

**EVALUATING THE IMPACTS OF TRANSPORTATION PLANS USING
ACCESSIBILITY MEASURES**

**L'ÉVALUATION DES PLANS DE TRANSPORT GRÂCE AUX MESURES
D'ACCESSIBILITÉ**

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EVALUATING THE IMPACTS OF TRANSPORTATION PLANS USING ACCESSIBILITY MEASURES

Abstract

Despite a growing awareness of the social and environmental impacts of transportation infrastructure, most transport plans aim to increase mobility while paying little attention to accessibility. The shift to planning for accessibility has been hampered by a lack of clear demonstrations of the usefulness of accessibility as a goal and norm for transportation planning. The purpose of this paper is to provide such a demonstration of the feasibility and value of accessibility evaluations with an analysis of Montréal's Transportation Plan. It shows how accessibility can be used by planners as a performance measure to evaluate a plan as a whole and to assess whether its goals will be attained, and/or to evaluate the plan on a project-by-project basis.

L'ÉVALUATION DES PLANS DE TRANSPORT GRÂCE AUX MESURES D'ACCESSIBILITÉ

Résumé

Malgré une reconnaissance accrue des impacts sociaux et environnementaux des infrastructures de transport, la plupart des plans de transport visent à augmenter la mobilité et donnent peu d'attention à l'accessibilité. Dans la pratique, le passage d'une planification axée sur la mobilité à une planification axée sur l'accessibilité a été lent, en partie à cause d'un manque de démonstrations claires de l'utilité de l'accessibilité comme objectif et comme mesure dans la planification des transports. Le but de ce travail est d'offrir une telle démonstration de la faisabilité et valeur de l'évaluation de l'accessibilité grâce à une analyse du Plan de transport de Montréal. Il montre comment l'accessibilité peut être utilisée par les urbanistes et planificateurs comme mesure de performance, d'une part, pour évaluer un plan dans son ensemble et estimer la mesure dans laquelle il permettra d'atteindre des objectifs de durabilité sociale et environnementale et, d'autre part, pour évaluer un plan sur la base des projets individuels qu'il contient.

INTRODUCTION

Since the 1990s, urban transportation planning has shifted in focus from strategies to increase infrastructure capacity for automobile traffic to broader policies with environmental and social dimensions (Banister & Gallent, 1999; Carmona & Sieh, 2008; Hall, 1997; Jabareen, 2006; Lindquist, 1998; Marsden, Lucas, Brooks, & Kimble, 2007). Plans now include goals that express principles of sustainable development, for instance improving air quality, reducing automobile dependency, and promoting active modes of transportation, including public transit. The adoption of such new goals has generated the need for performance measures to monitor progress toward their attainment. If no measures exist to monitor progress toward certain goals, planners may be loath to use them in the planning process or these goals may remain unaccounted for at the time of evaluation (Briassoulis, 2001; Handy, 2008; Meyer & Miller, 2000). Conventional performance-measures and indicators pertain to easily quantifiable objectives and are often one-dimensional. These measures appeal to the public and to decision-makers due to their simplicity and due to the fact that they can be intuitively grasped. Meanwhile, evaluating progress toward goals that reflect principles of sustainable development requires the integration of economic, social and environmental considerations and when measuring performance (Carmona & Sieh, 2008). Urban planners and engineers need multi-dimensional, spatially disaggregated indicators that help in examining the spatial distribution and interaction of various elements of their plans (Briassoulis, 2001). Despite these requirements, indicators must remain sufficiently simple and intuitively meaningful to be used in public forums and to become widely accepted measures.

In this paper, we explore the use of accessibility measures to evaluate how well the proposals put forward in transportation plans will help to attain less quantifiable goals linked to sustainable development. We generate simple, yet meaningful performance indicators based on accessibility measures and apply them to the Montréal Transportation Plan of 2008 (MTP) to examine the extent to which the proposed public transit and road infrastructure projects can work toward the plan's stated goals (Ville de Montréal, 2008). We use the Montréal Metropolitan

Region (MMR)¹ as our area of study, since some of the projects proposed in the plan have an effect outside the City of Montréal. We also examine the likely impact of the proposed projects on parts of the central city identified in the Montréal Master Plan as key revitalization areas, as well as the likely impact on the main employment centers of the metropolitan region (Ville de Montréal, 2004).

In the first part of this paper, we present a brief literature review of the application of accessibility measures to plan-making. This is followed by a short presentation of the MTP. We then summarize the results of our modeling analyses using several accessibility indicators. We conclude the paper with methodological comments on the use of accessibility as an index of performance, particularly in the context of urban planning.

ACCESSIBILITY AND PLAN-MAKING

Contrary to mobility, accessibility does not characterize movement itself, but rather the ease of reaching destination, which explains their spatial distribution. Accessibility measures describe how easily destinations of interest can be reached, and therefore can help to address many issues in planning, including economic and environmental impacts, and social equity (El-Geneidy & Levinson, 2007; Talen, 1998; Talen & Anselin, 1998). Accessibility measures can be applied to any mode of transportation at each stage of the planning and implementation process of a plan or strategy, and can be used to evaluate alternative plan or project options. Accessibility has an advantage on mobility in this aspect since it investigates both the land use and transportation component of the plan. Such measures vary from simple, easily understood graphic representations of isochrones (lines showing areas within which one can reach a given destination within a given travel time) to calculations based on complex theory. Accessibility-oriented analyses also make it possible to account for certain behavioral variables in urban transportation. For instance, they can help assess plans whose aim is to offer levels of reliability and travel times that are comparable, in both real and perceived terms, to those of the private automobile and are thereby likely to help retain existing and attract new users.

¹ The Transportation Plan and the Master Plan only apply to the City of Montréal proper (population 1.6 million), which occupies 366 km² of the 500 km² Island of Montréal within a metropolitan region of 4258 km² and a total Census Metropolitan Area population of 3.6 million (Collin, 2003; Statistics Canada, 2009; Ville de Montréal, 2009).

Accessibility is not easily felt by individuals as a number, which can help to explain why planners have continued to concentrate on mobility issues. Yet research has shown that accessibility does have effects on travel behavior as well as on home values (El-Geneidy & Levinson, 2006; Franklin & Waddell, 2003; Levinson, 1998).

Accessibility was first modeled in the late 1950s (Hansen, 1959), and many researchers have since developed the concept further. A number of review studies classify and evaluate accessibility measures according to various criteria (Baradaran & Ramjerdi, 2001; Cerdá & El-Geneidy, 2010; El-Geneidy & Levinson, 2006; Geurs, 2006; Geurs & Ritsema van Eck, 2001; Handy & Niemeier, 1997; Koenig, 1980). However, the gap between the theory of accessibility measurement and its practical application in a way that is useful to planners and to the public is not easily bridged. Many theoretically sound and very precise measures exist, but they are not always based on readily available data and are not often easy to calculate and to interpret.

The use of accessibility as a performance indicator in Regional Transportation Plans (RTP) has, until now, mostly focused on evaluating the social equity of existing and new transportation infrastructure. A few recently adopted RTPs have included performance measures based on accessibility to ascertain that no disproportionate increase in accessibility is given to wealthier populations as opposed to the less fortunate. For example, the increase in accessibility to parks and jobs within 30 minutes of travel by car and transit is used in the Los Angeles RTP (Southern California Association of Governments (SCAG), 2008), while accessibility to low-skilled jobs, weighted by low- and medium-income populations, with 30 minutes of travel by car and transit is used in the San Francisco Bay Area RTP (Metropolitan Transportation Commission (MTC), 2005).

A very interesting indicator of social equity that is used in this second RTP, which can also easily be applied to environmental assets, is the opportunity gap: the ratio between the number of opportunities available by car and those available by transit (Metropolitan Transportation Commission (MTC), 2005). This indicator can be used to show the extent to which a plan will help to reduce the difference between the number of opportunities that can be reached by transit and the number that can be reached by car, and thereby provide a good rationale for promoting transit use.

To the authors' knowledge, the Sacramento Regional Transportation Plan is the only plan that uses accessibility as a global performance measure (Sacramento Area Council of

Governments (SACOG), 2002). The regional average of the number of regional job centers accessible with a 45-minute transit trip or a 20-minute drive is one of the eleven key performance measures used to evaluate the plan.

Meanwhile, in the Canadian context transportation plans concentrate on mobility issues, while accessibility is rarely mentioned. For example, Calgary's recent transportation plan (2009) clearly includes affordable mobility and universal access among its main goals. On the other hand, the Ottawa Transportation Master Plan (2008) included as goals reducing automobile dependence and meeting mobility needs.

The development of accessibility measures offers two avenues for research on planning practice. On the one hand, researchers can examine the explicit use of such measures in plans such as the ones just mentioned. This avenue has merit, but it would limit research to those few cases where transportation plans explicitly include accessibility objectives. In fact, accessibility measures can be used to assess a great variety of plans (including land-use plans), and to show the accessibility impacts of policies and strategies that are aimed at other goals. This is the avenue we have chosen for this paper.

One of the main obstacles in using accessibility as a performance measure is that different accessibility measures will give different results. It is important, therefore, to consider the goal of the measure, the definition of opportunity, the access mode and the intended audience when selecting which measure to use (Morris, Dumble, & Wigan, 1979; Talen & Anselin, 1998). A balance between theoretical soundness and interpretability must be struck (Bertolini, Le Clerq, & Kapoen, 2005). All this goes to show that more work needs to be done to develop the methodology of accessibility measurement (in such a way as to make it both rigorous and easy to understand), and to demonstrate the modalities and usefulness of its application in practice. These are the two objectives we pursue in this paper.

THE MONTRÉAL STUDY CONTEXT

Montréal is located on an island in the St-Lawrence River, with an average metropolitan population density of about 6,000 persons per square mile of urbanized territory (outside the protected agricultural zones, which constitute 58% of the territory of the metropolitan region), and with a modal share of 22% for public transit in the morning commute to work (Communauté

métropolitaine de Montréal, 2010). Montréal has a subway (metro) system that extends into two off-island suburbs and a suburban train system that reaches far into the metropolitan periphery. Both systems are focused on downtown, the largest employment center of the metropolitan area. The other two largest employment centers are located elsewhere on the Island of Montréal, but employment is growing in off-island suburbs. The plans being discussed in this article are those of the City of Montréal and pertain only to its own territory, while taking into account regional transportation plans. Figure 1 shows the MMR, with the Island of Montréal in the middle, and the region's existing rail system. The boundaries of the City of Montréal are highlighted in the map.

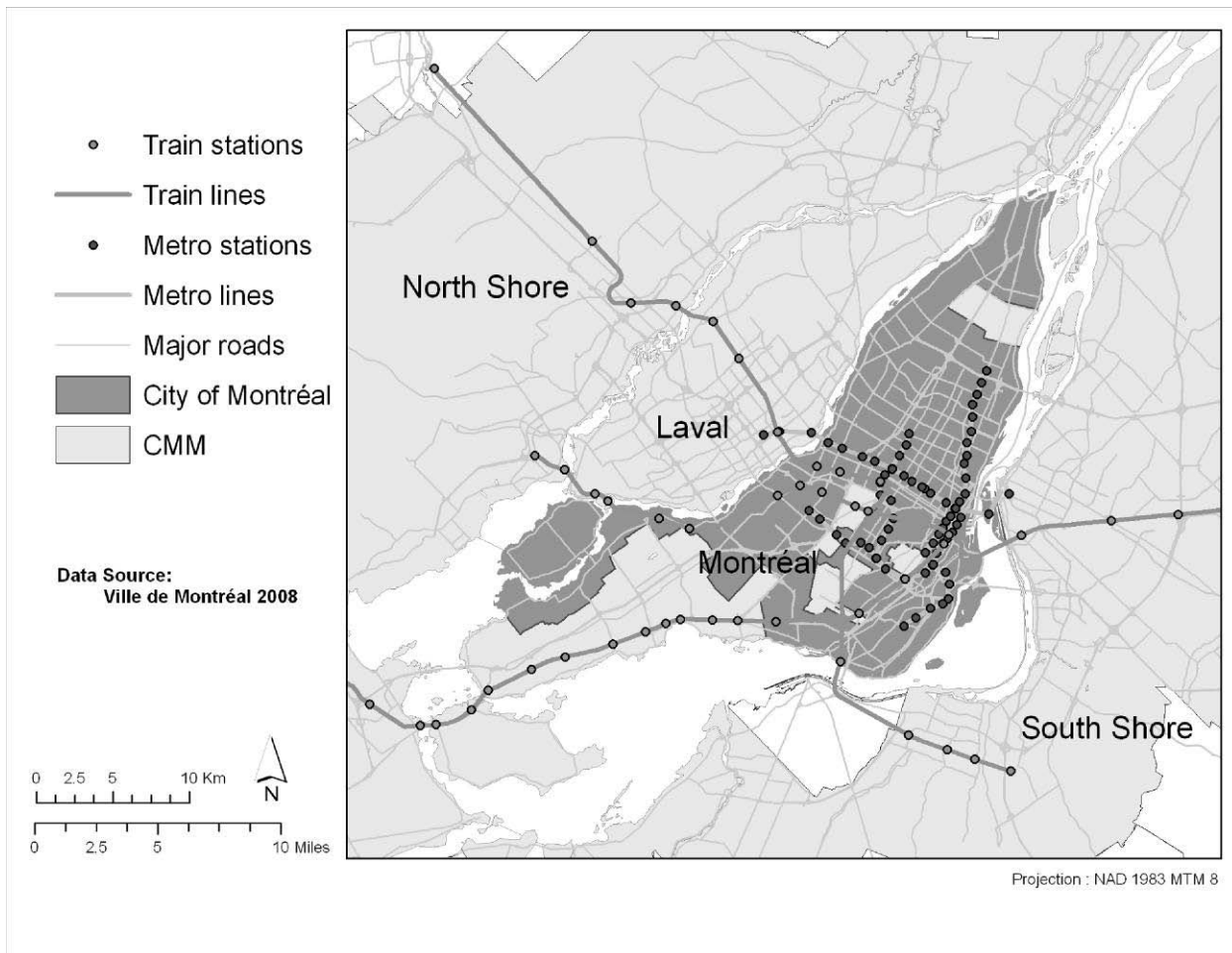


Figure 1: Montréal Metropolitan Region

The overarching goal of the MTP is to make public and active transportation the preferred modes of everyday travel, in order to reduce automobile dependency and to meet other

sustainability aims (Ville de Montréal, 2008). The MTP lists 21 strategic projects, nine of which concern public transit and four of which focus on active transportation. In this paper, we will concentrate on the public-transit portion of the plan. The MTP contains no performance measures or indicators to assess if in fact projects will help make transit and active transportation the preferred modes of travel. The authors of the plan present only one objective that can be easily measured: increase transit ridership by 8% by 2012, and by 26% by 2021. The remaining performance measures included in the plan are: variation in mode share, change in the volume of greenhouse-gas emissions, reduction in accident rates, and total transit-service hours (Ville de Montréal, 2008). None of these measures can effectively help to prioritize the various projects contained in the plan.

METHODOLOGY

The aim of our work is to develop tools that are both robust and simple enough to evaluate and communicate the impacts of the MTP on accessibility in a clear manner. In order to measure the changes in accessibility levels brought about by the projects proposed in the MTP, we first generated a Geographic Information System (GIS) model of the MMR with street and transit networks. We model only the heavy infrastructure projects of the MTP; for example, new transit and road improvement projects, but not projects related to pedestrian safety or bicycle infrastructure. The transit projects included in this analysis are the new Tramway (Light Rail Transit) lines, the rail link to the airport, extensions to the commuter rail system and to the metro system, the new Bus Rapid Transit (BRT) lines, and increased reliability and travel speeds for existing bus lines owing to signal-priority measures and/or reserved lanes. The road projects include: measures to increase speeds and capacity along certain arterials, new roads serving industrial brownfield areas, and a new highway section and bridge connecting the north side of the Island of Montréal to the Island of Laval. While this last project is not part of the MTP—it is, instead, a provincial project—it is included in the analysis because several important transportation projects are planned around it.

Accessibility is measured here using cumulative opportunity measures. These measures, which were among the earliest ones to be developed, are also among the simplest to calculate (Vickerman, 1974; Wachs & Kumagai, 1973). Cumulative opportunity reflects the number of

opportunities available from a predetermined point within a certain travel time or travel distance, using a certain mode of transport or even a combination.

An alternative to the measure of cumulative opportunity is the measure of gravity-based opportunity (Hansen, 1959), in which destinations are weighted according to their proximity to the point of origin. In this measure, distance or travel time affects the value of a destination. An empirically determined distance or travel-time decay function for a given transportation mode is derived based on travel surveys. The gravity-based measure of accessibility is more theoretically sound than the cumulative measure because it discounts opportunities according to their distance or travel time from an origin, rather than using an artificially determined threshold that accounts for opportunities within, for example, 30 minutes of travel time but not those that require 31 or more minutes of travel time. The gravity measure is also more representative of how users perceive the transport system because it strikes a balance between the utility of a destination and the cost of travel to it from a given origin (Miller, 2005). Although the gravity measure is widely acceptable in the transportation planning literature, it is a complex measure to calculate, and it can be difficult to interpret and to explain to the general public or to decision makers.

On the other hand, cumulative measures do not rely on assumptions about the value of destinations to users, but only assume the chosen threshold in travel time or distance (Geurs & Ritsema van Eck, 2001). Cumulative measures also allow for easy comparison of accessibility across modes and types of destinations, thereby simplifying the interpretation of results and their discussion in public forums.

Other measures, such as the *inverse balancing factors* of the *doubly constrained* spatial interaction model (Wilson, 1971) and *utility-based* measures (Ben-Akiva & Lerman, 1979) are not as widely used as gravity-based and cumulative measures, due to the complexity in calculations and difficulty in explaining them to the general public and stakeholders. For example, the *inverse balancing factors* measure suffers from the disadvantage of being more difficult to calculate and interpret than other measures because of the iterative process that incorporates both the locations of supply and demand. Utility-based measures, on the other hand, are the most complex and data-intensive of the location-based accessibility measures. They are

based on random utility theory, in which the probability of an individual making a particular choice is relative to the utility of all choices.²

For this study, we decided to use a cumulative opportunity measure because it represents a better balance between theoretical soundness and ease of understanding and communication. We also found a high correlation between the results obtained using gravity measures and those obtained with cumulative measures for travel by car and transit on the existing network, for trips varying from 20 to 45 minutes in duration (Figure 2). In fact, the resulting number of jobs that can be reached within 30 minutes by car and transit using the cumulative measure is very highly correlated to the resulting number of jobs using the gravity measure (0.9). A similarly high correlation was found in previous research (El-Geneidy & Levinson, 2006). The measures derived in Figure 2 relied mainly on travel time data obtained from a travel demand model, while the gravity measure depended on the same source for travel time and decay curves derived from an Origin-Destination survey (Agence métropolitaine de transport, 2003). The number of jobs is obtained from the Canadian Census.

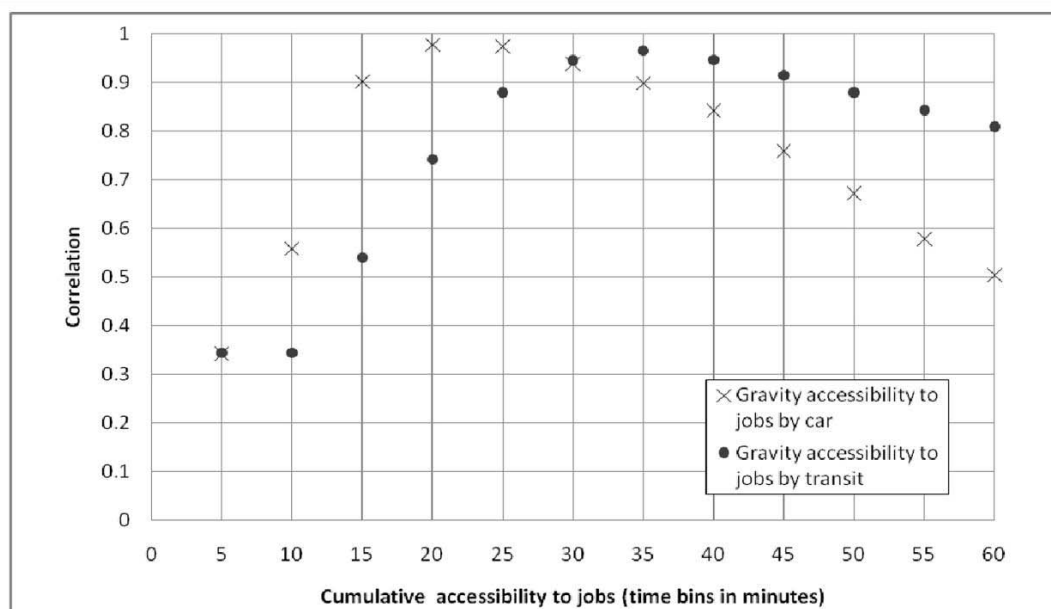


Figure 2: Correlation between the results of the gravity and cumulative opportunity measures of accessibility for travel by car and by transit using the existing Montréal road and transit network.

² For further comparisons of the various measures of accessibility and their advantages and disadvantages, see Baradaran & Ramjerdi (2001), El-Geneidy & Levinson (2006), Geurs (2006), Geurs & Ritsema van Eck (2001), Handy & Niemeier (1997), and Koenig (1980).

Accessibility indicators often focus on the home-work commute. This is, in part, because accessibility to jobs can be used as an economic indicator and because work is an important travel generator. Previous research has also shown a significant effect of accessibility to jobs on home sale value, indicating that home buyers value employment accessibility (El-Geneidy & Levinson, 2006). In Montréal, 50% of trips in the A.M. peak are work-related. Also, 73% of these trips are made by car during the same period. The average length of the daily commute (round-trip) in Montréal has risen from 62 minutes in 2001 to 76 minutes in 2005. On average, a transit user in Canada spends at least 41 more minutes commuting each day than those who drive (Turcotte, 2006). This raises the question of whether commuters have a real choice when it comes to choosing between the car and transit for their daily commute.

Making the commute by transit more competitive with the commute by car is one way of favoring transit and helping to reduce automobile dependency. The home-work commute is also the easiest to influence in terms of travel behavior because it is relatively habitual and unchanging. Policies to improve transit service, such as increasing transit capacity, reliability and frequency, can also help in making this option more attractive to users (Krizek & El-Geneidy, 2007). However, if transit is not competitive with the car, by failing to give people access to a similar number of destinations within a similar amount of time, these policies may be unsuccessful. For this reason, the indicators developed in this research aim to measure the possible impact of projects in the MTP in making transit a competitive mode, which can lead to a shift in the chosen transport mode for commuting to work.

Five indicators were developed to evaluate the extent to which the proposed projects in the MTP meet the plan's main goals of favoring public transit over private automobiles and reducing auto-dependency:

1. The overall change in accessibility to jobs by transit and by car in 30 minutes travel time and the spatial distribution of these improvements.³
2. The change in the ratio of jobs that can be reached by transit and by car in 30 minutes of travel time.

³ Travel time for car is measured as the travel time from the centroid of traffic analysis zone to the centroid of another traffic analysis zone. Travel time for transit is measured using access time to transit service from the centroid of a zone, waiting time at the station, in-vehicle time, transfer time, and egress time to the center of another zone.

3. The overall increase in accessibility to jobs due to each transit project in the plan, for trips with a maximum of 30 minutes of in-vehicle time.
4. The increase in accessibility to workers in Montréal's six employment centers by car and by transit in 30 minutes travel time.
5. The impact of each transit project in the plan on areas slated for revitalization in the Montréal Master Plan and on employment centers, in terms of accessibility to jobs with trips of 30 minutes of in-vehicle time or less.

With the average length of one-way commutes at about 30 minutes for the car and about 50 minutes for public transit, a 30-minute in-vehicle trip is a fair representation of travel habits in the Montréal Metropolitan Region. We used this standard wherever possible. In other cases, where total travel time (rather than in-vehicle travel time) is limited to 30 minutes, public transit is somewhat penalized. However, even this norm is valid in that it more truly represents the perception of drivers and transit users: the former tend to spend little travel time outside their vehicle, while the latter tend to incorporate out-of-vehicle time in their commuting time. Making public transit truly competitive with the private automobile requires that total travel times (including in-vehicle and out-of-vehicle time) be made more equal and, hence, that the level of accessibility attained by a 30-minute commute by transit be fairly equal to that attained by a 30-minute commute by car.

DATA AND ASSUMPTIONS

For this study, the main unit of analysis is the Traffic Analysis Zone (TAZ) defined by the Québec Ministère des transports (MTQ). The MTQ also provided the research team with travel time information for auto and transit that was generated by a travel demand modeling software. Employment and demographic information was extracted from the 2006 Census conducted by Statistics Canada. Street centerline files were obtained from CanMap, while the transit network information was received from the Société de Transport de Montréal (STM).

In order to compare both modes, and to model the proposed projects, new travel time matrices were generated. First, a free-flow travel-time matrix was generated in GIS for automobile trips. Next, a linear regression model was run using simulated congested travel times

obtained from the MTQ as the dependent variable, and free-flow GIS travel times and a set of variables representing if the trip origins and destinations are in the downtown district, the South Shore, Laval, and the North Shore as the independent variables. The results of this model were then used to generate a new congested travel time matrix for automobile travel based on the GIS network. This method assumes minor changes in congestion levels for automobile travel after the implementation of most of the projects proposed in the transportation plan.

A transit travel time matrix was also generated in a GIS environment, using each of the transit stops closest to each TAZ centroid as both origins and destinations. The trips were modeled from the origin to the destination by calculating access and egress time at both the origin and destination, from or to the closest stop (assuming an average walking speed of 5 km/h), and the shortest time on the transit network from the origin stop to the destination stop, which represents in-vehicle time. Travel times on the transit network were estimated based on the average operating speed of each individual transit line represented on the prepared GIS transit network. This method assumes that there is no waiting time at the start of the transit trip or at a transfer between lines. To correct this, a linear regression model was derived to compare the simulated travel times to the travel times provided by the MTQ. The latter include walking time to the transit stop, waiting time at the stop, in-vehicle time, transfer time (if a transfer is necessary), and walking time to the destination. A second set of travel time matrices was generated based on in-vehicle travel time. This was mainly generated based on existing schedules and accounts for congestion and the presence of any service enhancement strategies.

RESULTS

Overall impact

The first indicator we constructed is a measure of the change in accessibility to jobs in 30 minutes by car and by transit. In order to calculate this change, the total number of jobs that could be reached within 30 minutes by car and by transit was first calculated using the current network and then using the proposed network, and the two results are then compared. The transit travel time used in this calculation accounts for access, waiting, in-vehicle, transfer, and egress times.

The percent increase in accessibility by each mode is shown in Table 1. Overall accessibility to both jobs and workers will increase with the proposed projects, and the

accessibility gains for transit will be larger than those for the automobile. The differences between current and future levels of accessibility are mapped in Figure 3 and Figure 4. Mapping the spatial distribution of changes in accessibility levels makes it easy to identify the areas where MTP projects, such as a new bridge or metro line, will have an impact.

Table 1: Overall percent change in accessibility within 30 minutes of travel time with the implementation of the MTP.

Mode	Accessibility to jobs	Accessibility to workers
Car	0.22%	0.32%
Transit	5.93%	6.74%

As shown in Figure 3, the road projects in the MTP correspond to important links missing from the existing network. Although these projects are few in number, they will dramatically increase accessibility to jobs in certain areas, by connecting residential areas with employment centers. For example, the extension of a single road in the middle of the island (Cavendish Blvd) will connect two boroughs (Côte-St-Luc and St-Laurent), one of which is mostly residential in character and one of which has a very large number of jobs. The project will also open up isolated brownfield sites to new development. Here, the MTP is responding to important needs with strategic projects that improve accessibility in areas where it is currently weak.

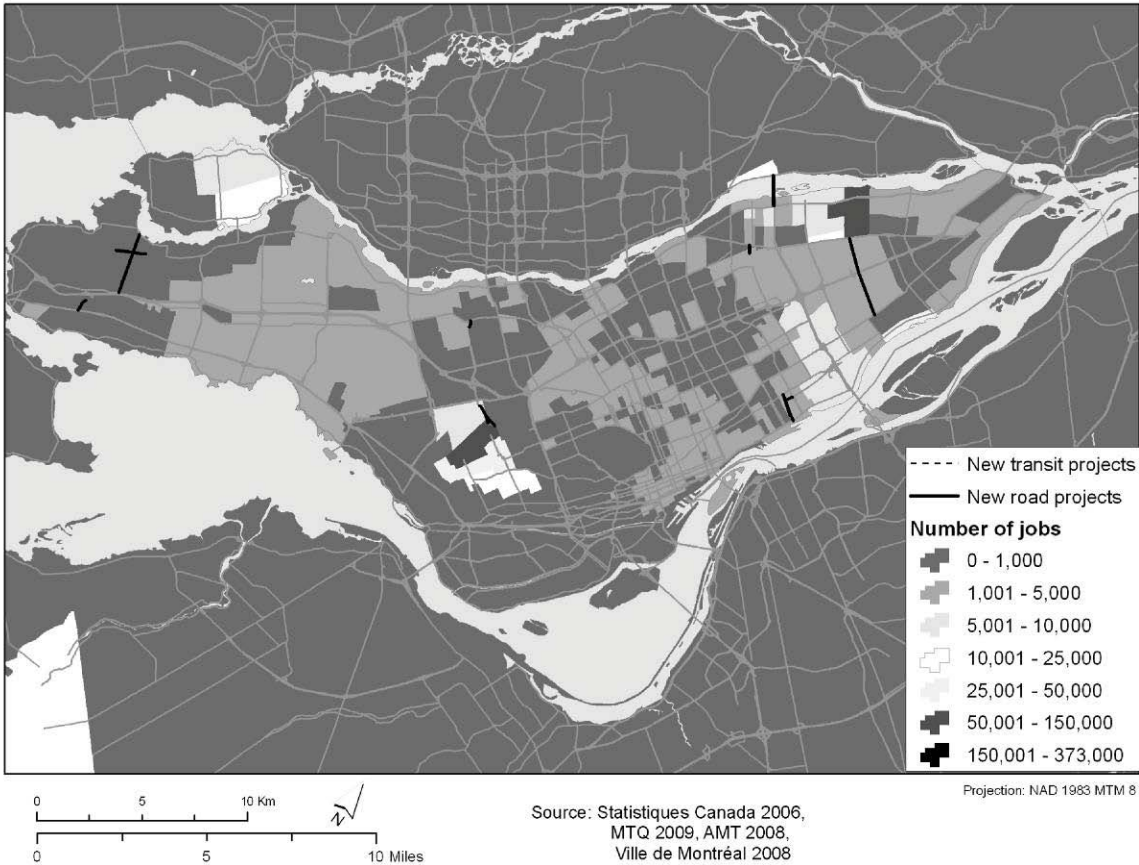


Figure 3: Changes in accessibility to jobs by car within 30 minutes travel time assuming full implementation of the MTP (cumulative opportunity measure).

Figure 4 shows the change in the level of accessibility by public transit. As said, the travel time used in this calculation accounts for access, waiting, in-vehicle, transfer, and egress times. The transit improvements impact more zones than the road improvements discussed above, especially in central areas. But since many of the proposed projects are set to improve existing lines rather than create new ones (for example, a light rail line replacing a high-frequency bus route), they do not extend the coverage of transit accessibility. These projects will have a major impact on increasing transit capacity, a minor impact on speed, and will perhaps increase comfort levels in the central neighborhoods. However, they will not help make transit competitive in the eastern and western parts of the island, despite two important infrastructure projects (commuter train and metro) being projected in the east. Furthermore, the transit improvements will impact areas off the Island of Montréal.

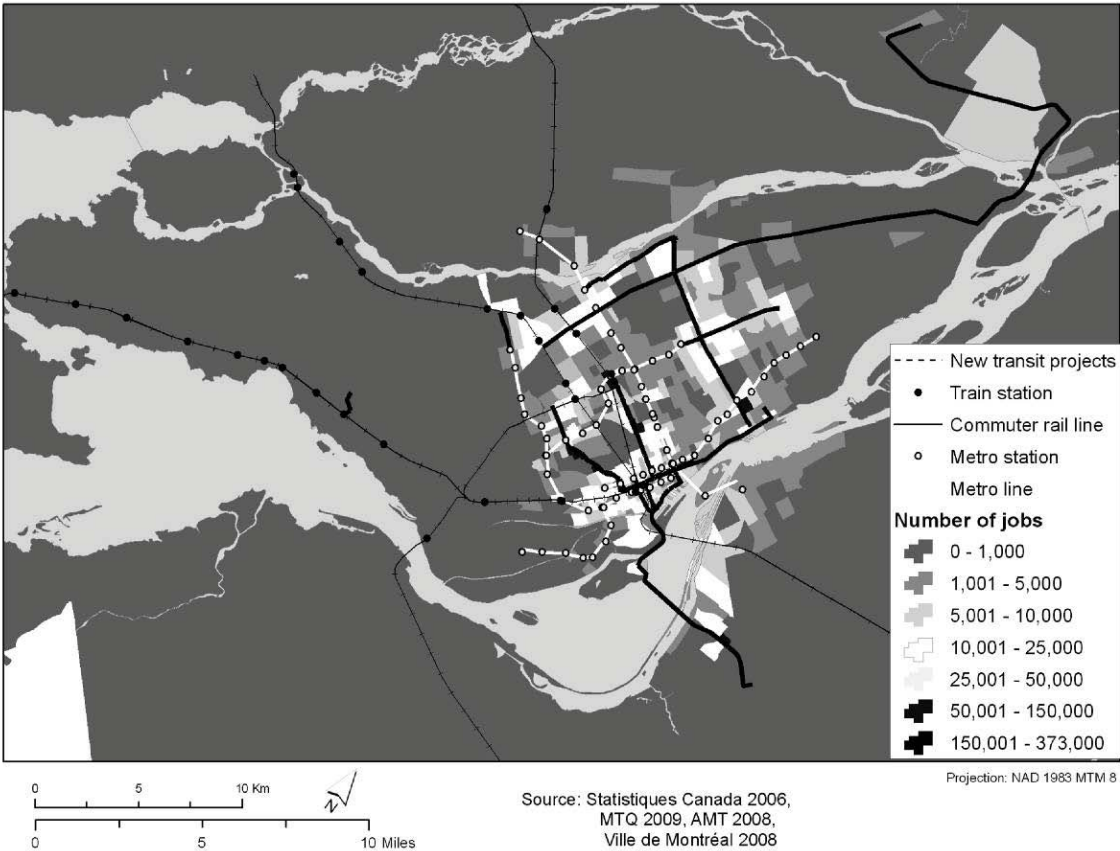


Figure 4: Changes in accessibility to jobs by transit within 30 minutes travel time assuming full implementation of the MTP (cumulative opportunity measure).

Reducing the opportunity gap

The second indicator is the change in the ratio of the number of jobs that can be reached within 30 minutes by transit and the number of jobs that can be reached within 30 minutes by car. Figure 5 shows the distribution of this change throughout the region. Orange to red shades represents greater gains in transit accessibility than in car accessibility, and grey to blue shades denote the opposite.

The zones where transit becomes more competitive in offering access to jobs are mainly located in the central part of the island. However, some of these zones are located off the Island of Montréal, in Laval and on the north and south shores, near improvements that extend the transit network. Enhanced accessibility to jobs by automobile is dominant in the east and west in the east and west ends of the island, and some parts of the central city. The new road projects

proposed in the MTP will undermine efforts to shift commuting trips to transit in these areas, by making the commute by car even more attractive than it is now.

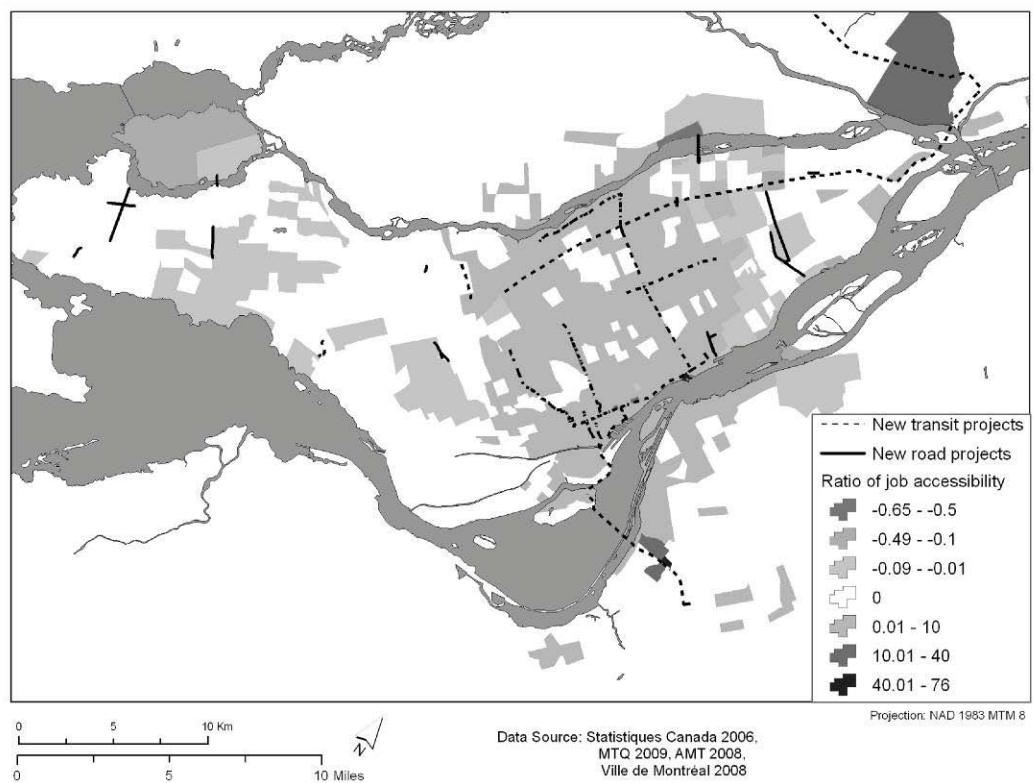


Figure 5: Change in the ratio of jobs accessible by transit and by car within 30 minutes travel time assuming full implementation of the MTP.

The results of this indicator confirm that the MTP meets its goal of favouring transit over the car, in terms of connecting commuters with work opportunities, in the central part of the city and in some suburbs off the island. It does not, however, meet this goal in the eastern and western parts of the island. In particular, the proposed suburban train extension toward the east of the island does not compete well with proposed road projects in that area, in terms of increased accessibility to jobs. There are two reasons for this. First, as noted earlier, the road projects in the MTP are very strategic and complete a very dense road network. Given that the transit network is less dense, individual projects may have less of an impact on job accessibility. Secondly, comparing car and transit accessibility requires making some assumptions about the way people travel and what they value. As a result of the longer walking access and egress times, in addition to the transfer and waiting times for transit, the transit network is at a disadvantage

when compared to the car. The use of a 30-minute travel time was essential in this comparison since it helps in comparing the accessibility measures across different modes, which is something that is not possible for other measures like the gravity-based measure.

Prioritizing projects

The previous indicators are useful to assess the extent to which the MTP is meeting its objectives. Other accessibility indicators can be useful in comparing different projects and can help set priorities among them. In order to examine the impacts of each transit project in detail, the overall increase in accessibility to jobs due to each transit project in the plan, for trips with a maximum of 30 minutes of in-vehicle time is modeled. The change in accessibility was measured by individually adding the proposed projects to the existing network and generating travel times. This enabled us to measure the impact of a specific project, rather than assess the accrued impact of several projects. However, the same process can be followed for a combination of improvements. For this indicator, the travel time threshold is also 30 minutes, but travel times do not include access, egress, waiting or transfer times; they simply represent TAZ to TAZ in-vehicle times. Travel times are modeled this way in order to compare the changes in accessibility brought about by projects in a way that does not advantage zones with a denser existing transit network (where users will walk a short distance to transit), over more suburban zones (where users might drive to transit). Figure 6 is a map showing the major transit projects, business centers and revitalization areas in the Montréal region.

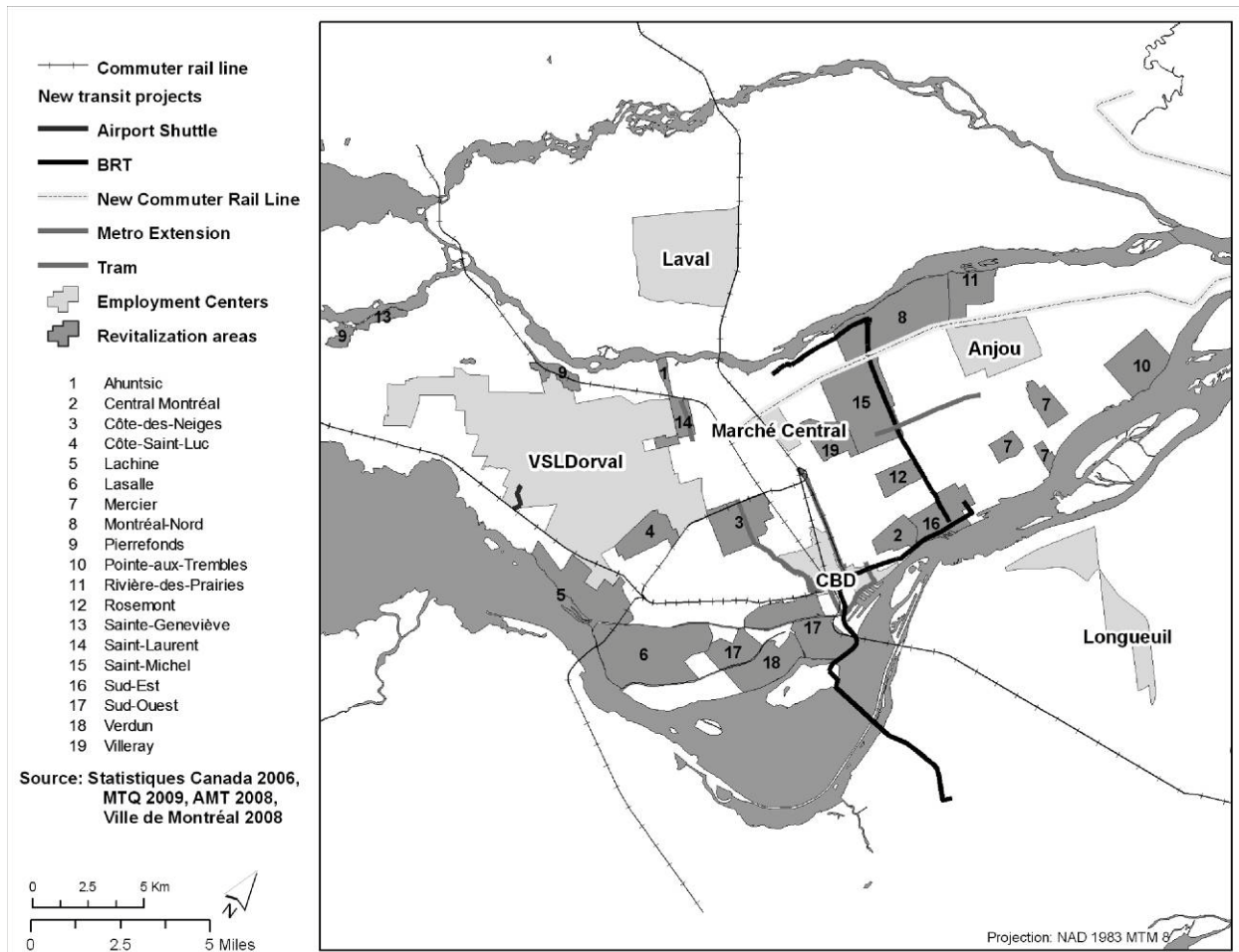


Figure 6: Major transit projects, business centers and revitalization areas in the Montréal region.

Table 2 shows the increase in accessibility to jobs and to workers, within 30 minutes of in-vehicle travel time, for each transit project in the MTP. This indicator should be used first and foremost to compare the potential of each project on accessibility, rather than to assess its impact on the competitiveness of transit vis-à-vis the car. When designing a specific transit project for implementation, access, egress, waiting and transfer times should be carefully considered. Providing adequate park-and-ride facilities near commuter-rail stations may contribute to keeping access times low and making transit more attractive for commuting.

Table 2: Percent change in accessibility of projected transit projects in the MTP

Project	Accessibility to jobs	Accessibility to workers
Commuter train	7.66%	7.10%
Airport shuttle	0.15%	0.06%
BRT (all)	5.69%	5.67%
Metro	3.07%	3.67%
Tramway (All)	1.77%	1.33%
All Projects	18.59%	17.06%

As shown in Table 2, the projects with the highest potential for increasing accessibility to both jobs and workers are the commuter rail line and the metro extension in the east end of Montréal. However, their potential competitiveness with the car is diminished by the amount of time devoted outside the vehicle. It is important to note that the Airport shuttle is part of the plan yet it is designed to facilitate moving visitors to Montreal directly from the airport to downtown. So its intention is not for providing access to jobs. As was seen in the analysis for the previous two indicators, these projects do not increase accessibility very much when total travel time is considered rather than in-vehicle travel time, and they are subject to increased competition from the car as a result of new road projects nearby.

Integrating changes with land use

Measuring changes in accessibility in specific areas can be useful for local planning or for promoting project-based coordination between different public agencies. Transportation projects, by themselves, cannot create denser, mixed-use and active neighbourhoods, but they can be catalysts for redevelopment and create conditions for improved economic development (Gospodini, 2005). Of particular importance in integrated transportation and land-use planning (in regional planning in general but especially in the prevention of sprawl), is planning for the location of new jobs (Bourne, 2001). In this respect, the Montréal Master Plan is clear: existing employment centers on the Island of Montréal should be reinforced (Ville de Montréal 2004). An increase in accessibility to workers by transit will be necessary before demand-management plans and policies promoting transit use can be effective.

To test how the MTP would contribute to making access to employment centers by transit more competitive, we measured the change in accessibility to workers in Montréal's six employment centers brought about by the implementation of the plan's various projects. To estimate accessibility gains, we used both overall travel times for the whole MTP and in-vehicle times for each transit project. The number of workers is defined as the population of individuals aged 15 and over who were employed or seeking employment, based on 2006 Census data and estimated at the TAZ level. Employment centers were defined according to the results of studies of Montréal's regional employment geography conducted for the government (Coffey & Shearmur, 2001; Shearmur & Coffey, 2002).

Table 3: Percent change in accessibility to workers at major employment centers in the MMR

Emp. center	Car	Transit	Tramway	Comm. train	Airport shuttle	BRT	Metro	All Projects
Anjou	0.86%	3.84%	0.14%	47.06%	0.00%	11.94%	45.16%	80.50%
CBD	0.36%	12.12%	7.81%	0.97%	0.00%	7.37%	0.89%	17.66%
Laval	0.00%	0.00%	1.02%	7.18%	0.00%	6.02%	4.19%	18.31%
Longueuil	0.07%	0.00%	1.35%	0.15%	0.00%	16.52%	5.23%	24.11%
Marché Central	0.11%	10.25%	0.15%	9.76%	0.00%	4.07%	6.60%	14.76%
VSL/Dorval	0.52%	0.00%	0.72%	0.89%	1.73%	0.39%	0.98%	6.10%

Table 3 shows the increase in the percentage of workers in the MMR with access to the six major job centers within 30 minute of in-vehicle travel time, after the implementation of the MTP. In other words, it shows the extent to which MTP projects help companies in major employment centers become more accessible to current or potential workers and, hence, make them more competitive employers, all else being equal. The projected transit improvements will increase employment accessibility by as much as 12% in the CBD and 10% in Marché-Central. Longueuil, Laval and VSL/Dorval do not benefit from any increased transit accessibility. Laval and Longueuil are off the island, and are not part of the Plan. However, regional planning will be important for the success of the MTP, especially in reducing car use on the island. In the morning peak period alone, 16% of work-related trips to the South Shore and 20% of work-related trips to Laval originate on the Island of Montréal (Agence métropolitaine de transport, 2003). This suggests that some kind of coordination between the transit agencies of Montréal,

Laval and Longueuil is warranted. The lack of improvement in the VSL/Dorval area is more important. No project increases the number of workers who can reach this very large employment in 30 minutes of in-vehicle time by more than 2%, and all projects together bring about only a 6% increase. Considering that in 2003, 92% of trips to and from the West Island, of which VSL/Dorval is a part, were made by car (Agence métropolitaine de transport, 2003), this area should benefit from a priority project to encourage transit use for the work commute in a more significant manner.

Another interesting conclusion is that both the metro and train projects could potentially almost double the number of workers who can access the Anjou employment center by transit within 30 minutes of in-vehicle travel time. In accordance with the goals in the Master Plan to favour transit access to employment centers, this would warrant giving these two transit projects priority over others. But their implementation should be accompanied by the adoption of demand-management plans and transit-promotion strategies by large companies in the sector. Finally it is important to note that the change in accessibility by car is generally minor compared to the changes being observed in transit. This is in line with the MTP goals of favoring public transit.

Impacts on recommended revitalization areas

The impact of each transit project in the plan on areas slated for revitalization in the Master Plan (Ville de Montréal, 2004) is the final stage of this analysis. Compared to the rest of the city, these areas have a poorer population, their housing stock is in worse condition, and they experience less economic development. To evaluate the contribution of the MTP to the goal of providing local residents better access to jobs, we applied the measure of accessibility to jobs specifically for the TAZs corresponding to the areas targeted in the Master Plan. The threshold used is 30 minutes of in-vehicle travel time. Here, too, the benefits accruing from the commuter train project are many. In particular, Montréal-Nord, a poor neighborhood with a low average socio-economic performance, will benefit from an increase of more than 100% in accessibility to jobs (Table 4). This should stimulate local economic development by improving the employment prospects of local residents and, in addition, by improving the attractiveness of areas near train stations for real estate development. The BRT project will also increase job accessibility significantly in Montréal Nord.

Using local accessibility to jobs as an indicator, we see that some of the proposed public transit projects can have important positive impacts, especially in poorer neighborhoods. Our analysis shows that three projects in particular (those related to the commuter train, the BRT and the metro), are more likely to play this role because they will significantly change the connection between neighborhoods subject to revitalization in the near future and the region's main employment centers.

Table 4: Percent change in accessibility to jobs in Montréal's revitalization areas

Revitalization Area	Tramway	Commuter Train	Airport Shuttle	BRT	Metro
Ahuntsic	4.00%	3.98%	0.00%	0.92%	2.63%
Central Montréal	0.17%	0.12%	0.00%	0.59%	0.51%
Côte-des-Neiges	2.89%	0.62%	0.00%	1.69%	3.90%
Côte-Saint-Luc	6.99%	0.00%	0.00%	0.17%	0.43%
Lachine	1.88%	0.00%	3.32%	0.33%	0.00%
Lasalle	6.48%	0.00%	0.10%	0.52%	0.01%
Mercier	4.15%	0.53%	0.00%	3.32%	7.81%
Montréal-Nord	0.25%	107.76%	0.00%	74.57%	5.20%
Pierrefonds	1.21%	4.69%	0.00%	0.06%	2.04%
Pointe-aux-Trembles	0.00%	10.49%	0.00%	0.73%	0.55%
Rivière-des-Prairies	0.00%	73.47%	0.00%	13.82%	9.00%
Rosemont	0.96%	0.72%	0.00%	10.04%	1.90%
Sainte-Genève	0.00%	0.00%	0.00%	0.00%	0.00%
Saint-Laurent	2.23%	4.53%	0.00%	0.67%	3.49%
Saint-Michel	1.52%	6.56%	0.00%	13.34%	5.42%
Sud-Est	0.59%	0.07%	0.00%	6.84%	0.19%
Sud-Ouest	0.91%	0.10%	0.02%	1.02%	0.92%
Verdun	1.07%	0.63%	0.00%	1.67%	0.26%
Villeray	1.05%	4.34%	0.00%	2.28%	4.67%

A significant point that emerges from the preceding analysis concerns the challenge of integrating land-use and transportation planning. The objectives of favouring public and active transportation and reducing automobile dependency can be pursued through a variety of projects and policies, which include but are not limited to the addition of infrastructure. Changes in land use can also be effective in increasing accessibility levels.

CONCLUSION

Using a simple accessibility measure, cumulative opportunity, to evaluate the impacts of network changes proposed in the 2008 Montreal Transport Plan (MTP), this study has shown one way in which transportation plans can be examined to determine how realistically they can be expected to achieve stated policy goals. In this case, the goals were drawn from the MTP itself and from the city's Master Plan. Thus, the MTP was analyzed for its possible contribution to making public transit more competitive with the private automobile and for its possible contribution to improvements in parts of the city designated as revitalization areas. The bus, rail and road projects contained in the MTP were modeled and accessibility to jobs and to workers were measured before and after network changes, for both automobile travel and travel by public transit. The respective changes in accessibility by car and by public transit were compared to determine which mode was more strongly favored by the plan. Improvements in accessibility were calculated for the plan as a whole and on a project-by-project basis. The latter approach was shown to be useful to establish priorities among projects that would require large public investments.

Further work on the MTP could include an evaluation of accessibility changes brought about by other elements of the MTP, such as the objective to increase the modal share of cycling and the proposal to expand the network of bicycle lanes and related facilities. Changes in accessibility can be evaluated for different travel times, comparing, for example, before-and-after conditions for 45 minutes of total travel time by car and by transit, or 30 minutes by car and 45 minutes by transit. The analysis could also be done for a future situation modeled to contain not only expanded transportation opportunities, but also increased densities in population and/or in employment along the corridors of major road or transit improvements. Accessibility can be measured for users and destinations other than workers and jobs; for instance, it can be measured for children and educational institutions, parks and other recreation facilities, or for shoppers and commerce. Also, accessibility can be studied by matching jobs with levels of skill and comparing which jobs are being accessed by which group of workers. Finally, the work presented here could be complemented by an analysis of social impacts, such as an evaluation of which groups in Montréal stand to gain the most from the proposed transportation projects of the MTP.

The concept and measurement of accessibility holds much promise for urban planners. Accessibility brings together both the location of people, places and activities, and the geography

of transportation in a single indicator. The analysis of accessibility enables us to evaluate the magnitude and the spatial distribution of benefits flowing from the implementation of transportation plans and of Master Plans that have transportation elements. Using accessibility as a performance indicator during the planning process itself makes it possible to assess objectively the likely impacts of alternative scenarios, thereby contributing to a more rational decision-making process. The performance that is so ascertained can also pertain to the equity of urban systems, as accessibility (and not just proximity) to opportunities for employment, education and recreation is examined for different groups.

Accessibility measures are not the only measures that can be used to evaluate transportation plans and to monitor their implementation, though they are uniquely suitable to understanding the interaction between transportation and land use, and hence to assessing the spatial impacts of transportation projects. Mobility measures are still expected to play a role in evaluating plans from the transportation side, and other measures, such as indices of economic impact, should be considered as well, depending on the stated goals of the plan. But the limited analysis presented here, we hope, has demonstrated the feasibility and usefulness of using accessibility measures to evaluate plans and their contribution to the improvement of cities and regions.

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