Assessing Levels of Walkability in Kelowna Using GIS and Open Data

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Amidst rapid urbanization, escalating environmental degradation, and rising vehicular dependence, enhancing walkability is critical for creating healthier, more cohesive, and sustainable communities. Walkability refers to the built and social factors influencing how easily and safely pedestrians can navigate an area. Simply put, a walkable place is easy and safe to traverse (U.S. EPA, 2021).

Walkable places offer numerous benefits. They promote active living and are associated with healthier populations, as walking helps to reduce obesity, diabetes, and cardiovascular disease rates. With over 30 percent of Canadian adults classified as obese (Statistics Canada, 2024), improving walkability provides an opportunity for controlling these rates (Gregg et al., 2003; Morris & Hardman, 1997). Walkable spaces also support mental well-being, happiness, and social cohesion by fostering community interaction and a strong sense of place (French et al., 2013).

Additionally, walkability contributes to environmental sustainability by reducing air pollution and traffic congestion. Among Canada's 13.1 million commuters, 11.0 million (83.9 percent) travel by car, truck or van (Government of Canada, 2025). The transportation sector accounted for 187.7 Mt CO_2e (28 percent) of greenhouse gas emissions in 2021, with nearly half released from personal vehicles. Reducing vehicular reliance is a critical step in mitigating climate change. As urbanization continues, with 73.7 percent of Canadians living in a large urban area (Statistics Canada, 2022), designing walkable communities is increasingly essential for efficient land use and long-term sustainability.

To improve walkability, it must first be assessed. Walkability reflects spatial characteristics of the built and social environment. As such, Geographic Information Systems (GIS) can be utilized to combine relevant indicators of walkability to produce a walkability index, a surface measuring the extent to which an area supports walking opportunities. This paper will analyze indicators of walkability for the City of Kelowna, to create a walkability index that highlights the relative ease of walking throughout the city.

Literature Review

Many studies use GIS to analyze walkability in an area. While no universally agreed-upon definition of walkability exists, and multiple measurement tools are used, certain trends consistently emerge. Walkability is an emergent property of the built and social environment. It arises not from any single feature, but the combination of many. Features affecting walkability exist at both the micro (street level) and macro (neighbourhood or city level) scales (Tobin et al., 2022), and tools exist to analyze walkability at both. Walkability indices generally focus on macro-scale features and may not directly assess pedestrian infrastructure.

Ewing and Cervero (2010), in a meta-analysis of over 200 studies, introduced the concept of "5D walkability" based on dimensions that strongly predict walkability: density, diversity, design, destination accessibility, and distance to transit. They define these variables as follows:

- Density: Household/population density.
- Diversity: Land use mix (entropy index).
- Design: Intersection/street density and % 4-way intersections.
- Destination Accessibility: Access by transit, distance to downtown.
- Distance to transit.

A core aspect of their model is proximity, as all five variables directly or indirectly measure how close people are to various amenities. Density indirectly measures proximity as when more people live in an area, amenities are more likely built nearby to support them. Consequently, walkability generally increases with density as residents have easier access to amenities to support them.

Land use entropy is measured by an entropy index which reflects the number of land use categories and their proportion. A high entropy value indicates a balanced mix of multiple categories while a low one indicates dominance by one or a few imbalanced categories. When an area has a high entropy value, it's more likely that required services are nearby, raising amenity accessibility and increasing walkability.

Intersection and street density represent the connectedness and extent of the pedestrian network in an area. As pedestrian networks are often integrated with roads, increased road connectivity raises the likelihood of more direct routes to amenities, enhancing walkability. Destination accessibility and distance to transit are direct measures of proximity, reflecting how easy amenities are to reach.

The 5D walkability model overlooks subjective features like safety, sidewalk quality, aesthetics, and physical features like walking barriers and slopes. Nonetheless, the model establishes a helpful framework for analyzing the built environment's influence on walking behaviour.

Telega et al. (2021) create a walkability index by assessing the proximity of various amenities. Their approach utilizes GIS to generate continuous density surfaces capturing the concentration and accessibility of key amenities, including public transportation, parks and recreation, core services, retail, and pavement networks. They combine these surfaces, measuring how the spatial distribution and frequency of amenities influence walking behaviour. Their approach assumes equal importance for all amenity categories and does not include street-level features affecting walkability or measures of attractiveness like slope or aesthetics.

One of the most popular online walkability indicators, Walk Score, also creates a walkability index by assessing the proximity of various amenities, for every address in the US and Canada. Walk Score is majorly a measure of proximity, calculating the distance between a point and various amenity categories within a radius of one mile. It assigns scores based on distance and weights them according to category importance. Essential services, like grocery stores, are weighted more heavily than non-essential services, like restaurants or retail shopping. Amenity density is not considered; unlike Telega et al.'s (2021) methodology, areas near a high concentration of a given amenity category are not scored differently from those adjacent to a single amenity of that category. Walk Score also considers intersections and building length density per neighbourhood as indicators of connectedness and active street frontage. Walk Score has been criticized for not considering the micro-features of the street landscape. Yet, multiple studies have validated Walk Score as a reliable surrogate for walkability (Carr et al., 2010; Duncan et al., 2012).

Masoud et al. (2022) created a walkability index for the City of Kelowna as part of a quality-of-life assessment of its neighbourhoods. Their approach followed a methodology proposed by Frank et al. (2009) for measuring walkability in quality-of-life studies. The index comprised four metrics: net residential density, retail floor area ratio, intersection density, and land use entropy. These metrics were defined at the dissemination area (DA) level, the smallest geographic unit for which complete census data is available. The variables were normalized by Z-score and summed to generate a relative walkability ranking for each DA. Their findings identified City Centre/Pandosy, Midtown, and parts of Rutland and Glenmore as areas with high walkability.

Study Area

The study area is the City of Kelowna, located in British Columbia's Okanagan Valley (Figure 1). Kelowna has experienced rapid population and physical growth, leading to urban sprawl. This has led to a mix of walkable urban centers (Downtown, Pandosy, Capri-Landmark, Rutland, and Midtown; City of Kelowna, 2022) and car-dependent suburban neighbourhoods (e.g., Upper Mission, Wilden). Between 2016 and 2021, Kelowna's population grew by 14 percent making it one of the fastest-growing metropolitan areas in Canada (Statistics Canada, 2024).

While traditionally car-centric, recent policy initiatives (e.g., City of Kelowna's 2040 Official Community Plan; City of Kelowna, 2022) prioritize active transportation, public transit, and denser urban development. The City of Kelowna (2018) has explicitly acknowledged the need to transition from a car-centric culture, stating, "Kelowna will be a city with vibrant urban centers where people and places are conveniently connected by diverse transportation options that help [the city] transition from [its] car-centric culture."

This study assesses Kelowna's current walkability to establish a baseline, offering insight into how urban planning decisions can shape pedestrian accessibility.

Data

The study integrates datasets representing Kelowna's built environment to evaluate walkability across the city. All spatial data were projected to NAD 1983 UTM Zone 11. Several walkability metrics were generated at the DA level, using polygons obtained from Statistics Canada. A polygon representing Okanagan Lake was sourced from British Columbia's Freshwater Atlas to ensure the exclusion of non-pedestrian water areas.

The addresses of 1569 amenities (e.g., grocery stores, restaurants, parks) were collected from Google Maps and categorized by amenity type. These addresses were geocoded into latitude/longitude coordinates using Python's pandas library and the Google Geocoding API. Locations for park and school amenities were sourced directly from Kelowna Open Data, while transit stop data was sourced from BC Transit Open Data. 27 amenity subcategories across 9 categories were included (Table 2).

Kelowna's pedestrian network data was derived from the Active Transportation Network, accessed from Kelowna Open Data. The dataset was filtered to only include mixed-use and pedestrian pathways. The road network, intersections, tree inventory, streetlights and traffic lights, and the digital elevation model (DEM) for the City of Kelowna were also sourced from Kelowna Open Data.

Methods

A walkability index was developed to assess the relative ease of walkability across the City of Kelowna, with scores ranging from 0-100, where 100 represents optimal walkability. The analysis incorporated five key indicators: proximity, density, diversity, connectedness, and attractiveness. Most indicators consisted of multiple sub-indicators (Table 1).

Some indicators were defined continuously while others were defined at the DA level. The DA level was chosen to allow for easy integration with census data and to enable meaningful comparisons across the city, ensuring analysis at the neighbourhood scale, a common scale in walkability studies (Almeida et al., 2021). To ensure only walkable areas were considered in the analysis, the Okanagan Lake polygon was subtracted from the DA polygons. Each indicator was normalized to a 0-100 scale, with 100 being the optimal condition. This standardization allowed the indicators to be weighed and then aggregated using a weighted average.

Table 1

Walkability Index Indicators and Weight Rationale

Indicator	Weight	Description
Proximity	35%	Divided into proximity from path (10%) and amenity (25%). Highest weight due to importance of amenity/path accessibility in literature (Sugiyama et al., 2016; Telega et al., 2021; Walk Score, 2025).
Density	16.25%	Divided equally into amenities density (8.125%) and population density (8.125%) at the DA level.
Diversity	16.25%	Measured by Shannon's Entropy Index of amenities within 15-ha grids.
Connectedness	16.25%	Divided equally into intersection density (8.125%) and road density (8.125%) at the DA level.
Attractiveness	16.25%	Divided into slope (11.25%), and aesthetics (5%) at the DA level. Lower aesthetic weight represents data quality limitations (streetlights/trees).

Note. Weights sum to 100%. See Table 2 for amenity-specific proximity weights.

Proximity

Proximity influences how easily pedestrians can access various amenities and path infrastructure. Closer distances encourage walking, increasing walkability.

The proximity score (35% weight) combined Euclidean distance scores to the nearest pedestrian path (10% of proximity weight; Figure 2) and amenities (25% of proximity weight; Figures 3.1, 3.2, and 3.3). The Euclidean distances were scored using logistic decay functions to model the diminishing accessibility with increasing distance. For both pedestrian paths and amenities, the decay function follows the form:

$$S(d) = \frac{100}{1 + e^{k(d-d_0)}}$$

Where:

- $S(d)$ is the proximity score (0-100),
- d is the Euclidean distance in meters,
- d_0 is the inflection point in meters at which the score equals 50,
- and k controls the rate of decay.

The inflection point represents the distance of an acceptable walk (5-minute walk for pedestrian paths, 15-minute walk for amenities), assuming an average adult walking speed of 1.3 m/s. To approximate Manhattan distances in Kelowna's grid-like street network, the Euclidean distance is scaled by $1/\sqrt{2}$.

Pedestrian Paths. A 5-minute walk (d_0 = 276 meters) was chosen as the acceptable distance, receiving a score of 50. This represents the idea that pedestrians should have easy access to pedestrian infrastructure for an area to be considered walkable. A steep decay rate (k = 0.02) was chosen to prioritize areas within a 5-minute walk of paths.

Amenities. A 15-minute walk (d_0 = 876 meters) was chosen as an acceptable distance, receiving a score of 50. This represents the idea in urban design that inhabitants have access to most essential services within 15 minutes on foot (Buliung, 2024; Monero, 2020). A gentle decay rate (k = 0.005) was chosen to reflect the greater tolerance for longer walks to key amenities.

Amenity proximity (Figure 3.3) was calculated as the weighted average of Euclidian distance scores for various amenities (Figures 3.1 and 3.2). The weights were assigned to 9 categories and further divided into subcategories (Table 2). The scheme reflects the relative importance of amenities to pedestrians, drawing on existing literature, data availability and quality, and subjective judgement (see Discussion).

Table 2

Amenity Categories and Proximity Weights Rationale

Amenity Category	Weight	Rationale
Grocery	20%	Represents the importance of food access, and its neccesity for daily living (Herrick et al., 2015).
Transit Stop	18%	Represents the importance of transit access for mobility (Tennøy et al., 2022).
Education	13%	Divided into primary/secondary schools (6.5%) and colleges/universities (6.5%), highlighting the importance of accessible educational institutions for both children and adults.
Core Retail and Service	14%	Includes various essential services, such as pharmacies (3.5%), childcare (3%), post offices (2%), department stores, hardware stores (2%), dry cleaners/laundromats (2%), and banks (1.5%). Higher importance was given to vital or frequently visited services.
Parks, Sports, and Fitness	12%	Includes various recreational and fitness options, with parks (5%), sports and fitness (gyms, pools, recreation centers, and yoga studios) (7%). Represents the importance of exercising and play infrastructure for daily living (El-Murr et al., 2021).
Healthcare	11%	Includes walk-in clinics (5.5%) and urgent care centers (5.5%), representing the importance of accessible healthcare services.
Discretionary Retail	5%	Includes stores for clothing (1.67%), footwear (1.67%), and furniture (1.67%). A low importance was given as this amenity is not necessary for daily living.
Resturaunt	4%	Includes restaurants (1.33%), cafes (1.33%), and bars (1.33%). A low importance was given as this amenity is not necessary for daily living.
Culture	3%	Includes museums (1%), theaters (1%), and art galleries (1%). A low importance was given as this amenity is not necessary for daily living, especially for non-tourists.

Note. Weights sum to 100% and are representative of pedestrian utility.

Density

In this analysis, density reflects the amount of people and amenities in an area. A greater population density means a greater likelihood of more amenities being built to support residents. More amenities in an area reduce distances pedestrians need to travel to access services, increasing walkability. Glazier et al. (2014) found using both measures of density to have better explanatory power for walkability.

Density (16.25% weight) combined amenity density and population density at the DA level (8.125% of density weight each). Each DA was assigned a percentile rank for both components, determining the score (Figure 4). A score of 100 indicates the highest relative density.

Diversity

Diversity reflects the distribution of amenity categories in an area. With greater diversity in amenities, it's more likely that required services are nearby, thereby increasing walkability. Diversity was measured by normalized Shannon's Entropy Index of amenity point categories per 15 hectares (Figure 5). The index is calculated as follows:

$$H = -\sum_{i=1}^{n} p_i \log(p_i)$$

Where:

- H is the entropy score,
- n is the number of categories,
- p_i is the proportion of each category.

Shannon's Entropy calculates diversity by calculating the deviation from a perfectly equal distribution in amenities. A high value indicates many types of amenity categories in roughly equal proportions, while a low value (close to 0) suggests dominance by one or a few categories. Shannon's Entropy was normalized by log(n), the maximum possible diversity, and then scaled to a 0-100 range by multiplying by 100.

This metric was calculated per 15 hectares rather than per DA, as diversity is scale-dependent. Using equal-sized areas allows for more meaningful comparisons across the study area. The 15-hectare area was chosen somewhat arbitrarily, but it ensured sufficient resolution.

Connectedness

Connectedness reflects how well amenities are linked through the pedestrian network. As pedestrian networks are often integrated with roads, increased road connectivity or density increases the likelihood of direct routes to amenities, enhancing walkability. Intersections are effective indicators of connectivity because they reflect the availability of route options within a network.

Connectedness (16.25 % weight) combined road density and intersection density at the DA level (8.125% of connectedness weight each). Each DA was assigned a percentile rank for both components, determining the score (Figure 6). A score of 100 indicates the highest relative density.

Attractiveness

Attractiveness reflects the appeal and quality of an area for pedestrians. Steeper slopes reduce attractiveness by making the area more difficult to walk in, thereby lowering walkability. Aesthetic and comfort features, like the number of trees or streetlights, enhance an area's attractiveness and increase walkability.

Attractiveness (16.25% weight) combined slope (11.25% of attractiveness weight; Figure 7) and aesthetics (5% of attractiveness weight). Aesthetics were equally composed between tree density and streetlight density at the DA level (Figure 8).

The slope was derived from the DEM for Kelowna and scored using an exponential decay function. The decay function followed the form:

$$S(m) = 100 \times (0.9^{m})$$

Where:

- S(m) is the slope score (0-100),
- m is the slope in percent.

This represents the idea that a 1% increase in slope makes a walk roughly 10% less attractive (Meeder, 2017).

Aesthetics combined tree density and streetlight density at the DA. Each DA was assigned a percentile rank for both components, determining the score. A score of 100 indicates the highest relative density.

Tree density was estimated from Kelowna's tree inventory, which only includes trees on city-owned land. As a result, this metric likely underestimates tree density. Streetlight density was derived from Kelowna's combined dataset on streetlights and traffic poles; however, due to a lack of clear differentiation between the two, this metric likely overestimates streetlight density. Further, trees and streetlights only capture a slim subset of aesthetic factors affecting walkability. Due to these limitations, aesthetics is given a lower weight in the overall walkability index.

Walkability Index

Once all indicators were calculated, they were weighted and aggregated into the final walkability index using a weighted average, following the formula:

$$Walkability\ Score = \sum_{i=1}^{n} w_i x_i$$

Where:

- n is the number of amenity categories,
- w_i is the category's weight factor,
- x_i is the category's score.

Many studies apply equal weighting to indicators, as assigning weights can be arbitrary (Agampatian, 2014; Lefebvre-Ropars & Morency, 2018; Telega et al, 2021). For this analysis, greater emphasis was placed on proximity, similar to the methodology used by Walk Score (2025). All other weights were distributed equally, with adjustments to account for data availability and quality. Table 1 outlines the walkability indicators and their respective weights.

Results

After completing the analysis, the data were meaningfully represented figuratively and tabularly. The final walkability index is presented in Figure 9, while Figure 10 shows the mean walkability score for each DA, also highlighting the top three most walkable DAs. Table 3 lists each DA ranked by walkability.

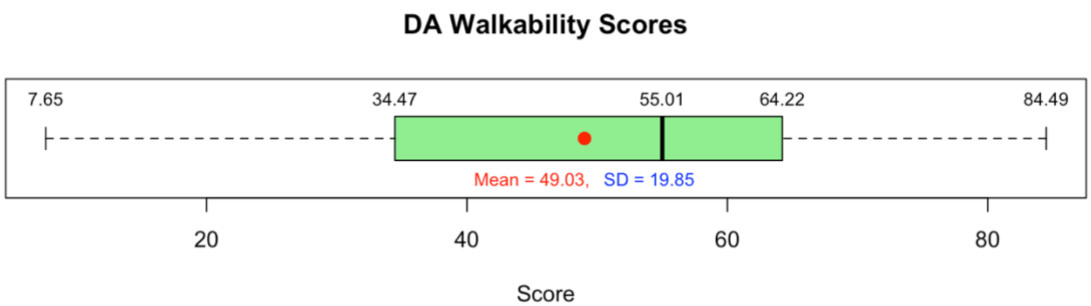
Figure 11 provides the summary statistics for mean walkability by DA. The walkability scores ranged from a minimum of 7.65 to a maximum of 84.49, with a mean of 49.03 and a standard deviation of 19.85 indicating high variance in walkability scores across DAs. The lower quartile (34.47) and upper quartile (64.22) highlight this disparity.

DA 59350057 (located downtown) scored the highest in the city (84.49) due to its strong performance in proximity and density of amenities, flat terrain, and well-connected pedestrian network (Table 3). However, it had moderate diversity and lower relative population density, suggesting mixed-use development and denser housing could further improve walkability.

DA 59350022 (Wilden area) scored the lowest in the city (7.65) due to its poor performance across most indicators, especially proximity, diversity, population density, and transit access (Table 3). As a low-density, car-dependent suburb, Wilden is an example of the urban sprawl challenges identified by Kelowna's 2040 Community Plan and highlights the need for denser urban development and improved active and public transit infrastructure.

Walkability scores were highest in the downtown core and areas adjacent to major roadways (Highway 97, Glenmore Road, and Lakeshore Road; Figure 9), reflecting high performance across indicators including amenity proximity, density, diversity, pedestrian network connectedness, population density, and favourable terrain. The urban cores (Downtown, Pandosy, Capri-Landmark, Rutland, and Midtown) had the highest walkability, with scores progressively decreasing toward the suburban and agricultural areas. This pattern aligns with Masoud et al.'s (2022) findings for walkability distribution across Kelowna's DAs.

Figure 11
DA Walkability Summary Statistics



Note. SD denotes standard deviation. The red dot indicates the mean. The box plot summarizes the five-number summary for DA walkability scores (min, Q1, median, Q2, max).

Discussion

Measuring proximity with Euclidean distance is limited as it fails to capture pedestrian route choice and physical movement barriers (e.g., buildings, highways, rivers, terrain). While Manhattan distance improves estimates, both methods are imperfect. Network-based metrics would greatly improve proximity analysis by accounting for walkable paths around obstacles and pedestrian choice. Xie (2024) found a significant reduction in walking speed with increasing uphill slopes versus flat ground, with slight improvement when walking downhill for small slopes but deterioration in speed on larger downhill slopes. A network analysis would better capture these direction-dependent components of slope.

The decision to apply a 10% loss in slope score for a 1% increase in slope was extreme and overestimated path utility loss, but still broadly approximated the growing difficulty of navigating steeper terrain. A more gradual score decrease (e.g., 5%) might provide a better estimate of walkability loss. A network analysis could much better capture the effects of slope on walkability by considering the actual path taken across the terrain.

The subjective choice of weights for the walkability index and the proximity scores introduced bias in the analysis. While they were loosely based on the available literature, few studies suggest specific weights, and when they do, the indicators often differ. The analysis would benefit from data-driven methods, and expert and/or stakeholder input to establish more reliable weights.

When compared to Euclidean distance, a Kernel density method for assessing the proximity of amenities provides a more realistic indicator of walkability. It measures both the ease of access to amenities and how many amenities are available in an area, where areas with close, dense clusters of amenities receive higher scores. Euclidean distance only measures the ease of access to the closest amenity and does not capture amenity density.

Switching from amenity points to zoning for generating metrics of density and diversity would provide a more reliable measure of amenity presence. Zoning provides a fuller representation of land use compared to amenity points, as point amenity data is often sparse or incomplete. For this analysis, amenity points were manually sourced from Google Maps, introducing potential error. Additionally, Google Maps is incomplete and does not list all available amenities. Because zoning regulations shape an area's built environment, they are more relevant for measuring density and diversity.

The availability of data limited the scope of the analysis. Walkability is incomplete without including an assessment of micro-scale environment features like sidewalk widths and obstructions, but this data was unavailable for this analysis. Additionally, Safety and security factors were also not assessed due to data limitations. Ultimately, capturing the full complexity of an environment is not feasible, especially when data is limited.

The study's results are relative and based on specific walkability indicators, which inherently introduce bias. Walkability reflects an individual's ease of navigating an environment, and different individuals have distinct needs (Gorrini, 2021). Thus, the walkability model will not reflect all individuals' diverse experiences.

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