work pertaining to characteristics and features that are most known to influence pedestrian environments as well as the review of pedestrian indices helped me narrow down the measurement tools that would be most relevant for use in this project. The next chapter, Methodology and Data Collection, outlines in detail how and why and how each index was used to measure pedestrian friendliness in Squamish.

Chapter 3. Methodology and Data Collection

3.1. Research Design

This research project utilized a mixed method approach to evaluate how neighborhood design and the built environment are related to measures of pedestrian friendliness at a neighborhood level in Squamish, British Columbia. First, data was evaluated using a quantitative spatial analysis. Geographic Information Systems (GIS) was used to describe how pedestrian friendly each neighborhood environment is based on measures of land use, density, and form. Secondly, observations were collected of neighborhood features at a street scale using the Microscale Audit of Pedestrian Streetscapes (MAPS) as a guide. The results of the quantitative spatial analysis were than compared to microscale neighborhood features using a systematic qualitative approach. In other words, neighborhood characteristics collected through observations of the study area as well as census data will help interpret the results of the spatial analysis. Finally, relevant municipal documents and media were reviewed. This gave a perspective into the planning history of the study area, especially focusing on development and pedestrian networks.

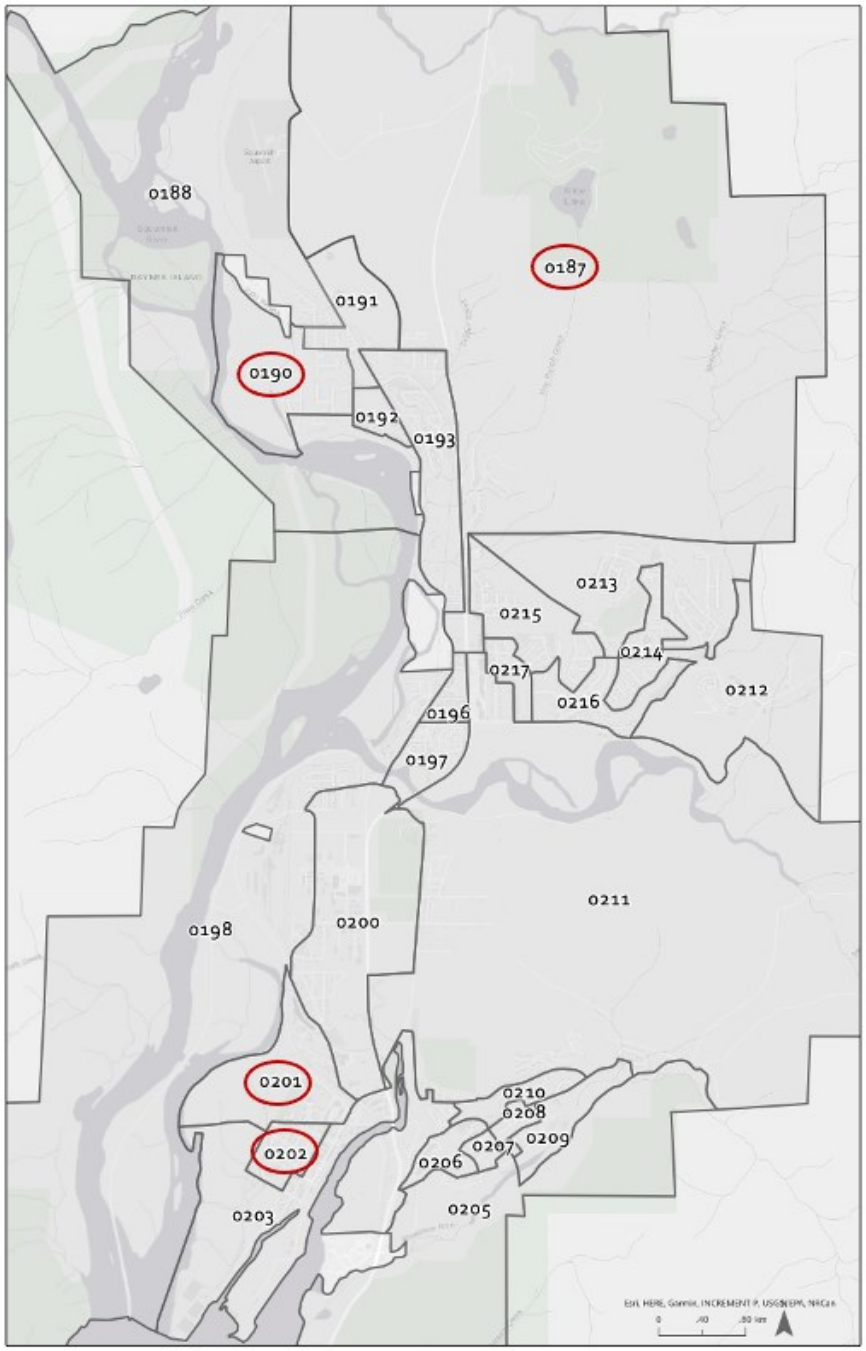
The content analysis was used to identify commonalities and differences between Squamish's stated active transportation goals and the results of the quantitative and qualitative findings in the research. This multiple method approach provides a strong empirical base and analytical framework on which to evaluate this case study. Furthermore, a sequential quantitative and qualitative research design helped to synthesize findings that are equivalent and to investigate gaps and contradictory findings (Fielding, 2012).

3.1.1. Study Area

This research assesses dissemination areas (DAs) in Squamish, British Columbia. The research area spans the boundary of the District of Squamish, from Britannia Beach at the southern end about 35 km north to Squamish North. Analysis was completed at a DA level because this is the smallest area unit that Statistics Canada provides for population and boundary data in Squamish (Figure 3.1). While the original intention was to identify and analyze the pedestrian friendliness of master planned

communities in Squamish, these developments are too small and for privacy and data aggregation reasons census data is not collected at this level. DAs have standard population size range and are designed for collection convenience.

Figure 3.1 DAs within Study Area



3.1.2. Comparative Analysis of Four Unique DAs

To gain a better understanding of pedestrian environments within Squamish four DAs with unique characteristics were chosen for an in-depth comparative analysis (Figure 3.1). This was necessary because while PEI scores could be calculated relatively easily for every DA, for the scope of this research it was not possible to take individual observational streetscape audits of every DA within Squamish.

Of the 26 DAs located within the District of Squamish boundary, the four DAs were selected because they offered a matrix of variables ideal for comparative analysis between them. The core variables used to select the DAs were location relative to the urban core and the presence or absence of newly built development communities. Other variables that were also considered were housing tenure, population, land use and access to services and amenities, as well as the age of occupied private dwellings within the DA (this served as proxy for comparing older and newer development and neighborhood design). To assist with analysis, criteria were chosen so that strategic comparisons could be made between pairs with similarities and differences. This approach was used to better understand if there are shared factors that are influencing both the quantitative and qualitative outcomes related to the friendliness of pedestrian environments.

The four DAs selected were 59310201 (201-DM), 59310202 (202-DN), 59310190 (190-PN), and 59310187 (187-PM) shown in Figure 3.1.[1] Two are downtown (201-DM and 202-DN) and the other two are located in the periphery, about 5 to 10 km north of the Squamish downtown area (187-PM and 190-PN). Of the four DAs, 201-DM and 187-PM were selected because they both had significant large scale planned communities built within the last 15 years. Solterra's Eaglewind 20-acre housing development, with about 200 townhomes, 100 one- and two-bedroom apartments, and an assortment of duplexes is contained within DA 201-DM ("Solterra Development Corp. | Past Communities," 2020). DA 190-PN also includes a 20-acre master planned community

[1] The notation DM, DN, PN and PM is provided to quickly remind the reader of the location relative to downtown, and presence of master planned community in each case study DA. The letters represent: P=Periphery, D=Downtown, M=Master Planned, N=Not Master Planned. Hence for example, DM denotes the Downtown DA which includes a master planned community.

developed by Diamond Head Development called Skyridge. It has about 30 single family lots, 20 duplexes, 26 townhouses, 44 apartment units, and a Montessori school ("Site Plan + Lots | Skyridge," 2020). While both DAs located downtown have a considerable amount of occupied private dwellings built between 2000-2016, DA 201-DM includes the Eaglewind MPC while DA 202-DN did not include any MPC in this period. Table 3.1 below highlights key characteristics of the four DAs picked for further analysis.

Table 3.1 Key Variables for Comparative Analysis of Squamish DA Pedestrian Environments

	187-PM	190-PN	201-DM	202-DN
Downtown Location			✓	✓
Periphery Location	✓	✓		
Presence of Master Planned Community	✓		✓	
Majority of occupied private dwellings constructed 2000-2016	✓		✓	✓
Majority of occupied private dwellings constructed before 1981		✓		
Majority attached dwellings			✓	✓
Majority single detached house	✓	✓		
Majority Renter			✓	✓
Majority Owner	✓	✓		
Considerable access to services and amenities			✓	✓
Main mode of commuting – walk	4.1 %	3.7%	12%	14.5%

(Statistics Canada, 2016)
Notes: P=Periphery, D=Downtown, M=Master Planned, N=Not Master Planned

3.2. Pedestrian Environmental Index

A quantitative spatial analysis called the Pedestrian Environment Index (PEI) was used to measure the pedestrian friendliness of Squamish. PEI is a measure of pedestrian ease at a neighborhood level. It uses a straightforward GIS calculation and accessible data to easily compute four components of neighborhood pedestrian friendliness that are then combined to calculate the PEI. The four components or sub-indices are: land-use diversity (LDI), population density (PDI), commercial density (CDI), and intersection density (IDI). These four sub-indices characterize neighborhood design features discussed in Section 2.1 that have been found in literature to support and

enhance pedestrian friendly environments. This method was chosen because it is objective, captures key walking related aspects of the neighborhood, as well as being simple enough to apply across multiple DAs within Squamish (Peiravian et al., 2014).

The following equations were used to analyze the Pedestrian Environment Index (Peiravian et al., 2014):

Table 3.2 Calculating the Pedestrian Environmental Index

Pedestrian Environment Index (PEI)	For each Neighborhood: PEI= 1/16 [(1 + LDI) x (1+PDI) x (1+CDI) x (1 + IDI)], 0 <PEI < 1
Intersection density index (IDI)	Measures the density of intersections (street crossings) in a given area
Population density index (PDI)	Measure of population density in each area
Land-use diversity index (LDI)	Measure of diversity of land-use (mix of residential, commercial, and other uses) in a given area
Commercial density index (CDI)	Measure of commercial activity in a given area

3.2.1. Data Collection and Preparation

The following spatial data was collected from Squamish's Open Data Portal (District of Squamish, 2016):

1. Street Networks – used to calculate IDI
2. Zoning and Land Use Designation – used to calculate LDI & CDI
3. Building Parcels – used to calculate CDI
4. Squamish Municipal Boundary – used to calculate IDI, PDI, LDI, & CDI
5. 2020 Business Licenses – used to calculate CDI

Dissemination Area boundary data was collected from Statistics Canada:

6. DA Boundaries – used to calculate IDI, PDI, LDI, & CDI

Sociodemographic spatial data while derived from the Canadian Census was downloaded from the University of Toronto's Census Analyser (CHASS Data Centre) at the DA level:

7. Population by DA – used to calculate PDI

To calculate the Gross Floor Area (GFA), a component of the CDI, the number of floors of commercial building was needed. Since there are few commercial spaces with more than one floor and this information could not be found in any previous online data sources, this data was collected through emails with the District of Squamish GIS staff, Google Maps Analysis, and a in person audit completed on Saturday May 29, 2021.

Once all the data was uploaded into GIS and before any further spatial analysis occurred the area covered by all waterways, airports, and highways were removed from the base layer because they are generally not used for pedestrian travel.

3.2.2. Intersection Density Index (IDI)

The IDI measures the density of street crossings in each DA. To determine this, first the sum of intersection equivalency factors within each DA must be calculated. The intersection equivalency factor is the number of streets that meet at an intersection. For example, a 4-way intersection would have equivalency factor of 4, whereas the end of a cul-de-sac would be 1. The intersection density is calculated for each DA by dividing the sum of intersection equivalency factors in each DA by the area of the DA. IDI is then determined by comparing intersection density of each DA with the DA with the maximum intersection density. Thus, the DA with the maximum intersection density will have an IDI of 1. IDI is defined mathematically by Peiravian et al as:

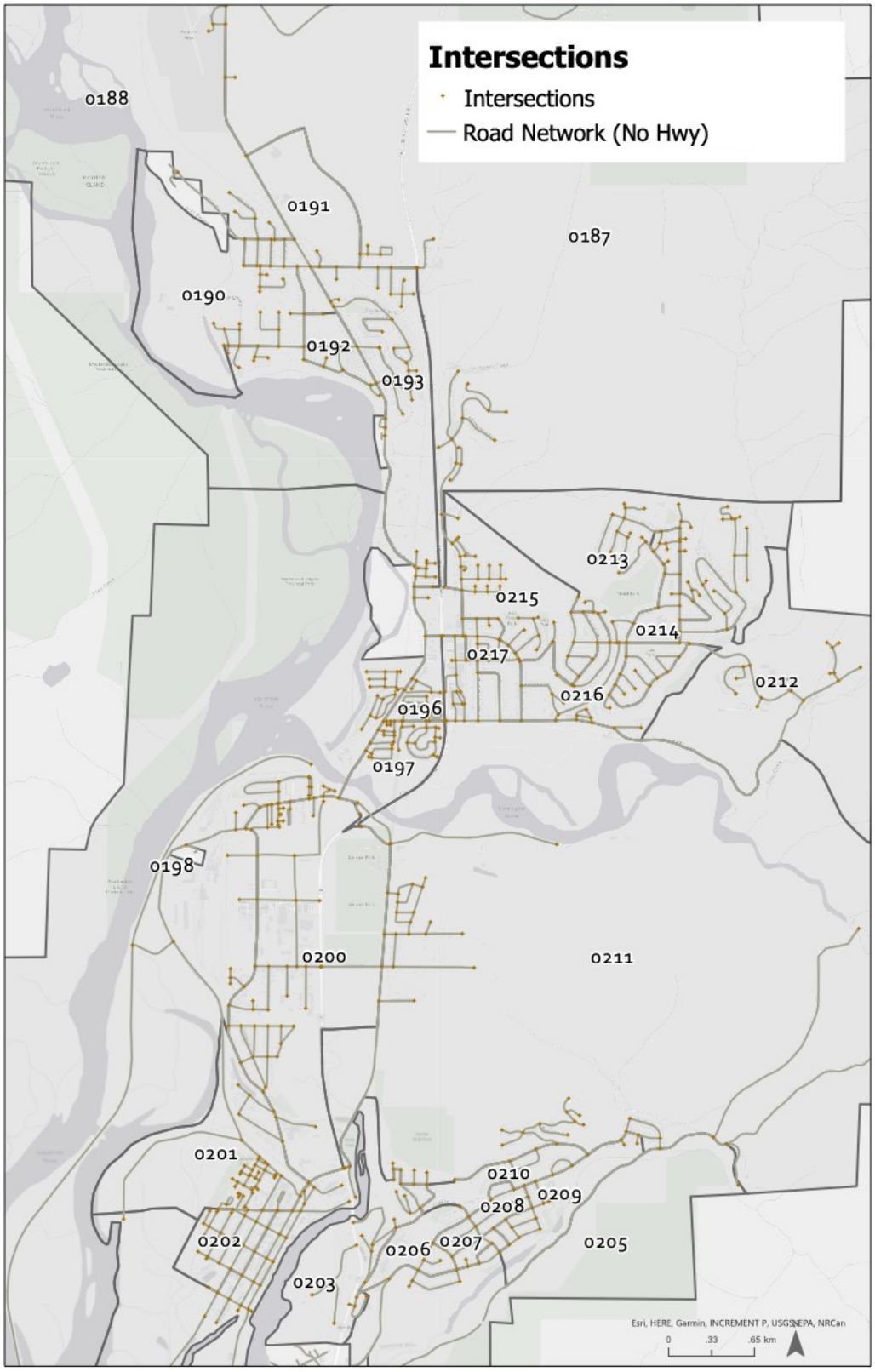
$$IDI = \frac{\left(\frac{\sum n_{ij}}{A_i}\right)}{max\left(\frac{\sum n_{ij}}{A_i}\right)}, 0 \leq IDI \leq 1$$

Where n_{ij} is the intersection equivalency factor for a given intersection j in zone i and A_i is the area of zone i . For all indices in the PEI, the denominator is the

maximum value of numerator across all DAs within the study zone. This is valuable to normalize the index and keep the index region specific. (Peiravian et al., 2014).

To calculate this in ArcGIS Pro, a custom geoprocessing script tool was used called the Create Junction Connectivity Features which was downloaded from the ArcGIS Analysis and Geoprocessing Tool Gallery. This tool counts the number of lines connected at a point in a line feature class, in this case the Squamish Street Network layer (Beale, 2012). Traffic islands, round-abouts, highway pull outs, and double lanes with a middle island were manually cleaned within the Squamish Road Network layer as to not inflate the intersection equivalency factor. As an example, a roundabout that has four streets connecting into it would have originally been counted as intersection equivalency of 12. However, after the layer was cleaned it was only counted as 4, to make the intersection count more accurately for pedestrian friendliness. Figure 3.2 shows intersection junctions and road networks as an example of the street layout within Squamish, BC.

Figure 3.2 Intersections and Road Networks by DA, Squamish BC



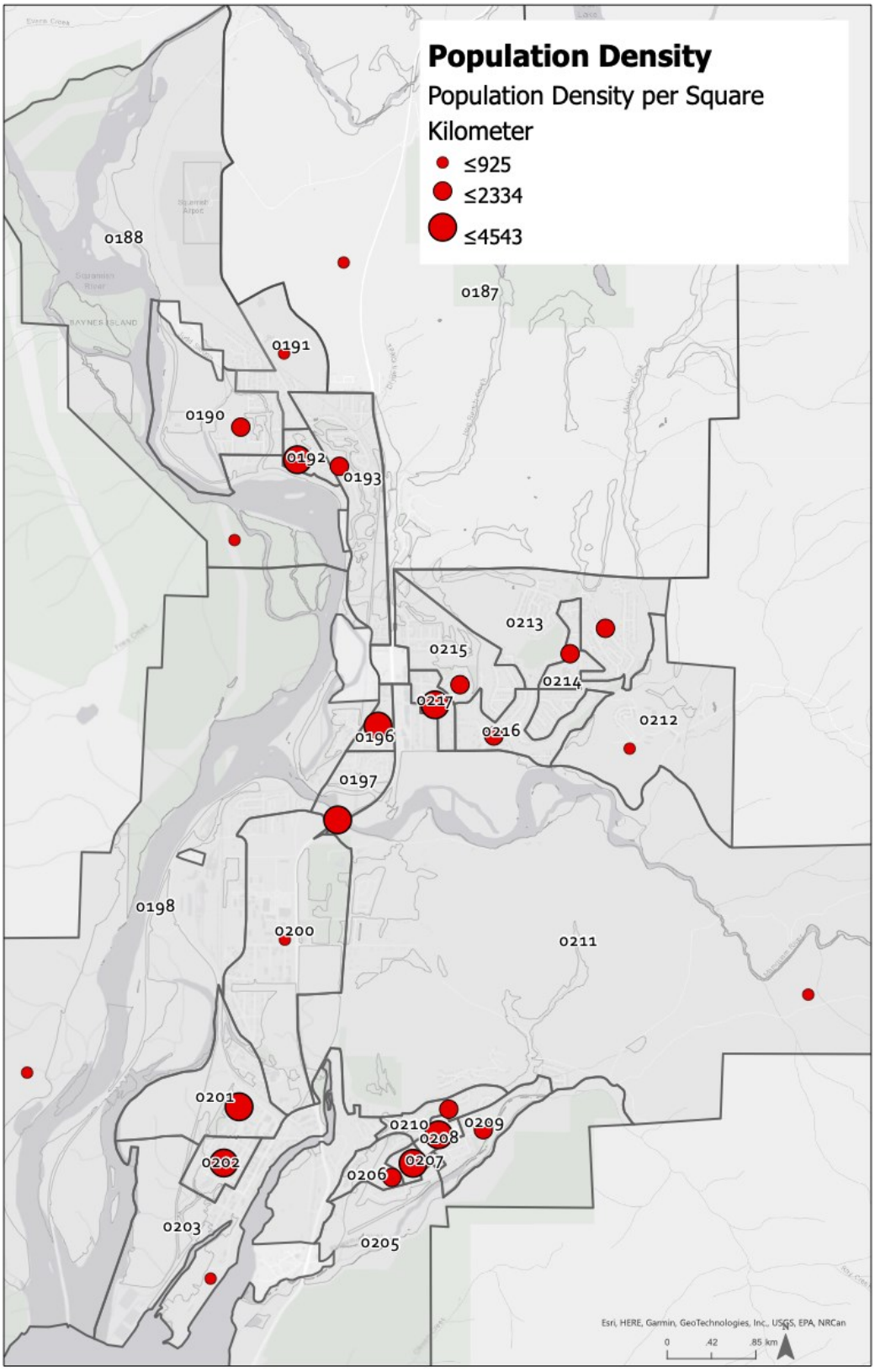
3.2.3. Population Density Index (PDI)

The PDI measures the population density in each DA. PDI is defined mathematically by Peiravian et al as:

$$PDI = \frac{\left(\frac{Pop_i}{A_i}\right)}{max\left(\frac{Pop_i}{A_i}\right)}, 0 \leq PDI \leq 1$$

Where Pop_i is the total population in the in the study zone i and A_i is the area of zone i (Peiravian et al., 2014). PDI is calculated in ArcGIS software using the population by DA spatial data downloaded through CHASS as well the area of each DA. The PDI is also normalized using the same method as in the IDI and other sub-indices. A score closer to one means that the population is denser. More densely populated areas are often found in and near downtowns where street lengths are often shorter and access to services and amenities is closer, two other characteristics that are also positively correlated with walking in the literature.

Figure 3.3 Population Density by DA, Squamish BC



3.2.4. Land Use Density

It has been well documented in many studies that a greater land use mix supports a higher share of trips made by walking. (Devlin, Frank, & Chair, 2009; Moudon et al., 1997; Saelens, Sallis, & Frank, 2003). Land use density is the ratio of different types of land use over a given area, or in other words, it is a measure of how homogenous or heterogeneous the land use is in a given area (Peiravian et al., 2014). This method uses the concept of entropy to calculate the Land Use Density Index (LDI). Entropy relates to the degree of randomness versus order within a spatial pattern (Ewing et al., 2001; Peiravian et al., 2014). In this case it captures the amount of land use mix within a given DA. Peiravian et al use the formula below to describe entropy:

$$E_i = -\frac{\sum_{j=1}^{k}(p_j + \ln(p_j))}{\ln k_i}$$

Where p_j is the ratio of area of land use type j compared to total area of the study zone i and k_i is the total number of different land use types chosen within the study area. A higher entropy score indicates a higher land use mix.

Peiravian et al do not specify particular land use types to be considered in this method thus to calculate the entropy of each DA in Squamish the number and type of land use mix categories needed to be selected (2014). It was important to consider that in this method a change in the types of land uses or number of categories used to measure the entropy score would change the results for the same area. The Squamish 2020 Zoning Bylaw Update, which outlines six fundamental zoning categories was used to determine the land use types selected to calculate entropy in this study ("2020 Zoning Bylaw Update - District of Squamish - Hardwired for Adventure," 2020). They are Residential, Commercial, Open Space, Institutional, Comprehensive Mixed Use, and Industrial. Because this research is focused on the characteristics that affect pedestrian environments within Squamish, these six zoning categories captured in current Squamish planning and policy were appropriate to calculate entropy for this project.

To calculate entropy in ArcGIS the zoning layer was used to identify 44 unique zoning descriptions and categorize them into the closest matching of the six land use types selected for calculating entropy (Table 3.3). Three zoning descriptions were removed from the data: 'Groundwater Protection,' 'Uncoded,' and 'Resource.' 'Groundwater Protection' was removed because the PEI methodology excludes waterways from the study area. 'Uncoded' was removed because the land use type is unknown.

Table 3.3 Land Use Categotization for Calculating Entropy

Land Use Type	Zoning Description
Commercial	Crematorium Commercial, Downtown Commercial, Gasoline Service Station Commercial, Highway Commercial, Local Commercial, Neighbourhood Pub Commercial, Recreation Commercial, Specialized Highway Commercial, Tourist Commercial
Comprehensive Development/ Mixed Use	Artisan Village, Comprehensive Development Comprehensive Development Zone Mixed Use District
Industrial	Business Park Industrial, General Industrial, Industrial, Industrial, Used Goods, Light Industrial, Light Industrial Small, Lot, Log Sort, Rail Marshalling Yard, Rail Transportation, Rock Processing, Specialized Business Service Centre, Specialized Industrial Business
Institutional	District Assembly, Neighbourhood Civic, University Campus University Housing
Park	Ecological Reserve, Neighbourhood Park and School, Park, and Public Use
Residential	Multi-Unit Residential, Multiple Family Residential, Residential Residential Mobile Home Park, Residential Modular Home, Residential Small Lot, Rural Residential

Finally, 'Resource' areas were originally classified into the land use type 'Park' because while the intent of this code is to classify land used 'for resource activities typically located in the rural portion of the municipality,' many recreational activities like hiking, biking, and camping also take place on this land. However, the decision was

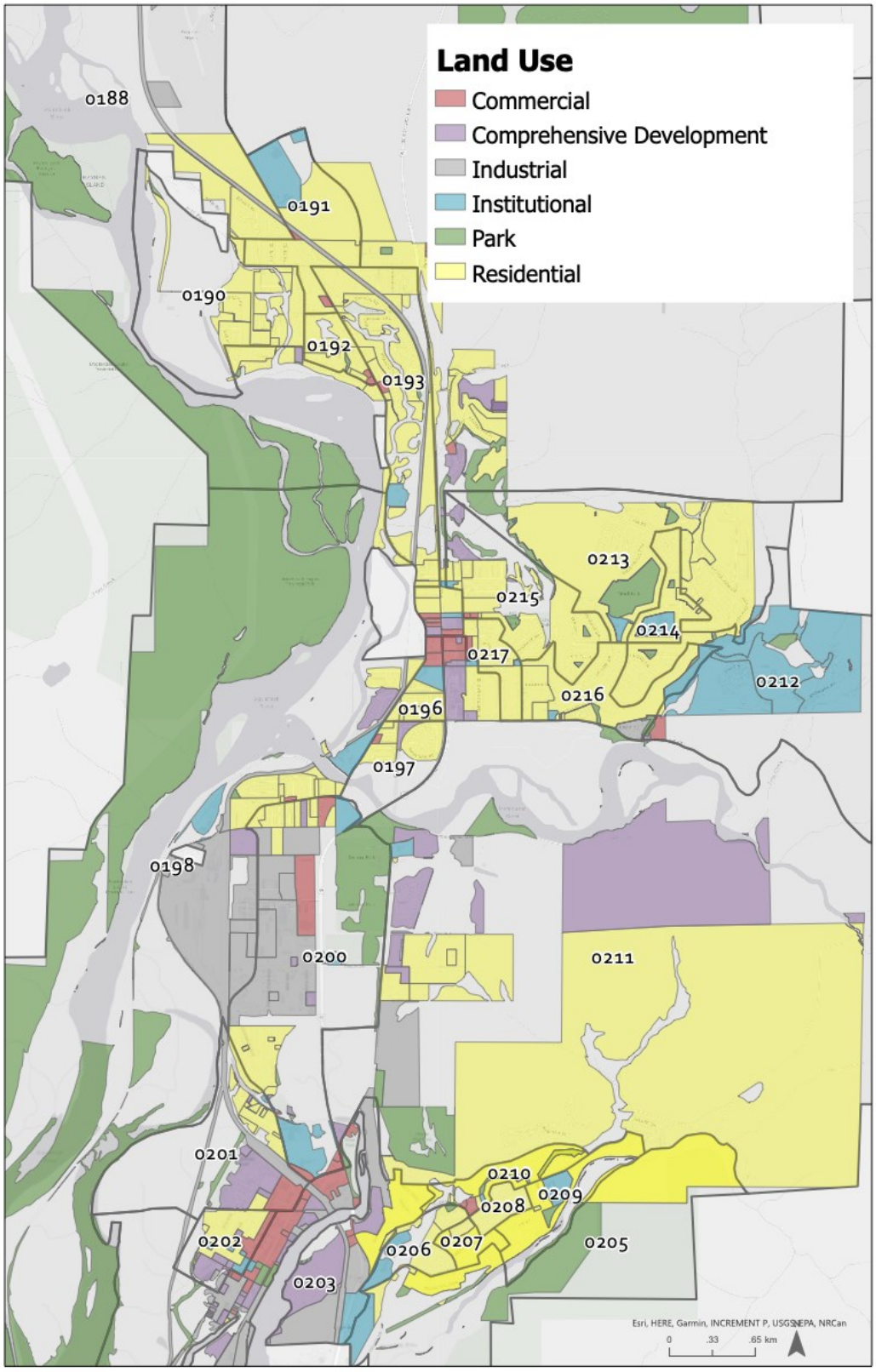
ultimately made to remove ‘Resource’ land from the study area. There were two reasons for this. First, there is a large amount, approximately 35,000,000 square meters of ‘Resource’ zoned land within the District of Squamish. The entropy calculation used by Peiravian et al is expressed by not only the number of diverse types of land use but also the total area of each land use type. Therefore, in many rural DAs where substantial portions of land was coded as ‘Resource’ entropy scores were inflated. Secondly, most of this land is undeveloped, forested land and while recreational activities occur in these areas, they are typically located in the rural portion of the municipality which would not be accessible through means of active transportation. There is an effort within this study to focus on urban uses of park or recreational space that residents are easily able to access through pedestrian travel. Most of this land was not within walking distance.

Once the zoning descriptions were recategorized into the six selected land use types in ArcGIS, the entropy of each DA was calculated using the summarize and calculated field function within the attribute table. When calculating entropy, according to Periavian et al “The numerator is maximized when all land-use types in a study zone have equal proportions. For instance, an area with 50% residential and 50% commercial leads to $E_i = -[0.5 \times \ln(0.5) + 0.5 \times \ln(0.5)] / \ln(2) = 1$.” The denominator for the entropy equation is the total number of different land use types chosen within the study zones. For this research, the denominator was $\ln(6)$ for all DAs since six land use categorizations were chosen. The authors use this entropy calculation to determine the Land Use Density Index which they define mathematically as:

$$LDI = \frac{E_i}{max(E_i)}, 0 \leq LDI \leq 1$$

Where E_i is the entropy for the given DA and the denominator is the maximum value of the numerator across all DAs in the study area. Periavian et al use this mathematical statement to describe LDI because it normalizes the index between 0 and 1 (2014). This means that it is region specific and can be used in this case for comparing entropy and LDI of each DA across the entire district. A DA with an outcome closer to 1 has a greater diversity of land use types in the area and may consequentially mean that residents have a greater opportunity to accommodate pedestrian trip for daily undertakings.

Figure 3.4 Land Use by DA, Squamish BC



3.2.5. Commercial Density

Areas with multiple businesses attract people from immediate surroundings and function as destinations for work or personal trips. Areas with higher volumes of commercial establishment increase the accessibility and availability of these destinations within a walking range. In a recent statistical analysis taking place in neighborhoods in Seattle and its surrounding suburbs, C. Lee & Moudon, (2006), while testing common variables often tied to walkability in literature, found that commercial density variables were in fact associated with walking. Peiravian et al use Commercial Density Index (CDI) to characterize the concentration of several types of businesses and services that are accessible for residents' daily needs (2014). The equation used to mathematically represent CDI is:

$$CDI = \frac{GFA_i}{max(GFA_i)}, 0 \leq CDI \leq 1$$

CDI is determined by a ratio of the total Gross Floor Area (GFA_i) of commercial establishments within a DA divided by the greatest total GFA_i measured across all DAs in Squamish. The GFA is a measurement that totals all areas available for commercial activity within a building across all the floors of the building. If a building's sole utility is for commercial use that is the sum of the products of the building footprint multiplied by the number of levels that building has.

GFA was calculated in Squamish using a combination of spatial data including the 2020 business licenses layer overlayed on top of building parcels and zoning and land use designations layers. There was some difficulty accounting for business locations within in Squamish due to many Business Licenses being registered to residential addresses. According to a GIS staff at the District of Squamish, one reason for this is that many family businesses operate the office administration for a business from their home while the labor occurs at a different commercial space. This arrangement also facilitates shorter term leases for commercial space. The same District employee also noted that many trades work out of self-storage units, as their work doesn't necessitate much space. Both of these experiences are either not substantiated or well-defined in the spatial data available. To not misrepresent the reality of where businesses are located in Squamish and because the intensity of commercial establishments, including work destinations are a key factor in determining pedestrian

accessibility, it was determined that any manufacturing, construction, or related business that was located in a residential neighborhood would not be included in the study. Specifically, business licenses of this nature that were in residential zoning were removed from the data. The main purpose of this commercial activity was likely not occurring at this location and thus including it in the data would likely inflate the total GFA and thus CDI in that DA. To eliminate business licenses in residential zoning areas the 2020 business licenses layer was combined with the Zoning layer. Businesses licenses classified as 'Manufacturing,' 'Construction,' 'Agricultural and Forestry' 'Utilities' and 'Transportation & Warehousing' were then removed from areas that were zoned residential. Other service-related sectors for example business licenses that included descriptions of 'Personal Services,' 'Day-Care Services,' 'Bed and Breakfasts,' 'Independent Artist,' and 'Professional, Scientific, and Technical Services' were left in residential zones. This was because these professions were more likely to have daily operations that are performed entirely at home offices or workspaces.

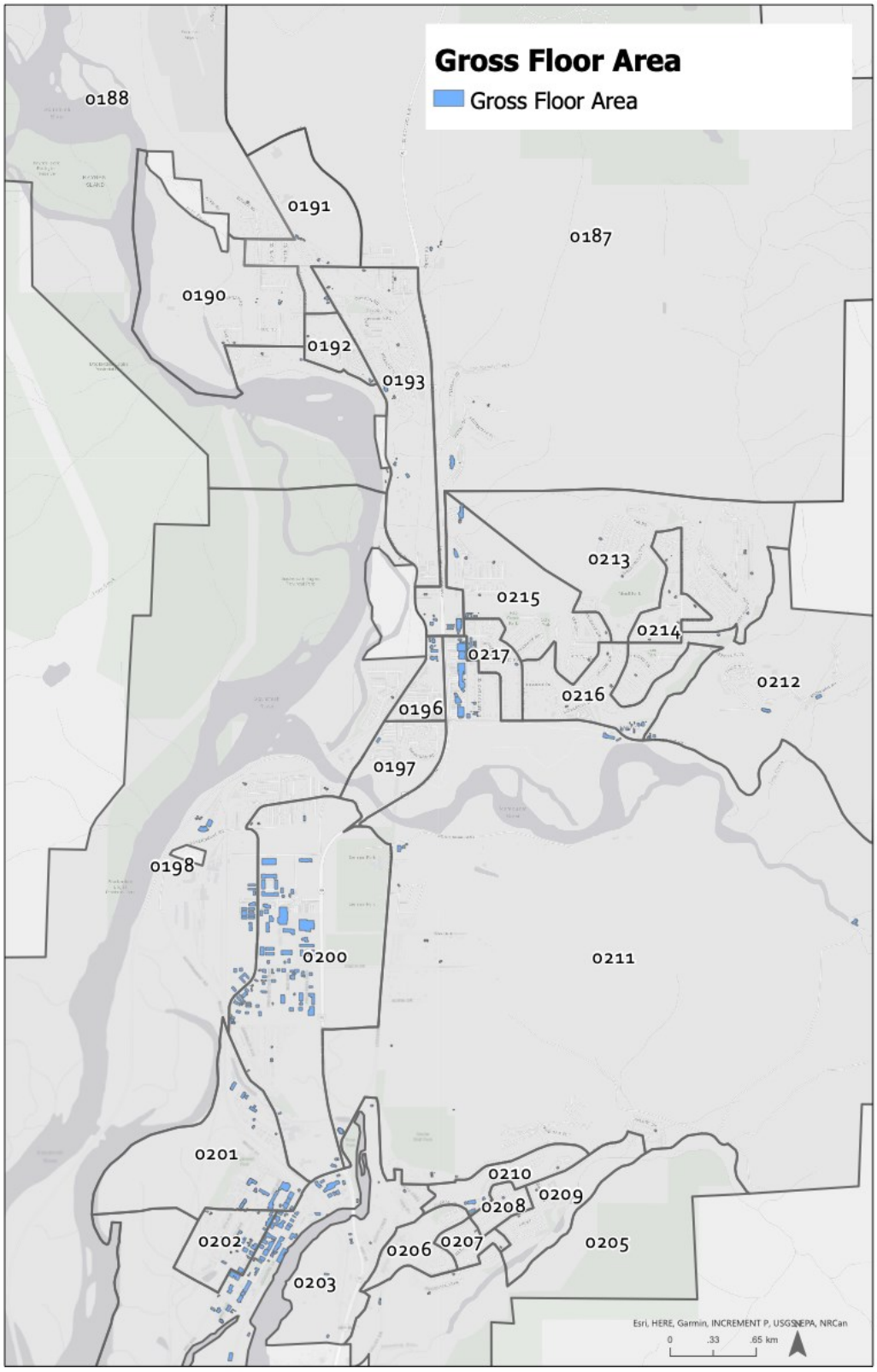
Another challenge in calculating GFA, and thus the CDI in Squamish is the lack of available spatial or non-spatial data for building heights or the number of floors of commercial properties. Data regarding commercial buildings with greater than one floor was collected through a combination of emails with the District of Squamish GIS staff, Google Maps Analysis, and finally a physical audit completed on Saturday May 29, 2021. Once this audit was completed, 2020 building licenses layer was overlayed with Squamish building parcels which includes data on the footprint area of the building. Parcels that did not include business license were eliminated from the data, in order to only keep parcels that are known business entities in Squamish. A column was added in the attribute table and the number of floors was added for all commercial sites. The calculate field function was used to calculate the total GFA for each DA. A combination of the summarize and calculate field functions were used to calculate CDI scores.

The authors of the PEI model chose to use GFA because in many urban areas with downtown business zones, commercial buildings have many floors. This calculation better represents the physical space used for commercial activity rather than a simple calculation of the building's footprint. However, the commercial landscape in Squamish is vastly different from a mid or large urban area and there are relatively few establishments that have more than one floor with business activities. While the GFA was collected and calculated for the commercial buildings in Squamish this likely had

little outcome on CDI in Squamish due to the small number of businesses that have greater than one floor.

The authors have again normalized the index for CDI like they did for the previous three indices. The denominator in the CDI equation is the maximum total GFA measured across all DAs. This means that the CDI falls between 0 and 1 for all the DAs calculated. DAs with a CDI closer to 1 indicate a greater number of commercial services in an area. This suggests that businesses would be easier to walk to in this DA.

Figure 3.5 Gross Floor Area by DA, Squamish BC



3.2.6. Pedestrian Environmental Index

Calculating the Pedestrian Environmental Index (PEI) was the final step in the defining the pedestrian environment through a landscape scale quantitative analysis. The resulting layers from the previously calculated four individual sub-indices were combined in order calculate the PEI for each DA. PEI as defined by Peiravian et al. (2014) is:

$$PEI = \frac{1}{16}[(1 + PDI) \times (1 + IDI) \times (1 + LDI) \times (1 + CDI)], 0 \leq PEI \leq 1$$

Where PDI is the population density index, IDI is intersection density index, LDI is land use density index, and CDI is commercial density index for each DA. This calculation combines each index to realize the total impact on the pedestrian landscape. The authors choose to use multiplication to join the indices, instead of summation to highlight the causality of factors influencing PEI within a neighborhood. For example, a change in land use density would likely also change the number of people who choose to live in an area, the population density.

The PEI was defined in the ArcGIS by joining the attribute tables of IDI, PDI, LDI, and CDI. Using the equation for PEI, the calculate field function was used to determine the PEI score for each DA. The results were then displayed on a map that showed a unit output that represents the Pedestrian Environmental Index, between 0 and 1 for each DA, where 1 is high walkability and 0 is low walkability.

The full analysis of the Pedestrian Environmental Index involved the interaction of data and maps together which enables the visualization and exploration of geographic information and analytical patterns and results. By combining maps, related tables, geospatial tools, and equations, as well as graphs and charts the analysis is a sequential iterative process of examination and the visualization of maps and data.

3.3. Microscale Audit of Pedestrian Streetscapes

The Microscale Audit of Pedestrian Streetscapes (MAPS) tool was chosen to both guide the observational aspect of this research and as means to examine streetscape features of the built environment. Microscale neighborhood features are

defined as environmental factors that are measured at a smaller scale. Microscale factors, like macroscale walkability variables, are thought to be important indicators in influencing pedestrian activity and safety but have not been studied as extensively as macro level attributes of the environment. The subcomponents of the first indices, PEI, used in this study, land use density, street connectivity, population, and commercial density are considered macro-scale environmental features. However, consideration of microscale feature allows for a more granular examination of how people experience the built environment. Microscale environmental factors reveal details about the condition and continuity of sidewalks, presence of bike paths, street characteristics, as well as design features including the existence of parks, trees, benches, and streetlights. The use of a microscale index in this study will help to answer the component of this research that asks if and what microscale neighborhood features relate to higher metrics on the PEI index. Further it will serve as a comparison index to the PEI index. The results from each index will be reviewed using the four comparative DA to better the validity and use cases for each measurement tool. Finally, this tool will allow me to make in person observations of each of the four case study neighbourhoods.

The original MAPS tool was adapted from prior instruments used to assess streetscape details connected to physical activity. The authors who developed the tool sought to find a systematic scoring system to examine a wide range of microscale environmental attributes. They did this through collecting segment level variables on every segment of the study area. Variables assessed but not limited to include sidewalks, sidewalk condition and slope, street buffers, trees, streetlights, and bicycle infrastructure and facilities(Cain et al., 2017; Millstein et al., 2013). The authors then used a tiered scoring system which classifies the variables into subscales at multiple levels of aggregation. The framework for developing the scoring system was based on relevant theory and expert insight and consensus. The MAPS scoring convention uses a coded system in order to simplify the scoring. Most questions are code dichotomously as 0 or 1, yes or no and in some instances where the question is asking about the frequency or description of an item, they are scored trichotomous as 0,1, or 2(+) (Millstein et al., 2013).

The validity of the MAPS observational variables were established through the correlation of multiple microscale features with multiple physical activity measures across four age groups. The results found that modifiable built environment features are

associated with physical activity, independent of macro-level walkability factors. The strongest correlation was with MAPS summary scores suggesting that walkability is more likely to be impacted by a collection of many microlevel environmental features, rather than an individual variable (Cain et al., 2014a, 2014b, 2017). The authors of the MAPS tool assert that these findings are especially significant because neighborhood and street level features are both feasible and affordable to modify unlike macro-scale adaptations which requires a complete restructuring of neighborhood or city layout. These studies took place in urban and suburban neighborhoods in three differing US regions, Seattle/King County, WA, San Diego, CA, and the Baltimore, MD-Washington, DC (Cain et al., 2014b, 2017; Millstein et al., 2013; Sallis et al., 2015)

3.3.1. Data Collection and Observations

The original MAPS measure is a 120-item audit survey meant for in depth researcher use. Given the constraints of this research including multiple DAs to observe with limited time and resources the abbreviated 15 question MAPS-Mini tool was adapted for observations in this study. The MAPS-Mini was developed for practitioner, advocacy, and community member use and has a high correlation with the full MAPS tool meaning that it is an effective means to measure the pedestrian environment of neighborhood at a street scale (Sallis et al., 2015).

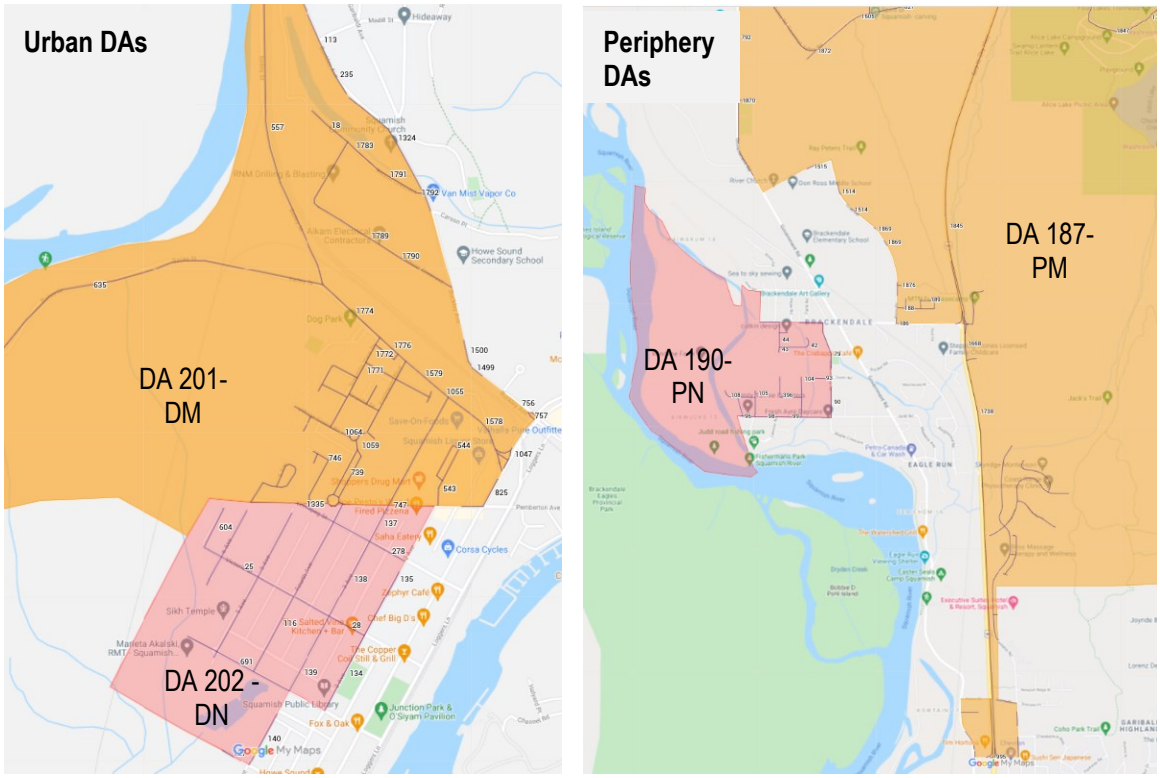
Typically, MAPS observations are conducted on ¼ mile route starting from a residential address towards a designated destination such as a shop, community center, park, or school. This method was chosen to standardize the method, limit observation time, as well as ensured observation were relevant to participants. However, this approach was not suitable in this research because the objective was to measure every street segment within each of the four chosen DAs. Instead, in this study segment- level data collection was used as the means to audit an area. This meant for this research data was collected on all the segment-level variable questions for every segment within the DA. A segment was defined as the section of a street between two intersections or if there was no intersection, a street name change also indicated a start of new segment. A segment was separately defined for each side of the street, while the segment number remained the same a N, S, W, E was added to indicate the side of the street surveyed.

Before data collection occurred, a map was created in GIS using the Street Networks layer from Squamish's Open Data Portal (District of Squamish, 2016). Each street segment, in all four DAs, was classified with a unique segment identification number. This was done to ensure that each street segment corresponded with the correct segment variables that were collected. The GIS map was then converted into a KML file and imported into Google My Maps so the map could be easily viewed in the field while completing the audit. The MAPS-Mini questions were also added to an online Microsoft Form so that observations could easily be inputted in a mobile device while in the field. Beyond the segment variable questions five other definition variables were also collected. These questions asked for the Segment ID #, DA, street name, cardinal direction of the side of the segment being reviewed (N, S, E, W), starting cross-street, and ending cross-street. Collecting these variables was an important aspect in data management. They were used for quality control and guaranteed accurate record keeping while in the field.

Four of the fifteen question were removed from the MAPS-Mini tool in this research. The first three questions in the MAPS-Mini tool pertain to street crossing or intersection variables. These three variables were measured at every intersection in the standard route-level data collection method described in section 3.3.1 above Data Collection and Observations above. A crossing occurred when the rater went through an intersection, whether a pedestrian crossing existed or not. However, because this study utilized segment level data collection for an entire area instead of route-level data collection, there was no systematic way to ensure that the crossing level variables for each intersection were both collected and coordinated with the appropriate segment level variables. The fourth question that was removed asked if any graffiti or tagging was present in the segment, it specified to not include murals. In the MAPS tool the presence of graffiti is connected to the negative aesthetic and social subscale along with other variables like abandon cars and broken windows, however the two later variables were not included as part of the MAPS-Mini tool. The decision was made to remove this question because intraclass correlation coefficients (ICC) scores were low in the original development of MAPS for this subscale. After reviewing additional literature, this was a consistent finding in other studies replicating this methodology. This suggests that this variable introduces a high degree of subjectivity in the surveyor's response (Fox et al., 2021; Millstein et al., 2013; Saito et al., 2022).

Three observation questions were also added to the form asking the surveyor how many people were observed as well as how many pedestrians were observed on the segment. The closing section was for any additional notes. For example, the presence of landscaping, parkways, art, bike racks, public trash cans, the number of driveways on the segment, width of sidewalk (especially narrow or wide), the amount of traffic, traffic calming measures, informal paths, building setbacks, building height, or crossing measures). This observational data was not used in the MAPS scoring system rather to support in qualitative analysis of pedestrian measures and activity in each DA. Microsoft Forms also records how long it takes for the survey to be completed for each segment.

Figure 3.6 Google Maps depicting Segment ID Numbers for each DA



The MAPS-Mini audit was conducted over three days during the summer of 2020. The survey was completed by me, Jordan Booth as the primary researcher as well as a secondary survey assistant, Taylor Martin. Both Taylor and I were trained using the Microscale Audit of Pedestrian Streetscapes (MAPS), Mini Version Training Manual & Picture Guide on how to review the streetscape and accurately measure and describe

each variable. This ensured that our survey data remained consistent and reliable. We also set up procedural guidelines which included which side of the segment each one of us would complete as well as the most efficient walking route to take to ensure every segment in the DA was surveyed. Taylor was also given the links and showed how to use the Google Map and Microsoft Form. The first day of surveying occurred on Monday June 22, 2020, starting at approximately 10:00 am and finishing at 5:35 pm. The weather was mostly overcast around 18° Celsius. Audit data was first collected by both Jordan and Taylor between 10:00 am and 12:45 pm in DA 202-DN, as well as four segments in DA 201-DM that are located on the border between the two DAs. At 1:45 pm Jordan continued the audit of DA 201-DM alone and concluded around 5:35 pm.

The second day of surveying took place on Monday July 6, 2020, from 11:00 am to approximately 5:35 pm. The weather in Squamish was partly around 23° Celsius. Both Jordan and Taylor started surveying DA187/PM around 11:00 am. DA 187-PM is geographically spread out and took significantly more time to audit. There were some segments in DA 187-PM located on rural forest service road that could not be completed on foot. The walkable segments for DA 187-PM were completed around 4:00 pm, a one-hour break was taken from 2:45 -3:45 pm. DA 190-PN/PN was considerably more condensed than DA 187-PM, and surveying was completed between 4:00 pm and 5:35 pm by both Jordan and Taylor. Tuesday July 7, 2020 was the final day of MAPS field observations. The weather was 18° Celsius. This day was used to confirm the reliability of the data. Any segments that were missed or incomplete were revisited and revised or completed. Any rural segments that were not able to be reach on foot were completed by car. In these instances, Taylor was driving, and Jordan completed the survey. If needed the car was pulled over to give enough time to complete the audit.

3.3.2. Data Cleaning & Systematic Scoring

After the audit was completed all 215 survey responses for each segment were imported from the Microsoft Form into Excel. All cells were reviewed and any data that was duplicated or inaccurate were removed or fixed. In instances where there were minor discrepancies, missing, or inconsistent data, Google Maps or Google Earth was used to clarify any collection errors. After the data was cleaned, segment scores were weighted by street length and normalized by the weighted segment total for the area. This was done so that segments within the study area were not over or underinflated

despite there being longer or shorter average block sizes in different DAs. This was done by taking the product of the total segment score and length of each segment and dividing it by sum of all the weighted scores in that DA. The segment lengths were imported from the same Squamish Street Networks layer used to organize the segment unique identifiers.

The last step to validate and analyze the data was to import the survey data and subsequent weighted scores into the GIS. This was done using the unique segment ID numbers originally created in the Squamish Street Networks layer. However, because data was collected for both sides of the street most segments had two sets of scores. First the Squamish Street Network layer was duplicated, and each segment number was uniquely identified by their directional aspect. After this was completed the survey data and scored were imported into GIS. Any segments that did not include both sides of the street were then manually deleted. The final scores were delineated into ranges based on distribution of the numerical weighted score and visually represented on the map. This representation of the scores allowed for a visual comparison of each of the variables as well as the overall MAPS weighted score for each of the four comparison neighbourhoods. This comparative examination is discussed in greater detail in the in a later section, 3.5 Qualitative Comparative Analysis.

3.4. Content Review

A content review to assess relevant documents was used to accomplish multiple objectives. The first objective was to place the site in context through an understanding of its planning history from a transportation and mobility perspective. Secondly, it was used to define the extent to which council, planners, and developers support pedestrian connectivity and how those efforts shape contemporary residential development. The final goal of the content analysis is to evaluate how the results of the quantitative and qualitative findings relate to Squamish's stated active transportation goals and actions. The main source of data used was the District of Squamish planning documents and guidelines including but not limited to the Active Transportation Plan (District of Squamish & Urban Systems, 2016), the 2031 Multi-Modal Transportation Plan (Lew & Rocchi, 2011),Trails Master Plan (The District of Squamish, 2010), Growth Management Strategy (District of Squamish, 2005) as well the Official Community Plan (District of Squamish, 2018) . Municipal policies, bylaws, neighborhood plans, newspaper articles,

photographs, maps, marketing materials, and previously conducted reports and research were also studied. As themes emerged, I noted subjects and regions that aligned or didn't align with the measurement tools I had used to quantify the performance of pedestrian environments in Squamish. This analysis was a flexible process of working and re-working data and analysis until it revealed a narrative, connections or relationships between pedestrian measures and current pedestrian connectivity planning strategies within Squamish.

3.5. Qualitative Comparative Analysis

Following the data collection, calculations, and review, a qualitative multidimensional comparison of the findings was conducted. The data was analyzed in a systematic format to understand and interpret the results of the PEI as they relate to unique neighborhood characteristics as well as emergent themes from the content review. I began analysis by organizing the emerging themes and sub-themes from the visual and numerical data and details revealed in the content evaluation. I conducted this analysis based on observable patterns that were exposed in both the visual and statistical quantitative and qualitative results. I then compared the results of each index in the four neighbourhood study areas side by side. This comparison focused on associating the neighbourhood results with the criteria that I used for selecting the four neighbourhood study areas to establish if there were any commonalities or not between them. The main variables considered were geographic location; near the downtown or in the periphery and development; the presence of a MPC or not. The comparisons between the four neighborhoods helped me to highlight areas of similarities and differences across the four case studies and if these findings might converge with the themes identified in Squamish's pedestrian related policy objectives. The qualitative comparison analysis was an iterative process that explored if specific conditions or combinations of conditions are sufficient or necessary for a specific outcome to occur.

I also analyzed the findings against other academic literature on this topic to help frame the data collected in this study with research conducted on pedestrian indices as well as their uses in other urban contexts. This examination along with further analysis and discussion of the results and overall themes are shared in Chapter 6 Themes and Findings as well as in Chapter 7 Conclusion, Limitations, and Future Research . I organized and summarized the results of the side-by-side comparison of the case

studies by the result of each index and sub index in Chapter 5 Case Study Neighbourhood Profiles. The next chapter, Chapter 4 Pedestrian Environment in Squamish, begins with the development and historic context of Squamish built environment including pedestrian accessibility and is followed by the themes that emerged from the content review of Squamish's pedestrian related policy goals.

Chapter 4. Pedestrian Environment in Squamish

As described in Chapter 3, the methodology I choose for this research was to measure pedestrian friendliness in Squamish, British Columbia using a GIS based model, PEI. The second aspect of the methodology was to review the current and historical planning and development goals within Squamish. Building upon these two methodologies, this section will provide an overview of the pedestrian environment in Squamish, starting with the significant historic and recent economic drivers and development patterns that have led to the current landscape that lacks integration and connections between developments, neighborhoods, and the city as a whole. It also explores the active transportation and growth management strategies presented in planning documents and district meetings. The main pedestrian travel focused goals from these documents were combined into four significant themes that are highlighted in this chapter. Finally, this chapter will include a summary and breakdown of the pedestrian environment expressed through PEI scores calculated in this research for every DA in the District of Squamish. These measurements expressed through comparative analysis will help the reader understand the specific use cases where indices such as PEI might be used in guiding or auditing pedestrian-oriented policy goals.

4.1. Development and Planning History

4.1.1. Historic Context

The area that encompasses the District of Squamish evolved from a small, isolated, community of farmers that settled in Brackendale around 1885. Brackendale is located about 9 km north of the present-day town center of Squamish. A road was eventually built from Brackendale to the Howe Sound in 1892 and two residential areas were established, ‘Squamish’ near the waterfront and ‘Brackendale’ up valley (McLane, 2000). For about 50 years these two neighbourhoods remained disconnected. Outside the one road connecting them, the land between consisted of dense forests with a few sporadic farming fields. This early iteration of the area was the foundation of a town today that is still disjointed.

While the first twenty years of white settlement was dominated by agriculture, by the early 1900s timber extraction was expanding into the valley and Squamish's economy was gradually shifting towards more industrial operations that continues to influence the layout of the town and surrounding area. The Woodfibre pulp mill located just a few kilometers southwest of Squamish where Mill Creek exits into the Howe Sound employed many Squamish families. When it began its operation in 1912, the mill was only accessible by boat, therefore most employees worked and lived at the site in a small town. Also in 1912, BC Premier Richard McBride, responded to growing demand for rail, by announcing a second phase of a privately-owned railway expansion project to create the Pacific Great Eastern Railway (PGE)(Stephenson, 2012). By 1914, the railway to Pemberton was completed and in that same year a deep-sea rail dock was built on the Squamish waterfront. This made it less complicated to service passenger steamships from Vancouver, freight barges, and other large vessels. The culmination of both railway freight shipping, passenger trains and steamships to Squamish's waterfront brought an emergence of new agricultural and industrial development (Andersen, 2014).

About a mile north of the waterfront is the original Squamish townsite that was first constructed in the early 1900s. This area today remains the downtown. Cleveland Avenue, as it is presently, was the main commercial street. By the 1928s there was a bakery, post office, barber shop, telegraph office, hardware store, hotel, drug store and department store. There were no houses past Pemberton Avenue and the homes that did exist in the downtown were small with expansive lawns. There were wooden sidewalks and small bridges over winding streams that connected the streets. The sidewalks would float away and cause problems during common flooding events (McLane, 2000). While the downtown was becoming the main commercial zone for the area, during this same time, lumber operations were substantially altering the landscape of the rest of the valley. There was a sudden increase in largescale railroad logging in the Squamish Valley around 1926. Companies acquired timber acreages stretching all around Squamish and Brackendale and into the upper valley. The logging railroads built to access the timber were quite different then the more advanced PGE line that was being built from Vancouver to Prince George.

> The mainlines which led to the log dumps were fed by an everchanging web of connecting spur lines from the settings, temporary sections of the track laid in the most direct line possible to connect with the mainline. In

> this fashion a few miles of track would be laid countless times crisscrossing over hundreds of miles of forest (McLane, 2000).

Below these steep and twisting lines that cut into dense forests, camps were built that included bunkhouses for nearly 200 loggers and locomotive servicing shops. These sites were the starting point for the neighborhood arrangement that would eventually take form in Squamish.

After WWII, ended Squamish was interested in building a road connection from Vancouver. However, the province rejected the idea and gave priority to moving forward on the PGE connection between Squamish and North Vancouver. However, in 1958, two years after the completion of the PGE Railway, from Squamish to North Vancouver, the highway was built (McLane, 2000). The highway, named the 'Seaview Highway' and ran parallel to the north-south PGE railway tracks (McLane, 2000; Ministry of Transportation and Highways, 2007). The highway became an instant tourist attraction. Seven thousand cars were counted along the highway in the first four days that it was opened (McLane, 2000).

Squamish's economy continued to be dominated by industry at this time. The waterfront land was owned by BC Rail and rented out to the Nexen Plant which made the agents needed to bleach pulp and paper (Aldous, 2012). Along with a rail yard, the area also included a sawmill originally owned by Weldwood and later purchased by Interfor that produced dimensional lumber for export also operated on the waterfront from 1962 to 2004. The waterfront land served almost an exclusively industrial purposes during this time. The infrastructure updates and industrial expansion led to a period of economic prosperity and construction boom in Squamish. In 1960, the Woodfibre residential town site was demolished. The mill wanted to expand its site and workers were enthusiastic about better access to Vancouver and Squamish.

The appeal of connectivity brought on by the new highway as well as a commuter ferry that opened between the pulp mill and Squamish meant many workers moved to Squamish and ferried to the site daily from the Squamish waterfront (Bridge, 2007; Hughes, 2021). To satisfy demands of the growing population the town acquired a piece of previously logged land and hired a developer to build housing. This new development was called Skunk Hollow, located in what today is called Valleycliffe, located southeast of downtown. The streetscape in this new neighbourhood were not strategically planned

and instead laid out on the old bed of the steep railroads and bunkhouses left by previous logging operations in the area. During this same time another developer in the area made another substantial change to the Squamish landscape. Moving away from the previously fragmented small lots interspersed amongst farmland he acquired a large parcel of land in the Mamquam area and evenly partitioned it into the first subdivision in Squamish. He sold these lots as the “Sunny Garibaldi Estates” competing with the other new development, which he labeled as inn “the cold shade of The Chief.” However, like the roads in Valleycliffe, most of the roads in Garibaldi Estates were unorganized and determined by the sites of abandoned railway tracks. Several of the lots in both developments were taken by families who were moving to Squamish from the Woodfibre townsite (McLane, 2000).

The growth and expansion of separate areas in the valleys was becoming more cumbersome to govern and manage independently. In 1964, the entire valley which had previously been separately governed communities, voted to amalgamate. Squamish, Brackendale and Mamquam incorporated into a new District Municipality of Squamish. Mamquam located between Brackendale and downtown Squamish in what is now Garibaldi Estates was originally governed by a Water Board and Sewer Board (McLane, 2000).

In 1965 the provincial government completed a gravel road to Whistler due to pressure from Garibaldi Lifts (now Whistler- Blackcomb Ski Resort), Pemberton residents, and loggers (McLane, 2000; Petersen, 2012). During the 1970s a new, paved access road was finished from Squamish to Whistler and Pemberton (Ministry of Transportation and Highways, 2007). While recreational development and tourism became the priority for Whistler, Squamish was defining itself as the transportation and communications corridor. Due to the convergence of coal, propane, liquefied natural gas, ore, lumber, and pulp, Squamish was considered an ideal place for a deep seaport. In 1971 the first deep- sea docking facility at Squamish Terminal was built. Industry continued to flourish. However, beyond the familiar backdrop of the logging and natural resource infrastructure, more commercial expansion was also beginning to take place. The 70s and 80s ushered in a period of highway centric planning. This included the construction of strip malls along the highway which featured big box stores and fast-food restaurants. Squamish was becoming known for the place you stopped for fuel or a quick bite to eat along the highway on the way to or from Whistler.

Downturns in forestry and other resources in the 1990s and early 2000s put a strain on Squamish's economy and their workforce. This started with the closure of Nexen, the chlor-alkali plant in 1991, followed by the shutdown of the neighbouring mill, Interfor in 2003. The subsequent year a rail maintenance yard was downsized. The final disappointment was the closure of Woodfibre in 2006 which caused over 300 in layoffs in the town. These factory closures not only left over 600 workers out of work in a short time but also significantly lowered the local governments annual tax revenue. Development also stagnated during this time, with less investment being made into new commercial and residential spaces. This string of difficult events caused concern about the future of the district. As continued attempts to appeal to new industry were ineffective in town, outdoor recreation was quietly taking off in the background. People were beginning to see Squamish as a place to visit for premier climbing, windsurfing, fishing, biking, and mountaineering. This influenced discussions about development and improvements that might provide new opportunities in Squamish.

Many Squamish Council members and residents were eager for a way to diversify the economy. The combination of sustainability, tourism and outdoor recreation emerged as a hopeful solution for the town's future. A plan for new waterfront redevelopment was one example of how the district hoped to accomplish this. In 2004, they acquired 105 acres of formerly industrial land on the waterfront, including the previous Nexen and Interfor sites. The local government partnered with the Fraser Basin Council, a non-profit organization that works to encourage social and economic sustainability and introduced a concept plan that featured sustainability and 'smart growth' principles into the project proposal. The plan included full scale marine terminal for passenger ferry service and small cruise ships, a 200-room hotel, a convention hall, light industry, an arts and culture centre, public beach, and walkways, and mix of housing that varied from single family to condos and town homes (Lazarus, 2004). The district and partners hoped the new space would facilitate and promote "not just the straight economic development investment, but also investments in other amenities that will help build community cohesion" (City Spaces, 2022). The concept of 'community cohesion' was certainly on the radar of those involved in the project, however at the time there no plans on how to facilitate that connectivity. Beyond the principles and design of the project, the financial viability of the plan was being reinforced by the announcement

of the 2010 Winter Olympics in Vancouver and Whistler which promised investment for the entire region.

4.1.2. 2010 Olympics and the Outcome

The announcement and occurrence of the 2010 Olympics in Vancouver was a substantial catalyst for change in Squamish. Beyond the considerable expansion plans to develop the waterfront, the council at the time was eager to take advantage of the potential visibility that the Olympics could bring to Squamish. Even before the official announcement, the mayor at the time envisioned a passenger ferry from Vancouver that transported tourists on the weekend and commuters on the weekday. He had also hoped that the Olympics would bring a renewed interest in passenger rail service with stops in Squamish. The district saw the prospect of the Olympics as a great way to transition and drive investment into the community.

One of the most significant legacies of the Olympics in Squamish was the rebuilding of the Sea to Sky highway. Even before Vancouver had secured the 2010 Winter Olympic bid, discussion on how to improve connectivity along the corridor focused on ways to decrease the driving time and increasing the allowable vehicular volume of the highway. Proponents of the Olympic games were concerned about the driving length, traffic problems, and poor conditions of the existing highway to Whistler (Whitson, 2012). The BC government viewed the prospect of hosting the Vancouver 2010 games as a means to improve road infrastructure to Whistler and drive investment into the future growth of BC tourism (British Columbia Government, 2004). In hopes of securing the bid for the Olympics, the BC government promised an enormous improvement project along the Sea-to-Sky highway. In 2006, the construction for the highway project began (Whitson, 2012). The project was a $600-million, public private partnership that smoothed curves, extended sightlines, improved intersection safety and most notably widened the road and allowed faster speed limits. The improvements were completed in December 2009, before the Winter Olympic Games that were hosted in February 2010 (Ministry of Transportation and Infrastructure, 2009).

The addition of four-lane highway with a barrier in between the north and southbound lanes through Squamish created a significant divide within the community. There was a pedestrian bridge built over the highway as part of the highway project

which relieved some safety concerns. However, this widening of the highway through Squamish added to the sense that the town was even more disconnected. Another outcome of the highway improvements in Squamish was it made it quicker for residents to drive the 55 minutes to Vancouver for work each day (Lehmann, 2018). As noted previously, many residents of Squamish commute to work by car. Click or tap here to enter text. The convenience of faster trips meant there was a higher likelihood that workers traveling south to Vancouver would continue to rely on single occupancy vehicle trips for their daily commute. This in turn causes more auto use within the town of Squamish as well, as a driving trip that has already been initiated has a high likelihood to continue in town before or after for stop overs or errands. Car commuting also leads to more habitual use of car use regardless of if the resident lives in pedestrian friendly neighborhood. Research has shown that routine car users choose to drive in other circumstances even if alternative modes of travel are available (Ramos et al., 2020).

The upgraded highway certainly allowed the flow of more drivers when it was first constructed, however new residential growth in Squamish and continued tourism has put increased pressure on transportation in the region. There has been 29% increase in the average daily vehicles driving along the highway between 2009 and 2017, this number is expected to rise to 62% increase by the year 2025. Numerically speaking, in 2009 there was an average of 13,600 daily vehicles traveling between Horseshoe Bay and Squamish along the Sea-to-Sky. In 2017, the volume increased to 20,300 daily vehicles and by 2025 the forecasted average daily vehicles are expected to be around 22,000 (BC Ministry of Transportation and Infrastructure, 2017; Ministry of Transportation and Infrastructure, 2009). However, the B.C. government continues to sponsor tourism and growth in this region by financing more highway and driving infrastructure over alternative mobility options. In the summer and fall of 2016, they invested $5.4 million on safety and mobility upgrades for the Sea-to-Sky Highway from Lions Bay to Pemberton (Ministry of Transportation and Infrastructure, 2016)

The highway expansion has in part facilitated an increase in population in Squamish. The perceived convenience of the new highways as well as the branding of Squamish as a mecca for outdoor enthusiast has persuaded many younger people and families to relocate. This new landscape in Squamish has set in motion an abundance of land development both planned and realized since the Olympics that at times has been difficult for the district to keep up with and manage. Even the announcement of the

Olympics generated quick and unanticipated changes. Newspapers reported huge spikes in housing prices and there were various business inquiries directed to the District of Squamish and Chamber of Commerce (Lazarus, 2004). Despite this, constructing new housing and promoting Squamish as a place for businesses was seen as a way for the district to start from scratch.

There is no projection that this growth will subside in the immediate future. Major development projects in Squamish were reenergized including the proposed Garibaldi at Squamish Resort which has not been approved or built yet but could add up to 1,500 hotel rooms and 2,000 residential units and approximations of 730,000 skiers a year (Findlay, 2016). Additionally, the Squamish Oceanfront development has been reimagined since its first iterations just before the Olympics however it is still expected to bring an additional 6,500 residents and potential employment for 2,300 (Newport Beach Development LP, 2018). Other projects since the Olympics that have been completed include low-density, high cost, single family home developments such as Crumpit Woods, North Crumpit Woods, and Legacy Ridge that have added to the already existing sprawl. Numerous other pseudo–New Urbanist style developments that often include townhome communities with amenities or larger condo complexes have also been constructed since the Olympics. This includes four out of the six phases of the downtown Eaglewind MPC as well as the Diamond Head Skyridge MPC both of which are research focuses of this study. These developments are often advertised to include a variety of amenities such as playgrounds, tennis courts, and community gardens as well as being close to schools, trails, or shopping. While the idea is that residents will be able to walk to these facilities the reality is that piecemeal planning and development has overlooked creating a cohesive environment that is conducive to pedestrian travel.

It is clear with the influx of development Squamish is quickly moving away from its industrial past. The Olympics were a major turning point in this transformation. They left a complicated a legacy in Squamish. In terms of potential transportation improvements, many felt there were some small successes. However, there was also a sentiment that there were major shortcomings around the expectations and outcomes proposed by the council on broader infrastructure and development planning. This is exemplified by two quotes from the former Squamish mayor, Patricia Heintzman and John French, who worked for the Vancouver Organizing Committee for the 2010

Olympic and Paralympic Winter Games (VANOC) as community and media relations manager:

> ‘On the whole, [the Olympics] was a positive for the town. I wish we’d gotten a train and not a bigger highway, it would have been a much better, more sustainable choice into the future.” … Squamish’s Corridor Trail, too, came out of the Olympics, Heintzman notes (Thuncher, 2020).

> …He [John French] acknowledges that Squamish could likely have gained more and that some in town were disappointed their expectations were not met. “The council of the day had tremendous opportunity, and they didn’t capitalize on it. The council of the day expected far more than it realistically should have,” he said. “Ultimately, VANOC opted to find other solutions outside of Squamish for things like parking and transportation hubs.” (Thuncher, 2020)

Some of this disappointment and contention have continued in the years following that have seen a dramatic population growth and continued widespread development with a lack of transportation solutions. Despite these issues, the council and planning and engineering departments have continued to search for tools to create a more integrated and walkable community. They have done this through numerous active transportation and environmental studies, policy guides and recommendations. The framework for current pedestrian planning in Squamish is the focus of the next section.

4.2. Current Pedestrian Focused Planning Goals

The District of Squamish is pursuing pedestrian friendly environments through policy, education and infrastructure initiatives outlined in varying guidelines and plans. Beyond the direction asserted in the Official Community Plan (OCP), active transportation policy in Squamish is guided by three major documents, the Active Transportation Plan, the Community Climate Action Plan (CCAP), and the Squamish 2031 Multi-modal Transportation Plan (District of Squamish, 2018; District of Squamish et al., 2020; District of Squamish & Urban Systems, 2016; Lew & Rocchi, 2011). These plans, as well as other media, meetings, and information relevant to active transportation objectives and projects in Squamish were analyzed for key principles related to planning

for pedestrian friendly environments. Four consistent and significant themes were identified across all the material that pertained to methods of achieving a greater degree of pedestrian friendliness in Squamish. They were (1) improvements in accessibility, (2) connectivity, (3) mode share shift, and (4) growth management strategies. Accomplishing a more pedestrian oriented built environment requires a combination of these ideas. In the next section, each theme is defined as it relates to active transportation literature. This is followed by a discussion of challenges within Squamish that are connected to each theme and the specific projects and policies that are aimed at improving them. In some cases, an objective might be multifaceted and target more than one of the four defined approaches through a single policy.

4.2.1. Accessibility

In transportation literature, accessibility is widely defined as the ease and distance of reaching services and activities from a defined location using a defined mode of transport (Dalvi & Martin, 1976; Litman, 2022; Saghapour et al., 2018). The performance of the transportation system is also considered to be an important component of accessibility (M.-S. Lee & Goulias, 1996; Litman, 2022). In other words, accessibility is comprised of both the spatial distribution of destinations, the land use component, and the ability to move from one location to the next, the transportation component. Each of these factors are outlined in different aspects of Squamish's active transportation guidelines and objectives.

Accessibility recommendations, especially in the OCP, focus on increasing diversity of land uses within a walkable area. Two objectives that support this effort are the Healthy Food for All in Every Neighborhood Objective and the Natural Open Spaces, Parks, & Greenways Objective the later ensures access to neighbourhood parks and recreation amenities within a reasonable walk of all existing and new residential developments (District of Squamish, 2018). This policy would address neighborhoods such as Dentville, North Yards, Garibaldi Estates, Valleycliffe, and Garibaldi Highlands that have less access to parks and play spaces in their communities. Garibaldi Estates, Valleycliffe, and Garibaldi Highlands all scored on the mid to lower range for PEI, validating that among the non-rural DAs in Squamish, the index tracks with current district strategies. Dentville and North Yards do have higher PEI scores, due to their density and distribution of a variety use types, but further analysis into the spatial data

and the land use in this area would reveal the need for more open spaces in these areas as well. The MAPS tool also could be used to determine the prevalence of open space as it asks a question pointed at the presence of parks on the segment. However, due to the time-consuming nature of audits, a spatial analysis focused on green spaces and pedestrian friendliness would likely be most useful and efficient for this. The Healthy Food for All in Every Neighborhood policy works to similarly incorporate more healthy food options, markets, grocers, and restaurants within a short walking distance (District of Squamish, 2018).

The district is also focusing on fostering existing neighborhood nodes where residents can meet their daily needs within walkable zones. This policy, also included in the OCP, encourages the concentration of local commercial activities, recreational amenities, institutional services, and transit connections within new and existing residential areas. It also supports commercial development near key intersections, transit hubs, or other commercial areas. The development of new mixed-use neighborhoods with residential offices, green space or natural areas, and professional services above commercial spaces is also encouraged within this policy. These complete communities would be supported through amending zoning bylaws to incentivize or requiring a greater amount of commercial and public spaces in mixed use builds (2018). Other policies such as targeting the development of day-to-day commercial amenities in neighborhood nodes would also support this objective. Finally, new large-scale developments will require multi-modal transportation network and circulation plans, including pedestrian and cycling trails, neighborhood connectivity and linkages (District of Squamish, 2018). For many of these developments focused goals, both for current neighbourhoods and future building sites, PEI or a similar spatial analysis modeling tool would be useful to enhance understanding of how changes or additions to these areas might change the pedestrian environment.

The second aspect of accessibility is dependent on a well-maintained pedestrian infrastructure. A good quality active transportation system has also proven to be important in determining transport decisions. This has been addressed through recommendations in the District of Squamish Active Transportation Plan (2016) focused on upgrading pedestrian networks through better and safer infrastructure. According to Active Transportation Plan (2016) there are currently insufficient existing policies that are focused towards pedestrian improvements on already established road networks. This

plan emphasizes that more attention should be given to building pedestrian amenities in the areas outside the downtown area. It also calls for prioritizing the creation of safe, complete streets where possible (District of Squamish & Urban Systems, 2016). This means identifiable and appropriate intersection crossing with enhancements like crosswalks marked with pavement marking, audible and visible signage, or pedestrian activated flashing signals as well as pedestrian refuge islands and curb extensions. Within the downtown area the goal is to focus on maintaining and upgrading the sidewalks that are in poor condition. The direction of this plan also encourages the increase of sidewalk coverage on major routes and connections to key destinations such as public transit zones, schools, and commercial areas. On many of these route's sidewalks are inconsistent or nonexistent and, in some cases, pedestrians are forced to walk along paved shoulders on roads with high traffic volumes. For these goals focusing on better accessibility through improving the street and sidewalk system, the combination of the intersection density index and MAPS tool in an abbreviated format could be used for the planning and timing of making these improvements. The long-term focus of accessibility related to improved pedestrian infrastructure is the consideration and priority of sidewalk design in the implementation of new development and infrastructure projects in Squamish. This will require collaboration of multiple district departments and outside partners (District of Squamish & Urban Systems, 2016).

Planning documents recommend increased personal safety measures as a key measure requiring action by the district. Residents identified that insufficient lighting and low visibility on pathways and streets cause pedestrians to feel unsafe especially after dark. Policy actions focused on personal safety and visibility include improving lighting where appropriate along streets, pedestrian pathways, and underpasses. Again, the MAPS tool would be useful in this scenario as it incorporates specific questions on the amount of street lighting on a given segment. The guidance also recommends following Crime Prevention Through Environmental Design (CPTED) standards for future infrastructure design maintenance and construction. This approach "supports the provision of good lighting and visibility for pedestrian and cyclists as one of the most effective crime deterrents. Incorporating the principles of CPTED in facility design increases security in public areas and will in turn promote walking as a transportation mode choice" (District of Squamish & Urban Systems, 2016).

Finally, 2021 budget documents outline a plan for creating conceptual street designs especially in the downtown area where sidewalk and curbs are not in suitable condition. Without these plans the district has not been able to enforce or communicate what is required for these streetscapes. Creating conceptual street designs would allow the Planning and Engineering departments to guide developers on how to build appropriate frontage. The district has highlighted Third Ave, Main St, and Government Ave as priority streets for upgrades (District of Squamish, 2021). Third Ave is within the boundaries of DA 202-DN, one of the case study neighbourhoods in this study. The streetscape audit outputs for Third Ave correspond with the city's assessment for needed updates. The audit completed between Pemberton St and Vancouver St. on both sides of Third Ave did indicate there was sidewalks present everywhere, except for the east side between Pemberton St. and Baily St. and on the west side Main St. and Vancouver St. as well as Winnipeg St to Pemberton St. However, only two of the nine blocks measured included a sidewalk buffer and only one was entirely continuous. The conditions of the sidewalks were mixed, with some segments in suitable condition, while others were uneven or cracking.

The upgrading of pedestrian infrastructure will not only contribute to ease and quality of mobility within the district but will also help resolve the lack of connectivity between the neighbourhoods of Squamish, especially for non-motorized transportation. The next section will outline the specific policies aimed at achieving a greater degree of connectivity for pedestrian travel in Squamish.

4.2.2. Network Connectivity

As noted above, a quality pedestrian network is a critical component of an accessible transportation system. While the presence of sidewalks, trails, width, and condition of the sidewalk, which were addressed in the previous section have been found to influence foot travel, network connectivity is also correlated with greater pedestrian use (Guo, 2009; Zahran et al., 2008). Connectivity is an especially complicated issue in Squamish because there are constraints within the built and natural environment that make joining neighborhood zones more difficult. The highway, the railway corridor, major intersections, the Squamish and Mamquam rivers, as well as steep geography especially for the neighborhoods on the east side of the town are all obstacle to a well-connected pedestrian network.

The primary challenge is the presence of Highway 99 which runs north south through the town. While it connects different areas of the city well for auto travel it acts as a barrier for other modes of transportation. The road network is more developed than active transportation corridors in Squamish. Consultation with the public and other stakeholders identified that lack of sidewalks, insufficient lighting, and lack of direct pedestrian routes were some of the key issues that restrict connectivity and walkability in Squamish. Residents in Squamish have noted that, “while many respondents placed high value on the number of trails and pathways throughout Squamish, they did also note that the lack of direct pedestrian routes was sometimes a barrier to walking (District of Squamish & Urban Systems, 2016). It was also noted that more pedestrian cut throughs could help to make routes more direct” (District of Squamish & Urban Systems, 2016).

There is an extensive trail network within Squamish however, it is used mostly for recreational purposes and the vast majority of these trails are located in natural areas in the town periphery. There are two crosstown multi-use trails called the Corridor Trail and Discovery Trail. The Corridor Trail runs along the east side of the highway and is paved but only portions of it are lit. The Discovery Trail runs along the west side of the highway however it is mostly unpaved and unlit. There are nine designated highway crossings, four over and under passes and five designated crossings however there are significant gaps and shortcomings for both of these primary trails and in the wider pedestrian system in Squamish. The Discovery Trail faces major challenges where the path intersects with major roads. Both trails lack integration east west networks into neighborhood areas and with existing sidewalk infrastructure.

There are recommendations in the Active Transportation Plan, OCP, and Squamish 2031 Multi-modal Transportation Plan, which are aimed at establishing a completer and more connected network of pedestrian infrastructure across the district (District of Squamish, 2018; District of Squamish & Urban Systems, 2016; Lew & Rocchi, 2011). The language outlined in the Active Transportation (2016) plan focuses on establishing principles of complete streets with specific direction to improve connectivity through expanding and enhancing the sidewalk network as well as completing and enhancing both north/south and east/west connectivity for walking. Many of the policies relating to expanding and enhancing the sidewalk network were previously discussed in the Accessibility section and can be summarized as increasing sidewalk coverage on

major routes and connection to key destinations, upgrading and replacing sidewalks that are in bad condition in the downtown area, and implement new sidewalk in conjunction with other plans, projects, or developments(District of Squamish & Urban Systems, 2016).

Actions to improve north/south pedestrian connectivity focused on improvement to the multi-use pathways, or off-street pathways, the Corridor and Discovery Trails. These trails especially when built accessibly, are an effective tool for creating safe transportation networks despite interruptions from major highways or roads, railway corridors, or other geographical constraints. Proposed enhancement include filling in gaps and adding lighting and better wayfinding on both trails. For better accessibility, the Discovery Trail should be widened and paved (District of Squamish & Urban Systems, 2016). Finally, the Active Transportation Plan (2016) recommends upgrading infrastructure along Government Road a major corridor that provides access to many schools as well as commercial zones on the west side of town. Much of the corridor does not include sidewalks. It is advised that this throughway be upgraded to AAA route with protected bicycle lanes separating cyclist, pedestrians, and motor vehicles. This may require eliminating parking in some places. It also urges the addition of sidewalks on both sides of the street. The last part of this recommendation includes a call to action to conduct a feasibility report evaluating the creation a AAA crossing over the Mamquam River that would be wide enough to accommodate both pedestrians and cyclists (2016).

The OCP (2018) also points to expanding and addressing gaps in sidewalk network infrastructure. It more broadly refers to “pursuing options to increase local road and trail connectivity” while also minimizing reliance on the highway. This will be done through connecting all new and future neighborhoods, employment areas, business districts as well as recreation and tourism destinations and improving north/south and east/west connection. There are many similar calls to action with the Active Transportation Plan including improving the continuity of the Discovery Trail, continuing effort to improve the Corridor Trail, as well as working to create safer east/west connectivity into existing and future neighborhoods especially across Highway 99 intersections(District of Squamish & Urban Systems, 2016).

Evaluation of trails networks is an important aspect of improving pedestrian access, especially in Squamish. Unfortunately, this an area where both indices

underperform. The components of the PEI calculation don't include data related to pedestrian networks. Instead, it uses intersection density as an indicator of how well the network is connected. This is useful for determining the overall layout, which is predictive of the connectivity of a neighbourhood, however it doesn't offer contextual understanding of whether or not an area has suitable sidewalks like the MAPS tool does or a more nuanced perspective of pedestrian links that using a footpath layer in a pedestrian spatial analysis would. In this case both indices fail to consider the opportunities that pedestrian or active transportation only infrastructure, like trails or cut throughs contribute to the pedestrian connectivity of an area. This is especially important is an area like Squamish where the highway and other major throughways break up the communities of the city.

An important consideration of all the planning documents is to prioritize active transportation connectivity between neighbourhoods with the highest density as well as other important commercial and economic destinations within Squamish. These neighbourhoods are downtown, North Yards, and Garibaldi Estates. Yet Squamish includes many distinct communities which have differing levels of pedestrian inclusive infrastructure as well as varying degrees of residential density (District of Squamish, 2018). The next section will focus on the municipalities strategies to increase residential density among all existing neighbourhoods through strategic policies that focus on promoting compact infill within a contained growth boundary rather than extending new development further into the valley.

4.2.3. Growth Management

Squamish is one of the fastest growing communities in British Columbia. From 2011 to 2016 the population grew 14% to 19,512 people. This is well above the provincial growth rate of 5.6% and national rate of 5% during the same period (Statistics Canada, 2016). However, Squamish also has a significantly lower population density then other similar sized communities located in BC. It has a population density of 140.9 residents per a square kilometer in comparison with the average of 547.1 residents per a square kilometer of other municipalities of the same size in BC. This growth and development coupled with existing sprawl has led Squamish to push for a firm growth management strategy that limits growth to existing neighborhood as well as vacant and underutilized lands in a compact designated growth area. The district argues that this

approach will enable more walkable communities while also preserving open space and environmentally sensitive areas. Furthermore, development and infill within existing communities makes the best use of current infrastructure and is less burdensome on taxpayers.

The main objective to contain growth within the OCP (2018) is straightforward. It states to “promote infill development rather than sprawling greenfield development to make efficient use of limited land base and existing infrastructure” (p. 31). The OCP Bylaw that supports this directs that residential development should occur within the Growth Management Boundary (GMB). The GMB contains the following areas; Downtown, Waterfront Landing, Oceanfront Peninsula, Quest University, Tantalus Road area, Ross Road area, as well as infill of vacant or other brownfield sites within these areas. Another aspect of the growth management strategy outlined in the OCP (2018) is the creation of sub-area and neighbourhood plans. Sub-area plans are detailed plans for defined areas within the OCP that identify specific rules for land use, density, neighbourhood design, transportation, municipal services, public amenities, and environmental protection Broadly these will help guide land use and development in existing or future neighbourhood regions (2018). The goal is that these plans will support the creation of comprehensive and connected communities with access to housing, services, nature, and straightforward sustainable transportation networks.

Other municipal documents also addressed growth management in conjunction with the OCP (2018) guidelines for densification and improving pedestrian environments. Many of the topics are parallel to principles that will subsequently be addressed including that growth within Squamish should prioritize design that favours transportation options beyond private vehicles and that jobs are brought closer to home (District of Squamish, 2005; Lew & Rocchi, 2011). The Active Transportation Plan focuses (2016) on ensuring that developers and other stakeholders create complete communities that do not omit pedestrian considerations in their design. For example, developers should create shortcuts, especially when the communities are not designed in a grid format, so that pedestrians are ensured the shortest possible trip distance. It includes clear language that suggest the city must be firm and thorough when working with and approving development applications to ensure that suitable sidewalks and pedestrian systems are in place. As noted in the Active Transportation Plan (2016):

> It will be important that the District continues to provide guidance regarding site design that supports active transportation as part of the Development Permit Areas. This includes ensuring infrastructure considerations for walking and cycling are made within strata-owned developments which can also be addressed through the OCP and as part of Development Permit Areas. The District should continue to work with developers and other stakeholder and examine existing policies and standards to ensure new developments are permeable for people walking and biking and ensuring sidewalks are provided within all new subdivision (p. 63)

The difficulty of this directive is that creating suitable walking conditions is context specific for each neighbourhood. Each development has distinctive design and road configurations so plans for adequate pedestrian infrastructure must be addresses individually in each development proposal. The challenge is that to accommodate space for one activity, in this case prioritizing sidewalks, other space is more limited. This negotiation for space can cause conflict between stakeholders.

The complicated trade-offs that come with growth in a city are certainly apparent in the development approval process within Squamish. This was evident at a council meeting on February 1, 2022, where a variance proposal for a new townhouse development by Accorde Properties Ltd in Wilson Crescent was rejected. Wilson Crescent is a small area just north and across the train tracks from downtown. It is officially a part of the Dentville neighbourhood. The area is known among residents for its challenges including complicated crossings with Buckley Ave, a high traffic road, lack of pedestrian movement around the neighbourhood, as well as unmanaged and chaotic street parking. The variances requested were for reducing setbacks on all sides of the primary and accessory building. Members of the public, mostly from the adjacent Arbutus Grove development were against the variance because they were concerned about privacy, shadows, and blocked views. On the other side of the issue, Mayor Karen Elliot was in favour of the variances because in exchange for setbacks the developer agreed to build a sidewalk on its portion of the street. She argued that the Wilson Crescent neighbourhood had been built for cars, not people and council should prioritize creating walkable infrastructure through private property in this case because there is not room on this road right of way to create pedestrian and cycling routes(Chua, 2022a).

Councillor Eric Anderson disagreed that the neighborhood was built for cars not people. He and three others, a majority of council were in favour of deferring the application (Chua, 2022a). Councillor Anderson is an example of someone with a more moderate stance on the urgency of pedestrian infrastructure. However, a letter from a resident submitted to The Squamish Chief argued that, given Squamish's growth, improved infrastructure is necessary yet piecemeal planning where the city bargains with developers on variances to incorporate sidewalks is not working. This resident believed that the city should be providing these necessities through master planning and financed by higher costs to developers (Menezes, 2022). The former mayor, Patricia Heintzman is concerned that the eruption of large-scale developments are "based in a 1950s mindset" and they are "unimaginative and unstainable in their concept and design". She asserts that any sprawling development should not be approved unless is truly innovative (Manzul, 2022).

Others in town have formed advocacy groups to oppose higher density infill altogether. The Stop the Squamish Infill movement was conceived when out of town land speculators began engaging with residents to explore potential opportunities in Garibaldi Estates neighbourhood. This created a backlash in the community (Chua, 2021). Residents were concerned that the outcome of the neighbourhood planning process was predetermined. They did not want to see the character of their neighbourhood change and perceived infill not as way to provide affordable housing for locals but as a means for developers to deepen their pockets while creating housing for commuters to the Lower Mainland (Chua, 2021).

As part of the neighbourhood planning process the district was working towards a proposed repeal of Bylaw 211, 1966 dictated by OCP direction that would allow the municipality to support future growth in the Garibaldi Estates neighbourhood. This area was determined suitable for additional population given its proximity to existing infrastructure and central location. However, the Bylaw currently restricts subdivision of parcels known as Veteran's Land Act Lands; parcels that were created for soldier resettlement post WWII. These are historically larger than average, single-family parcels to allow for small scale farming (Chua, 2021). However, after the land speculation ordeal, The Stop the Squamish Infill created a petition to urge council to avoid densifying the neighborhood (Ghumann, 2021). Planners and council emphasized the Garibaldi Estates Neighborhood Planning process is not intended to support speculative real

estate activities of companies or developers and that the community engagement and neighborhood planning process had not even began yet (Chua, 2021). At a more recent May 2022 meeting, the municipal staff briefed the attendees on the findings of districts small group discussion engagement with the public regarding the Estates. Council members also gave feedback regarding the planning process. Councillor Chris Pettengill emphasized that density was being confused with building height. He assured that there is a way to add density without creating skyscrapers. Councillor Eric Anderson spoke on gentle density "Regarding gentle density…[one] of the comments that I noted [is]: 'The missing middle can't be solved on the backs of legacy neighbourhoods…I'm somewhat sympathetic to this. It's unnecessary for us to be heavy-handed" (Chua, 2022c) This neighbourhood plan is still in flux. Council is working to navigate locals' desires with current policy direction. While residents of Garibaldi Estates are still concerned about adding density to their neighbourhood, the district staff continue to explore ways to diversify housing in this area. Nothing has been finalized, however, the process is focused on what types and where infill might be appropriate for this neighbourhood (Chua, 2022c).

Despite the hardships facing Squamish around finding a balance between infill and sprawl, according to the online monitoring indicator for Growth Management, the city has continued to contain all new residential development within the GMB (District of Squamish, 2019). There is still substantial capacity with the district to continue doing so. Projects like the Cheema lands has not been approved because it is located outside the GMB(Chua, 2022b). Another development that has been blocked by the current growth management strategy, among other setbacks, is the massive $3.5 billion dollar Garibaldi at Squamish, all season resort that would be located on Brohm Ridge (Chua, 2019). The district continues to use neighbourhood planning as well as anticipating growth to contain development within the boundary. By working to upgrade growth management strategies as well as the connectivity, and accessibility of the pedestrian environment in Squamish, the district hopes to promote residents from vehicular travel to other more sustainable form of transportation, including walking. Goals and policies that are aimed at reducing reliance on single occupancy vehicles within the community will be discussed next.

4.2.4. Mode Share Shift

Driving is the primary mode of transportation in Squamish. As of 2016, the SOV mode share was 85.2%(Statistics Canada, 2016). Because land use types are generally spread out and the highway connects different areas of the city well it is most straightforward for residents to make regular trips using a car. These issues of limited connectivity and accessibility which were discussed in detail earlier, have exacerbated this issue. Seasonal and inclement weather, steep geography, and a substantial portion of the town's labour force being employed outside the community are also significant barriers to achieving a reduction of mode share for single occupancy vehicle trips. Nevertheless, the district has implemented strategies and actions to impact the mode share distribution to be weighted more towards non-single occupancy vehicle travel. The Squamish Multi Modal Transportation Plan set a target of lowering SOV mode share to 63% by 2031. This requires a further reduction of 22% from 2016, or 1.5% reduction each year over the next 15 years (2011).

Objectives to reduce reliance on SOV through focusing on improving the walking, cycling, and transit environments so that they were more accessible, convenient, safe, and connected were mentioned in the OCP, Active Transportation Plan, District of Squamish Multi Modal Transportation Plan, and Community Climate Action Plan (District of Squamish, 2018; District of Squamish et al., 2020; District of Squamish & Urban Systems, 2016; Lew & Rocchi, 2011). Many of the policies aimed at achieving this objective are connected to polices previously described in the Accessibility and Connectivity sections including expanding and addressing gaps in the sidewalk network as well as supporting mixed use development within compact neighborhood nodes so that daily activities can be fulfilled in short walking trips and there is less need for vehicle trips. The OCP (2018) dictates a hierarchy of transportation modes as a general approach to guiding transportation decisions. It prioritizes walking and is followed by cycling, transit, commercial vehicles, high-occupancy vehicles/taxi, and lastly private automobile. Modes at the top of the hierarchy will not necessarily receive priority on all streets, especially in cases where a specific transportation mode is already accommodated on a parallel or nearby route.

Squamish has also been employing other creative strategies to persuade residents to use alternate, more sustainable modes of transportation. In the CCAP, the

district is utilizing outreach and education options as one of these methods. For example, developing community engagement around active transportation through the district website, online dashboard, and social media. Another more difficult education piece is to illustrate the benefits of densification to the community. On the community engagement side, there is an initiative to host car free days, on Cleveland Avenue once a week during warmer seasons in conjunction with the farmer's market. Other ideas included temporary public realm interventions, such as pocket parks, temporary seating, pedestrian covers, and other leisure spaces that promote walking especially in the downtown core (2020).

Another target is to have more residents working in Squamish. They hope to do this through creating high value business opportunities in Squamish as well as increasing employment density and align zoning with commercial demand. People who work locally would have a shorter commute (District of Squamish et al., 2020). However, the municipality acknowledges some work will take place outside Squamish and hope to encourage carpooling in this case. Designating carpool meetup locations is another method the municipality is hoping would help to minimize SOV mode share. The city is also continuing to support the establishment of car-sharing as an option when residents must drive. They hope this encourages less car ownership amongst residents in the long term. This includes some on street carsharing parking and collaborating with developers to provide car sharing or car memberships within new developments (District of Squamish et al., 2020; Lew & Rocchi, 2011).

The city is also working to improve the reliability, frequency, infrastructure, and routing of public transit. Improving transit services is a key focus in order to provide a more balanced transportation system (District of Squamish et al., 2020). The combination of direct and clear pedestrian networks within a transit walkshed combined with a reliable public transit system can shift people away from driving. If a trip offered through walking and transit is more comfortable, direct, and reliable then the alternative there is a greater chance of the trip being made by the combination of walking, biking, and/or public transit. Well-designed transit stops make a street more comfortable and pleasant as well as can be used as a gateway into neighborhoods. Infrastructure upgrades including more shelters, benches, wayfinding, and accessibility is another action the district plan to take to make alternative mode shares more attractive. Finally, Squamish continues to work with BC Transit, the regional transportation authority, to

establish an optimal frequency on the Squamish network during peak times (District of Squamish et al., 2020; Lew & Rocchi, 2011).

Along with incentivizing other means of transportation, the council is also using policy tools to dis-incentivize the use of private vehicles. They have done this through updating parking requirement to maximize land use efficiency and increase residential and employment density as well as reduce parking minimums for new developments. It has always been free to park most places in Squamish however there are plans to create and implement a parking price strategy especially in the core transportation zones. This pricing would be adequately enforced to incentivize mode shift (District of Squamish et al., 2020).

4.3. Pedestrian Environmental Index Results in Squamish

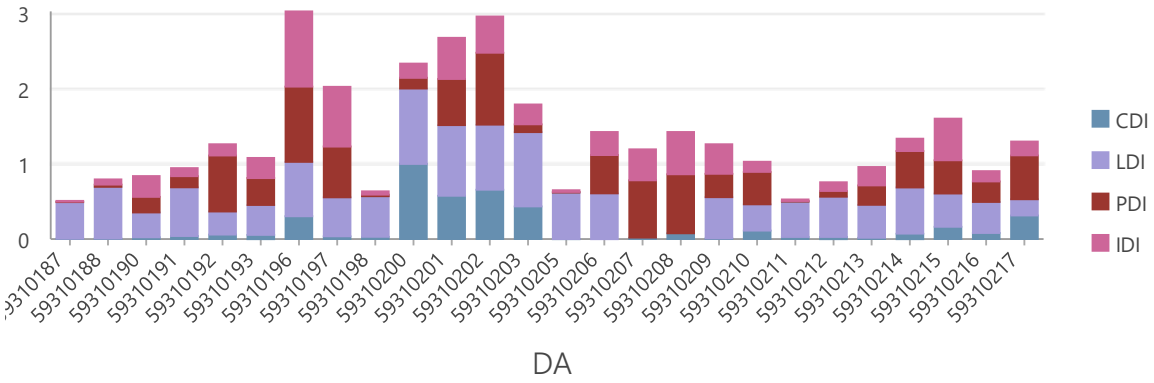
It is clear that planners and the municipality recognize the importance of providing high quality pedestrian environments within Squamish. However, as described efforts to increase walkability are often complex and difficult to measure. As noted in the sections above pedestrian environmental models are another tool to help understand and visualize barriers to pedestrian mobility. These indices allow cities to use data driven results as one method to assess and compare geographic areas most in need of walkability measures. One reason the PEI was chosen for this research is because of its relative ease of use. This could also be practical for small city governments who may not have the resources or time for more costly or onerous assessments. It is an easily computable measure that utilizes existing city data.

PEI was originally selected for this research to understand if specific large scale neighborhood developments are more pedestrian oriented, as they are often advertised to be. There were limitations to answering this question due to the availability of geographic data at a small enough boundary size to pinpoint specific MPCs. The smallest zonal geometry available for Squamish was dissemination areas (DAs). However, because the results of this assessment are region specific, the PEI scores for the entire municipality were calculated at a DA level. Due to the method of calculation, the scores are only comparable between the DAs within the study area of Squamish. This is beneficial for the city government because the results are region specific and can be used to compare different areas of the city with one another. In other walkability

indices, like Walk Score this is not the case (Peiravian et al., 2014). In this index the highest achievable score is 1 and lowest is 0. A score of 1 on the PEI is unlikely. This would mean a DA scored the maximum score of 1 in all the subindices, LDI, PDI, IDI, and CDI. However, the subindex scores are normalized within the DA, thus for each subindex calculation one DA will always receive the maximum score of 1 (Peiravian et al., 2014). PEI scores in Squamish ranged from at 0.09 to 0.56 for the 26 DAs calculated in Squamish (Figure 4.2). The median score in Squamish was 0.17 and the average score was 0.21. Overall, results corresponded closely with expectations of the degree of walkability across various parts of the municipality.

In spatial terms, DAs that encompass smaller areas and that are located near to Highway 99 scored higher on the index. In contrast, DAs that cover larger areas of land and extend further into the outer boundaries of the district have lower PEI results. All the lowest scoring DAs have substantial area located outside of the GMB. DA 187-PM, one of the selected case study periphery neighborhoods, had the lowest PEI score in Squamish of 0.09. It encompasses the informal neighbourhoods of Tantalus which has several newer residential developments as well as the Alice Lake & Mashiter area which is primarily rural and park land located at the northeast end of the district. DA 187-PM, along with being the northern most DA in Squamish, is also the largest, covering 38.11 sq kilometers of land. Other DAs with large areas, located on the district boundaries were all associated with low PEI scores. DAs 211, 198, and 205, have the second, third, and fourth largest amount of land area in the district, and are also located on the edge of the town. All relate to the next lowest PEI scores in Squamish, 0.1, 0.11, and 0.1 respectively (Figure 4.2). The DAs with the lowest PEI results all displayed similar distributions for their sub-indices scores. All had little to no commercial area, low populations, and a small degree of intersection density. Land use entropy was the only contributing factor to each of these areas PEI scores (Figure 4.1).

Figure 4.1 Comparison of CDI, LDI, PDI, & IDI Scores



4.3.1. Downtown & Willow Park – south/central west

The DAs in the downtown area measured highest on the index, however DAs located in or near to the newer commercial zones in the town also scored quite well. The presence of CDI as a part of a DAs overall score distribution was also a factor in all of the DAs with the highest PEI. Many DAs in Squamish had a score of 0 or an exceptionally low score for CDI. This is because the CDI measurement uses GFA as a component of measuring commercial area and most businesses in Squamish are in one story buildings and located in the downtown, industrial park, and the Garibaldi Village Shopping Centre. Geographically, the five DAs with the highest PEIs were all located on the west side of Highway 99. Although not a variable in the PEI calculation, slope which could affect other subindices like IDI or PDI may be factor in this result. The terrain on the east side of the town is significantly steeper as it sits at the foot of Garibaldi Mountain Range, while the west part of town is located on a flood plain.

DA 202-DN, 196, and 201-DM are the only DAs that scored above .4 on the PEI. Unsurprisingly both DA 201-DM and 202-DN, because they are neighbouring DAs close to downtown had similar sub index distributions (Figure 4.2). The land use and intersection density were evenly distributed for both, with DA 202-DN, which is slightly closer to downtown having marginally higher population and commercial density. DA 196, referred to as the Willow Park neighborhood is located on the west side of the highway between the Garibaldi Estates and Mamquam neighborhood. Conversely, it scores lower for commercial density but has a higher intersection density. It is a small, densely populated DA, which includes a school, small commercial area, and a diversity of housing types. The small size and shape of the DA likely contributed to its high

intersection density score. Furthermore, it is situated between two commercial areas, Garibaldi Village and Dentville. Dentville is a growing area with many light industrial businesses and a newly developed master planned business park called Sea to Sky Business Park.

4.3.2. Garibaldi Estates, Highlands, University Hill – central east

Across the highway from the Willow Park neighbourhood is the Garibaldi Estates, Garibaldi Highlands, and University Highlands neighbourhoods. These were some of the neighbourhoods (referenced in Section 4.1 Development and Planning History) which were developed along old forestry railway lines and camps. The Garibaldi Estates neighbourhood is centrally located along the east side of the highway and close to the main transit network in Squamish. It has a diversity of land types and includes the major commercial hub of Garibaldi Village as well as residential lots, parks, and office space. It also includes some larger parcels of VLA Lands. When VLA lands in the Garibaldi Estates were originally established, they were primarily 1 acre lots. Later on, landowners requested that the district allow them to subdivide the parcels into half acre lots. Many of these lots have remained with large gardens, mature trees, and food production. Currently the Garibaldi Estates neighbourhood comprises of the entire DA 217 as well as sections of DA 211, 216, 215, and 187-PM. The PEI score for DA 217 is 0.19, close to the average score for Squamish. This DA is primarily residential with the PDI being the largest contributing factor to the score. DA 211 is the second largest DA by landmass in Squamish. It is 22.2 square kilometers. While it includes Garibaldi Village, a major commercial development serving the neighbourhoods on the north side of Squamish, the majority of the DA is rural forested land located outside the Garibaldi Estates neighbourhood. Due to its large area and vast amount of unused land the commercial area was not substantial to the overall score. It also has almost no residential area thus the PDI score was close to 0. It has one of the lowest overall PEI scores in Squamish of .1.

DA 215 and 216 are located partially within the Garibaldi Estates and Garibaldi Highlands neighbourhoods. Both have similar PDI, CDI, and LDI however, DA 215 has a higher IDI due to a larger amount of housing developments with road intersections. Garibaldi Highlands is located on a hillside northeast of Garibaldi Estates. It encompasses all of DA 214, most of DA 213 as well as half of DAs 215 and 216. DA 214

scored slightly better on index 0.19 then DA 213 at 0.14. Both DAs have similar residential lots, street configurations, neighbourhood businesses, and land use diversity however DA 214 includes the Garibaldi Highlands Elementary school and slightly denser with a smaller land area while DA 213 is larger and includes a significant section of steeper forested land and trails. A small section of DA 212 is located in Garibaldi Highlands however most of this DA is encompassed in the University Highlands, the newest neighbourhood in this area. University Highlands is located adjacent to Garibaldi Highlands on the east side. This neighbourhood includes Quest University. It is mostly single-family homes on large lots with some townhouse and apartments. DA 212 includes residential, university, park, as well as uncategorized forested land. However much of the land in the residential areas are zoned as institutional because it is part of the university. DA 212 scored 0.12 on PEI. While it has a variety of land uses. It has a low population, little road infrastructure, and no commercial zones in a fairly large area.

4.3.3. Brackendale – northwest

Brackendale, like University Highlands is another neighbourhood with more open space. However, unlike University Highlands, it is one of the oldest communities in the region. It is the most northern neighbourhood in Squamish that is not rural residences or farmland. It is located on the west side of Highway 99 and the Squamish River runs through the valley along the west end of the neighbourhood. It has two small commercial areas as well as an elementary school and middle school on the north end of the neighborhood that service the rural Upper Squamish and Paradise Valleys. It is a mix of new and older detached single-family homes with limited multifamily housing. Brackendale contains DA 190-PN (one of the case studies in this research), 191, 192, and most of 193. It also includes a small section of both DA 188 and 187-PM. All the DAs within Brackendale are rated low to fairly low on the PEI. The scores range from .09 to .17. This is likely due to the lower population density and larger residential lot size. There is also relatively small number of businesses and services in Brackendale. DA 192 has the highest PEI score in the neighbourhood. It is ranked .17. It is the smallest by area as well as the DA with the most diverse housing types and smallest lots. It also includes a small commercial area with a gas station along Government Rd. DA 193, has a similar score of .16. It is slightly larger by area but also has a greater variety of housing types compared to the rest of Brackendale and one small commercial zone also along

Government Rd. Both 190-PN and 191 are more spread out. DA 190-PN is mostly single detached housing on larger lots. Most of the streets end in a cul-de-sac or dead ends. DA 191 has a much lower population density due to a greater amount of forested land, however it includes more land use types including an art gallery, restaurant, and both schools.

4.3.4. Valleycliffe & Crumpit Woods – southeast

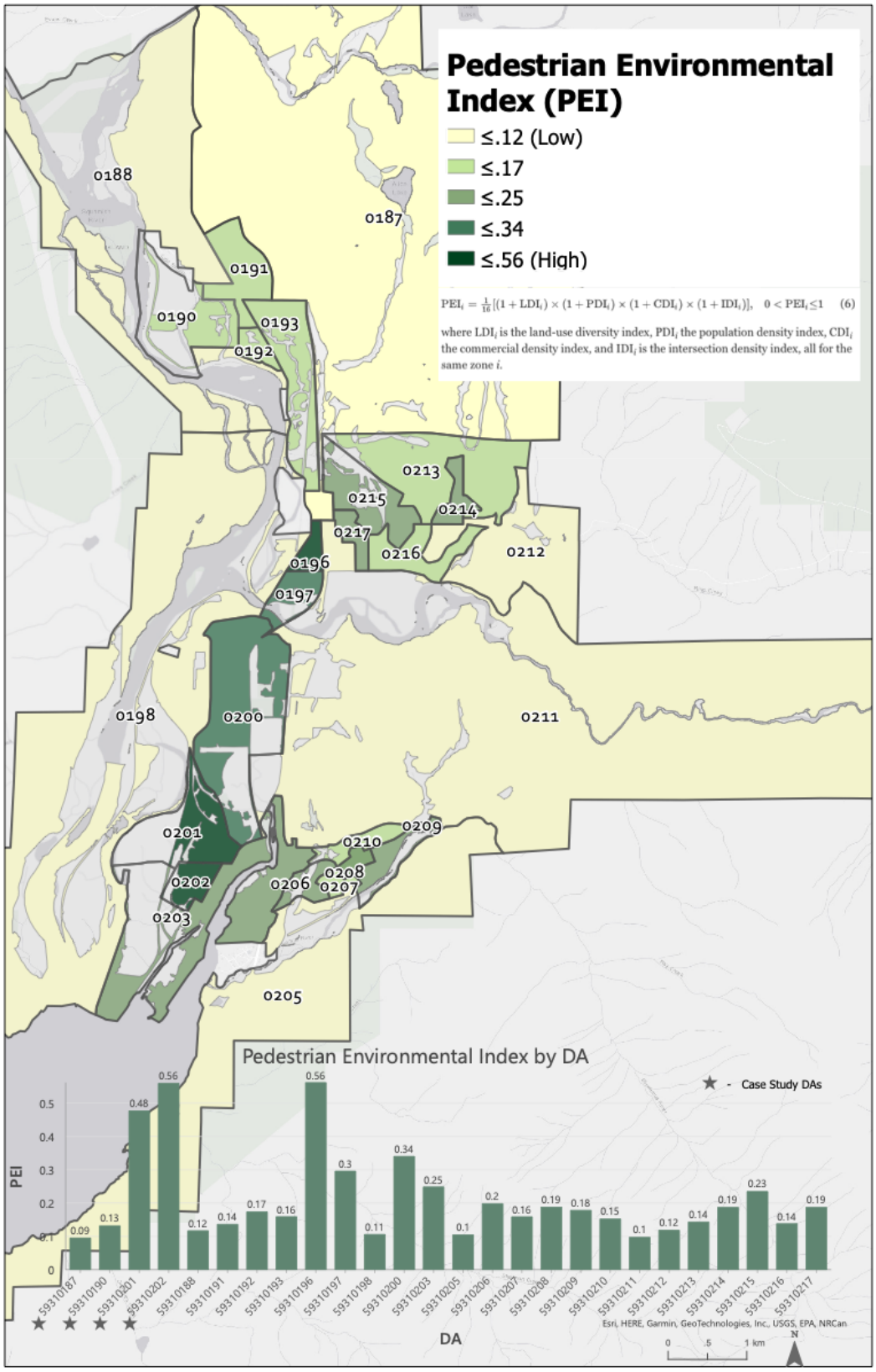
On the other end of the valley to the southeast, DA 206, 207, 208, 209, and 210 are in the Valleycliffe and Hospital Hill neighbourhoods. These are located due east of downtown. The original street layout for this area is established on historic forestry railways as referenced previously. The DAs in this area scores ranged from 0.16- 0.20, close to the median score for the district, 0.17. DAs 207 and 208 which are located within the residential neighbourhood of Valleycliffe have high population densities but incredibly low CDI and LDI scores. Both DAs are the smallest by landmass in the district each only about .10 sq km and they include exclusively residential land use. DA 206 has the highest PEI score in this area. It is slightly bigger, 0.23 sq km and intersects both the Hospital Hill and Valleycliffe neighbourhoods. It includes the hospital, residential areas, and a small park.

The Crumpit Wood neighbourhood is approximately 255 acres of land north of Valleycliffe and includes parts of DA 211. In contrast to the smaller DAs in Valleycliffe, DA 211 is 22.2 sq km, the second largest area in the district. While it encompasses many land use types; residential, park, comprehensive development and industrial in its large area, because of its mostly rural nature, it scores low at .1 on the PEI scale. However, the North Crumpit Wood neighbourhood is in the process of expanding. The Diamond Head Land Company submitted a development application to the district for an OCP amendment to prepare a neighborhood plan for the North Crumpit Lands. The district is in the process of conducting technical reports and public engagement to determine the future neighbourhood plan. Based on recent technical studies, the district is reporting that only about one third of the land can be developed due to steep slopes and environmentally sensitive areas. Of the potential remaining 96 acres, they are stressing a range of housing forms should be included in the development that emphasize missing middle such as duplexes, triplexes, fourplexes, townhomes, and apartments as well as a small number of single-family homes. Community Amenity

Policy must also be addressed according to the district staff. Amenities the must be present include affordable housing, recreation and day care amenities, parks, and active transportation. However, current development in the Crumpit Woods area are large lots with single family homes and in public engagement surveying of about 600 predominantly Squamish homeowners, the preference was for compact single-family housing and housing tenure that was free market or non-market/ affordable ownership (Diamond Head Land Company, 2022). PEI or similar analysis could be useful in this neighbourhood planning process for the district and developer to understand the outcomes of various scenarios on the pedestrian environment.

To summarize, there are a wide range of pedestrian environments in Squamish as represented by the results of the PEI analysis in each DA. The next chapter, Case Study Neighbourhood Profiles is a deeper examination of four of these DA's pedestrian environments as well as a comparison of their index results. These four DAs are 201-DM & 202-DN, both located downtown, 190-PN, in Brackendale and 187-PM which includes the Tantalus and Alice Lake & Mashiter areas, as well as a small sections of the Brackendale and Garibaldi Estates. Interestingly and unintentionally, both the lowest and highest PEI scores are attributed to two of DAs that were chosen for the in-depth case studies. DA 202-DN being the highest scoring, and 187-PM scoring the lowest. The comparative analysis that follows in Chapter 5 helps to make sense of these and other results.

Figure 4.2 Pedestrian Environmental Index Map & Graph



Chapter 5. Case Study Neighbourhood Profiles

As described in Chapter 3 Methodology and Data Collection, four DAs within the district were selected to conduct an in-depth analysis of their specific pedestrian environment. To gain a better perspective of the microlevel environments of those DAs, observational examination of the streetscapes was also conducted. Comprehensive results, and observations for each of the four unique DAs are discussed in further detail in this chapter. A dynamic comparison of key similarities and differences between the pedestrian environment of the four different areas is also considered, as well as key themes from the Literature review. This chapter begins with an overview of both the context and geography for each case study neighborhood. It concludes with a comparative analysis between all of the case study DA's results from both indices and PEI subindices.

5.1. Neighbourhood Profiles

5.1.1. DA 187-PM: northern periphery with new housing stock

Table 5.1 DA 187-PM Census Summary

Population	Population Density per Square Kilometer	Occupied Private Dwelling constructed before 1981	Occupied Private Dwelling constructed from 2000 – 2016
834 people	23.2	22.3%	68.1%

DA 187-PM is the northernmost DA in Squamish. It is also the largest by area and furthest from the downtown. It spans from Garibaldi Way on the southern boundary following the Sea to Sky highway north about 16 km to the Culliton Creek Hydro Dam just before the Culliton Creek Bridge. It covers the Alice Lake Provincial Park on the east side and on the northern end it extends past the west side of highway including Squamish Valley Rd to Government Rd and north to the Paradise Valley. It is mostly rural hinterland but due to its large area includes many other land types including residential areas, farmland, Provincial Park land, some small commercial area, and a school. As noted in Table 5.1 most of the housing in this DA is newer built construction. The reason for selecting this as a comparison DA is because there is a substantial 20-acre, master planned community being developed. There are also some new smaller townhouse developments and single-family homes in this same area. The small amount

of older housing stock in this DA are single family homes located in northeast Brackendale and small farms and single-family homes located in Paradise Valley.

5.1.2. DA 190-PN: northern periphery with older housing stock

Table 5.2 DA 190-PN Census Summary

Population	Population Density per Square Kilometer	Occupied Private Dwelling constructed before 1981:	Occupied Private Dwelling constructed from 2000 – 2016
441 people	401.2	81.1%	5.4%

Like DA 187-PM, DA 190-PN is in the periphery of the town. It is situated along the Squamish River on the west side of the neighbourhood commonly known as Brackendale. It is bound by Judd Rd on the south and Depot Rd to the north. The Squamish River and Cottonwood Rd form its west and east boundaries. Before analysis, the DA covers 1.1 sq km of land and water, however for the purposes of this study a significant portion of land was removed on the west end of this DA along the Squamish River. Both the Aikwuks 15 and Waiwakum 14 were not included as this is Squamish Nation land that is not a part of the District of Squamish. With this land as well as the river removed the area is .468, slightly below the median land area for DAs in this study of .528 sq km. This is one of the older residential neighbourhoods in Squamish with most of the housing being constructed before 1981 (Table 5.2). There are no new residential developments or MPC in this area that are under construction or built within the last 20 years. DA 190-PN is almost entirely residential consisting of primarily single-family homes.

5.1.3. DA 201-DM: northwest downtown with a master planned community

Table 5.3 DA 201-DM Census Summary

Population	Population Density per Square Kilometer	Occupied Private Dwelling constructed before 1981:	Occupied Private Dwelling constructed from 2000 – 2016
1,504 people	1,418.6	26.8%	41.5 %

DA 201-DM is in the northwest corner of the downtown peninsula. It is located south of Buckley Ave, in between Cleveland Ave to the east and Bailey Rd and the

Squamish Estuary Wildlife Management Area on the west side. The southern boundary is Pemberton Ave. The DA also extends north, across the railroad tracks between Bailey and Buckley Rd to the Wilson Crescent residential area. This is where most of the older housing stock is located in DA 201-DM, the remaining housing in this DA is located in a 25-acre residential community. This development, known as Eaglewind contains townhomes and condos that were constructed between 2007 – 2018. It was one of the first master planned developments that was realized in Squamish. The DA is .54 sq km, with some open land removed close to the estuary as it was coded as resource land. The other land is residential, a commercial shopping area, a large park, and estuary walking trails.

5.1.4. DA 202-DN: central downtown with no master planned community

Table 5.4 DA 202-DN Census Summary

Population	Population Density per Square Kilometer	Occupied Private Dwelling constructed before 1981:	Occupied Private Dwelling constructed from 2000 – 2016
1,035 people	3,550.6	26.7	54.6

DA 202-DN is located two blocks west of the main downtown commercial thoroughfare, Cleveland Avenue. It is relatively small by area. about .3 sq km. It is bound on the west side by 2nd Avenue. It shares its northern boundary, Pemberton Ave, with neighbouring case study DA, 201-DM. The estuary borders the southern and eastern edges of the DA. On the southernmost end of 202-DN is a smaller townhouses and condo development that is less than a quarter of the size of the Solterra's Eaglewind and Diamond Head Development, the MPCs specified in the case study DAs 201-DM and 187-PM. Despite the DA's compact size there is a combination of apartments, single family lots, commercial units, as well as some institutional and industrial land types dispersed throughout the DA.

5.2. Population Density Index

Table 5.5 Population Density Index DA Summary

Population Density Index (PDI)	DA 187-PM *Northern periphery with MPC*	DA 190-PN *Northern periphery with no MPC*	DA 201-DM *Northwest downtown with MPC*	DA 202-DN *Central downtown with no MPC*
	0.001	0.21	0.61	0.96

The population of DA 187-PM, the northern periphery DA with newer housing stock and MPC, is about 834 people. This is close to the mean and median populations of Squamish DAs of 750 and 640 people. However, it has a low population density of 23.2 people per square kilometer (Table 5.1). This is largely because it covers a vast amount of land and there is a significant amount of space that is uninhabited or unused forested land. The most northern 8.5 km of the DA is rural land that includes a provincial park, and several dispersed country and farmland properties in Paradise Valley. The denser residential and few commercial areas in this DA, known as the Tantalus neighbourhood, are mostly located adjacent to Highway 99 on the southeast side of the DA. The dispersed nature of this DA, which includes provincial park land, rural land, and relatively little residential density correlated to an extremely low PDI output of 0.001 (Table 5.5). It was the lowest PDI calculated among the four case studies and all of Squamish.

The other periphery DA with older housing stock, has the next lowest PDI score between the case study DAs. However, DA 190-PN's PDI score of .21 is exponentially larger than DA 187-PM of .001. While only 441 people live in DA 190-PN, which is a lower than the absolute number living in DA 187-PM, DA 190-PN, encompasses a much smaller area of land. Several other smaller exclusively residential DAs, mostly in the Valleycliffe neighbourhood in the southeast part of town have similar small population sizes in a more compact area. Given the smaller land size of DA 190-PN and that the primary land use is residential, the population density is not as low as neighbouring DAs in the periphery that cover large areas of land with numerous land uses.

DA 201-DM, located in northwest downtown and including the MPC, has the largest population of the four comparative DAs. In 2016, it was the second most populous DA in Squamish with 1,504 people residing within its boundaries (Statistics Canada, 2016) (Table 5.3). This is larger than the targeted dissemination area size of

between 400-700 persons indicated by Statistics Canada. While DA 201-DM does include more medium and high-density housing compared to other neighbourhoods in Squamish, because it also includes park and commercial space, it did not score as high on the PDI then some other exclusively residential single-family neighbourhoods that are within smaller land areas. These residential neighbourhoods are not part of the four DAs within the case study. PDI in DA 201-DM is 0.61 which given its downtown location, is unsurprisingly above the two periphery DAs. While this DA also, has some removed 'resource' or 'open space' land like its counterpart DA in the periphery that also includes a MPC, it scored well beyond DA 187-PM in PDI. It is clear in this example, that geographical context is significant in predicting population density, despite the presence or absence of a MPC.

In comparison to the other downtown DA, 202-DN, which has no MPC, 201-DM has a lower PDI score. DA 202-DN, has the second highest PDI score in Squamish of 0.96. Its overall population in the 2016 census was just over 1,035 people (Table 5.4). Due to its size, population, and downtown location, it is one of the most densely populated DAs in Squamish. Like DA 201-DM, 202-DN has a combination of medium, high density, and minimal single-family homes within its boundaries. However, between the two downtown DAs, 202-DN has a higher proportion of residential zoned land as well as a greater amount of high-density condo and apartment buildings. The significant difference causing DA 202-DN to score higher on the PDI than 201-DM is that 202-DN has significantly less land use designated towards open space. This difference is evident in the LDI scores where DA 201-DM, has a slightly higher entropy score because it has more land use diversity than its neighbouring downtown DA.

5.3. Land Use Density Index

Table 5.6 Land Use Density Index DA Summary

Land Use Density Index (LDI)	**DA 187-PM** *Northern periphery with MPC*	**DA 190-PN** *Northern periphery with no MPC*	**DA 201-DM** *Northwest downtown with MPC*	**DA 202-DN** *Central downtown with no MPC*
	0.49	0.33	0.94	0.86

DA 187-PM is one of the largest DAs by area in Squamish. All five land use types are represented in this area. While all the land use is represented and despite a sizable portion of ‘resource’ land being removed land use is still rather dispersed and separated within the DA. The overall LDI in this DA is 0.49 (Table 5.6) is below the mean and median LDI score of 0.52 for all of Squamish. This attributed to its large size as well as vast amount of undeveloped land. Beyond a provincial park, there are pockets of comprehensive development and residential areas. There is only a small area of commercial land use, despite the substantial size of the DA. The only intuitional zoning is a Jehovah’s Witness Church located at the south end of the DA along the Sea to Sky Highway and Harris Rd. The main residential neighborhood starts north of the Executive Suites Hotel and Resort Squamish on Tantalus Road continuing north to the end of Tantalus Road. The neighborhood also extends east up Doward Rd to the newest part of the neighborhood which includes the Skyridge Master Planned Community. This master planned community is zoned for comprehensive development and includes a combination of over 100 single-family homes, town houses, and apartments combined. While there are no grocery stores and relatively few other commercial services in this development or DA, Skyridge does include a Montessori school and day care as well as direct access to mountain biking and hiking trails. Immediately below the Skyridge development are two additional streets, Tantalus Rd and Rockridge Pl, which contain only single-family housing. Further south along Tantalus Rd, there is another residential development, Greenside Estates that includes 60-unit combined townhouses and 2 story apartment complexes with a small amount of commercial space at the bottom. The space on the west side of the highway in the Cheekeye area along Squamish Valley Rd and Government Rd are mostly industrial land uses. There is also small section of commercial space, a resort, café, and some ranches before crossing the river on Paradise Valley Rd. north to the Paradise Valley. This is rural forested land along the Cheakamus River. The road is mostly gravel and lots are significantly larger. This area is classified as Residential and Comprehensive Development. It is primarily residential but there is also a campground, ecological reserve, and hatchery in this area. While the LDI score is still on the lower side of all DAs in Squamish because it encompasses every land use, the score is higher than other smaller DAs that have less variety of land types within their borders. This is case for the other periphery DA 190-PN that does not include a MPC.

Entropy in DA 190-PN is low. The land use mix is entirely residential with two small parks. The LDI score in DA 190-PN is 0.33 (Table 5.6), the lowest index score of the four DAs in the case study evaluation. Overall, there are little services or amenities located in this neighbourhood. However, on the immediate periphery of DA 190-PN, along Depot Rd there is a comprehensive development area with a day care and a dog care business. Also, just outside DA 190-PN, along Government Rd there are few small commercial areas with cafes and restaurants. Overall, the Brackendale neighbourhood, the DAs and area surrounding DA 190-PN is largely residential with few small pockets of commercial spaces for example a bike store and gas station. The closest grocery store is about an hour walk. In contrast, the DAs located in the downtown have a wide-ranging choice of amenities within short walking distances to the residential areas.

In DA 201-DM, the downtown DA with a MPC, there is a varied amount of land use, making it one of the highest LDI scores within the district. The LDI in 201-DM is .94 this is slightly higher than the other downtown DA, without the MPC and significantly higher than the DAs located outside the core. All five land use types are represented in this DA relatively proportionally. The Eaglewind development is zoned as comprehensive development. While originally the expectation was for more retail space in the Eaglewind community, there is a small amount of commercial space in the ground level of the residential units built in early phases of the development. Directly east of the Eaglewind MPC along Third St is a strip mall consisting of both services and commercial uses. It includes a grocery store, liquor store, pharmacy, pet store, ICBC, Canada Post, and a few other restaurants and shops. There is a park located east of the MPC that has tennis and pickleball courts, a dog area, a kids play structure and a community garden. There is also a walking path that connects to some of wilderness estuary hiking trails. Exclusively residential zoned land is represented in the older housing in the Wilson Crescent area. Northeast of Wilson Crescent is a small church that is situated on institutional zoned land. Finally, the CN rail line which passes through the DA, separating the Eaglewind community from the other older residential area is zoned industrial.

Like DA 201-DM, all the six land use types realized in the LDI calculation are represented in DA 202-DN. While there are quite a few new residential development buildings in 202-DN, unlike in DA 201-DM, there is no large-scale master planned developments. however, there is a 61 unit a townhouse and condo development, Soleil Coastal Village, coded as comprehensive development, on the south end of the DA.

There is one massage therapy business in this development. The eastern boundary of the DA is one block west of the town's main downtown commercial street, Cleveland Ave, and thus has a significant amount of spill off businesses and services. This street, 2nd Ave has many restaurants, a bookshop, the Sheriff station, multiple salons, and beauty services, as well as government buildings including Municipal Hall, the Engineering Department and Squamish Administration to name a few. Progressing west from 2nd Ave toward 3rd, 4th, 5th, and 6th Ave changes from a combination of scattered business and condos on 3rd Ave to almost entirely single-family homes on 5th and 6th Ave. While all the land use types of land use are represented within this relatively small DA, the overall LDI score of .86 is just below the neighbouring downtown DA 202-DN. This can be explained by the difference in ratio of area of land use type to total area in each DA. The total ratio of residential land use is greater in DA 202-DN while, DA 201-DM has a more evenly distributed ratio of land use type.

5.4. Commercial Density Index

Table 5.7 Commercial Density Index DA Summary

Commercial Density Index (CDI)	**DA 187-PM** *Northern periphery with MPC*	**DA 190-PN** *Northern periphery with no MPC*	**DA 201-DM** *Northwest downtown with MPC*	**DA 202-DN** *Central downtown with no MPC*
	0.01	0.02	0.58	0.66

The small number of business licences in the large land area of DA 187-PM, the periphery DA with a MPC resulted in one of the lowest CDI scores in Squamish, at 0.01 (Table 5.7). Access to commercial space in this DA is limited. Skyridge, the MPC has no commercial space however another new development located below Skyridge, nearer the highway is adjacent to a small commercial development with some professional services, education, and health services. At the far south side of the DA, there is a fire station, chain and local restaurants, a bank, and a few local businesses dispersed on the east and west side of highway. While there are a few other commercial zoned areas in this DA, this is the main cluster of businesses in DA 187-PM. As mentioned in the Methodology Commercial Density chapter, the PEI model uses GFA to calculate CDI, very few commercial entities in Squamish that have multiple floors. However, surprisingly, of the four case study DAs the only commercial building with two floors off commercial space is a bank located in DA 187-PM. These businesses are adjacent to a

larger retail strip mall in the neighboring DA that has many essential retail services, including a grocery store, pharmacy, and gas station. However, as an example, to walk from this commercial area to the top of the Skyridge MPC is about 2.5 km and 35 minutes according to Google Maps. The dispersed and disjointed nature of each residential community in this DA makes it so that access to services in one development are not convenient for that of another residential area to easily walk to.

One of the difficult aspects of utilizing this model in Squamish was defining commercial space. Compared to larger urban centers, Squamish has limited multi-level commercial buildings. In fact, many businesses operate out of home offices or locations that are not necessarily zoned as commercial areas. DA 187-PM has a wider variety of land use mix that included commercial parcels than 190-PN, the other periphery DA which has no land zoned for commercial use. However, applicable businesses that operate from a home space were included in the CDI calculations. DA 190-PN has a small number of arts, food services and accommodation business licenses in residential zoning that generated a CDI of 0.02. This is slightly higher than the juxtaposing DA, 187-PM, which is similarly in the periphery but that has newer housing stock and includes a MPC. It is likely assumed that the DA with newer developments and MPC would produce a higher CDI score because MPCs are known to typically include recreational and commercial areas for residents. However, this is not the case for these neighbourhoods. While the Skyridge MPC does include recreational facilities there are no commercial amenities. Furthermore, DA 190-PN does have fewer overall businesses and commercial space, but the spread-out nature of DA 187-PM reduces access, especially walkable access, to businesses and services. In reality however, both DAs in the periphery have extensively less access to businesses than the DAs located in Squamish downtown. As expected, this is evident in the difference in scores in CDI between the periphery and downtown DAs. Both downtown DAs scored similarly and considerably higher on this metric.

The CDI in the downtown DAs are 0.58 in 201-DM which contains the MPC, and 0.68 in 202-DN, without the MPC (Table 5.7). As mentioned in the Land Use Density Index section there is one main commercial zone in a strip mall in DA 201-DM. In the strip mall there are about twenty single level businesses surrounding a large parking lot. There are a few other businesses located south of the MPC as well as on northwest side of the DA, across the rail tracks along Buckley Ave. In the early marketing plans for the

Eaglewind MPC, there were proposals for shared residential and retail space. However, because there were mostly townhouses developments built, there are only a few services based commercial spots at the base of the Eaglewind Rockcliffe condo building and no other business directly in the MPC. Despite this, due to compact nature of the downtown area, the previously mentioned strip mall as well as other downtown services and amenities are all within walking distance to the MPC. In contrast to the major commercial areas in DA 201-DM being centered around a parking lot, the businesses in DA 202-DN, are mostly scattered on street near the DA's eastern border of 2nd Avenue (Table 5.7). This is one block west of the major pedestrian oriented commercial street in the downtown. While DA 201-DM, includes more big retail stores including a grocery store, liquor store, pharmacy, and auto part store, DA 202-DN has some smaller restaurants, shops, salons, and services.

5.5. Intersection Density Index

Table 5.8 Intersection Density Index DA Summary

Intersection Density Index (IDI)	**DA 187-PM** *Northern periphery with MPC*	**DA 190-PN** *Northern periphery with no MPC*	**DA 201-DM** *Northwest downtown with MPC*	**DA 202-DN** *Central downtown with no MPC*
	0.01	0.28	0.55	0.48

There are not a substantial number of intersections in DA 187-PM. In the main residential areas, in the Tantalus neighbourhood, the street pattern is curvilinear meaning the development pattern is characterized by streets that are non-linear or curvy. It is typical in many modern subdivisions and is often seen as advantageous by developers as a way to create more marketable land. However, it is also thought to be a detriment to pedestrians. Curvilinear street patterns generally have lower intersection or network density and lack connectivity. This is along with the undeveloped nature of the DA is substantiated by the PEI outcomes as DA 187-PM had the lowest IDI score in Squamish of 0.01 (Table 5.8). The spread-out nature of this DA, particularly in the provincial parks and rural residential areas, reduces the magnitude of intersections in the more condensed residential and commercial areas within the same DA. The other periphery DA 190-PN with no MPC also has few intersections. Intersection density was calculated as .28 (Table 5.8). Again, this is higher than DA 187-PM, and lower than the two downtown DAs 201-DM and 202-DN. While the streets are more compact than in

DA 187-PM, the street pattern is similarly irregular and disconnected. Government St, which is located just outside the DA is the major thorough way through the Brackendale neighbourhood. From Government St. local streets branch off and follow a disconnected and dead-end pattern into DA 190-PN.

The street pattern within DA 201-DM, the downtown DA that includes a MPC is also characterized by irregular and disconnected streets like the periphery neighbourhoods in some areas. The main roads in this DA, Buckley, Bailey, Pemberton, and Cleveland do not run perpendicular to each other, instead they meet at irregular angles or curves. The streets specifically within the Eaglewind MPC are more of a broken grid with a mix of dead ends, roundabouts, and fragmented grids. The combination of these two dynamics makes pedestrian access more complicated in this DA. Despite this, the IDI score was highest in 201-DM, compared to the other four DAs. One explanation for this is because the block size in this DA, especially within Eaglewind are shorter than in the other DAs thus there are more occurrences of intersections, even if some of them are dead ends. The streets in DA 202-DN, the other downtown DA, are in a grid like formation. While they are the most uniform of the four case study DAs and would likely be expected to produce the highest IDI, the score in the other downtown DA with the MPC, 201-DM, scored just above DA 202-DN. DA 202-DN scored an IDI of 0.48 and DA 201-DM scored 0.55 (Table 5.8). Beyond the small street segments in the other downtown DA increasing the IDI score for 201-DM, a few of the farthest streets in DA 202-DN on west and south ends of the DA dead end or terminate on the estuary which would constrain the IDI score in DA 202-DN. Although at some of these endpoints there are often informal pathways that lead onto the estuary trail system. This model doesn't account for any formal or informal pedestrian pathways which is potentially problematic when considering the usefulness of formal and/or informal pedestrian infrastructure, especially in these scenarios.

5.6. Pedestrian Environmental Index

Table 5.9 Pedestrian Environmental Index DA Summary

Pedestrian Environmental Index (PEI)	DA 187-PM *Northern periphery with MPC*	DA 190-PN *Northern periphery with no MPC*	DA 201-DM *Northwest downtown with MPC*	DA 202-DN *Central downtown with no MPC*
	0.09	0.13	0.48	0.56

Overall, DA 187-PM has the lowest PEI score in Squamish of .09 (Table 5.9). The CDI, PDI, and IDI were all less than the three other DAs in this analysis. DA 187-PM's limited population, commercial area, and intersections are all contributing factors to unsatisfactory pedestrian environment. The vast and sprawling nature of this DA, including a significant amount of land that is rural and undeveloped also deter pedestrian travel. On balance, the PEI score for 190-PN was one of the lower scores in Squamish. Of the four DAs profiled in this analysis, DA 190-PN has the second lowest PEI score at 0.12, slightly higher than DA 187-PM's PEI. DA 190-PN scored above DA 187-PM in all subindices except LDI and its highest score was for PDI. This is likely because it is an exclusively residential neighbourhood. Not surprisingly, DA 190-PN did not score above the downtown DAs for any of the subindex calculations.

DA 201-DM had one of the highest overall PEI scores in Squamish. The PEI in DA 201-DM is 0.48, this is just below DA 202-DN, which is also located downtown but does not include a MPC. DA 202-DN has the highest overall PEI metric of the case study neighbourhoods as well as being tied with one another DA for the highest PEI score in all of Squamish of, 0.56. Compared to DA 202-DN, 201-DM scored lower on the PDI and CDI, However, it scored higher than the other DA 202-DN on IDI and LDI. The LDI result is understandable because DA 202-DN is smaller so there is less opportunity for varied land use types. However, the IDI outcome is somewhat surprising given that DA 201-DM which has the MPC has a more irregular street pattern than 202-DN which has a grid formation. Overall, most the downtown subindices scores were within a similar range. The index where the two DAs diverged the most was in population density. DA 202-DN had a PDI score of 0.96 while DA 201-DM only scored 0.61. In terms of comparative pedestrian environments, DA 201-DM, scored higher on the final PEI measure then DA 187-PM, which also has a MPC within its boundary but is located outside the downtown core. As expected, it also scored considerably higher than 187-

PM in all the related indices, LDI, PDI, CDI, and IDI. The equivalent result occurred for the two DAs which do not contain MPC. The downtown DA without the MPC, 202-DN scored significantly higher on the PEI then the DA in the periphery without the MPC. While the score differences were not as pronounced between the downtown and periphery DAs without the MPC than those with there is not enough data to suggest that the MPC is the cause for this. There are many other variables including the DA size and extent that may be attributed to these differences.

5.7. Microscale Audit of Pedestrian Streetscapes

Table 5.10 Microscale Audit of Pedestrian Streetscapes DA Summary

Microscale Audit of Pedestrian Streetscapes	DA 187-PM *Northern periphery with MPC*	DA 190-PN *Northern periphery with no MPC*	DA 201-DM *Northwest downtown with MPC*	DA 202-DN *Central downtown with no MPC*
	3.21	1.72	4.21	4.04

DA 187-PM scored 3.21 (weighted by segment length) on the streetscape audit, which evaluates the level of pedestrian ease on a microscale. DA 190-PN's average streetscape score weighted by segment length was 1.72. This is 83% lower than DA 187-PM's score. While DA 190-PN scored higher than DA 187-PM in nearly all aspects of the macroscale index, except for land use, when it comes to microscale measurements of walkability DA 190-PN underperformed compared DA 187-PM. DA 187-PM scored highest of all case study DAs on the presence of bike lanes, parks, and commercial streets. Although no DA scored especially high (close to 1) on any of these features. The tables in the Appendix display the individual weighted scores for each microscale neighbourhood feature. According to the streetscape audit, benches, sidewalk buffers and building conditions are neighbourhood features that are not as prevalent in DA 187-PM. Also, while incline was not a factor in the abbreviated MAPS audit, I conducted, the segments from Doward Rd towards the Skyridge MPC were especially steep. Overall, the sidewalks in DA 187-PM were much steeper on average compared to elevation of segments in the other three DAs analyzed in this research. It was also observed that especially in this steep area near the MPC the pedestrian infrastructure was updated and very well maintained likely because it is one of newest neighborhoods in Squamish.

Pedestrian enhancing features that were scarce in DA 190-PN were commercial streets, parks, benches, public transit stops, and tree coverage. There were no sidewalks in this DA, thus scores for presence of sidewalk, sidewalk condition, continuity, and buffer scored 0. Occurrence of streetlights and bike paths as well as the condition of buildings in the DA scored above or similarly with the other three comparative DAs. Low scores on the streetscape audit might be explained by the older nature of this neighbourhood. Compared to the other neighbourhoods there has not been recent construction or development which often corresponds with updated infrastructure.

Both periphery DAs scored below both downtown DAs in this audit. However, DA 187-PM, scored 3.21 which was much closer to the downtown DAs than in the macroscale audit. 201-DM, the downtown DA with a MPC and 202-DN, the downtown DA without the MPC scored similarly at 4.21 and 4.04, respectively. Overall weighted scores for the downtown DAs were comparable however, there were some key differences in which microscale neighbourhood features elevated their MAPS score. For example, public transportation stops were more widely available on street segments in DA 201-DM, then in 202-DN, as were bike lanes. Benches however were more prominent in 202-DN, the DA without the MPC.

Sidewalks were not prevalent on both sides of the street in any of case study DAs except for DA 202-DN, the downtown DA with no MPC. However, in DA 202-DN, the condition of the many of the sidewalks was insufficient. While sidewalk presence was slightly higher in 202-DN both downtown DAs scored in about the same range for condition and continuity of the sidewalks. This is because both downtown DAs include some deteriorating pedestrian infrastructure, especially in the older areas of downtown. While the condition of sidewalks in the Eaglewind MPC are newer and in good condition there is an overall lack of sidewalks in the community. Many residents park on the small driveways that intersect the limited sidewalks that do exist in the neighbourhood. Despite almost all the townhomes having street level garages, residents manly use their garage for storage instead of parking. While vehicles being parked disrupting the sidewalk is not a permanent break in the continuity of a walking path or is not related to the condition of the physical sidewalk it does cause an obstruction for pedestrian travel on a walkway. In the longer MAPS version, the survey includes two questions that distinguish between permanent and temporary sidewalk obstructions, however, the abridged version created

for this research did not determine between temporary and permanent obstructions and parked vehicles were not counted towards a discontinuous sidewalk. The compact nature of the MPC in 201-DM has further added to an interesting landscape for pedestrian travel as well as vehicle storage in this area. Even though every townhouse has a garage, parking is an issue in the neighborhood. The arterial road, Bailey St. just outside the MPC is lined with parked cars from the neighbourhood. The streets within the MPC are narrow and include no parallel street parking and sidewalks are scarce. This neighborhood has many families and these conditions, including narrow streets where cars can't drive fast create an environment where kids are often playing on the streets and people choose to walk on the roads instead of the obstructed narrow sidewalks.

Regardless of whether this was an intended or unintended result of the neighbourhood design, based on observations, residents within this MPC prefer to use the streets for pedestrian travel. Another key component of the Eaglewind MPC in DA 201-DM, is that the road segments are short, while getting around within the community is straightforward, the design of developments and street formation creates limited ways to walk in and out of the community. This is a setback for increased pedestrian connectivity within the town and is further discussed below in Finding 3: Streetscape features produce localized pedestrian conditions; macroscale features are important for connectivity & accessibility.

Chapter 6. Themes and Findings

This chapter uses the details of the case studies and comparative analysis as well as themes taken from the content review to develop key findings stemming from the results of this thesis project. The findings in this section are broken up into those that relate to the key neighbourhood features that were or were not reflected in the PEI measure. The second part of the findings reflect the validity of the indices and how well they correspond to the overall planning guidelines related to pedestrian environments in Squamish. These findings and themes draw upon the literature on this topic to help understand and explain how the outcomes from the indices used in Squamish compare to findings in other contexts.

6.1. Finding 1: Centrally located DAs score higher on both indices and periphery neighbourhoods are overall unfavorable to pedestrian conditions and connectivity

Unsurprisingly, the neighbourhood feature that most clearly related to high scores on the pedestrian environmental index as well as the microscale audit was the neighbourhood's proximity to the downtown core. Conversely, neighbourhoods located on the periphery of town were universally connected to lower PEI scores. 201-DM & 202-DN, the DAs located in downtown scored five times higher on the final PEI than the DAs located on the edge of the town, 187-PM and 190-PN. The downtown DAs also scored higher on all the sub-indices. While population density and land use density were the highest scores for the downtown DAs, commercial density and intersection density were also significantly higher than in periphery.

While the PEI results confirm what was largely expected, downtown and more centrally located neighbourhoods are more walkable, while periphery neighbourhoods are less connected with more unsuitable pedestrian environments, the data analyzed in this study has quantified and built upon those concepts, especially for smaller or border cities. It provides more details on the pedestrian landscape within Squamish and allowed for the contextualization of the results within a small town. The model is useful here in showing that despite Squamish being an edge city, components usually noticed in larger cities, for example, population density, diversity of land use, and smaller more connected

streets still exist more readily in downtown areas of this smaller towns and indicate a more favourable environment for pedestrians.

Higher streetscape audit scores (MAPS) were also associated with the DAs located near to the center of town. However, the results were not as pronounced here. While location was still significant in the relationship to microscale walkability features, the downtown DAs still scored highest on this index compared to the periphery DAs, the condition of local infrastructure also was a factor in contributing to MAPS outcomes. Table 6.1 PEI & MAPS Score Summary help visualize the difference between the PEI and MAPS results as they relate to each case study DA. The score distinction between the periphery and downtown is much more pronounced in PEI than in the MAPS score. The two indices consider different variables and scales which reflect the varied results. This will be explored in greater detail in Finding 3 that explains in this context, how enhanced streetscape features provide localized pedestrian accessibility but do not necessarily create more connected and walkable communities on a larger scale.

Table 6.1 PEI & MAPS Score Summary

	DA 187-PM *Northern periphery with newer housing stock*	**DA 190-PN** *Northern periphery with older housing stock*	**DA 201-DM** *Northwest downtown with newer housing stock*	**DA 202-DN** *Central downtown with newer housing stock*
Pedestrian Environmental Index (PEI)	0.09	0.13	0.48	0.56
Microscale Audit of Pedestrian Streetscapes (MAPS)	3.21	1.72	4.21	4.04

6.2. Finding 2: MPC DAs align in land use diversity, however context matters in determining overall pedestrian friendliness

One important sub question of this research was to understand how the recent development of MPC influence pedestrian environments in Squamish. MPCs are often inherently characterized as mixed use or walkable because they are planned or marketed to replicate the principles of New Urbanism which highlight the importance of dense neighbourhoods with wide ranging retail and employment offerings and pedestrian oriented design (Congress of New Urbanism, 2000). An original aspect of this research project was to measure the pedestrian environment of specific MPCs within Squamish to clarify if previously built MPC developments within Squamish performed comparatively better than other residential areas on the PEI. However due to spatial data limitations, it wasn't possible to conclusively measure the numerical PEI index and subindex outputs for individual MPCs. The components or subindices that make up the PEI calculation require demographic inputs and DAs are the smallest boundary for which census data are distributed. For this reason, in its standard form, the index is not helpful in indicating the performance of the pedestrian environment of a specific large-scale development or MPC in Squamish. This is one limitation of the use of the index in smaller population zones.

Despite shortcomings with PEIs ability to measure pedestrian friendliness for a particular MPC, I was able to evaluate specific factors, including MPCs, that could potentially influence different results on the PEI. In order to complete this analysis, two of the four DAs selected included a MPC. The DA with the MPC were compared against the DA in the same geography with no MPC. This method of comparison help identify if the existence of a MPC within a DA would have an effect on the indices results. The comparison revealed that both DAs with MPCs, 201-DM, in the downtown and 187-PM, in periphery had higher LDI scores in comparison to their counterpart DA that shares a similar geographic location within the municipality. The LDI subindex is used to describe an area with greater access to diverse types of land uses for example retail, services, parks, and institutions.

The higher LDI scores indicate an emerging pattern that DAs in Squamish with MPCs, have a higher density of land use. This is an initial finding and should be

replicated in other environments within Squamish for more conclusive results. In a broader context, the DA level LDI results calculated throughout the district indicate the regions in Squamish that have lower and higher amounts of accessible amenities. The implications of both these findings are important. The results of the LDI scores confirm that in each of their geographic locations, the DAs with MPC have slightly more accessibility to different services, businesses, and recreational areas then the counterpart DA located in a similar part of town. This is significant because this accessibility measurement can be linked to existing policy in the OCP and other planning documents that commit to developing current neighbourhoods and new developments into zones where residents are able to walk for their daily needs and recreation. While the PEI index itself does not produce specific measurement of new or prior developments, it does serve as a baseline understanding of how well a certain DA is performing compared to other DAs in the district. The municipality could use this information to pinpoint where to focus resources and enhancements that would improve zones of accessibility in both existing neighbourhoods as well as new developments.

Ultimately, it's important to emphasize that while the multidimensional comparison between DAs help to parse out the influence of MPC within each particular landscape, the results of the comparison do not indicate that the DAs with the MPCs should be equated even on factors such as LDI. The reality is that DA 201-DM, the downtown DA with the MPC scored nearly 100 times that of 187-PM, the periphery DA with an MPC, on the LDI subindex, indicating that access to multiple land uses is far easier in the centrally located DA. This is underlined by the fact the other downtown DA, 202-DN, scored just under the downtown DA with the MPC on the same LDI sub index score. The ease of walking and accessing retail spaces and other services in the downtown versus the periphery was made abundantly clear through the in-person survey and MAPS audit that was conducted. In fact, as mentioned above in Finding 1: Centrally located DAs score higher on both indices and periphery neighbourhoods are overall unfavorable to pedestrian conditions and connectivity. All the downtown DAs scored higher than the periphery DAs in all sub-indices and indices in this study. This emphasizes the fact that geographic location was the most important indicator in determining how pedestrian friendly a landscape was based on pedestrian index tool.

The PEI comparative analysis was a useful tool in contrasting variables across the four case studies. However, when more context was needed or instances where the

index is not able to calculate for specific boundaries, observations of the individual MPC or residential area, neighbourhood surveys, and resulting scores from the microscale audit were valuable in adding dimension to the pedestrian landscape of the four DAs. This supplementary data helps to contextualize the PEI findings and clarify the validity of the index. In contrast, PEI offers a zoomed out or expanded perspective where the MAPS results become too specific. This idea of the indices dual purposes is expanded upon below in Finding 3: Streetscape features produce localized pedestrian conditions; macroscale features are important for connectivity & accessibility. Drawing upon these revelations further helps define the ways the tool is useful in policy and development discussed in Finding 4: .

6.3. Finding 3: Streetscape features produce localized pedestrian conditions; macroscale features are important for connectivity & accessibility

The MAPS results for the four case study DAs illustrated the necessity to observe and study both macro and micro feature inputs to pedestrian environments. While DA 187-PM, the periphery DA with the MPC still scored below the downtown DAs on the microscale audit, the difference in scores were much closer in this index in comparison to the macroscale PEI measurements. In the PEI audit, there were drastic differences in results between the periphery DAs and the centrally located DAs, however the new infrastructure, and amenities in the newer developments and MPC in DA 187-PM, the periphery DA with a MPC, related to a higher score on the MAPS audit. For example, the new sidewalks and bike paths that were constructed in and around the Skyridge MPC were all in pristine condition when the neighborhood was surveyed. These microscale infrastructure improvements are important in creating more accessible pedestrian transportation system, one of the key components of Squamish's current policy goals to create improved pedestrian experiences. However, these localized improvements do not solve the macroscale challenges illuminated by the PEI results for the periphery neighbourhoods. While sidewalks, streetlights, and bike lanes are improvements to the pedestrian landscape the lack of mixed land use, and residential neighbourhoods with nearby amenities and businesses does not entice people from switching their mode of travel from vehicular to walking, another core planning incentive to expand pedestrian environments in Squamish.

Conversely, the specific street segments in Eaglewind MPC located downtown in DA 202-DN scored quite low on the MAPS audit (Microscale Audit of Pedestrian Scores Map). As previously mentioned, there is a lack of sidewalks within this DA. However, Eaglewind development is near many amenities and services and this DA scored comparatively high in LDI and PEI. Walking to the main commercial street or the grocery store is not a far distance, yet there are few pedestrian throughways to make this travel efficient. The built form of the MPC is closed off from walking to surrounding areas especially on the east and west sides of the development. There are a few informal pedestrian pathways that connect to trails, the tennis court, and a playground however, overall, there are limited sidewalks within the community. There is either one side of the street with a sidewalk or there is no sidewalk on either side of street. This is an example of a neighbourhood where macrolevel neighbourhood features including pedestrian density and entropy have created favorable pedestrian conditions however the localized infrastructure is lacking. Reflecting on the accessibility theme, as noted in Chapter 4, Squamish has set guidelines in the OCP that new large-scale developments should include multi-modal transportation networks that include pedestrian trails with neighbourhood linkages and connectivity. In this scenario, the land use component of the accessibility policy goal is being met, but the transportation system components falls short in creating an accessible pedestrian environment.

Finally, it is interesting to note that DA 201-DM scored quite well on IDI, which is used as an indicator for connectivity of road and sidewalk networks. In theory this is because an area with greater intersection density provides more potential routes for walking and requires less out of direction travel to get from one point to another (Fonseca et al., 2021). One of the reasons for the higher score on IDI in DA 201-DM is the shorter street segments in the Eaglewind MPC which increase the density of intersections within the MPC. However, on the MAPS audit the Eaglewind MPC did not score as well comparative to the rest of the DA on streetscape performance indicators for walkable environments. As mentioned above while the few sidewalks in the MPC are in good condition, there are few of them. As noted above in 5.7 Microscale Audit of Pedestrian Streetscapes, it was observed that residents used the streets for pedestrian functions but that the connection into and out of the DA was difficult. This is to say, that even with in a small area it is complicated to create a standard metric of what a successful connected pedestrian network looks like. While the two metrics are

measuring two completely different components of the environments, both are used as proxies for some degree of determining the effectiveness of sidewalk networks and connectivity. These examples demonstrate the use cases and shortcomings for each model in highlighting areas where policy goals might be needed or are falling short. While the PEI is helpful in providing a baseline summary of an area, the specific context and practices of the community are important in understanding the full picture of how pedestrian environments function in Squamish.

6.4. Finding 4: A combination of pedestrian indices are useful for assessing pedestrian environments related to Squamish's current policy objectives

The second part of this thesis evaluates how helpful indices measuring pedestrian friendliness are in advancing and/or measuring active transportation goals defined by District of Squamish. Congruency was found between the Pedestrian Environmental Index (PEI) and Microscale Audit of Pedestrian Streetscapes (MAPS) and local policy objective for increased walkability in Squamish. In Section 4.2 Current Pedestrian Focused Planning Goals, four themes were indicated that were prevalent across Squamish's key planning documents in relation to fostering a more walkable community. They were (1) improvements in accessibility, (2) connectivity, (3) mode share shift, and (4) growth management strategies. These themes were used to not only define the several types of pedestrian challenges throughout Squamish but also to organize multiple policies across document into congruent groupings. This delineation of policies helped to analyze where the PEI and MAPS indices would be the most valuable.

Throughout Section 4.2, challenges that could be mitigated and policies that could be supported by the use of either index were noted. In some instances where a walkability policy is not aimed at changes to the built environment or attitudes or pushback from residents was a barrier to progress of a policy that would improve the pedestrian environment, the indexes are not useful. There are some policies (Table 6.2) where language was broad and multifaceted and in these instances all or most of indices and subindices would be valuable to some extent in advancing the goal. An objective from the OCP like "Create complete neighbourhoods where residents can meet their daily needs in a walkable gathering place" touches on all the identified themes and could be enriched by the use of multiple indices outputs. For example, the overall PEI index is

a helpful base for measuring what residential areas necessitate a more walkable landscape. The LDI subindex could further indicate where amenities and services that residents rely on daily are lacking. PDI might indicate to staff an area that has a greater number of residents living in and thus should be a focus for quicker action. Once an exact zone or neighbourhood is determined to need actions a streetscape audit like MAPS might be useful to determine the safety and reliability of the sidewalk or trail network in that zone. In other instances where policies are more specific the index can perform in a more targeted capacity. For instance, the Natural Open Space, Parks, & Greenway Objective which ensure safe, convenient access to neighbourhood parks and recreation amenities within a 10-minute walk of all existing and new residential development is primarily focused on land use and accessibility. In this case a spatial analysis of parks and greenspaces as well as the use of LDI & PEI would be useful tools in determining areas in Squamish to focus this policy.

This examination has indicated that the PEI is a beneficial preliminary measurement tool for understanding the pedestrian environment in edge cities like Squamish. As specified throughout this research, PEI outputs have for the most part been substantiated based on prior knowledge of the area, the index's alignment with current policy goals, as well as field observations and survey results. This serves as a validation of the index as a baseline measurement tool or model that could be readily used by a municipality. The specification of it as a baseline tool is because as will be discussed in detail in the next finding, the index has some shortcomings. GIS and spatial variables are less detailed, meaning further exploration into specific zones is critical for comprehensive pedestrian-oriented planning. PEI is helpful in identifying largescale patterns of pedestrian landscapes at a region-specific level; however, its accuracy could be improved by more detailed street level data.

Given that finer scaled variables are unlikely to be captured at the DA level covered by PEI, a modelling process used by the planning department could involve two steps. First a spatial model, like PEI which uses landscape GIS variables is generated. After the results of the first index are analyzed and areas necessitating further research are identified, a second index at street level could be produced, which uses finer scale variables measured on the ground. This secondary audit would be similar to the Microscale Audit of Pedestrian Streetscapes (MAPS) mini audit tool adapted for this research. This multiscale approach is advantageous for practical purposes too. The use

of PEI as a preliminary tool, captures key walking related aspects of DAs or neighbourhoods across an entire region using dependable yet widely available data that are continually and methodically updated. This two-prong method cuts down on expensive and time-consuming field visits, however, does not eliminate their capacity to show a finer level of detail through a secondary audit when needed. The application of both indices uses the complementary information they provide to derive the most essential information needed to improve pedestrian environments.

Table 6.2 Correlation between Policy Goal and Indices

Policy Goal	High Level Objective/Theme	Document	Index or Audit Measure to Advance Policy Goal
Support economic growth and new development of businesses	Connectivity, Growth Management Strategy	District of Squamish Active Transportation Plan, OCP	CDI
Reduce SOV Trips	Mode Share Shift	District of Squamish Active Transportation Plan, OCP, Squamish Multi Modal Plan	PEI, LDI, CDI, IDI, PDI, & MAPS
Expanding and addressing gaps in sidewalk, trail, and bike network infrastructure	Connectivity, Accessibility, Mode Share Shift	District of Squamish Active Transportation Plan, OCP, Squamish Multi Modal Plan	PEI, IDI, MAPS
Ensure safe, convenient access to neighbourhood parks and recreation amenities within a 10-minute walk of all existing and new residential developments.	Accessibility	OCP	PEI, LDI, MAPS
Create complete neighbourhoods where residents can meet their daily needs in a walkable gathering place	Growth Management Boundary, Accessibility, Mode Share Shift	OCP	PEI, LDI, CDI, PDI, MAPS
New large-scale developments will require multi-modal transportation network and circulation plans including neighborhood connectivity and linkages	Accessibility, Connectivity	OCP	PEI, IDI, MAPS
Identifiable and appropriate intersection crossing	Accessibility, Connectivity	District of Squamish Active Transportation Plan	MAPS
Maintaining and upgrading the sidewalks that are in poor condition, increasing sidewalk coverage	Accessibility, Connectivity	District of Squamish Active Transportation Plan	MAPS
improving lighting along streets, pedestrian pathways, and underpasses	Accessibility, Connectivity	District of Squamish Active Transportation Plan	MAPS
Improve north/south pedestrian connectivity focus to the multi-use pathways, off-street pathways, and the Corridor and Discovery Trails	Connectivity	District of Squamish Active Transportation Plan	MAPS, LDI, PDI

Finally, PEI is not limited to its use as a measurement tool for previously constructed neighbourhoods. If data is available or modeled at different scales the tool can be adapted to proposed and future landscapes at varying stages of the planning process. Beyond the index's scope to measure and enhance policy decisions relating to pedestrian environments, PEI or other spatial models could also be useful audit tools to track how specific policy goals set out by the District of Squamish are trending. While there is extensive documentation of strategies for improving pedestrian environments within Squamish there is less public information on how the district tracks its numerous approaches to creating a more walkable community. The OCP does include performance indicators for OCP goals and strategies, and PEI outputs could be used as an additional data source or indicator for a number or these policies (District of Squamish, 2018). Furthermore, Squamish has a publicly published dashboard that reports on key indicators, as specified by the district, stemming from the OCP's five core goals. While one of the five core goals is 'Connectedness,' none of the indicators relate to pedestrian or even active transportation goals (District of Squamish, 2019). The addition of a spatial pedestrian environmental index like PEI to this community performance indicator tracker would be a valuable data driven way to measure and visualize improvements in pedestrian environments for both government official and planners alike.

6.5. Finding 5: Limitations of Pedestrian Environmental Index (PEI)

There are limitations of both pedestrian indices used in this research. Although network features as measured in PEI are important in determining pedestrian environment, by using only macrolevel data, microlevel analysis is omitted. Street design, pedestrian infrastructure, atmosphere, comfort, and safety are not considered. For example, variables such as lighting, the presence, continuity, and condition of sidewalks, bike lanes, parking, and the amount of tree cover or benches.

As expected with GIS, there are limitations to its application and data quality. The Modifiable Aerial Unit Problem (MAUP) in this research occurs from grouping data according to different zonal patterns, in this case DAs. According to Statistics Canada, DAs boundaries have a target population of 400-700 people based on the block

population counts from the previous census year. However, quite a few DAs within Squamish have a much higher population. After this criterion, the boundaries are delineated by census subdivisions, census tracts and seek to follow roads or other geographic features (Statistics Canada, 2016). This means that while population size is standardized across DAs, the geographic space that contains the population is variable. The arbitrary nature of administrative boundaries causes differences in the results of geographic analysis. Depending upon the boundary placed around the data, the outcome of the data will be inconsistent. For example, DA 187-PM would have greater PDI and lower LDI with a tighter boundary around the residential area.

There are also issues with data quality inherent with GIS analysis. The PEI calculation uses secondary data which means there is uncertainty with the data. There is likely some data that is incomplete or inaccurate due to the data collected at different time periods or being combined from different sources. For the spatial analysis portion, some of the raw data related to the intersection and commercial variables was modified by me so that the data was in the proper format to properly calculate the sub-indices values. These data adjustments may have caused some discrepancies in terms of orientation and minor displacements of data. Data and theory-based issues with three of the sub-indices are expanded upon in the subsequent part of this finding.

6.5.1. Intersection Density

Intersection density is widely used and positively correlated with increased walking and network connectivity in much of the literature (Ellis et al., 2015; Ewing & Cervero, 2010; Fonseca et al., 2021; Frank et al., 2005), however, it is often difficult to calculate or obtain reliable data for. As referenced above, as well as in the Methodology and Data Collection Chapter of this study, I had to manually modify the Squamish Road Network, specifically traffic islands, round-abouts, highway pull outs, and double lanes with a middle island as many of these segments had multiple nodes that would overstate the intersection density factor. Furthermore, many of the streets were multiple segments within the Road Network Layer which had to be joined to avoid overcalculation of intersections. This was not only time consuming but can lead to error in the positional accuracy and logical consistency of the data.

While intersection density is a common measure of network connectivity, there is some debate among authors if it's the most appropriate variable to use for measuring pedestrian connectivity. Chin et al., found that using a true pedestrian network increases the connectivity of both conventional and traditional neighbourhoods. The authors assert that parks and paths can provide direct pedestrian routes and connect streets that might otherwise intersect (2008). Findings such as these are significant in Squamish where much of the district is disconnected, and the city is focused on connecting trails and other nonmotorized paths to increase connectivity throughout the city. It makes sense that in densely populated urban areas, where the street pattern is mostly traditional, that road centre lines would broadly mirror the pedestrian network with most walkways being sidewalks along side roads. However, in areas with a high degree of trails, accessible open space, or pedestrian short cuts, street networks perform less well as a proxy for pedestrian connectivity and potentially depress certain results of walkability indices (Chin et al., 2008; Ellis et al., 2015). However, the opposite can also be true. On busier streets where there are no sidewalks or lacking pedestrian infrastructure residents might not be comfortable walking. This is a scenario that also exists in Squamish and calculating intersection density in this case may exaggerate pedestrian connectivity. As a final example of challenges with the IDI in this study, DA 201-DM which contains the Eaglewind MPC contains many intersections because the blocks within the community are shorter, however the street arrangement also makes it more difficult to exit development. This configuration makes it easier to get around the community but more challenging to access the services and amenities outside the boundaries of the development. Depending on the context and the scale of analysis, an area with a complex and variable intersection pattern density could be misrepresented in IDI and PEI results, like in this example. In other similar instances an area with high intersection density could overcompensate an area with low intersection density leading to a misleading result of overall connectivity.

While it seems logical to use a sidewalk or footpath layer for examples noted in this section, it's worth pointing out, that pedestrian networks are even more difficult to obtain than road network layers. Footpath data in a complete format that includes sidewalks, trails, informal footpaths, and pedestrian crossings is not available in the majority of publicly available data portals. Furthermore, recreating or tracing a pedestrian network would be onerous and difficult.

6.5.2. Entropy & Land Use

Land use density and entropy also present limitations within walkability indices. Variable land use definitions and calculations are known to impact the outcomes of the scores. For example, accessibility can be described as land use mix, retail floor area ratio, access to amenities, residential density, or a mix of these factors (Shashank & Schuurman, 2019). In research deconstructing the methods, variables, and outcomes of three different pedestrian indices and rebuilding them in Vancouver, BC, Shashank & Schuurman found that different variable definitions, caused variability in walkability scores, especially in the outer peripheral neighbourhoods that were less pedestrian friendly (2019). They found specifically that the number of categories used to calculate entropy scores for the differing indices resulted in conflicting scores for the same neighbourhoods in some places. Calculating for different number of land use mix categories can result in divergent entropy scores and thus a different interpretation of the land use diversity in an area (Hajna et al., 2014; Shashank & Schuurman, 2019). PEI does not specify how many land use categories should be employed but does explicitly note that the total amount of land use types should be standardized across all neighbourhoods. For this research land use was organized based off the Squamish 2020 Zoning Bylaw Update, which outlines six fundamental zoning categories that remained constant for each DA ("2020 Zoning Bylaw Update - District of Squamish - Hardwired for Adventure," 2020). However, changing the number or classification of the land use categories would certainly alter the overall results. Beyond these constraints, the current LDI equations only calculates the proportionality of the land uses within the boundary not the location, amount, or its contact or separation from other land uses. It does not account that some land use or configuration of land use might be more important for pedestrian friendly environments. For example, research has shown that walkability has increased when food supplies and basic domestic necessities are nearby (Hajna et al., 2014; C. Lee & Moudon, 2006).

Furthermore, in areas like Squamish where the geographic area of the DAs vary dramatically in size, there is an chance for more land use types to be represented in DAs with more area than ones that are smaller. This question of boundaries and scale also lead to issues with the MAUP. "MAUP refers to the sensitivity of analytical results to the definition of the areal unit from which data are reported and measures are derived. It

arises from the fact that the area units are usually subjectively defined, and their boundaries are modifiable" (Zhang & Kukadia, 2005). Therefore, MAUP can distort analytical results and subsequently mislead policy decisions. In Squamish, because the population is lower, the smallest spatial unit that data is aggregated into is much larger than areas with much more dense populations. Zhang & Kukadia (2005) studied the effect of MAUP on urban form at eight different boundaries some of which were conventional census boundaries and some of which were grids at various scales. They found that grids with the cell size of half mile performed the best among all the spatial boundaries studied. Their findings also establish that results from grid system were more stable and changed more systematically but the conventional census geography results were more variable. They assert that census unit size fluctuates significantly as they move from the city centre to the outer towns and suburbs and these zonal and scale effects are noticeable in the aggregation of the data within variable boundaries (Zhang & Kukadia, 2005). This is a situation with varying boundaries is not unlike what Squamish faces. Finally, they found specifically on entropy and land use, that there were connections between mode of travel and land use. However, they were only statistically significant when calculated at a grid size of a half mile or larger but not when calculated at any census geography location (Zhang & Kukadia, 2005).

While a half mile grid size is an important revelation for best practice in the specific context of Zhang & Kukadia (2005) research, an important realization of this study is that the interaction between human behaviour and the physical environment, or the motivation behind their action has a significant baring on what scale or areal unit to consider when measuring pedestrian environment. This is to say that from the perspective of this research, in some instances MAPS might be better suited for measuring pedestrian behaviours while in other case PEI might be justified. In summary, improvements in defining variables, methodology, and analysis of land use density are critical to advance the validity and useability of pedestrian environmental models and indices (Hajna et al., 2014; Shashank & Schuurman, 2019; Zhang & Kukadia, 2005). Despite limitations inherent to entropy and land use density, it remains one of the most valuable tools for measuring land use mix.

6.5.3. Commercial Density

The final PEI variable that poses some limitations and issues is commercial density. The theory behind measuring commercial density for pedestrian environmental indices is that proximity to more businesses satisfy a wide range of potential destinations for people to walk to. CDI represents the extent of commercial, financial, and other business services that are useful for daily activities in one area. In the PEI, CDI is calculated using the GFA of the commercial unit and multiplied by the corresponding number of commercial related floors in the building(Peiravian et al., 2014).

This type of measurement is preferable for larger cities with commercial and financial services that are often represented in vertical area that would be overlooked if only using a building footprint. However, in a city like Squamish where commercial entities are mostly located in one story buildings or one unit within a residential building, the additional value of a CDI factor is more uncertain. While the CDI calculation may better represent the physical space used for commercial activity where there are multiple commercial entities in one building, in Squamish the opposite was observed. In some shared commercial and residential establishments, for example a condo building with one unit of commercial space or a home business where the commercial activity is conducted in one room of the house, calculation of the GFA or building footprint overstated the amount of area that is being used for the business. The limitation being that data for specific units or areal boundaries for such businesses are not available and are likely not possible to obtain.

On a broader scale, among the DAs in Squamish, the CDI measure, as expected, demonstrations there are more options for destinations where goods and services may be purchased and more local employment opportunities that can be reached by walking in the downtown DAs. However, as previously explained in the Commercial Density section of the Methodology and Data Collection Chapter the commercial landscape is complex and, in some cases, there are certain areas within Squamish where CDI may be misrepresented. For example, due to the inclusion of home offices and businesses in the CDI calculation there are DAs that have no commercially zoned land use, however, have a higher CDI score than a DA the does have commercial zoned land use but not as many businesses licence appearing in the data.

Beyond the limitations noted above with CDI, LDI, and IDI sub-indices of PEI as well as other spatial analysis of pedestrian environment, this chapter has also highlighted that there are opportunities to improve the operationalization of GIS-based measures of neighborhood walkability. This research has made it clear that dependent on use and scale there are some circumstances where the MAPS tool is better utilized for measuring pedestrian environments over PEI however, there are also constraints of microscale audit tools like MAPS. The final finding examines the limitations and improvements that could be made to the MAPS tool, the other index employed in this study.

6.6. Finding 6: Limitation of Microscale Audit of Pedestrian Streetscape (MAPS) Tool

Despite whether a tool uses aggregated data, audit data, GIS based measurements, or a scoring system based on theory and statistical criteria, quantifying any realm of urban form is complex and one model or index will never fully account or adequately describe all situations. The MAPS tool was designed specifically to measure microscale features of the built environment that are related to walking. This tool differs from other streetscape level audits as it examines association of microscale environmental attributes using a “reliable instrument and systematic scoring system” (Millstein et al., 2013). While many items within the scoring system had good reliability and were associated with physical activity, there are still some limitations. There were a few items within the primary MAPS tool that consistently had lower agreement. These were questions assessing slope, subjective qualities, and questions that required more complicated response options. As previously noted in the Methodology and Data Collection Chapter, this research used a modified version of the MAPS- Mini tool which is correlated to the original 120 item MAPS tool (Sallis et al., 2015). In the survey used for this research there were no questions related to slope or necessitated complicated responses. However, one of the questions examining subjective qualities of the environment, graffiti was removed however one asking about building maintenance was included.

There are also some other practical use concerns of using the MAPS or even MAPS-Mini tool on a broader scale. The MAPS tool is intended to be used as an

observational tool measuring street segment on a 0.25-mile route toward the nearest destination from the participant's home. However, for this study I audited every segment within the four case study DAs to be able to make parallel comparison to the results of a microscale audit related to scores of the PEI. This was time consuming and a limitation to me auditing any more than the four DAs. While the MAPS-Mini tool was designed to be short enough for use by practitioners it is likely too time consuming, and a smaller town government wouldn't have the resources for this. Instead, it might rely on the community members to conduct their own observations which is not only difficult to organize but the level of involvement would be unpredictable. While the authors note that MAPS-Mini is feasible and easy to train non-researchers to use there would still be some reliability and consistency challenges from gathering data from different researchers (Sallis et al., 2015).

Finally, there is an option for planners and policy makers to use online imagery to do remote microscale audits. Studies have shown that this type of online surveying has good reliability with local in field audits (Fox et al., 2021). This would be less time consuming and more cost effective. However, some context would be lost from not making in field observations.

Chapter 7. Conclusion, Limitations, and Future Research

7.1. Conclusion

There is no doubt that Squamish is in a transition period. While it continues to contend with its history in auto dependence, it is also moving forward with its vision to create a community that is more walkable, mixed-use, and high-density. As a means to support this goal and the growing population the District of Squamish local government continues to approve large scale MPC projects. In theory these communities follow New Urbanism principles which at its core attempts to create walkable neighbourhood with dense housing. However, while the development and changing landscape seem perpetual in Squamish, it's not definitive that it is becoming more well connected for non-motorized travel. This observation led me consider if there was a system of measurement that would be useful for planners and key decision makers to define and measure the pedestrian landscape in this context. The use of pedestrian models to measure dense urban areas has been studied previously but their use is more limited in in dealing with, identifying, and evaluating exurban conditions.

From this framework, this thesis sought to answer the questions: *What neighborhood features relate to higher results on the Pedestrian Environmental Index (a measure of pedestrian friendliness) calculated at a neighborhood level in Squamish, British Columbia? And how well do measures such as PEI align with active transportation strategies outlined by the District of Squamish?* In answering these questions, I provided context to the historic challenges and geographic limitations that have held Squamish back in achieving a more pedestrian oriented community. My research specifically focused on understanding if some of the new development patterns that Squamish is undertaking, like the construction of MPCs, are beneficial to overall pedestrian connectivity in Squamish.

To address these research questions, I calculated metrics for the pedestrian environment in Squamish using PEI. I then contrasted that data with observational audit scores collected using a modified version of the MAPS- Mini tool. I focused on understanding the characteristics and regions that were most influential or helped clarify

the results of the PEI. The last step in the analysis portion of the research compared the outcomes of both indices to objectives and policy goals set out by the District of Squamish. This comparative analysis not only helped me gain an understanding of the factors that most influence the pedestrian environment in Squamish but also guided me to the general uses, applicability, and value of indices like the PEI in the exurban context.

My findings highlight, as expected, that certain characteristics, especially proximity to the downtown, is the most significant factor that contributed to a higher score on the PEI. The same was true of the results of the MAP tool, however to a lesser extent. Other characteristics, like the inclusion of a MPC within a DA, had a more varied influence on the results of both indices. The evidence I collected from each index and the comparison between their results suggest that there are benefits to both. Where PEI offers a broad landscape level perspective of the pedestrian environment, the MAPS tool provides specific details on street level infrastructure. Drawing upon these revelations helped define the ways the tool is useful in measuring policy and development related to Squamish's ongoing walkability agenda. The combination of the MAPS tool as well as the review of city's key strategies and focus areas for pedestrian improvements helped contextualize the PEI findings.

This research further revealed the application of both indices as a planning tool for ex-urban or periphery communities. PEI is useful in capturing across a broad region, macrolevel characteristics of the pedestrian environment. It not only reveals an overall evaluation of the relative effectiveness of the pedestrian environment it also identifies areas with higher or lower land use mix, population density, commercial hubs, and network connectivity. This allows for planners to direct policies or improvements to areas where they are most needed. Once, a general region is identified for needing improvement through PEI, the secondary use of the MAPS tool allows for a more detailed and specific streetscape perspective. Due to their differing scales and measurement factors, the use of both indices are complementary in a planning context. In summary, pedestrian indices such as PEI and MAPS were found to be both a useful pre planning and post development metric, with inherent limitations, to help guide and inform policy and future development in the pedestrian realm.

7.2. Limitations & Future Research

Beyond the limitations of the indices used in this research, noted in the Themes and Findings Chapter, this thesis project has its own limitations. First, the PEI calculation normalizes the results to the region of Squamish. Furthermore, this analysis and observation is a snapshot measuring the specific characteristics and dynamics of one city. For these reasons, the specific results of the indices in this case study cannot be generalised to a broader context.

Additionally, the scope of this study was limited. Only four out of the twenty-six DAs in Squamish were examined comprehensively in this research. This decision was made to limit the complexity and time it would take to do a comparative observational analysis of every DA. However, this means that the findings stated here are not the complete picture of the pedestrian environment in Squamish nor are all the results from the PEI index validated by additional observational and streetscape surveys.

Finally, there are other methods to help validate the results of both indices that were not explored in this research. There was no sensitivity analysis performed for the variables in the indices. Therefore, it is unclear each variables sensitivity or the combined effect of each variable. Furthermore, this work, only considered one geospatial index and one microscale audit. The consideration of other indices would likely reveal incongruencies in results and help clarify how differing definitions within the models' effect indices outcomes.

A more wide-ranging study of this nature would go beyond Squamish to include other exurban or edge cities within Canada. These types of urban forms have been given less attention in research on pedestrian behaviors and environments. The inclusion of more of such cities would help to better understand the relationship between the built environment and walkability within this context. Further research could also explore how cites or towns with differing densities and varied urban form performed on PEI. The expansion of this work could help define how these variables respond at different thresholds and scenarios and if there is evidence that the indices are transferrable.

While this study included four core components of the macroenvironment found within the research to effect pedestrian environments, intersection density, population density, land use density, and commercial density, other environmental variables indicated to be significant in pedestrian friendly environments that are not widely available in GIS were missed. For example, as mentioned previously, sidewalk or footpath networks are often not collected or included in city databases. Furthermore, the availability of spatial data at the microscale level of the environment, like those surveyed in the MAPS-mini, including sidewalk presences and conditions, tree cover, or streetlighting, that have also shown to influence walkability are also difficult to obtain or do not exist. Ideally, such geospatial variables will become more routinely gathered and available in open GIS databases and will be included in future variations of such indices and models.

Although much exploration and fine tuning remains to be done for both types of pedestrian indices, this research involving analysis combing both GIS evaluation and an infield audit of pedestrian environment is rare. The findings of this study are useful in shaping local policy decisions and metrics as well as contributing to a better understanding of pedestrian environments in an exurban environment. It is hoped that this knowledge can help to inform planners and policy makers as they evaluate, design, and implement future pedestrian-friendly projects.

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Appendix. Supplementary Information

MAPS- Mini Audit Questions

1. Intro – DA?
2. Intro – Segment ID?
3. Crossing – Intersection of?
4. Crossing – Crossing from N, S, E, W to N, S, E, W?

   Example format: North to South = NS
5. Segment – Street?
6. Segment – N, S,E, W?
7. Segment – Starting Cross Street?
8. Segment – Ending Cross Street?
9. Segment – Type of street?

   Answer format: Residential = 0, Commercial =1
10. Segment – How many public parks are present?

    Answer format: No parks = 0, 1 park =1, 2 or more parks = 2
11. Segment – How many public transit stops are present?

    Answer format: No stop = 0, 1 stop =1, 2 or more stops = 2
12. Segment – Are there any benches or places to sit (include bus stops benches)?

    Answer format: No=0, Yes =1
13. Segment – Are streetlights installed?

    Answer format: None= 0, Some = 1, Ample = 2
14. Segment – Are the buildings well maintained?

    Answer format: 0-99%= 0, 100% = 1

15. Segment – Is there a designated bike path?

    Answer format: No=0, Painted line = 1, Physical barrier = 2

16. Segment – Is there a sidewalk present?

    Answer format: No=0, Yes =1

17. Segment – Are there poorly maintained sections of the sidewalk that constitute a MAJOR trip hazard? (example: misalignment, haves, cracks, overgrowth, incomplete sidewalk)

    Answer format: Any hazard/or no sidewalk present= 0, no hazards = 1

18. Segment – Is the sidewalk continuous?

    Answer format: No=0, Yes =1

19. Segment – Is a buffer present?

    Answer format: No or no sidewalk present = 0, Yes =1

20. Segment – What percentage of the length of the sideway/walkway is covered by trees awning or other overhead coverage?

    Answer format: 0-25% = 0, 26-75%=1, 76-100%=2

21. Segment Observations – Number of people observed?

    Not scored

22. Segment Observations – Number of people observed walking?

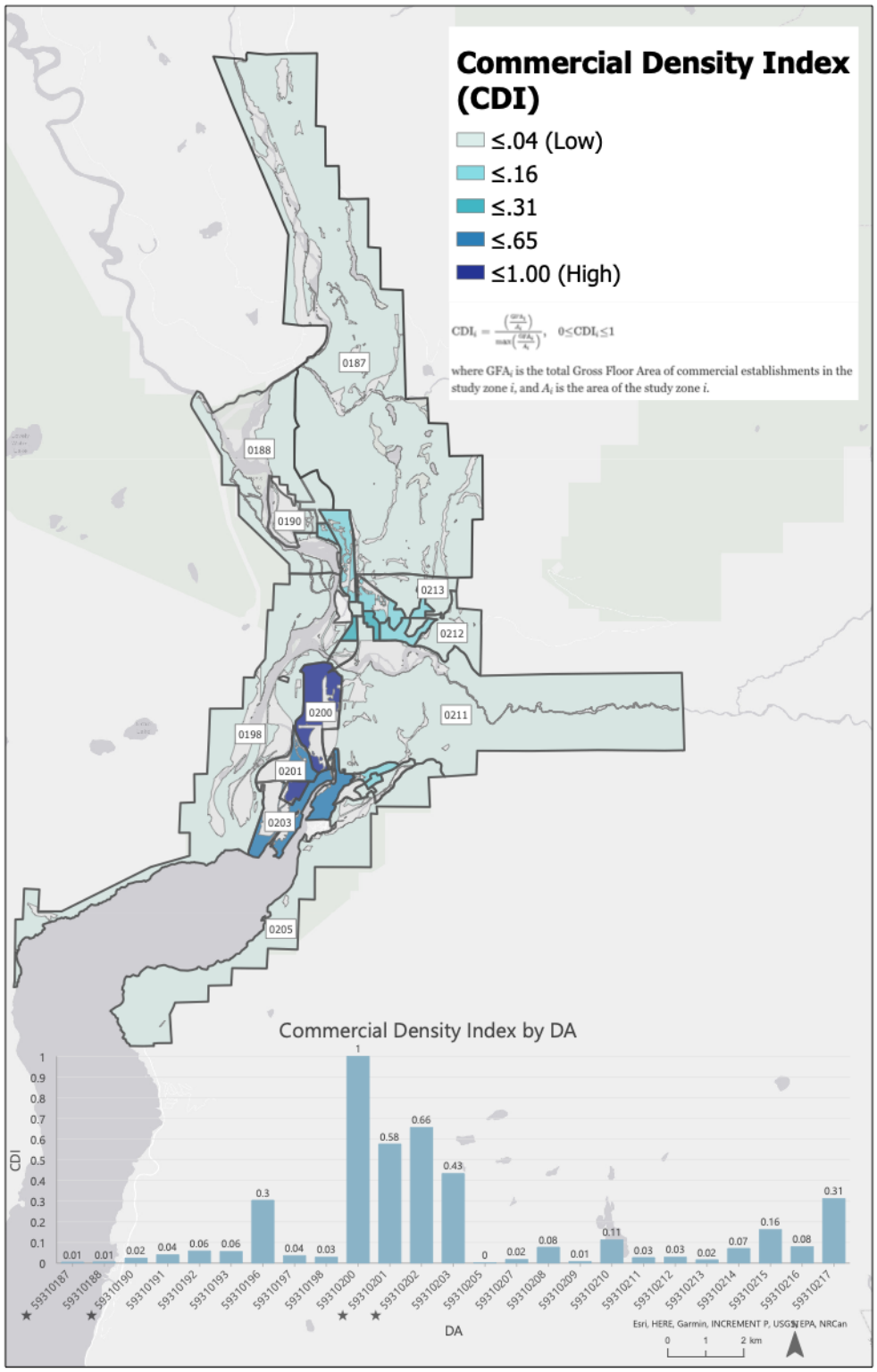
    Not scored

23. Segment Observations – Additional Notes (for example presence of nice landscaping/parkways, art, bike racks, public trashcans, number of always/driveways on the segment, width of sidewalk (especially narrow or wide?) traffic, traffic calming measures, informal paths, building setbacks, building height, crossing measures, etc)

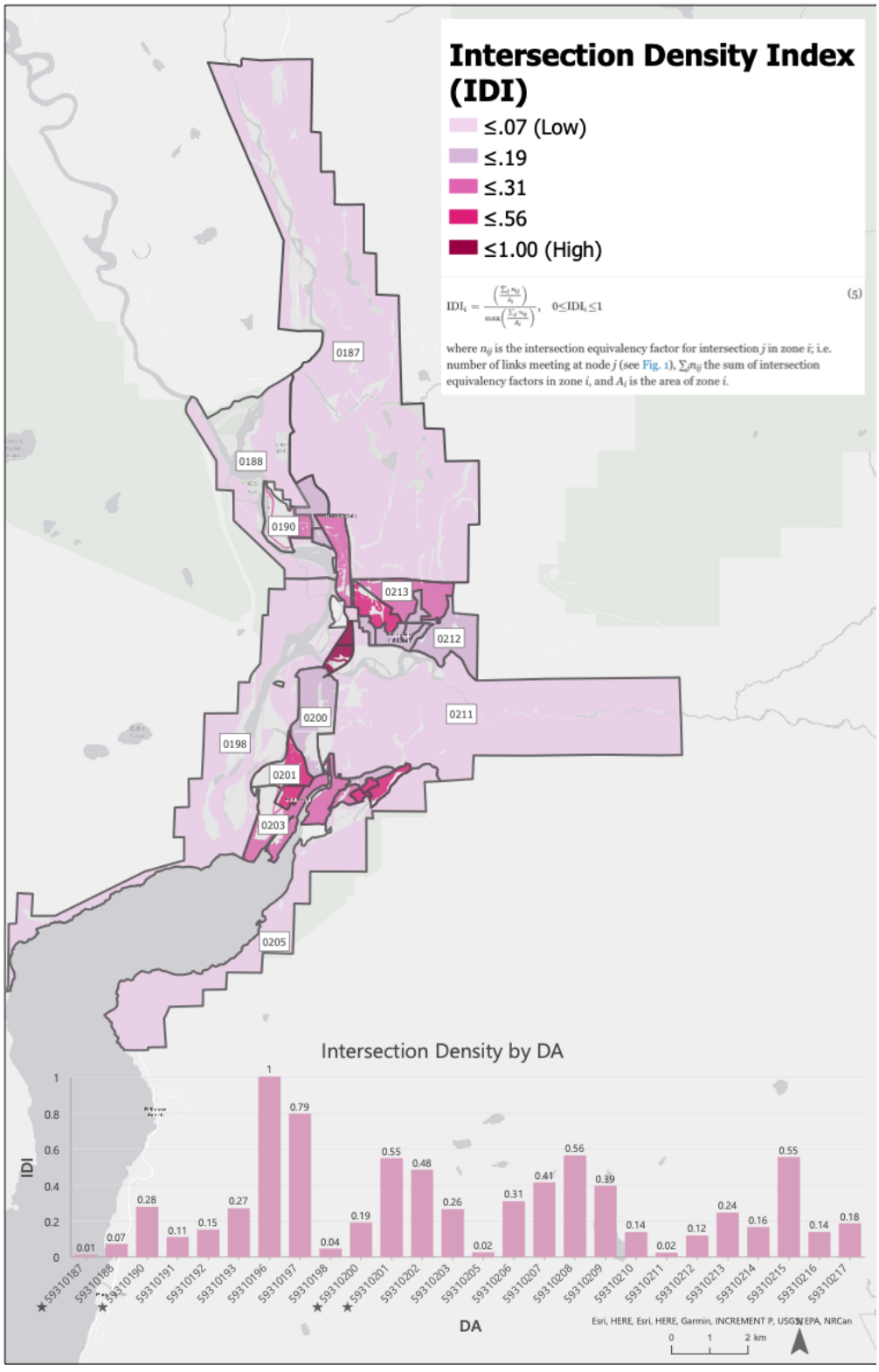
    Not scored

Figures

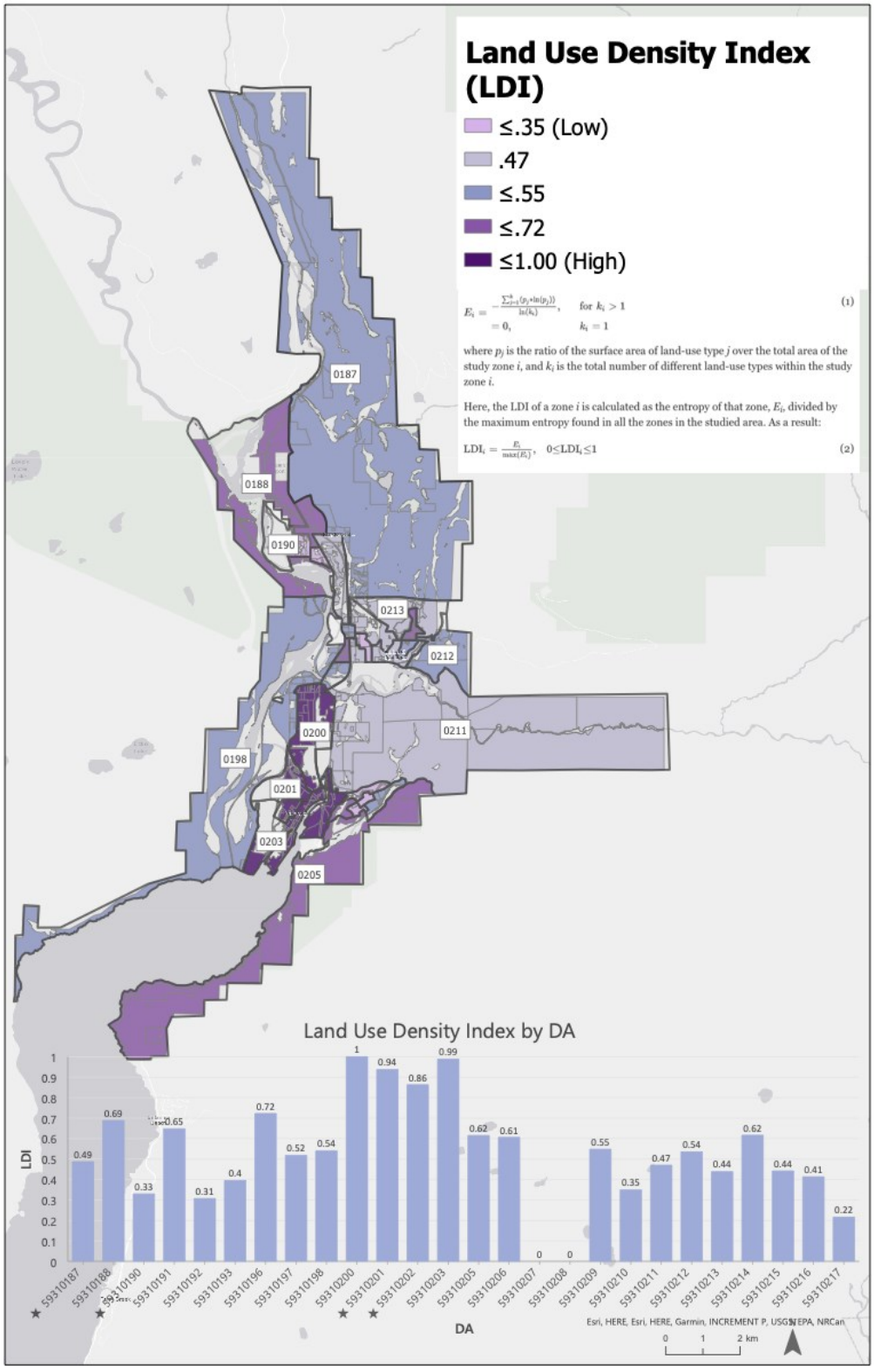
Commercial Density Index Map & Graph



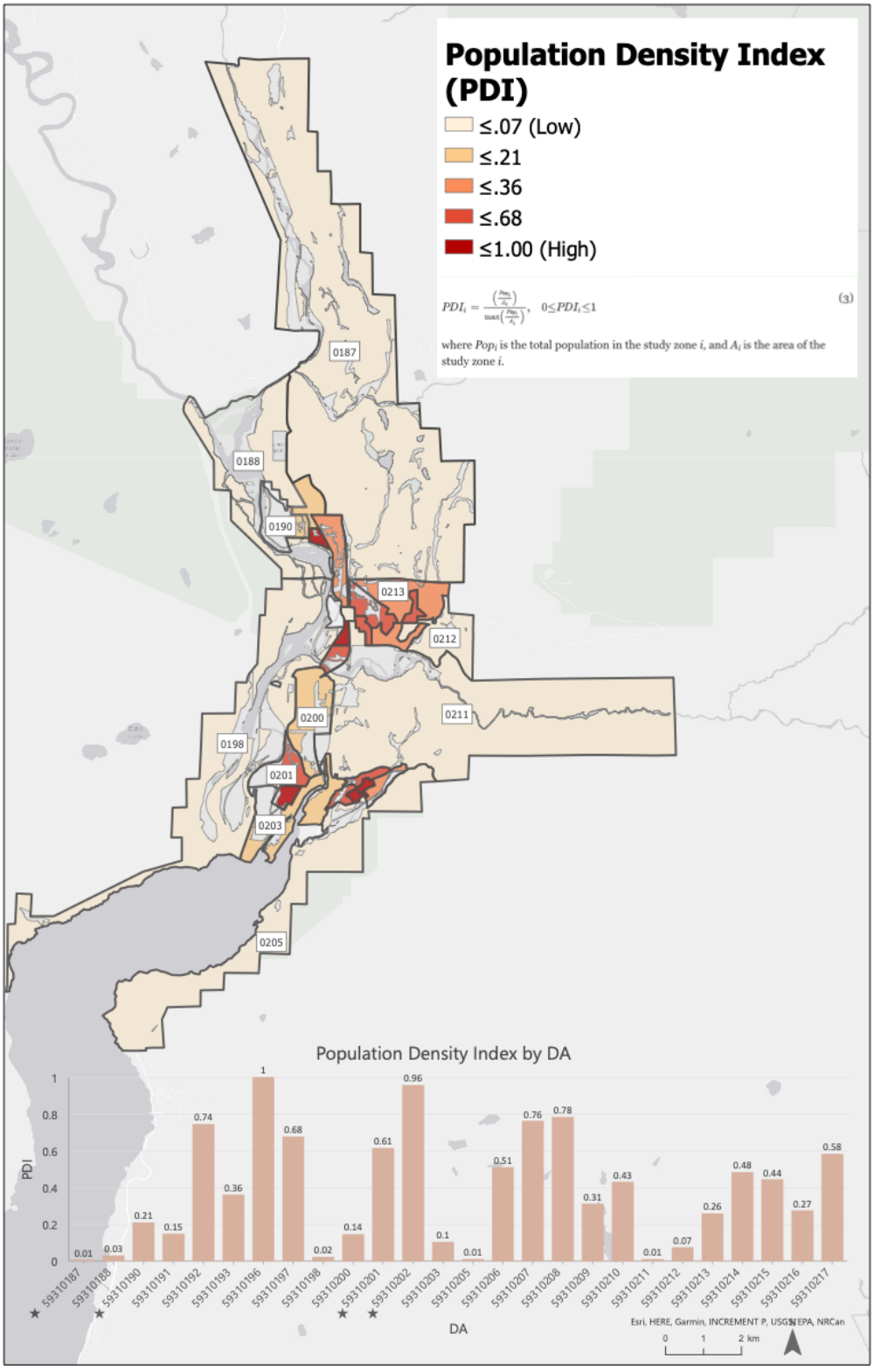
Intersection Density Index Map & Graph



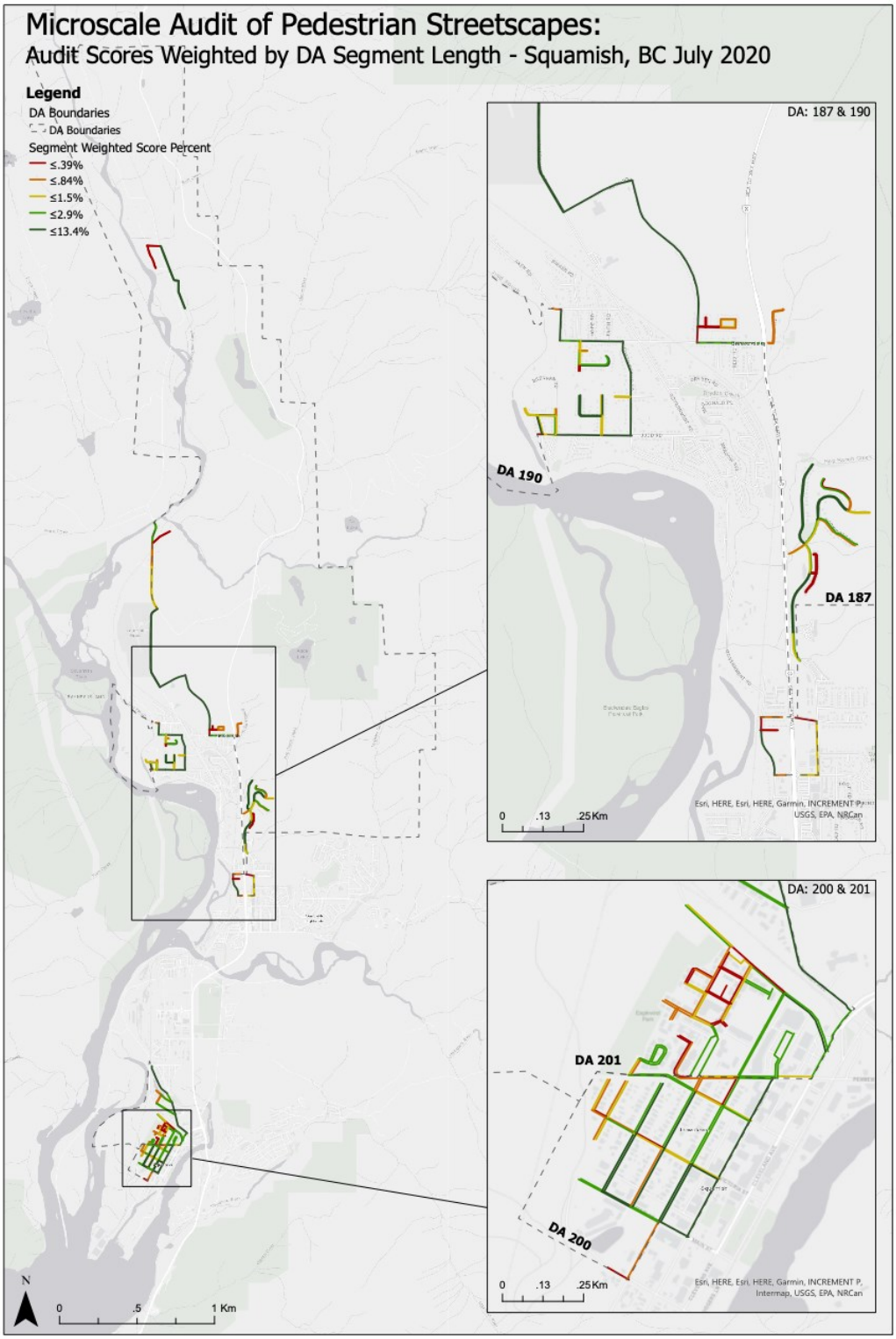
Land Use Density Index Map & Graph



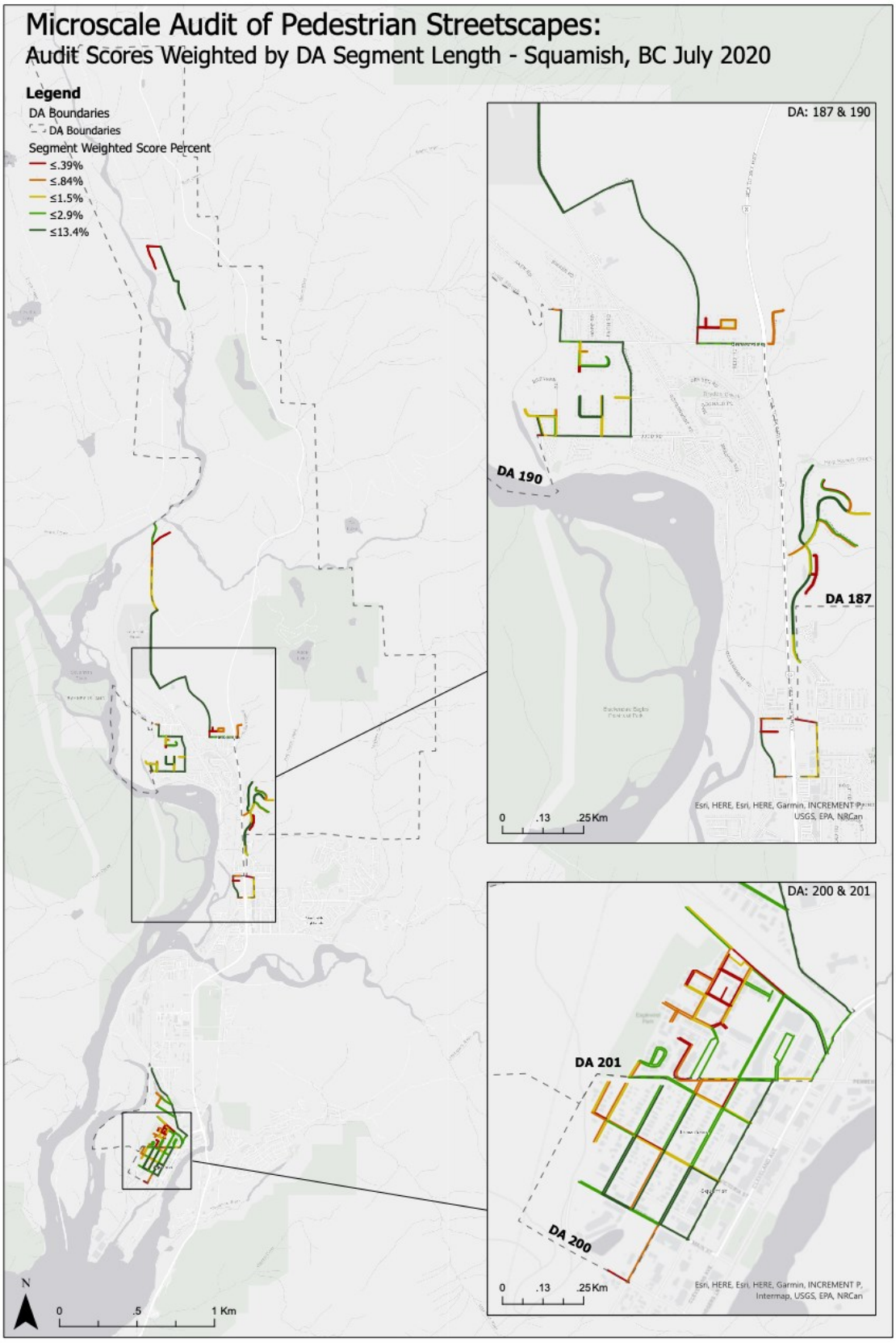
Population Density Index Map & Graph



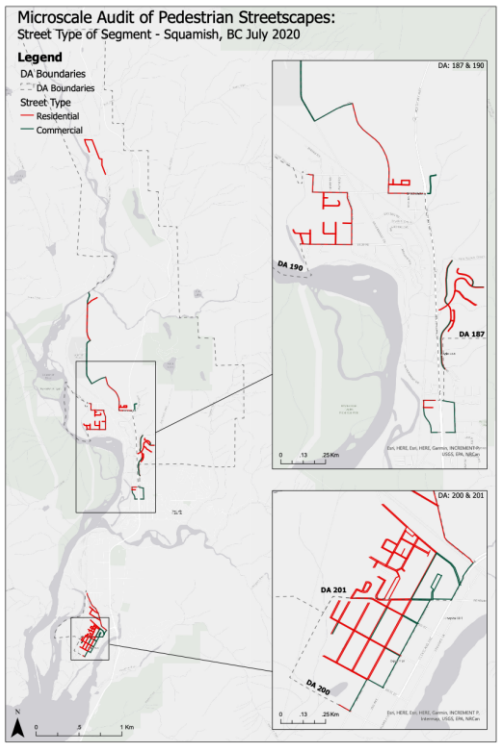
Microscale Audit of Pedestrian Scores Map



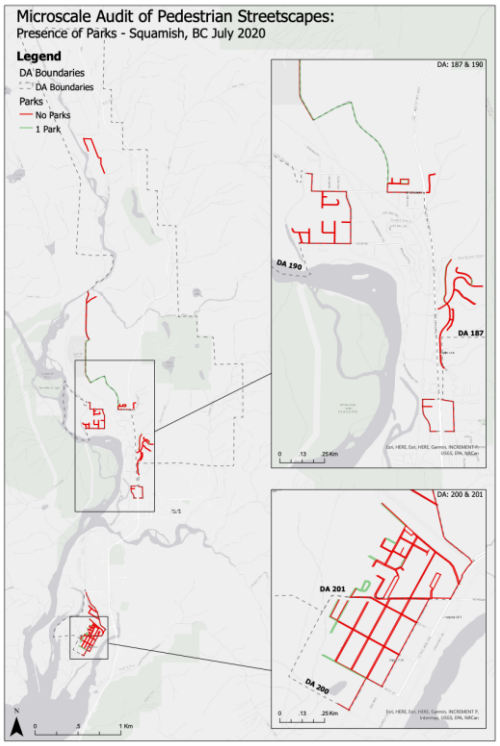
Microscale Audit of Pedestrian Scores Map



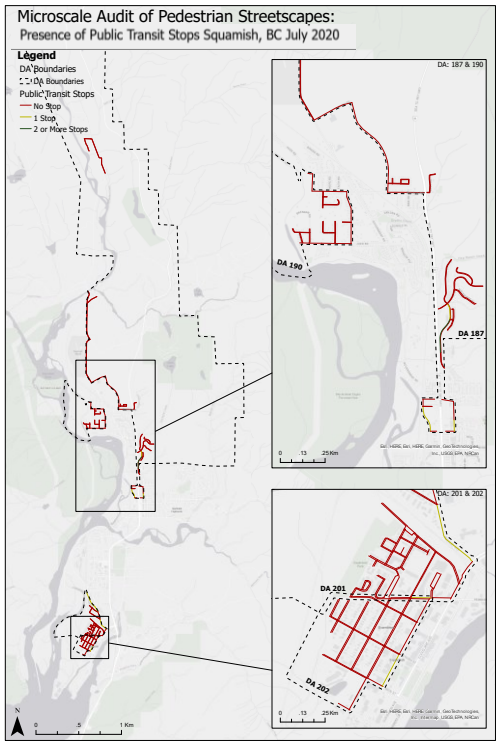
MAPS – Street Type



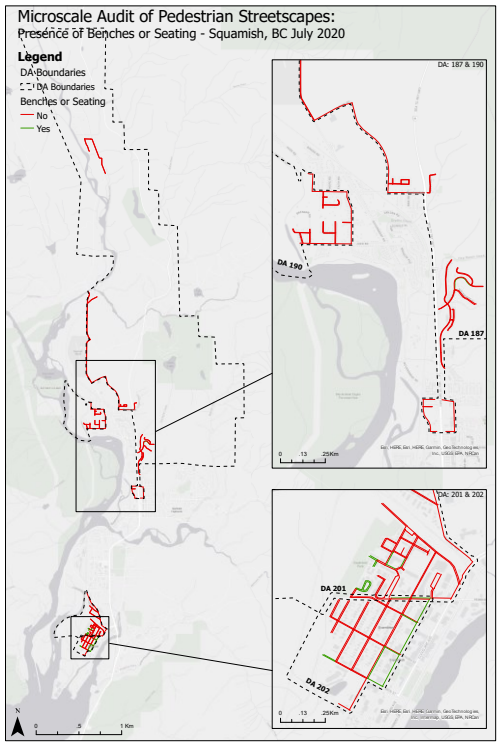
MAPS – Presence of Parks



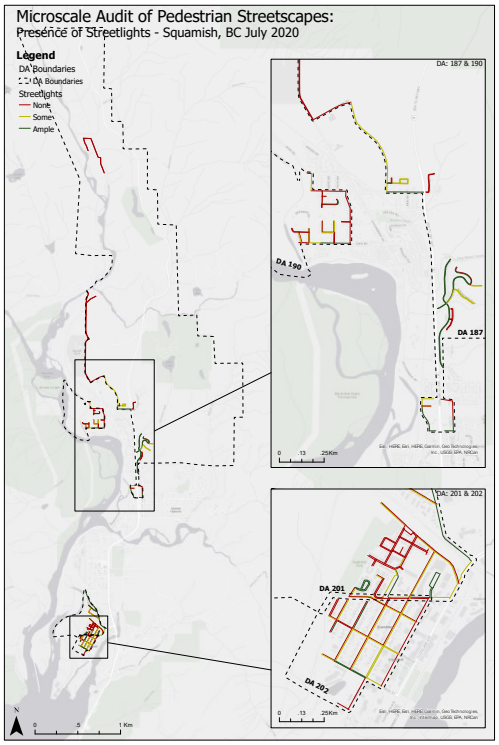
MAPS - Quantity of Public Transit Stops



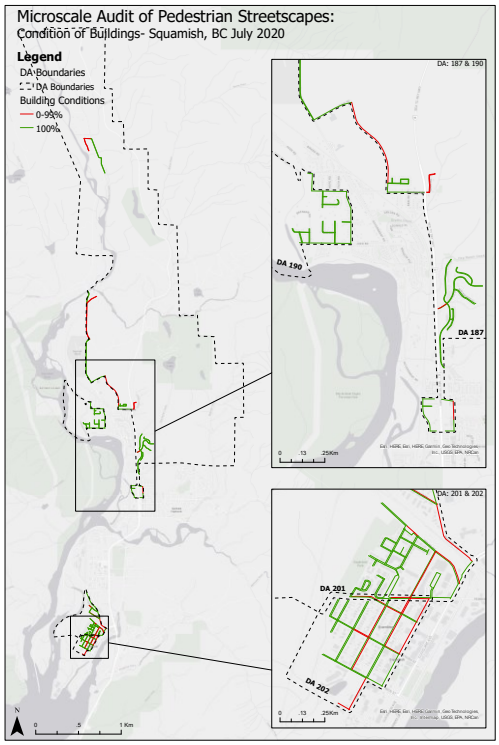
MAPS - Presence of Benches and Seating



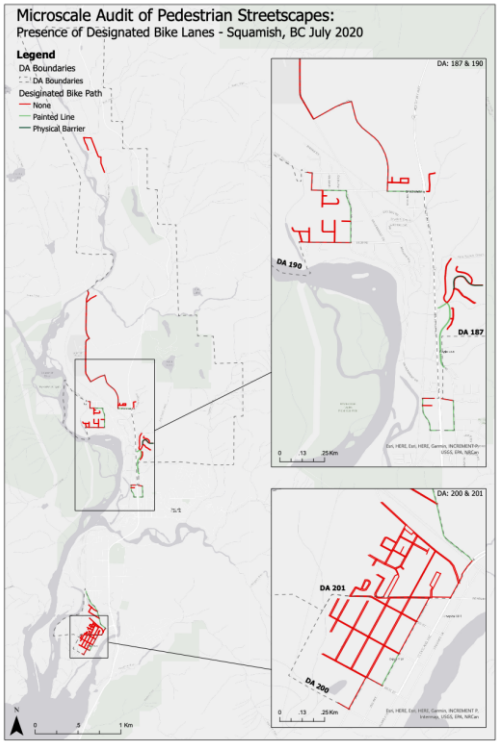
MAPS – Presence of Streetlights



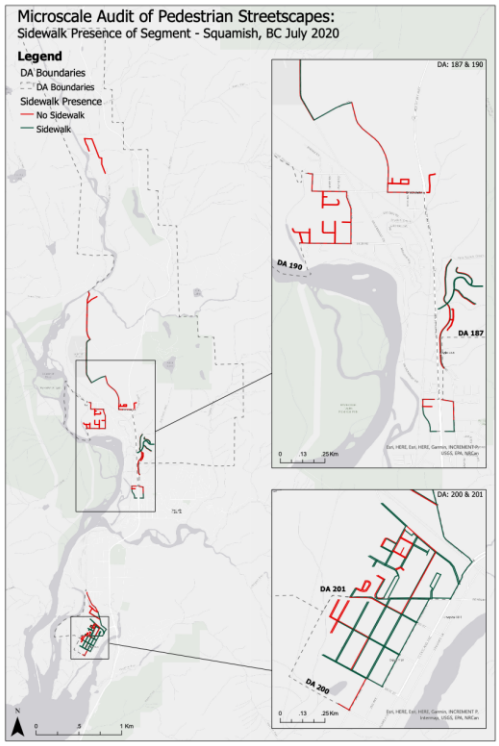
MAPS- Condition of Buildings



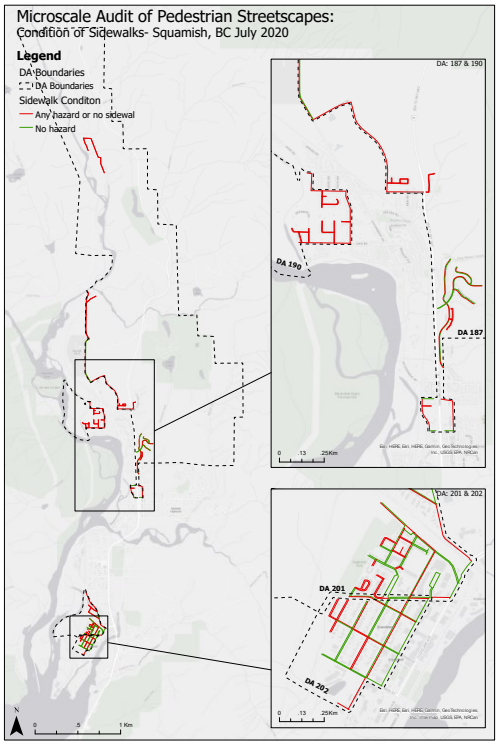
MAPS Presence of Designated Bike Lanes



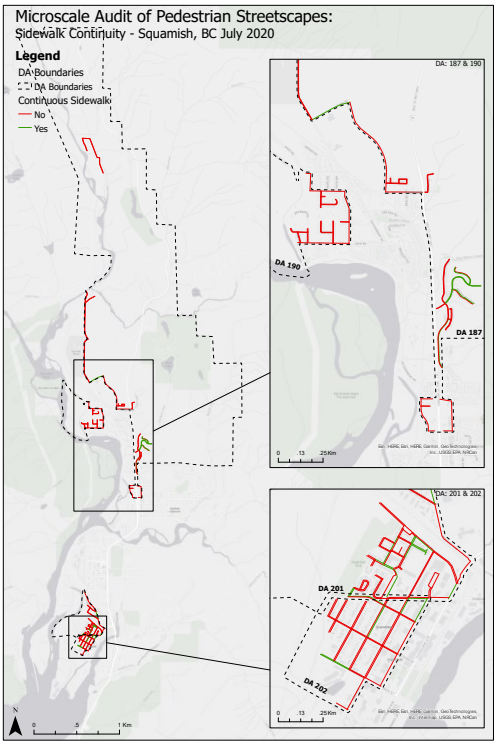
MAPS – Presence of Sidewalks



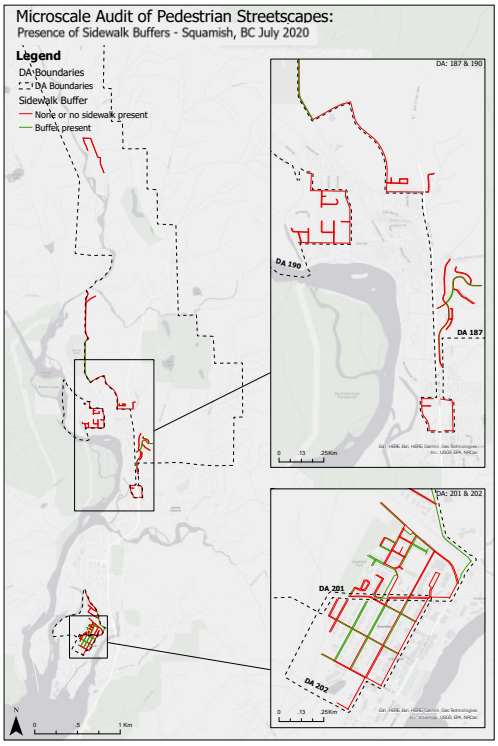
MAPS – Condition of Sidewalks



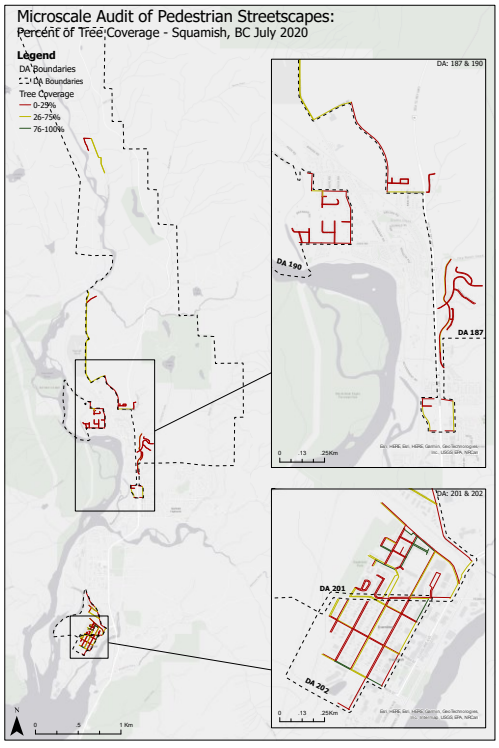
MAPS- Continuity of Sidewalk



MAPS – Presence of Buffer



MAPS- Percent Tree Coverage



Tables

DA Census Summary, Indices, Streetscape Audit

	187-PM	190-PN	201-DM	202-DN
Population	834 people	441 people	1,504 people	1,035 people
Population Density per Square Kilometer	23.2	401.2	1,418.6	3,550.6
Occupied Private Dwelling constructed before 1981:	22.3%	81.1%	26.8%	26.7.6%
Occupied Private Dwelling constructed from 2000 – 2016:	68.1%	5.4%	41.5%	54.6%
Commercial Density	0.005	0.02	0.58	0.66
Intersection Density	0.01	0.28	0.55	0.48
Land Use Density	0.49	0.33	0.94	0.86
Population Density	0.006	0.21	0.61	0.96
Pedestrian Environmental Index	**0.09**	**0.13**	**0.48**	**0.56**
Average DA Streetscape Audit Score (Weighted by Segment Length)	**3.21**	**1.75**	**4.21**	**4.04**

PEI Indices & Individual Audit Pedestrian Streetscape Indicators

Street Type

Street Type – (Residential or Commercial) Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.30	0.00	0.16	0.24

Parks

Parks Weighted Average Score Max Score = 2	187-PM	190-PN	201-DM	202-DN
	0.18	**0.03**	0.08	0.10

Public Transit

Public Transit Weighted Average Score Max Score = 2	187-PM	190-PN	201-DM	202-DN
	0.06	0.00	0.13	0.03

Benches

Benches Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.02	0.00	0.10	0.19

Street Lights

Streetlights Weighted Average Score Max Score = 2	187-PM	190-PN	201-DM	202-DN
	0.60	0.52	0.79	.55

Building Condition

Building Condition Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.66	1.00	0.81	.90

Bike Path

Bike Path Weighted Average Score Max Score = 2	187-PM	190-PN	201-DM	202-DN
	0.18	0.17	0.14	0.03

Presence of Sidewalk

Sidewalk Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.27	0.00	0.58	0.72

Sidewalk Condition

Sidewalk Condition Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.21	0.00	0.48	0.53

Continuity of Sidewalk

Sidewalk Continuous Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.14	0.00	0.17	0.14

Prescence of Sidewalk Buffer

Sidewalk Buffer Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.13	0.00	0.25	0.37

Tree Coverage

Tree Coverage Weighted Average Score Max Score = 1	187-PM	190-PN	201-DM	202-DN
	0.47	0.04	0.53	0.43