Characterizing Land use and Transportation For Transit-Oriented Development in the Montreal Metropolitan Region

Supervised Research Project Report Submitted in partial fulfillment of the Masters of Urban Planning degree

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ABSTRACT

This report presents an indicator-based approach to evaluating the Communauté métropolitaine de Montréal's (CMM) regional transit-oriented development (TOD) objective. Montreal's regional governing body identifies 154 access points to the regional public transit network to be developed according to TOD principles by 2031. The purpose of this report is to establish planning priorities for the identified TOD zones by characterizing their existing land use and travel characteristics. It establishes priorities based on each zone's performance in regard to residential density targets and public transit mode share. The lowest-performing 10% of zones served by each public transit service type (train, metro/LRT, park-and-ride/bus terminal), for a total of 16 zones, was identified as a priority group. Each priority zone was characterized using a series of indicators evaluating travel characteristics, density, land use diversity, street network design and development potential. Indicators were selected based on their performance in the land use and transportation literature. Many of the identified priority zones share similar issues to be considered in planning for transit-oriented development. Several station areas, particularly those around commuter train stations, lie significantly below a residential density that would be conducive to a modal shift from the automobile to public transit. Station area land use mix and design are other common issues that must be addressed to increase accessibility to public transit and to nearby destinations via walking. The report concludes with general policy recommendations for addressing these issues. Land value capture, intensification, station area design and parking policy are proposed as general avenues for improving TOD planning the Montreal Metropolitan Region.

ABRÉGÉ

Ce rapport présente une évaluation de l'objectif de TOD (*Transit-Oriented Development*) à l'échelle régionale de la Communauté métropolitaine de Montréal (CMM). La CMM a ciblé 154 points d'accès au réseau de transport en commun métropolitain à développer selon des critères de TOD avant 2031. L'objectif de ce rapport est d'identifier des priorités d'aménagement pour les aires TOD par le biais d'une caractérisation des usages du sol et des tendances de transport à l'intérieur de ces aires. Des priorités sont assignées parmi les aires selon l'écart entre leur densité résidentielle actuelle et ciblée et selon leur part modale de déplacements effectués en transport en commun. Le 10% des aires TOD les moins performants desservies par chacun des types de service (train, métro/SLR, stationnement/terminus), pour un total de 16 aires, a été ciblé en tant de groupe prioritaire. Chacun des aires comprises dans ce groupe a été caractérisé par des indicateurs de tendances de transport, de densité, de mixité d'usages, de connectivité et de potentiel de développement. Les indicateurs ont été choisis selon leur performance dans des études antérieures sur l'usage du sol et le transport urbain. Plusieurs aires prioritaires partagent des enjeux similaires à considérer en anticipation d'un aménagement de type TOD. Plusieurs d'entre elles, notamment celles autour des gares de train de banlieue, demeurent en dessous d'un seuil minimal de densité résidentielle qui encouragerait une hausse de la part modale du transport en commun. De plus, la mixité d'usages et le design des réseaux piétonniers et cyclistes à proximité des points d'accès doivent être priorisés afin d'augmenter l'accessibilité au transport en commun et aux destinations avoisinants. Le rapport conclut avec des balises d'aménagement générales ciblant l'amélioration de la planification des aires TOD de la CMM. Celles-ci comprennent la captation de la valeur foncière, l'intensification du développement des milieux urbains existants, le design axé sur le transport actif et la reformulation de l'aménagement et l'opération des stationnements incitatifs.

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1.0: INTRODUCTION

As a response to the environmental and social impacts of an auto-centric urban form, many cities have created plans for transit-oriented development (TOD). Dunphy *et al.* (2004) found that concentrating urban development in mixed-use nodes around public transit lines and stations reduces the number and duration of household trips made by car by providing individuals with services in close proximity to their homes and an efficient regional public transit system. The success of a TOD policy, however, depends largely on its design, and the policy design can only be formulated once the state of the existing built environment has been characterized.

At the end of 2011, The Communauté métropolitaine de Montréal (CMM) adopted the *Plan métropolitain d'aménagement et de développement* (PMAD), Montreal's first regional plan. The first goal of the plan is to create sustainable living environments in Greater Montreal, and one of the underlying objectives of this goal is to orient 40% of future households toward transit-oriented hubs, both existing and proposed, throughout the region (CMM 2011). The regional governing body has identified 154 existing and future public transit nodes and established residential density targets that vary according to the capacity of the current or proposed public transit service. More analysis is needed, however, to characterize the existing built environment in these areas and to propose actions tailored to their specific context.

Given this need, the two following research questions are considered:

1. How can the current built form and travel characteristics of the CMM TOD zones be evaluated?

2. Which TOD zones are furthest from residential density and public transit mode share targets and how might these zones be addressed given their current land use characteristics?

The goal of this research is to describe the existing conditions in the identified TOD zones, to establish priorities, and to suggest policies supportive of the CMM's TOD objective. The zones will be assessed using key indicators of transit-supportive land use from the literature, drawing on the 3D's framework proposed by Cervero and Kockelman (1997): density, diversity and design. This information will serve to identify priority zones and actions, thus guiding the effort to improve the land use-transportation integration in the Montreal region. The report begins with an overview of transit-oriented development in general and in the Montreal context, drawing on best practices from the literature and on the CMM TOD objective. The most heavily used indicators of transportation-land use interaction in previous studies are then identified and discussed. This research is used to develop a list of indicators with which to characterize the TOD zones in the CMM plan. The results of the indicator calculations are then used to identify priority zones and to inform land use policy recommendations.

1.1: The CMM TOD Objective

The Montreal regional public transit network is currently composed of five commuter train lines, four metro lines, several park-and-ride facilities, and numerous local bus networks. The PMAD outlines plans for an additional commuter train line, extensions to the metro network, and new bus rapid transit and light rail lines (Figure 1.1). As previously described, the first action item of Objective 1.1 of the PMAD is to orient at least 40% of residential growth toward TOD zones located at strategic access points to the regional public transit network by 2031. In addition, Objective 2.2 calls for modernization and development of the regional public transit network, namely through a 30% increase in public transit mode share over this same time period (CMM 2011). Each of the 154 transit access points, existing or proposed, was assigned a circular buffer within which TOD principles must be enforced. The radii of the buffers range from 0.5km for tramways, buses and bus rapid transit to 1km for metros, commuter trains and light rail. Each buffer is assigned a target gross average residential density based on TOD best practices, the existing or anticipated level of transit service, the existing context and the objectives of the jurisdiction within which they are found (Table 1.1; CMM 2011).

Table 1.1: Residential Density Targets (units/ha) by Transit Mode

Gross average residential density target	Metro/LRT	Commuter train	Tram/BRT/Reserved bus lane
Very high	150	110	80
High	110	80	60
Medium	80	60	40
Low	60	40	30

The CMM also created a guidebook outlining the characteristics of different TOD typologies and presenting policy options for addressing the opportunities and constraints presented by each type. The typologies were defined by function, travel options, density and urban morphology (Table 1.2). A station area's function is defined by the intensity and mixture of land uses it accommodates and by the presence of special uses such as agricultural land or historic sites (CMM 2011b). Transit service types include existing and projected metro stations, commuter train stations, LRT and tramway stations, bus terminals and park-and-ride lots. The morphological characteristics considered were street patterns, block sizes, building placement and the presence of major infrastructure (highways, bridges, ports, etc.).

Figure 1.1: Overview of the CMM TOD Objective

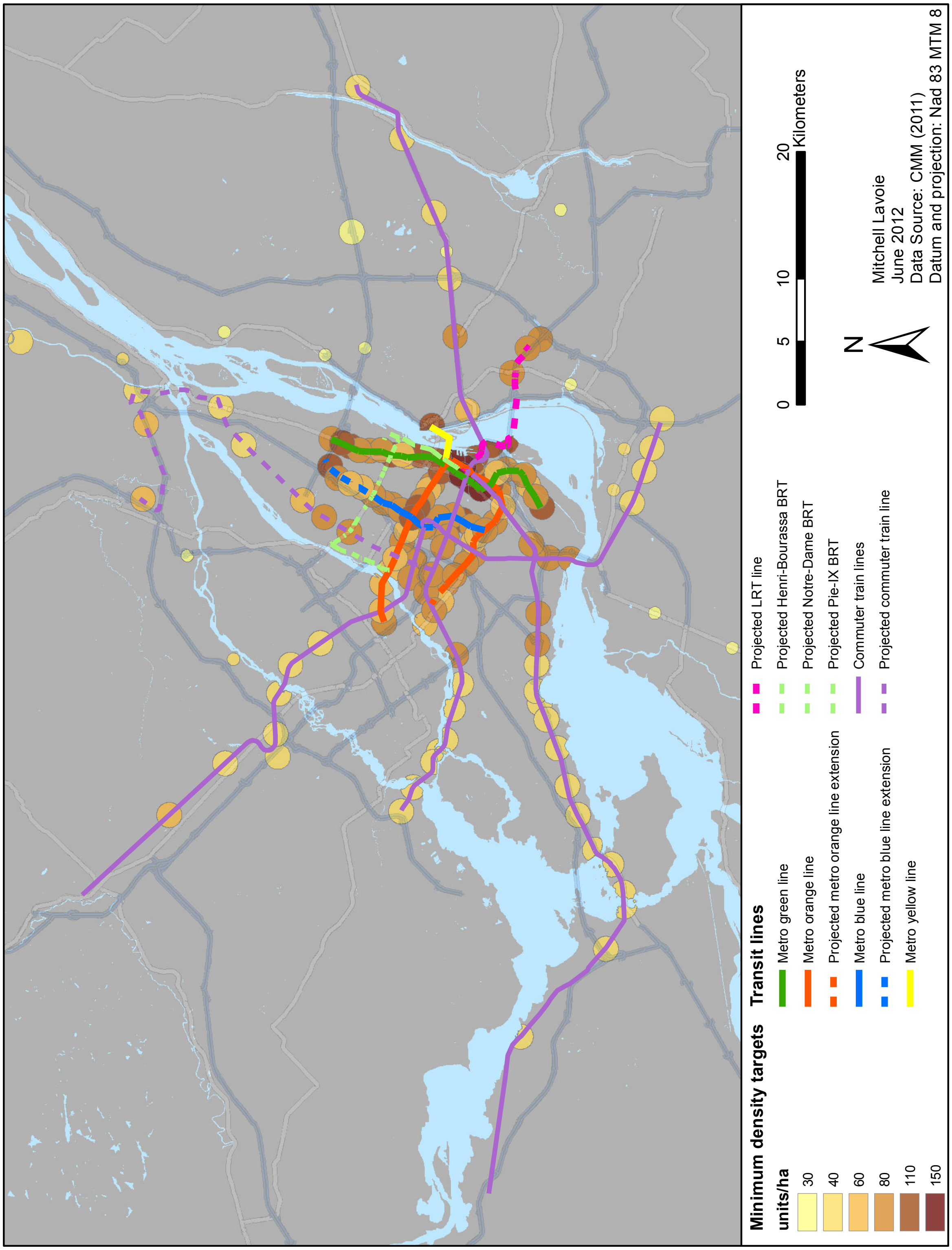


Table 1.2: TOD Typologies Identified by the CMM

TOD Typologies	Characteristics
Hypercentre (CBD)	Grid street pattern Buildings facing street Mix of transit modes Concentration of activity Regional/provincial destination Cultural and institutional hub
Urban regional centre	Grid street pattern Presence of metro, train and/or tramway station(s) Presence of large infrastructure Presence of activities with regional vocation Varying lot sizes and shapes
Urban centre	Primarily residential uses in grid street pattern Presence of metro and/or train station(s) Presence of large road infrastructure Varying lot sizes and shapes
Suburban regional centre	Irregular street pattern Presence of train and/or bus station(s) Presence of large road infrastructure Presence of activities with regional vocation Varying lot sizes and shapes
Suburban centre	Mixture of uses in irregular street pattern Presence of train and/or bus station(s) Presence of large road infrastructure Varying lot sizes and shapes
Urban neighbourhood	Primarily residential uses in grid street pattern Presence of metro station(s) Consistent lot size
Suburban neighbourhood	Primarily low-density residential uses in irregular street pattern Presence of train and/or bus station(s) Varying lot sizes and shapes

The typologies presented above reflect the variety of urban forms in the Montreal Region and the resulting need to tailor TOD planning to specific local contexts. The success of a TOD scheme therefore depends on the assessment of current land use characteristics around existing and proposed transit access points. The following literature review explores the state of knowledge on transit-oriented development, identifies indicators of urban form that exhibit a relationship to travel behaviour, and suggests which indicators might be applicable to TOD planning.

2.0: LITERATURE REVIEW

Hundreds of studies have been published in the past 20 years on the effects of land use and other built form characteristics on transportation. The purpose of these works varies, but all attempt to characterize the built environment in some way in an effort to grasp an understanding of individual travel behaviour. Very disparate results between studies have caused a rift in the travel behaviour research community. On one side are those who have shown that the built environment has a significant impact on travel behaviour notwithstanding residential self-selection (Frank and Pivo 1994). On the other hand, there are those who treat built environment variables as proxies for pre-established consumer preferences, demographics and travel costs (Crane and Crepeau 1998). While most authors in either camp agree that self-selection is not negligible, many have shown that the built environment has a significant impact on travel behaviour even when residential self-selection is controlled for (Ewing and Cervero 2010).

It is therefore important to provide people with residential location options that reduce the need for personal vehicle travel and increase the attractiveness of alternative modes of transportation. One strategy to achieve this goal is to foster transit-oriented development (TOD). Similar in principle to New Urbanism, TOD involves designing neighbourhoods that can support an efficient, competitive public transit service and that provide abundant proximity services in a safe walking environment. In the immediate vicinity of a transit station or route, this means building at densities that can generate sufficient transit ridership, fostering a mixture of land uses, and designing streets to be well-connected and pedestrian-friendly. At the regional scale, one can imagine a series of TOD nodes with different vocations linked by a high-quality transit network. The resulting polycentric urban form is thought to be less dependent on the automobile as displacements for work and non-work purposes are either shortened to walking distance or made by public transit (Dunphy *et al.* 2004). However, the benefits of transit-oriented development go far beyond reduced auto-dependence. Transit-oriented development can:

- Increase overall mobility by increasing mode choice (Cervero, Ferrell and Murphy 2002)
- Create an environment conducive to aging in place (OMT 2012)
- Improve air quality due reduced automobile travel (OMT 2012)
- Reduce energy consumption from the residential and transportation sectors (Cervero, Ferrell and Murphy 2002)
- Reduce the ecological footprint of urban development (OMT 2012)
- Reduce individual travel costs (Cervero, Ferrell and Murphy 2002)
- Reduce infrastructure costs (OMT 2012)
- Increase fare revenues for transit agencies (Cervero, Ferrell and Murphy 2002)
- Catalyze redevelopment (Cervero, Ferrell and Murphy 2002)
- Increase urban land values (Dunphy *et al.* 2004)
- Foster socioeconomic mixing (Cervero, Ferrell and Murphy 2002)
- Support the creation of agglomeration economies (Drennan and Brecher 2012)

Many studies have shown, intuitively, that people choosing to live near transit stations are more likely to use public transit. For instance, Stringham (1982) found that over half of apartment dwellers living near commuter rail stations in Toronto chose to commute using the latter service. Cervero (1993) discovered that 52.3% of people who previously drove to work shifted to public transit upon moving to with ½ mile of a rail station in the Bay Area. A later study surveying residents in 26 TOD housing projects in the same region showed the transit mode share to be six times higher among these residents than for those living elsewhere in the region (Cervero 2007). One way to encourage the use of modes of transportation other than the private vehicle is to concentrate housing and employment near public transit stations. Drennan and Brecher (2012) provide empirical evidence that cities with well-used public transit systems can command higher rents for office space than automobile-oriented cities. The number of automobiles that an employment centre can accommodate is limited, which reduces the maximum achievable employment density. An employment centre with good public transit access, on the other hand, is less constrained by automobile congestion and, as a result, can accommodate higher densities and command higher rents (Drennan and Brecher 2012). A TOD can have a similar effect on the housing market, as the demand for housing in transit-oriented developments often far outweighs the supply (Renne 2008).

One of the first steps toward a TOD plan is evaluating the transit-supportiveness of the existing built environment. In the context of travel behaviour research applicable to TOD, the built environment appears to affect displacement choices at two scales. Certain built environment characteristics have been linked to reduced private vehicle mode share and decreased vehicle kilometres travelled (VKT) on a regional scale (Ewing and Cervero 2010), while others predict mode choice for more local displacements, namely to and from a public transit route or neighbourhood amenity (Renne 2008; Brownson *et al.* 2009). It follows that there are certain built environment indicators better suited to predicting public transit use, and others that are more indicative of travel behaviour to and from a public transit station. The following section compares the performance of several of these indicators.

2.1: Characterizing Land Use and Transportation

The use of urban form indicators is essential to developing long-term land use models for a metropolitan region (Ritsema van Eck and Koomen 2008). Among the most well-known frameworks for studying the relationship between urban form and transportation is Cervero and Kockelman's (1997) three D's: density, diversity and design. The authors propose that the three main built environment characteristics that influence travel behaviour are population and employment densities, the extent to which compatible land uses are mixed, and street design (ibid.). When grouped using factor analysis, the selected indicators had relatively low yet statistically significant explanatory power over travel behaviour data collected in the San Francisco Bay Area at the census tract level. Since this seminal article was published, many authors have proposed additional D's be added as influential variables, namely destination accessibility (Ewing and Cervero 2001) and distance to transit (Ewing et al. 2009). The built environment indicators that have been used as input variables in travel behaviour models have varying explanatory power over individual travel choices. Ewing and Cervero (2010) compile much of this literature into a review examining the elasticity of various dependent travel behaviour variables given a change in a series of built environment variables. In most studies, travel behaviour is inelastic to individual built form indicators, but in the aggregate, built form variables have a significant impact on travel outcomes. The authors found 38 studies that demonstrate significant built environment effects on travel behaviour (Ewing and Cervero 2010). The following subsections discuss the relative strength of different types of built environment indicators in order to identify those most appropriate to the context of a regional transit-oriented development objective.

2.1.1: Indicators of Density

Most travel behaviour studies include urban density as a potential factor in individual transportation choices, although the formulation and explanatory power of density indicators vary considerably (Ewing and Cervero 2010). Some indicators may be more suitable than others for characterizing areas in anticipation of transit-oriented development. Several authors have also shown that critical density thresholds exist beyond which individuals are likely to shift modes of transportation (Frank and Pivo 1994; Ewing 1997; Holtzclaw *et al.* 2002; Dunphy *et al.* 2004).

Frank and Pivo (1994) observed significant correlations between employment density and walking and public transit use at the census tract level in the Central Puget Sound area of Washington State. In fact, employment density at both ends of a trip had the highest explanatory power over public transit use for work and shopping trips. Population density only modestly correlated with the percent of individuals who walked to work or to retail stores. The authors estimate that attaining thresholds of 20-75 and 125 employees per acre lead to significant changes in travel mode choice. In addition, a population density threshold of 13 residents per acre, or 7-9 dwelling units per acre, is a significant threshold for mode choice shift for shopping trips (Cervero and Kockelman 1997). These results reflect a need to characterize urban form in terms of primary vocation. For instance, a neighbourhood that is largely residential with a local business area will have a different relationship with the transit system than an employment node.

Cervero and Kockelman (1997) further demonstrate this in showing that density has the strongest influence over travel for personal needs, while the concentration of retail shops exhibits the strongest relationship with work trips in the Bay Area. One of the key lessons from this study is that travel behaviour is shaped by much more than residential density, which tends to be the main focus of land use planning for transit-oriented development. Employment density may even be a stronger indicator of single-occupant vehicle travel than residential density (Kockelman 1997).

Many authors have identified residential density as a confounding factor in relationships between travel behaviour and other variables such as vehicle ownership, income, urban design characteristics and accessibility (Badoe and Miller 2000). Holtzclaw *et al.* (2002) note a decrease in auto ownership levels and a 32-43% decrease in vehicle miles travelled when residential density is doubled. However, Kockelman (1997) suggests that density measures are used so extensively in travel behaviour research because they are proxies for more relevant variables, such as the availability of opportunities in a given area. The latter study shows that controlling for accessibility, or the number of opportunities attainable by a certain mode of transportation, renders the impact of density on travel behaviour negligible. While this finding indicates a need to consider additional urban form indicators, it does not suggest that density is irrelevant. Ewing (2008) supports this finding in suggesting that density might only lead to increased use of alternative modes of transportation because it is associated with mixed-use environments.

At the local scale, high accessibility may in fact require high concentrations of residents and employment alongside mixed use and a high-quality pedestrian environment (Krizek 2003). A measure of gross density also reflects the amount of land allocated to streets and sidewalks, which provides additional insight into neighbourhood walkability (Ibid.). Forsyth et al. (2008) demonstrate that higher residential densities alone cannot explain increases in walking mode share, but can lead to a higher proportion of walking trips for travel versus leisure purposes. Density measured in terms of residential units per land area yielded the highest correlation with total walking of all built environment variables included. Density measured in terms of population per unit area within an 850 x 850-metre grid cell of participants' residences explained 49% of the variation in walking for travel purposes. Furthermore, Frank *et al.* (2008) found that a 10% increase in *retail density* at trip origins and destinations, measured in floor-area ratio (FAR), was associated with a 1.2% increase in walking to work and a 4.3% increase in public transit demand, respectively.

The surveyed literature shows that different expressions of density have been linked to different travel outcomes, which compels policy-makers to use multiple indicators of density in land use and transportation action plans. An increase in residential and employment densities at trip origins and destinations, together representing activity density, has been linked to an increase public transit ridership at the regional scale. Most studies agree that a critical threshold of between 30 and 40 jobs and/or residents per hectare exists beyond which private vehicle dependence decreases (Newman and Kenworthy 2006). The Ontario Ministry of Transportation's recent TOD planning guidelines suggest a slightly higher target of 50 jobs and/or residents per hectare (OMT 2012). Furthermore, an increase in population and retail densities has been shown to encourage walking for travel purposes at the local level. In characterizing land use for transit-oriented development, it is important to consider both population and employment densities as it is the relationship between the two that leads to travel outcomes (Krizek 2003).

2.1.2: Indicators of Land Use Diversity

As the previous section illustrates, density must be conceptualized alongside land use mix in understanding the impact of urban form on travel behaviour. In fact, land use mix has been shown to have stronger explanatory power over travel behaviour than urban density (Badoe and Miller 2000; Kockelman 1997). A mixture of land uses concentrated around a transit station can increase off-peak ridership for non-work travel, foster sharing of parking spaces between uses and bring services closer to residents (Krizek 2003). In California, mixed-use suburban nodes were shown to have 3.5% higher transit ridership than single-use nodes (Cervero, Ferrell and Murphy 2002). Land use diversity has been measured with a vast range of indicators, from simple counts to complex indices inspired by landscape ecology and economics. However, there is widespread disagreement as to the usefulness and accuracy of these different measures for capturing the relevant effects of land use mix on travel outcomes (Hess, Moudon and Logsdon, 2001).

The most extensively used metric is land use entropy, an area-based indicator that measures the degree to which different land uses are evenly distributed (Frank, Andersen and Schmid, 2004). Scores fall between 0 and 1, where 1 indicates a perfect mixture of all land uses in a given area. The predictive strength of the entropy measure varies considerably between studies and appears to have a stronger effect on particular travel outcomes. Frank and Pivo (1994) show a modest yet statistically significant relationship between entropy score and pedestrian mode share for work trips at the census tract level in the Central Puget Sound Area of Washington State. Similarly, Kockelman (1997) shows a significant relationship between mean entropy and both vehicle miles travelled and the choice to walk or bike in the Bay Area.

One shortcoming of the entropy measure, however, is its inability to capture land use diversity on a smaller scale, namely within a parcel or building. For this reason, many researchers have used the index of dissimilarity to determine the proportion of the eight adjacent land use grid cells that are dissimilar from the central cell (Cervero and Kockelman 1997; Kockelman 1997; Krizek 2003). The Bay-Area study by Kockelman (1997) evaluating the relationship between both detailed and generalized dissimilarity indices and travel behaviour found that the general form, with fewer land use classifications, had higher predictive power. The advantage of this index is that it captures more localized variations in land use, which is valuable for measuring land use diversity in small-scale study areas such as the neighbourhoods surrounding public transit stations, particularly in suburban environments. However, the calculation of the index requires a rasterized land use layer and provides no indication of the number of land uses abutting the central cell (Krizek 2003). It also assigns cell values according to the dominant land use, thus missing fine-grained land use interactions. Although this shortcoming can be avoided by using highly detailed land use information, the index also fails to account for land use complementarity (Kockelman, 1997).

Another summary measure is Simpson's diversity index (equal to the negative of the Herfindahl-Hirschmann index), which has been used for land use modelling, travel behaviour studies, and health studies of neighbourhood walkability (Yamada and Brown 2012; Ritsema van Eck and Koomen 2008; Forsyth *et al.* 2008). The index calculates the sum of squares of the area of different land use within a neighbourhood, which effectively weights dominant land uses more heavily than secondary uses (Ritsema van Eck and Koomen 2008). This measure might therefore be useful for defining the primary vocation of an urban or suburban area and assessing the need for additional supportive uses. However, the entropy score and Simpson index share the weakness of being unable to assess the complementarity of land uses. Furthermore, Yamada and Brown (2012) found that the area of six different land uses were independently better at predicting participants' BMI in a study of the built environment and obesity than any summary measure.

Hess, Moudon and Logsdon (2001) attempt to clarify why certain summary land use mix measures were performing poorly in travel behaviour research. They argue that employing indicators at a high level of spatial aggregation, such as the census tract, does not effectively capture the development patterns that lead to auto-centric travel behaviour. The authors instead developed a series of measures reflecting the interaction between land uses. By characterizing the different types of edges surrounding land use patches based on the characteristics of adjacent patches, they developed a series of indicators capturing different interactions between land use and travel behaviour. For instance, the contagion index, or the length of edge shared between patches as a proportion of the total edge length of the landscape, measures the grain of urban development. Edge contrast, or the degree of complementarity between two adjacent land uses, measures the propensity of a land use interaction to generate travel. For example, a patch of residential land use abutting a patch of retail would constitute a high-contrast edge likely to lead to non-work travel. Although this study takes a more complex approach to researching the land use-transportation interaction, it deals with some of the aggregation issues present in area-based studies of land use. It also provides a methodology for measuring land use complementarity and predicting travel outcomes at the neighbourhood level, which are critical indicators for TOD plans.

In a similar but less data-intensive manner, Manaugh and Kreider (in press) tackle the measurement of land use interaction by using easily accessible aggregate land use data in Vancouver, Toronto and Montreal. The authors shed light on the problems associated with area-based land use mix indices such as the entropy score, namely their inability to measure land use configuration and compatibility. They contend that the choice to walk or cycle from origin to destination is encouraged by the mixing of complementary land uses and, as a result, propose a measure focused on interactions at the edges of land use polygons. This measure was shown to have stronger predictive power over active transport trips than the entropy score and drastically improved model fit for Toronto. It is therefore valuable for characterizing land use-transportation interactions at a finer scale. However, it fails to capture land use intensity and over-generalizes the relationship between different land uses and their associated travel outcomes.

Although the vast majority of travel behaviour studies use relatively abstract measures of land use mix, many authors have found statistically significant relationships between travel behaviour and simple business, jobs and housing counts (Ewing and Cervero, 2010). While not explicitly measuring land use mix, retail counts and the local jobs-housing balance can provide an idea of the number and intensity of opportunities available in an area. Both retail counts and jobs-housing balance have exhibited statistically significant elasticity with public transit trips in studies conducted in North America (Ewing and Cervero, 2010). Cervero and Kockelman (1997) also discovered a 75% higher probability of commuting by modes other than the single-occupant vehicle in neighbourhoods where people live within ¼ mile of a convenience store. Such measures complement the area-based and interaction indices by characterizing the nature and density of land use in an area.

Choosing appropriate indicators of land use diversity depends on the scale and travel outcomes of interest as well as the geographic context. Characterizing station areas in anticipation of transit-oriented development requires indicators that account not only for generators of transit ridership, but also for factors that lead to walking and biking *within* a TOD. Combining the Simpson index with an interaction measure and a jobs-housing balance calculation would provide a comprehensive assessment of the proportion, nature, grain and compatibility of the land uses present in a station area. These characteristics have all been associated with increased public and active transportation use. Furthermore, pre-calculated walkability indices such as Walk Score® may be useful to account local land use characteristics in an intuitive way (Walk Score®, 2011).

2.1.3: Indicators of Neighbourhood Design

The success of transit-oriented developments depends to some extent on how origins and destinations are connected. The commonly-used indicators of street network design draw heavily on the principles of New Urbanism, which suggest that well-connected, pedestrian-friendly streets encourage people to walk as a mode of transportation (Dunphy *et al.* 2004). Neighbourhoods that are dense, diverse and connected by reliable public transit may attract people to the service, but the design of the station area affects how people choose to access it (Renne 2008). Furthermore, Hess *et al.* (1999) found that pedestrian activity varies according to neighbourhood design factors when density is held constant. The three recurring TOD design characteristics are street connectivity, pedestrian environment quality and station access, each of which have been measured with multiple indicators.

Numerous studies use intersection counts or intersection densities as indicators of neighbourhood design. In a meta-analysis by Ewing and Cervero (2010), intersection density was found to have one of the highest elasticities for walking and public transit trips. Others show that the proportion of 4-way intersections is more indicative of a well-connected built environment, with a statistically significant relationship to walking and non-motorized trips (Forsyth *et al.* 2008; Cervero and Kockelman 1997). As a general guideline, the Ontario Ministry of Transportation suggests a minimum intersection density of 0.6 intersections/ha to ensure connectivity between local destinations (OMT 2012). Small blocks and a grid street pattern allow pedestrians to easily access destinations via multiple routes while maximizing trip efficiency. Although Cervero and Kockelman (1997) found only a modest correlation between non-work travel and pedestrian-oriented design, individuals living in areas with a grid street pattern with lower parking allowances were found to have lower vehicle miles travelled (Forsyth *et al.* 2008). Street connectivity is particularly relevant for travel behaviour at trip destinations where public transit riders typically must walk to their final destination, thus affecting their initial choice to commute via public transit (Cervero 2007). Krizek (2003) indicates intersections spaced 400 feet or less are conducive to high neighbourhood accessibility, while Dunphy *et al.* (2004) suggest a block length of no more than 500 feet for transit-supportive development.

An alternative measure of connectivity is street density, or the total length of roads per unit area (Forsyth *et al.* 2008; Ewing *et al.* 2004). This measure reflects not only the connectivity of the built environment, but also the amount of space allocated to the public right of way in a given area. Forsyth *et al.* (2008) found a significant correlation of 0.53 between street density and pedestrian miles travelled for transportation, as determined by travel diaries in the Twin Cities. Schlossberg and Brown (2004) suggest classifying streets by type and purpose such that major arterials and expressways with high-speed vehicle traffic can be treated as impedances in the pedestrian network.

Proponents of New Urbanism argue that streets can actually be supportive of walking if the pedestrian environment is safe and of high quality (Dunphy *et al.* 2004). As a response to environmental and health concerns associated with driving and a low-density urban form, several indicators of pedestrian-oriented design and walkability have been developed. The most intuitive is a ratio of sidewalk length to total road length, which exhibited a strong correlation with walking for transportation in the Twin Cities study by Forsyth *et al.* (2008). This study and others go into further detail on the characteristics of the pedestrian realm, such as the spacing between lamp posts, the availability of street furniture and the placement of business parking (for example, Cervero and Kockelman 1997). However, this type of data is difficult to obtain and unreliable when used independently of ground-truthed field observations.

Parking policy and the micro-scale urban design characteristics of the station itself are also critical to successful transit-oriented development (Renne 2008; Schlossberg and Brown 2004). The availability and placement of parking affects how people choose to access the station. While the availability of parking may partially determine a person's choice to commute via public transit, a station surrounded by vast parking lots discourages access by foot (Renne 2008). Therefore, the design of existing and future stations must be sensitive to the needs of all potential users. The presence of pedestrian paths and the placement and size of parking facilities are potential indicators of station design. These factors are typically studied qualitatively given a lack or inaccuracy of data, but may be useful for addressing specific stations. Determining the mode share for access to stations is also essential to understanding the needs and potential of the specific urban context (Brinklow 2010).

In thinking about urban design for transit-oriented development, one must consider the quality and practicality of the street network for pedestrians above all (Dunphy *et al.* 2004). Although the research on this topic often includes qualitative observations, much can be learned through fairly simple GIS calculations using street network and cadastral files. More detailed design characteristics of stations and station areas might only be considered for a smaller sample of TOD zones requiring particular attention.

2.2: Summary

An extensive review of the literature on travel behaviour and urban form, health and the built environment and transit-oriented development yielded a list of approximately 150 indicators that can be used to characterize existing land use (Table 2.1; full table with authors in Appendix A). The above sections summarized the findings of various authors to determine which indicators were most successful at predicting travel choices that align with TOD principles. While their level of complexity varies considerably, the indicators tend to fall within Cervero and Kockelman's (1997) 3D's framework. The main lessons from this research are summarized below:

- Although residential density is important for supporting good public transit service, it must be considered alongside other measures of land use intensity, such as employment density

- Area-based measures of land use mix fail to account for land use complementarity and, consequently, are best used with more detailed measures of land use interaction

- The urban design characteristics of both the station area and the station itself must be considered to understand why people choose to commute via public transit and, given this choice, how they choose to access the station

Most studies found relatively weak yet statistically significant relationships between built environment variables and travel behaviour (Ewing and Cervero 2010). However, there is evidence that the urban form characteristics considered in these studies are associated with more sustainable travel choices (Dunphy *et al.* 2004). Characterizing land use with indicators based on these characteristics may then lead to better planning for land use-transportation integration.

Table 2.1: Summary of Land Use Indicators Used in the Literature

DENSITY INDICATORS			
Indicator	Number of studies	Indicator	Number of studies
Population density (gross)	11	Parcel density	1
Employment density	8	Employment within walking distance	1
Dwelling density	6	Contagion index	1
Population density (net)	3	Commercial FAR	1
Retail FAR	2	Circularity ratio	1
Activity density (population+employment)	2	Building FAR	1

DIVERSITY INDICATORS			
Indicator	Number of studies	Indicator	Number of studies
Land use entropy	14	Distance to nearest park	1
Walkability index	4	Distance to 12 essential goods/services	1
Dissimilarity index	3	Land use edge contrast	1
Retail employment density	3	Grocery/pharmacy dummy	1
Retail store count	3	Housing typologies	1
Simpson's diversity index	3	Job mix	1
Distance to closest commercial use	2	Job-housing imbalance	1
Job-housing balance	2	Land use patch density	1
Land use interaction length	2	Land use patch size	1
Land use percentages by parcel	2	Parks/rec density	1
Number of businesses and facilities	2	Percentage of parcels that are residential	1
Number of destination types	2	Percentage nonresidential buildings	1
Area covered by different land uses	1	Retail shop/mixed use dummy	1
Distance to closest large grocery store	1	Shopping mall dummy	1

DESIGN INDICATORS			
Indicator	Number of studies	Indicator	Number of studies
Intersection density	8	Block perimeter (median)	1
Percent 3-way intersections	4	Cul-de-sac density (high/low)	1
Sidewalk ratio	3	Percent 4-way intersections	1
Block face length	2	Proportion of blocks with flat terrain	1
Census block area	2	Proportion of blocks with overhead lights	1
Percent cul-de-sacs	2	Proportion of blocks with planting strips	1
Sidewalk length	2	Proportion of blocks with grid shape	1
Sidewalk width	2	Proportion of blocks with sidewalks	1
Street density	2	Quantity of accessible paths (high/low)	1
Average length of network segments	1	Ratio of land use patch area to perimeter	1
Block dimensions	1	Residential building age	1

3.0: METHODS

3.1: Understanding the TOD Shapefile

The public transit station areas identified in the PMAD as zones slated for TOD are stored as circular buffers with radii of either 0.5km or 1km depending on the level of service offered or projected. In the instance where a station area encompasses areas on different landmasses, the buffer is nonetheless marked with a single identifier. In addition, the short distance between some stations causes certain TOD zones to overlap. This presents a methodological issue requiring buffers to be aggregated, partitioned into odd shapes, or simply allowed to overlap. In regards to this problem, the PMAD calls for overlapping buffers to meet the strictest criteria among the affected station areas (CMM 2011). Given the large number of instances where this occurs, it was decided that buffers would be treated independently, regardless of the extent to which they overlap, in the first phase of analysis. Built environment and travel behaviour indicators were derived as averages to prevent double-counting. Partitioning the zones into erratic, non-overlapping areas would have been marginally useful in a planning context, as local TOD planning will be undertaken at the municipal or borough level and will consider the entire station area.

3.2: Assigning Priorities

The goal of the first phase of analysis was to determine how far the TOD zones are from meeting residential density and public transit mode share targets. The CMM provides residential densities for 2010, target densities for 2031 and travel modes for 2006 for each zone, among other basic characteristics. First, the zones were partitioned into separate datasets according to public transit mode. Metro stations and projected LRT stations were grouped together due to the small number of the latter and the similar targets assigned to both. The same was done for park-and-ride facilities and bus terminuses. Second, z-scores were calculated for the difference between current and target residential densities and for public transit mode share for each zone grouped by mode type. The two z-scores were then summed to obtain an indicator of the performance of each zone in regard to residential density and mode share targets. This indicator reflects how much better or worse a zone is performing relative to the mean performance of all stations offering a particular public transit mode. Finally, the best- and worst-performing 10% of zones for each mode were isolated for further analysis. The goal of this approach was to allow for comparisons between the built environments of best- and worst-performing zones in subsequent analyses. Some discretion was exercised in that zones of particular interest to the CMM were also included as priorities.

3.3: Characterizing the Priority Zones

The second phase of analysis consisted of selecting and deriving appropriate land use indicators and using them to characterize the priority zones in greater detail. Given the great variety of indicators used in the literature, it was necessary to develop a ranking system to assess the priority and feasibility of each according to the needs of the CMM, the strength of the indicator, and the availability of data. While the CMM has characterized the demographics and basic travel characteristics of the people currently inhabiting the zones, very little information has been collected about the land use patterns and design of the station areas. The assigned priorities take into account the built environment characteristics beyond residential densities that the CMM must consider in order to foster transit-oriented development.

The ranking procedure also reflects the reliability and strength of each indicator. As shown in the literature review, each indicator comes with a set of assumptions and limitations that affect its interpretation. For this study, it was critical to select indicators that can capture built environment characteristics at the small scale of a TOD zone without engendering severe aggregation problems. The selection of indicators also reflects the desired outcome, namely to measure land use characteristics that are likely to affect public transit use at the regional scale and active transport use at the station area scale. The amount of evidence amassed in the literature, in terms of the measured strength and number of times each indicator was used, was therefore considered.

Finally, the availability and quality of data presented constraints that rendered the calculation of certain indicators infeasible or undesirable. The available datasets, listed in Table 3.1, originate from various sources and are stored in different spatial units. Residential and employment density calculations rely mostly on census data stored in census units, which inevitably means that all calculations at the TOD buffer level are estimates. Furthermore, the lack of data on vertical mixing of uses within parcels greatly limits the possibility of using more sophisticated land use diversity measures. Capturing detailed transportation network design characteristics is also difficult as the datasets typically favour coverage over detail. While it is possible to derive basic design indicators using a street centreline file, characterizing station area pedestrian environments in greater detail requires either detailed data or qualitative observations. The scope of available data nonetheless allows for a fairly comprehensive overview of current land use and travel characteristics in the TOD zones.

The indicators were grouped into five categories, namely performance, density, diversity, design and capacity indicators. Performance indicators track the status of the TOD zones in terms of goals set by the CMM, which include residential density and mode share targets. Density, diversity and design indicators reflect the land use characteristics of the zones in an effort to obtain a more complete assessment of their current state. Finally, capacity indicators demonstrate the extent to which a TOD zone can be developed in terms of current public transit service levels, vacant land and estimated additional residential capacity.

Table 3.1: Characteristics of Available Datasets

Dataset	Year	Source	Spatial unit	Coverage
Canadian Census Data	2006	Statistics Canada	CT, DA	CMA
Characteristics of TOD zones	2006-2011	CMM	TOD zone	CMM TOD zones
Detailed land use, 23 classes	2011	CMM	Land use polygon	CMM
Aggregate land use, 7 classes	2007	DMTI Spatial	Land use polygon	Province
Origin-Destination Survey data	2008	AMT	Point	CMM
Enhanced Points of Interest	2008	DMTI Spatial	Point	Province
Street centreline files	2007	DMTI Spatial	Line	Province

Unless previously calculated by the CMM, indicator values were derived in ArcMap using the same basic procedure (detailed procedures for each indicator are listed in Appendix B). Spatial datasets were first associated to the priority TOD zones via the *Intersect* tool. Values were then calculated for areas falling within the zones using *Field Calculator*. If needed, the values were averaged for the entire TOD zone using *Summarize.* Indicators requiring no additional data than that provided by the CMM, pre-clipped to the TOD zones, were simply calculated in Excel.

Performance indicators

- **Performance index:** This measure was created to assign priorities among the TOD zones. It is the sum of the z-scores of the differential from the target residential density and of the public transit mode share of a TOD zone as an origin.
- Differential from target residential density: The 2010 residential density of a TOD zone was subtracted from its 2031 target, yielding a positive value for high-performing zones and a negative value for low-performing zones

- **Public and active transport mode shares:** Mode shares were calculated based on data from the 2008 Origin-Destination Survey. Origins lying within a TOD zone were clipped to the zone and the proportions of public and active transport trips were calculated. The same procedure was repeated for the TOD zones as destinations, where the end points of trips lying within a zone were clipped to the zone.

Density indicators

- **Activity density:** This measure is simply the sum of gross population and employment density (2006) and reflects the total amount of activity within a TOD zone.

Diversity indicators

- **Jobs-housing balance:** Also known as jobs-housing mix, this measure is a ratio of the number of jobs (2006) and the number of housing units (2006) in a TOD zone.

- **Entropy score:** The entropy score is defined as

$$LUM = - \frac{\Sigma\, p_i \ln p_i}{\ln n}$$

  where p_i is the ratio of each land use classification area to the area of the TOD zone and n is the number of land uses considered. Scores fall between 0 and 1, where 1 indicates a perfect mixture of all land uses in a given area. In this study, 2007 land use data from DMTI Spatial, Inc. were used. Five land uses were considered, namely residential, commercial, government and institutional, industrial and parks. Although detailed 2011 land use data was available, other diversity measures were impossible to calculate from the latter due to the inclusion of streets as distinct land uses.

- **Simpson's diversity index:** The index is defined as

$$S = 1 - \Sigma\, p_i^2$$

  where p_i is the area of each land use type found in a particular TOD zone. The index calculates the sum of squares of the area of different land use within a neighbourhood, which effectively weights dominant land uses more heavily than secondary uses. The 2007 DMTI land use shapefile, excluding open space and water, was also used to calculate this measure.

- **Land use interaction length:** This indicator measures the length of shared edges between compatible land uses. In its original form, commercial, institutional, government and industrial uses are grouped into employment lands, and parks, recreation and water into recreational opportunities (Manaugh and Krieder (in press)). Together with residential land use, these coarse classifications group land uses according to likely trip purposes, thus allowing meaningful interactions to be identified. The aggregated land use polygons were converted to lines and only the lines bordering two complementary land uses were preserved. The total length of interaction lines per TOD zone was then calculated as an indicator of land use mix and of the likelihood of active transport trip generation. An interaction length of zero means a TOD zone exhibits no interaction between compatible land uses and likely has one dominant land use. The 2007 DMTI land use layer was used in lieu of the detailed 2011 CMM land use layer due to the impossibility of detecting interactions in the latter. The CMM data treats streets as separate land uses, making it impossible to determine whether two complementary land uses on different sides of the street interact.

- **Walk Score®:** The calculation of this measure of land use mix is provided in Walk Score® (2011). For the purposes of this study, the postal code-level Walk Scores were intersected with the TOD zones and averaged.

- **Number of essential services per 1000 population:** This indicator was calculated from the DMTI Enhanced Points of Interest shapefile. Essential services defined as those with SIC codes 5411, 5431 or 5912, namely grocery stores, fruits and vegetable markets and drug stores

Design indicators

- **Intersection density:** The indicator is defined as the number of intersections within a TOD zone, excluding intersections with expressways (2007 data).

- **Street density:** A streets layer with expressways removed was first intersected with the TOD zones (2007 data). The length of street segments was then recalculated and expressed as a ratio of TOD zone area.

- **Average commercial/institutional lot size:** This measure was derived by calculating the area of commercial and institutional land use polygons in the detailed 2011 land use data provided by the CMM. The commercial and institutional land use “patches” in this dataset are indicative of the morphological barriers created by large lots.

Capacity Indicators

- **Number of bus lines:** This measure indicates the number of bus lines passing through each TOD zone, excluding different route paths of the same line (2012 AMT Open Data)

- **Number of bus agencies:** An indicator of intermodality, this measure counts the number of bus service providers passing through a TOD zone (2012 AMT Open Data).

- **Estimated additional residential capacity, area of vacant land and announced residential projects:** These are CMM estimates of the capacity of a TOD zone to accommodate new development. They not only reflect the total number of additional residential units a TOD zone could accommodate but also the number of residential units already slated for construction (2011 data).

Table 3.2: Indicators selected for analysis

Performance indicators	Datasets used
Performance indicator	CMM (2008-2011)
Differential from target residential density	CMM (2010, 2011)
Public transit mode share (as origin)	AMT OD survey (2008)
Active transport mode share (as origin)	AMT OD survey (2008)
Public transit mode share (as destination)	AMT OD survey (2008)
Active transport mode share (as destination)	AMT OD survey (2008)
Density indicators	
Population density (gross)	Statistics Canada (2006)
Employment density	Statistics Canada (2006)
Activity density	Statistics Canada (2006)
Diversity indicators	
Job-housing balance	CMM (2006)
Entropy score	DMTI Land Use (2007)
Simpson's diversity index	DMTI Land Use (2007)
Length of land use interactions	DMTI Land Use (2007)
Walk Score®	Walk Score®
Number of essential services per 1000 pop.	DMTI EPOI (2007)
Design indicators	
Street density	DMTI Streetfiles (2007)
Intersection density	DMTI Streetfiles (2007)
Average commercial/institutional lot size	CMM Land Use (2011)
Capacity indicators	
Number of bus lines	AMT Open Data (2012)
Number of bus agencies	AMT Open Data (2012)
Total area of vacant land	CMM characterization (2011)
Estimated additional residential capacity	CMM characterization (2011)
Announced residential development	CMM characterization (2011)

3.4: Benchmarking

The only concrete targets currently used by the CMM are for dwelling density. Although the PMAD calls for an increase in public transit mode share to 30%, this is a region-wide target (CMM 2011). Suitable benchmarks were therefore required to characterize the TOD zones along other dimensions of density, diversity and design. To maintain a methodological consistency, all indicators, with the exception of dwelling density, were benchmarked according to their mean value among the previously selected priority zones, by service type. Although this method may not account for contextual factors affecting each station differently, it provides guidelines for setting priorities.

The z-score of each indicator value reflects the distance that value lies from the mean, which offers insight into the performance of a particular zone in regards to a given land use characteristic. The magnitude of the z-scores were used to group indicator values by the number of standard deviations they are away from the mean. These groupings correspond to four levels of priority represented by a colour-coding scheme. In most cases, a z-score above 0 indicates a good performance and is represented by a green dot. Z-scores between -1 and 0 received a yellow dot, between -2 and -1, a red dot, and less than -3, a black dot, indicating the lowest performance. In the case of Simpson's diversity indices and commercial and institutional lot sizes, the inverse is true, as z-scores above 0 reflect a lower performance. Capacity indicators were not benchmarked as they are absolute values rather than means.

4.0: IDENTIFICATION AND CHARACTERIZATION OF PRIORITY ZONES

Of the 154 TOD zones, 100 are currently below residential density targets. The areas surrounding commuter train stations are, on average, significantly below residential density targets and have relatively low public transit mode shares (Table 4.1). The neighbourhoods along metro lines, however, tend to be above density targets and have significantly higher public transit mode shares. The two major projected transit lines, namely the Mascouche-L'Assomption commuter train line and the South Shore LRT, are both currently below residential density targets. The station areas along the South Shore LRT nonetheless benefit from existing high residential density and relatively frequent transit service.

Table 4.1: Mean Density and Mode Share Characteristics of TOD zones by Transit Line

Line*	Residential density (units/ha)	Differential from target density (units/ha)	Public transit mode share (as origin)
Train Blainville-Boisbriand-Saint-Jérôme	32.6	21.4	14%
Train Delson-Candiac	28.8	-28.3	13%
Train Deux-Montagnes	27.4	-29.3	19%
Train Mascouche-L'Assomption (projected)	31.3	-24.3	14%
Train Mont-Saint-Hilaire	16.2	-33.8	13%
Train Vaudreuil-Hudson	17.5	-30.0	13%
Metro Green Line	123.1	19.0	32%
Metro Orange Line	110.5	21.0	30%
Metro Longueuil (station)	53.1	-56.9	33%
Metro Blue Line	87.5	4.6	30%
South Shore LRT (projected)	94.8	-2.3	27%
North and South Shore park-and-rides	19.6	-13.2	11%
North and South Shore bus terminuses	33.0	-0.3	12%

**Train line summaries exclude intermodal metro stations; all lines include current and projected stations*

The procedure described in the previous section yielded 32 TOD zones slated for further analysis, namely the zones scoring within the upper and lower 10% of the residential density and mode share performance indicator for each mode type (Figure 4.1). Among the selected zones were 6 current and 6 projected commuter train stations, 11 existing and 2 projected metro stations, 3 projected LRT stations, 1 existing and 2 projected park-and-ride facilities, and 1 existing bus terminus.

4.1: Characterization by Service Type

The following subsections describe the collective performance of priority zones by service type. Comparing the density and mode share of the highest- and lowest-performing zones provides an indication of the characteristics that lead to successful transit-oriented development. However, it is important to consider the location of a TOD zone within the metropolitan region. A high-performing zone, as identified by the performance indicator described previously, is likely to be closer to the central business district. Furthermore, the performance of a zone for particular indicators compared to others might provide evidence of the type of TOD a zone might become. For instance, a zone exhibiting high employment density relative to population density might suggest it is likely to become an employment center.

4.1.1: Commuter Train Stations

As expected, the highest-performing commuter train station zones are located closer to the CBD, while the lowest-performing are located in suburban areas (Figure 4.1). The lowest-performing stations are all significantly below their target dwelling densities, while the highest-performing stations are typically very close to their targets (Figure 4.2). Although the lowest-performing zones have significantly lower public and active transport mode shares on average, A-13 (projected) and Saint-Hubert stations exhibit higher relative public transit mode shares within this group. With public transit mode shares of approximately 15%, these stations are about halfway to the regional target of 30%. Evidently, the projected train stations have the lowest non-automobile mode shares and lowest activity density. A-13, Mascouche, Terrebonne and Saint-Hubert stations have activity densities near or below 20 inhabitants and jobs per hectare yet contain a good balance of housing and employment.

Figure 4.1: Location of Highest- and Lowest-Performing Train TOD Zones

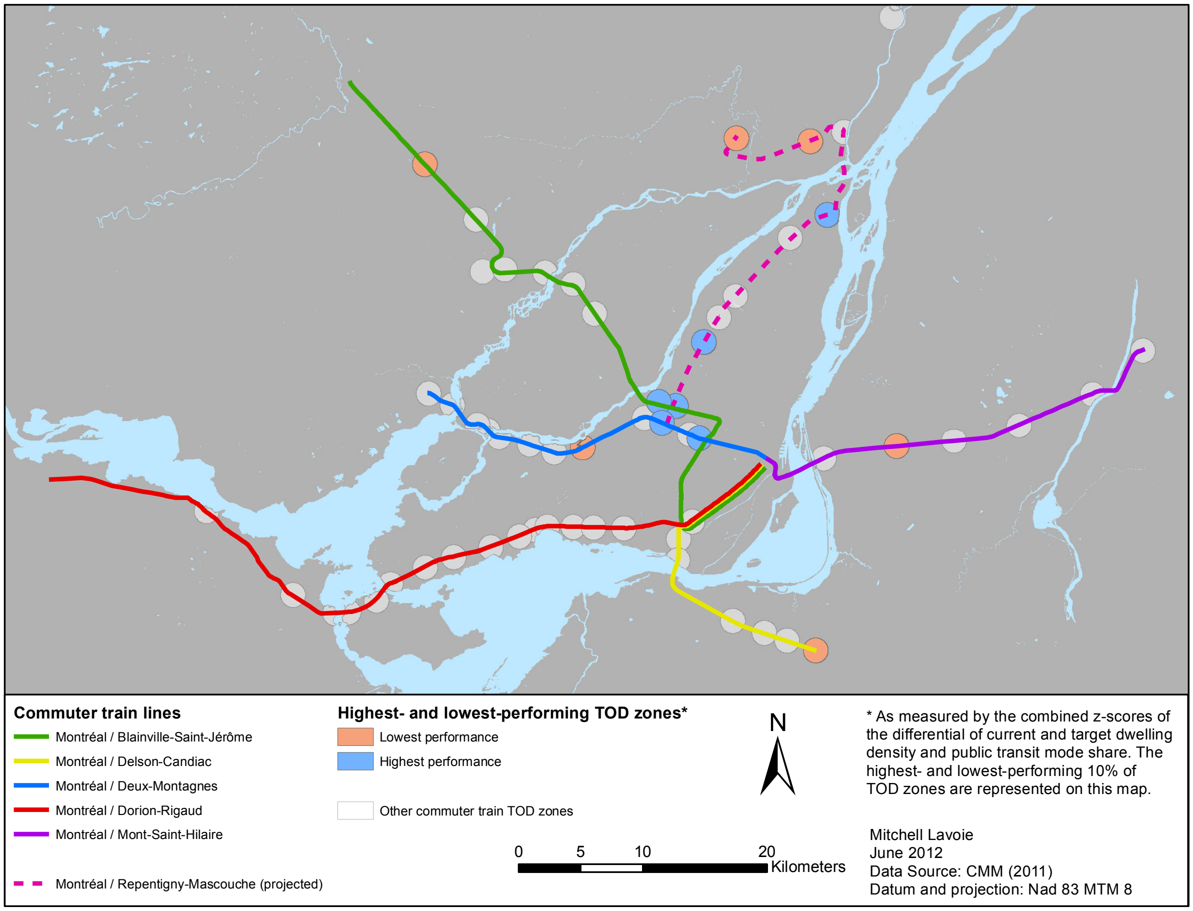
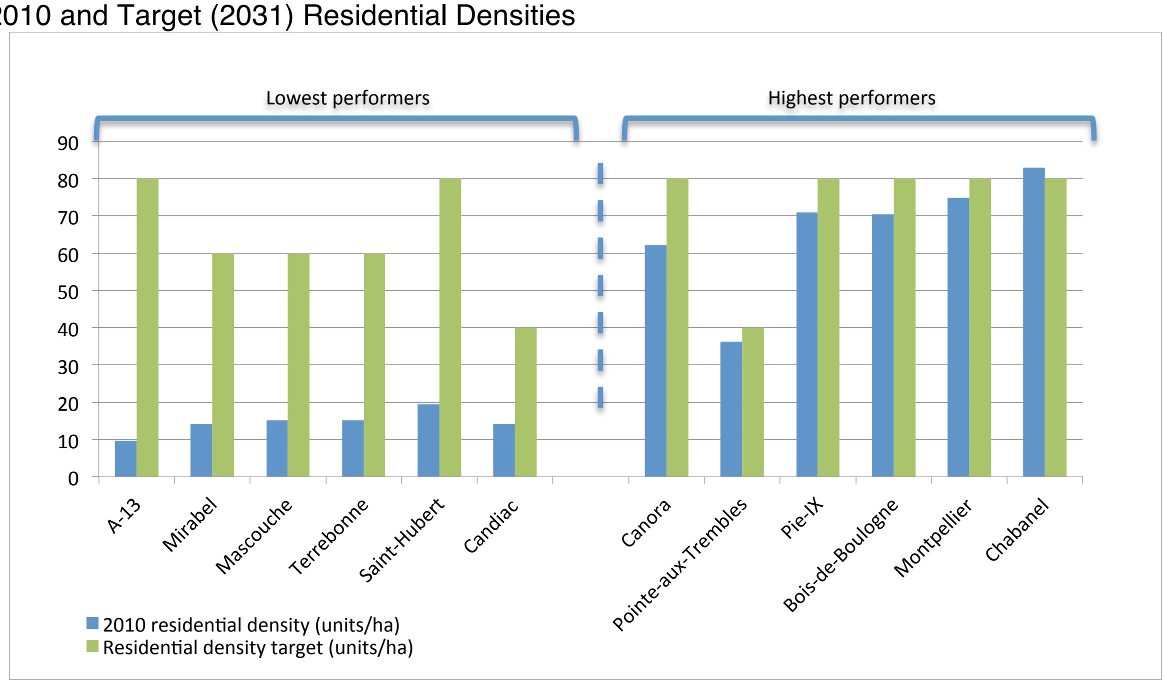
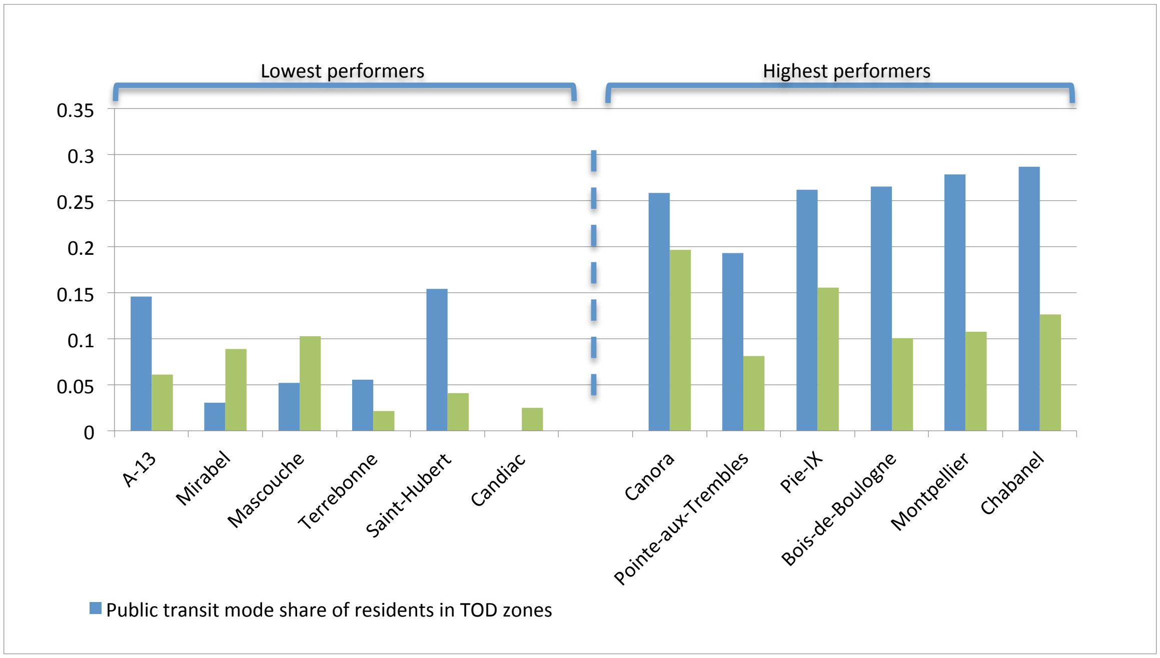


Figure 4.2: Characteristics of Highest- and Lowest-Performing Train TOD Zones

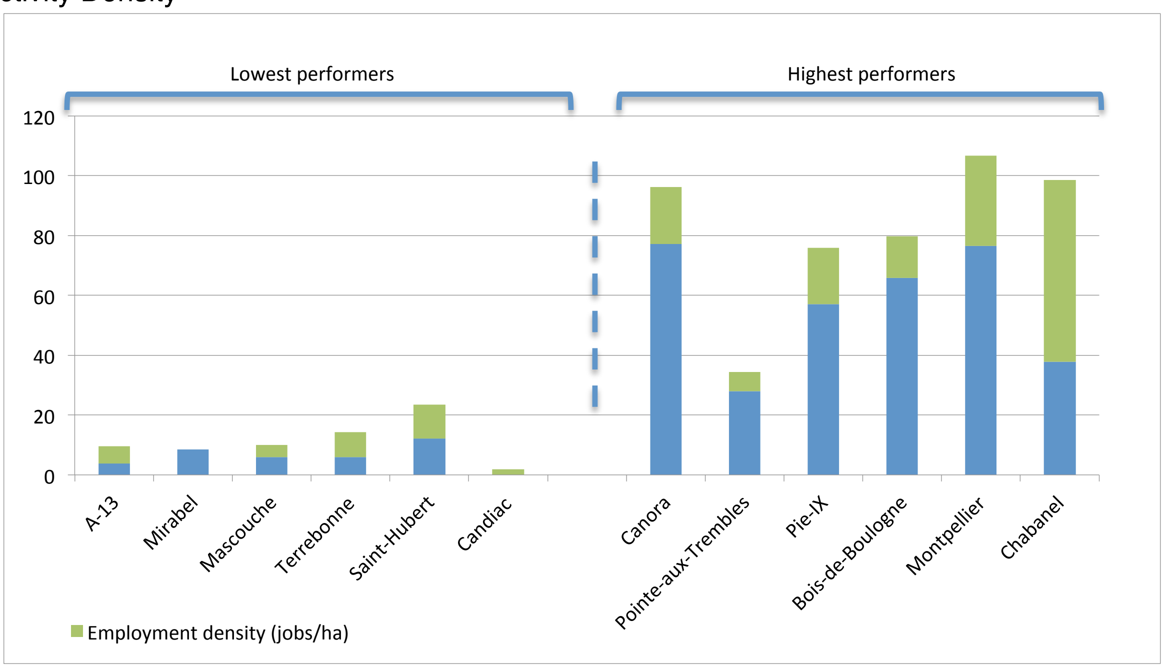
a) 2010 and Target (2031) Residential Densities



b) Public and Active Transport Mode Share as Origin



c) Activity Density



4.1.2: Metro and Projected LRT Stations

Given the very high capacity of metro and LRT services, residential densities around their stations are expected to be higher than those of commuter train stations. The highest-performing zones of this group are in central areas, most notably in the central business district, namely around Square-Victoria and Place-d'Armes metro stations (Figure 4.3). However, the high-performing yet lower-density stations in well-established neighbourhoods, such as Jarry, Joliette and de Castelnau, are more suitable precedents for the low-performing zones. The existing residential densities in these neighbourhoods are similar to the targets set for the low-performing zones (Figure 4.4). Although the low-performing zones are generally closer to their residential density target than commuter train station areas, most have low public and active transport mode shares and low activity density. Of particular interest are the three recently-opened metro stations in Laval, namely Cartier, de la Concorde and Montmorency. The mode shares and activity densities at these stations are approximately half those of high-performing stations in well-established neighbourhoods. Other stations, such as Brossard-Chevrier and Langelier stations, are expected to perform relatively poorly given that they are not currently in service.

Figure 4.3: Location of Highest- and Lowest-performing Metro/LRT TOD Zones

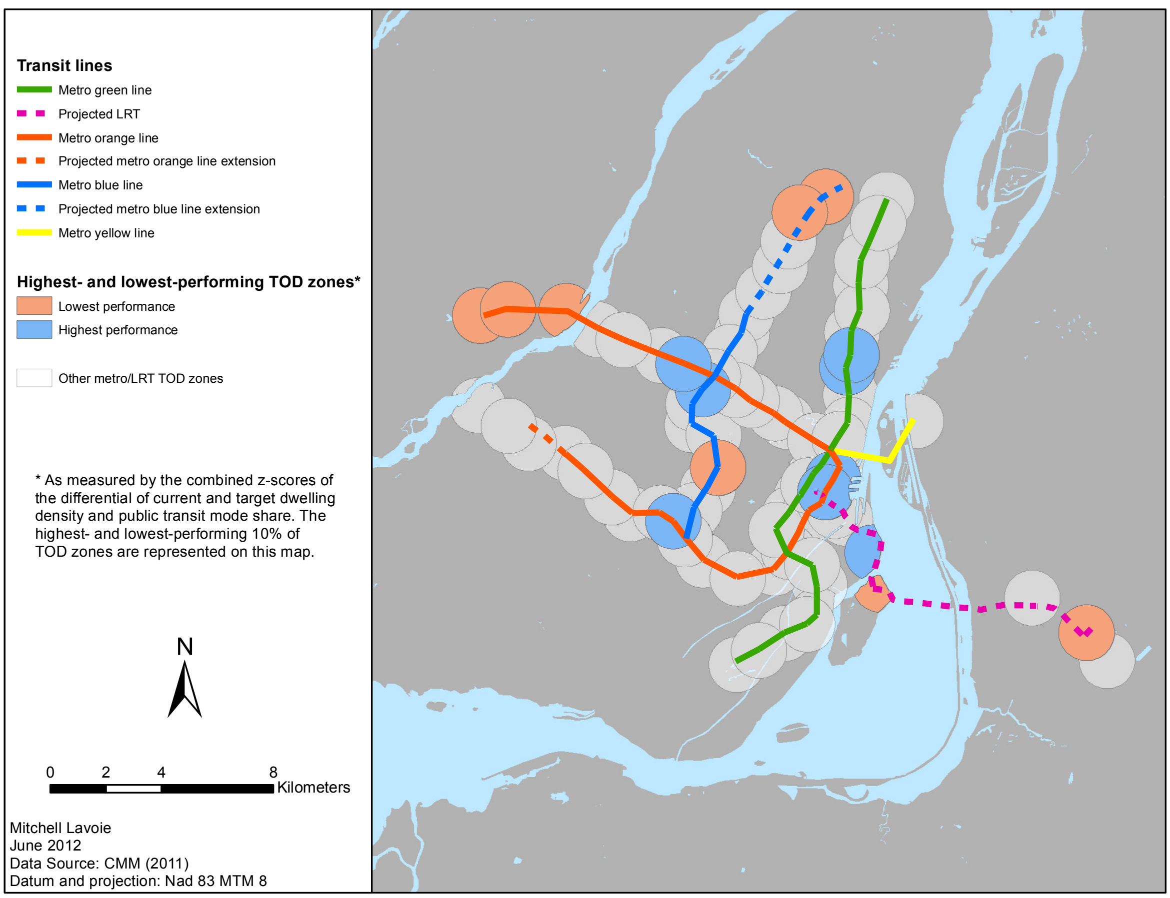
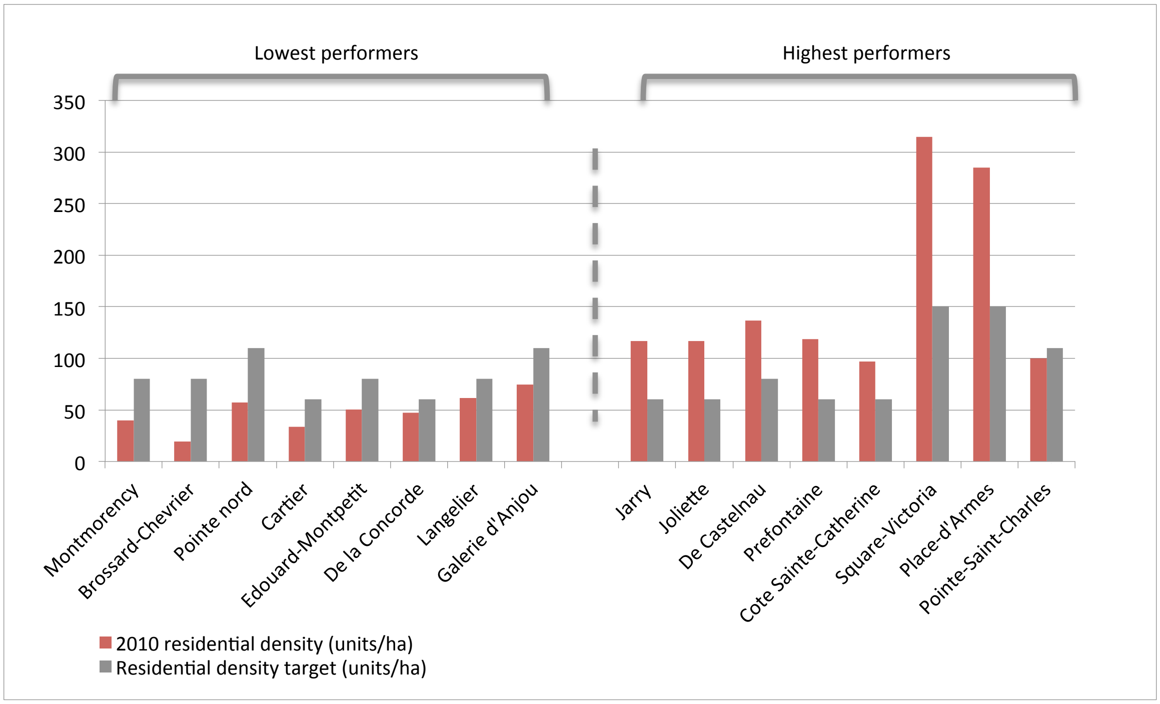
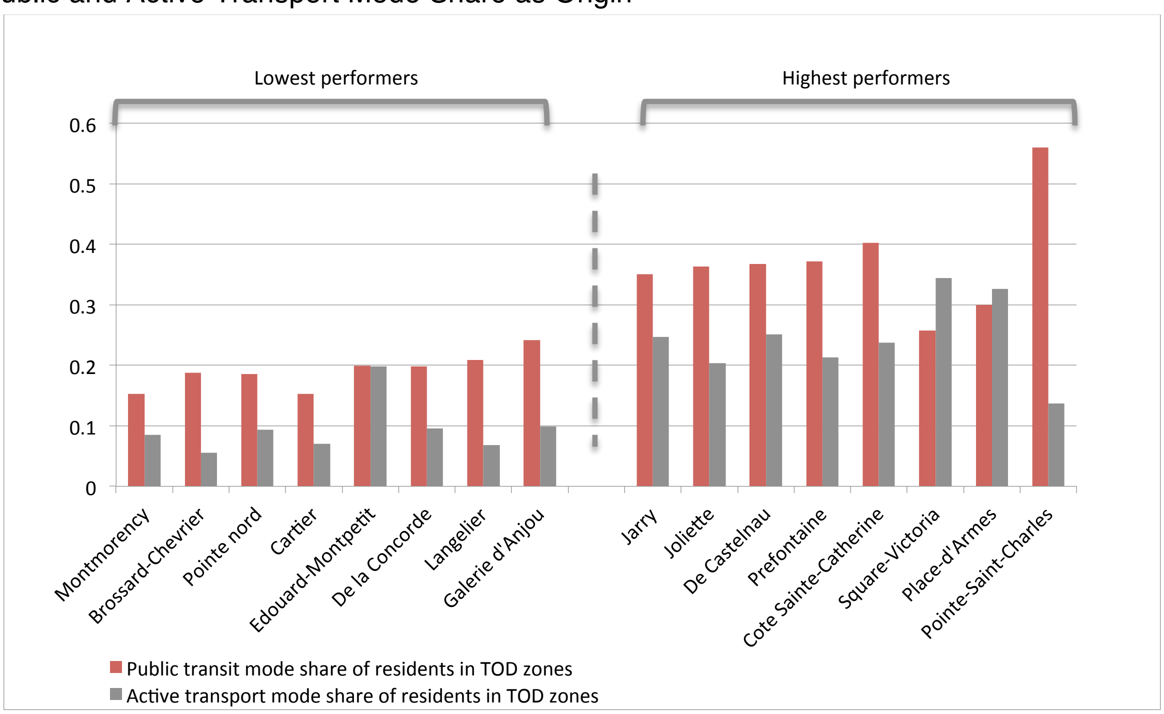


Figure 4.4: Characteristics of Highest- and Lowest-Performing Metro/LRT TOD Zones

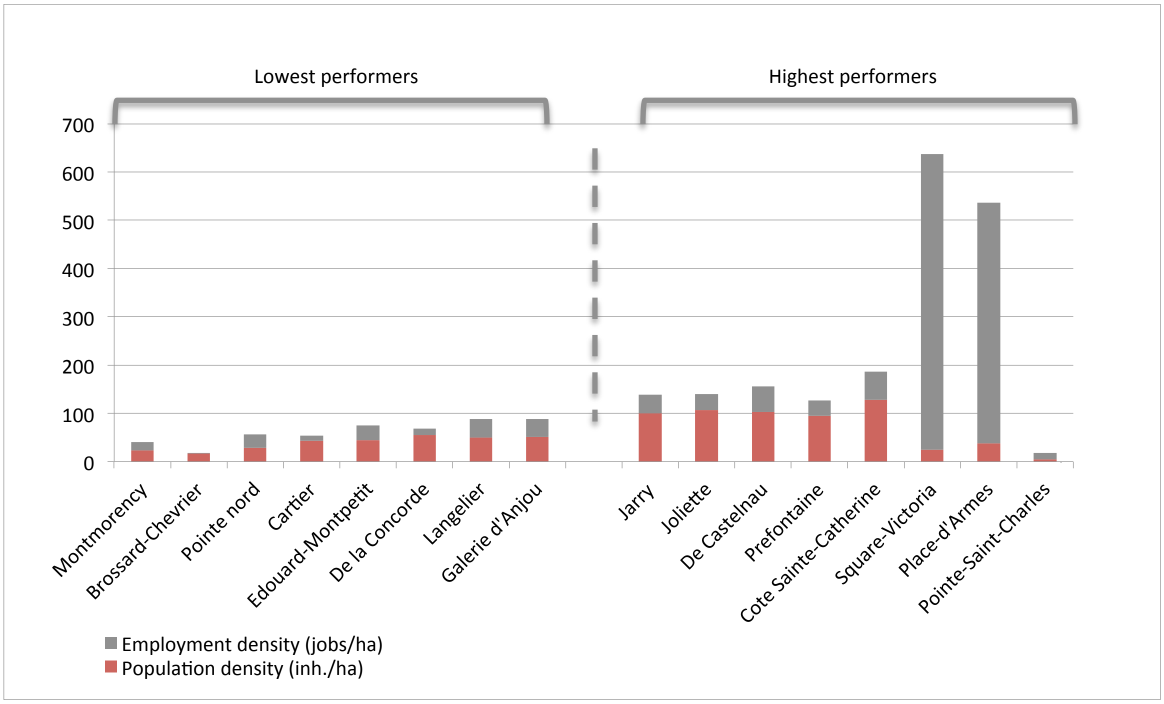
a) 2010 and Target (2031) Residential Densities



b) Public and Active Transport Mode Share as Origin



c) Activity Density



4.1.3: Park-and-Rides and Bus Terminals

These types of facilities are typically located in suburban areas with low residential densities. The La Prairie park-and-ride facility and the De Montarville bus terminal are examples of station areas that have surpassed residential density targets (Figure 4.4). In particular, De Montarville station achieves a relatively high public transit mode share of 25%. Delson and Bois-des-Filion, both projected park-and-ride facilities, are less than halfway to their residential density targets, which is reflected in their relatively low public transit mode shares. The activity density in these station areas indicates a primarily residential vocation with proportionally less employment than La Prairie and de Montarville stations.

Figure 4.5: Location of Highest- and Lowest-Performing Park-and-Ride/Bus Terminal TOD Zones

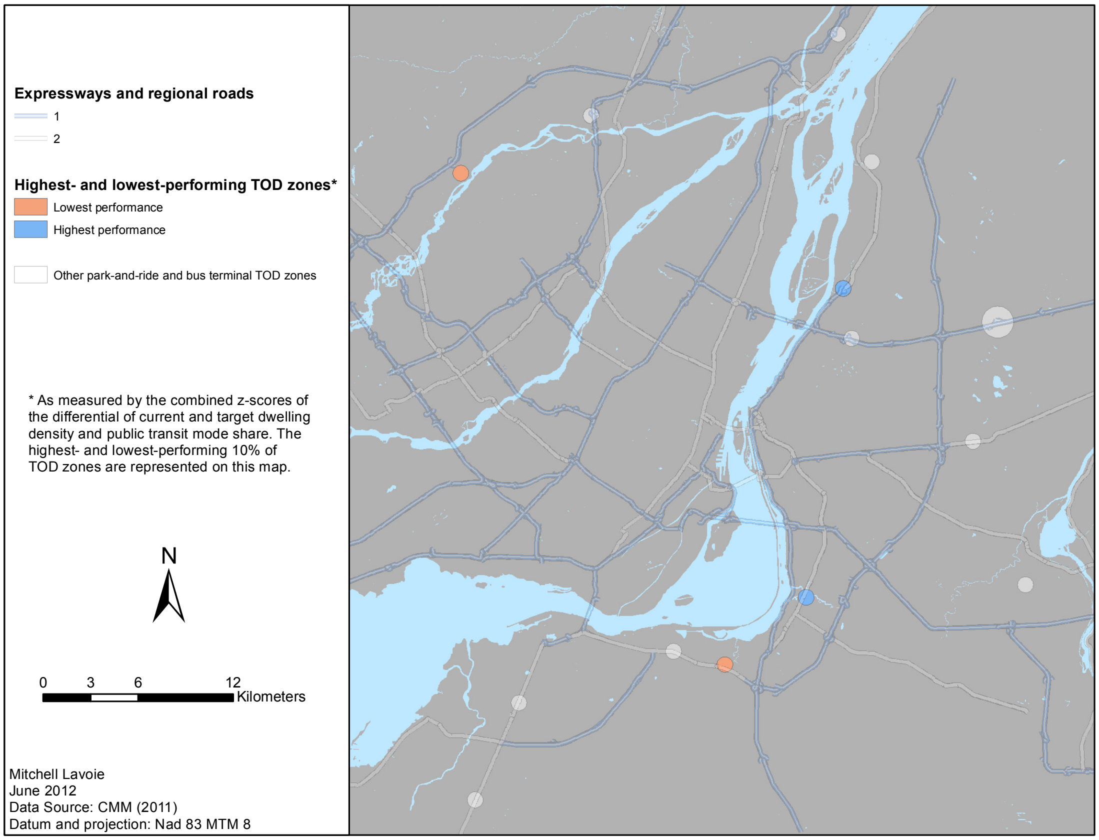
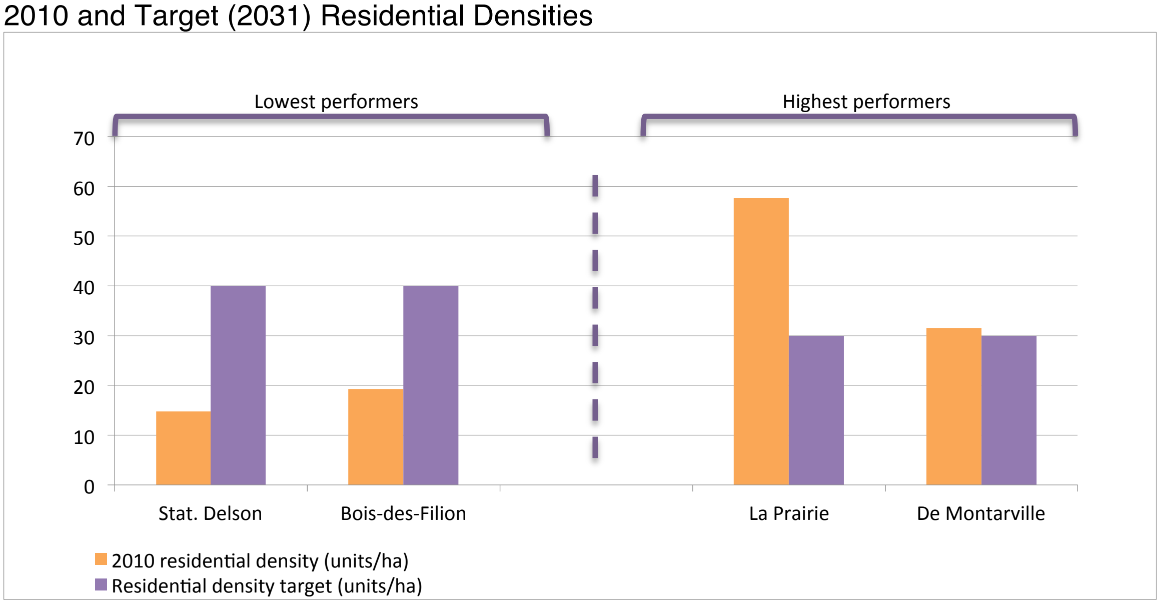
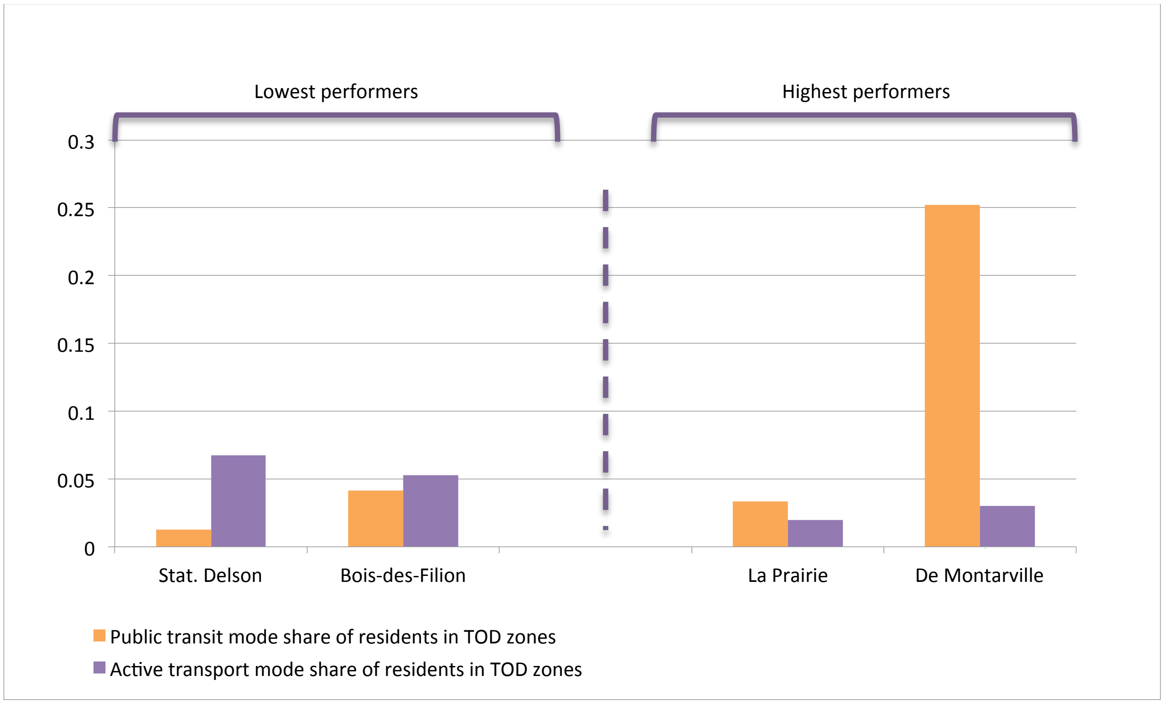


Figure 4.6: Characteristics of Highest- and Lowest-Performing Park-and-ride and Bus Terminal TOD Zones

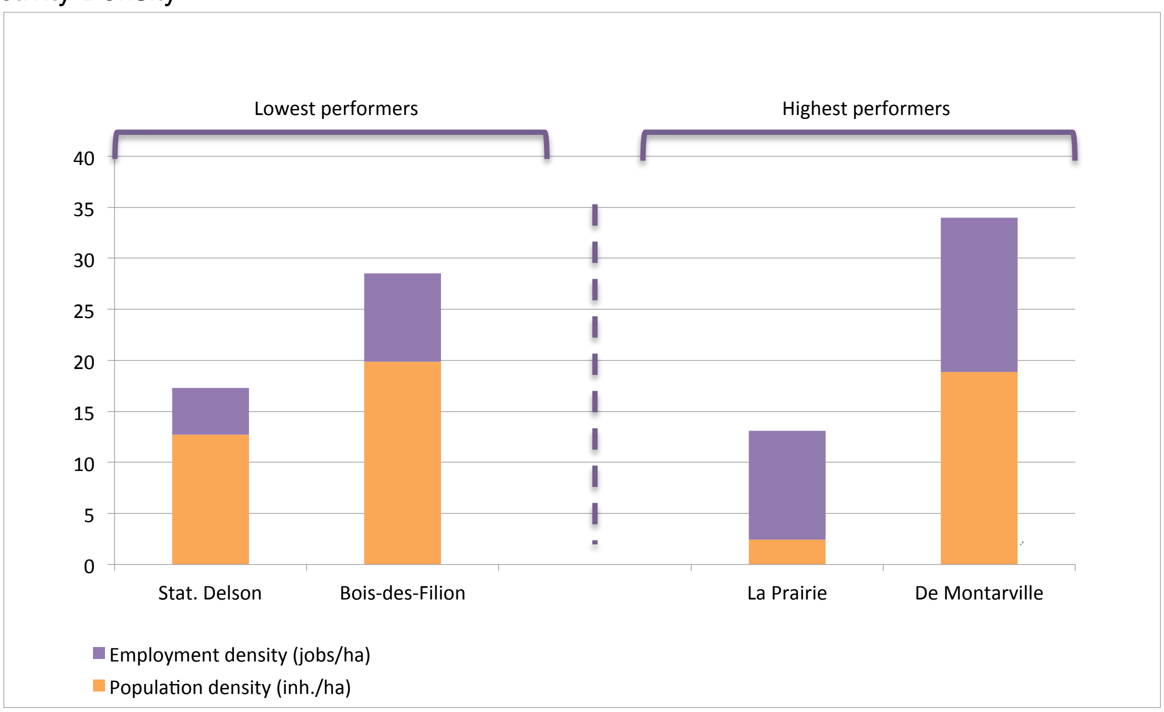
a) 2010 and Target (2031) Residential Densities



b) Public and Active Transport Mode Share as Origin

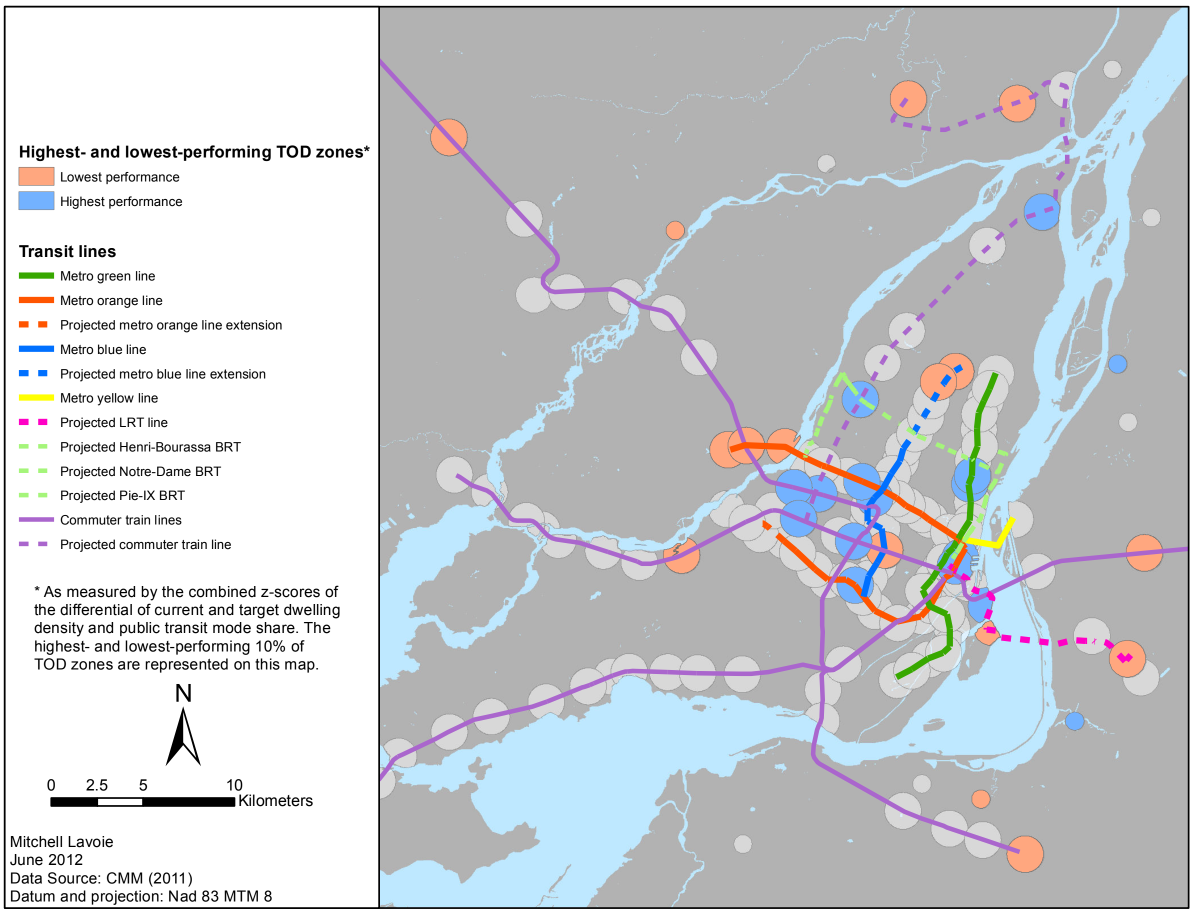


c) Activity Density



The information presented above clearly indicates that priority should be given to TOD zones in suburban environments. The current and future access points to the public transit network in greatest need of planning are primarily located along commuter train lines, at the extremities of metro lines and at suburban commuter parking and bus facilities (Figure 4.7). The 16 lowest-performing zones lie significantly below target residential densities and exhibit low activity density and low public transit mode share. These characteristics demonstrate a need to look deeper into the context of land use and transportation at each individual station.

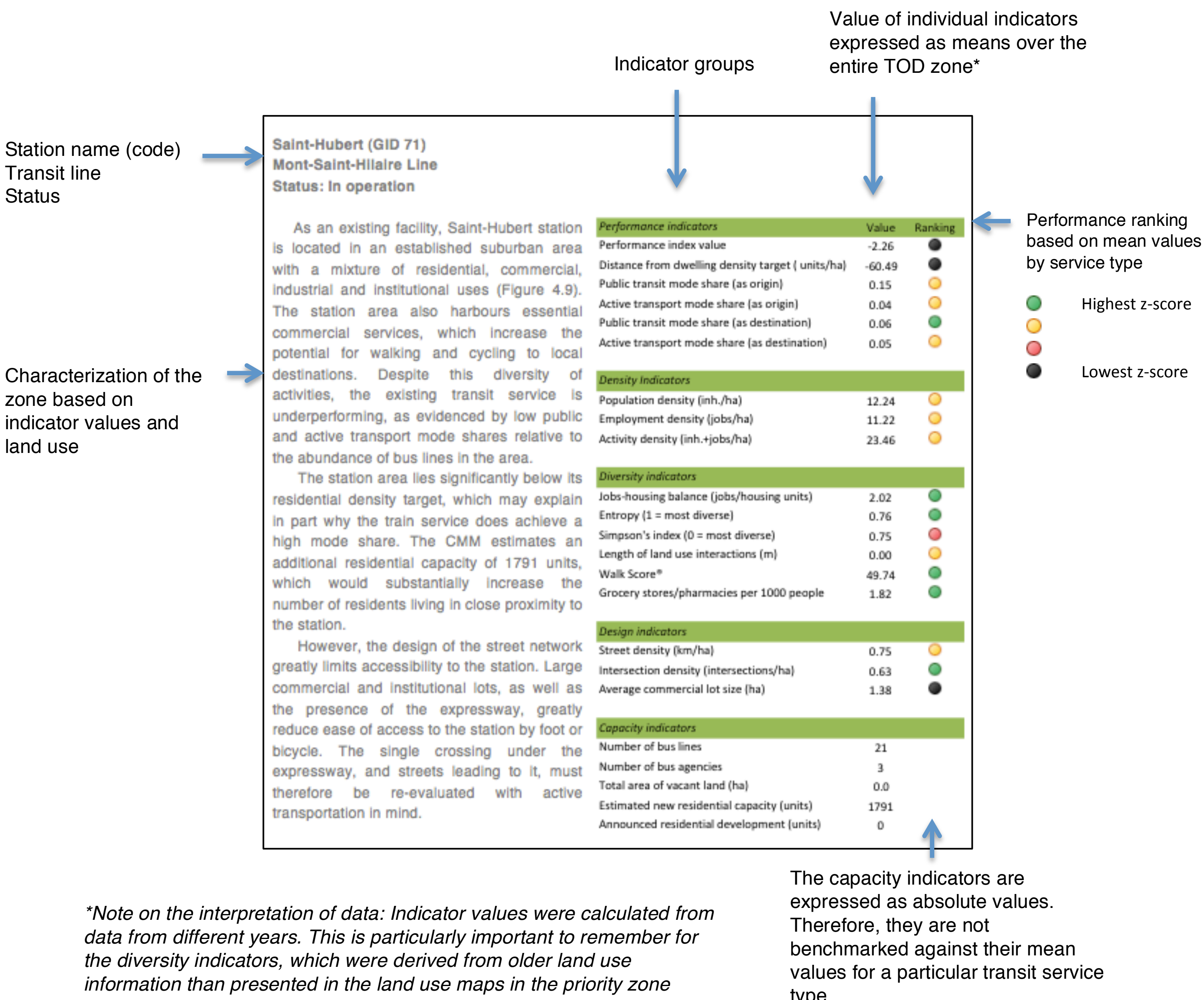
Figure 4.7: Location of Highest- and Lowest-Performing TOD Zones Among all Service Types



4.2: Characterization by Zone

The following sections describe in detail the performance of each priority zone in regards to the series of land use and transportation indicators outlined previously. The stations are grouped according to service type and, where applicable, by line. Indicators of mode share, density, diversity, design and capacity to accommodate growth inform an assessment of priorities for each zone. Figure X presents a guide for understanding the elements of the priority zone profiles.

Figure 4.8 : Guide for understanding the priority zone profiles



Saint-Hubert (GID 71)
Mont-Saint-Hilaire Line
Status: In operation

As an existing facility, Saint-Hubert station is located in an established suburban area with a mixture of residential, commercial, industrial and institutional uses (Figure 4.9). The station area also harbours essential commercial services, which increase the potential for walking and cycling to local destinations. Despite this diversity of activities, the existing transit service is underperforming, as evidenced by low public and active transport mode shares relative to the abundance of bus lines in the area.

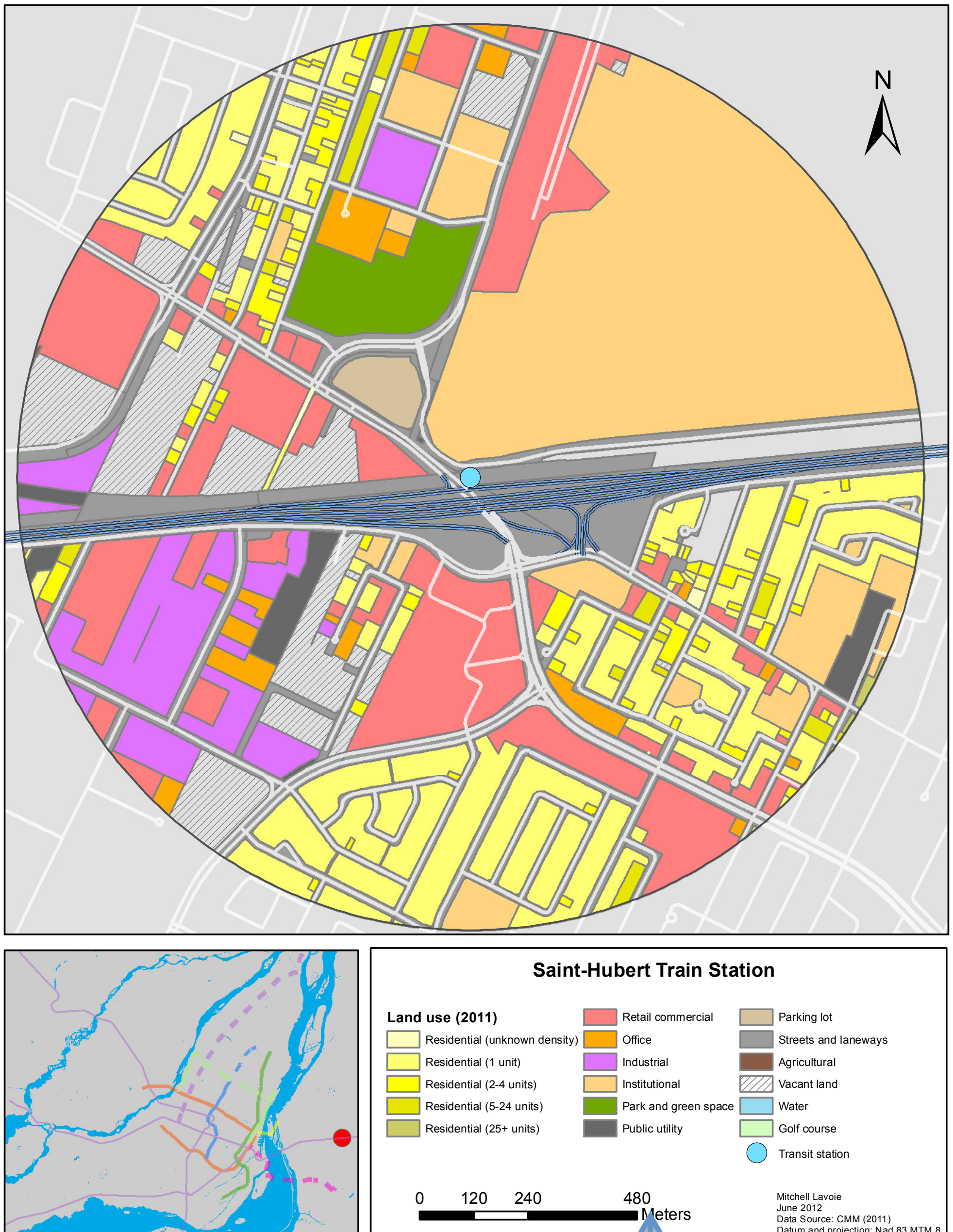
The station area lies significantly below its residential density target, which may explain in part why the train service does achieve a high mode share. The CMM estimates an additional residential capacity of 1791 units, which would substantially increase the number of residents living in close proximity to the station.

However, the design of the street network greatly limits accessibility to the station. Large commercial and institutional lots, as well as the presence of the expressway, greatly reduce ease of access to the station by foot or bicycle. The single crossing under the expressway, and streets leading to it, must therefore be re-evaluated with active transportation in mind.

Performance indicators	Value	Ranking
Performance index value	-2.26	● (black)
Distance from dwelling density target (units/ha)	-60.49	● (black)
Public transit mode share (as origin)	0.15	● (yellow)
Active transport mode share (as origin)	0.04	● (yellow)
Public transit mode share (as destination)	0.06	● (green)
Active transport mode share (as destination)	0.05	● (yellow)
Density Indicators		
Population density (inh./ha)	12.24	● (yellow)
Employment density (jobs/ha)	11.22	● (yellow)
Activity density (inh.+jobs/ha)	23.46	● (yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	2.02	● (green)
Entropy (1 = most diverse)	0.76	● (green)
Simpson's index (0 = most diverse)	0.75	● (red)
Length of land use interactions (m)	0.00	● (yellow)
Walk Score®	49.74	● (green)
Grocery stores/pharmacies per 1000 people	1.82	● (green)
Design indicators		
Street density (km/ha)	0.75	● (yellow)
Intersection density (intersections/ha)	0.63	● (green)
Average commercial lot size (ha)	1.38	● (black)
Capacity indicators		
Number of bus lines	21	
Number of bus agencies	3	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1791	
Announced residential development (units)	0	

**Note on the interpretation of data: Indicator values were calculated from data from different years. This is particularly important to remember for the diversity indicators, which were derived from older land use information than presented in the land use maps in the priority zone profiles. Please refer to the Methods section for additional information on the calculation of each indicator.*

Detailed land use map of the priority zone
(CMM 2011)



Location of the TOD zone
in the Montreal region

17 land use classes (the original dataset
contains 23 classes; different types of
institutional land use and public rights of way
were aggregated to simplify the maps.

4.2.1: Commuter Train Stations

A-13 (GID 64)
Deux-Montagnes line
Status: Projected

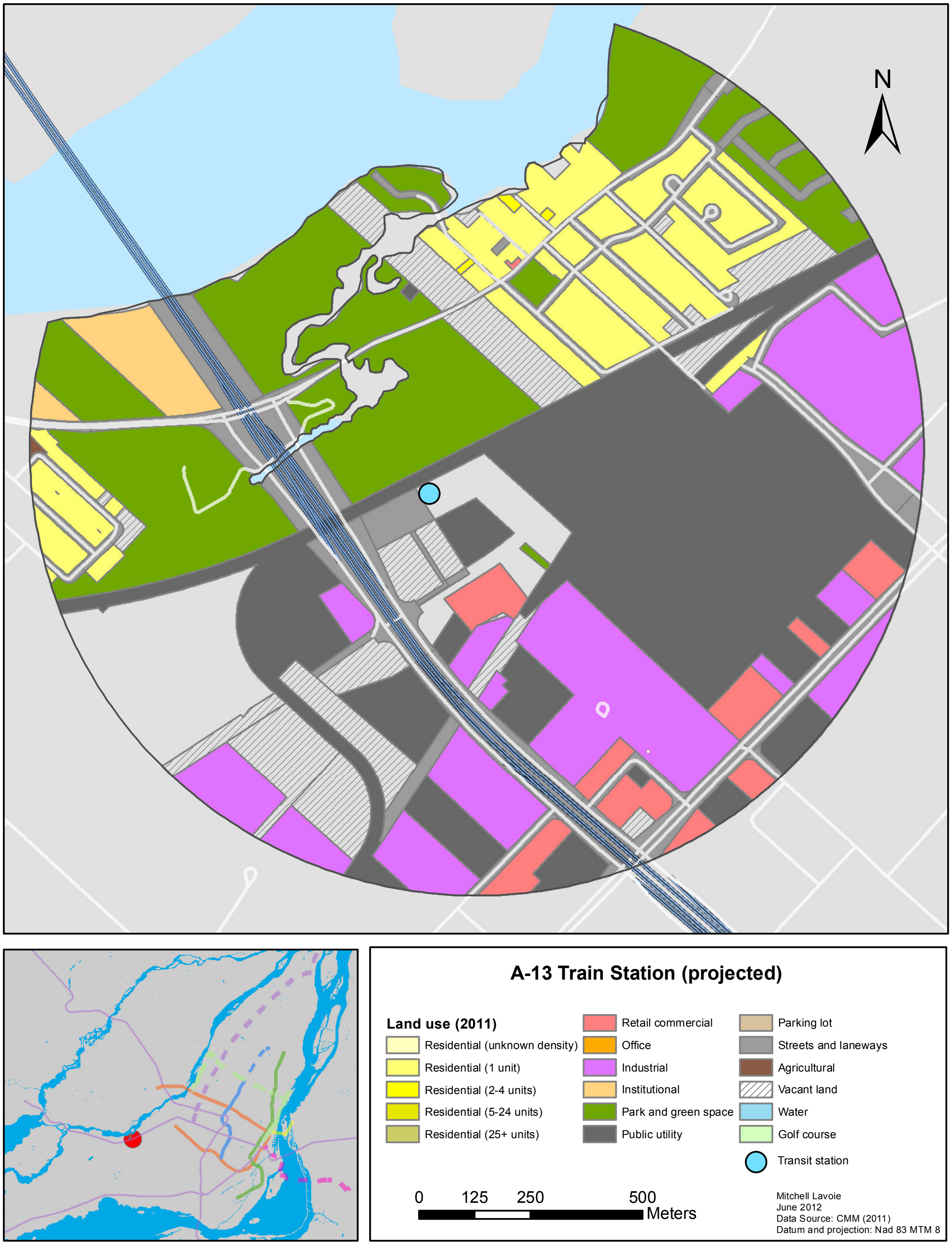
A-13 station currently lies substantially below its residential density target of 80 units/ha. However, the zone performs relatively well in regards to public and active transport mode share and displays a significant public transit mode share as a destination.

Above-average jobs-housing balance and land use entropy indicate a mixture of land uses conducive to increasing use of public and active transportation. The way in which the mixture of uses occurs may need improvement, however, as evidenced by below-average scores for Simpson's diversity index and land use interaction length. The zone's performance in these dimensions point to large lot sizes and land uses that dominate over others (Figure 4.5). Large industrial and public utility lots, as well as the Bois-de-Liesse Nature Park, might explain why the existing type of land use mix limits non-automobile travel.

The projected TOD zone is currently accessible via 14 bus lines operated by two transit agencies (STM and STL). Although the CMM indicates that there is no capacity for additional residential development, the high number of jobs relative to housing in this area suggests it can become a suburban regional centre geared towards employment.

Performance indicators	Value	Ranking
Performance index value	-3.07	● (black)
Distance from dwelling density target (units/ha)	-70.33	● (black)
Public transit mode share (as origin)	0.15	● (yellow)
Active transport mode share (as origin)	0.06	● (yellow)
Public transit mode share (as destination)	0.08	● (green)
Active transport mode share (as destination)	0.03	● (yellow)
Density Indicators		
Population density (inh./ha)	3.71	● (yellow)
Employment density (jobs/ha)	5.87	● (yellow)
Activity density (inh.+jobs/ha)	9.58	● (yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	5.03	● (green)
Entropy (1 = most diverse)	0.73	● (green)
Simpson's index (0 = most diverse)	0.87	● (black)
Length of land use interactions (m)	0.00	● (yellow)
Walk Score®	25.19	● (yellow)
Grocery stores/pharmacies per 1000 people	1.02	● (green)
Design indicators		
Street density (km/ha)	0.87	● (green)
Intersection density (intersections/ha)	0.43	● (yellow)
Average commercial lot size (ha)	1.09	● (red)
Capacity indicators		
Number of bus lines	11	
Number of bus agencies	1	
Total area of vacant land (ha)	9.8	
Estimated new residential capacity (units)	0	
Announced residential development (units)	0	

Figure 4.9: Land use around A-13 Commuter Train Station (Projected)



Mirabel (GID 32)
Blainville—Saint-Jérôme Line
Status: Projected

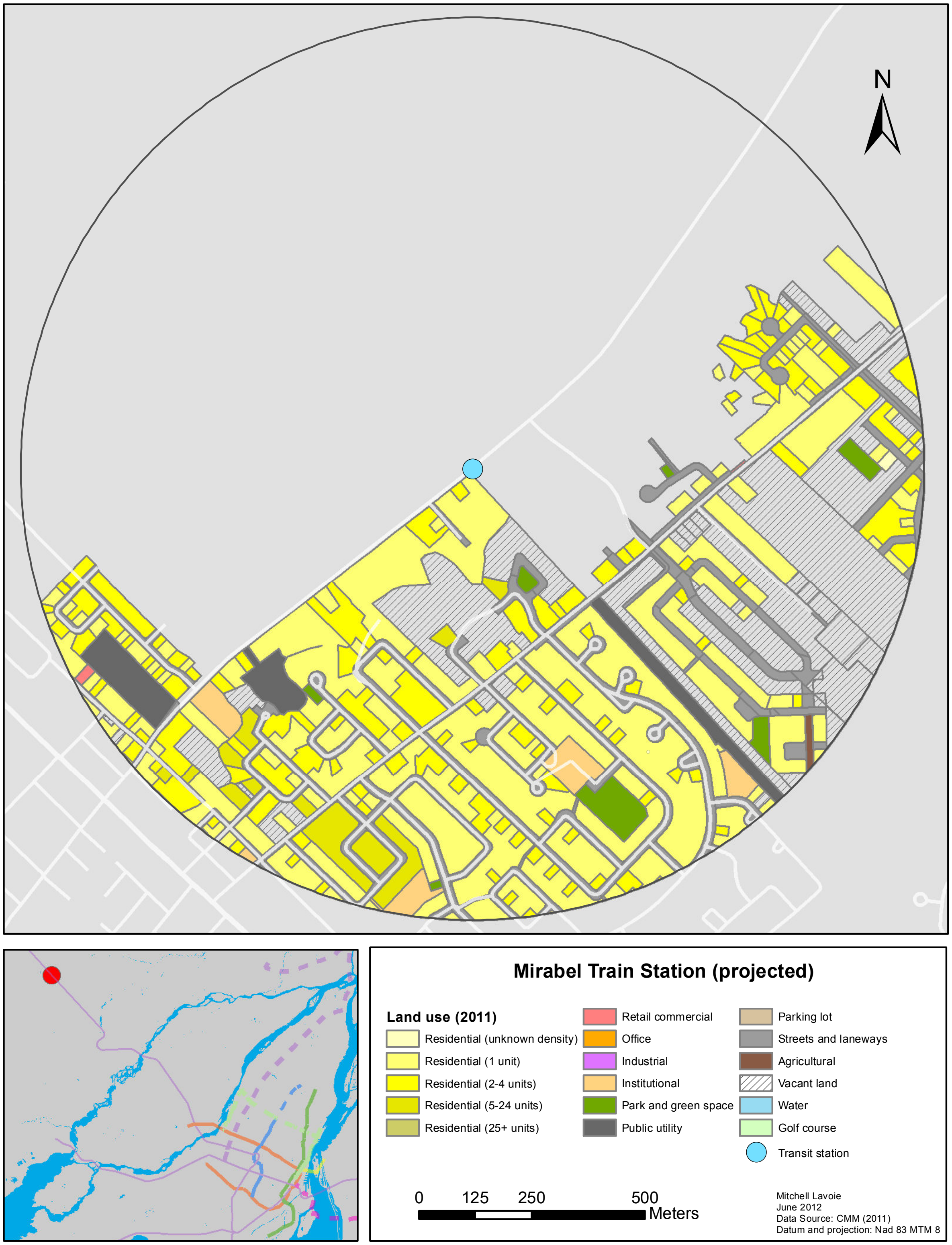
This station will occupy land that is currently agricultural, which explains its relatively low performance in both dwelling density and public transit mode share. The station area comprises some recent greenfield development but remains mostly undeveloped. As expected, all measures of land use diversity indicate little mixture or interaction of uses. This is also evident in Figure 4.6, which shows a predominance of 1-4-unit residential land use. There is a notable absence of essential commercial services and no interaction between complementary land uses, characteristics that would become important if future residents are expected to make trips using active transportation.

The design of the street network and the grain of development in the station area must be addressed. A predominance of cul-de-sacs also limit the number of possible routes a person walking or bicycling to the future station can take. The design of any upcoming development should therefore consider connectivity.

The CMM indicates a potential of 1163 new dwelling units in this area, suggesting the station area has capacity to accommodate greater numbers of residents in close proximity to the future train station. However, new or modified bus lines must serve the area if residents within and beyond the station area are expected to reach the station without the use of a personal vehicle.

Performance indicators	Value	Ranking
Performance index value	-2.77	⚫
Distance from dwelling density target (units/ha)	-45.81	🔴
Public transit mode share (as origin)	0.03	🔴
Active transport mode share (as origin)	0.09	🟡
Public transit mode share (as destination)	0.01	🔴
Active transport mode share (as destination)	0.20	🟡
Density Indicators		
Population density (inh./ha)	8.50	🟡
Employment density (jobs/ha)	0.00	🟡
Activity density (inh.+jobs/ha)	8.50	🟡
Diversity indicators		
Jobs-housing balance (jobs/housing units)	0.00	🟡
Entropy (1 = most diverse)	0.27	🔴
Simpson's index (0 = most diverse)	0.90	⚫
Length of land use interactions (m)	342.95	🟡
Walk Score®	25.82	🟡
Grocery stores/pharmacies per 1000 people	0.00	🔴
Design indicators		
Street density (km/ha)	0.90	🟢
Intersection density (intersections/ha)	0.24	🟡
Average commercial lot size (ha)	0.33	🟡
Capacity indicators		
Number of bus lines	0	
Number of bus agencies	0	
Total area of vacant land (ha)	32.3	
Estimated new residential capacity (units)	1163	
Announced residential development (units)	0	

Figure 4.10: Land Use Around Mirabel Commuter Train Station (Projected)



Mascouche (GID 34)
Repentigny-Mascouche Line (projected)
Status: Under construction

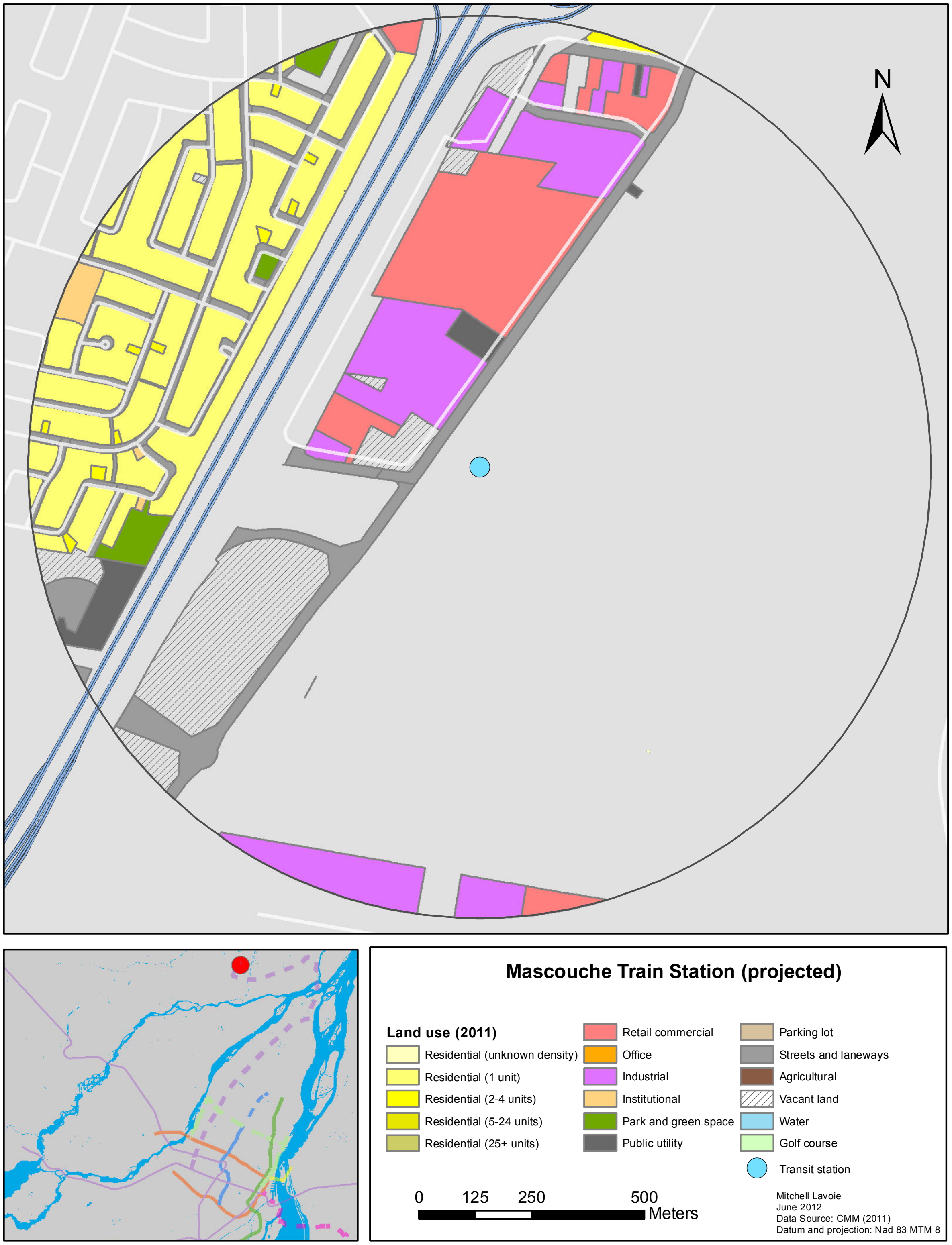
Currently under construction, this station lies significantly below its target residential density and exhibits low overall activity density. Although over 28 hectares of land are theoretically developable, the CMM predicts no additional residential capacity. An existing industrial park and small municipal airport further constrain residential development around the station (Figure 4.7). These existing uses explain why there is an abundance of jobs relative to the number of housing units in the area.

In its current state, the station area does not appear to be conducive to the use of either public or active transportation, as evidenced by its poor performance in public transit mode share, land use interaction and Walk Score. As a primarily industrial and large-scale commercial sector, it also contains very large lots that limit street connectivity. The entropy score and Simpson's diversity index point to a lack of land use diversity, particularly in the case of local commercial services.

An expressway acts as an additional barrier between the existing residential neighbourhood and the station area. Safe pedestrian and cyclist crossings over the expressway must be considered to encourage the use of active transportation to the station. The existing bus lines serving the area must also be reconfigured to ensure rapid access to the projected facility.

Performance indicators	Value	Ranking
Performance index value	-2.42	black
Distance from dwelling density target (units/ha)	-44.82	red
Public transit mode share (as origin)	0.05	red
Active transport mode share (as origin)	0.10	green
Public transit mode share (as destination)	0.01	yellow
Active transport mode share (as destination)	0.13	yellow
Density Indicators		
Population density (inh./ha)	5.90	yellow
Employment density (jobs/ha)	4.17	yellow
Activity density (inh.+jobs/ha)	10.07	yellow
Diversity indicators		
Jobs-housing balance (jobs/housing units)	2.08	green
Entropy (1 = most diverse)	0.44	yellow
Simpson's index (0 = most diverse)	0.90	black
Length of land use interactions (m)	0.00	yellow
Walk Score®	32.66	yellow
Grocery stores/pharmacies per 1000 people	0.00	red
Design indicators		
Street density (km/ha)	0.90	green
Intersection density (intersections/ha)	0.11	red
Average commercial lot size (ha)	1.73	black
Capacity indicators		
Number of bus lines	5	
Number of bus agencies	2	
Total area of vacant land (ha)	28.9	
Estimated new residential capacity (units)	0	
Announced residential development (units)	0	

Figure 4.11: Land Use Around Mascouche Commuter Train Station (Under Construction)



Terrebonne (GID 8)
Repentigny-Mascouche Line (projected)
Status: Under construction

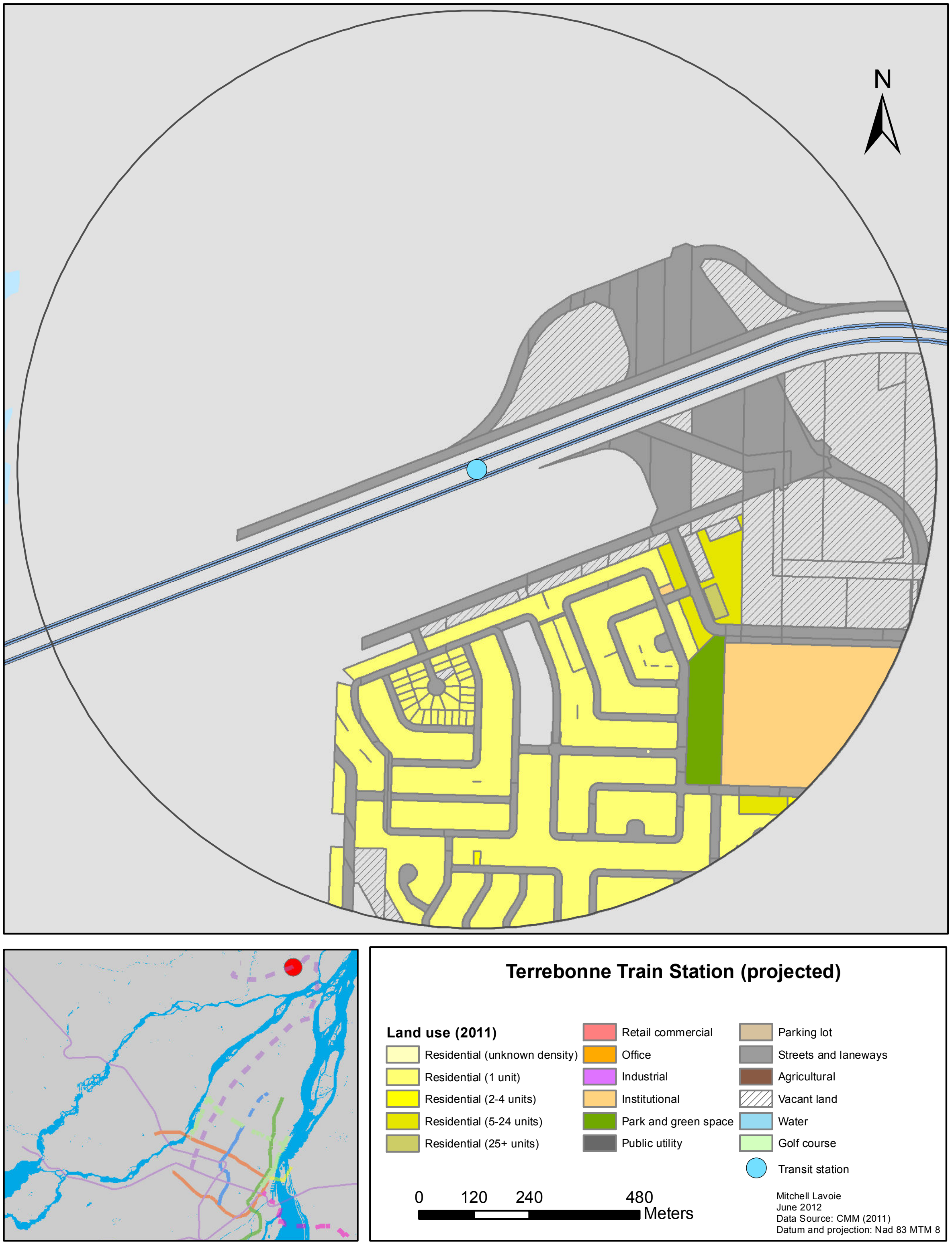
This projected station is equally distant from its residential density target as neighbouring Mascouche station, but contains a significantly greater area of developable land. The CMM estimates that the station area can accommodate an additional 2267 units, which would bring the latter closer to its target density. Although the area performs poorly in terms of public and active transport mode share, additional residential development, as well as the displacement-generating capacity of the station itself, would support additional public transit service. Currently served by two bus lines run by two separate bus agencies, the station has the potential to become a local intermodal hub.

Despite a surplus of jobs relative to housing, the lack of interaction between employment and residential uses greatly inhibits the use of non-automobile modes of transportation. A low performance on most diversity indicators reflects the dominance of low-density residential uses (Figure 4.8). Furthermore, the low intersection density brought by curvilinear street patterns and large residential lots reduces the connectivity of the street network.

To increase future commuter train ridership, any new residential development in the station area must be of higher density than what currently exists. The intensification of residential uses must be supported by ease of accessibility to the station.

Performance indicators	Value	Ranking
Performance index value	-2.38	● (black)
Distance from dwelling density target (units/ha)	-44.82	● (red)
Public transit mode share (as origin)	0.06	● (red)
Active transport mode share (as origin)	0.02	● (red)
Public transit mode share (as destination)	0.05	● (yellow)
Active transport mode share (as destination)	0.03	● (red)
Density Indicators		
Population density (inh./ha)	6.02	● (yellow)
Employment density (jobs/ha)	8.26	● (yellow)
Activity density (inh.+jobs/ha)	14.28	● (yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	4.40	● (green)
Entropy (1 = most diverse)	0.11	● (red)
Simpson's index (0 = most diverse)	1.00	● (black)
Length of land use interactions (m)	0.00	● (yellow)
Walk Score®	30.03	● (yellow)
Grocery stores/pharmacies per 1000 people	0.00	● (red)
Design indicators		
Street density (km/ha)	1.00	● (green)
Intersection density (intersections/ha)	0.15	● (red)
Average commercial lot size (ha)	3.13	● (black)
Capacity indicators		
Number of bus lines	2	
Number of bus agencies	2	
Total area of vacant land (ha)	85.6	
Estimated new residential capacity (units)	2268	
Announced residential development (units)	0	

Figure 4.12: Land Use Around Terrebonne Commuter Train Station (Under Construction)



Saint-Hubert (GID 71)
Mont-Saint-Hilaire Line
Status: In operation

As an existing facility, Saint-Hubert station is located in an established suburban area with a mixture of residential, commercial, industrial and institutional uses (Figure 4.9). The station area also harbours essential commercial services, which increase the potential for walking and cycling to local destinations. Despite this diversity of activities, the existing transit service is underperforming, as evidenced by low public and active transport mode shares relative to the abundance of bus lines in the area.

The station area lies significantly below its residential density target, which may explain in part why the train service does achieve a high mode share. The CMM estimates an additional residential capacity of 1791 units, which would substantially increase the number of residents living in close proximity to the station.

However, the design of the street network greatly limits accessibility to the station. Large commercial and institutional lots, as well as the presence of the expressway, greatly reduce ease of access to the station by foot or bicycle. The single crossing under the expressway, and streets leading to it, must therefore be re-evaluated with active transportation in mind.

Performance indicators	Value	Ranking
Performance index value	-2.26	●
Distance from dwelling density target (units/ha)	-60.49	●
Public transit mode share (as origin)	0.15	●
Active transport mode share (as origin)	0.04	●
Public transit mode share (as destination)	0.06	●
Active transport mode share (as destination)	0.05	●

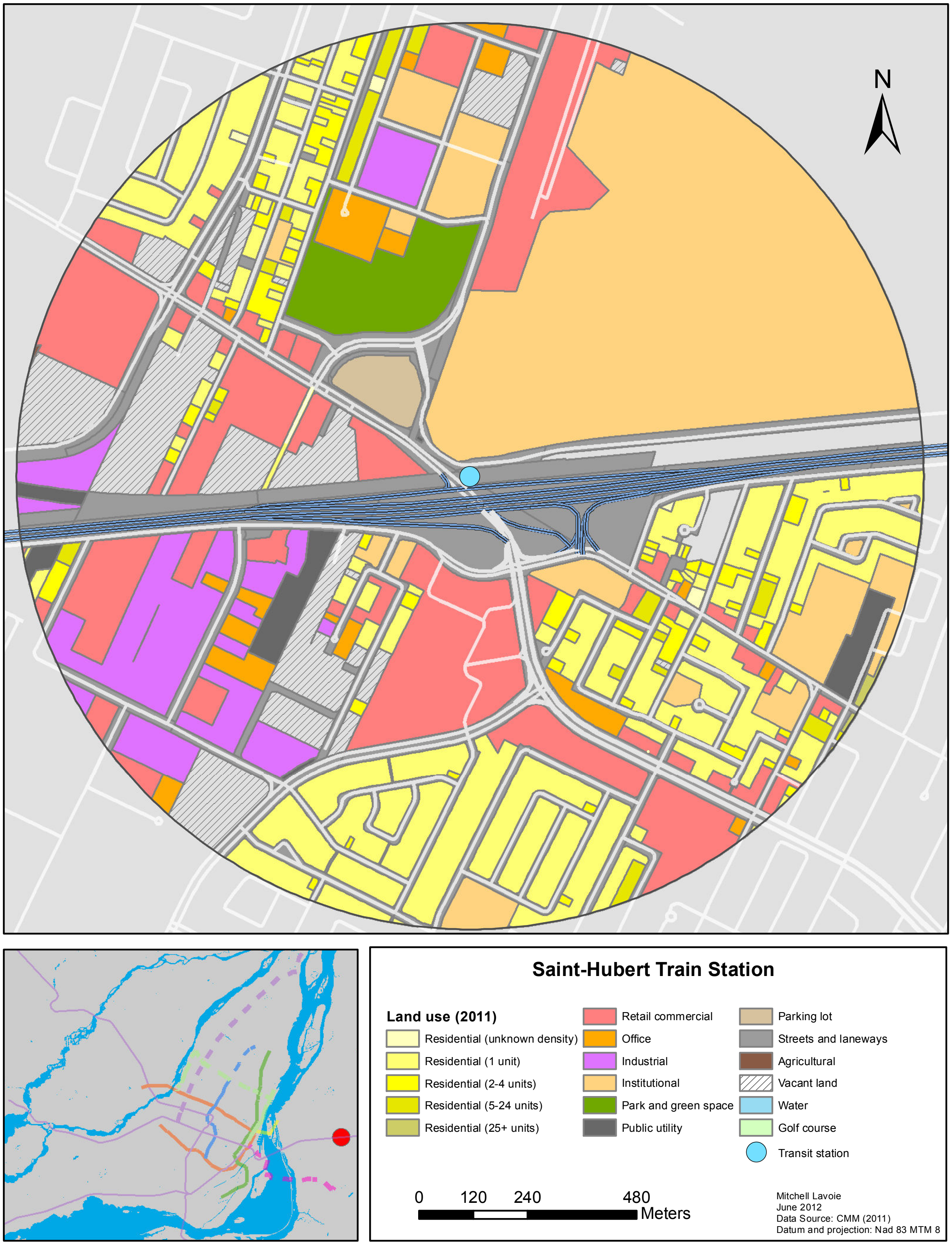
Density Indicators		
Population density (inh./ha)	12.24	●
Employment density (jobs/ha)	11.22	●
Activity density (inh.+jobs/ha)	23.46	●

Diversity indicators		
Jobs-housing balance (jobs/housing units)	2.02	●
Entropy (1 = most diverse)	0.76	●
Simpson's index (0 = most diverse)	0.75	●
Length of land use interactions (m)	0.00	●
Walk Score®	49.74	●
Grocery stores/pharmacies per 1000 people	1.82	●

Design indicators		
Street density (km/ha)	0.75	●
Intersection density (intersections/ha)	0.63	●
Average commercial lot size (ha)	1.38	●

Capacity indicators		
Number of bus lines	21	
Number of bus agencies	3	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1791	
Announced residential development (units)	0	

Figure 4.13: Land Use Around Saint-Hubert Commuter Train Station



Candiac (GID 44)
Delson-Candiac Line
Status: In operation

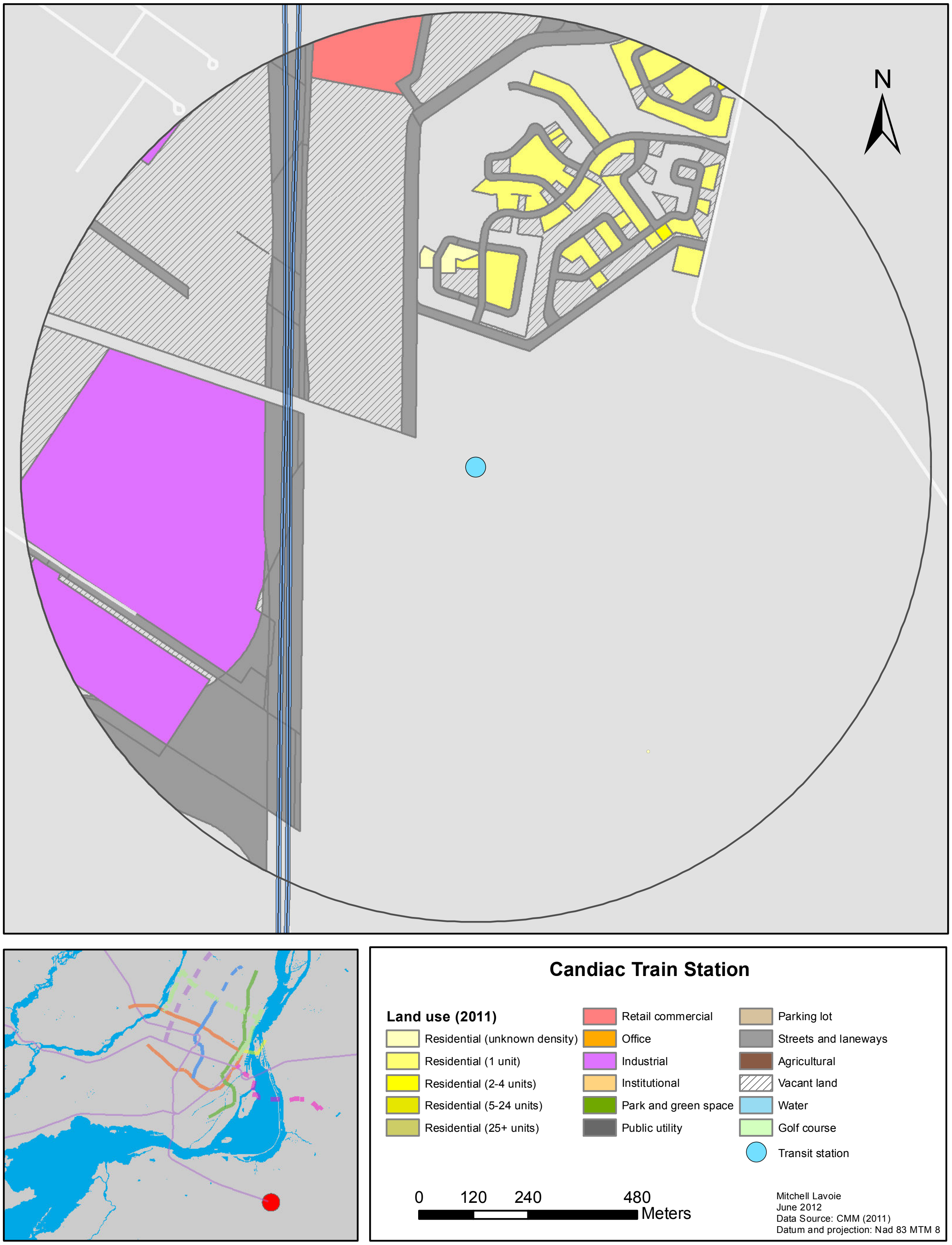
Although in service, Candiac station currently lies in a largely undeveloped area with a significant amount of agricultural land. The small amount of recent residential development to the north of the station failed to achieve a density in line with the CMM's TOD goal (Figure 4.10). Furthermore, the residents of this development largely opt to travel via automobile.

The station area can accommodate an additional 866 residential units, which will bring more potential public transit riders. However, the developable land in the area is not immediately adjacent to the station and lies mostly on the opposite side of the expressway, which reduces the attractiveness of walking as a means of accessing the facility. The absence of essential services also increases the need to access destinations via automobile. Thus, increasing the use of public and active transportation depends on the inclusion of proximity services, which can be achieved by encouraging higher-density, mixed-use development.

One bus currently serves the station, leaving little alternative to residents than to access the facility by car. A more consolidated residential built form, with greater street connectivity, would increase the area's capacity to accommodate additional bus service to the train station.

Performance indicators	Value	Ranking
Performance index value	-1.72	red
Distance from dwelling density target (units/ha)	-25.91	yellow
Public transit mode share (as origin)	0.00	red
Active transport mode share (as origin)	0.03	red
Public transit mode share (as destination)	0.05	red
Active transport mode share (as destination)	0.03	red
Density Indicators		
Population density (inh./ha)	0.00	red
Employment density (jobs/ha)	1.78	yellow
Activity density (inh.+jobs/ha)	1.78	red
Diversity indicators		
Jobs-housing balance (jobs/housing units)	0.00	yellow
Entropy (1 = most diverse)	0.07	red
Simpson's index (0 = most diverse)	1.00	black
Length of land use interactions (m)	0.00	yellow
Walk Score®	6.75	red
Grocery stores/pharmacies per 1000 people	0.00	red
Design indicators		
Street density (km/ha)	1.00	green
Intersection density (intersections/ha)	0.01	red
Average commercial lot size (ha)	1.44	black
Capacity indicators		
Number of bus lines	1	
Number of bus agencies	1	
Total area of vacant land (ha)	48.5	
Estimated new residential capacity (units)	866	
Announced residential development (units)	0	

Figure 4.14: Land Use Around Candiac Commuter Train Station



4.2.2: Metro and Projected LRT Stations

Montmorency (GID 83)
Metro Orange Line
Status: In operation

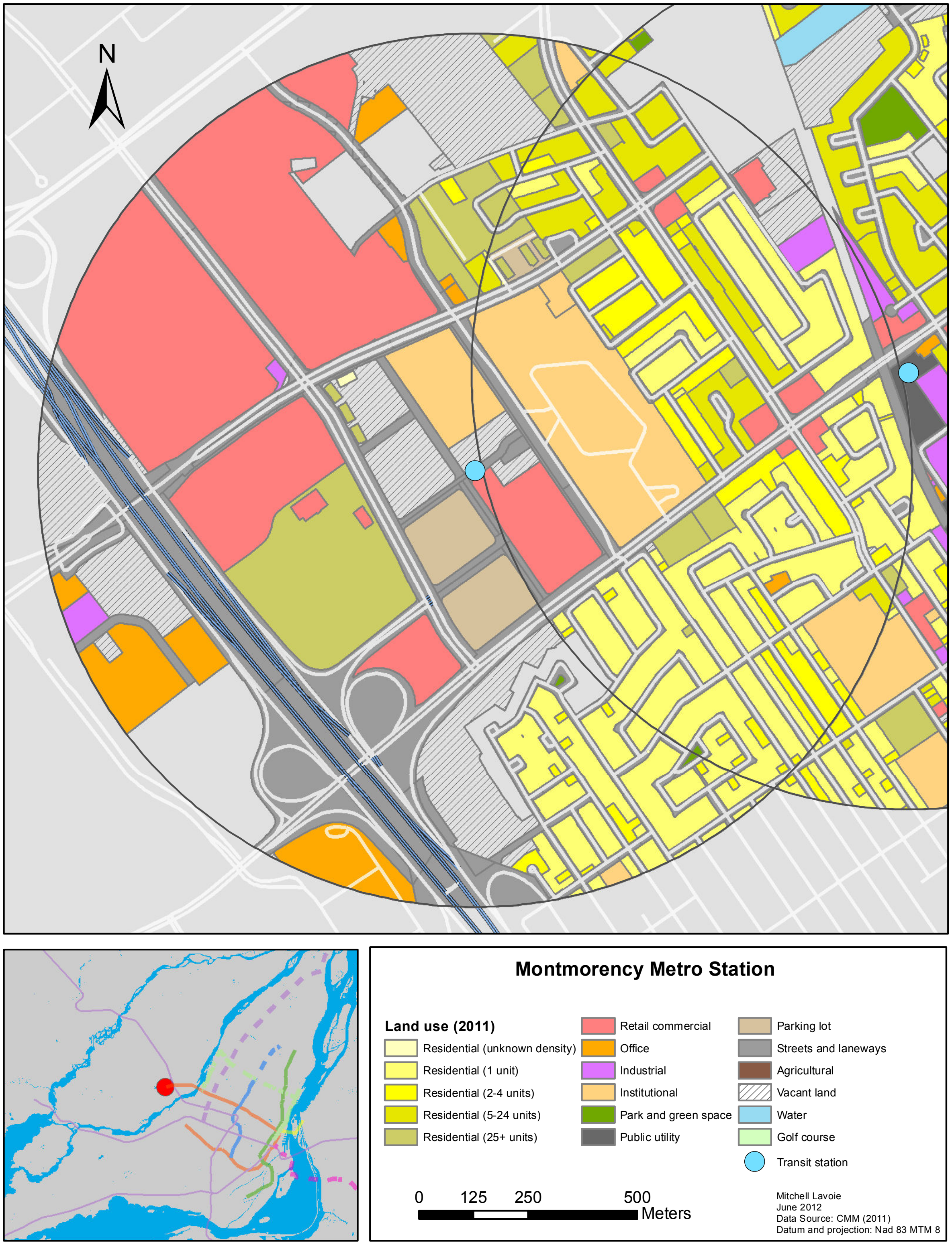
One of the three Laval metro stations opened in 2007, Montmorency lies below its residential density target by 40 units/ha. The station area's public transit mode share of 15% is relatively low considering the capacity of the metro service. While this may not reflect the daily ridership through the station, it indicates that the surrounding built environment must continue to develop along principles of transit-oriented development. The surrounding neighbourhood can accommodate an estimated 1919 additional residential units, 943 of which have been announced. Given the number of buses and bus agencies converging at this station, it has the potential to become a suburban regional centre.

In its current state, the station area is marginally conducive to active transportation. The entropy score and Simpson's diversity index indicate a mixture of uses, but large commercial and institutional lot sizes and a relatively low intersection density inhibit good interaction between these uses (Figure 4.11). For instance, the Montmorency Cégep property and wide boulevards create pedestrian barriers around the metro station.

Thus, the success of this station as a TOD zone will depend on continued medium-to-high-density, mixed-use development and an emphasis on pedestrian and cyclist access to the station.

Performance indicators	Value	Ranking
Performance index value	-3.55	● (black)
Distance from dwelling density target (units/ha)	-40.01	● (yellow)
Public transit mode share (as origin)	0.15	● (red)
Active transport mode share (as origin)	0.08	● (yellow)
Public transit mode share (as destination)	0.21	● (yellow)
Active transport mode share (as destination)	0.05	● (red)
Density Indicators		
Population density (inh./ha)	23.38	● (yellow)
Employment density (jobs/ha)	17.14	● (yellow)
Activity density (inh.+jobs/ha)	40.52	● (yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.54	● (yellow)
Entropy (1 = most diverse)	0.59	● (yellow)
Simpson's index (0 = most diverse)	0.65	● (black)
Length of land use interactions (m)	111.58	● (red)
Walk Score®	53.08	● (yellow)
Grocery stores/pharmacies per 1000 people	0.95	● (yellow)
Design indicators		
Street density (km/ha)	0.65	● (green)
Intersection density (intersections/ha)	0.64	● (yellow)
Average commercial lot size (ha)	1.70	● (black)
Capacity indicators		
Number of bus lines	22	
Number of bus agencies	3	
Total area of vacant land (ha)	22	
Estimated new residential capacity (units)	1919	
Announced residential development (units)	943	

Figure 4.15: Land Use Around Montmorency Metro Station



De la Concorde (GID 82)
Metro Orange Line
Status: In operation

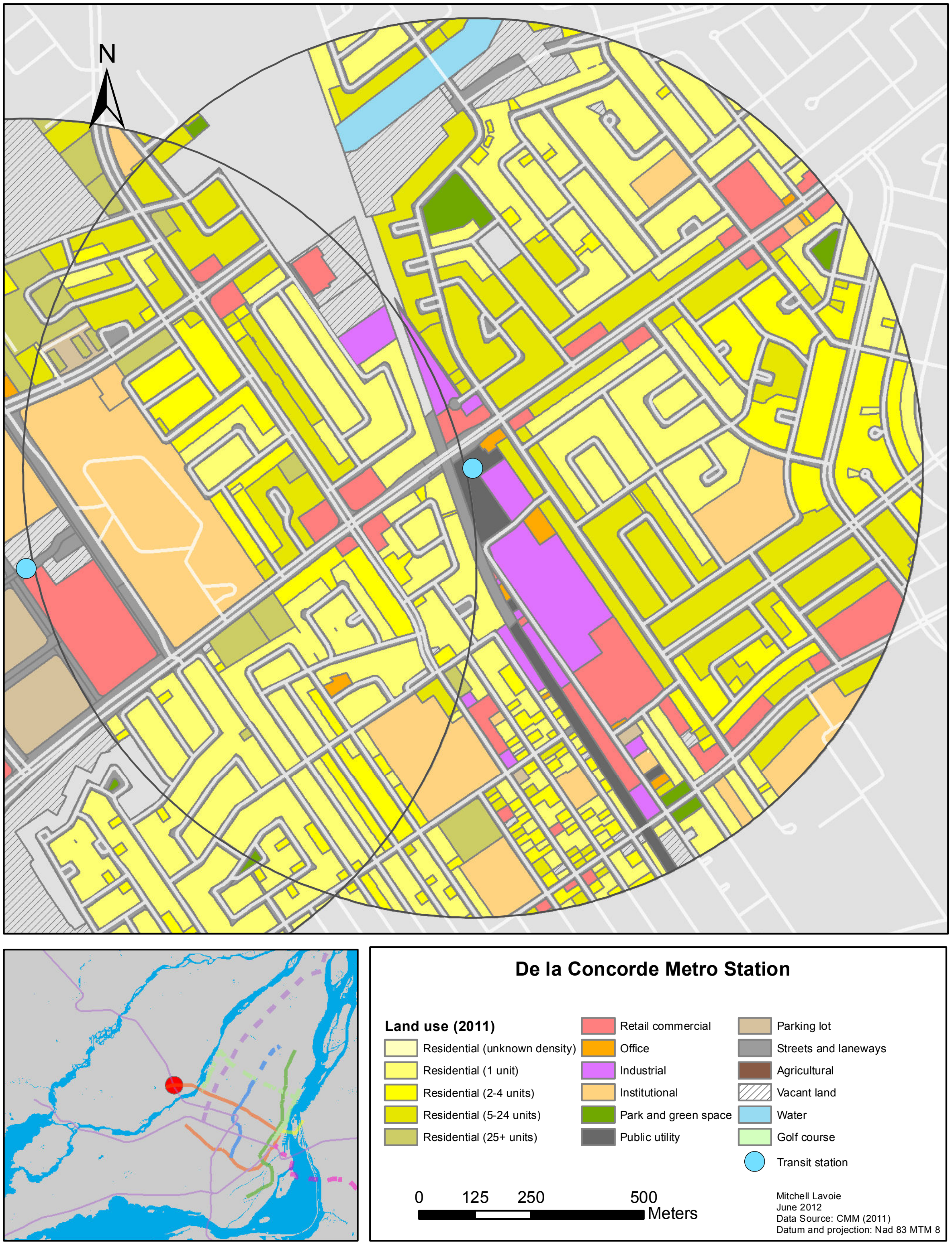
As an intermodal metro and commuter train station, De la Concorde attracts ridership from both its immediate neighbourhood and from municipalities along the commuter train line. As a result, the public transit mode share among its residents and among visitors is slightly higher than that of neighbouring Montmorency station. However, only 10% of residents and visitors walk or cycle to their destination.

As a mature neighbourhood with existing mid-density housing, the station area lies below but near its target residential density. The vocation of the neighbourhood is primarily residential, although measures of land use diversity indicate some mixture of uses and approximately one job per two housing units. The main issue inhibiting more successful TOD is the type and quality of land use mix. For instance, the station is surrounded by industrial uses, which creates a barrier for pedestrians wishing to access the station from nearby residential sectors (Figure 4.12).

If possible, rezoning industrial lots adjacent to the station to mixed commercial-residential uses would bring more activity to the immediate neighbourhood of the transit facility. Lot subdivision and site design that accounts for pedestrian accessibility would also improve the interaction between the station and its vicinity.

Performance indicators	Value	Ranking
Performance index value	-2.23	⚫
Distance from dwelling density target (units/ha)	-12.85	🟡
Public transit mode share (as origin)	0.20	🟡
Active transport mode share (as origin)	0.10	🟡
Public transit mode share (as destination)	0.22	🟡
Active transport mode share (as destination)	0.10	🟡
Density Indicators		
Population density (inh./ha)	54.99	🟡
Employment density (jobs/ha)	13.85	🟡
Activity density (inh.+jobs/ha)	68.84	🟡
Diversity indicators		
Jobs-housing balance (jobs/housing units)	0.52	🟡
Entropy (1 = most diverse)	0.55	🟡
Simpson's index (0 = most diverse)	0.47	🟡
Length of land use interactions (m)	1982.13	🟡
Walk Score®	52.38	🟡
Grocery stores/pharmacies per 1000 people	0.87	🟡
Design indicators		
Street density (km/ha)	0.47	🔴
Intersection density (intersections/ha)	0.83	🟡
Average commercial lot size (ha)	0.71	🔴
Capacity indicators		
Number of bus lines	22	
Number of bus agencies	3	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1283	
Announced residential development (units)	473	

Figure 4.16: Land Use Around De la Concorde Metro Station



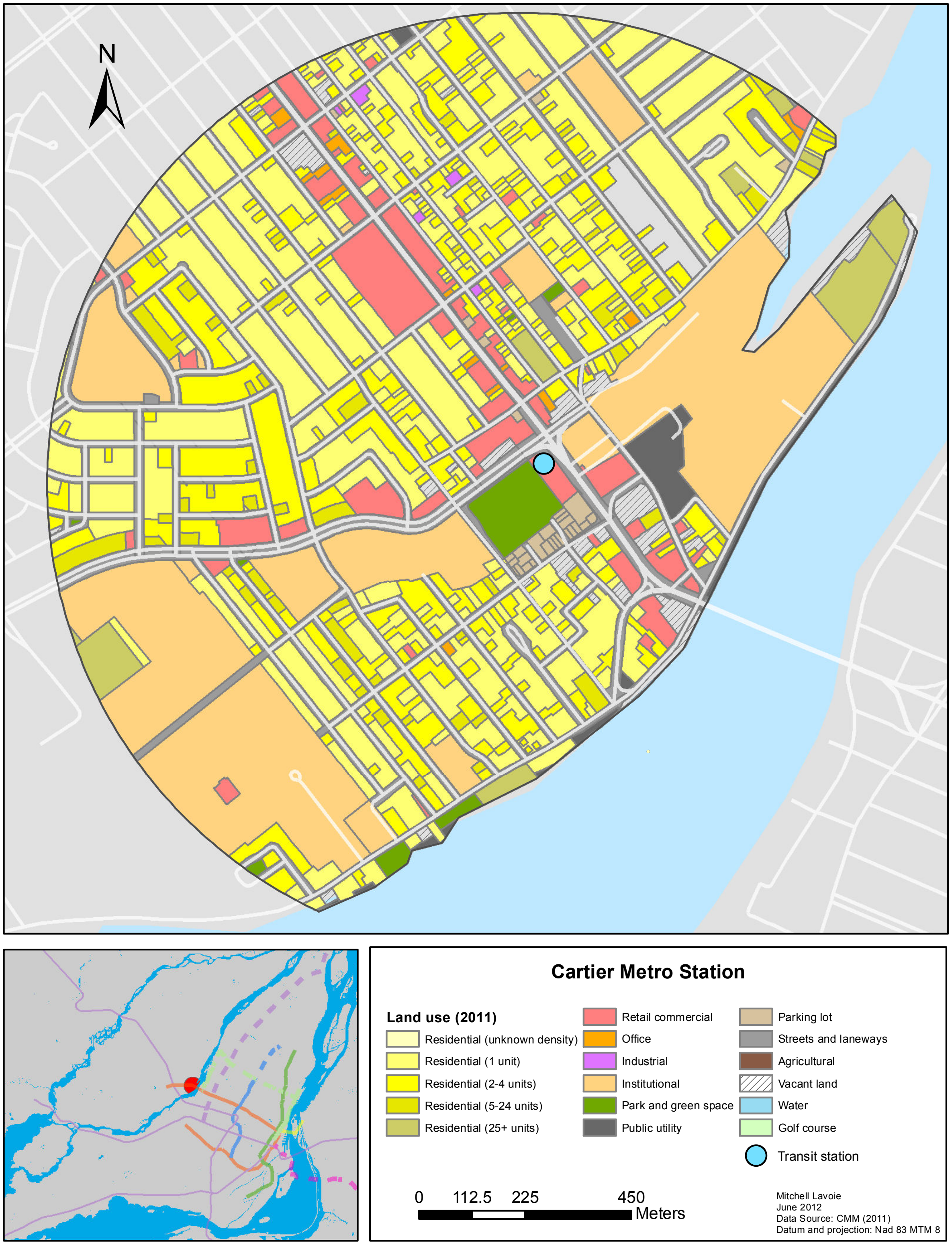
Cartier (GID 80)
Metro Orange Line
Status: In operation

As a regional intermodal bus terminal, Cartier station attracts riders from far beyond its station area, yet the public transit mode share of nearby residents is fairly low. This station was built in a well-established, primarily residential neighbourhood, which partly explains its below-target residential density and modr share. However, vacant lots in close proximity to the station represent a development potential of 1348 residential units, 388 of which have been announced. The strategic development of these lots may help increase the local public transit mode share by increasing the dwelling density in the immediate vicinity of the station.

Although large institutional and commercial lots and wide boulevards reduce the walkability of the area, a grid street pattern allows the station to be reached via multiple routes (Figure 4.13). The land use interaction score indicates a substantial amount of interaction between commercial and residential land use, but large lot sizes reduce the quality of this interaction. These indicators suggest a need for a finer grain of commercial development near the station.

Performance indicators	Value	Ranking
Performance index value	-3.26	⚫
Distance from dwelling density target (units/ha)	-26.19	🟡
Public transit mode share (as origin)	0.15	🔴
Active transport mode share (as origin)	0.07	🔴
Public transit mode share (as destination)	0.18	🟡
Active transport mode share (as destination)	0.09	🟡
Density Indicators		
Population density (inh./ha)	43.56	🟡
Employment density (jobs/ha)	9.72	🟡
Activity density (inh.+jobs/ha)	53.29	🟡
Diversity indicators		
Jobs-housing balance (jobs/housing units)	0.48	🟡
Entropy (1 = most diverse)	0.54	🟡
Simpson's index (0 = most diverse)	0.47	🟡
Length of land use interactions (m)	2450.97	🟡
Walk Score®	56.72	🟡
Grocery stores/pharmacies per 1000 people	1.40	🟡
Design indicators		
Street density (km/ha)	0.47	🔴
Intersection density (intersections/ha)	0.82	🟡
Average commercial lot size (ha)	0.63	🔴
Capacity indicators		
Number of bus lines	23	
Number of bus agencies	2	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1348	
Announced residential development (units)	388	

Figure 4.17: Land Use Around Cartier Metro Station



Langelier (GID 143)
Metro Blue Line Extension (projected)
Status: Projected

As a projected station area, Langelier has not yet been subject to explicit TOD planning. Bus service on 14 lines nonetheless brings the public transit mode share of residents to 21%. The large industrial and commercial uses in the area make it a regional employment centre, a desirable characteristic for TOD.

Although the station area exhibits high land use entropy, the Simpson's diversity index indicates a disproportionately high concentration of commercial and industrial uses. Extremely large lot sizes and the presence of the expressway greatly inhibit the interaction between residential areas and retail services (Figure 4.14).

Thus, fostering TOD in this station area involves increasing the connectivity of the street network. This might be accomplished by intensifying the low-density commercial lots with mixed-use residential and commercial development. Increasing the safety of pedestrian crossings on Boul. Langelier would also ensure the station is easily accessed by neighbouring residents and shoppers.

Performance indicators	Value	Ranking
Performance index value	-2.19	Black
Distance from dwelling density target (units/ha)	-18.55	Yellow
Public transit mode share (as origin)	0.21	Yellow
Active transport mode share (as origin)	0.07	Red
Public transit mode share (as destination)	0.17	Yellow
Active transport mode share (as destination)	0.08	Yellow

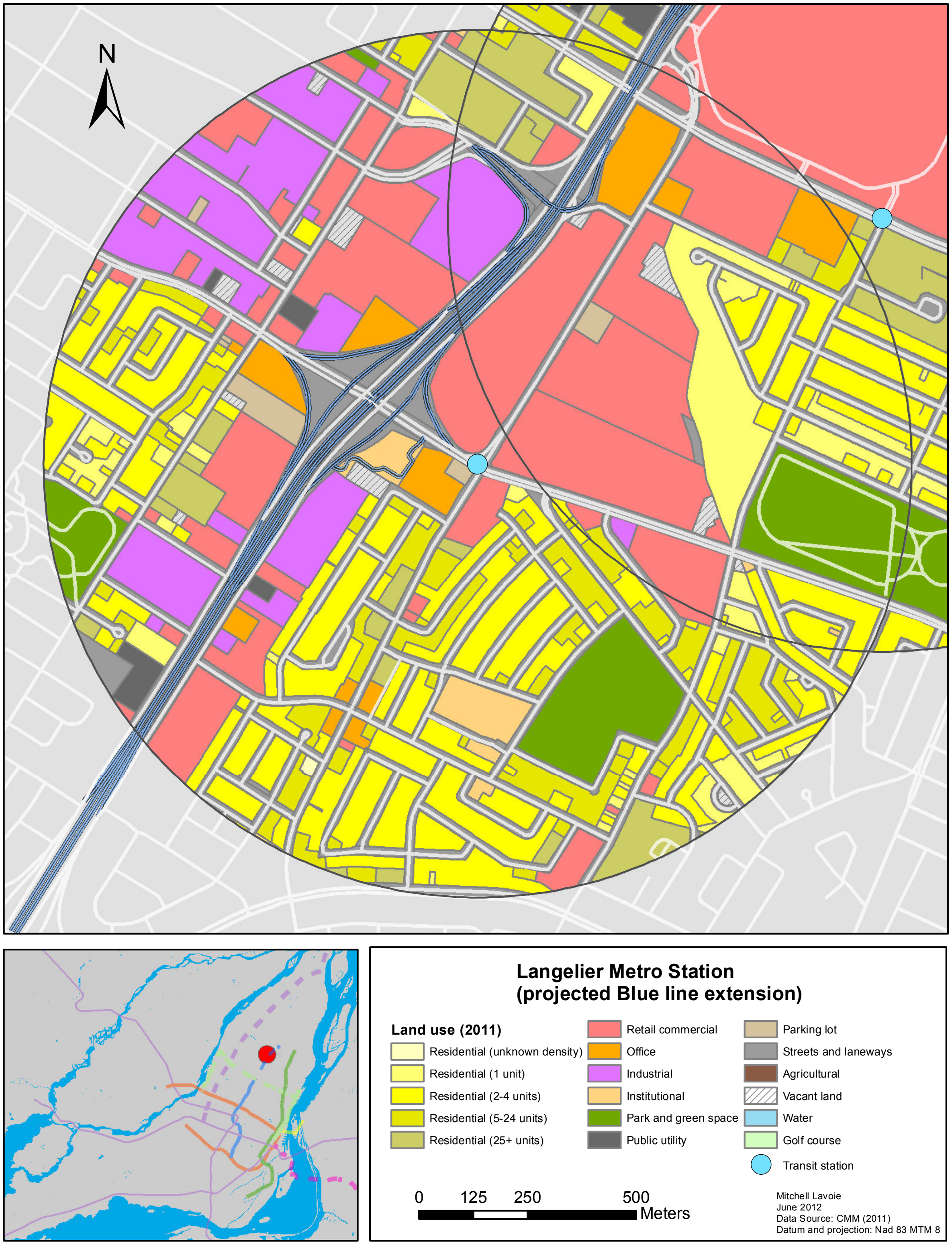
Density Indicators		
Population density (inh./ha)	50.28	Yellow
Employment density (jobs/ha)	37.78	Yellow
Activity density (inh.+jobs/ha)	88.06	Yellow

Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.71	Yellow
Entropy (1 = most diverse)	0.79	Green
Simpson's index (0 = most diverse)	0.74	Black
Length of land use interactions (m)	3805.34	Yellow
Walk Score®	63.02	Yellow
Grocery stores/pharmacies per 1000 people	1.39	Yellow

Design indicators		
Street density (km/ha)	0.74	Green
Intersection density (intersections/ha)	0.78	Yellow
Average commercial lot size (ha)	0.93	Black

Capacity indicators		
Number of bus lines	14	
Number of bus agencies	2	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1259	
Announced residential development (units)	0	

Figure 4.18: Land Use Around Langelier Metro Station (Projected Blue Line Extension)



Galeries d'Anjou (GID 139)
Metro Blue Line Extension (projected)
Status: Projected

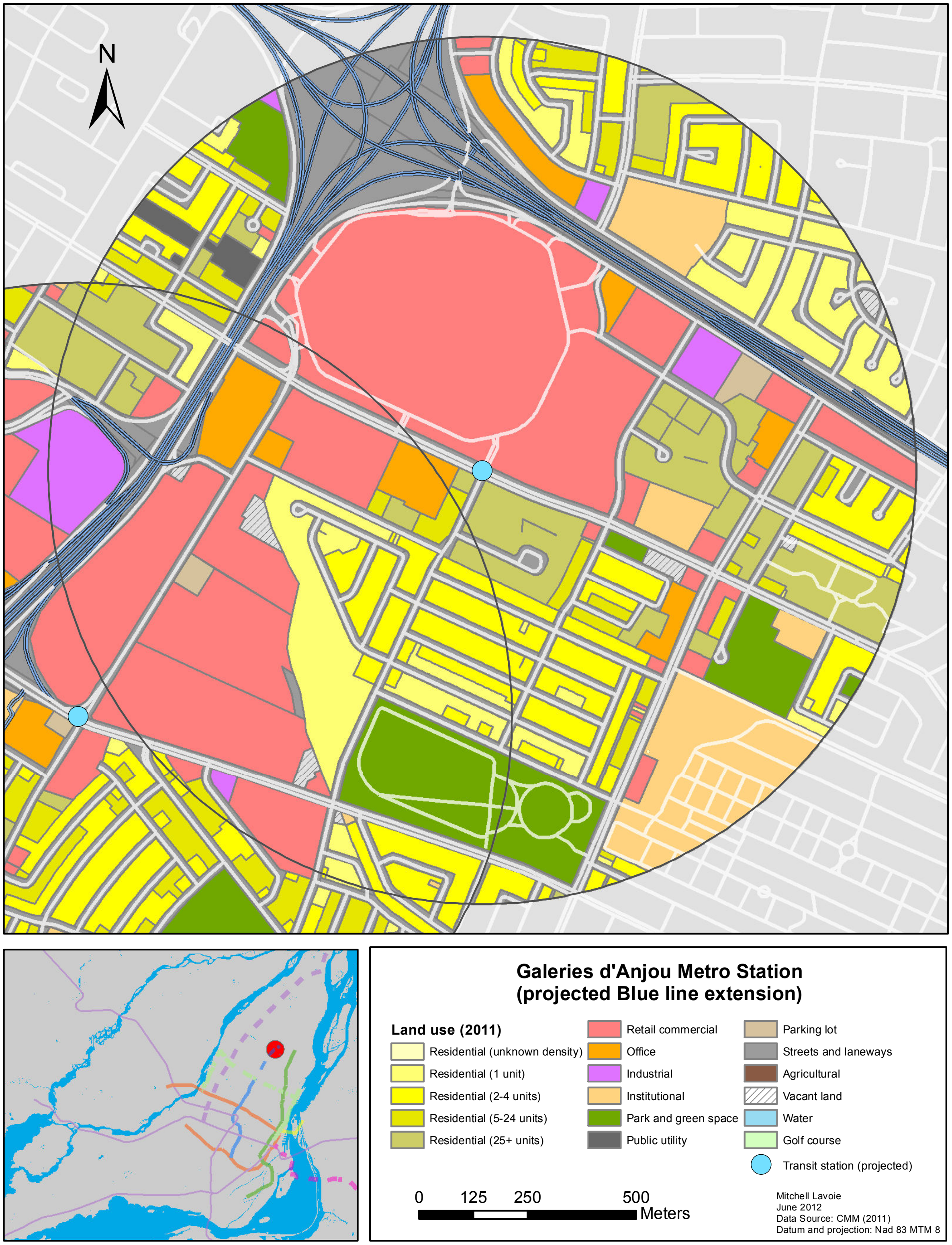
This station will be located adjacent to a major regional shopping centre, which presents both constraints and opportunities in regards to TOD. As a primarily commercial destination surrounded by well-established residential neighbourhoods, the station area's dwelling density is significantly below target (Figure 4.15).

The existing retail services and offices attract daytime activity. The CMM estimates a substantial residential development potential of 2052 units, presumably made possible by future intensification of large commercial lots with abundant surface parking. This type of development would shift the travel patterns in the area to encourage activity throughout the day.

Although the station area scores high in land use entropy, the type of land use diversity is not conducive to walking. For instance, the shopping centre does not offer the sort of convenience retail service that would be easily accessible while walking from the future metro station to one's place of work or residence. Increasing the walkability of the shopping mall area, as well as reducing the amount of parking, would encourage the use of public and active transportation to access destinations within the future station's neighbourhood.

Performance indicators	Value	Ranking
Performance index value	-2.03	
Distance from dwelling density target (units/ha)	-35.30	
Public transit mode share (as origin)	0.24	
Active transport mode share (as origin)	0.10	
Public transit mode share (as destination)	0.17	
Active transport mode share (as destination)	0.09	
Density Indicators		
Population density (inh./ha)	50.41	
Employment density (jobs/ha)	37.40	
Activity density (inh.+jobs/ha)	87.81	
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.45	
Entropy (1 = most diverse)	0.75	
Simpson's index (0 = most diverse)	0.75	
Length of land use interactions (m)	2166.81	
Walk Score®	57.80	
Grocery stores/pharmacies per 1000 people	1.07	
Design indicators		
Street density (km/ha)	0.75	
Intersection density (intersections/ha)	0.99	
Average commercial lot size (ha)	1.76	
Capacity indicators		
Number of bus lines	21	
Number of bus agencies	4	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	2052	
Announced residential development (units)	0	

Figure 4.19: Land Use Around Galeries d’Anjou Metro Station (Projected)



Édouard-Montpetit (GID 76)
Metro Blue Line
Status: In operation

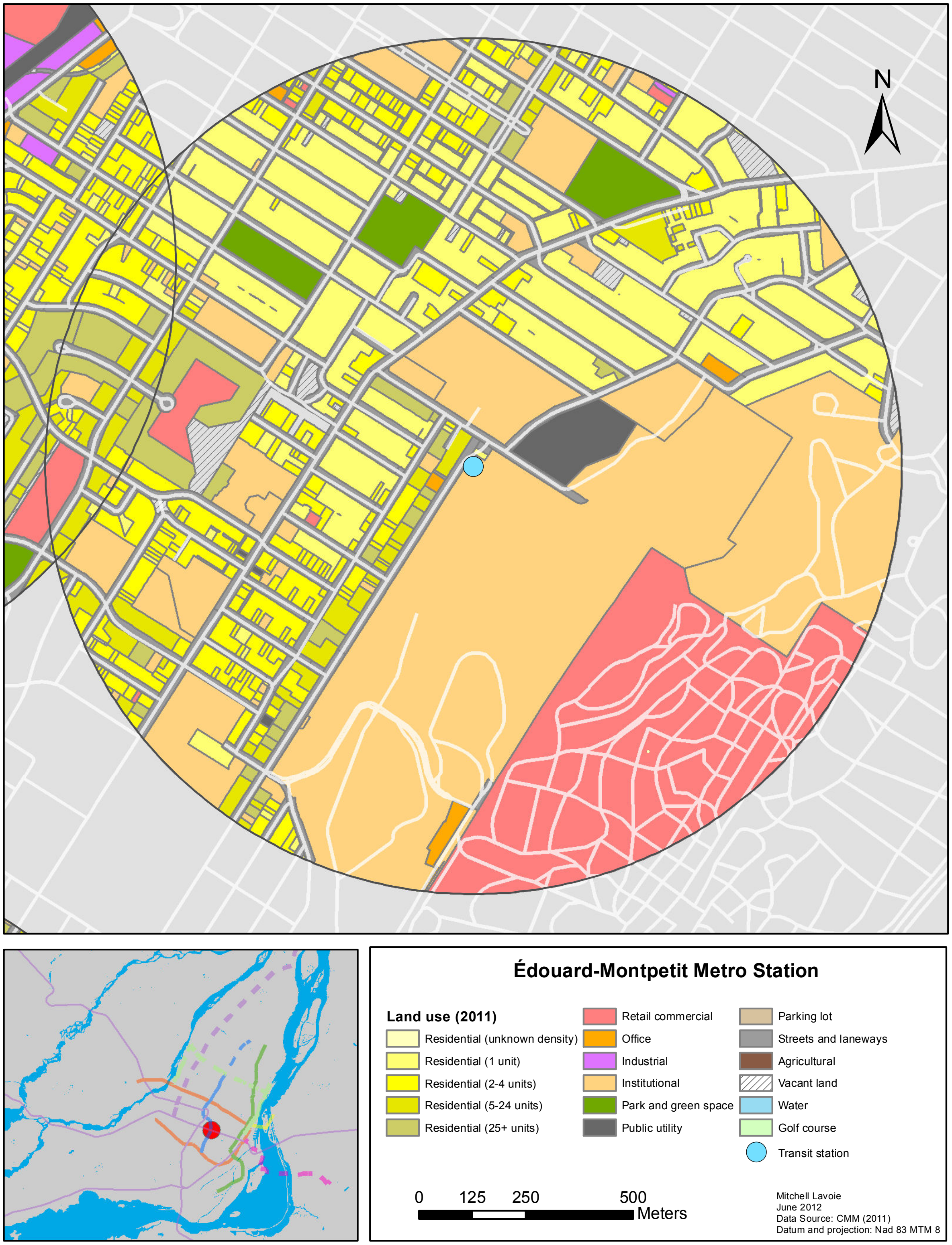
Future development at this station is greatly constrained by the existing built environment, which includes part of the Université de Montréal campus and the Mount Royal Cemetery (Figure 4.16). As an existing destination for students and faculty, the public and active transport mode shares of trips with destinations within the station area are relatively high. Approximately 20% residents also use public transit to reach their destination.

The main issue constraining more effective TOD may therefore be the average residential density of a typical Outremont block. While the blocks adjacent to the university campus have relatively high residential densities, most of the station area is composed of buildings with four units or less. In addition, the CMM estimates little development potential due to the small number of vacant lots.

Indicators of diversity point to a lack of mixed use, particularly in regard to essential services. Although the large interface between residential and institutional land uses generates short trips, the immediate vicinity of the metro station offers little to no small-scale retail to commuters or residents. Any development in this station area should therefore include proximity services where possible.

Performance indicators	Value	Ranking
Performance index value	-2.59	
Distance from dwelling density target (units/ha)	-29.53	
Public transit mode share (as origin)	0.20	
Active transport mode share (as origin)	0.20	
Public transit mode share (as destination)	0.39	
Active transport mode share (as destination)	0.15	
Density Indicators		
Population density (inh./ha)	45.01	
Employment density (jobs/ha)	30.10	
Activity density (inh.+jobs/ha)	75.11	
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.52	
Entropy (1 = most diverse)	0.69	
Simpson's index (0 = most diverse)	0.66	
Length of land use interactions (m)	2886.50	
Walk Score®	60.38	
Grocery stores/pharmacies per 1000 people	0.50	
Design indicators		
Street density (km/ha)	0.66	
Intersection density (intersections/ha)	0.88	
Average commercial lot size (ha)	2.32	
Capacity indicators		
Number of bus lines	12	
Number of bus agencies	1	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	142	
Announced residential development (units)	142	

Figure 4.20: Land Use Around Édouard-Montpetit Metro Station



Brossard-Chevrier (GID 165)
South Shore LRT (projected)
Status: Projected

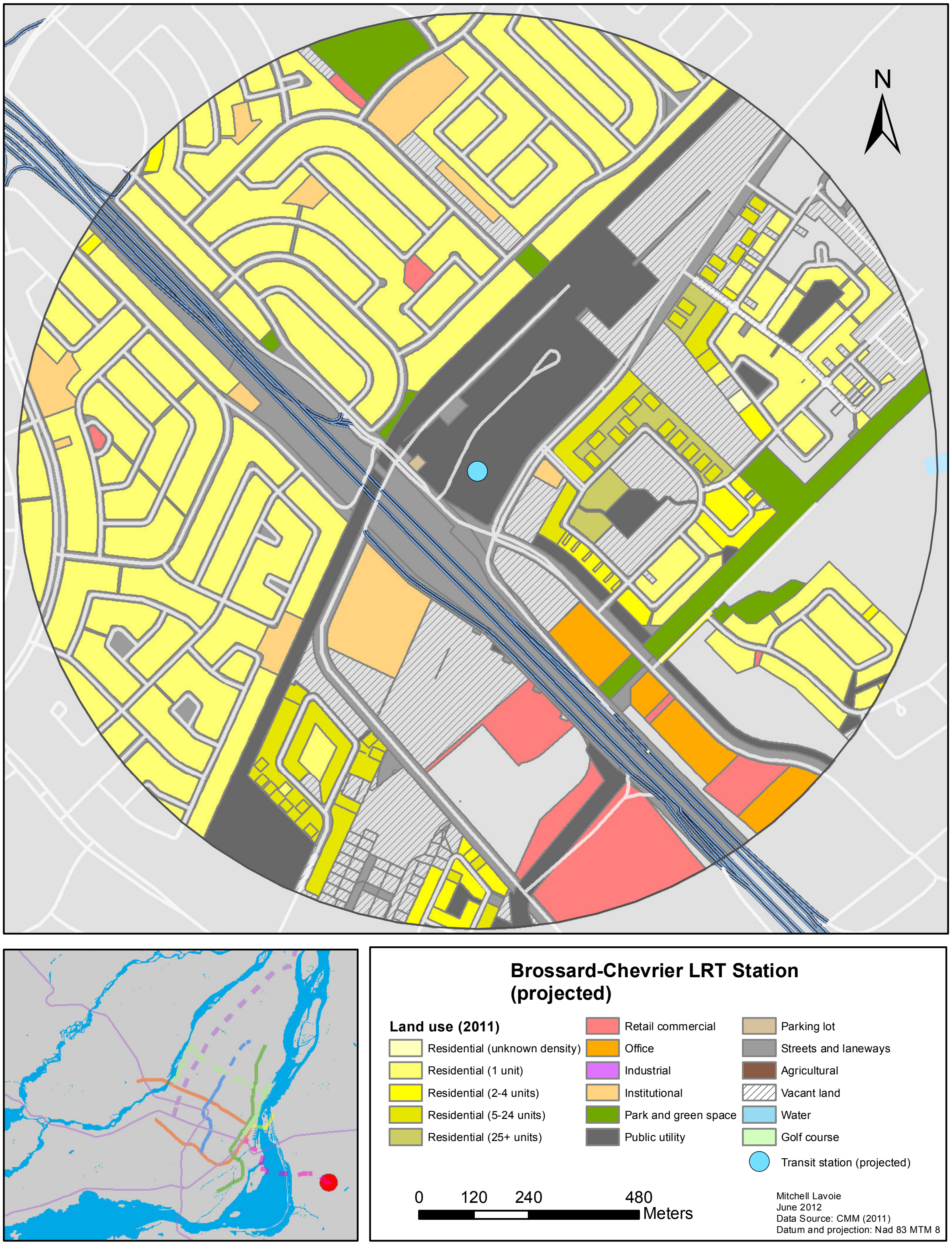
As seen in Figure 4.17, a large proportion of this station area remains to be developed, including the station itself. This explains why current residential densities are substantially below target. Currently operating as a park-and-ride, the station generates a relatively small proportion of public and active transport trips compared to automobile trips. The projected LRT service, along with nearly 2000 estimated additional residential units, will likely cause a change in mode split in favour of public transit.

However, the success of this station area as a TOD will depend on the density, land use and design of future development. New residential buildings east of the station have been built at a higher density than nearby suburban subdivisions, a trend that is likely to spread to remaining vacant lots. On the other hand, diversity indicators show that land use is predominantly residential, and the commercial services that do exist are on large lots adjacent to the expressway. The new residential areas east of the station should therefore include accessible local retail.

While the residential density of the station area is well aligned to increase, the layout of the street network inhibits pedestrian and cyclist access to the station. A relatively low intersection density provides evidence of this. To counter potential barriers to accessibility, pedestrian and cyclist paths leading to the station should be integrated into future development.

Performance indicators	Value	Ranking
Performance index value	-3.43	● (black)
Distance from dwelling density target (units/ha)	-60.89	● (yellow)
Public transit mode share (as origin)	0.19	● (yellow)
Active transport mode share (as origin)	0.06	● (red)
Public transit mode share (as destination)	0.15	● (red)
Active transport mode share (as destination)	0.07	● (yellow)
Density Indicators		
Population density (inh./ha)	16.57	● (red)
Employment density (jobs/ha)	1.40	● (yellow)
Activity density (inh.+jobs/ha)	17.97	● (yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	0.22	● (yellow)
Entropy (1 = most diverse)	0.46	● (red)
Simpson's index (0 = most diverse)	0.67	● (black)
Length of land use interactions (m)	256.46	● (red)
Walk Score®	31.19	● (red)
Grocery stores/pharmacies per 1000 people	0.77	● (yellow)
Design indicators		
Street density (km/ha)	0.67	● (green)
Intersection density (intersections/ha)	0.49	● (yellow)
Average commercial lot size (ha)	0.80	● (red)
Capacity indicators		
Number of bus lines	37	
Number of bus agencies	7	
Total area of vacant land (ha)	3.5	
Estimated new residential capacity (units)	1980	
Announced residential development (units)	1041	

Figure 4.21: Land Use Around Brossard-Chevrier LRT Station (Projected)



Pointe-Nord (GID 179)
South Shore LRT (projected)
Status: Projected

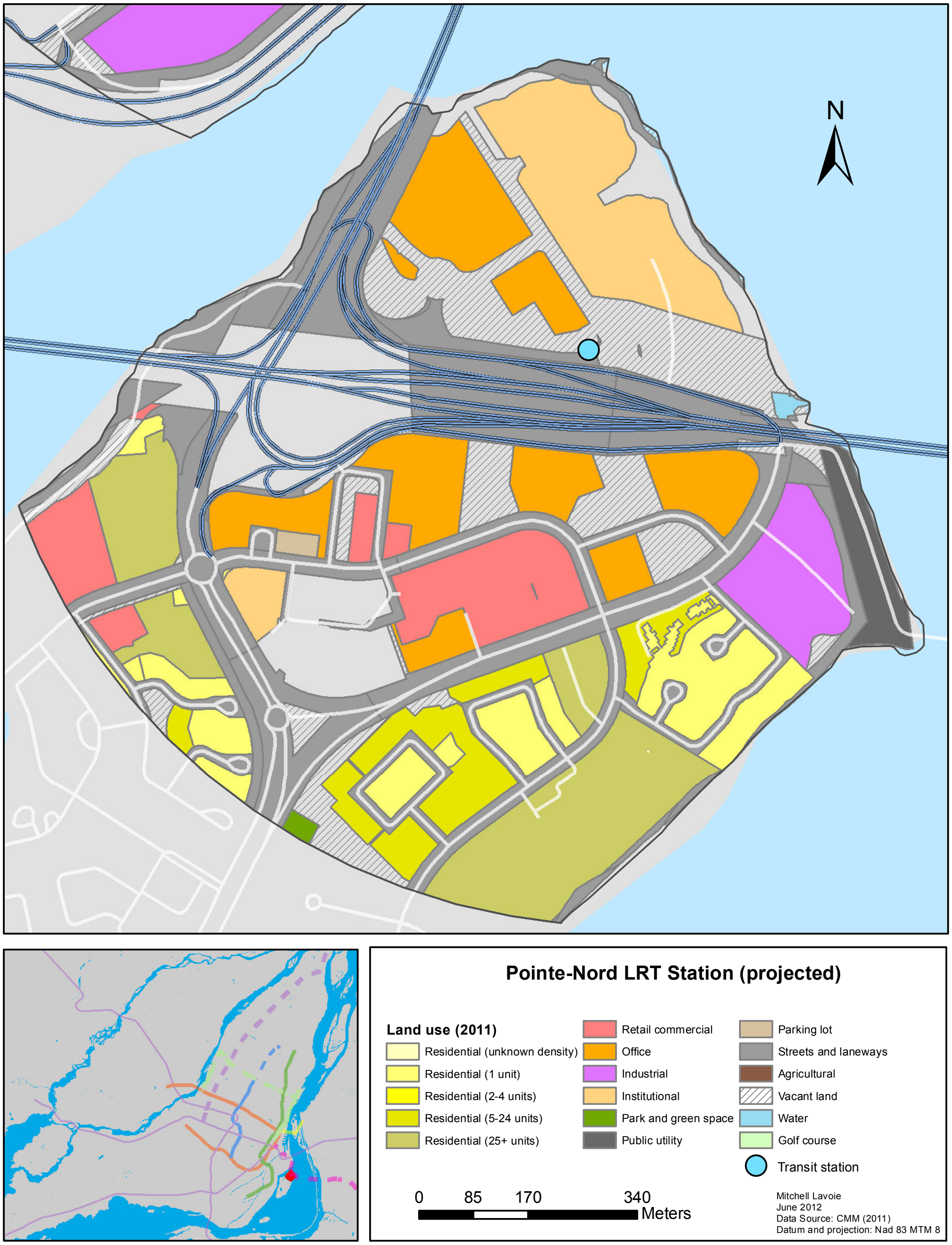
This station will be located in a high-density residential and employment hub on the northern tip of Nun's Island. Although still under development, the station area has comparable population and employment densities, which indicates that it is likely to both attract and generate trips.

Discrepancies between the land vacancies indicated in Figure 4.18 and CMM residential capacity indicators reflect the pace of development in this area. All 1600 estimated residential units have been confirmed and are under construction.

However, the area is car-oriented in its current state, as evidenced by low public and active transport mode shares. Furthermore, the island is currently accessed only by expressway, which not only encourages car-dependence, but also isolates the projected station area. As a result, TOD planning in this area should focus on accessibility to the station via public and active transportation with particular emphasis on safe expressway crossings.

Performance indicators	Value	Ranking
Performance index value	-3.29	Black
Distance from dwelling density target (units/ha)	-52.87	Yellow
Public transit mode share (as origin)	0.19	Yellow
Active transport mode share (as origin)	0.09	Yellow
Public transit mode share (as destination)	0.14	Red
Active transport mode share (as destination)	0.08	Yellow
Density Indicators		
Population density (inh./ha)	28.56	Yellow
Employment density (jobs/ha)	28.03	Yellow
Activity density (inh.+jobs/ha)	56.60	Yellow
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.87	Yellow
Entropy (1 = most diverse)	0.54	Yellow
Simpson's index (0 = most diverse)	0.74	Black
Length of land use interactions (m)	301.25	Red
Walk Score®	49.71	Yellow
Grocery stores/pharmacies per 1000 people	2.17	Yellow
Design indicators		
Street density (km/ha)	0.74	Green
Intersection density (intersections/ha)	0.55	Yellow
Average commercial lot size (ha)	1.02	Black
Capacity indicators		
Number of bus lines	73	
Number of bus agencies	8	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	1600	
Announced residential development (units)	1600	

Figure 4.22: Land Use Around Pointe-Nord LRT Station (Projected)



4.2.3: Park-and-Rides and Bus Terminals

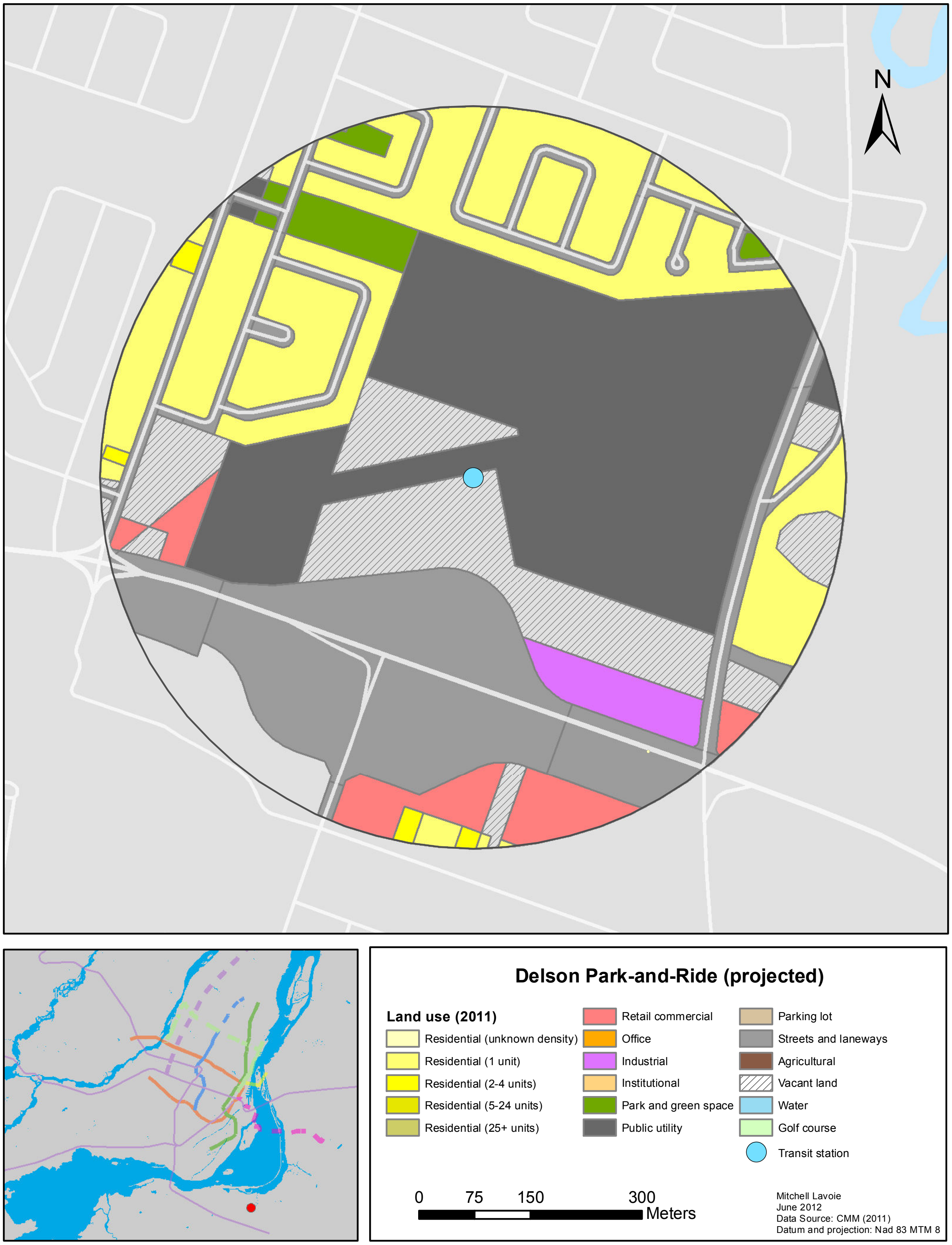
Delson Park-and-Ride (GID 172)
Status: Projected

Currently a large swath of vacant land, this projected station area is expectedly below its residential density target (Figure 4.19). As an origin and destination, the area sees a very small proportion of public transit trips, yet the active transport mode share is high relative to other park-and-rides and bus terminals in the CMM.

By virtue of its design, a park-and-ride facility encourages people to drive to reach public transit. However, if current and future residents of the station area were offered proximity services and easy access to the bus terminal, the need for additional automobile trips may be reduced. This might be accomplished by designing the parking lot in a way minimizes the amount of walking needed to reach the terminal from surrounding residential neighbourhoods. Improving the local feeder bus service to the main terminal might also reduce the number of automobile trips originating in more distant residential neighbourhoods.

Performance indicators	Value	Ranking
Performance index value	-2.21	(black)
Distance from dwelling density target (units/ha)	-25.27	(red)
Public transit mode share (as origin)	0.01	(yellow)
Active transport mode share (as origin)	0.07	(green)
Public transit mode share (as destination)	0.01	(yellow)
Active transport mode share (as destination)	0.06	(green)
Density Indicators		
Population density (inh./ha)	12.72	(yellow)
Employment density (jobs/ha)	4.58	(red)
Activity density (inh.+jobs/ha)	17.30	(yellow)
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.13	(yellow)
Entropy (1 = most diverse)	0.41	(red)
Simpson's index (0 = most diverse)	0.51	(black)
Length of land use interactions (m)	0.00	(yellow)
Walk Score®	41.26	(green)
Grocery stores/pharmacies per 1000 people	2.00	(yellow)
Design indicators		
Street density (km/ha)	0.51	(red)
Intersection density (intersections/ha)	0.33	(yellow)
Average commercial lot size (ha)	0.64	(black)
Capacity indicators		
Number of bus lines	12	
Number of bus agencies	1	
Total area of vacant land (ha)	25.0	
Estimated new residential capacity (units)	196	
Announced residential development (units)	0	

Figure 4.23: Land Use Around Delson Park-and-Ride (Projected)



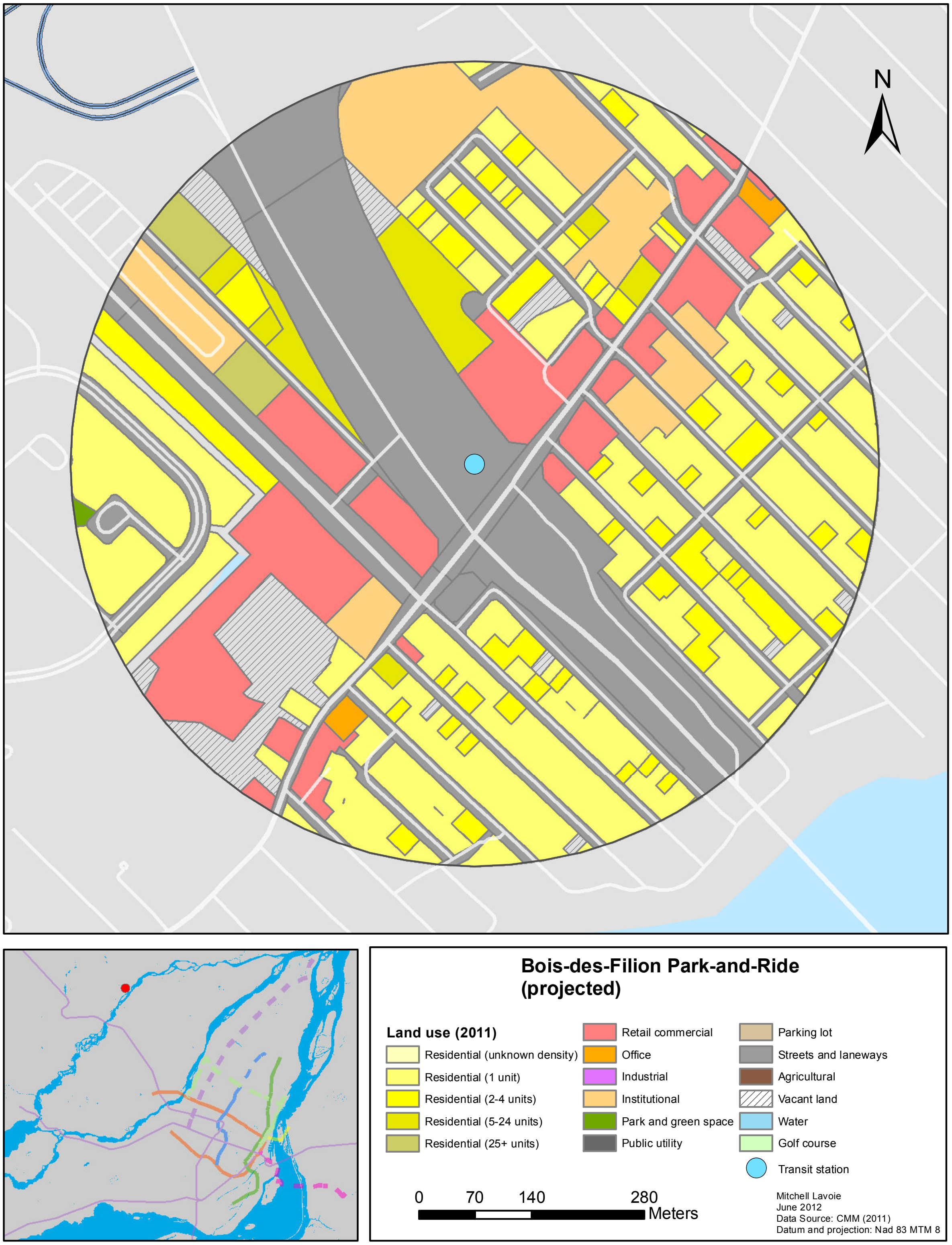
Bois-des-Filion Park-and-Ride (GID 169)
Status: Projected

Located in an established suburban retail area, this projected facility will offer existing and future residents a single, more consolidated access point to the public transit network. The current public and active transport mode shares for origins and destinations within the station area are low yet higher than that of the average park-and-ride in the CMM. However, the residential built form is at significantly lower densities than the CMM target.

The area's activity density is relatively high and leans significantly toward population density, but a notable concentration of retail commercial land use creates a slight surplus of jobs relative to housing. Although this mixture of commercial and residential land use generates local trips to convenience services, the mode with which people choose to reach these services depends partly on how easily pedestrians and cyclists can reach them. Given the relatively large size of commercial and residential lots, destinations within this station area may not be quickly accessed (Figure 4.20). The development of the park-and-ride facility should therefore be complemented with measures to increase non-automobile access to the bus stops and to nearby destinations.

Performance indicators	Value	Ranking
Performance index value	-1.57	red
Distance from dwelling density target (units/ha)	-20.71	red
Public transit mode share (as origin)	0.04	yellow
Active transport mode share (as origin)	0.05	green
Public transit mode share (as destination)	0.06	green
Active transport mode share (as destination)	0.06	green
Density Indicators		
Population density (inh./ha)	19.84	green
Employment density (jobs/ha)	8.65	yellow
Activity density (inh.+jobs/ha)	28.50	green
Diversity indicators		
Jobs-housing balance (jobs/housing units)	1.11	yellow
Entropy (1 = most diverse)	0.53	green
Simpson's index (0 = most diverse)	0.68	black
Length of land use interactions (m)	1463.77	green
Walk Score®	44.14	green
Grocery stores/pharmacies per 1000 people	3.21	yellow
Design indicators		
Street density (km/ha)	0.68	green
Intersection density (intersections/ha)	0.74	green
Average commercial lot size (ha)	0.53	black
Capacity indicators		
Number of bus lines	7	
Number of bus agencies	2	
Total area of vacant land (ha)	0.0	
Estimated new residential capacity (units)	0	
Announced residential development (units)	0	

Figure 4.24: Land Use Around Bois-des-Filion Park-and-Ride



5.0: CONCLUSION

This concluding chapter outlines general policy recommendations for addressing the planning issues affecting the identified priority zones. The recommendations take into account the differences between operational and projected transit stations and between different types of service. Although the selected policies reflect the particular needs of the identified priority zones, they are applicable to other TOD zones with similar issues.

5.1: General Policy Recommendations

1. Acquire land around transit stations early and capture land value increases

Applicable to all TOD zones, this recommendation serves as an overarching vehicle for achieving land use change that is conducive to reduced automobile use. Land value capture refers to the recovery of increased land values brought by a publicly provided transit service improvement in order to finance the service itself (Smith and Gihring 2006). Landowners pay a municipal betterment tax for accruing the benefits of being located close to a transit station (Ibid.). This not only makes the construction of the station more financially viable, but also encourages developers to maximize the benefit of locating near the station by building at higher densities.

However, this type of scheme requires municipalities and transit agencies to purchase land around projected transit stations before the construction of the station is publicly announced. This allows the public body to acquire the land at low cost and to prepare it for transit-oriented development. Once the construction of the station has been announced, the banked land can be resold at a higher price and with TOD-supportive zoning requirements.

This type of land-banking scheme proved very successful in Vancouver, where multiple station areas have been built at very high densities (Trillium Business Strategies 2009). TransLink, the regional public transit service provider in Vancouver, has launched a new real estate division whose goal is to acquire land around future transit stations and corridors and to resell it at a higher price with higher-density zoning requirements (Ibid.).

Such a strategy can catalyze the realization of many other TOD planning interventions. It is an attractive approach for the Montreal regional context, where TOD planning is in its initial stages. Many TOD zones in the CMM are merely beginning to develop, which provides public bodies an opportunity to consider strategic financing strategies coupled with comprehensive TOD planning.

2. Maximize the benefits of intensification

Large, low-density commercial lots with abundant surface parking offer an immense opportunity for intensification in existing neighbourhoods. Engaging in partnerships with commercial landowners may bring benefits to all stakeholders through the creation of a comprehensive intensification plan (OMT 2012). Intensification not only implies higher density, but also provides an opportunity to increase the connectivity and pedestrian-friendliness of a station area.

Brentwood LRT Station in Calgary, Alberta is the subject of such an intensification plan (OMT 2012). What is currently a strip of low-density, car-oriented strip malls along a major expressway will become a dense, mixed-use development with buildings placed near the street. With this redevelopment will come an increased number of pedestrian crossings and new green space (Ibid.). Given the difficultly of balancing the needs of private developers and members of the local community, the plan calls for gradual intensification over time. An important asset of the plan is its use of intensification as a vehicle for increasing connectivity between destinations in the station area. For instance, the increased foot traffic brought by new residential, office and commercial uses justified proposing a new pedestrian bridge across the expressway. The plan also encourages active uses on the ground floor of buildings to foster a mixture of uses and a more dynamic street life.

Several of the priority zones identified in this report suffer from similar density and accessibility issues as Brentwood Station. Galeries d'Anjou and Langelier stations, for instance, have a similar context of large commercial lots along a major expressway near projected metro stations. Assessing the potential for intensification on the large surface parking lots in these areas is a beneficial early approach to fostering TOD.

3. Ensure transit stations are well connected to surrounding destinations

The design or redesign of any transit station should prioritize pedestrians both within and around the station itself (OMT 2012). Pedestrian, bicycle and automobile routes should be clearly delineated and walking distance between a station and surrounding destinations should be minimized (Ibid.). In the case of stations with large park-and-ride facilities, this means locating boarding areas as close as possible to the surrounding sidewalk and street network. Stations surrounded by surface parking greatly increase walking distances and render the use of the transit service less practical. Intermodal stations in particular should be designed to simplify, to the extent possible, transfers between public transit modes. Long walking distances between modes increase travel times and decrease the attractiveness of using public transit.

The Ontario Ministry of Transportation recommends making transit station areas "pedestrian priority areas" in which public realm design features are introduced to increase pedestrian comfort. Wider sidewalks, clear wayfinding signage, abundant street furniture and clearly marked crosswalks are meant to enhance the conviviality of walking to and from the station. Separating pedestrian paths from cycling routes may also reduce conflicts and ensure safe connections to the station for all transit riders (OMT 2012).

These recommendations are especially relevant for existing and projected stations located in high-traffic, automobile-oriented areas in the CMM. The projected Blue metro line stations, the Laval metro stations and the projected South Shore LRT stations are in particular need of pedestrian priority planning due to their location along high-traffic thoroughfares. In addition, the projected park-and-rides at Bois-des-Filion and Candiac should be designed to minimize walking distance between bus boarding areas and the surrounding sidewalk network.

4. Encourage innovative parking policy and design

The availability and cost of parking at a trip destination are among the most important factors in a person's choice to drive (Dunphy *et al.* 2003). Particularly in suburban contexts, inexpensive and abundant parking attracts riders to a regional public transit service. However, innovative parking policy and design can lead to a decrease in automobile trips, an increase in accessibility by other modes of transportation and more efficient land use around a transit station.

Dunphy *et al.* (2003) recommend favouring parking structures over large surface parking lots at stations with park-and-ride facilities. Although more expensive, the cost of building a parking structure can be offset by charging for parking and/or selling the surplus of land otherwise reserved for surface parking (Ibid.). Evidently, this strategy requires that the public entity own the land surrounding the station (see recommendation 1 above).

In the Ohlone/Chynoweth Commons area of San Jose, California, surface parking was used as a land banking strategy (Dunphy *et al.* 2003). The station initially featured an 1,100-space surface park-and-ride, a large portion of which was later sold and redeveloped as an affordable housing project. The sale of the publicly owned land offset the cost of building a parking structure on the remaining parking area.

A parking structure can also be wrapped in retail or built over to maximize the use of space and to contribute to the quality of the public realm around the station. This type of relationship between parking and displacement-generating uses is also conducive to shared parking. For instance, a commuter park-and-ride in the San Diego transit system serves as a parking lot for an adjacent movie theatre, which occupies the lot later in the day (Dunphy *et al.* 2003).

These strategies might be considered for both existing and future park-and-ride facilities in the CMM, particularly where development demand makes structured parking economically feasible. It not only frees up land for development near the station, but also reduces the distance barrier created by large surface parking lots. Coupled with a pricing scheme that changes according to demand, structured parking can also indirectly foster the use of feeder buses during rush hours (Ibid.).

5.2: The CMM TOD Objective: Moving Forward

The large scale and long time frame of the CMM TOD objective demand a well crafted planning process. This report represents an attempt to lay the groundwork for a more comprehensive, performance-based TOD action plan for the Montreal Metropolitan Region. The methodology it employs to assign priorities and to characterize the TOD zones offers a straightforward, replicable approach to evaluating a regional TOD plan. This type of evaluation is necessarily undertaken in partnership between the regional government and local jurisdictions. An indicator-based assessment, as presented in this report, is limited in the sense that it does not account for the political and regulatory context unique to each jurisdiction. Nonetheless, the value of this type of assessment lies in its ability to inform local and regional planning efforts with empirical evidence of successful transit-oriented development.

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APPENDIX A: DETAILED INDICATORS LIST WITH AUTHORS

(Organized alphabetically by indicator)

DENSITY

Author	Location	Indicator
Forsyth et al. (2008)	Minneapolis	Activity density (population+employment)
Ewing et al. (2004)	Gainesville, FL	Activity density (population+employment)
Forsyth et al. (2008)	Minneapolis	Building footprint area/area in parcels excluding vacant/agricultural land use
Ritsema van Eck and Koomen (2008)	Netherlands	Circularity ratio (how much a shape deviates from its smallest possible form, ie a circle)
Hess, Moudoun and Logsdon (2001)		Contagion index (total length of edge shared as percentage of whole landscape)
Bhatia (2004)		Dwelling density
Forsyth et al. (2008)	Minneapolis	Dwelling density
Lee and Moudon (2006)	Puget Sound	Dwelling density (net per buffer)
Greenwald (2009)		Dwelling density (net)
Frank, Andersen and Schmid (2004)	King County WA	Dwelling density (net)
Lee and Moudon (2006)	Puget Sound	Dwelling density (residential parcel)
Cervero and Kockelman (1997)		Employment density
Frank and Pivo (1994)		Employment density
Ewing et al (2009)		Employment density
Greenwald (2009)		Employment density
Zhang (2004)		Employment density
Forsyth et al. (2008)	Minneapolis	Employment density
Zhang (2004)		Employment density
Kockelman (1997)	San Francisco	Employment density (net at origin and destination)
Kuby et al (2004)		Employment within walking distance
Fan (2007)		Parcel density
Cervero and Kockelman (1997)	San Francisco	Population density
Brinklow (2010)		Population density
Cervero (2006)		Population density
Ewing et al (2009)		Population density
Rajamani et al (2003)		Population density
Reilly (2002)		Population density
Rodriguez and Joo (2004)		Population density
Zhang (2004)		Population density
Frank and Pivo (1994)	Puget Sound	Population density (destination)
Cervero (2002)		Population density (gross)
Yamada and Brown (2011)		Population density (gross)
Kockelman (1997)	San Francisco	Population density (net at origin and destination)
Frank and Pivo (1994)	Puget Sound	Population density (origin)
Forsyth et al. (2008)	Puget Sound	Population density (parcels)
Forsyth et al. (2008)	Puget Sound	Population density (residential parcels)
Badland, Schofield and Garrett (2008)		Population density (weighted average within 2km commute route network buffer)
Kuby et al (2004)		Population within walking distance
Frank et al (2008)		Retail FAR
Frank et al (2008)		Retail FAR
Lopez (2004)		Sprawl index (% total population in low density and high density CTs)
Ross et al. (2007)		Sprawl index (Proportion of CMA dwellings that are single or detached, dwelling density, %CMA population living in urban core)
Ewing, Brownson and Berrigan (2006)		Sprawl index (residential density (7vars), LUM(6vars), street accessibility(3vars)
Ritsema van Eck and Koomen (2008)	Netherlands	Urban patch area distribution

DIVERSITY

Author	Location	Measures
Yamada and Brown (2011)	Salt Lake City	Area of education (sq. km)
Yamada and Brown (2011)	Salt Lake City	Area of entertainment (sq.km)
Yamada and Brown (2011)	Salt Lake City	Area of multifamily residential (sq. km)
Yamada and Brown (2011)	Salt Lake City	Area of office (sq. km)
Yamada and Brown (2011)	Salt Lake City	Area of retail (sq.km)
Yamada and Brown (2011)	Salt Lake City	Area of single family residential (sq.km)
Ewing et al. (2004)		Commercial floor area/commercial land area
Cervero and Kockelman (1997)	San Francisco	Dissimilarity index
Kockelman (1997)	San Francisco	Dissimilarity index (11 land use classes)
Kockelman (1997)	San Francisco	Dissimilarity index (4 basic land use classes)
Reilly (2002)		Distance to closest commercial use
Yamada and Brown (2011)	Salt Lake City	Distance to closest large grocery store
Krizek and Johnson (2006)		Distance to closest retail (based on NAICS categories)
Lee and Moudon (2006)	Puget Sound	Distance to closest specified destination
Kitamura et al (1997)		Distance to nearest park
Guy (1983)		Distance to purchase each of 12 convenience goods and services (avg shortest path)
Hess, Moudoun and Logsdon (2001)	Puget Sound	Edge contrast (extent to which adjacent uses are complementary)
Forsyth et al. (2008)	Minneapolis	Employment density (major retail subcategories)
Forsyth et al. (2008)	Minneapolis	Employment density (retail)
Cervero (1996)		Grocery/pharmacy dummy (between 300ft and 1 mile)
Brinklow (2010)	Various	Housing types
Ewing et al. (2004)		Job mix (number of commercial, industrial, service jobs)
Greenwald (2009)		Job-housing balance
Ewing et al. (2004)		Job-housing balance (TAZ)
Bento et al. (2003)		Job-housing imbalance
Hess, Moudoun and Logsdon (2001)	Puget Sound	Land use complementarity (pre-selection)
Cervero and Duncan (2003)		Land use diversity factor (entropy, resident-job balance, resident-services, residentialness index)
Rajamani et al (2003)		Land use diversity index
Ritsema van Eck and Koomen (2008)	Puget Sound	Land use entropy
Brinklow (2010)	Various	Land use entropy
Cervero (2002)		Land use entropy
Frank et al (2008)		Land use entropy
Zhang (2004)		Land use entropy
Yamada and Brown (2011)	Salt Lake City	Land use entropy
Kockelman (1997)	San Francisco	Land use entropy
Frank and Pivo (1994)	Puget Sound	Land use entropy (destination CTs based on destination)
Greenwald (2009)		Land use entropy (employment lands)
Kockelman (1997)	San Francisco	Land use entropy (mean of developed area entropies per 0.8km buffer neighbourhood)
Cervero and Kockelman (1997)	San Francisco	Land use entropy (mean)
Kockelman (1997)	San Francisco	Land use entropy (nonwork uses)
Frank and Pivo (1994)	Puget Sound	Land use entropy (origin CTs based on destination)
Frank and Pivo (1994)	Puget Sound	Land use entropy (origin CTs based on origin)
Manaugh and Kreider (in press)	Montreal, Toronto, Vancouver	Land use interaction index

Frank, Andersen and Schmid (2004)		Land use mix (evenness of distribution of sq.ft. of residential, commercial, office)
Rundle et al. (2007)		Land use mix (residential and commercial building area)
Hess, Moudoun and Logsdon (2001)	Puget Sound	Land use patch density
Hess, Moudoun and Logsdon (2001)	Puget Sound	Land use patch size
Lindsey et al. (2006)		Land use percentages by parcel
Forsyth et al. (2008)	Minneapolis	Land use percentages by parcel (major land uses, night time, social, retail, industrial, auto-oriented)
Brinklow (2010)	Various	Number of bedrooms
Boer et al. (2007)		Number of business types in a neighbourhood
King et al. (2005)		Number of businesses and facilities
Tilt et al. (2007)		Number of destination types
Handy, Cao and Mokhtarian (2006)		Number of types of businesses and establishments
Cervero and Kockelman (1997)	San Francisco	Parks/rec density (number of parks/rec facilities/developed acre)
Epstein et al (2006)		Percentage of parcels that are residential
Rutt and Coleman (2005)		Percentage of total buildings that are nonresidential
Handy (1996b)		Proportion of households within walking distance of retail district
Badland, Schofield and Garrett (2008)		Proportion of residential land use
Cervero and Kockelman (1997)	San Francisco	Proportion of residential land use within 1/4 mile of convenience or retail store
Boarnet and Sarmiento (1998)		Retail and service employment density per CT
Cervero and Kockelman (1997)	San Francisco	Retail density (number of stores/developed acre)
Cervero (1996)		Retail shop/mixed use dummy (within 300 feet)
Fan (2007)		Retail store count
Hanson and Schwab (1987)		Retail store count (every 0.5km increment)
Clifton and Handy (1998)		Retail store count (using Standard Industrial Code)
Lawton (1997)		Retail workers within 1 mile of residence
Yamada and Brown (2011)	Salt Lake City	Land use entropy
Michael et al. (2006)		Shopping mall dummy
Ritsema van Eck and Koomen (2008)	Puget Sound	Simpson's diversity index (entropy weighted by areas of each land use classification)
Forsyth et al. (2008)	Minneapolis	Simpson's diversity index (entropy weighted by areas of each land use classification)
Yamada and Brown (2011)	Salt Lake City	Simpson's diversity index (entropy weighted by areas of each land use classification)
Cervero and Kockelman (1997)	San Francisco	Vertical mixing (proportion of commercial-retail parcels)

Author	Location	Measures
Lindsey et al. (2006)		Average length of network segments
Renne (2009)	San Francisco	Block dimensions
Cervero and Kockelman (1997)	San Francisco	Block face length
Boer et al (2007)		Block length
Forsyth et al. (2008)	Minneapolis	Block perimeter (median)
Forsyth et al. (2008)	Minneapolis	Census block area (avg)
Forsyth et al. (2008)	Minneapolis	Census block area (median)
Rodriguez and Joo (2004)		Commute time difference with/without paths
Cohen et al. (2006)		Composite measure of alpha, beta, gamma indices (ratio of intersections to street segments)
Cohen et al. (2006)		Composite measure of block size (average street length, block area, block perimeter)
Schlossberg and Brown (2004)	Portland, OR	Cul-de-sac density (high/low)
Cervero and Kockelman (1997)	San Francisco	Distance between overhead lights
Brinklow (2010)	Various	Existence of physical street amenities
Schlossberg and Brown (2004)	Portland, OR	Impedance pedestrian catchment area ranking (good/poor)
Frank et al (2008)		Intersection density
Frank et al (2009)		Intersection density
Greenwald (2009)		Intersection density
Frank, Andersen, Schmid (2004)		Intersection density
Yamada and Brown (2011)	Salt Lake City	Intersection density
Forsyth et al. (2008)	Minneapolis	Intersection density (4-way)
Schlossberg and Brown (2004)	Portland, OR	Intersection density (high/low)
Levine, Inam and Torng (2000)		Intersection density (TAZ)
Hess, Moudoun and Logsdon (2001)	Puget Sound	Length of juxtaposed edges between compatible land uses
Renne (2009)	San Francisco	Number of 3+way intersections
Ball et al. (2007)		Number of 4+-way intersections
Brinklow (2010)	Various	Number of bike parking spaces at station
Brinklow (2010)	Various	Number of car parking spaces at station
Epstein et al (2006)		Number of intersections per length of street network
Renne (2009)	San Francisco	Number of street links
Forsyth et al. (2008)	Minneapolis	Number of transit access points
Rodriguez and Joo (2004)		Path directness
Brinklow (2010)	Various	Pedestrian activity index
Schlossberg and Brown (2004)	Portland, OR	Pedestrian catchment area ranking (good/poor)
LUTRAQ (1993)		Pedestrian Environment Factor
Cervero and Duncan (2003)		Pedestrian/bike friendly design factor
Forsyth et al. (2008)	Minneapolis	Percent 3-way intersections
Cervero and Kockelman (1997)	San Francisco	Percent 4-way intersections
Cervero (2007)		Percent 4-way intersections
Forsyth et al. (2008)	Minneapolis	Percent 4-way intersections
Lund et al (2004)		Percent 4-way intersections (destination)
Fan (2007)		Percent connected intersections
Rajamani et al (2003)		Percent cul-de-sacs
Rutt and Coleman (2005)		Percentage cul-de-sacs
Rodriguez and Joo (2004)		Percentage of shortest route to closest bus stop with sidewalk
Cervero and Kockelman (1997)	San Francisco	Proportion front and side parking
Cervero and Kockelman (1997)	San Francisco	Proportion of blocks with flat terrain (< 5% slope)
Cervero and Kockelman (1997)	San Francisco	Proportion of blocks with overhead lights
Cervero and Kockelman (1997)	San Francisco	Proportion of blocks with planting strips
Cervero and Kockelman (1997)	San Francisco	Proportion of blocks with quadrilateral shape
Cervero and Kockelman (1997)	San Francisco	Proportion of blocks with sidewalks
Cervero and Kockelman (1997)	San Francisco	Proportion of commercial parcels with paid parking
Badland, Schofield and Garrett (2008)	New Zealand	Proportion of intersection nodes to intersection+cul-de-sac nodes (250m commute route network buffer)
Schlossberg and Brown (2004)	Portland, OR	Quantity of accessible paths (high/low)
Schlossberg and Brown (2004)	Portland, OR	Quantity of impedance paths (high/low)
Forsyth et al. (2008)	Minneapolis	Ratio airline/network distance to destinations
Hess, Moudoun and Logsdon (2001)	Puget Sound	Ratio of patch area to perimeter
Yamada and Brown (2011)	Salt Lake City	Residential building age (median)

Rodriguez and Joo (2004)		Sidewalk coverage
Fan (2007)		Sidewalk length
Lee and Moudon (2006)		Sidewalk length
Cervero (2002)		Sidewalk ratio
Forsyth et al. (2008)	Minneapolis	Sidewalk ratio
Cervero and Kockelman (1997)	San Francisco	Sidewalk width
Ewing et al. (2004)		Sidewalk width (avg)
McGinn et al. (2007)		Street characteristics factor
Zhang (2004)		Street connectivity
Forsyth et al. (2008)	Minneapolis	Street density
Ewing et al. (2004)		Street density
Levine, Inam and Torng (2000)		Total length of streets
Doyle et al. (2006)		Walkability index
Frank, Schmid and Sallis (2005)		Walkability index (LUM, residential density, intersection density)
Cervero and Kockelman (1997)	San Francisco	Walkability index (Presence of sidewalks, street lights, block length, planted strips, lighting distance, flat terrain)
Berke et al. (2007)		Walkability index (proximity/density of grocery stores/other retail destinations, educational parcels, office mixed use complexes, block size)

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