Photo credit: TransLink, Sarah Kertcher

A SYSTEMATIC FRAMEWORK FOR QUANTIFYING AND EVALUATING TRANSIT-ORIENTED AREA PERFORMANCE

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DISCLAIMER

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This project was conducted under the mentorship of the City of Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the City of Vancouver or the University of British Columbia.

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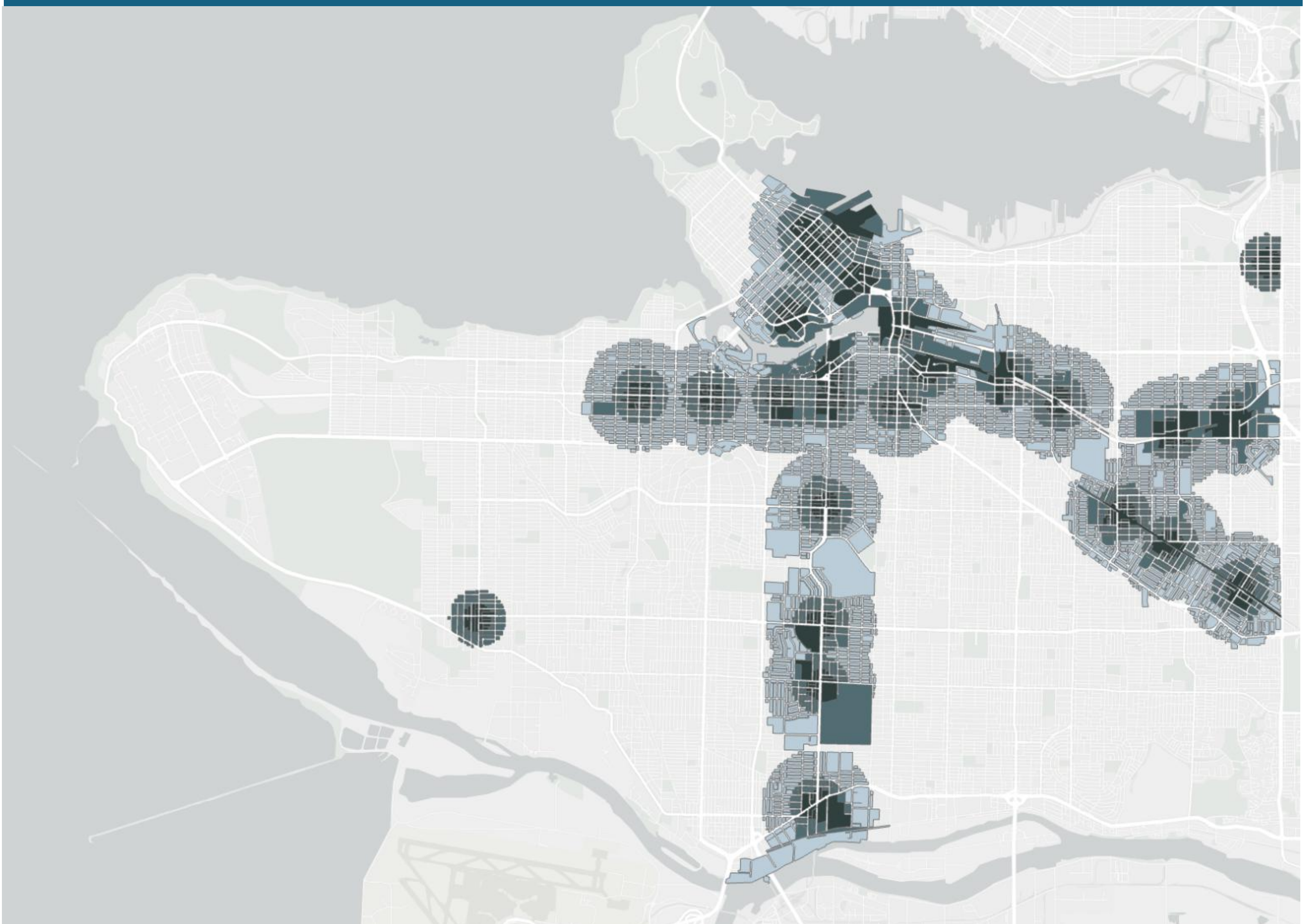

Figure 1 Designated Policy Area of TOA in City of Vancouver

BACKGROUND

Rapid urban population growth, stringent emission-reduction targets, and the need for reliable mobility have recently led the British Columbia government to place Transit-Oriented Development (TOD) at the centre of its transport-and-land-use agenda. A core strategy is planning the Transit-Oriented Area (TOA): a walkable catchment (roughly 400–800 m) around each rapid transit station and bus exchange. The TOAs aim to deliver high-density, mixed-use, people-focused communities that encourage travel by a full spectrum of multi-modal options, for instance, walking, cycling, micromobility, conventional transit, shared-mobility, and offer seamless, comfortable transfers between those modes. By concentrating development and access around rapid transit stations, TOAs make it convenient for people to reach a wide variety of destinations and public places quickly and efficiently using public transit and active transportation.

PROJECT MOTIVATION

Every TOA exhibits a unique mix of land-use intensity, multi-modal capacity, and user demand; given differing existing conditions and future growth, the corresponding planning and design interventions should be tailored accordingly. Currently, there is no city-wide planning framework followed with TOA classification criteria to measure TOA performance, identify gaps and needs, and prioritize interventions and recommendations, to ensure that streets, transportation facilities, and land use function together as an integrated, multi-modal transit and land use system. Provincial, regional, and municipal guidelines articulate overarching principles. For example, TransLink promotes 6D's design framework for TOA planning, including Destinations, Distance, Design, Density, Diversity, and Demand Management. However, very few quantitative indicators are available for these dimensions to guide monitoring, measure performance, or inform targeted improvements. The BC Active Transportation and Transit-Oriented Development Design Guide provides a TOA typology description, including small and rural communities, municipal nodes, regional centres, and metro core. Still, the categories are based only on transit service type and land use mix and density, without sufficient numeric thresholds and detailed classification factors. Existing policies and design guides also contain some detailed design advice, such as minimum sidewalk width, but without data-driven TOA classification, these recommendations are difficult to apply systematically. This project, therefore, aims to create an indicator-based framework and evaluation matrix to guide multi-modal transportation and land use planning and design across Vancouver's TOAs.

PROJECT OBJECTIVES

Phase 1 of this project **reviews current policy and planning literature**, builds on existing frameworks, **extracts measurable factors**, and **gathers insights through city planners' and managers' interviews (n=4) for framework and factor validation**. The findings inform the creation of an evaluation matrix —comprising a broad set of indicators—to assess TOA performance and classify them according to their multimodal function and needs. Deliverables include summaries of the policy and literature review, an interview synthesis, and the framework model with its list of evaluation factors.

Phase 2 of this project develops and tests quantification methods for the evaluation matrix. The **evaluation matrix is piloted across all of Vancouver's Transit-Oriented Areas (TOAs) using GIS data** to assess its practical applicability. Based on pilot results, the project delivers **actionable recommendations** for a selected TOA by addressing its lowest-performance indicators. This serves as a **demonstration of the practical application** of the evaluation framework and matrix to enhance overall TOA function. Deliverables include a detailed methodology document for the evaluation matrix, pilot data analysis results with supporting maps, and a recommendation pyramid to guide future planning and improvements for the selected TOA.

KEY CONCEPTS

Transit-Oriented Development

“Transit-oriented development (TOD) generally refers to a type of urban form and land use plan that maximizes the amount and density of residential, commercial, employment, and other land uses near public transit.”

---*BC Active Transportation and Transit-Oriented Development Design Guide*

Transit-Oriented Area

A TOA is the land within a prescribed radius, 400 m for bus exchanges or West Coast Express stations and 800 m for SkyTrain/subway stations, measured from the transit station. Within this catchment, the province expects higher density, mixed-use, complete community development that supports mode shift to transit and active transportation.

---*B.C.’s Provincial Policy Manual: Transit-Oriented Areas*

Active Transportation

Active transportation refers to all forms of everyday travel powered primarily by human effort or low-power electric assist rather than internal combustion engines. Core modes include walking, running, wheelchair travel, cycling (including e-bikes), and the use of scooters and other micromobility devices that rely mainly on human power. Because these modes are most practical over short to medium distances, they effectively bridge the “first- and last-mile” gap between a transit stop and traveller’s origin or destination, making them an essential component of the public transit system.

Beyond supporting daily mobility, active transportation yields wider benefits: it promotes public health by increasing physical activity, improves local air quality, and lowers traffic-related greenhouse gas emissions.

Multi-modality

Multi-modality describes travel patterns in which an individual relies on two or more different modes of transportation, either by chaining them within a single trip or by using them repeatedly over a set observation period. These two different types are defined as Multi-modal Transportation (or Individual-level Multimodality) and Intermodal Transportation (or Trip-level Multimodality)

Multi-modal Transportation/ Individual-level Multimodality

Multi-modal transportation refers to the behaviour of an individual or population that applies two or more different transport modes (e.g., walking, cycling, bus, Skytrain, private car) within a given observation period, such as a day, week, or year, to meet their travel needs. The concept captures mode diversity across separate trips, not within a single trip chain (compared to intermodal transportation).

Intermodal Transportation/ Trip-level Multimodality

Intermodal transportation describes a trip or trip chain in which two or more transport modes are used sequentially, for instance, walking to a bus stop, boarding a bus, and transferring to the Skytrain, to achieve daily mobility. This concept emphasizes real-time integration and coordination among modes (transfer hubs, seamless transition, first/last-mile connections).

When these elements function seamlessly, a multimodal system becomes a practical alternative to private-vehicle travel over longer distances for both multi-modal and intermodal transportation. By closing the first- and last-mile gap, enhancing network resilience, and enabling smooth transfers, it contributes directly to lower greenhouse-gas emissions and greater overall accessibility.

Rapid Transit

“Rapid transit is designed to run long distances at high speeds, with stops usually spaced about a kilometre apart.”

---*Transportation 2040*

Local Transit

“Local transit travels at slower speeds, with stops spaced more closely together.”

---*Transportation 2024*

Mobility Hub

“A mobility hub is a recognizable place with an offer of different and connected transport modes supplemented with enhanced facilities and information features to both attract and benefit the traveller.” It’s designed to facilitate access to and transport between transportation modes.

--- Collaborative Mobility UK (CoMoUK) 2019

Pedestrian Shed, Walksheds and Bikesheds

The area can be covered in a 10-minute walk or a 10-minute bicycle trip. Usually, it is defined as roughly 800 m for walksheds and 2.5 km for bikesheds. Its actual size depends on street connectivity and the absence of barriers.

BACKGROUND POLICY REVIEW

Provincial Policy Manual: Transit-Oriented Areas (BC Ministry of Transportation and Infrastructure, 2024)

In response to rapid population growth, housing pressures, and the provincial objective of reducing transportation emissions by encouraging multimodal, transit-oriented travel, this manual legally defines a Transit-Oriented Area (TOA) as all land within 800 meters of a SkyTrain station or within 400 meters of a bus exchange or West Coast Express stop. Municipalities are required to up-zone these catchments to minimum heights and floor-area ratios and embed active transportation considerations in local bylaws. The manual signals a strong provincial commitment to higher density, mixed-use development, and transportation mode shift. It serves as a land-use compliance tool, while leaving a gap in how to design, measure, or prioritize multimodal function inside the TOAs.

BC Active Transportation & TOD Design Guide (BC Ministry of Transportation and Infrastructure, 2021)

This provincial guide categorizes TOD into four typologies: Small/Rural Community, Municipal Node, Regional Centre, and Metro Core, and provides comprehensive, detailed design-element recommendations for each, covering pedestrian facilities, bicycle facilities, crossings, end-of-trip amenities, and more. However, its typology relies solely on transit service type and broad land-use mix and density categories, lacking precise numeric thresholds or detailed classification factors. For instance, density is assessed only by “Units per Hectare,” with qualitative descriptors such as “medium” or “medium to high density,” rather than clearly defined breakpoints. Key aspects commonly documented in the literature, such as accessibility, connectivity, and other quantitative indicators that strongly influence TOA performance and quality, are not incorporated. Nor does the guide address transit demand variations tied to community socio-economic status and demographics. Even so, it offers a solid foundation for TOD classification and remains a valuable resource of detailed design guidance.

Transport 2050 (TransLink, 2022)

Transport 2050 is Metro Vancouver’s long-term transportation strategy, envisioning “Access for Everyone” through an integrated, sustainable, and inclusive regional system. The plan identifies key goals and collaborative actions to address growth, equity, climate, and mobility challenges over the next 30 years. It closely aligns with Transit-Oriented Area (TOA) principles by advocating for compact, walkable, highly connected, and mixed-use communities focused on major transit corridors. It prioritizes placing accessible and affordable housing and employment near high-frequency transit, expanding pedestrian and bikeway networks around transit stations, and supporting reliable, multimodal access and active transportation for all residents. While Transport 2050 emphasizes evidence-based and measurable progress, it does not provide a detailed quantitative framework or standardized metrics for evaluating TOA performance. As a result, there remains a gap in robust, ongoing performance evaluation tools specifically designed to assess multimodal connectivity and TOA functions.

Transit-Oriented Communities Design Guidelines (TransLink, 2012)

TransLink's Transit-Oriented Communities Design Guideline promotes the "6 Ds", including Destinations, Distance, Design, Density, Diversity, and Demand Management, as a conceptual framework for land-use and transportation planning within the 400 and 800-metre catchments around stations and exchanges. Each "D," however, is expressed as a principle and goal rather than a metric: the document offers planning and design suggestions but provides no quantitative indicators to evaluate current performance or track improvement. Published over a decade ago, it also predates micromobility and today's curb-space pressures, omitting guidance on other micro-mobilities like scooter corrals, freight micro-hubs, or ride-hail staging. Even with these gaps, the guideline remains a valuable foundation for an evaluation matrix because it identifies key factors that influence travel behaviour and points to areas where more detailed, measurable standards are needed.

Transit Passenger Facility Design Guidelines (TransLink, 2011)

Compared to Transit-Oriented Communities Design Guidelines, which focus on the design elements inside the walking and biking catchment, the Transit Passenger Facility Design Guidelines (TPFDG) center on the design of the transit passenger facilities and their immediate surroundings. The document provides the region's most detailed station-level numbers: pedestrian flow Level of Service (LOS), escalator flow, waiting-area density, plus minimum dimensions for bike-parking rooms, taxi and Kiss-and-Ride areas, lighting levels, and tactile warnings. These metrics make the TPFDG especially valuable for any evaluation matrix that needs station-performance indicators. However, the TPFDG relies on early-2000s crowd-flow tables and offers no guidance on micromobility, ride-hail operations, curb management, or climate resilience. These gaps leave important multimodal access and connection factors unaddressed, limiting the document's usefulness for a complete TOA evaluation. Still, it is the region's only source with quantified station capacity and space standards, making it a necessary reference for any multimodal TOA assessment and improvement recommendations.

Transportation 2040 (City of Vancouver, 2012)

Transportation 2040 is the City of Vancouver's long-range mobility strategy. It sets a headline target that at least 50 percent of all trips be made by walking, cycling, or transit by 2040, with a parallel goal of cutting transport-related greenhouse-gas emissions and per-capita vehicle-kilometres travelled by roughly one-third. The plan is organized around six categories: Land use, Walking, Cycling, Transit, Motor Vehicles, Goods, Services, and Emergency Response, and Education, Encouragement, and Enforcement, each backed by broad actions, for instance, encourage rich destinations, high density, and mixed land use around major transit stations and along transit corridors; build an all-ages-and-abilities (AAA) walking and cycling network; expand the transit network and integrate with other mobility modes; and regulate parking with demand-based management, dynamic pricing, and car-share priorities.

While the document clearly states its long-term, city-wide transportation-related goals, it remains at the policy level without providing detailed implementation measures. It does not include sub-area targets, numeric standards, and performance thresholds to trigger interventions and improvement. As a result, Transportation 2040 provides the vision, principles, and city-wide goals for transportation and land-use, but leaves a gap in the detailed, spatially specific metrics required for evaluating and planning at the TOA level.

LITERATURE REVIEW SUMMARY

TOA TYPOLOGY MODELS

1. Node-place model

Introduction

The node-place model (Figure 2) is the most commonly applied and studied model that evaluates the quality of transit nodes in transportation planning literature, first developed and tested by Bertolini (1999), then followed by other extended and improved models. In Bertolini's initial node-place model, main station areas are categorized based on their features along two axes: as a transportation node[1] (how many, how frequent, and how diverse the transit connections are) and a place (the intensity and mix of surrounding activities). This model highlights the station's accessibility and the intensity and diversity of the activities in that place. In this two-dimensional model, a station's accessibility represents the potential for physical human interactions, and the intensity and diversity of the activities represent the realization of physical human interactions in that station area (Bertolini, 1999).

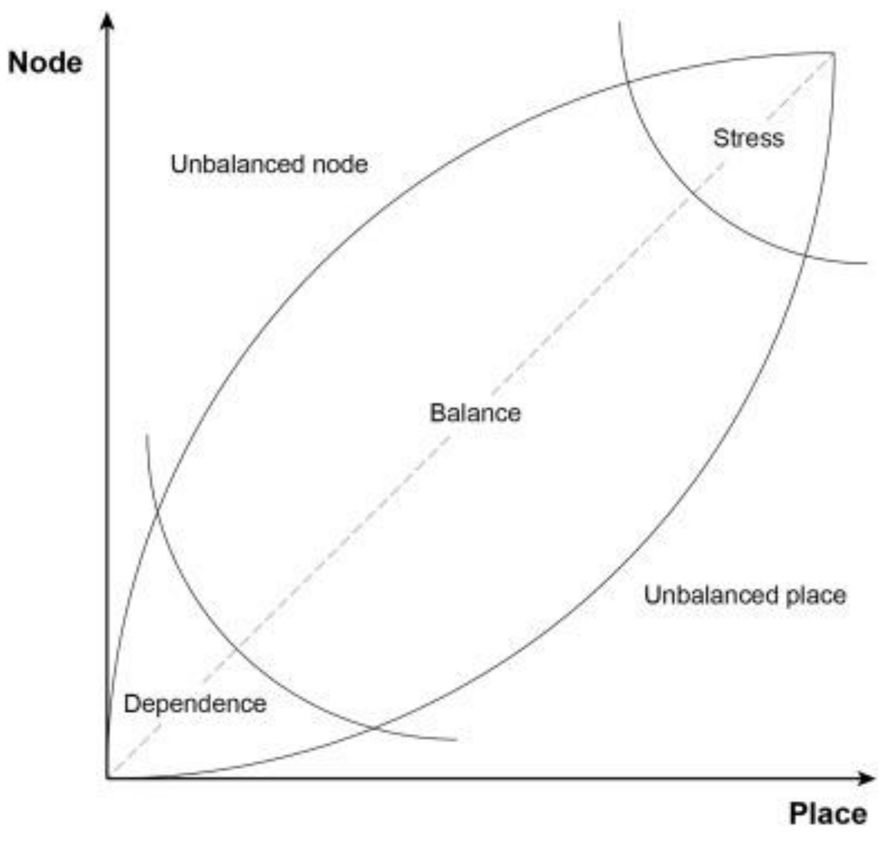

Figure 2 The node-place model developed by Bertolini (1999)

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[1]A node in a transportation system usually represents an activity center or hub where multiple transportation routes meet

Plotting the scores for node and place yields four distinctive TOD types (see Figure 2):

- **Balanced area**: A station area lies on the diagonal between the two axes, both easy to reach and worth reaching, delivering benefits to a broad range of users.
- **Under-stress area**: A station area scores high on both axes; it attracts heavy flows of travellers and activities but needs space management to avoid congestion.
- **Unbalanced node area**: A station area combines excellent transit service with limited local land use; it risks being underused unless new housing, jobs, or amenities are added.
- **Unbalanced place area**: A station area has intense, diverse activity with weak transit access. These areas demand improved service to match their land-use potential.
- **Dependent area**: A station area with low scores on both dimensions, typically requiring external subsidies or interventions to stimulate transit use and local development.

The original node-place model simplifies the connectivity and accessibility to its links with other regional network nodes. However, the accessibility within a TOA's catchment area and its internal connectivity also directly influence travel behaviour, especially for multi-modal trips. Therefore, TOA internal street connectivity is another key aspect when assessing both the quality of a transit node and the surrounding catchment. Several studies have added this third dimension to the model, termed spatial configuration or urban design. Monajem & Ekram Nosratian (2015) quantify spatial configuration through three variables: the subway station's position relative to economic activities, the local street network, and prevailing movement patterns. Similarly, Vale et al. (2018) link TOA design qualities to pedestrian access and overall walkability. Common metrics for this dimension include the pedestrian-shed ratio and accessible-network length, which estimate the area reachable by active transportation from the station. Incorporating these measures yields an enhanced node-place model that can visually demonstrate TOA classifications, as shown in Figure 3.

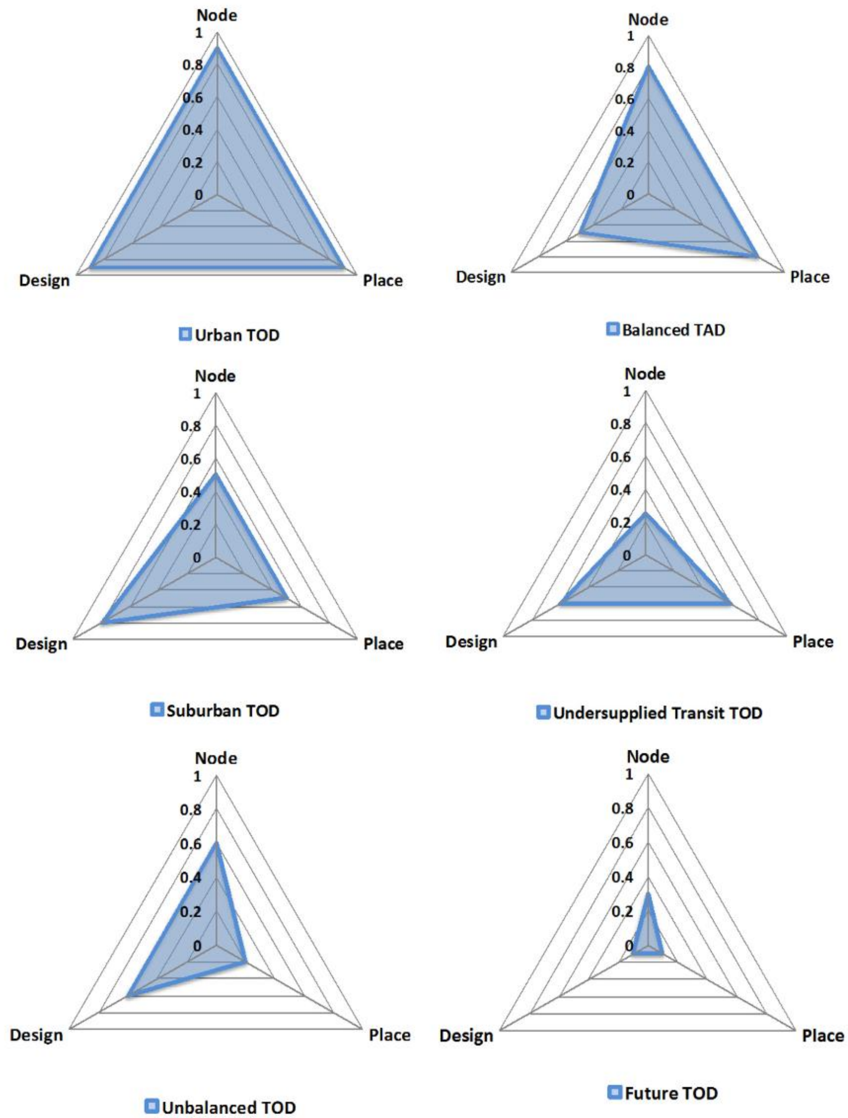


Figure 3 The extended node-pace model and six typologies of TODs (Vale et al., 2018)

Limitations and Potential Applications

As one of the most commonly applied models in transit station area evaluation and classification literature, a key shortcoming in current node-place models is their limited ability to capture local multimodal transportation capacity and needs within a TOA. Continuous efforts are needed to include a dedicated transit index that quantifies the number of available modes, the quality of their interconnections, and the seamlessness of resulting trip chains. As a result, a TOA may score highly on a node-place model yet still fail to facilitate convenient transfers between walking, cycling, shared micro-mobility, and public transit. In addition, the “place” dimension in node-place assessments typically measures only the presence of physical activity and interaction; there are limited considerations about the actual demand for multimodal options among residents whose travel behaviour varies by income, age, gender, or mobility status. Without indicators that capture socio-economic and demographic differences, there is a risk that communities most in need of multimodal networks will be overlooked in the planning process.

2. Performance-based TOD topology

Introduction

Compared to the node-place model, the performance-based TOD typology model developed by the Center for Transit-Oriented Development (CTOD) in the U.S. also considers two dimensions: the total vehicle miles travelled (VMT) of households within a transit zone (as the performance indicator) and the percentage of workers within a TOD (as the place indicator) (Austin et al., 2010). The place indicator is a similar measurement compared to the “place” dimension in the node-place model, while the performance indicator is more distinct than other TOD classification and evaluation frameworks. The key assumption of the VMT measurement is that lower VMT within a TOD indicates higher rates of active transportation and public transit usage, further signalling stronger overall performance of a transit zone.

Limitations and Potential Applications

Using VMT as a performance indicator highlights the TOD classification's emphasis on reducing greenhouse gas emissions and proximity to employment, retail, and educational destinations. However, VMT alone cannot capture specific planning and design factors that drive observed performance differences (therefore, it is unable to provide targeted improvement recommendations), nor does it consider the integration of multi-modal transit in a TOD, which is a key focus of this project.

Moreover, CTOD’s VMT estimates are derived from a regression model that includes household income, household size, commuters per household, journey-to-work time, household density, block size, transit access, and job access as variables. As these variables are widely recognized as key determinants of travel behaviour, they can be used as more direct indicators of multimodal transportation needs to support the objectives of this evaluation framework better. Therefore, direct estimation of VMT is not included in the evaluation matrix; instead, indicators of multimodal demand are derived from the relevant variables.

WALKABILITY ASSESSMENT FRAMEWORKS

Although accessibility and connectivity within a TOA have been included in advanced node-place models, most studies rely on a limited set of indicators and, therefore, miss other factors that shape travel behaviour. Many existing walkability frameworks can serve as a strong measurement framework for this dimension and complement the node-place model. Most of these walkability frameworks especially highlight that they include indicators and measurements that capture the connectivity within a specific area and accessibility to the transit stations, which directly influence travel behaviour, especially between the choice of active transportation and motor vehicles. Some frameworks go further, incorporating experiential factors like comfort and conviviality, treating accessibility as a mediating construct, or accounting for topographic factors. These frameworks supply and inform a broader list of indicators for a more comprehensive evaluation framework.

Among the elements identified in established walkability frameworks, certain small-scale design features can also significantly influence walking behaviour, such as street trees, trash bins, drinking fountains, etc. However, these features are often difficult to quantify through direct measurement and are not directly associated with mobility needs or the core transit and land use functions of a TOA. Consequently, such features are recommended to be considered as context-specific design guidelines rather than evaluation variables. It is also important to note that, as diversifying mobility modes is a key objective, existing walkability frameworks may be limited in addressing accessibility for other modes such as cycling and e-scooters.

The following section reviews major frameworks for assessing walkability and built environment factors that influence travel behaviour, highlighting key insights for TOA evaluation and classification.

1. 5D, 7D, and 3D+A frameworks

Ewing & Cervero's (2010) 5D/7D frameworks quantify how the built environment shapes travel behaviour by measuring Density, Diversity, Design, Destination accessibility, Distance to transit, and additionally adding Demographics and Demand management (Figure 4). They condense hundreds of empirical studies, showing, for example, that higher intersection density and land-use mix have the strongest positive effect on walking. Vale et al. (2018) extend the discussion with their 3D + A model, arguing that Density, Diversity, and Design around both trip origins and destinations influence commuter walking behaviour, while Accessibility is not an independent "D" but a mediating outcome of those three variables (therefore it should not be treated as a separate built-environment variable). Although the authors also test commuting distance, they note it is a contextual factor, which is essential for regional modelling but less actionable for the design of any individual TOA. Compared with experiential frameworks such as the 7C framework (discussed below), both models stay at the meso-scale and use available GIS data, making them ideal for benchmarking multiple station areas. The 5D/7D framework provides evidence-based land-use and street-network indicator selection for TOA evaluation matrix development. In comparison, the 3D + A framework highlights the need to measure conditions not only around stations but also around the key destinations they serve and to treat route accessibility as the product of those built-form attributes rather than an extra design dimension.

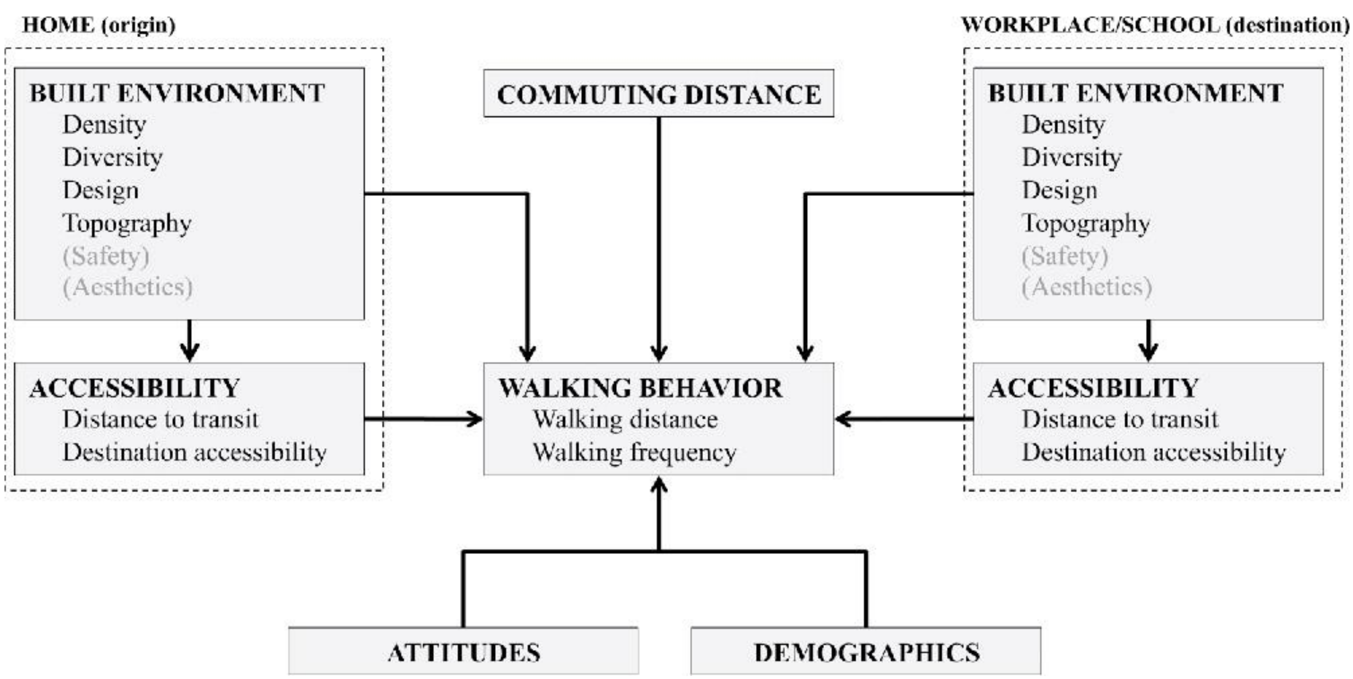


Figure 4 Conceptual framework showing the determinants of Transport-related walking behavior, Vale and Pereira (2016)

2. 7C walkability framework

Moura et al. (2017) present a 7C walkability framework built around seven dimensions: Connectivity, Convenience, Comfort, Conviviality, Conspicuousness, Co-existence, and Commitment. This framework combines GIS metrics with on-street audits and, importantly, weights each indicator through a participatory process for specific pedestrian groups (adults, children, seniors, mobility-impaired users) (Table 1). The tool aims to reveal how the same street network performs differently for different user groups. Unlike broader "5 D" or density-driven models, this framework captures experiential qualities such as shade, seating, and perceived safety, producing a granular, user-sensitive walkability assessment framework. Applied to TOA evaluation and planning recommendations, these group-specific weights can slot directly into design recommendations tailored to TOA demographics, helping to prioritize upgrades that make station areas accessible and supportive for all travellers.

Table 1 The included key factors and corresponding weights defined by each pedestrian group

7 C's	Key-concerns selected by each pedestrian group	Pedestrian groups							
		Adults		Children		Seniors		Impaired Mobility	
		Utilitarian	Leisure	Utilitarian	Leisure	Utilitarian	Leisure	Utilitarian	Leisure
C1: Connectivity	1 – Pedestrian infrastructure (path/sidewalk) continuity	17%	4%			11%	7%		
	2 – Path directness			19%	9%				
	3 – Accessible pedestrian network							11%	15%
C2: Convenience	4 – Land use diversity	6%	19%	15%	23%				
	5 – Sidewalk effective width							16%	10%
	6 – Daily commerce (e.g., bakery) and services (e.g., cash machine)					16%	27%		
C3: Comfort	7 – Vigilance effect or perception by pedestrians			19%	18%				
	8 – Pavement quality	17%	12%			21%	17%	21%	20%
C4: Conviviality	9 – Meeting places					11%	17%		
	10 – Existence or visibility of anchor places (e.g., shoping malls, public facilities, transport interfaces)			4%	18%			11%	15%
	11 – service hours	17%	23%						
C5:Conspicuousness	12 – Existence or visibility of landmarks (e.g., monuments, distinctive buildings, squares, etc.)	11%	19%	12%	14%	5%	3%		
	13 – Street toponomy (street names, signposting, wayfinding,etc.)							5%	5%
C6: Coexistence	14 – Traffic safety (at pesdestrian crossings)	22%	15%			21%	17%	21%	15%
	15 – Pedestrian crossing location ("desire lines")			23%	14%				
C7: Commitment	16 – Enforcement of pedestrian regulations (law enforcement)	11%	8%			16%	13%	16%	20%
	17 – Existence of design standards and planned public space design interventions			8%	5%				

3. Microscale walkability index

Rahman (2022) shifts the focus from the catchment scale and aggregated indicators to a micro-scale walkability index that rates each street segment against 15 disaggregated variables, including pavement quality, crossings, lighting, street furniture, active frontages, traffic speed, and more, then adjusts the indicators for terrain sensitivity by counting contour lines and catchment size. This approach captures how topography and block-by-block design details shape actual pedestrian activity. Its factor list closely matches (while more explicitly instantiating) the pedestrian-realm features suggested in the BC TOD Guide, such as crossings, furnishings, lighting, tree canopy, etc. Because many elements appear only as components within the composite index, the study demonstrates their collective value for encouraging walking but does not prove every item has a stand-alone statistical effect; therefore, only the most predictive factors need to enter the TOA evaluation matrix. Still, the other elements are valuable for design recommendations targeting improvements in specific aspects. Enhancing micro-level walkability can be highly cost-beneficial (Park et al., 2015). Moreover, short-term, modifiable upgrades often require neither large-scale planning nor multi-level authority collaborations.

Other studies also support the importance of micro-scale elements for creating pedestrian-friendly street environments. Park et al. (2015) develop a micro-scale "path-walkability" framework that reduces thirty-eight street-level variables to four statistically robust factors, including sidewalk amenities, traffic impacts, street scale & enclosure, and landscaping elements, and shows that these factors significantly enhance walking activities. The framework is route-based rather than catchment-scale, captures terrain and block-by-block design detail, thereby identifying low-cost, short-term upgrades (benches, crossings, tree canopy) that can shift access trips from driving to walking. Ewing et al. (2016) test twenty streetscape features on 588 New York blocks and find that three design elements, ground-floor windows, active frontage, and street furniture, are the only elements that still predict pedestrian volume after density, land-use mix, and transit access are controlled for. Together, the two studies complement mesoscale 5D/7D metrics by pinpointing the specific micro-elements that matter most and confirming that targeted, minor improvements can boost walking activities independently of broader land-use change.

OTHER RELATED PLANNING PRINCIPLES AND CONCEPTS

1. Complete Street

Originally a planning principle, Complete Street has been formally adopted as a transportation and land-use planning framework and policy in many jurisdictions, including Canadian cities like the City of Vancouver, Toronto, and the U.S. nationwide. Policy details vary locally, but the core principles remain consistent. These include serving all users and travel modes, ensuring pedestrian safety, enhancing street network connectivity, designing context-sensitively, and integrating land use planning. Interventions based on the Complete Street concept are proven to effectively leverage mode shifting from motor vehicles and increase the use of active transportation, for example, reducing perceived traffic stress and providing highly connected, user-comfortable bicycle networks and facilities (Bas et al., 2023; Brown et al., 2016). Although Complete Street aims to focus on core local corridors and the development and planning of TOAs are specific to a catchment area around transit stations, it presents a street-level design toolkit that lets people move within and through a TOA with specific support for various travel modes beyond personal vehicles.

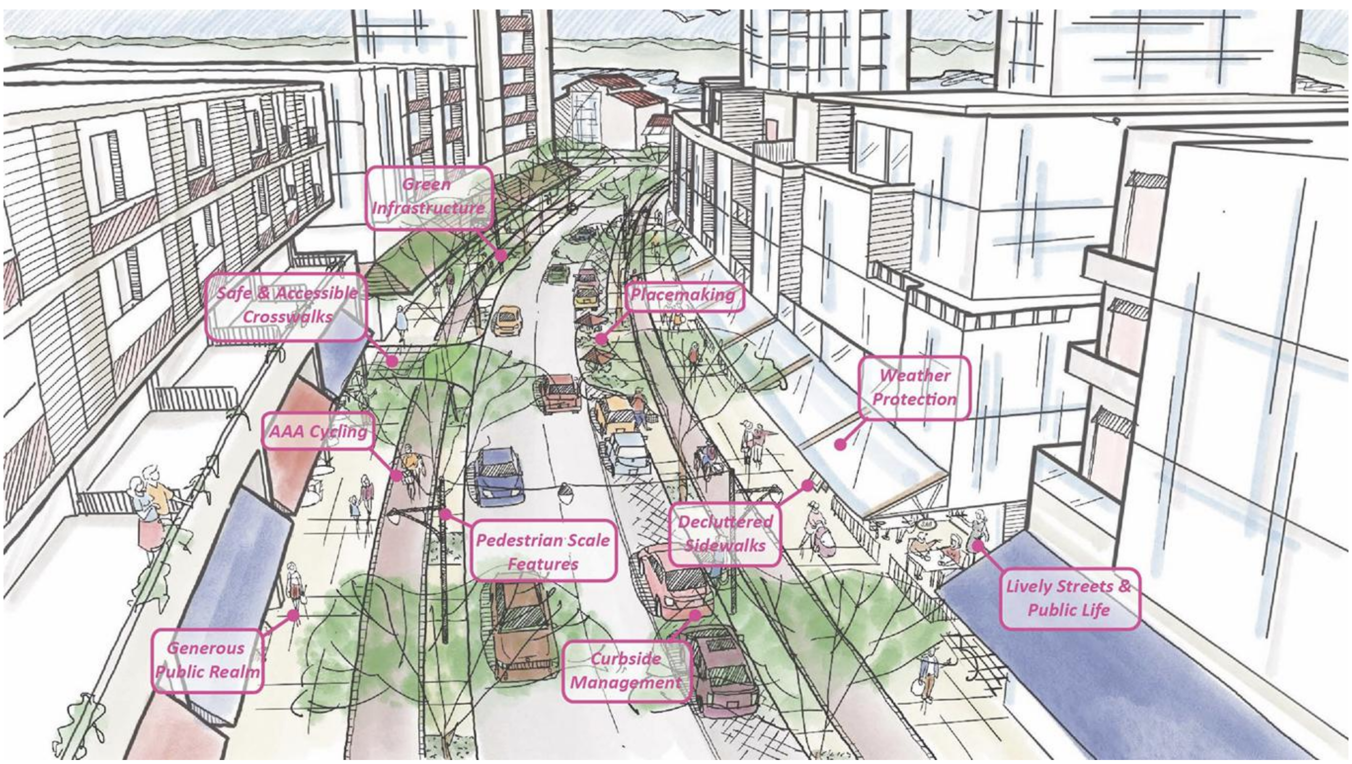


Figure 5 An illustrative example of a Complete Streets Policy Framework (City of Vancouver, 2017)

2. Mobility Hub

The mobility hub concept aligns naturally with TOA multimodal-transit planning by treating the station catchment as an integrated transfer zone. A hub intentionally clusters high-frequency public transit service with other mobility modes like shared bikes, e-scooters, and car share, as well as support facilities like accessible drop-off space, real-time information, and other amenities in one area. It emphasizes goals like encouraging mode shifts, supporting seamless transfer between modes, and connecting the first- and last-mile gaps (Arnold et al., 2023; CoMoUK, 2019). The key design and planning guidance derived from the mobility hub is practical and readily applicable to TOAs.

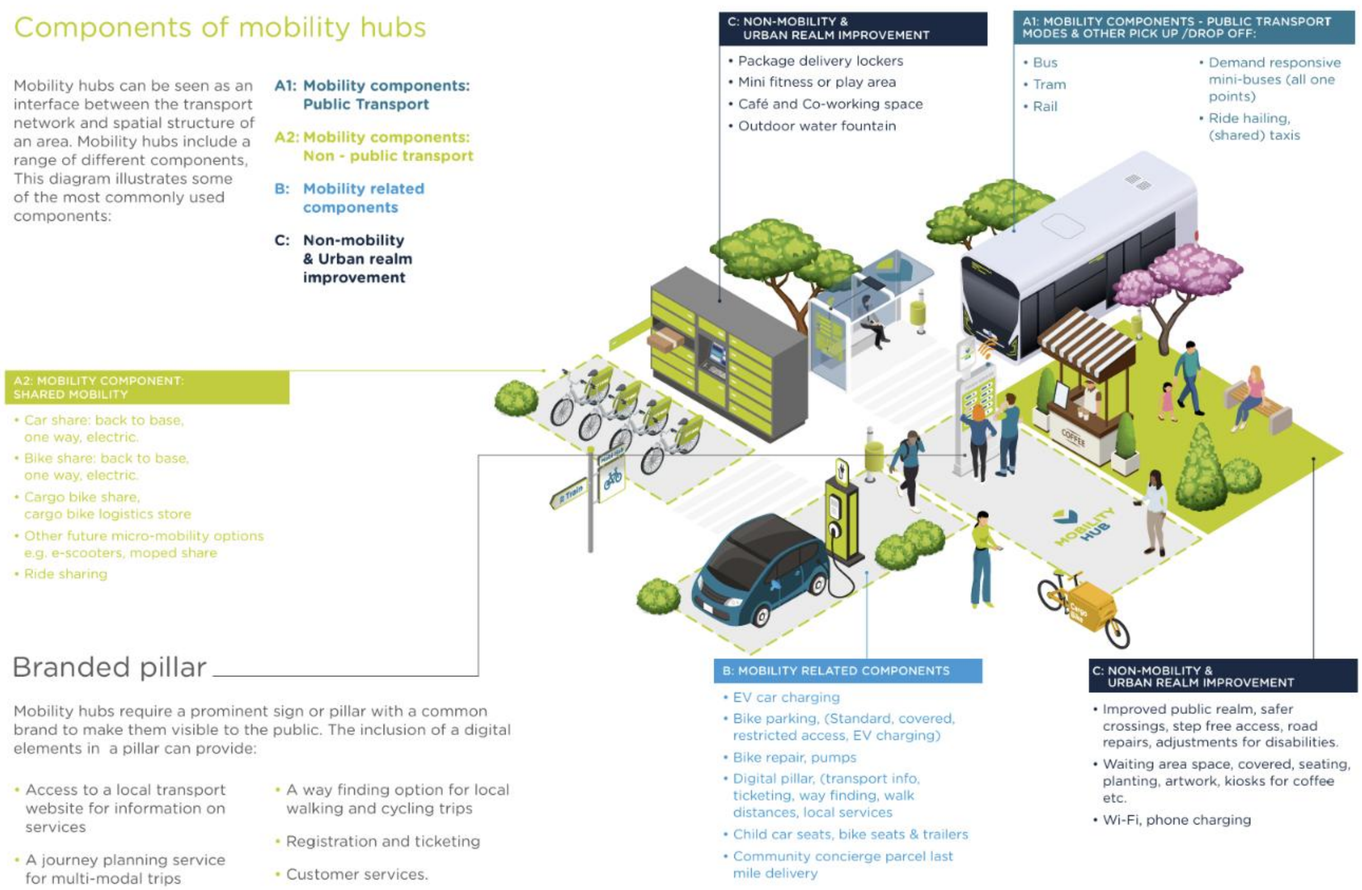


Figure 6 The illustrative model of mobility hub presented by CoMoUK (2019, P9)

Research has also been done on mobility hub topology (Weustenenk & Mingardo, 2023). This study scopes a mobility hub as a local passenger interchange that bundles at least two public or shared transport modes and excludes airports, seaports, and single-mode stops. The key properties of a mobility hub are identified as transport modes, services, and facilities. The empirical regularities of services and facilities of each primary mode of transport are also listed. Building on these key properties, mobility hubs are classified based on the quantity and complexity of transport modes available and services or facilities. Further, the framework accounts for geographical context (the hub's location) and market scale (local, regional, or national catchment). There are six types, as shown in Figure 7 and described in the text box.

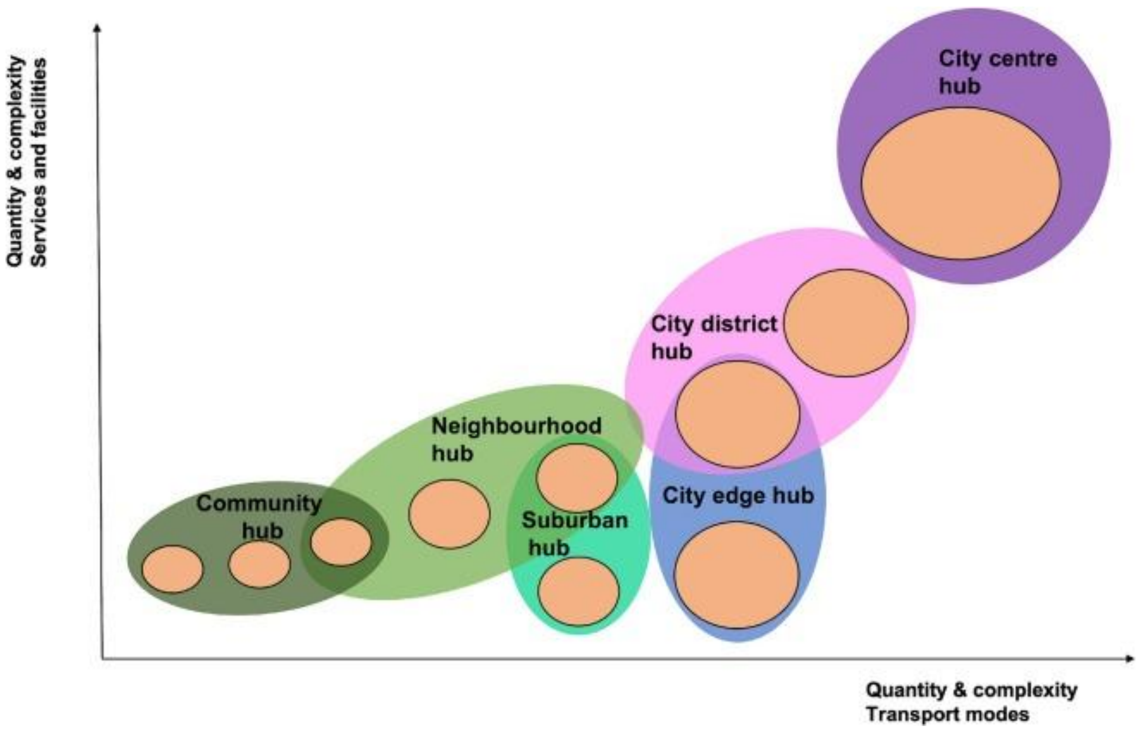


Figure 7 The proposed mobility hub types based on Weustenenk & Mingardo (2023)'s framework

Mobility Hub Types (Weustenenk & Mingardo, 2023)

Community hub: private sites serving a closed user group with shared cars/bikes and almost no public transport or amenities.

Neighbourhood hub: local shared mobility plus a bus or tram stop, modest amenity mix near everyday shops.

Suburban hub: small rail or bus nodes, accessible by car, and with sufficient parking spaces.

City district hub: urban clusters that restrict car access, provide diverse modes (rail, metro, tram, buses, shared mobility) and add retail or parcel services.

City edge hub: park-and-ride sites, supporting transfers from private cars to public transit modes, but with limited on-site services.

City centre hub: major downtown stations where the complete set of modes, highest service density and national-scale connectivity converge.

The classification system suggests what a TOA evaluation matrix should consider regarding the inter-mobility integration dimension. Yet, this typology stays conceptual and descriptive. The evaluation of the quality and complexity of service facilities and transport modes remains undefined. It does not specify thresholds for “high frequency” transit, define how many amenities equal “modest amenities,” or establish the performance levels that triggers a higher tier. For TOA evaluation and classification, the typology is a helpful checklist of mode and service elements to include, but it requires the addition of quantitative benchmarks.

3. Public multi-modal transit demand

Public demand for multimodal transit is strongly shaped by demographics, with some population groups showing a greater tendency to choose travel modes other than private motor vehicles. This is described as the multimodal majority (Buehler & Hamre, 2015). Buehler & Hamre (2015) argue that multimodality is prevalent: about two-thirds of adults drive but also make at least one weekly trip by walking, cycling, or transit. Multinomial-logit models position travellers from “monomodal car” to “car-free” and identify the demographic profiles most likely to sit in the multimodal band: younger adults (16–34), highly educated and higher-income individuals, single-adult households, people living in high-density areas with public transit service, and households with zero or only one car. Other studies hold inconsistent conclusions on how income level influences multi-modal travel behaviour; for example, Huang et al. (2024) argue that socioeconomic effects are heterogeneous: low-income multimodal travellers fall into two groups: “captive” multimodal users who combine modes because they lack a car, and the transport-poverty who travel so little or don’t have access to transit infrastructure and services that they appear non-multimodal.

For TOA evaluation and classification, these findings should form the demand dimension of the matrix. TOAs with high proportions of the “multimodal majority” (younger, educated, small-households, car-free households, or those with strong transit access) warrant higher performance targets for diverse and seamless mode integration. In contrast, areas dominated by households with children or car-dependent demographics signal a need for design measures that lower barriers to shifting some trips away from private vehicles.

INTERVIEW FINDINGS SUMMARY

DRIVERS OF MULTIMODAL TRAVEL DEMAND

Interviewees consistently pointed to a combination of demographic and land-use conditions as the primary forces shaping how people travel within TOAs. Mode choice varies with income, housing tenure, and household characteristics: higher-income residents and homeowners tend to rely on cars, while renters and lower-income households tend to use public transit. High land-use density, along with the concentration of jobs, housing, and daily amenities near transit stations, increases the likelihood that more residents live or work within a convenient distance of the station. This, in turn, makes active transportation modes such as walking and cycling more feasible and attractive for first- and last-mile connections than car use.

Multiple interviewees mentioned that work trips, i.e., commuting, are the dominant trip purpose. In many cases, being able to reach a major station quickly from the workplace matters more than living next to it. They also noted the importance of considering not only today's demographic profile but the projected shifts in population and employment because future demand can look very different from current conditions.

When offices, shops, and services are concentrated within a compact, well-connected street grid, these destinations and public places attract regular visits and activities, boosting higher levels of walking and cycling. Safe, comfortable sidewalks and bike lanes connected to the station entrance further facilitate walking, cycling, and seamless transfers between transit options within TOAs. Additionally, parking supply and pricing policies influence car dependence: both research and practice indicate that reducing parking availability or increasing parking costs are effective strategies for limiting motor vehicle trips.

PLANNING AND DESIGN PRIORITIES

Across the interviews, connectivity emerged as the core consideration for TOA planning and design. The interviews repeatedly highlighted the importance of the short-block layout, frequent crossings, and direct walking and cycling lanes that connect the stations well to the surrounding neighbourhoods, particularly residential areas. The quality of these linkages, for instance, adequate sidewalk width, continuous bike lanes, and supporting facilities, was described as being equal in importance to land-use density. This emphasis exists alongside the focus on building complete streets and neighbourhoods with rich destinations both on and off arterials to ensure everyday services, public spaces, and community amenities keep pace with residential growth.

Vancouver's current policy agenda also emphasizes equity: recent city frameworks and plans, such as the Broadway Plan, seek to expand affordable housing options within walking distance of rapid transit. Universal accessibility, from children to seniors, is now also a headline goal.

Inter-modal connectivity and seamless transfer is another key theme repeatedly mentioned by the interviews. A “same-block” change of mode is identified as ideal, and distances of about 200 m or more already deter transfers. The application of a mobility hub (multiple modes and amenities concentrated within the station block) is noted by an interviewee, but said efforts in Vancouver are still at an early stage, showing the concept is appealing yet challenging to deliver.

Nonetheless, interviewees noted persistent challenges in delivering high-quality public space around stations and achieving advanced integration between station infrastructure and surrounding development parcels.

CHALLENGES AND TRADE-OFFS

Older SkyTrain stations often lack pedestrian and cycling facilities, which are now considered standard, and redeveloping these areas is challenging given the limited space. Space constraints make it difficult to widen sidewalks, insert protected bike lanes, or accommodate additional bus bays without displacing other functions. Full station-area integration, including coordinating private development, public realm, and transit entrances, also remains difficult.

Interviewees also pointed to weak transfers between SkyTrain and surface transit, especially at older stations where bus stops are dispersed along different arterial streets. Seamless transfer and connection to other high-capacity mobility modes, such as integrated transfer hubs, are also relatively lacking, which could hinder intermodal mobility. This makes trip chaining (linking several modes in one journey) called out as under-addressed, and applying a gender-equity lens to these chained trips is still new territory.

Interviewees also highlighted a broader coordination gap between land-use decisions and the timely provision of essential community infrastructure. This realm is largely outside the City's direct control and requires multi-level efforts and decisions. Policy often lags development, which could slow the delivery of new mobility-hub facilities.

INTERNATIONAL REFERENCE POINTS

While interviewees did not identify any single city that excels in every dimension of multimodal integration, they cited several instructive examples. Hong Kong demonstrates exceptionally tight rail-to-rail connectivity, yet long blocks and multi-level routing hinder its pedestrian accessibility. Paris exhibits dense, multimodal coverage but has struggled with accessibility for people with disabilities. Copenhagen offers exemplary cycling networks that feed directly into rail stations. Other cities mentioned, like Sydney, Toronto, and New York, illustrate how multiple station entrances, coordinated service planning, and generous platform space can improve the passenger experience, even if each place still grapples with its own legacy constraints. Auckland was highlighted as a live example of clustering LRT stops on "transit streets" in the city centre.

THE ROLE OF QUANTITATIVE INDICATORS

All interviewees supported the idea of some measurable targets to guide TOA evaluation and monitoring, but also highlighted that flexibility is needed. Population and employment densities, housing tenure mix, mode-share targets, walkability scores, and station ridership volumes are some examples identified as helpful metrics with clear measurements. These different metrics can be set and justified by different data or policy goals. For example, the City's headline goal that two-thirds of all trips be made by active transportation and public transit by 2030 was flagged as a prime driver of project priorities. Another example is that, in practice, pedestrian lane width can be determined by the projected pedestrian flow with a range hierarchy.

Interviewees also suggested additional metrics, for instance, the share of residents within a set distance of high-quality bike lanes, the proportion of the cycling network meeting TransLink's design standard, and safety indicators based on collision data. Interviewees acknowledged, however, that some elements, such as network connectivity or the influence of topography and barriers, are sometimes difficult to quantify and may need case-by-case targets. This was flagged as an important aspect for the TOA evaluation framework to address.

SUMMARY

Taken together, the key messages are:

1) Travel choices in TOAs depend on who lives and works near the station and how closely housing, jobs, and services are grouped.

2) High connectivity, adequate and safe walking and cycling routes, and seamless transfers between mobility modes are ideal for TOA planning and multi-modal integration; however, in practice, planners must deal with tight spaces, existing infrastructure and facilities, and shared decision-making.

3) Multiple interviewees emphasized the need for mobility hubs (short transfer distance), trip-chaining support, and a stronger equity lens.

3) Other cities offer practical one-off examples, not complete models.

4) Simple and straightforward measures such as density, land use mix, and transit ridership can track progress and adjust plans. Street connectivity is flagged as an interesting metric to measure, but is currently missing. Some other factors are either hard to measure or require case-by-case targets, so planners could keep those flexible or use future-proofed approaches.

THE EVALUATION FRAMEWORK

INTRODUCTION

Building on established models and frameworks and integrating insights gathered from expert interviews, the proposed evaluation framework (Figure 8) consists of two components: a **grey box** assesses public demand for multimodal transit, and **a radar chart** evaluates the existing functional characteristics of each TOA. By combining these components, the framework provides a comprehensive understanding of TOA performance and supports systematic classification, with the aggregate result displayed as the **overall rating bar** at the bottom.

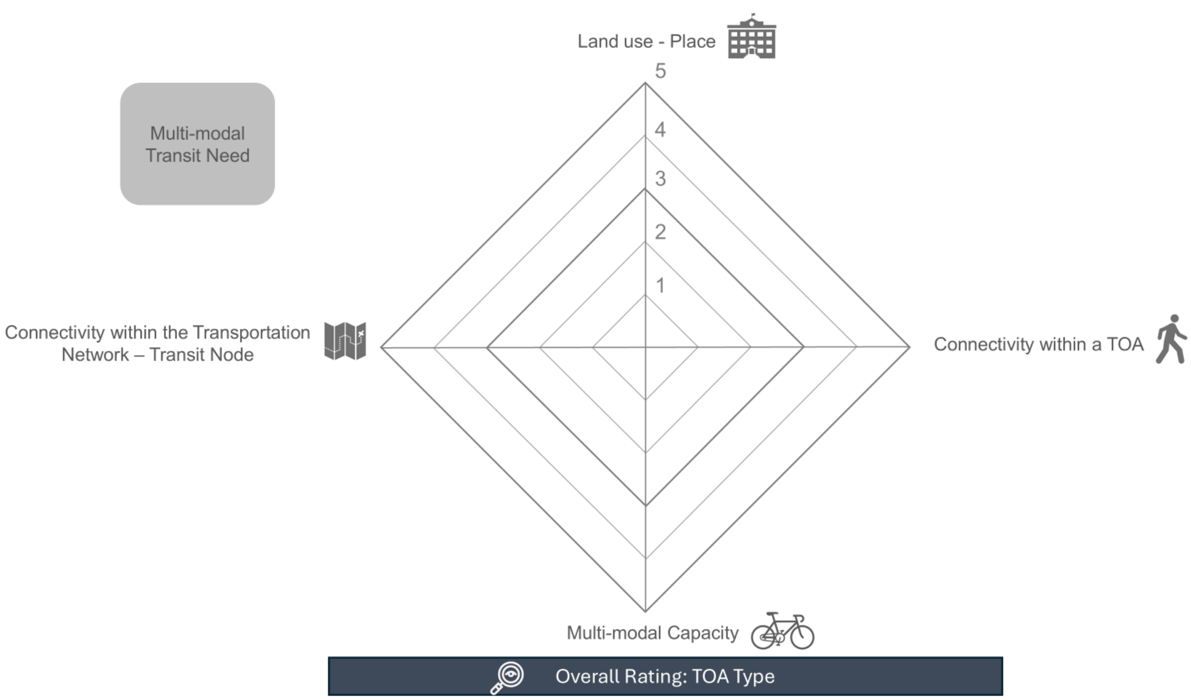


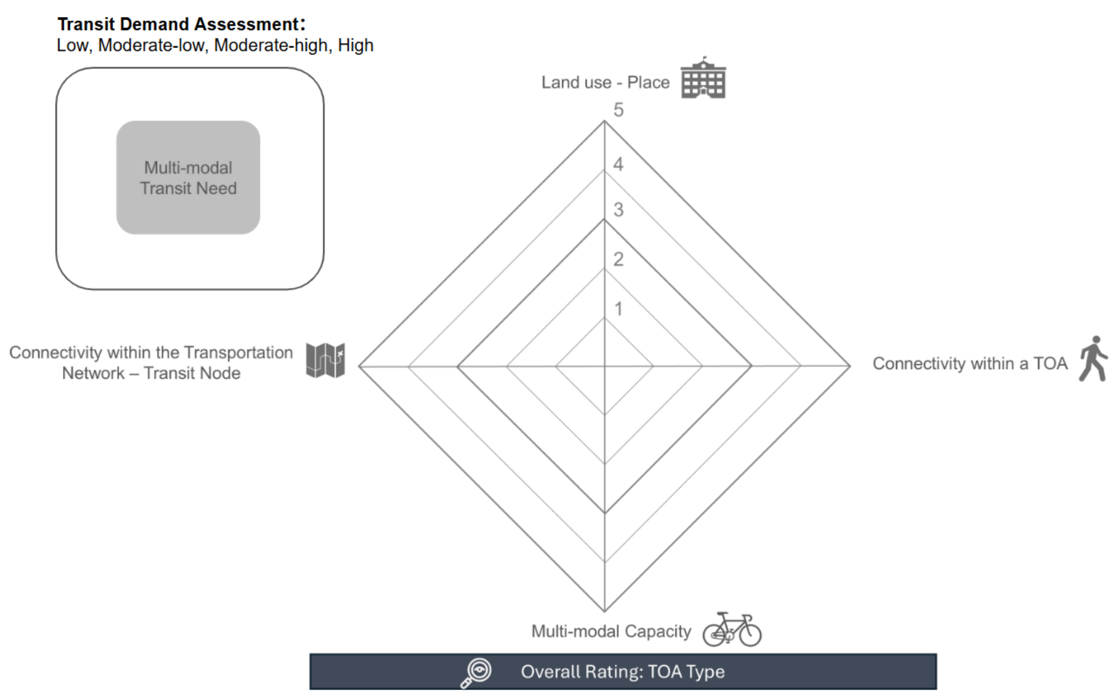
Figure 8 The schematic diagram of the TOA evaluation framework, including the transit demand assessment box, the TOA function radar chart, and the overall rating of the TOA type

Transit Demand

The TOA function primarily addresses planning factors such as land use and transportation infrastructure. In contrast, transit demand focuses on the characteristics and behaviours of people living or working within the area. Demand can be classified as low, moderate-low, moderate-high, or high, based on both demographic characteristics and actual transit demand. While demographic indicators, such as age, household composition, and vehicle ownership, can inform planning, their relationship with multimodal demand varies by context. Direct measures, such as transit ridership and pedestrian counts, could offer the most reliable indication of actual system usage.

TOA Function: the radar chart

An integrated TOA requires functions in land uses, street connectivity, multi-modal infrastructure, and transit services to work as one system. To capture that integrated function, the TOA function evaluation radar examines four complementary dimensions, drawing on the literature and interview results and covering the goals and targets in related policies, including Provincial Policy Manual: Transit-Oriented Areas, TransLink Transit-Oriented Communities Design Guidelines, Transportation 2040, Transportation 2050, BC Active Transportation and Transit-Oriented Development Design Guide. TOA performance can be evaluated independently within each dimension, or the dimensions can be combined to assess overall function



FOUR DIMENSIONS OF TOA FUNCTION RADAR CHART

Land use and place activity measures, commonly including density, land-use mix, diversity, and the presence of daily amenities, suggest that compact, fine-grained mixed-use, and destination-rich neighbourhoods attract people's visits and generate walking and transit trips inside a TOA.

Pedestrian accessibility and TOA internal connectivity show the street configuration aspects, demonstrated by short blocks, high street and intersection density, well-connected and gently sloped of sidewalks and bike lanes, which reduce barriers and support the convenient use of active transportation and public transit.

Multimodal capacity and inter-modal transfer highlight both the infrastructure and facilities for multiple travel modes and the seamless transfers between these modes and public transit.

Transit-node dimension, which considers transit service frequency, network reach, and route diversity, highlights how well the rapid-transit station itself functions and how it connects to the regional transportation network.

Together, these four dimensions ensure the matrix rates a TOA as an integrated area that supports smooth movement between homes and jobs and seamless transfers among multiple modes of travel.

INDICATOR NORMALIZATION AND AGGREGATION

Each evaluation dimension contains several equally weighted indicators. Scores for each indicator are first normalized to a 0-1 scale, where one denotes the most favourable performance and zero the least. The normalized values are then averaged and rescaled to a 0-5 scale. A score of 5 indicates that, for this dimension, all indicators match the highest levels observed across Vancouver's TOAs. This pilot assessment applies only some of the recommended indicators for each dimension because of current data and time constraints. Future assessments can substitute alternative indicators, add new ones as priorities change, and assign different weighting schemes as needed.

THE EVALUATION MATRIX AND METHODOLOGY

TOA CATCHMENT AREA

Provincial Policy Manual: Transit-Oriented Areas, published by the BC Ministry of Transportation and Infrastructure, explicitly defines TOA as all land within 800 m of a SkyTrain or subway station and 400 m of a bus exchange or West Coast Express stop. The literature also commonly applies 400m and 800m catchment areas as representations of a 5-minute and 10-minute walk (Vale et al., 2018). This study follows the definition from the Provincial Policy Manual, applying the straight-line 400 and 800m buffer from the center of the stations[2]. Alternatively, the 400 to 800m buffer can be drawn from the multiple station entrances, resulting in a not-perfect circle of TOA shape (Vale et al., 2018). Another method is drawing the TOA based on inside network accessibility, which is defined as a pedestrian shed (pedshed) of a TOA. In this way, the 400 and 800-meter distance buffer is based on the length of streets and roads extending from the stations. For indicator calculations, only the reachable land within the 400- or 800-metre buffer is counted; any portion over open water or other inaccessible areas is excluded.

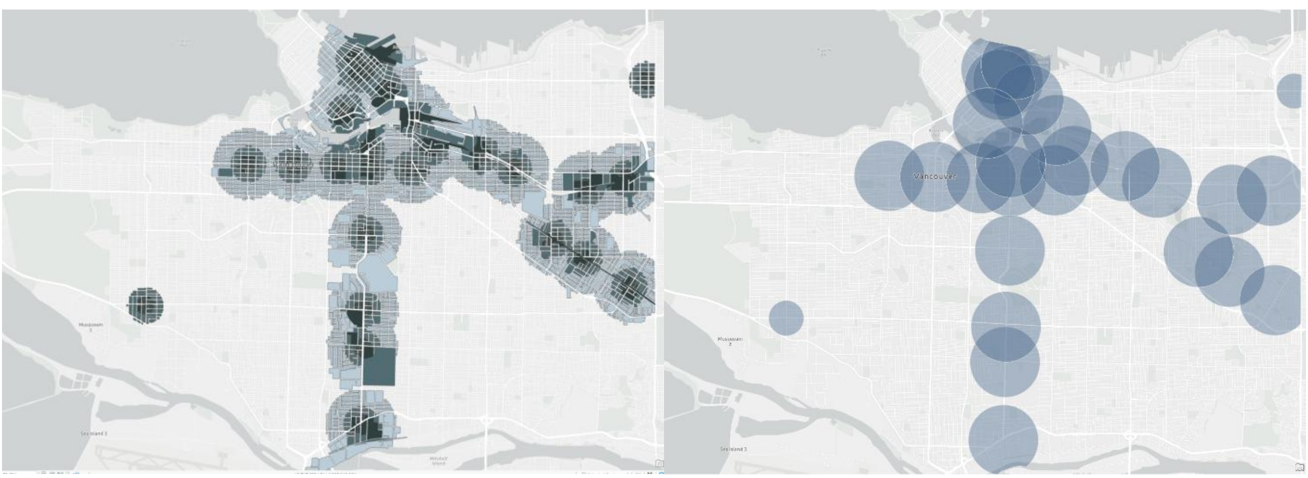


Figure 9 The policy designated area of TOA (the left map) V.S. the analysis unit of this study (the right map)

[2] Note: The current TOA policy area dataset provided by the City consists of a feature class representing a collection of block polygons, which do not include roadways and do not delineate discrete polygons for individual TOAs. As a result, it is not possible to directly analyze each TOA as a single, unified area. For this analysis, each TOA is instead represented by an 800- or 400-meter radius circular buffer centered on the core of the TOA (see Figure 9). If, in the future, dedicated polygon data for each TOA becomes available, it would significantly enhance the precision and effectiveness of subsequent analyses.

LAND-USE AND PLACE ACTIVITY DIMENSION OF A TOA

A balanced mix of land uses, a diversity of destinations, sufficient density, and regulated parking supply are consistently identified in the land use and travel behaviour literature as key factors that promote transit ridership and encourage a shift from private vehicles to active transportation. These findings are further validated by interviews and reflected in city and provincial policy guidance. Incorporating these variables enables the evaluation matrix to assess how effectively each TOA's land-use pattern attracts mode shift and helps to identify areas where zoning adjustments or parking reform should be prioritized.

Land-use mix and diversity

Land-use mix describes the balance or proportion of different major land uses within an area, while diversity refers to the number of distinct destination and place types present.

Land-use mix is used to capture the mixture of basic categories, often including commercial, residential, institutional, office, and other land uses. A higher land-use mix, measured by the entropy index (ranging from 0 to 1), correlates with reduced VMT, and increased walk trips and transit use (Manaugh & Kreider, 2013; Moura et al., 2017). Other indices are discussed in the literature, including the Herfindahl index, the Simpson Diversity Index, and other advanced methods (Bordoloi et al., 2013; Manaugh & Kreider, 2013); however , these improvements mainly address measuring the clustering of different land uses in a relatively large study area, for instance, at the city level. Since the spatial unit of this study is the walking and biking catchment around a transit station, the spatial clustering or dispersion inside this walkable area is negligible.

Recommended Indicators

1) Entropy Index for land-use mix

$$E_j = -\frac{\sum_{i=1}^{N_j} A_{ij} \ln A_{ij}}{\ln N_j}$$

Where:

E_j = Entropy index for TOA j (ranges 0 – 1; higher = greater mix)

A_{ij} = Proportion of land-use class i in TOA j (area of class i ÷ total land area of TOA j)

N_j = Number of distinct land-use classes present in TOA j (count of classes with $A_{ij} > 0$)

Interpretation:

$E_j = 0$: TOA contains a single land-use class (no mix)

$E_j = 1$: land area evenly distributed among all N_j classes (maximum mix)

Natural logarithms are used; dividing by ln N_j rescales the index, so the upper bound is 1 regardless of the number of classes present.

However, the land-use mix index cannot capture the specific mix of places like services, facilities, amenities, and housing types under each main land use category. Reflecting on feedback from city planner interviewees and guided by Transportation 2040, the rich and diverse destinations around major transit stations could largely attract people shifting to public transit and active transportation. This is further evidenced by Moura et al. (2017)'s work and the principle of Complete Street, suggesting that daily commerce and services, meeting places, and other anchor places all contribute to a more walkable community. Other benefits mentioned by TransLink's Transit-Oriented Communities Design Guidelines include reducing peak crowding, spreading travel demand, and creating inclusive housing opportunities and equitable transportation access. Still, the specific services, amenities, and housing types highly depend on local context and vary across neighbourhoods, making the standard quantification and evaluation challenging. Measuring the Z-score of the point of interest (POI) is one of the ways to measure destination diversity, applied by the Canadian Active Living Environment Index (Ross et al., 2018), (POI data extracted from OpenStreetMap). However, the included POIs must be manually filtered based on their relevance to multi-modal transit and active transportation behaviour.

Residential, job, and commercial density

Residential, employment, and commercial density are commonly recognized as the most crucial measurements suggesting a given area's activity levels and transit demand. Interviewees all emphasized that housing and job proximity to rapid transit stations strongly induce active transportation and public transit, which densities could measure. Practically, high density around transit stations indicates the potential for highly efficient public transit usage, which will stimulate the transit market expansion. Moreover, the increasing transit service will, in turn, attract higher transit ridership. For example, TransLink TOD design guidelines refer to a clear benchmark: "every 10% increase in population and employment density results in a 5%–8% increase in transit ridership." Correspondingly, provincial legislation establishes clear policy anchors to guide transit-oriented development by setting minimum density requirements based on geographic location and proximity to transit stations. Grounded in literature, from the TOA performance evaluation perspective, over-dense TOAs with insufficient transit service and oversupplied transit stations with low density both need adjustment to reach equilibrium (Bertolini, 1999). From the travel behaviour alteration perspective, even though high density itself usually cannot flip the mode share, it can amplify the effects of other planning factors that support active transportation and public transit, such as high connectivity and a diverse land use mix (Moura et al., 2017; Vale & Pereira, 2016). In other words, if densities are low, improvements such as better streetscapes, bike lanes, or infrastructure yield only limited shifts away from driving. That being said, when the TOA density thresholds are met, a multimodal network can function effectively, meaningfully boosting sustainable mode share and cutting transport-related emissions.

Recommended Indicators

2) Residential, 3) job, and 4) commercial density

$$\mathrm{RD}_j = \frac{U_j}{A_j}; \quad \mathrm{JD}_j = \frac{J_j}{A_j}; \quad \mathrm{CD}_j = \frac{C_j}{A_j}$$

Where:

RD_j = Residential density in TOA *j* (dwelling units / acre)

JD_j = Job density in TOA *j* (jobs / acre)

CD_j = Commercial density in TOA *j* (commercial establishments / acre)

U_j = Total *dwelling areas* located within TOA *j*

J_j = Total *office area (for employment)* within TOA *j*

C_j = Total *commercial area* within TOA *j*

A_j = Land area of TOA *j* in acres

Note: Alternatively, based on data availability, the commercial density metric can be measured by count of commercial establishments per area, resulting in establishments/acre instead of m²/acre; also, the job/employment density can be measured by number of jobs per area, resulting in jobs per acre instead of m²/acre

Because density is both important and easy to measure, it is suggested to be scored in the evaluation matrix on a 0–1 scale for each of the residential, job, and commercial dimensions based on the relative performance of all TOAs in the City. Alternatively, the score ranges can refer to TransLink's and provincial policy manuals' density thresholds, keeping the evaluation consistent with municipal and regional policies. Unlike land-use diversity, which is hard to measure consistently, density provides a clear, comparable indicator for TOA classification.

Parking availability

Parking availability, location, and price all show significant impact on people's travel behaviour. To encourage multi-modal transit, limiting parking availability and increasing parking rates inside a TOA could make active transportation more convenient than motor vehicle trips. However, providing Park and Ride facilities around major stations (Figure 10) could also increase people's access to rapid transit, increase transit ridership, and reduce vehicle VKT, especially for long and regional trips, which is already adopted as a guideline by TransLink for regional facility planning but is currently missing in the City of Vancouver (Park and Ride Guidelines; TransLink, 2021). In summary, the relationships between parking availability, park-and-ride facilities, and travel behaviour are highly context-dependent and challenging to quantify. As such, these variables are not included in the current pilot TOA classification analysis.

Figure 10 Example of Park and Ride facility (Park and Ride Guidelines; TransLink, 2021)

TOA INTERNAL CONNECTIVITY

Street network connectivity and pedestrian accessibility inside a TOA are essential for multimodal mobility and active transportation. A well-designed, permeable street grid with direct, continuous links minimizes the first- and last-mile gap, making walking and cycling attractive and practical ways to reach transit while expanding the station's effective catchment area. Such a configuration also boosts ridership, supports reliable mode shifts, and enhances network resilience by providing alternative paths for different users. Together, these qualities maximize the mobility benefits of the TOA.

Recommended Indicators

1) Intersection density

$$\mathrm{ID}_j = \frac{RN_j}{A_j}$$

2) Street density

$$\mathrm{SD}_j = \frac{L_j}{A_j}$$

3) Connected-node ratio
(indicator for existence of dead end)

$$\mathrm{CNR}_j = \frac{RN_j}{N_j}$$

4) Link-node ratio
(indicator for network redundancy)

$$\mathrm{LNR}_j = \frac{Lk_j}{N_j}$$

5) Pedratio
(pedestrian shed ratio, indicator for route directness)

$$\mathrm{PS}_j = \frac{A_j^{\mathrm{net}}}{A_j^{\mathrm{buf}}}$$

Where:

ID_j — Intersection Density in TOA *j* (real nodes / m²)
SD_j — Street Density in TOA *j* (metres of street / m²)
CNR_j — Connected-Node Ratio in TOA *j* (0 – 1)
LNR_j — Link-Node Ratio in TOA *j* (dimensionless)
RN_j — Number of *real nodes* (3- or 4-way intersections) inside TOA *j*
PS_j — Pedshed ratio for TOA j (percentage, 0 – 1)
N_j — All nodes (real nodes + dead-ends) in TOA *j*
L_j — Total street length (sum of link lengths) within TOA *j* (m)
Lk_j — Total links (street segments) counted in TOA *j*
A_j — Land area of TOA *j* (m²)
A^{net}_j — Area reachable via the pedestrian network within the chosen walking distance D (m²)
Note: set D to 400 m for a 5-minute walk, 800 m for 10 minutes
A^{buf}_j — Area of the TOA *j* (m²)

Connectivity to the station

High connectivity that shortens the first- and last-mile distance and improves pedestrian convenience promotes active transportation and transit ridership; this has been brought up by multiple interviewees, policy documents, and extensive literature. Many factors play a role in impacting street network connectivity inside a TOA, for instance, block size and length, intersection density, street density (including main street and back lanes), the existence of dead-ends, network redundancy (availability of alternative routes, representing mobility resilience and mode shift availability), and route directness (the percentage by which the actual path exceeds the shortest possible route) (Berrigan et al., 2010; Ellis et al., 2016; Mishra et al., 2012).

The variables used to measure connectivity could be correlated due to similar measurements (Berrigan et al., 2010; Ellis et al., 2016). A variable selection method could be considered before including all the variables in the final evaluation matrix for higher accuracy, efficiency, and matrix interpretability. The variable selection method can be manual selection, for example, block size and length can be partially captured by intersection density and street density, therefore, are not included in the final matrix. The variables can also be selected based on data availability and quality. Other statistical methods could also be applicable, including correlation analysis, Least Absolute Shrinkage and Selection Operator (Lasso), Principal Component Analysis (PCA), etc.

This study applies the manual selection method, including the following measurements: intersection density (the number of 3-way and 4-way intersections from all level of streets including back lanes), street density, connected-node ratio (to assess the existence of dead-ends), link-node ratio (to quantify network redundancy), and pedshed ratio (to quantify route directness).

There are also design elements that could support a greater connectivity of the street network and the neighbourhood to the stations, such as mid-block connectors (breaks in buildings to connect back lanes to main streets) and underground connected pathways.

Sidewalk and bike lane grade

The high slope of sidewalks and bike lanes greatly hinders people's use of active transportation and pedestrian accessibility. Literature suggests that a 1% increase in slope can lead to a 10% decrease in walking attractiveness (Meeder et al., 2017)This is also supported by clear instructions from government policies and planning guidelines, which usually suggest a slope lower than 5 - 8% without additional complementary design elements like railings, ramps, ladder sidewalks, and stairways (BC AT Design guide, 2019).

> **Recommended Indicators**
>
> 6) Terrain Steepness (Contour-Frequency Proxy)
>
> $$\mathrm{TS}_j = \frac{N_{\mathrm{contour}j}}{A_j^{\mathrm{km}^2}}$$
>
> Where:
> TS_j — Terrain-steepness index for TOA j (contour lines per m²)
> $N_{contourj}$ — Total 1 m interval contour lines intersect with all levels of street (including back lanes) in TOA_j
> A_j — Catchment area of TOA j (m²)

The count of contour lines is recommended as the measurement to capture terrain steepness instead of average slope. This method has already been applied in previous research (Rahman, 2022). Compared to average slope, the count of contour lines 1) captures both how often elevation changes occur and how closely they are spaced (areas with more, closely spaced contours are steeper than those with fewer, widely spaced lines); 2) avoids the bias created when complex topography is reduced to a single average-slope value, which can make steep roads appear identical to much gentler ones; and 3) relies on readily available vector contour data, avoiding the need for high-resolution DEM processing while still behaving as an intuitive, scale-free indicator that is negatively associated with observed pedestrian volumes.

MULTIMODAL CAPACITY AND INTER-MODAL TRANSFER

Multi-modal capacity describes how well a TOA hosts different travel modes. The first dimension is multi-modal infrastructure and facilities. Sufficient bike lanes, wide sidewalks, and safe pedestrian crossings provide cyclists and pedestrians with a safe path to the station. Other mobility facilities like shared-mobility docks extend access for people using car-sharing or other micro-mobility.

The second dimension is inter-modal transfer around the station, which reflects the ease with which travellers shift between transport modes in the station area. This dimension is repeatedly emphasized by the interviewee, highlighting the value of ease and seamless transfer for encouraging active transportation. Here, applying a mobility hub can greatly enhance travellers' experiences; however, it requires continued effort, as interviewees noted and based on the current limited existence of mobility hubs in Vancouver. For example, TransLink recently launched a pilot program for a mobility hub in Coquitlam months ago.

Strong infrastructure and smooth transfers work together to support active travel and multimodal transit. Travellers can combine walking, cycling, and transit in one seamless trip. This flexibility reduces car dependence, boosts ridership, and helps the TOA meet its sustainability goals.

Multi-modal Infrastructure and Facility

Available infrastructure and facilities for walking, cycling, and other micromobility modes in a TOA encourage travellers to shift from personal vehicles to multi-modal transit. In the City of Vancouver, more than 50% of trips are made by walking, cycling, and public transit. The City's Transportation 2040 Plan sets a core goal of raising this share to two-thirds by 2040. As the most significant modes of transportation, separate and sufficient walking and biking lanes (as part of the multi-modal network), safe pedestrian crossings, and availability of bus stops are the top essential infrastructure and facilities. As a result, it is recommended that quantitative indicators for these elements be included with equal weight. The provision of other micro-mobility facilities and amenities is also important in providing diverse and convenient first- and last-mile options and further strengthening multi-modal capacity, such as bike docks and storage, bike-share and e-scooter stations. These elements are also brought up in multiple existing policies and guidelines. For example, BC Active Transportation and Transit-Oriented Development Design Guide suggests key design elements, including pedestrian facilities, bicycle facilities, intersections and crossings, end-of-trip facilities, transportation amenities, and other elements less essential for quantification, like wayfinding and trip planning information.

Recommended Indicators

1) Meters of bike lanes and sidewalks per TOA

2) Density of pedestrian crossing per TOA

Note: Currently, the data used for this indicator from City of Vancouver signals "marked and signed crosswalks at unsignalized intersections only. This includes zebra and parallel line crosswalks. It excludes rectangular rapid flashing beacon (RRFB) crosswalks, pedestrian signals, and full signals."

3) Density of bus stops within a TOA

4) Number of modes or density of active transportation facilities and amenities in a TOA

Note: Currently, the data for bike rack is not available; therefore, the analysis applies number of modes for this indicator. The mobility modes include car share, public bike share, personal bike, e-scooter (Lime), and public transit. Therefore, the maximum modes available is five for each TOA.

Transfer between multiple modes and transit lines in a TOA

> **Recommended Indicators**
>
> 5) Number of transferable mobility modes (including the number of bus lines) within a 200-meter buffer around the station

One of the core functions that a TOA provides is seamless transfer between transport modes and transit lines. Interviews with local planners show that passengers prefer transfer distances of one city block or less, while distances of 200 metres or more begin to discourage use. Direct walking and cycling lanes that reach the rapid-transit station also rank as critical features. Existing design guidelines support these findings. TransLink's Transit Passenger Facility Design Guidelines call for clear links among pedestrians, cyclists, taxis, kiss-and-ride zones, and park-and-ride lots. The UK Mobility Hubs Guidance (CoMoUK, 2019) adds demand-responsive minibuses, ride-hailing services, and shared cars and bikes. A detailed quality audit of a mobility hub lies beyond this study. As a practical measure, the number of transport modes available within a 200-metre radius of the station can serve as a straightforward indicator of inter-modal transfer capacity. This measurement is practically applied by the International Association of Public Transport (UITP), interpreted as "the more modes available at an interchange, the higher the level of multimodal integration". Alternative indicators can be used to better capture the transfer quality and ease in the future.

TRANSIT NODE DIMENSION OF A TOA

The transit node dimension rates how well the station moves people and links the TOA to a broader regional transportation network. A strong node is characterized by frequent, reliable service across multiple routes and modes (e.g. bus and SkyTrain), enabling riders to reach a wide range of destinations within predictable travel times. In addition, it maintains direct and time-efficient connections to other high-capacity nodes, ensuring that regional, long-distance journeys remain convenient and competitive with private vehicle travel. This function speaks to the core goal of transit-oriented development: concentrate growth around transit so residents can drive less and travel more by sustainable modes.

Accordingly, key indicators include service frequency, operating-hour span (the average operating hours of buses and Skytrain in Vancouver are very similar and therefore excluded from the matrix), connectivity to other stations and bus stops, and the number of major nodes reachable within a defined travel window, which are elements widely recognized in node-place analysis as measures of node strength (Bertolini, 1999).

Degree centrality is often used to measure how well a node connects to others by counting its edges (bus and Skytrain lines between stops and stations) (Mishra et al., 2012). This measure highlights basic transfer capacity: a station with many lines provides passengers with more transfer options and helps the network manage service disruptions. All bus stops and the

Recommended Indicators

1) Degree Centrality
(Connectivity to other stations and stops in the city's transportation network)

$$DC_j = \frac{\sum_{p \neq j} d_{jp}}{N-1}$$

Where:
DC_j — Degree centrality of station j (including all bus stops and the rapid transit station within a 100-meter radius, counting as a transfer hub) (dimensionless)
d_{jp} — Binary link indicator: 1 if station *j* has a direct transit link to station *p*; 0 otherwise
N — Total number of stations (nodes) in the network
$\Sigma_{(p \neq j)}$ — Summation over every station p except j

Note: Future TOAs are processed as part of the Millennium Line

2) Ability for a long-distance trip measured by the number of other rapid stations accessible within 20 minutes of travel

Note: The number of stops is calculated based on the average speed of the transit lines (40 km/h for the Expo and Millennium Lines; 32 km/h for the Canada Line); 20 minutes of travel allows transfer between rapid transit lines; transfer time between Skytrain lines is assumed to be 8 minutes every transfer

3) Fixed-schedule transit service frequency

$$SF_j = \frac{R_j}{\Delta_h}$$

Where:
SF_j — Average scheduled service frequency in TOA j (runs · h^{-1})
R_j — Total scheduled departures ("runs") by all fixed-route bus and SkyTrain lines whose stops/stations lie inside TOA *j* during each service hour
Δh — every service hour

Note: Bus service frequency is from TransLink General Transit Feed Specification (GTFS) static data; SkyTrain service frequency is calculated as average service frequency for each line from published TransLink SkyTrain Schedule information.

central Skytrain station within a 100-meter radius of the TOA centre are regarded and calculated as a single transit node (i.e., an integrated transfer hub). When a more detailed perspective is necessary, eigenvector centrality could serve as an alternative indicator for transfer potential, emphasizing that connections are not equal. It assigns weights to each link based on the importance of the station at the other end, so links to highly connected stations increase the score more than those to peripheral stops. However, using eigenvector centrality requires data for the entire regional network, not just stations inside the City of Vancouver, to prevent biased results.

Table 2 Table showing the final included factors and measurements across four evaluation dimensions

		Themes	Factors	Indicators/measurements
TOA Function	**Land-use mix and place activity dimension**	**Land use and density**	Land use mix	Entropy index
			level of density	Residential, job (work), and commercial density
	TOA internal connectivity	**Street configuration**	Intersection density	The number of both 3 way and 4 way intersections per unit area in the TOA
			Street density	Total length of all-level streets per TOA
			Existing of dead-ends	Connected-Node Ratio
			Network redundancy	Link-node ratio
			Route directness for pedestrain	Pedshed Ratio
		Topography	Sidewalk and bike lane slope	Contour frequency: total 1-m interval contour lines intersect with all levels of street (including back lanes) per TOA
	Multi-modal capacity and inter-modal transfer capacity	**Multi-modal infrastructure and Facility**	Sidewalk, walkways, and bike lane length	Meters of bike lanes and sidewalks per TOA
			Pedestrian crossing	Density of pedestrian crossing
			Number of bus stations	Density of bus stops
			Provision of micro-mobility facilities (bicycle facilities, bike parking and storage, free-floating escooters)	Number of mode types with exisiting facilities in a TOA
		Transfer between multiple modes and transit lines in a TOA	Connection to multiple modes of transport available around the station (shared mobility, bus, bikes, ebikes, e-scooters)	Number of transferable modes (incuding number of bus lines) within 200 meters buffer around the station
	Transit node dimension	**Public transit service and connectivity with other nodes in the regional transportation network**	Connectivity to other stations outside this TOA (including bus stops)	Degree centrality of each rapid transit station (center of TOA)
			Ability supporting long-distance trip	Number of other rapid staionts within 20 mins of travel
			Service frequency	Average fixed-scheduel service frequency for buses and Skytrain lines of that TOA

MULTI-MODAL TRANSIT DEMAND

The evaluation of the transit demand could be based on two dimensions: the area's current (or future, if it's applied to a future TOA) demographic profile and its observed (or forecasted) travel volumes. Qualitative categorization and expert elicitation are alternatives if detailed data are not available. For example, one may draw on local expert knowledge about the TOA or apply the service categories defined by TransLink, which align with its 6D assessment framework and ridership levels.

> **Recommended Indicators**
>
> 1) Passenger frequency measured by transit ridership, the minimum average passenger demand/revenue hour for each bus line and Skytrain line in a TOA
>
> 2) Pedestrian flow for walking and biking measured by minimum average pedestrian demand/hour for each walking and biking lane in a TOA
>
> 3) Percentage of 65+ years old adults
>
> 4) Percentage of 16 to 30-year-old residents
>
> 5) Percentage of households that don't have personal vehicles
>
> 6) Percentage of population with college and university degrees
>
> 7) Percentage of Households without children
>
> 8) Percentage of tenancy for residential housing

Passenger boardings on bus and SkyTrain routes, along with pedestrian and bicycle flow, provide a direct measure of current or expected demand. For this study (as a demonstration of the evaluation framework), average public transit ridership is the only indicator used to measure transit demand. Based on population quartiles, ridership is categorized into high, moderate-high, moderate-low, and low, resulting in each category containing a similar number of TOAs (around 7 in the current Vancouver context).

In future steps, demographic characteristics can refine the planning directions and guide design choices. Younger residents, smaller households, people with higher education, and households without cars tend to combine several modes in a single trip and use active transportation or transit options more often (Buehler & Hamre, 2015). Interview findings indicate that renters follow the same pattern: tenancy is typically linked to higher multimodal and transit use than owner-occupancy.

The effects of income level are more heterogeneous based on vehicle ownership and proximity to transportation services and infrastructure (Huang et al., 2024). The basic mechanisms are 1) a multi-modal pattern is necessary for low-income people without personal vehicles, and 2) some low-income populations are not associated with multi-modal travel since they live in remote areas and don't have access to public transit services. Since we measure transit demand in TOAs, the assumption is that all residents in TOAs have access to basic transit service, so vehicle ownership stands out as the most consistent demographic indicator of demand.

Identifying and mapping these demographic factors helps planners tailor infrastructure and policies that both serve existing riders and encourage further shifts toward active and transit modes.

EVALUATION OF TOA PERFORMANCE

EXAMPLE RESULT FOR SINGLE INDICATOR

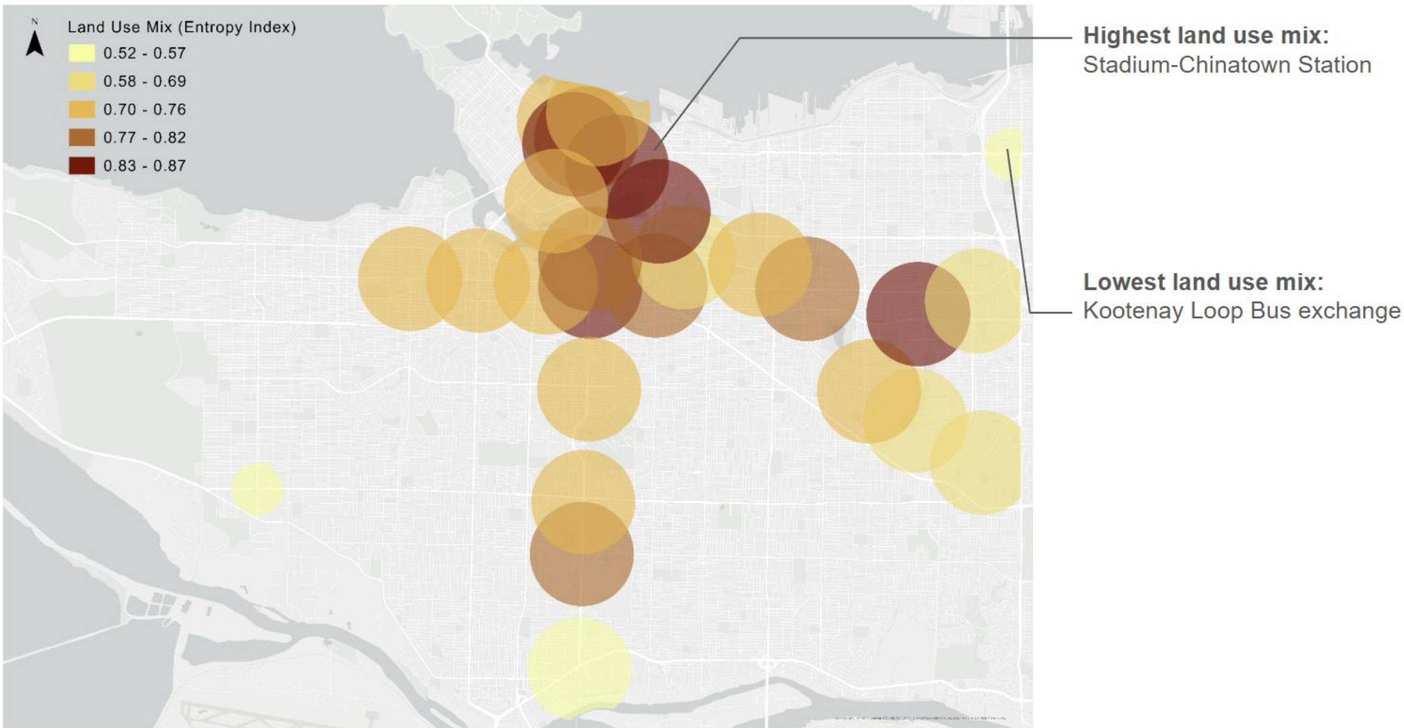


Figure 11 Map for Land Use Mix Measured by Entropy Index: higher value shows higher mix

Summary

Indicators can reveal distinct levels of performance across different TOAs. Figure 11 presents an illustrative map of a single indicator, land use mix, measured by the entropy index. Currently, the Stadium-Chinatown Station has the highest mixed-use land, while the Kootenay Loop bus exchange has the lowest level of mixed-use land. It is important to note that a TOA could have high performance for one indicator while low performance on others. Therefore, having a high value for one indicator does not always result in a high score for the whole dimension and vice versa.

PERFORMANCE OF TOA INTERNAL CONNECTIVITY

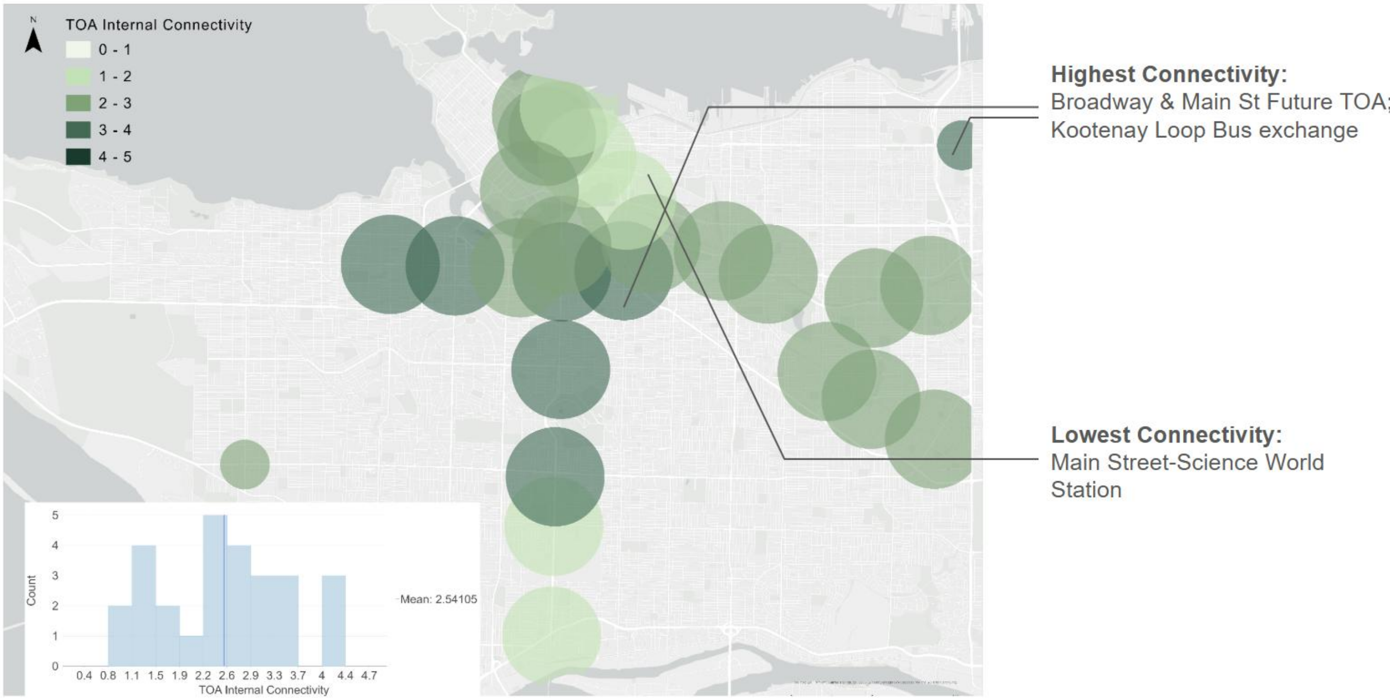
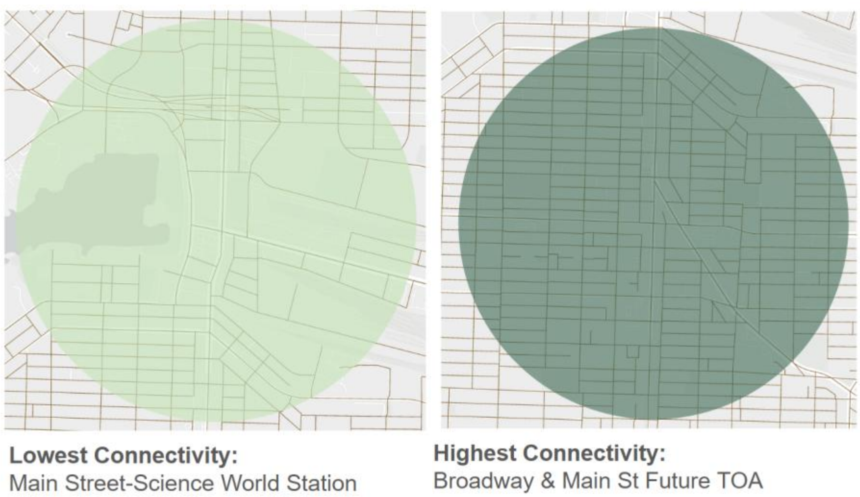


Figure 12 Maps for TOA connectivity performance and statistical distribution: higher value shows higher connectivity



Summary

The Kootenay Loop bus exchange has the highest street connectivity within its TOA, while Main Street-Science World Station has the lowest connectivity. This could be observed and explained by the low street density and intersection density, as well as the smaller pedestrian walkable shed with the same walking distance, given the less direct street configuration. It also partially reflects the reduced connectivity brought by the large open area (False Creek) and large blocks.

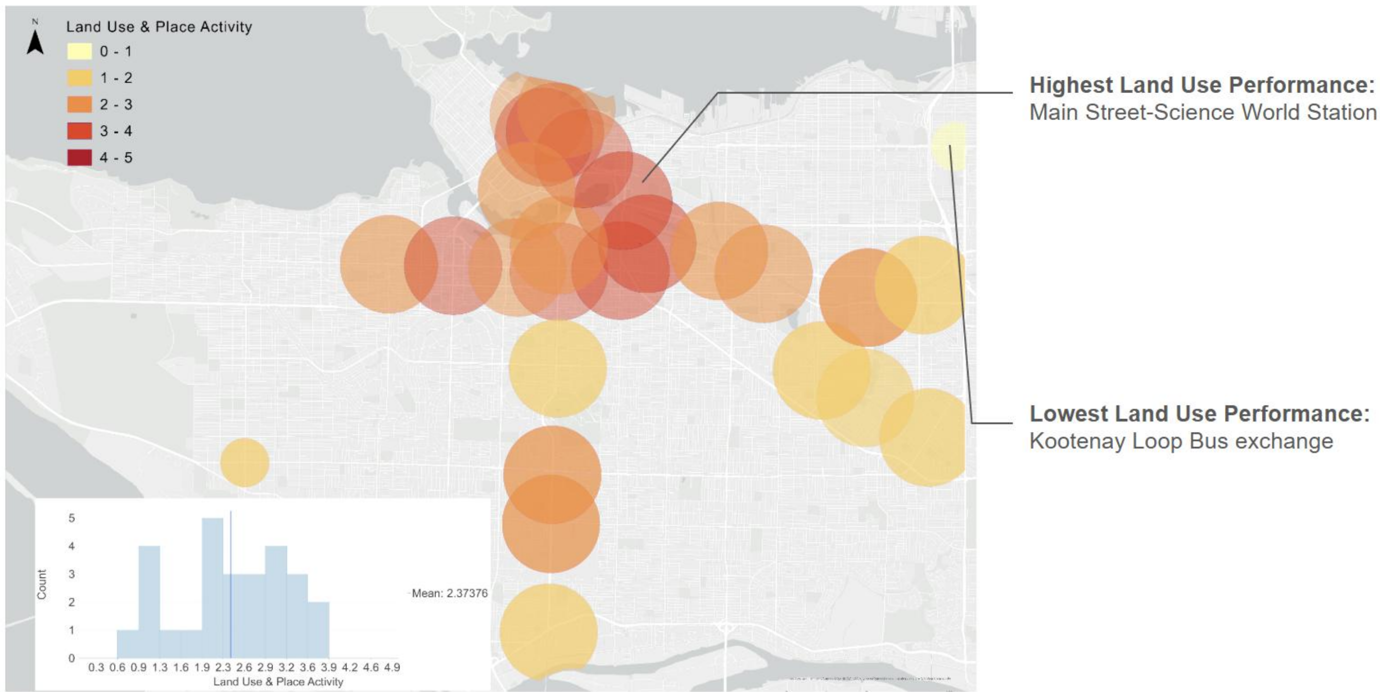


Figure 13 Map for TOA Land-use performance and statistical distribution: higher value shows higher land use level

Summary

For land use and place activity performance, Main Street–Science World Station has the highest performance, with a high level of land use mix and high commercial and office densities. In comparison, the Kootenay Loop bus exchange has the lowest performance, as most blocks are designated for residential use. A higher land use mix and place activity usually bring a higher use of public transit and active transportation; however, an indicator of land use diversity, measuring the points of interest and destinations that actually attract different types and numbers of visitors, could better capture how the TOA could support passengers and pedestrians' daily activities. Since this indicator is missing in the current analysis, the results could be less robust.

PERFORMANCE OF TOA MULTI-MODAL CAPACITY

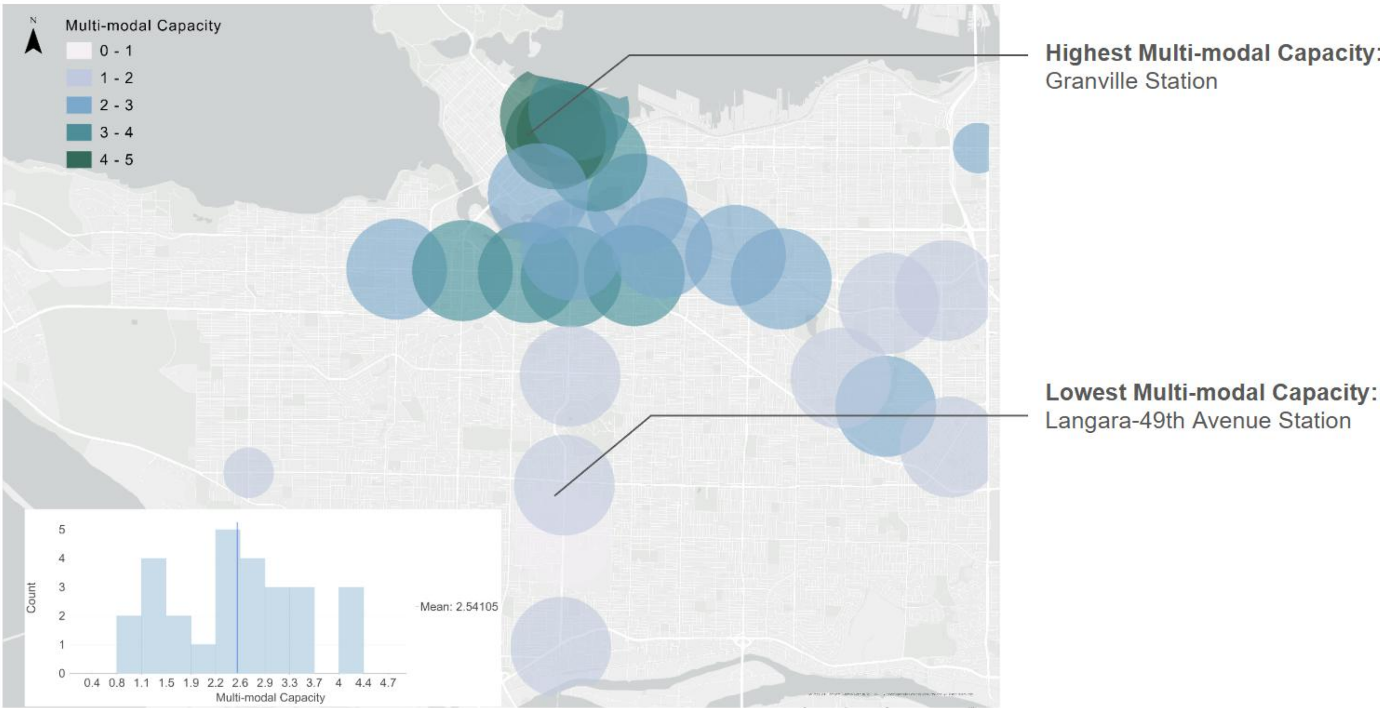


Figure 14 Map for TOA multi-modal capacity and statistical distribution: higher value shows higher multi-modal capacity

Summary

Granville Station demonstrates the highest level of multi-modal capacity, characterized by extensive sidewalks and bike lanes, a high density of bus stops, and a diverse range of modes available within an ideal transfer distance. In contrast, Langara-49th Avenue Station has the lowest multi-modal capacity, with fewer active transportation facilities, amenities, and bus stops. Due to the unavailability of geospatial data on bike racks, analysis of this dimension is limited to the number of available modes, rather than the density of facilities and amenities.

PERFORMANCE OF TOA TRANSIT NODE DIMENSION

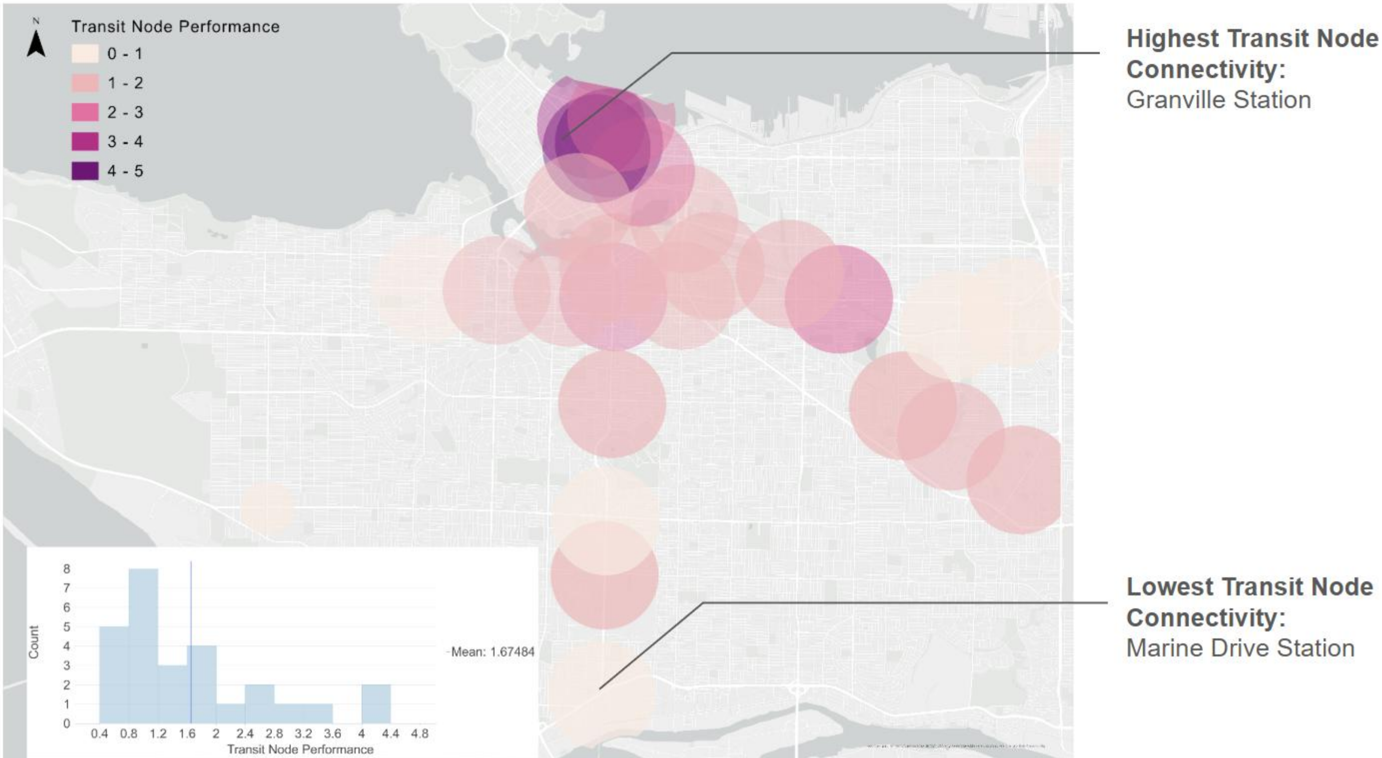


Figure 15 Map for TOA transit node performance and statistical distribution: higher value shows higher performance

Summary

Granville Station shows the highest connectivity as a transit node in Vancouver's public transportation network, with the greatest number of bus and rapid transit lines intersecting at this location. Although the Marine Drive Station has the lowest score for this dimension, it only demonstrates the relatively few connections within the transportation network in the City of Vancouver. However, Marine Drive Station serves as a key transit node linking to Richmond; if the analysis extends to the broader Metro Vancouver region, its performance would be considerably higher. This limitation applies to all TOAs situated at the city's boundaries with other municipalities.

MAP FOR TRANSIT DEMAND

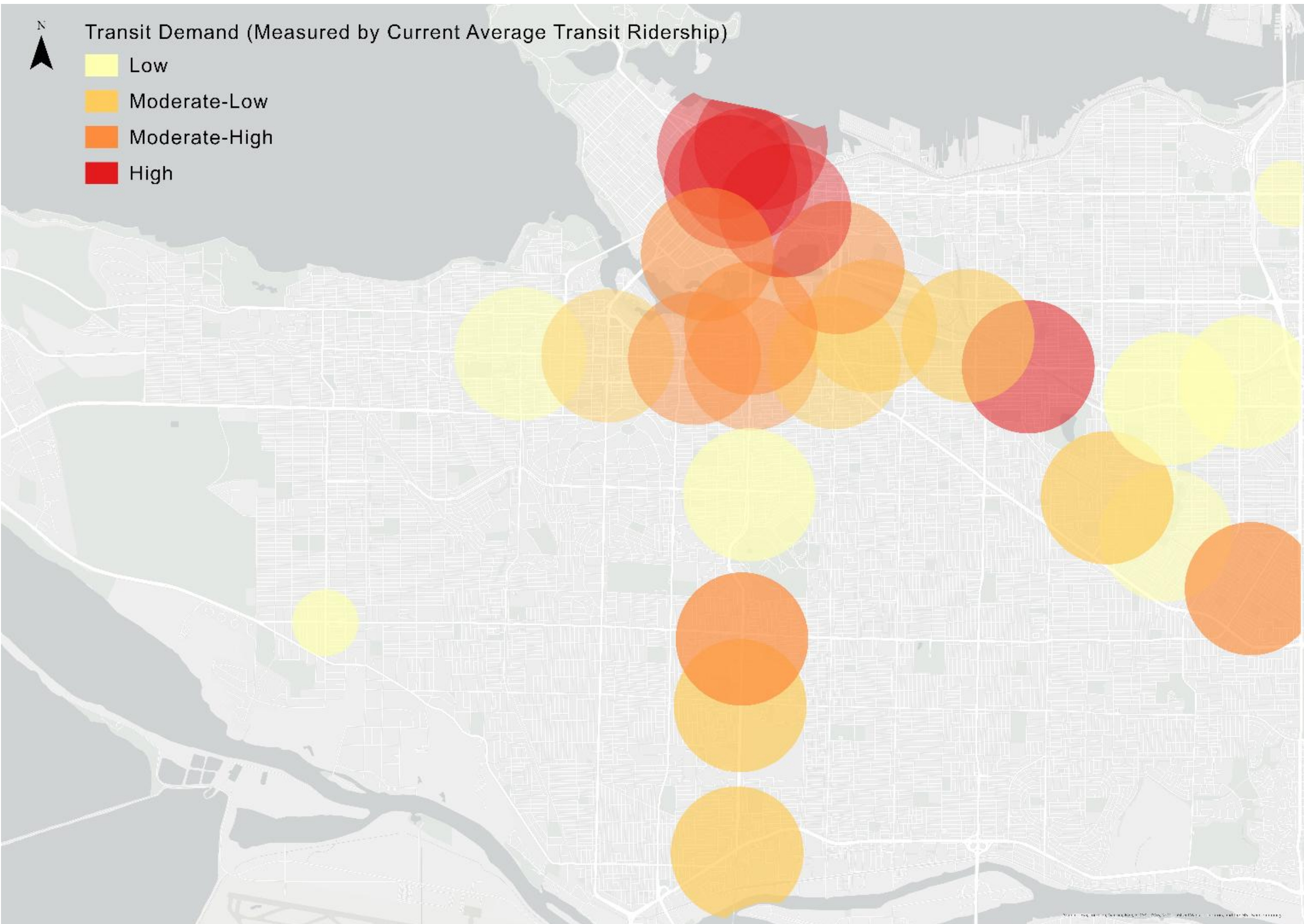


Figure 16 Map showing TOA transit demand, measured by the current average transit ridership

Summary

Transit demand, as measured by average public transit ridership, is highest and most clustered in TOAs located in Vancouver's downtown area. However, because transit demand and active transportation tendencies are influenced by a wide range of complex factors (e.g., socioeconomic status and demographic characteristics), and due to significant overlap among downtown TOAs, these results may be subject to bias. Nevertheless, this analysis demonstrates how transit demand can be integrated into the evaluation framework.

THE OVERALL TOA FUNCTION EVALUATION

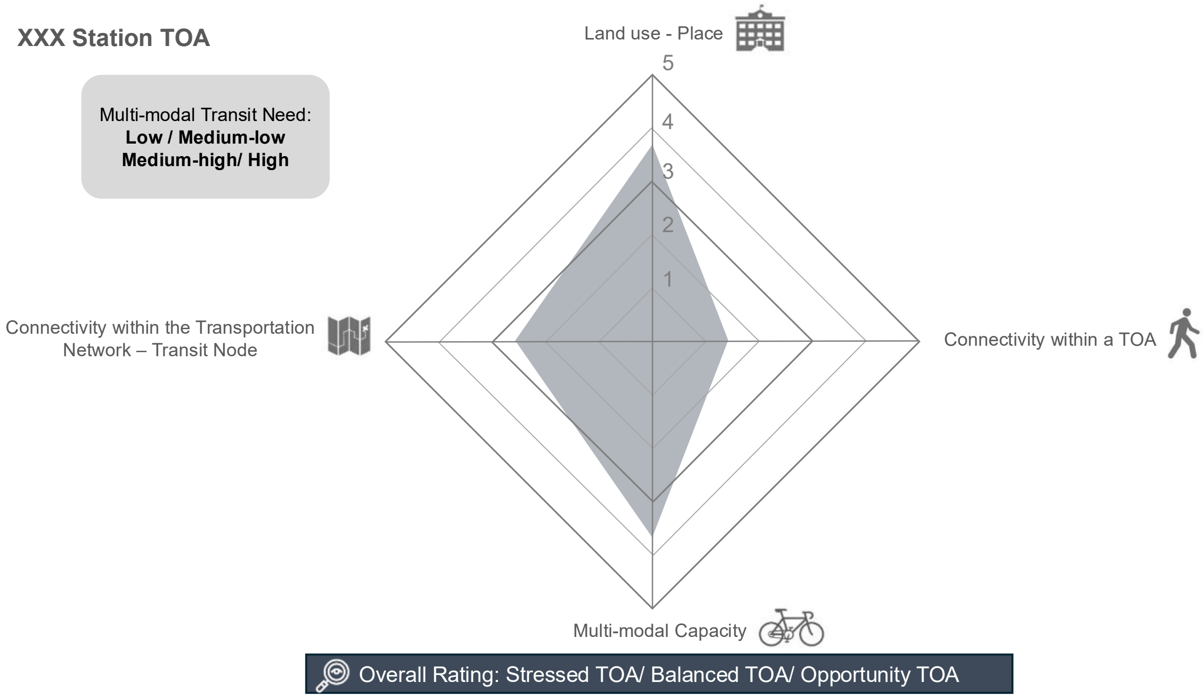


Figure 17 The proposed TOA evaluation template

With each dimension scored from 0 to 5 and transit demand assessed from low to high, this framework enables the identification of gaps and disconnects between transit demand and the TOA function, supporting performance assessment and classification. For instance, some areas may have substantial infrastructure in place but low user demand, while others may demonstrate strong demand for public transit and active transportation but lack sufficient facilities or services (see the above figure as an example). Based on the evaluation results, both existing and future TOAs in Vancouver can be classified into distinct types, with tailored recommendations provided for each category.

Basic TOA Types

Based on the relative performance between transit need and TOA function, each Transit-Oriented Area in Vancouver can be classified as a **Stressed TOA, Balanced TOA, or Opportunity TOA**.

Stressed TOA

A stressed TOA is characterized by transit demand that exceeds the relative baseline of existing function, indicating the need to strengthen TOA infrastructure and services.

Balanced TOA

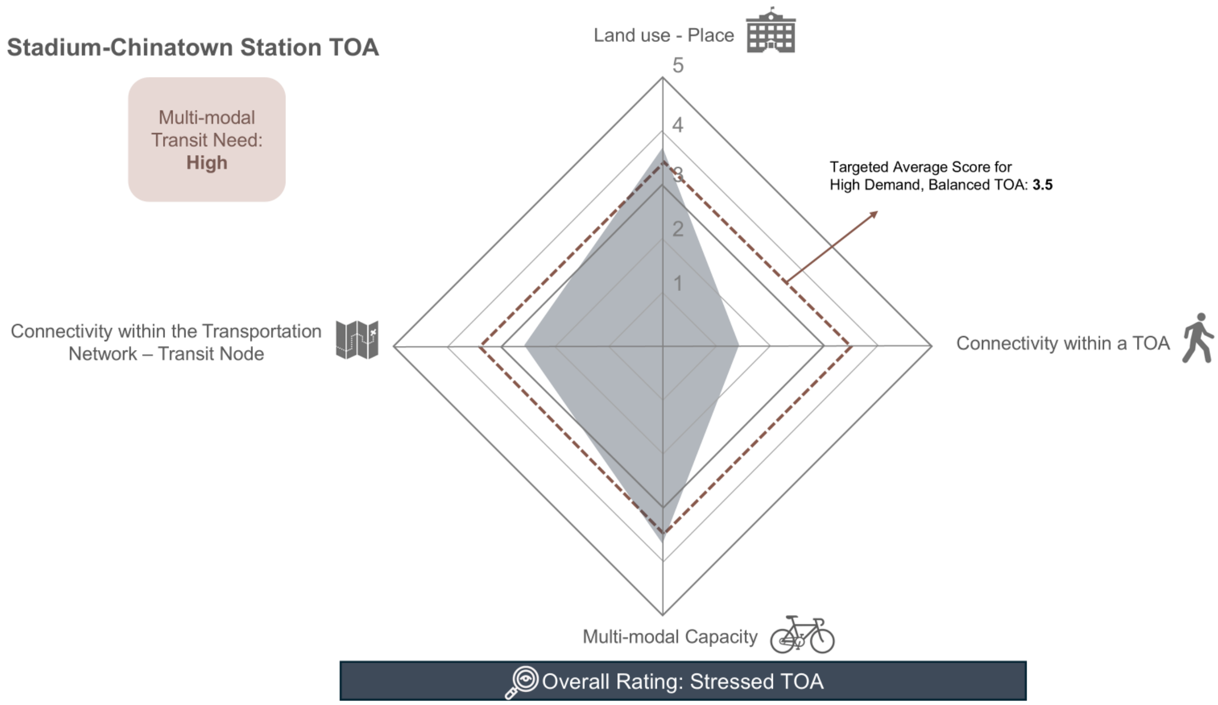
A balanced TOA is where transit needs and function are well-aligned.

Opportunity TOA

An opportunity TOA is defined by lower demand relative to function, representing areas where there is potential to further promote active transportation and public transit usage.

Drawing on the results for each dimension shown in the previous section, the three stations below each represent one of the three typical forms, illustrating the evaluation and classification process.

Example of a Stressed TOA



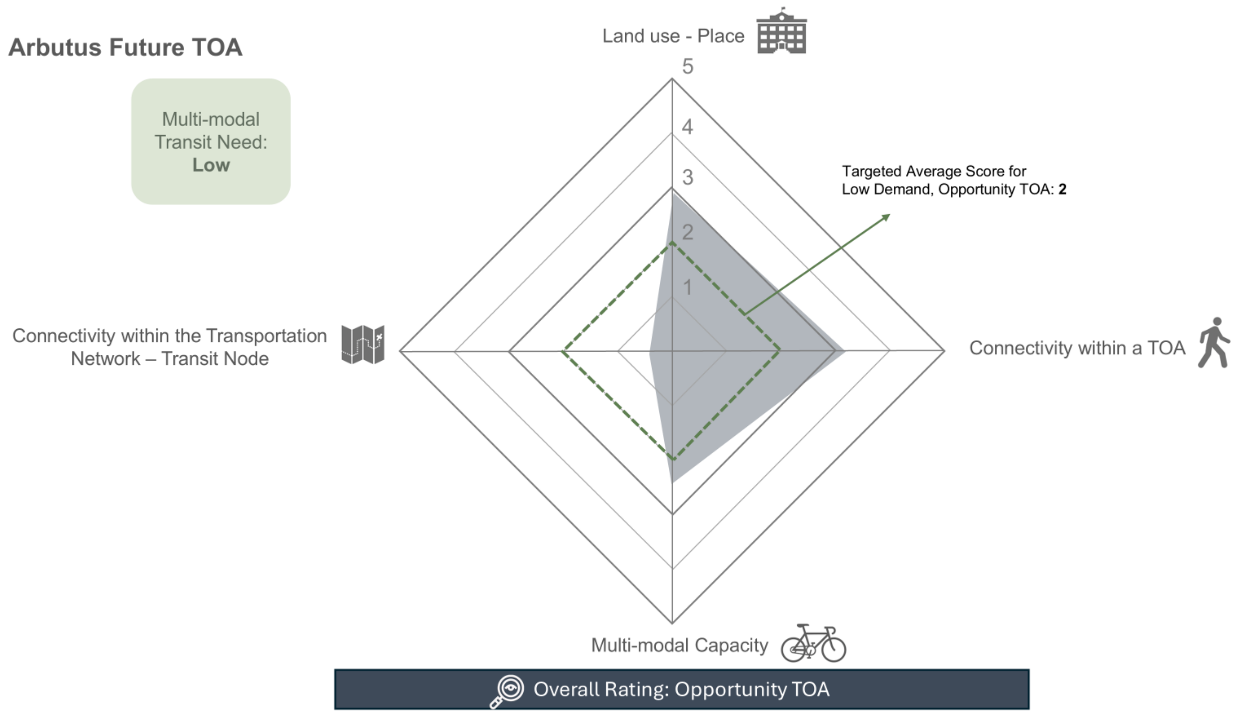
Description

Given the high level of multi-modal transit demand, the Stadium-Chinatown Station TOA is suggested to have an overall average score of 3.5 across the four evaluation dimensions. However, both TOA connectivity and transit node dimensions fall below this benchmark, and the performance of the multi-modal capacity dimension remains well below the optimal level.

Takeaway

- Stadium-Chinatown Station TOA is classified as a **Stressed TOA.**
- The largest gaps are in **TOA internal connectivity** and the **transit node dimension** (below the benchmark); **multi-modal capacity** is below optimal but secondary in urgency.
- **Overall**, improvements to infrastructure and service levels are required to meet current demand.

Example of an Opportunity TOA



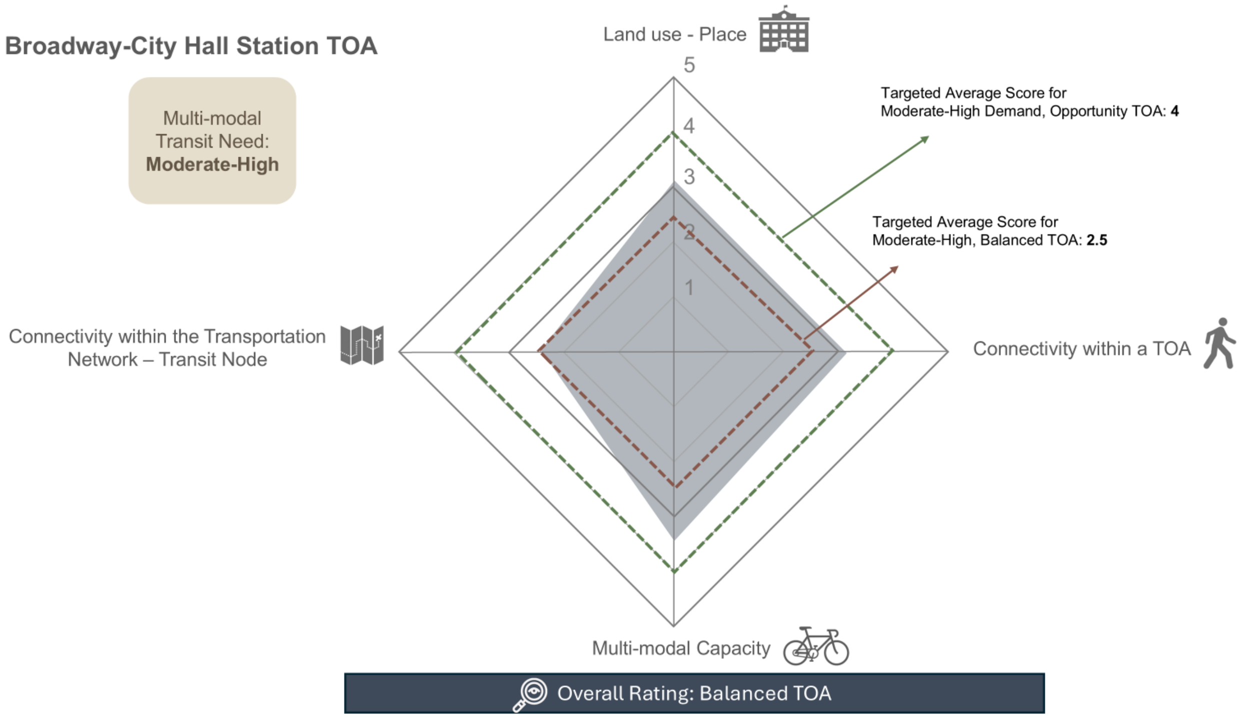
Description

Arbutus Future TOA is currently assessed as having low transit demand. While an overall average score of 2 is suggested as the benchmark for identifying Opportunity TOAs, the scores for land use, TOA connectivity, and multi-modal capacity at the Arbutus TOA result in an overall performance that exceeds this benchmark.

Takeaway

- Arbutus Future TOA is classified as an **Opportunity TOA**.
- Performance in **land use**, **TOA internal connectivity**, and **multi-modal capacity** exceeds the demand-based benchmark (overall score > 2).
- **Overall,** increased use of active transportation and public transit should be encouraged to better utilize existing infrastructure and services.

Example of a Balanced TOA



Description

The benchmark for a balanced TOA with moderate to high demand is an overall average score between 2.5 and 4. An average score below 2.5 indicates a stressed TOA, while a score above 4 identifies an opportunity TOA. The Broadway–City Hall Station TOA has scores that fall within the 2.5 to 4 range across all four dimensions.

Takeaway

- Broadway–City Hall Station TOA is classified as a **Balanced TOA**.
- Scores across **land use**, **TOA internal connectivity**, **multi-modal capacity**, and **transit node** fall within the 2.5–4 benchmark for moderate to high demand, indicating alignment between demand and function.
- **Overall**, multi-modal transit demand aligns with existing infrastructure and services; no urgent interventions are needed. Performance should be maintained through ongoing monitoring, with opportunity-driven improvements.

The Summary TOA evaluation Table

Table 3 The overall evaluation table and proposed TOA classification benchmark

TOA ID	Land use - Place	Connectivity within TOA	Multi-modal Capacity	Transit Node	Average Score	Transit Demand	TOA Type
Dunbar Loop Bus Exchange	1.03	2.27	1.06	0.87	1.31	Low	Balanced TOA
Kootenay Loop Bus Exchange	0.60	3.49	2.34	0.84	1.82	Low	Balanced TOA
29th Avenue Station	1.17	2.84	2.42	1.16	1.90	Low	Balanced TOA
Broadway-City Hall Station	3.08	3.25	3.45	2.52	3.08	Moderate-high	Balanced TOA
Burrard Station	2.38	2.36	4.31	3.32	3.09	High	Stressed TOA
Commercial-Broadway Station	2.13	2.65	2.65	2.28	2.43	High	Stressed TOA
Future Arbutus Station	2.98	3.24	2.45	0.55	2.30	Low	Opportunity TOA
Future South Granville Station	3.02	3.10	3.25	1.46	2.71	Moderate-low	Balanced TOA
Future Oak-VGH Station	2.42	2.57	3.10	1.23	2.33	Moderate-high	Balanced TOA
Future Mount Pleasant Station	3.33	3.44	3.12	1.84	2.93	Moderate-low	Balanced TOA
Future Great Northern Way-Emily Carr Station	3.50	2.43	2.73	1.22	2.47	Moderate-low	Balanced TOA
Granville Station	3.16	2.21	4.38	4.38	3.53	High	Balanced TOA
Joyce-Collingwood Station	1.14	2.81	1.89	1.04	1.72	Moderate-high	Stressed TOA
King Edward Station	1.69	3.04	1.81	1.30	1.96	Low	Balanced TOA
Langara-49th Avenue Station	2.09	1.94	0.79	1.16	1.49	Moderate-low	Stressed TOA
Main Street-Science World Station	3.91	1.58	2.86	1.72	2.52	Moderate-high	Balanced TOA
Marine Drive Station	1.23	1.67	1.17	0.44	1.13	Moderate-low	Stressed TOA
Nanaimo Station	1.30	2.38	1.70	1.08	1.61	Moderate-low	Balanced TOA
Oakridge-41st Avenue Station	2.17	3.15	1.42	0.74	1.87	Moderate-high	Stressed TOA
Olympic Village Station	2.62	2.34	2.74	1.91	2.40	Moderate-high	Stressed TOA
Renfrew Station	2.45	2.64	1.31	0.78	1.79	Low	Balanced TOA
Rupert Station	1.94	2.15	1.29	0.71	1.52	Low	Balanced TOA
Stadium-Chinatown Station	3.71	1.60	3.61	2.73	2.91	High	Stressed TOA
Vancouver City Centre Station	3.56	2.58	4.23	4.27	3.66	High	Balanced TOA
VCC-Clark Station	2.72	2.26	2.40	1.12	2.13	Moderate-low	Balanced TOA
Waterfront Station	2.13	1.89	3.57	2.86	2.61	High	Stressed TOA
Yaletown-Roundhouse Station	2.64	2.33	2.57	1.70	2.31	Moderate-high	Stressed TOA

Balanced TOA	
Transit Demand	Average Score
Low	0.5 - 2
Moderate-low	1.5 - 3
Moderate-high	2.5 - 4
High	3.5 - 5

Stressed TOA	
Transit Demand	Average Score
Low	≤ 0.5
Moderate-low	≤ 1.5
Moderate-high	≤ 2.5
High	≤ 3.5

Opportunity TOA	
Transit Demand	Average Score
Low	≥ 2
Moderate-low	≥ 3
Moderate-high	≥ 4
High	-

Summary for TOA evaluation and classification

The final evaluation table presents scores for each dimension across all TOAs, along with the final average score and the corresponding TOA type. Maximum and minimum values in each column are highlighted in bold green and red frames, respectively. The three TOA types, Balanced TOA, Stressed TOA, and Opportunity TOA, are defined by the range of average scores and levels of transit demand (see the **demand-based benchmarks** below the main table).

A score of 5 in any dimension represents the highest performance of all indicators among all TOAs in the city for that dimension, while a score of 0 indicates the lowest. No TOA in this evaluation achieves an extreme value of 5 or 0, and most scores cluster around the middle range. This demonstrates that disparities between TOAs are not significant, but improvement opportunities remain for all areas.

According to this evaluation framework, the majority of Vancouver's TOAs are identified as either Balanced TOAs or Stressed TOAs, highlighting clear opportunities for planning and design interventions. Only one TOA, the future Arbutus Station, is classified as an opportunity TOA, suggesting a need for further promotion of active transportation and public transit use to make efficient use of existing infrastructure and facilities. Most high and moderate-high demand TOAs are classified as Stressed TOAs, indicating that urgent improvements are needed to meet user demand.

STADIUM-CHINATOWN STATION TOA DEEP DIVE:
Framework-based Planning & Design Recommendations

The purpose of this pilot project in the section is to demonstrate how the evaluation framework and matrix translate into planning and design recommendations for a stressed TOA, using the Stadium–Chinatown Station area as a case study. The intent is not to produce a complete station-area plan, but to show a replicable method for guiding TOA planning and improvement.

Recommendation Screening Approach

1. Drawing on scores across the four TOA function dimensions and the transit demand assessment, the matrix pinpoints gaps between need and function and highlights components falling below demand-based benchmarks.
2. While recognizing some actions could address an entire dimension, the matrix aims to identify the lowest-scoring indicators within a dimension to target the most cost-effective interventions.
3. Addressing each lowest-scoring indicator, recommendations are organized in a three-level pyramid (Figure 18) from the most basic mobility need to higher-order needs, including basic mobility infrastructure, safety measures, and comfort enhancements.

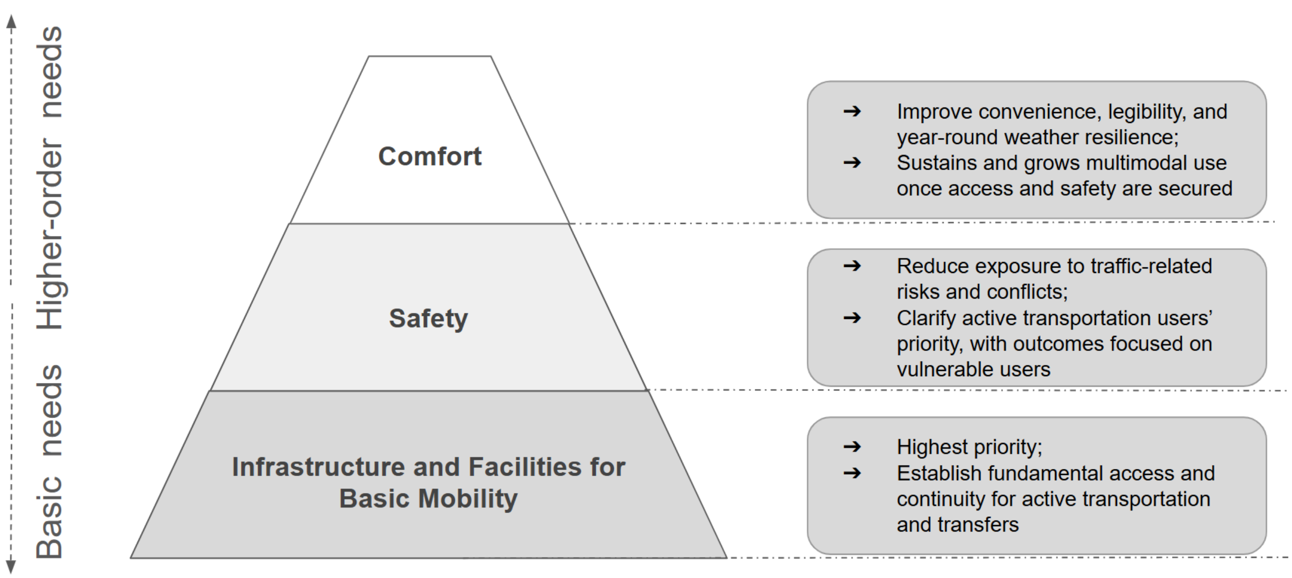


Figure 18 The three-level recommendation pyramid

CASE STUDY TOA EVALUATION

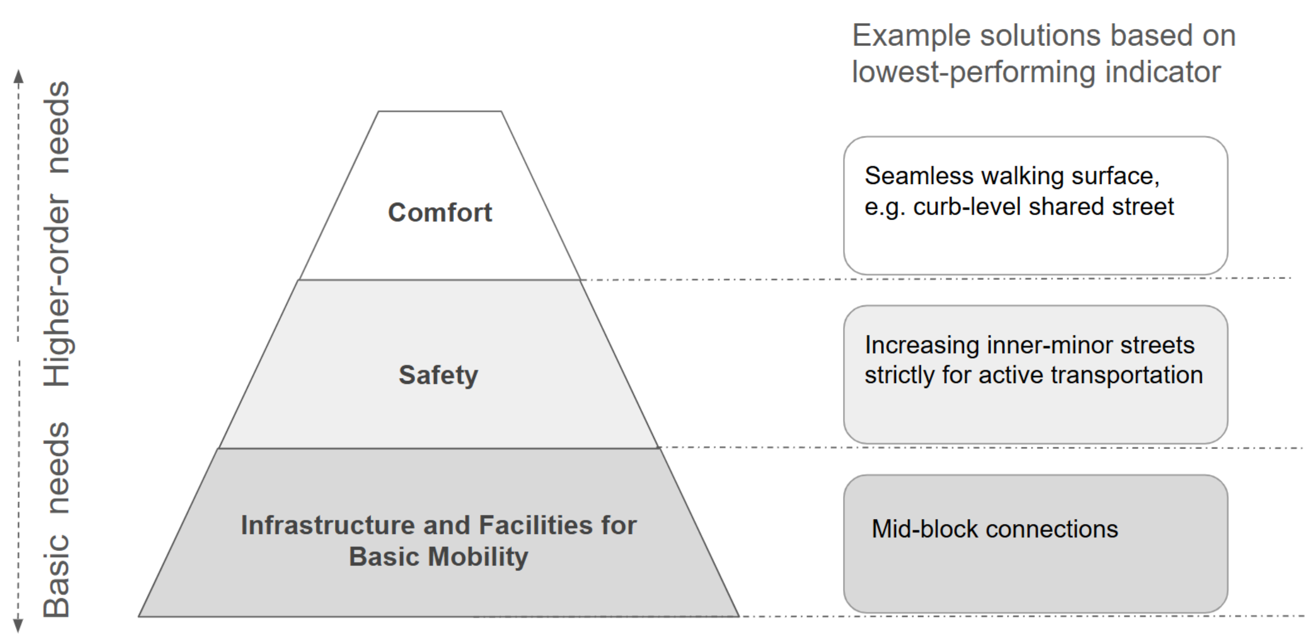
The evaluated scores for the Stadium–Chinatown Station TOA are as follows: 3.71 for the land use and place activity dimension, 1.60 for TOA internal connectivity, 3.61 for multi-modal capacity, and 2.73 for the transit node dimension. Compared to the overall average benchmark of 3.5, **TOA internal connectivity** and the **transit node dimension** reveal clear gaps, while **multi-modal capacity** also shows room for improvement relative to the maximum score in this dimension (4.38 at Granville Station TOA).

To identify the most effective interventions using the proposed framework, the lowest-performing indicators within each dimension should be prioritized. In this case, **route directness for TOA internal connectivity**, **number of transfer modes for multi-modal capacity**, and **connectivity with other bus stops and transit stations for the transit node dimension** are key targets. Planning and design recommendations are provided for the first two indicators, based on a three-level recommendation pyramid. The recommendations presented are not intended to be exhaustive but rather serve as an illustration of how recommendations can be systematically developed using the proposed framework.

RECOMMENDATIONS FOR TOA INTERNAL CONNECTIVITY

Targeted Dimension: TOA Internal Connectivity

Targeted Lowest-performing Indicator: Route Directness



Core Consideration: Infrastructure and Facilities for Basic Mobility

Recommendation: Mid-block Connection

Introducing mid-block connections can significantly enhance route directness within a TOA, especially for pedestrians and micro-mobility users. For example, converting existing laneways into pedestrian-friendly links leverages the existing context and offers a low-cost, easily implementable solution. In future planning, particularly for new corridor or TOA area plans, incorporating mid-block connections as a standard design guideline for parcel organization is recommended.

Precedents

Montreal's Ruelle Verte ("Green Alleys") Program

Image source: City of Montreal

Image source: Valérie Vincent

Since 1997, Montreal has officially designated and funded over 350 green alleyways (by 2019) as pedestrian-only corridors with landscaping, seating, and public art. These "ruelles vertes" provide quieter, greener midblock routes that link neighbourhoods directly to nearby Métro stations such as Mont Royal and Berri UQAM.

Content source: City of Montreal (2020) and The Main (2024)

Vancouver's "Awesome Alleys" Transformation

In 2024, Vancouver released its Downtown Laneway Transformation Strategy, targeting pedestrian corridors along primary routes (e.g., Granville Mall and Hornby Street) for public realm upgrades. Enhanced lighting, paving, and signage now link these midblock alleys seamlessly to bus corridors, SkyTrain entrances, and existing public realms, boosting Downtown Vancouver walkability and connectivity.

Content source: Downtown Van (2024)

Core Consideration: Safety for micro-mobility users

Recommendation: Increasing Inner-minor Streets Strictly for Active Transportation

Designating inner-minor streets strictly for active transportation can substantially enhance connectivity within a TOA and improve safety for pedestrians and micro-mobility users. By restricting automobile access, through-traffic is shifted to perimeter roads, keeping neighbourhood inner-minor streets calm and low-speed or even strictly automobile-free. This reduces crash risk, clarifies priority for vulnerable users, and creates seamless walk- and bike-priority corridors. Such a design encourages more walking, cycling, and transit use, while discouraging short car trips and reducing noise and air pollution, resulting in cleaner, greener, and cooler local environments.

Precedents

Barcelona's Superblocks

Image source: Ajuntament de Barcelona

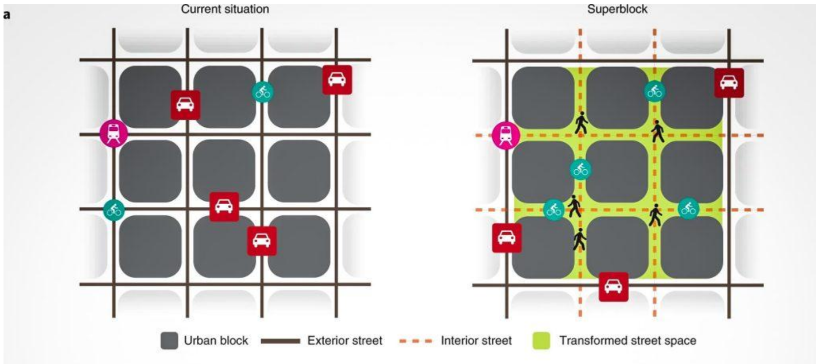


Image source: Nature Sustainability / Sven Eggimann

Content source: Castrezzati (2023); Eggimann (2022); Postaria (2021)

Barcelona's Superblocks are urban planning units typically spanning 3×3 traditional city blocks (about 400-500 m per side). They have restricted through-traffic inside, and vehicular circulation has been rerouted to the perimeter. Barcelona's municipality plans to install more than 500 Superblocks in the city by 2030.

Within Superblocks, interior streets are limited to resident or service vehicles, usually capped at speeds of 10 km/h; most streets become pedestrian and bike priority zones. This design establishes a continuous, seamless network for pedestrians and cyclists, boosting local connectivity and accessibility within each superblock. With reduced vehicle presence, accidents decline sharply, and micro-mobility users enjoy clearer right-of-way and safer routes.

Core Consideration: Comfort for micro-mobility users

Recommendation: Seamless walking surface

Introducing seamless walking surfaces, such as eliminating vertical curbs, can significantly enhance comfort for micro-mobility users and improve TOA internal connectivity. Removing vertical gaps and level changes enables strollers, wheelchairs, walkers, and other wheeled devices (e-scooters, longboards) to move smoothly, improving accessibility, inclusivity, and the overall walking experience.

Precedents

Chicago's Argyle Shared Street

Before After

Image source: Landscape Architecture Foundation (LAF), site design group

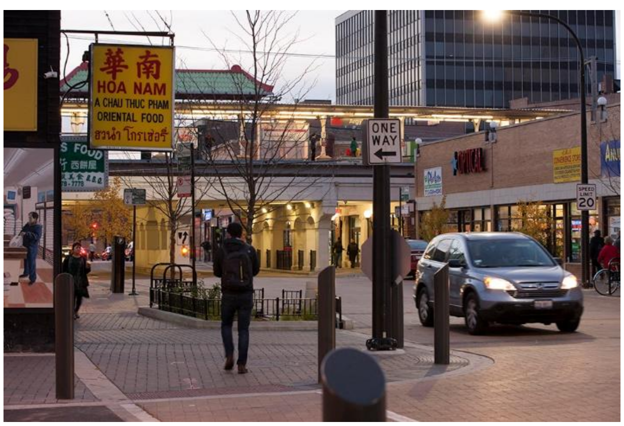


Image source: LAF, site design group

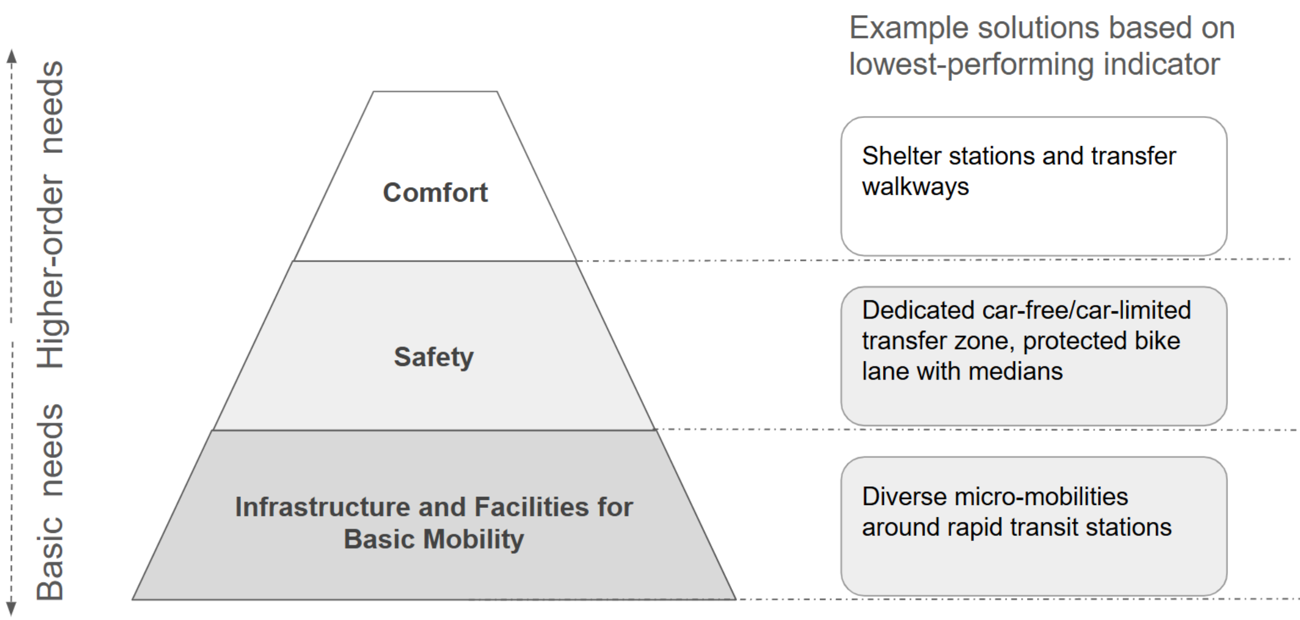
Completed in 2016, Argyle Street is Chicago's first curb-less "shared street." The roadway was raised to sidewalk level and rebuilt with 35,000 ft² of permeable unit pavers, chicanes, bollards, and continuous tactile warnings, creating a plaza-like environment where pedestrians and cyclists have clear priority. Removing vertical curbs and redirecting vehicles to nearby main roads lowered operating speeds to 20 mph and calmed motor traffic, greatly increasing comfort and safety for micro-mobility users.

Post-construction surveys found that 96 % of visitors rated the street's aesthetics, accessibility, and overall quality higher than the previous design, and attendance at the weekly Argyle Night Market rose from 25,000 to 45,000, indicating stronger pedestrian activity. The project illustrates how seamless walking surfaces can boost active-transportation comfort, support local businesses, and deliver co-benefits such as stormwater capture and expanded public space.

Content Source: NACTO (2017); Sarah Hanson & Matthew Callone (2019)

Targeted Dimension: Multi-modal Capacity

Targeted Lowest-performing Indicator: Number of Transfer Mode within a 200-metre buffer around the transit station



Core Consideration: Infrastructure and Facilities for Basic Mobility

Recommendation: Diverse micro-mobilities around rapid transit stations

To enhance multi-modal transfer around transit stations, it is recommended to promote a greater diversity of micro-mobility options within a 200-metre buffer. This can be achieved through both small-scale interventions, such as providing in-station micro-mobility facilities like bike connections and bike parking, and larger-scale strategies like establishing mobility hubs in high-demand TOAs. Integrating these facilities with transit stations will support seamless transfers and expand mobility choices for all users.

Precedents

Indoor bike parkade at Metrotown Skytrain station, Burnaby

Image source: TransLink

As highlighted in the BC Active Transportation Design Guide (2019), TransLink has introduced in-station bike parkades at major rapid transit stations such as Metrotown SkyTrain Station to support diverse micro-mobility options. These facilities help integrate active transportation with public transit, providing continuous and seamless connections for cyclists and transit users. This approach encourages walking, cycling, and transit to function as a mutually supportive network.

Bicycle parking garage at Utrecht's Central Station, Netherlands

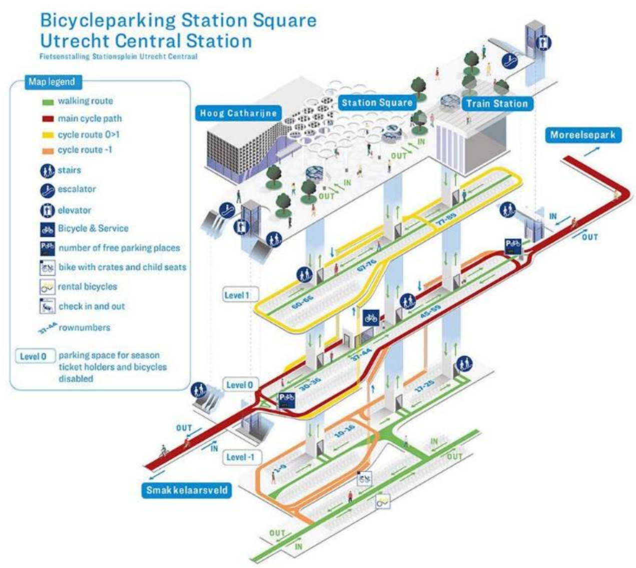


Image and content source: Bicycle Dutch (2024)

The world's largest bicycle parking garage in the Netherlands exemplifies how infrastructure can promote cycling through convenience and seamless connectivity. The facility features a spacious design, including a two-lane spiral ramp that allows cyclists to ride directly from the street to any floor. Digital screens at each decision point display real-time information on available parking spaces. The garage provides direct access to train platforms from the basement and convenient connections to surrounding destinations from the upper levels. This approach greatly enhances cycling comfort and encourages multimodal travel by integrating bike and transit access.

Core Consideration: Safety for micro-mobility users

Recommendation: Dedicated car-free/car-limited transfer zone, protected bike lane with medians

Establishing dedicated car-free or car-limited transfer zones, along with continuous protected walkways and bike lanes separated by medians, can significantly improve safety for pedestrians and micro-mobility users around transit stations. These design measures create safer and more intuitive spaces for transferring between mobility options, reducing conflicts with private vehicles, and making active transportation and multi-modal trips more appealing. By prioritizing non-motorized movement in these key areas, transit stations better support safe, convenient, and accessible multi-modal connections.

Precedents

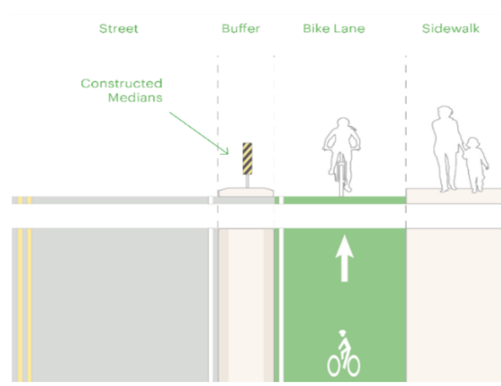
Transformation of the Nørreport Station, Copenhagen

Image source: GPA and Jens Lindhe

Nørreport Station is the busiest transit hub in Copenhagen, serving as a central connection point for regional trains, the Metro, and multiple bus lines. The station features a car-free transfer plaza designed to prioritize safe and efficient movement for pedestrians and cyclists. More than 2000 bicycle parking spaces are integrated directly into the plaza, creating a "bike bed" that encourages seamless bike-to-transit transfers. The open, unobstructed layout ensures clear sightlines across the station area, improving safety and wayfinding. By removing private vehicle access and emphasizing active transportation, Nørreport Station exemplifies how a central transit station can function as an accessible, multi-modal transfer hub. *Content source: ArchDaily (2016); Cycling Embassy of Denmark (2012)*

Protected bike lane with medians, Downtown Vancouver

Protected bike lanes with medians are essential for providing safe access to micro-mobility users during transit transfers. Downtown Vancouver features such protected bike lanes, but ensuring they are continuous and connect directly to station entrances would further improve safety and accessibility.



Core Consideration: Comfort for micro-mobility users

Recommendation: Sheltered stations and transfer walkways

Sheltered stations and covered transfer walkways enhance comfort for pedestrians engaging in multi-modal travel and transfers near transit stations. By providing protection from rain, snow, and other adverse weather conditions, these features improve weather resilience and help ensure that active and multi-modal travel remain attractive options year-round.

Precedents

Walk2ride promgamme in Singapore

Singapore's Walk2Ride programme has developed an extensive network of sheltered walkways up to 400 meters in length, linking transit stations with nearby amenities. This initiative supports comfortable, all-weather multi-modal travel by making it easier for people to walk to and from transit, regardless of rain or sun.

Image and source: Singapore Land Transport Authority (2018)

Canopy bus station Leidsche Rijn Centre, Netherlands

Image and content source: Bultink Technology

This innovative bus station is sheltered by a lightweight, cathedral-like canopy composed of steel-supported tensile membranes over a footprint of about 2,860 m². The design creates a spacious, weather-protected plaza directly adjacent to the nearby train station, facilitating smooth transfers between bus and rail service.

Smart shelter bus stop, Korea

Image and content source: Observatory of Public Sector Innovation

Seongdong District in Seoul has piloted a "smart shelter" system at busy bus stops, integrating cutting-edge technologies, such as real-time transit displays, public Wi-Fi, phone charging, intelligent CCTV, and automated sanitization systems, to enhance user comfort and safety.

CONCLUSION

KEY OBSERVATIONS

- A TOA may perform well in one dimension but poorly in others (e.g., Kootenay Loop Exchange TOA has the lowest score in land use with the highest score in TOA internal connectivity). This reminds planners that strong performance in one dimension does not imply holistic success, and that **integrated planning and design** are needed to advance multi-modal mobility.
- All TOAs show clear opportunities for improvement. **No TOA can be considered fully optimized** under the current framework. Scores for each dimension and overall TOA function performance cluster around mid-range values, indicating room to elevate performance across multiple dimensions. This provides a baseline for future iterative upgrades.
- TOAs experiencing the greatest passenger demand usually demonstrate high levels of functional stress. These **high-demand areas should thus be prioritized** for targeted interventions and resource allocation.
- Literature shows that phased, small-scale improvements aligned with the user-need hierarchy and feasibility, such as upgrading street and station amenities and furniture, can independently **encourage multi-modal travel behaviour**, even without broader land use changes. These targeted interventions are often more cost-effective and can deliver meaningful benefits to active transportation behavior.

FRAMEWORK APPLICATIONS

- **Assessment of current conditions**

  Assessment based on this standardized evaluation framework provides a systematic profile of each TOA's current strengths and deficiencies across land use and activity intensity, TOA internal connectivity, multimodal capacity, and transit node connectivity. It can produce comparable scores, maps, and tables that establish a baseline for benchmarking and tracking change over time.

- **Gap-oriented planning**

  By identifying specific weaknesses (e.g., low route directness and a limited number of transfer modes around stations for Stadium-Chinatown Station TOA), the framework guides specific evidence-based policy, planning, and design decision-making. Future work can also prioritize interventions by impact level and feasibility, aligning with City and provincial targets.

- **Scenario evaluation**

  The framework and evaluation matrix enable robust comparison of alternative scenarios using consistent metrics and thresholds. It can further support sensitivity testing, cost-effectiveness comparisons, and phased investment decisions to identify the most effective option for each TOA context.

POTENTIAL CONTRIBUTIONS

- Back up investment and intervention decisions and priorities
- Track progress over time
- Support policy, planning, and design decisions
- Coordinate across departments
- Guidance for developers
- Public communication

LIMITATIONS AND FUTURE WORKS

- **Increase spatial data availability and quality**

  Accessibility and availability to specific datasets will significantly enhance the reliability and robustness of current analysis, for example, a policy TOA polygon layer (one polygon per area), point of interest (trip destinations like clinic, various stores, schools, restaurants, and community centers), micro-mobility facilities and amenities (both on-street and in-building), mid-block crossings and in-building connections, and car ownership data (at an appropriate aggregation level to protect privacy).

- **Extend the analytical scope**

  Current analysis is limited to the City of Vancouver, and the scoring system reflects each TOA's relative performance within the city context. Expanding the framework analysis to the Metro Vancouver region, at least for the transit node dimension, would better capture intermunicipal transportation services and regional network effects. A regional application would mitigate boundary bias and enable assessment of relative performance across the entire region.

- **Enhance demand measurement**

  In this pilot, the transit-demand indicator is limited to existing ridership data and serves only to demonstrate the framework; it neither tailors results to demographic characteristics nor captures active-transportation tendency. To fully operationalize the framework, current and future transit demand and active transportation tendencies can be captured through more direct measures such as extracting from expert elicitation, surveys, passive counts (pedestrian flow and ridership), and advanced passenger-demand models.

- **Monitoring and governance considerations**

  For future work, a regular update cycle for data refresh and scoring enables consistent progress monitoring. Additionally, clarifying roles and responsibilities for data stewardship and intervention implementation across the city, TransLink, and regional partners can increase project feasibility and support coordinated delivery.

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