Incorporating issues of social justice and equity into transportation planning and policy

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ABSTRACT

For most of the 20th century transportation planning goals were almost entirely mobility-based; transportation systems were primarily seen as a means to efficiently, safely, and quickly connect people and freight to desired destinations. However, as the century progressed, cultural, societal and ecological movements had major impacts on how planners perceive transportation networks and public transit more specifically. Several overlapping concerns have altered the role that planners and policy-makers see for transportation and land use planning. Environmental degradation, air pollution, traffic congestion, an unsure energy future, and global climate change, for example, have drastically redefined priorities for planners and policy-makers. These concerns have led to an increasing interest in public transit and active transportation—walking and cycling—as potential solutions to many environmental problems. Concurrent to these shifts, concerns of social equity and environmental justice have also entered the transportation planning framework.

However, while transportation planning goals have shifted in recent decades to encompass social justice and environmental goals, many of these aims do not have clear indicators or accepted ways of measuring progress. In addition, while these diverse values and ideals do often underlie policy, they can have contradictory influence on transportation planning decisions. Transportation benefits include, what might be termed "tangible" or easily measured outcomes, such as reduced congestion, increased coverage of public transit, or increased length of bike paths. However, many goals that address issues of social equity have "intangible" outcomes. Not only are the former easier to measure and to present to the public, but they often have more political capital than more socially progressive goals.

While a rich body of research has explored these issues, most current planning documents do not make explicit that these conflicts of value exist. The concern from an equity planning standpoint is that very real and important environmental concerns will lead away from the other important roles that transportation systems can play in providing equitable outcomes. In light of these concerns, this dissertation sets out to address four research questions:

- How do municipalities and transit agencies balance economic, social, and environmental goals and objectives in transportation plans?
- How do these decisions affect outcomes, particularly with regards to social equity?
- How can current methods of measuring and understanding active transportation and neighbourhood walkability be improved to better capture these wide ranging objectives?
- How can these findings be used to improve decision-making in the future?

These four questions are addressed through a series of four empirical studies using mixed-methods and a range of geographic scales, moving from the regional

to the neighbourhood scale, and encompassing households and individual-level travel decisions.

An examination of eighteen transportation plans from North America suggests that, while many plans include social equity goals as part of their stated objective of achieving sustainability, these plans have an over-emphasis on environmental outcomes. Further, indicators to measure progress toward social equity objectives are often absent or inappropriate. This research explores a gap in the current understanding of the social equity implications of sustainable transportation and suggests a set of indicators to capture the often-elusive characteristics of social equity in a transport context.

Using current and projected regional accessibility measures and detailed home and work locations, the effects of the Montreal Transportation Plan are analyzed with a focus on benefits throughout the socio-economic spectrum. Accessibility and travel time changes are modelled before and after the proposed transit infrastructure. These two measures are used to quantify the benefits at the regional and personal scale. Based on this analysis, the Montreal transportation plan is relatively equitable, though some areas benefit much more than others. It is recommended that policy makers carefully consider who will benefit from transit improvements when prioritizing among projects. The methodology developed here offers a clear and easily reproducible way in which to do so.

A study of how household activity space (defined as the subset of geographic space that includes all activity locations of a household on a given day—or some other unit of time) varies by household type while controlling for regional and local accessibility factors reveals important trends in the importance of understanding mode and destination choice as not just dependent on external, physical built form factors but on needs and desires of household members. In addition, this research (N=11,633) presents a novel methodology for measuring the area and dispersal of daily activity in space.

An analysis of 44,266 home-based trips obtained from the 2003 Montreal Origin-Destination survey examines the complex relationships between neighbourhood walkability and behaviour. Several statistical models are developed to examine the effect of different walkability scores on a given household's travel behaviour while controlling for individual, household and trip characteristics. The findings show that the examined walkability indices are highly correlated with walking trips for most non-work trip purposes; however, socio-demographic characteristics play a vital role. More importantly, the results show that households with more mobility choices are more sensitive to their surroundings than those with fewer choices. This highlights the fact that a walkability index will not have the same correlation with travel behaviour for all individuals or households. Therefore, solutions to encourage non-walkers to adopt this behaviour might have to take this into account in order to be successful.

A concluding chapter ties these strands together and presents policy and research implications. This dissertation highlights the importance of adopting a multi-dimensional and mixed methods approach to examining complex urban issues and processes, and contributes to knowledge in three ways:

- Identifies a set of indicators that capture elements of social equity in transportation planning and decision-making;
- Develops methodologies to measure outcomes of transportation infrastructure using accessibility measures that focus on the desired destinations of residents; and
- Deepens the understanding of how people and households of different socio-economic status "respond" to measures of local and regional accessibility. While most—if not all—studies do "control for" socio-economic factors, my work makes these factors the primary focus.

In doing so, this research brings awareness of important transportation-related social equity goals and increases the role that these goals may play in decision-making processes.

RESUME

La planification des transports au 20e siècle a été principalement fondée sur l'objectif de la mobilité : les systèmes de transport ont été vus avant tout comme un moyen sécuritaire, rapide et efficace de mettre en réseau des personnes et de transporter des marchandises. Cependant, au fil du siècle, les mouvements culturels, sociétaux et écologiques ont peu à peu changé la façon dont les planificateurs perçoivent le transport en général et le transport en commun spécifiquement. Plusieurs préoccupations se chevauchant ont profondément modifié le rôle que les urbanistes et les élus attribuent au transport et à l'aménagement du territoire. La dégradation de l'environnement, la pollution atmosphérique, la congestion routière, l'avenir énergétique, et les changements climatiques, ont radicalement redéfini les priorités du transport. Ces préoccupations ont conduit à un intérêt croissant pour le transport en commun et pour le transport actif, la marche et le vélo, apparaissant de plus en plus comme des solutions potentielles aux problèmes environnementaux.

Cependant, en dehors de ces préoccupations environnementales, des questions importantes se posent en matière de redistribution et de justice sociale. Les nouvelles infrastructures de transport offrent des avantages évidents tels que l'accès facilité a une destination voulue, la stimulation du développement économique ou la réduction des temps de déplacement. De plus, la planification des modes de transport actif permet de faire le lien avec la sociabilité, les rapports de voisinage et la cohésion sociale ; des retombées positives sur la santé sont aussi observées. La compréhension des bénéfices, tout comme des charges en jeu, et de la manière dont ils se répartissent et sont vécus par les différents groupes est une préoccupation majeure dans l'évaluation des systèmes de transport.

Bien que les objectifs de transport aient évolué au cours des dernières décennies, intégrant les préoccupations de justice sociale et d'environnement, la plupart de ces objectifs ne réfèrent pas à des indicateurs clairs ni à des méthodes de mesure faisant consensus pour observer les progrès en la matière. En outre, bien que diverses valeurs et idéaux sous-tendent une politique, ceux-ci peuvent influencer de manière contradictoire les décisions prises en matière de planification des transports. Les facteurs d'amélioration du transport comprennent ce qu'on pourrait appeler des facteurs «tangibles» ou des résultats facilement mesurables, telles que la réduction de la congestion routière, l'amélioration de la qualité de l'air, l'expansion des réseaux de transport en commun afin d'étendre la couverture du service sur le territoire, ou encore le prolongement des pistes cyclables. Cependant, de nombreux objectifs ayant trait aux questions d'équité sociale sont «intangibles» en matière de résultats quantifiables. Cela les rend difficiles à présenter à la population, ce qui conduit à des décisions aux gains potentiels plus grands en terme de capital politique que ne le sont des objectifs de progrès social difficilement mesurables.

Ces dernières années, les plans de transport se concentrent de plus en plus sur l'offre de lieux permettant de vivre, travailler, magasiner et socialiser à proximité, conduisant à raccourcir les voyages motorisés et à augmenter le potentiel du transport actif. De même, la convivialité des espaces piétonniers est devenue un objectif de plus en

plus courant en ce qui à trait aux politiques de transport. En réponse à cela, les méthodes de mesure de la «marchabilité» (walkability) des quartiers ont gagné en popularité. Cependant, ces méthodes peuvent masquer d'importantes questions de justice et d'équité sociale. Par exemple, les gens adoptent des habitudes locales de déplacement parce que leur quartier répond à leurs différents besoins et à leurs aspirations ; ou peut-être y a t-il d'autres raisons (manque d'options de mobilité, contraintes de temps et d'argent, peur plus large de se déplacer dans certains quartiers)? Ne pas tenir compte de ces facteurs peut sérieusement influencer les déplacements locaux en tant qu'objectif politique, ou exagérer l'importance des formes bâties et d'autres caractéristiques physiques objectives pour déterminer soit le mode de transport d'un usager ou son choix de destination.

Malgré un riche corpus de recherches traitant de ces questions, les documents de planification les plus récents ne font pas explicitement mention de l'existence de ces conflits de valeur. Beaucoup de plans se concentrent sur des définitions étroites de la durabilité en mettant l'accent sur les aspects environnementaux. La volonté d'intégrer la planification de l'équité sociale, implique que les préoccupations réelles et importantes de l'environnement, plus la qualité de l'air des émissions de gaz à effet de serre, ainsi que la volonté de limiter la congestion routière, soient mis à l'écart des autres fonctions que les systèmes de transport peuvent jouer en fournissant des résultats équitables.

À la lumière de ces préoccupations, cette thèse vise à répondre à quatre questions de recherche:

- Comment les municipalités et les organismes de planification du transport équilibrent le traitement des objectifs économiques, sociaux et environnementaux dans les plans de transport?
- Comment ces décisions influencent les résultats, en particulier en ce qui concerne l'équité sociale?
- Comment les méthodes de mesure actuelles, la compréhension du transport actif et le potentiel piétonnier d'un quartier peuvent être améliorés afin de mieux en saisir les des objectifs généraux?
- Comment ces résultats seront utilisés à l'avenir pour améliorer la prise de décision?

Ces quatre questions sont abordées à travers une série de quatre études empiriques utilisant des méthodes mixtes et à différentes échelles géographiques, passant de l'échelle régionale à l'échelle du quartier, et qui englobent les ménages et les décisions de voyage au niveau individuel.

L'examen de dix-huit plans de transport en Amérique du Nord suggère que, bien que de nombreux plans comprennent des objectifs d'équité sociale dans le cadre de leur objectif déclaré de durabilité, ces plans privilégient trop largement les résultats environnementaux. En outre, des indicateurs pour mesurer les progrès accomplis vers l'atteinte des objectifs d'équité sociale sont souvent absents ou inappropriés. L'absence d'indicateurs clairs et multidimensionnels conduit à enfermer les éléments de justice et

d'équité sociale comme étant «intangibles» avec peu de buts aidant à prioriser ces aspects dans l'utilisation du sol et dans la planification des transports. Cette recherche explore ce qui est encore une lacune dans la compréhension actuelle des répercussions du transport durable sur l'équité sociale et propose un ensemble d'indicateurs permettant de cerner les caractéristiques souvent insaisissables de l'équité sociale.

En utilisant les mesures d'accessibilité régionale prévues et enregistrées des déplacements domicile-travail, les effets du Plan de transport de Montréal sont analysés en mettant l'emphase sur les avantages qu'on observe sur l'ensemble du spectre socio-économique. L'accessibilité et la variation des durées de déplacements sont modélisés avant et après le projet de l'infrastructure de transport. Sur la base de cette analyse, le plan de transport de Montréal est relativement équitable, bien que certaines régions en retirent plus de bénéficies que d'autres à l'échelle régionale. L'équilibre entre les objectifs économiques, environnementaux et l'équité dans les plans de transport est un processus complexe et difficile. Il est préférable que les décideurs examinent attentivement les bénéficiaires de l'amélioration des transports lorsqu'ils hiérarchisent et priorisent des projets. La méthodologie développée ici propose une façon de faire claire.

L'étude de la façon dont l'espace d'activité des ménages (défini comme le sous-ensemble de l'espace géographique qui inclut tous les lieux d'activité d'un ménage sur un jour donné, ou de quelque autre unité de temps) varie selon le type de ménage, tout en contrôlant les facteurs d'accessibilité régionale et locale, permet de révéler l'importance des tendances du mode de compréhension et l'importance du choix de la destination ; cette variation n'est pas seulement dépendante d'un facteur externe, soit des facteurs physiques, mais est aussi dépendante des désirs des ménages. De plus, cette recherche (N=11 633) présente une nouvelle méthodologie pour mesurer la surface et la dispersion des activités quotidiennes dans l'espace.

Une analyse de 44 266 déplacements depuis le domicile obtenue à partir de l'enquête Origine-Destination de 2003 à Montréal met en lumière les relations complexes entre le potentiel piétonnier d'un quartier et le comportement adopté. Plusieurs modèles statistiques sont construits pour examiner l'effet du potentiel piétonnier sur les comportements de déplacement d'un ménage donné considérant les caractéristiques individuelles, les ménages et le voyage. Les résultats montrent que les indices de potentiel piétonnier examinés sont en forte corrélation avec les déplacements à pied pour la plupart des motifs de déplacement en dehors du travail ; dans ce sens, les paramètres sociodémographiques jouent un rôle de premier plan. Plus important encore, les résultats montrent que les ménages dont les possibilités de mobilité sont élevées, sont plus sensibles à leur environnement que ceux qui ont moins de choix de mode de transport et de possibilité de mobilité. Cela met en évidence le fait que l'indice de walkability n'aura pas la même influence sur les comportements de déplacement selon l'individu ou selon le ménage. Par conséquent, les solutions pour encourager les non-marcheurs à adopter ce comportement devrait en tenir compte pour réussir.

Le chapitre de conclusion relie ces préoccupations ensemble et présente l'intérêt social, politique et scientifique de la recherche. Cette thèse met en évidence l'importance d'adopter des méthodes multidimensionnelles et des approches mixtes lors de l'examen

des questions complexes et des processus urbains ; elle contribue à l'enrichissement de la connaissance de trois façons:

- Par l'identification d'un ensemble d'indicateurs qui rendent compte des facteurs d'équité sociale dans la planification des transports et dans la prise de décision;

- Par l'élaboration des méthodes permettant d'évaluer une infrastructure de transport en utilisant des mesures d'accessibilité qui se concentrent sur les destinations souhaitées par les résidents;

- Par une meilleure compréhension de la façon dont les gens et les ménages de différentes catégories socio-économiques «répondent» à des paramètres d'accessibilité locale et régionale. Alors que la plupart, sinon toutes les études ne font qu'utiliser les facteurs socio-économiques, mon travail se concentre directement sur ces facteurs, avec pour objectif principal de les mettre au premier plan.

Ce faisant, cette recherche participe à une prise de conscience de l'importance des objectifs d'équité sociale reliés au transport et souligne le rôle que ces objectifs peuvent jouer dans les processus décisionnels.

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AUTHOR CONTRIBUTIONS

This dissertation contains four manuscripts that have been submitted to peer-reviewed journals. This work was completed with co-authors; details of author contribution are given below.

Chapter 2 *"Integrating social equity into urban transportation planning: A review of Metropolitan transportation plans in North America"* by Kevin Manaugh, Madhav Badami and Ahmed El-Geneidy. Prof. El-Geneidy and Prof. Badami shared valuable insights and contributed to the writing and editing of the manuscript. Kevin Manaugh was the primary author.

Chapter 3 *"Who Benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in public transport provision"* by Kevin Manaugh and Ahmed El-Geneidy. Ahmed El-Geneidy contributed intellectually and provided comments and edits on the manuscript. Kevin Manaugh performed all of the statistical analysis and was the primary author.

Chapter 4 *"What makes travel "local": Defining and understanding local travel behaviour"* by Kevin Manaugh and Ahmed El-Geneidy. Ahmed El-Geneidy contributed intellectually and contributed to the writing and editing of the manuscript. Kevin Manaugh was the primary author.

Chapter 5 *"Validating walkability indices: How do different households respond to the walkability of their neighbourhood?"* by Kevin Manaugh and Ahmed El-Geneidy. Ahmed El-Geneidy contributed intellectually and contributed to the writing and editing of the manuscript. Kevin Manaugh performed all of the statistical analysis and was the primary author.

PUBLICATION DETAILS AND PERMISSIONS

Chapter 2 "*Integrating Social Equity into Urban Transportation Planning: A Review of Metropolitan Transportation Plans in North America"* is currently under review at the Journal of the American Association of Planning.

Chapter 3 "*Who Benefits from new transportation infrastructure? Using accessibility measures to evaluate social equity in public transport provision*" has been published as a book chapter in *Accessibility and Transport Planning: Challenges for Europe and North America*, Edited by Karst Geurs, Kevin Krizek and Aura Reggiani and is used with permission from Edward Elgar.

Chapter 4 "*What makes travel "local": Defining and understanding local travel behaviour*" has been accepted for publication in The Journal of Transportation and Land Use, used by the permission granted by the Creative Commons.

Chapter 5 "*Validating walkability indices: How do different households respond to the walkability of their neighbourhood?"* is reprinted from Transportation Research Part D: Transport and Environment, Volume 16, number 4, Validating walkability indices: How do different households respond to the walkability of their neighbourhood? 309-315, copyright (2011), with permission from Elsevier.

CHAPTER ONE: DISSERTATION INTRODUCTION AND OBJECTIVES

1.1 OVERVIEW OF INTRODUCTORY CHAPTER

This dissertation is fundamentally about how issues of social equity, justice and fairness are being conceptualized, presented and measured in current transportation planning contexts. This introductory chapter establishes the overarching themes of the dissertation. To contextualize my work, I will briefly introduce and describe four interrelated topics:

- the changing goals, objectives, and indicators that transportation and land use planners utilize to present their visions, ideals and values;
- debates over the role that transportation planning and provision of public transit plays in meeting larger societal goals;
- social equity implications of current planning paradigms and the trade-offs between conflicting values; and
- measurement issues and social equity concerns regarding current conceptions and methodologies to capture elements of travel behaviour and neighbourhood walkability.

After these broad concepts are introduced, I will highlight the gaps in knowledge that this research aims to address. The chapter ends with a detailed description of the four chapters to follow.

1.2 TRANSPORTATION AND SUSTAINABILITY

In recent years transportation planners have begun situating their visions, goals, and objectives in a wider framework of sustainability. Most definitions of sustainability rely on some form of triple-bottom line thinking encompassing economic, environmental, and social goals. In the early years of the 20th Century transportation goals were almost entirely mobility-based. The idea that public transit, for example, might play a role in combating environmental degradation or climate change was simply not present. However, as the century progressed, several cultural, societal and ecological movements had major impacts on how the public perceives public transit provision and transportation networks more generally. Energy crises and increased environmental awareness in the 1970's led to the focus on other benefits that transit could provide, particularly lessening fuel use and air pollution. Throughout the early 21st century, the greenhouse gas emissions reducing potential of public transit has become more and more central, even playing a major role in how transit agencies advertise themselves. Concurrent to these shifts, especially in the U.S., institutionalized racism in the transit system, as exemplified by the Rosa Parks bus case, led to a shift in how public transit could strive to better serve *all* users. Examples of transit planning in Cleveland in the 1970's started to highlight some of the conflicts developing around which role transit should play—and what role it played best.

While a rich body of research has explored these issues, most current planning documents fail to make explicit that these conflicts of value exist. Many plans, for example, focus on narrowly-defined definitions of sustainability with a focus on environmental aspects. Issues of equity and environmental justice are often absent from transportation plans of major North American cities. This can lead to the de-prioritizing of these values in decision-making processes. The continuing concern from an equity planning standpoint is that very real and important

environmental concerns over air quality, GHG emissions, as well as a desire to limit road congestion, will lead away from the important role that transit can play in providing equitable outcomes. As transit use becomes almost synonymous with environmental concerns, it is important that the other roles that transit plays, and may in fact perform much better in, are not over-shadowed by other pressures.

Transportation planning is uniquely situated to address many important societal goals beyond mobility-based concerns. These could include: reducing greenhouse gas emissions, improving public health, giving access to destinations regardless of car ownership, and reducing mobility-based social exclusion. However, while transportation goals have shifted away from mobility and road-capacity goals in recent decades to encompass these social justice and environmental goals, many of these aims do not have clear indicators or accepted ways of measuring progress. In addition, while these diverse values and ideals do often underlie policy, they can have contradictory influence on transportation planning decisions. Transportation benefits include, what might be termed "tangible" or easily measured outcomes, such as reduced congestion, improved air quality, increased coverage of public transit, or increased length of bike paths. However, many goals that address issues of social equity or more broad concepts of liveability or walkability have "intangible" outcomes. Not only are the former easier to measure and to present to the public, but they often have more political capital than more socially progressive goals. This can be problematic as more easily quantified goals can be prioritized at the expense of these "intangible" objectives (Handy 2008). It is worth noting that these concerns are not new, as the following quote originally published in 1966 shows:

> "The provision of transportation is not an intrinsic end (in general), but is an instrumental one: the purpose of transportation is to aid in the achievement of other goals in society . . . Therefore, transportation facilities must be evaluated, ultimately, in terms of the extent to which they achieve the broader goals of society." (Manheim, 1966, p. 7). Quoted in Current and Min (1986).

1.3 EQUITY IMPLICATIONS

Findings from the 2001 National Household Travel Survey show clear correlations between income and transit use. Roughly 57% of all transit trips and 78% of bus and light rail trips are made by households with income less than $40,000, while only 13% of commuter rail trips are in this income category (Pucher and Renne 2003). However, while transit users are predominantly poor, it does not follow that transit provision always benefits poorer residents as common perception might imply. In many regions, in fact, it is just as likely that suburban residents enjoy new, efficient, and comfortable transit, while inner-city residents ride uncomfortable, unreliable, and often overcrowded bus lines. Los Angeles and Washington DC are examples of cities where research has shown this to be the case. Also, wealthier individuals make much longer transit trips. As many transit providers either charge a flat fee for transit use or fares that are not truly related to distance, it is possible that poor users are "subsidizing" the rich (Bae and Mayeres 2005). Taylor and Breiland (2011) have pointed out that the public may in fact prefer a transit system with clear environmental benefits with little public subsidy over a system that deliberately seeks to serve disadvantaged users; referring to this as "transit's dirty little secret".

There is a long history of discussion about the meanings of "equity," "fairness," and "justice" in fields ranging from philosophy to economics. The ambiguity of the meanings of these concepts has in all likelihood led to confusion about what equity might mean to a transportation planner (Murray and Davis 2001). In the planning context, "equity planning" has come to mean a responsibility that planners have to "influence opinion, mobilize underrepresented constituencies, and advance and perhaps implement policies and programs that redistribute public and private resources to the poor and working class" (Metzger 1996, p. 113). In a transportation setting, this could refer to providing increased accessibility and mobility choices to disadvantaged

populations – regardless of ability to pay, perhaps even at reduced rate. This view, commonly known as *vertical* equity deliberately gives benefits to one group – the poor – and not those deemed to be well-served and/or with an ability to pay full price for a given service. *Spatial* equity commonly refers to a situation where access to some service or facility is relatively equally distributed spatially. A goal to achieve spatial or *horizontal* equity ("equal treatment of equals") might miss important subtleties of needs and rights. Perhaps offering better walking environment or transit accessibility to poor, car-less, "captive" users has more social value than improving the situation of richer areas where residents may be less likely to use transit. From an urban planning standpoint, reducing discrepancies in transit access and the availability of a quality walking environment throughout the socio-economic spectrum is a key concern (Taylor et al. 2006). Some research (Tsou, Hung, and Chang 2005) focuses on spatial equity but without a socio-economic element. While this can be useful; without a social equity contribution, the meaning and value is somewhat limited. It would be highly unlikely that all areas of a city have equal access (Lindsey, Maraj, and Kuan 2001) , what is much more edifying is understanding whether some groups of people are disproportionally over- or under-served by a given service or facility.

Norman Krumholz and John Forester (1990) describe many of these issues in the context of the 1970's. Krumholz—who, as a city planner in Cleveland, was an active participant in many of the events described in the book—passionately recalls the conflicts between the interests of "big business" and minority and other socially disadvantaged groups including captive transit riders. Besides being a fascinating look at how planners can influence decision-makers and outcomes, the book offers two excellent transportation case studies, the five-county transit study and the "downtown people mover" project. In fact, while the book covers much more than transportation equity issues, their description of the causes and effects leading to the rise of the automobile and

its consequences for the poor, the young and seniors is relevant today and worth quoting at length:

> "Although most Americans enjoy the freedom of movement conferred by automobiles, those without access to automobiles have found their mobility reduced in both relative and absolute terms. Indeed, the rise of the private automobile society has contributed to the decline of the public mass transit systems. Once more people were driving, public transit ridership dropped, fares increased, and service declined. For the transit-dependent rider, each passing year brought fewer destinations options, longer waits, and higher costs. […] In addition, the scattered patterns of new development in metropolitan areas make many destinations virtually inaccessible to those without a car.
> This might be a relatively unimportant problem except the fact that the transit-dependent—the poor, the elderly, the young, the sick, and the infirm—make up a substantial group in most central cities. In a very real sense these transit-dependent households have been injured by the private automotive society. It follows that they deserve some redress through transportation measures directed specifically at their welfare. (Krumholz and Forester 1990, p.123-124)"

Krumholz describes his objections to the proposed 1969 draft plan; it placed much more emphasis on "massive rail construction" than improved equity. Eventually, after a series of public meetings and the aid of the media, the planners managed to secure an agreement through the federal government, that "no federal funds would be made available for rail development in the Cleveland area until an exhaustive analysis of less capital-intensive alternatives had been undertaken" (Krumholz and Forester 1990, p. 129). In a more extreme example of activism, Krumholz and his staff actively fought against the mayor and council in stopping a proposed elevated "downtown people mover". In an unprecedented move, the city handed back a $40 million grant to the federal government.

1.4 TRADEOFFS AND CONFLICTS AMONG TRANSPORTATION GOALS

Previous work points out that transportation planners must ask themselves difficult questions about the nature of transportation systems and what benefits they can actually provide (Taylor and Breiland 2011; Walker 2008). Krumholz and Forester lamented the fact that, even in the

early age of increased environmental awareness (writing about the 1970's), "Implicit in this turn to mass transit was a commitment to make transit service more accessible and attractive to those *with automobiles*—not necessarily to those who were transit-dependent." (Krumholz and Forester 1990, p. 124, emphasis added).

Walker (2008) claims that there are two opposed "poles" in urban transport goals. One is based on the idea of patronage while the other is focused on coverage. Patronage goals are an integral part of both economic and environmental focuses; more people using transit represents both more revenue and fewer people using more polluting modes. Coverage goals, on the other hand would include such ideas as minimizing discrepancies in levels of accessibility amongst socio-economic, racial and immigrant status categories regardless of whether the route is profitable or the level of patronage. Thus, environmental and economic goals of transit could lead planners to focus on capturing new riders at the expense of current transit users. Replacing car trips has more emission-reducing and revenue-generating potential, but the benefits to an inner-city transit-captive resident is minimal. While these two goals may not be mutually exclusive in all cases, Walker contends that they often lead to difficult decisions A large and growing body of work explores these tradeoffs between equity and other "traditional" transport goals (Grengs et al. 2010; Kwan and Weber 2003; Murray and Davis 2001).

This issue was at the heart of the *Bus Riders Union* case in Los Angeles; not only was suburban rail being prioritized over inner-city bus service, but fare increases on the bus system were implemented in order to offset construction expenses of the rail lines (Soja 2010). To fight this fare increase a class action lawsuit was filed against the Los Angeles Metropolitan Transit Agency. The lawsuit was settled in 1996 with a consent decree stipulating: the reintroduction of the monthly pass at a reduced cost, the expansion of the bus fleet, the establishment of a joint working group between the MTA and representatives of bus riders, and the appointment of a

mediator to monitor and resolve disputes (Grengs 2002). In many ways, this case was an overwhelming success of the victory of social goals of transit over other goals. It was one of the first high profile transit equity cases to go in favour of the socially disadvantaged; lawsuits in New York and Philadelphia in the 1990's had been ruled in favour of the transit agencies.

Grengs asks, summing up many of these concerns, "What is the purpose of transit? Should transit get drivers out of their cars, or should it serve people who have few transportation alternatives?" (2002, , p. 170). A major barrier towards using transit to capture "choice" riders is that those with a choice might require a highly attractive service to change modes. On the other hand, keeping "captive" riders using the system requires very little—if any—effort. These are complex, difficult questions. How planners chose to answer will have effects in regards to fairness, equity, and justice in the long-term. To explore these issues empirically, Chapter 3 of this dissertation examines who could benefit from proposed infrastructure changes in Montreal, while Chapters 4 and 5 examine the stratified response to local and regional accessibility in determining mode choice and other aspects of travel behaviour.

1.5 NEIGHBOURHOOD WALKABILITY

In recent years, walkability has become a central concern in urban transport planning. An environment conducive to walking has been linked to: better health outcomes, reductions in GHG emissions, improved human interaction, and increased social capital (Wilkinson and Marmot 2003). At its most basic, walkability is defined by *form* (for example, street grid, size of blocks, intersection design) and *content* (for example, the proximity and type of available retail, schools and parks). In short, in an area with many four-way intersections, short blocks and lots of retail variety, the proximity of destinations and the quality of path would allow for easy utilitarian walking. Southworth (2005) identifies 6 major factors in defining walkability, these include: a

fine-grained mixing of land uses, connections to other modes, and quality of sidewalks. These models therefore take into account *form*, *content*, and *path* in defining walkability.

A staggering amount of literature has been generated exploring these issues in the context of linking objectively measured elements of walkability to outcomes such as mode choice or body-mass index. In general, this research upholds the underlying assumptions, more people walk in areas with high walkability (for example Carr, Dunsiger, and Marcus 2010; Cerin et al. 2007; Frank et al. 2009). What is missing from many of these studies, however, is a sense of people, what do residents want or expect from their neighbourhood? How will different individuals, with their unique desires, expectations, and concerns respond to elements of their local built environment? Recent work has tried to more explicitly bring these important elements into the discussion. In particular, Alfonzo (2005) developed a "hierarchy" of walking needs, a five-step pyramid of elements that are thought to be necessary for a person to choose to make a particular trip by walking.

In Alfonzo's view the most important precondition that may lead to a walking trip is feasibility. This includes some of the above-mentioned form, content, and path elements but, more importantly includes a health and ability element. In other words, before even speaking of built form factors, her model takes into account the simple element of ability; can a particular person actually make the trip on foot? Alfonzo as well as Franzini (2010) make an important contribution to this body of research by taking into account individual, social, and cultural factors that are at play when choosing whether to walk. A person, in this view, might not simply decide whether a given trip is feasible by walking, but (consciously or not) ask "how does my family, peer group, and community feel about walking?" At this level might also be attitudes towards exercise or environmental awareness. Also including in the hierarchy are elements of safety, crime and fear. The higher levels of the pyramid take into account other important, albeit less

fundamental, aspects such as the presence of street furniture, shade trees, and views. The model also includes the acknowledgement that different cultural groups may value different aspects of parks and other elements of walkability.

The importance of this research is in pointing out walkability is not simply an entity that exists or can be provided by planners, but a complex interaction of these elements. In this view, walkability lies at the intersection of built form and neighbourhood content, along with the desires, needs, expectations, and values of residents. Neighbourhoods with this match will, in all likelihood have more people walking in them. Several issues of social equity are imbedded in much past research, policy frameworks, and outcomes. These can be summarized as:

- discrepancies in the provision of walkable neighbourhoods throughout the socio-economic spectrum,
- performance measures or indicators that gloss over important equity issues, and
- research methodologies that do not adequately differentiate among various motivations for walking.

1.5.1 Provision of walkable neighbourhoods

Previous studies have found that many poor, predominantly minority areas of North American cities actually score quite high on objectively measured scales of walkability. However, more subjective or qualitative research often finds that these areas often have poor sidewalk quality, unsafe intersections, and both real and perceived issues of crime (though perception is often worse than reality). The implications are potentially clear; fully understanding whether the provision of walkable neighbourhoods is equitable cannot be fully understood without using a

mix of quantitative and qualitative methods. In addition, health and activity outcomes (minutes walked per week, BMI) in these neighbourhoods is often worse than more affluent areas.

Regrettably, much of the research into this issue, particularly coming from the health field, uses outdated and unsophisticated geographical methods. Several recent studies use methods that attempt to link access to parks and a quality walking environment but fail to differentiate between whether an area actually has access to a park just outside the boundaries. This "container fallacy" is an almost textbook example of the modifiable areal unit problem (MAUP). Such studies make it difficult to determine whether walkable neighbourhoods are evenly distributed.

On the other hand, some fascinating research has examined not only the current situation but historical factors that led to it. For example, research in Baltimore and Columbus, Ohio found that current high walkability for inner city black residents was in fact a remnant of former, in fact racist, policies that attempted to provide these qualities to wealthy whites—now since relocated to the suburbs (Abercrombie et al. 2008).

1.5.2 Methodological Concerns

The choice of indicators and performance measures can also lead directly or indirectly to issues of equity. For example, many municipalities rely on modal split numbers to measure progress towards walkability. This is not completely unreasonable of course; the number of people walking in a neighbourhood *might* be a reflection of the walkability of the area. However, it may just as well be a reflection of some other underlying condition, a population with no other choice but to walk for example. More importantly, this could lead to perverse planning and policy outcomes. For example, attempts to improve the "walkability" of wealthy neighbourhoods because they—based on modal split or pedestrian counts—are much less walkable than a poor,

disadvantaged areas with high pedestrian numbers. While this may be an extreme example, it highlights the importance of understanding whether people are walking *because* a neighbourhood is amenable to such activity, or simply that, due to other circumstances, they have no choice. From an equity perspective, this distinction is absolutely vital.

With some notable exceptions (Forsyth 2009, for example) much previous research has failed to adequately attempt to explain how different people and households will respond to elements of built form and walkability. This can exacerbate many of the issues explained above. In addition, many studies do little to address the fact that a walkability index that may predict or explain travel choices within certain age, income or gender constraints might have little explanatory power for others. These could include seniors for example, or variation between the very wealthy (who may drive regardless of local factors) or extremely poor (who may walk regardless of local conditions). Children represent another level of uncertainty. Their walking behaviour is more likely to be influenced by parental attitudes, preferences, and fear of traffic or crime. All of this points again to the usefulness of Alfonzo's work. However, the major drawback is the fact that her model is difficult to operationalize. This makes the objective GIS-based measures, with all their drawbacks, a viable option to explore walkability.

The provision of a safe, comfortable, and inviting pedestrian realm is a central policy goal of many transportation plans; however, many of these goals are ill-defined or articulated. Increased walking offers perhaps one of the easiest and least expensive ways in which to address vital societal preoccupations such as: lessening road congestion, improving human health, and improving community sense of place and "liveability". However, it is important that a thorough understanding of the determinants of walking are understood. The notion that walkability is an interaction among several built form and content factors and resident needs, perceptions and desires is a useful one. This nuanced view can complement more "blunt" metrics such as

pedestrian counts or land use mix indices that can, by themselves, do little to address issues of equity. While it may border on the over-cautious, the concern from an equity standpoint is that without understanding motivations or perceptions of pedestrians, important distinctions might be missed. In an ideal situation, people would walk out of choice, not circumstance. Chapter 5 offers an in-depth look at measurement issues related to walkability and offers a novel approach to quantify a stratified response to built form factors.

1.6 ACTIVITY SPACE

Due to pollution, congestion, efficiency, and climate change goals, recent transportation plans focus more and more on providing opportunities to live, work, shop and play in close proximity. This could lead to shorter motorized trips and provide an opportunity to use active transportation. Research has attempted to isolate and identify the built-environment factors that may lead to these behaviours. A household's daily activity space (defined as the subset of space that includes all activity locations of a household on a given day—or some other unit of time) can be used to measure the degree to which travel is local.

However, and more central to this dissertation, this framework may mask important issues of social justice and equity. For example, do households exhibit local travel behaviour because their neighbourhood fulfills all of their needs and aspirations, or are there perhaps other reasons (lack of mobility options, time and money constraints, fear of travelling—in general or in certain neighbourhoods). Failure to account for these factors may seriously misrepresent the desirability of local travel or, from a methodological point of view, may overstate the importance of built-form and other physical characteristics in determining either mode or destination choice.

1.7 GAPS IN KNOWLEDGE

The previous section has pointed out that, although issues of social justice and equity are undoubtedly an important aspect of academic, political, and public discourse on transportation, exactly how to define and measure these concepts is far-from decided. In addition, specifically in a transportation planning context, much more work is needed to understand how municipalities and transit providers are conceptualizing, presenting and measuring progress towards meeting the fundamental societal goals that these transportation solutions can provide.

The walkability section has shown that current, oversimplified ways of conceptualizing neighbourhood walkability have implications for both research methodologies and social equity. For example walkability measures are seen as a "one-size fits all" that do not take into account socio-economic factors of travelers. Also the models generated in this area do not adequately control for trip purposes and fail in differentiating between those who walk because an area is "walkable" and those who simply have no other choice. The following section will detail how I propose to address the gaps identified above.

1.8 RESEARCH OBJECTIVES

My research began by asking basic questions: What benefits should a transportation system bring to society as a whole? How can its success in meeting these goals be best measured? These questions led me to formulate the following more specific questions:

- How do municipalities and transit agencies balance economic, social, and environmental goals and objectives in transportation plans?
- How do these decisions affect outcomes, particularly with regards to social equity?

- How can current methods of measuring and understanding active transportation and neighbourhood walkability be improved to better capture these wide ranging objectives?
- How can these findings be used to improve decision-making in the future?

By addressing these questions, this work explores an important gap in the current understanding of the spatial and social equity implications of sustainable transportation. This section details each of the four chapters which address different aspects of the above-detailed questions and preoccupations. To better visualize and the relationships among the various parts of the dissertation, Figure 1.1 is provided. Section 1.9 offers additional detail about each step.

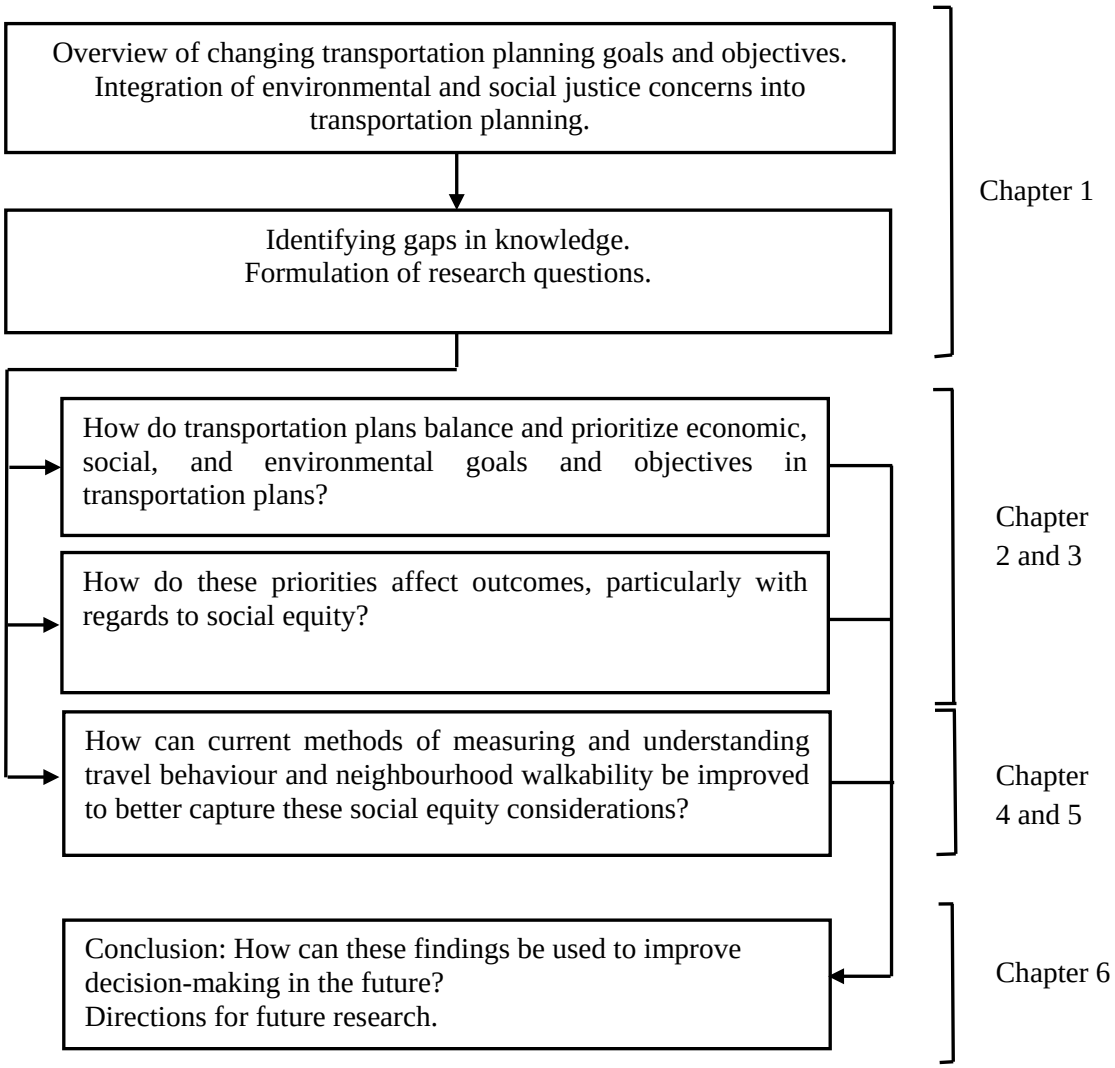


Figure 1.1: Schematic Diagram of Workflow

1.9 DISSERTATION STRUCTURE AND OVERVIEW OF CHAPTERS

This thesis comprises four manuscripts that address the themes and research objectives outlined in the previous sections. Each subsequent chapter contains a brief introduction prior to the manuscript text. Each chapter has a separate introduction, literature review, and methodology section to describe the data, study context and the quantitative and qualitative research methods used. Chapter six summarizes the findings and puts them in context of the broader research

objectives. This chapter also details the contributions to knowledge and points toward future research possibilities. I will briefly introduce each chapter below.

The second chapter is primarily qualitative. It focuses on how current transportation master plans in large North American cities are conceptualizing, defining, presenting, trading-off, balancing, and measuring progress towards social equity and other "intangible" goals of transportation systems. I find that, while progress towards environmental goals policy is relatively easy to present and quantify, few plans adequately explain or measure progress towards more socially responsible goals and objectives. This is troubling as many municipalities and transit agencies focus on the greenhouse-gas reducing and congestion-reducing potential of new transit infrastructure, for example, without a full accounting of who pays for and benefits from these outcomes. In addition, many goals, objectives, and indicators proposed to measure progress toward them often lack the nuance to measure social justice issues. Modal split figures, for example, rarely differentiate between those who use environmentally friendly modes of transportation (walking, cycling, and transit) as a positive response to these modes being convenient, safe, efficient, and comfortable or simply as a negative response to financial or other barriers (this is also a key aspect of Chapter 4 and, especially, Chapter 5). The latter could arguably be seen as an instance of the poor paying for the greenhouse gas emissions of the wealthy. However, this chapter also addresses to what extent these more "intangible" social justice and equity goals can realistically be addressed by transportation planners.

Following this, three empirical studies address more specific issues related to outcomes of transportation projects and measurement issues. Chapter 3 uses Geographical Information Systems (GIS) and statistical analysis to understand who would benefit from the proposed public transit infrastructure changes in the Montreal Master Plan. By measuring accessibility to employment and potential travel-time savings to current jobs, this study offers a more nuanced

picture of who could benefit from each addition to the system. This study makes a methodological contribution by simultaneously addressing issues of social exclusion, job accessibility, and travel time savings based on a rich dataset of home and work locations made available by Statistics Canada. By using both technical rigor (GIS and statistical analysis) and asking basic question of social justice, this research points toward how transportation decisions may be improved. While many studies have looked at job accessibility, few have examined who actually benefits from new or proposed transit infrastructure. In addition, many of these studies rely on broad categories of jobs and workers. Studying accessibility to job opportunities stratified by education and job type using sophisticated accessibility measures is a necessary step to better understand these issues.

Chapter 4 addresses several issues. At the heart of the chapter is an attempt to understand what encourages people to work, shop, and socialize in their local neighbourhood. The environmental, health, and social benefits of making local trips by active modes has been well established. Researchers have attempted to understand the link between neighbourhood-level built form and the use active modes for decades. Planners and urban designers have also attempted to design and make more available the types of neighbourhoods that could encourage this behaviour. However, a major contribution of this research is the explicit acknowledgement that many travel behaviours seen as "good" or desirable from an environmental and energy-saving perspective (active modes, short trips by car) can potentially have quite negative underlying motivations or consequences. To address these issues, a new measure of household activity space is developed and presented, and then statistical models explain the variance in a household's activity space as a function of regional and local accessibility and household structure (number and ages of children, work status) and income.

A final empirical study examines how various methods of measuring a neighbourhood's walkability are correlated with the walking behaviour of residents. Similar to the concerns raised in the previous paragraph, a major impetus of this study was to understand how people's desires, preferences, and needs interact with elements of the local environment. Far from being a "one size fits all" measurement, my hypothesis is that "walkability" can only really be understood as an interaction between personal, household, and cultural characteristics, with the form and content of a neighbourhood. At its most basic, people are different, their response to built-environment factors often assumed to be uniformly associated with walking will therefore also be different. Much past research fails to make this important distinction. A major methodological value of this chapter is the use of stratified regression by household type to extract a more nuanced analysis of how local walkability may matter much more to some people than to others.

CHAPTER 2: INTEGRATING SOCIAL EQUITY INTO URBAN TRANSPORTATION PLANNING: A REVIEW OF METROPOLITAN TRANSPORTATION PLANS IN NORTH AMERICA

2.1 OVERVIEW OF CHAPTER

Urban transport policies are characterized by a wide range of impacts, and trade-offs and conflicts among these impacts. As well, policy impacts affect different groups differentially, and are unevenly distributed across them. The task of integrating and reconciling these impacts for different groups poses daunting challenges, because they are incommensurable; also, impacts such as those related to social equity, are intangible, and hard to define, conceptualize, and measure. The concern is that economic objectives, and even some environmental ones, such as those relating to GHG emissions, which are relatively easily measured, will be prioritized at the expense of social equity in transport planning.

I therefore address two inter-related questions in this research: How is social equity conceptualized, operationalized, and prioritized relative to environmental and other objectives; and how might social equity be more effectively integrated into and operationalized, in urban transportation plans in North America?

To this end, I critically analyze how social equity is incorporated into regional transportation plans from 18 large North American cities, in terms of the quality of the related objectives, how meaningfully these objectives are measured through the choice of related performance measures or indicators, and their prioritization relative to other objectives. Based on the findings of our plan evaluation, and by drawing on the “value-focused thinking” approach employed in multi-criteria decision making, I discuss considerations for generating objectives and measures for better integrating social equity into urban transportation plans.

While the plans, taken together, have goals and objectives related to social equity, few plans do so in a comprehensive manner. In general, most plans have a stronger focus on environmental (and congestion reduction) rather than social equity goals. Further, social equity goals are in many cases not translated into clearly specified objectives; and even in the case of such objectives, appropriate measures for assessing their achievement, meaningfully and in a disaggregated manner, is often lacking. While the relative weighting of objectives is indicated in a few plans, it is unclear how the extent to which policies perform on each objective is assessed. While some plans appear not to focus on equity on first reading, they in fact have reasonably well-developed objectives and performance measures to cover this issue. Several plans make virtually no explicit mention of social justice goals.

Clear value focused thinking about and clear specification of objectives and measures that capture the multiple dimensions of social equity, in terms of various policy impacts that differentially affect various disadvantaged individuals, groups, and communities, will help better understand social equity impacts, and make progress toward communicating and achieving social equity goals in urban transport.

2.2 INTRODUCTION

Most transportation plans now explicitly encompass wide-ranging sustainability goals in addition to operational performance and economic goals. Objectives such as reducing GHG emissions, providing access to destinations regardless of car ownership, improving public health, reducing mobility-based social exclusion, as well as promoting neighbourhood livability and walkability are now present in most regional transportation plans. However, while these environmental, economic and social equity goals and objectives often underlie policy, they can have a contradictory influence on transportation planning decisions (Walker, 2008). In addition, many

of these goals and objectives do not have clear performance measures or indicators. Also, the fear, from a social equity standpoint, is that very real concerns of climate change, GHG emissions, and air quality—which are relatively easily measured and receive vast amounts of media attention—will continue to get more consideration in the planning process than issues of equity.

Most current transportation plans explicitly present their vision within a context of "sustainability"; however, two issues arise in this regard. First, what exactly is meant by sustainability? And, second, what meaningful approach can be adopted to adequately operationalize this elusive concept? Most conceptions of sustainability focus on some version of the "3Es" (Environmental, Economic, and Equity).[1] While rarely made explicit in planning documents themselves, the challenge of delicately balancing these sometimes competing values has long been addressed in the plan evaluation and sustainable transportation literature (Andrews, 1997; Baer, 1997; Berke & Conroy, 2000; Black, Paez, & Suthanaya, 2002; Boschman & Kwan, 2008; Garnett & Taylor, 1999). Campbell (1996) and Walker (2008), among others, give specific examples of "disputed ground" or areas where competing goals fight for attention from policy makers. Litman (2007) decries narrow notions of sustainability that overlook interconnections among, and suggests useful approaches for reconciling, various economic, environmental, and social goals. Lehtonen (2004) makes the case that it is within the "environmental-social interface" that key decisions must be made in order to maximize any true sense of sustainability. In addition, he highlights assumptions inherent in the various paradigms of sustainability, as well

[1] While "triple bottom line" thinking has become intrinsically linked to most conceptions of sustainability, some have criticized the inclusion of economic considerations into the definition at all. Brugman (2007) argues that what was originally almost entirely a framework of social and environmental concerns was "blended" into "a less rigorous concept of economic growth" (p. 59). While his argument is somewhat out of the scope of the current research, it does set an interesting tone to the rest of this analysis (footnote 3 shows an opposing viewpoint).

as their strengths and weaknesses, and the conflicts between the paradigms. Most importantly, Lehtonen highlights the fact that a chosen paradigm will affect decision making.[2]

Transportation policies narrowly focused on mitigating energy use, air pollution and climate change, by way of, for example, fuel efficient vehicles or alternative fuels, are likely to do little to alleviate social inequities, such as those related to poor accessibility for pedestrians and cyclists. These policies might even exacerbate such impacts, as in the case of highway infrastructure development to achieve these ends by increasing motor vehicle speeds and smoothening their flows. Even policies to generate more non-polluting trips by increasing transit ridership might have social equity implications. Transit providers may struggle to address two opposing objectives: providing service that attracts new riders, and striving to better serve current users (Walker, 2008). Both environmental and economic goals tend to focus on attracting new riders, as replacing car trips has more emission-reducing and revenue-generating potential than improving service for current users. This dichotomy can manifest itself in many North American regions as municipalities prioritize suburban rail systems over improved inner-city bus lines (Bae & Mayeres, 2005). Suburban rail has the potential to reduce air pollutant and GHG emissions if it succeeds in causing a mode shift. However, the benefit to an inner-city resident with low accessibility to employment and other desired destinations due to poor or unreliable public transit is minimal – apart from universal gains in air quality enjoyed by all. Many market-driven solutions to limit car use (congestion pricing and parking policy, for example), arguably have disproportionate effects on low income groups, who will either be "priced out" of their preferred

[2] This could even be as a result of visual cues, i.e. are environmental, economic and social values presented as "pillars" or points on a triangle, or instead as overlapping—or concentric—circles? These distinctions could lead to important differences in how these values are conceptualized, balanced, and integrated. See also, for example, the work of Campbell (1996), Agyeman & Evans (2003), Feitelson (2002) and Baer (1997).

mode more quickly or will pay a larger share of money to use the same service. Likewise, in active transportation, while increased modal share of pedestrians and cyclists could represent both decreased road congestion and less polluting trips, not distinguishing between people who walk or cycle because their neighbourhood is amenable to such activity and people who do not have access to a vehicle or other means of mobility might miss key issues of spatial justice and social equity. In addition, understanding who pays and who benefits from transportation systems is equally important.

Transportation benefits include what might be termed "tangible" or easily measured outcomes, such as reduced congestion, improved air quality, safety, increased coverage and use of public transit, or increased cycling and walking. They also include less tangible outcomes resulting from goals that address issues of social equity or exclusion—as well as broad concepts of walkability or livability. However, the former are not only easier to measure and to present to the public, but often have more political cachet than goals that are more focused on social justice. This can be problematic as more easily quantified goals can often be prioritized at the expense of these "intangible" objectives (Handy, 2008). Past work has highlighted the fact that, compared to ecological and economic indicators, social sustainability indicators remain "frustratingly abstract" (Dale & Newman, 2009, p. 670).

Astoundingly, recent work has challenged the inclusion of equity indicators in discussions of sustainability (Black, 2010).[3] However, it is surely not unreasonable to measure and understand whether (and which) groups suffer more—or benefit more—as a result of transportation infrastructure decisions. Indeed, as Solow (1991) argues eloquently and

[3] A full critique of this viewpoint is not within the scope of this work, but suffice it to say that intentionally ignoring issues of who benefits and suffers from transportation projects in the name of sustainability appears to be almost indefensible, apart from misconstruing sustainability.

persuasively, a focus on inter-generational equity often masks current inequities, be it local, regional, or international in scale.

Lastly, in the context of sustainability, it is vital to consider the system boundaries—both spatial and temporal—in the evaluation of transportation impacts. For example, efforts to reduce congestion in the short term might exacerbate congestion in the long term. Likewise, attempts to improve air quality locally—by the use of electric vehicles for example—could lead to trade-offs in air quality or waste elsewhere (whether by electricity generation or waste disposal). The many trade-offs that exist among multiple policy impacts for multiple groups must be clearly understood by planners, as well as be transparently integrated into the planning process. The key preoccupation of this research is to investigate the manner in which plans balance these, sometimes conflicting, goals and whether appropriate indicators and performance measures are being utilized.

2.3 RESEARCH FRAMEWORK

Long-range transportation plans (LRTP) document a City's or Region's goals, objectives, and methods of defining and measuring progress. To understand how issues of social equity are being conceptualized, measured, operationalized, traded-off and reconciled in current transportation plans, this paper examines the following questions:

- How are social equity objectives considered along with environmental and other objectives in urban transportation plans in North America?
- What performance measures or indicators are used to evaluate progress toward social equity objectives? Are these measures appropriate and easily measured?
- How are social equity objectives prioritized and traded-off against environmental and other urban transport performance measures in these plans? and

- How might social equity objectives be better operationalized in urban transportation plans?

The chapter is structured as follows: I first describe the methodology for plan evaluation and associated challenges, after which I critically discuss the selected plans in terms of their objectives and related performance measures or indicators to assess progress toward social equity goals. Based on the findings of the plan evaluation, and by drawing on the "value-focused thinking" employed as a part of multi-criteria decision making, I conclude by discussing some considerations for generating objectives and measures for better integrating social equity into urban transportation policy and planning.

2.4 SAMPLE SELECTION AND METHODOLOGY

I am most concerned with how large, populous cities are addressing and reconciling multiple, conflicting urban transport objectives; plans were therefore selected accordingly to address the research questions. The final sample included plans from 18 large cities—five in Canada and 13 in the U.S (See Table 2.1).[4] The search criteria were as follows: cities or regions with a population over 500,000 with a recent (post-2005) Transportation Plan, with a full plan available from an official government website. Including the plans, appendices, and other supporting documents, roughly 4000 pages of text were analyzed.

Several approaches were adopted to address the research questions. An effort was made to be systematic and to adopt a replicable methodology. A key underlying assumption of this research is that values, preoccupations, and priorities of plan makers can be gleaned by

[4] While the focus of this work was on plans from the most populous cities in North America, most with extensive public transportation systems, much could also be gained from examining small and mid-sized cities.

examining LRTPs. Three areas were of the most interest; these are, in increasing order of importance: broad "mission statements" or other opening remarks that set the tone for the documents; plan goals and objectives; and performance measures used to gauge achievement and progress towards these goals and objectives.

Most of the transportation plans examined were written to conform to regional growth and land use plans. Furthermore, the U.S. plans are required to conform to Federal Highway Administration SAFETEA-LU constraints. It is important to note that the current research is not concerned with whether and to what extent cities actually achieve their stated objectives, but rather focuses on the quality of the objectives and related measures, particularly those related to social equity, and how they are prioritized and traded-off relative to other objectives.

Initially, a basic 'keyword in context' content analysis approach was adopted to quickly assess the importance accorded to social equity relative to other goals in each plan. Though not reported in full in this chapter, footnote 5 provides more details about this analysis.[5] This assessment was followed by an analysis of whether and how multiple aspects of social equity are incorporated into transportation planning, of the quality of the related objectives, and of how meaningfully these objectives are measured through the choice of related performance measures or indicators. The analysis will refer to Table 2.1, in which the social equity related goals

[5] Echoing Berke and Conroy (2000), further examination revealed that word choice is often an issue. For example, while Calgary speaks of "affordable and universal access for all", Atlanta mentions "accessibility for all people". These equity goals were not counted using the keyword in context approach. The authors are well aware of the limitations of this content analysis method, and therefore only used it to gain a quick overall view of the plans. Each and every instance of a word was carefully considered to ensure proper counting. While related words (equity, equitable, inequity etc.) were counted, the use of 'equity' in a financial context, for example, was not. Other uncounted examples include "the built *environment*", "progress towards this goal has been *fair* to good". The intent here was to quickly gather an overview of each plan, and to help lead us towards which plans to focus on for further analysis of whether a plan that mentions fair and just outcomes dozens of times actually provides meaningful performance measures towards these goals.

indicated in the various plans are listed, along with the related objectives and performance measures.

2.5 OBJECTIVES AND PERFORMANCE MEASURES FOR SOCIAL EQUITY GOALS

The key word in context analysis indicated that most cities focus on "environmental sustainability" in their plans. As well, nearly all the plans acknowledge social equity issues as being important, and articulate social equity in addition to environmental goals and objectives. As Agyeman and Evans (2003) note, there has been significant progress since the early 2000's in this regard. In some plans, a particularly strong case is made for considering justice and fairness in transportation policy. The Chicago plan, for example, includes a powerfully eloquent statement. [6] In general, however, most plans have an overwhelmingly stronger focus on environmental rather than social equity goals. Overall, environmental sustainability (or related concepts) are mentioned more than five times as are equity, fairness, or justice. While I do not intend to set up a dichotomy between environmental and social equity objectives, this fact is worthy of note, especially because, whereas environmental objectives can potentially benefit all, trade-offs between these two sets of objectives are in fact possible, as argued in the Introduction. This discrepancy is more pronounced in certain plans.

[6] The statement reads: "Environmental justice addresses questions of distributive fairness in public decisions. Transportation decisions, inasmuch as they affect allocation of public goods, often raise questions relating to the "equity" of their benefits and the burdens or "externalities" they may produce. The variability in burdens and benefits resulting from transportation decisions are often obvious, but their full impact is difficult to account for completely." (Chicago Metropolitan Agency for Planning, 2008 p. 13).

Table 2.1: Plans with summarized social equity goals, objectives, and performance measures

City	Goal/Objective	Measure
Atlanta (Atlanta Regional Commission, 2011)	**Goal**: Improve accessibility and mobility for all people and freight. **Objective:** Improve connectivity between low income and minority populations to major employment and activity centers Increase the security of the transportation system for motorized and non-motorized users. Reduce [safety] incidents on all modes (p. 36)	None
Baltimore (City of Baltimore, 2007)	**Objective**: Provide system accessibility and increase transportation alternatives for all segments of the population. (p. 16) Accessible, balanced, integrated regional transportation network (p. 16)	Mobility for special needs populations – young, elderly, poor, disabled, unemployed. Reflects consensus opinion of key (local) interest groups and private sector.[7] (Appendix 5, p. 51)
Boston (Boston Region Metropolitan Planning Organization, 2009)	**Goal**: Regional Equity (p. 4-5) Objective: Provide better access for all, including youth, elderly and disabled users, and members of zero-vehicle households. (p. 4-3) Assess regional equity (p. 4-5)	Accessibility to needed services and jobs, Mobility and congestion, Stratified by EJ and non EJ zones or areas (p. 14-3) Assess regional equity by analyzing mobility, accessibility, and congestion for communities with a high proportion of low-income and minority residents. (p. 4-5)
Calgary (City of Calgary, 2009)	**Goal**: Promote safety for all transportation system users. Provide affordable mobility and universal access for all. (page 1-6) **Objective**: A range of affordable, accessible, fixed-route and specialized door-to-door transit services should be provided to address the mobility needs of persons with disabilities and low income Calgarians who depend on public transit for their mobility (p. 3-15)	None

[7] These are listed under "Prioritization Methodology" in Appendix 5 and therefore serve a slightly different role than performance measures, however, as these elements are being measured, their inclusion here seems appropriate.

City	Goal/Objective	Measure
Chicago (Chicago Metropolitan Agency for Planning, 2008)	**Objectives:** Support links from disadvantaged communities to jobs and services. Provide travel benefits to persons of all ages, abilities, incomes, races and/or ethnicity. Avoid placing disproportionate burdens on minority or low-income populations. Reduce dependence on personal transportation assets. Provide improved transportation choices to economically disadvantaged persons. Stimulate balanced and sustainable development in communities with concentrations of disadvantaged residents. Support programs providing financial incentives to low-income persons residing in communities that provide a wider variety of transportation choices. Balances project burdens among all who benefit. Minimizes or mitigates project burdens on disadvantaged populations. (p. 28)	"Areas with concentration of minority population more than twice the regional mean" and "Areas with average median income less than ½ the regional mean" have different/higher stated targets in terms of work time commute and access to jobs. (p. 59)
Houston (City of Houston, 2007)	None	None
Montreal (City of Montréal, 2008)	**Vision Statement**: Meeting the transportation needs of all Montréal residents by providing our community with a high quality of life and ensuring its role as a prosperous and environmentally friendly economic powerhouse (p. 34)	"A gradual review should be conducted of the transportation system and its related structures to see how they measure up in terms of universal access principles, particularly in terms of travel by foot or by public transit" (p. 40)
Minneapolis (City of Minneapolis, 2009)	None	None
New Orleans (New Orleans Regional Planning Commission, 2010)	**Objective:** Ensure that the transportation system equitably serves all members of the community (p. 20)	"Projects implemented and dollars invested in traditionally disadvantaged or underserved populations." (p. 21) Percentage of population that has access to employment centers via different modes (p. 29)
New York (New York Metropolitan Transportation Council, 2010)	None	None

City	Goal/Objective	Measure
Ottawa (City of Ottawa, 2008)	**Goal:** Provide adequate and equitable funding. (p. 22) Reduce unwanted social and environmental effects (p. 86)	Reduce air emissions, road salt use, and road surface per person) (p. 86)
San Antonio (San Antonio-Bexar County Metropolitan Planning Organization, 2009)	**Goal:** Enhance the effectiveness of the regional transportation system by addressing the social, economic, energy and environmental issues of the region in all transportation planning efforts. Increasing accessibility for the traditionally under-served segments of the community. (p. 1-5)	None
San Diego (SANDAG, 2007)	**Goal**: Provide equitable levels of transportation services for low-income, minority, and elderly and disabled persons (p. 2-2)	Stratified goals ("non-minority" - "minority", "non-low-income" - "low-income") in "average travel time", "work/school/non-work trips within 30 minutes" ,"homes within half mile of a transit stop" (p. 2-8)
St. Louis (City of St. Louis, 2010)	**Goal**: Addressing the complex mobility needs of persons living in low-income communities, the elderly, and persons with disabilities. (p. 19)[8]	None
San Francisco (Metropolitan Transportation Commission (MTC), 2005)	**Objectives:** Equitable Access, livable communities, Improve affordability (p. 13) Decrease by 10 percent the combined share of low-income and lower-middle-income residents' household income consumed by transportation and housing (p. 26)	Access to low-income jobs access to non-work activities (such as shopping, school and recreational trips), and affordability (p. 135)
Seattle (Seattle Department of Transportation, 2005)	None	None
Toronto (Metrolinx, 2008)	**Goal**: People will have a wide range of options available to them for getting around regardless of age, means or ability, including walking, cycling, public transit and automobiles. (p. 15) **Objective:** Improved accessibility for seniors, children and individuals with special needs and at all income levels (p. 15)	None
Vancouver (Translink, 2008)	**Goal**: Travelling in the region is safe, secure, and accessible for everyone(p. 27)	None

[8] The term used is "Focus Area".

2.6 DIFFERENTIAL TRANSPORTATION IMPACTS

It is desirable, in order to gain a nuanced understanding of the transport situation, to measure, in a disaggregated fashion, how various transport impacts differentially affect different groups in society, stratified based on, for example, income, age, gender, social disadvantage, mode(s) used, and location. An examination of Table 2.1 shows that, while all of the plans, taken together, have goals and objectives related to the various policy impacts that differentially affect different groups, such as accessibility, safety, and transportation expenditure, and which therefore have a bearing on equity, only few plans (such as Chicago's and Calgary's) do so in a somewhat comprehensive manner. Further, and as importantly, social equity goals are in many cases not translated into clearly specified objectives; and even in cases where there are such objectives, appropriate measures for assessing achievement of these objectives, meaningfully and in the disaggregated manner, is often lacking.

While Chicago's plan has a wide range of objectives related to social equity, as already noted, it also requires that various policy impacts be minimized (or enhanced, as the case may be) for various individuals, groups, and communities, disaggregated by age, ability, income, race, ethnicity and social disadvantage. As well, Chicago's plan has clearly specified measures, incorporating targets in terms of accessibility to jobs and journey to work commute time for clearly defined areas with high proportions of low income and minority populations. Boston, San Diego, and San Francisco's plans also call for assessment of impacts such as accessibility and affordability disaggregated for various disadvantaged groups, albeit to a lesser degree. Each of these plans also specifies related performance measures incorporating baselines and targets for parameters such as average travel time to jobs and transportation expenditure, stratified by income or minority status or "environmental justice" zones, as well as by destination type, such

as low income jobs and essential services. While Boston's performance measures are not as clearly specified as San Diego's or San Francisco's (it is unclear in precisely what terms "accessibility" is to be measured), its plan uniquely specifies regional equity as an objective; meanwhile, San Francisco's is the only one of those examined that has a clearly specified indicator, in terms of the share of household income spent on transportation and housing, to measure affordability.

While some plans appear not to focus on equity on first reading, I find -- echoing work by Berke and Conroy (2000) – that they in fact have well-developed objectives and performance measures to cover this issue. The New Orleans 2040 Transportation Plan appeared weak at first glance in terms of social justice and equity, which was surprising, especially given the concerns raised over race and income disparities in the response to the Katrina disaster. However, closer examination revealed that social equity considerations are in fact subsumed within goals and objectives related to other issues. For example, the objectives, performance measures and strategies within Goal 4 (Economic Competitiveness) are some of the most appropriate and clearly specified objectives, for addressing social equity issues; additionally, the plan calls for clear guidelines for public participation. However, note that the first performance measure related to "traditionally disadvantaged or underserved populations" in Table 2.1 focuses only on dollars invested, rather than on outcomes, which are what really count; the second measure is better, but it is hard to tell how precisely it captures equity impacts.

While Atlanta and Calgary's plans have fairly clearly specified goals and objectives that cover multiple transport impacts, and account for differential impacts for various disadvantaged groups, neither plan has any indicators by means of which achievement of the objectives might be measured. Other plans have less clearly specified objectives, besides offering no related performance measures, including Toronto's, which calls for improved accessibility for various

disadvantaged groups, and “a wide range of options” for various modes, San Antonio’s, which calls for improved accessibility for “traditionally underserved communities”, St. Louis’s, which calls for addressing the “complex mobility needs” of various disadvantaged groups, and Vancouver’s, one of whose goals is that “travelling in the region is safe, secure and accessible for everyone”. Finally in this regard, Baltimore’s plan stresses the need to increase “accessibility and alternatives for all population segments”, and to promote “mobility for special needs populations” for the “young, elderly, poor, disabled, unemployed”. These objectives, and that of “an accessible, balanced, integrated regional transportation network” are rather vague, and not amenable to objective and consistent assessment—it is not clear in precisely what terms these objectives are to be measured. The second objective is to be assessed based on “consensus opinion” (which of course at least means that various groups will be consulted).

Montreal’s plan contains a rather vague and general vision statement that commits to “meet the transportation needs of all Montreal residents”, and proposes a gradual review of the extent to which “universal access principles” are being met for walking and transit, without indicating the precise terms in which it ought to be done. As for Ottawa’s goal of providing “adequate and equitable funding”, it is unclear with reference to what groups, modes, regions, etc. it is to be achieved. Further, for the objective “reduce unwanted social and environmental effects”, which shows a lack of separation of different kinds of objectives, the measure focuses on environmental, but no social impacts. Finally, Houston, Minneapolis, New York and Seattle make virtually no explicit mention of social justice goals (of course, this does not by any means signify that these cities do not consider social equity in policy-making).

2.7 WEIGHTING OF SOCIAL EQUITY RELATIVE TO OTHER OBJECTIVES

While most plans do not explicitly consider the relative importance of various goals and priorities in the decision-making process, Baltimore's plan offers one of the more transparent means for doing so (San Francisco also has specific guidelines to be used in the plan prioritization process). In a section entitled Prioritization Methodology (City of Baltimore, 2007 Appendix 5, section 3) seven broad sets of objectives (including those related to safety, environment, and accessibility) are listed along with related performance measures, each of which is weighted. While the objective "contributes to short and long term achievement of air quality targets" is assigned 8 points, "enhanc(ing) mobility for special needs populations – young, elderly, poor, disabled, unemployed" is accorded only 4 points. Meanwhile, "reduction of congestion" is worth 5 points, whereas "an accessible, balanced, integrated regional transportation network" qualifies for only 4 points. Finally, within the Environmental Quality section, "promoting efficient use of natural resources" and "Helps sustain/clean up the Chesapeake Bay" are worth 2 and 5 points respectively.

While Baltimore's plan explicitly considers the relative importance of a range of transportation policy goals, the foregoing examples show that local issues outweigh global, and even regional concerns, and the much stronger focus on environmental (and congestion reduction) rather than social equity goals (of course, as I discussed earlier, tradeoffs between these two sets of objectives are by no means inevitable, although they are possible, and do occur). But perhaps most importantly, while the relative weighting of objectives is indicated, it is not at all clear how to assess the extent to which policies perform on each objective.

Atlanta and Houston are in particular more focused on issues of congestion and mobility. In Atlanta "Regional policy-makers identify congestion as the biggest issue impacting our

region's quality of life"(Atlanta Regional Commision, 2007, p. 99); this prioritization is clearly reflected in the structure of goals, objectives and performance measures throughout the plan, and the city puts considerable effort into reducing congestion. While other sections of the plan detail Environmental Justice neighbourhoods and call for their consideration in plan making, highway and transit infrastructure projects are weighted 70% for their congestion reduction potential and 30% for their "environmental impact" in a document entitled "Prioritization of System Expansion Projects"; this prioritization could create adverse social equity effects if Atlanta indeed plans to "build-out" of its congestion problems.

2.8 MCDM AND VALUE-FOCUSED THINKING FOR INTEGRATING SOCIAL EQUITY INTO TRANSPORTATION PLANNING

Urban transport is characterized by a wide range of socio-economic, health and welfare, environmental, and resource use impacts; at the same time, urban transport policies—which importantly reflect decision maker values and priorities—produce a wide range of these impacts, both positive and negative, for both current and future generations. Different policy alternatives produce different kinds of trade-offs and conflicts among these impacts.

The challenge in reconciling trade-offs and conflicts associated with, and discriminating among, policy alternatives, is not merely to reliably estimate the range of socio-economic, health and welfare, environmental, and resource use impacts associated with each alternative, which is hard enough, but also to value and weigh each of these impacts, in and of themselves, but also relative to each other. This is particularly difficult because the various impacts are essentially incommensurable; further, many, such as those related to social equity, are intangible, and hard to define, conceptualize, and measure. While recent work (Feitelson, 2002; Geurs, et al., 2009; Stanley & Villa-Brodrick, 2009) examines the difficulties of considering issues such as social

exclusion in evaluating transport policy, the task of integrating and reconciling such intangible impacts—which is indeed a central challenge in policy analysis—has been well recognized since the late 1960s (Hill, 1968).

The response to this challenge from within welfare economics is to reduce all policy impacts, both positive and negative, to monetary terms, in a social cost-benefit analysis (CBA) framework, so that they can be weighed and traded-off against each other on a common basis. Economists have devised many creative methods for monetary valuation of policy costs and benefits, which are not traded, and therefore priced, on markets. While these monetary valuation approaches have proven useful in terms of for example, accounting for and internalizing environmental externalities by way of taxes, and estimating the environmental costs and benefits of public projects, they have been extensively criticized in terms of their reliability and validity, and on more fundamental, conceptual and moral-philosophical grounds; while a detailed discussion of these criticisms is outside the scope of this paper, some of these criticisms may be found in Gregory, Lichtenstein & Slovic (1993), Diamond and Hausman (1994), Hobbs & Horn (1997), Kahneman & Knetsch (1992), Sagoff (1981), and Vatn & Bromley (1994).

The multi-criteria decision making (MCDM) approach, drawing on multi-attribute utility theory (Keeney & Raiffa, 1976), which has been used in a number of policy contexts, is ideally suited to complex decision problems characterized by multiple stakeholders with multiple conflicting objectives. While a detailed discussion of its mechanics and strengths, covered in Gregory, Lichtenstein & Slovic (1993), Hobbs and Horn (1997), Keeney (1982, 1988, 1992), and Keeney & McDaniels (1992 and 1999), among others, is beyond the scope of this paper, suffice it to say that, whereas CBA monetizes non-market impacts to make them comparable to other monetary impacts in policy analysis, MCDM, recognizing that monetization of non-market values may be difficult and inappropriate, integrates diverse policy impacts by measuring

economic values for which markets exist, in monetary terms, and non-economic values for which they do not, in terms appropriate to them, rather than reducing them to money proxies.

Briefly, the MCDM approach consists in directly involving actors and affected and interested groups to: identify and structure multiple policy objectives relevant to the situation; develop measures to assess the achievement of these objectives; investigate trade-offs representing their priorities among the objectives; and combine objective functions incorporating these trade-offs, with expert assessments of policy impacts in terms of the measures, to generate a multiple objective evaluation of alternatives. Explicitly accounting for the objectives and trade-offs of various groups allows policy alternatives to be evaluated from their perspective and the selection of alternatives that better serve their values. Crucially, from the point of view of this chapter, MCDM enables the vitally important equity issue to be addressed explicitly. This is particularly important because, not only do conflicts typically exist between the objectives of different groups, it is also the case that policy impacts affect different groups differentially, and are unevenly distributed across them, as I discussed, and as acknowledged in plans such as Chicago's and New Orleans's. Finally, directly involving various groups in the MCDM process facilitates mutual appreciation of multiple perspectives and trade-offs, helps foster compromise and reconcile conflicts, and enhances the chances of long-term policy success.

Particular attention is paid in MCDM to "value-focused thinking", which consists in clarifying and structuring values on which policy objectives should be based, rather than simply deciding based on existing alternatives. First, fundamental policy objectives are separated from means objectives, which are merely ways of achieving the fundamental objectives, to avoid double counting. Next, the fundamental objectives elicited are clearly specified in terms of all the important related impacts on which to evaluate alternatives. The multiple objectives so elicited are structured into categories for each group, and integrated into a common objectives hierarchy

for all groups. Finally, trade-offs between objectives are assessed from various groups, by having them weight objectives relative to each other.

It is ensured that objectives are comprehensive yet mutually exclusive, to avoid double counting, and that they are not so broad that alternatives other than those in the decision context can influence their achievement; conversely, objectives that do not discriminate between alternatives are either ranked low or eliminated (Keeney, 1992). After all, as Stanley and Vella-Brodrick (2009) point out, transport policies can only do so much to contribute to goals such as community cohesion.

Next, measures or attributes are carefully defined, by which to judge the extent to which the objectives are achieved. Structuring objectives and developing measures are an inter-dependent process; while clarifying objectives sharpens selection of measures, thinking about measures can help clarify objectives. Measures must be specified precisely, so that they convey accurately what the related objectives mean, with a clear theoretical link with them; this of course is especially challenging for social impacts (Meyer, 2001). While intangible issues such as social equity will remain so, with little to ensure their effective inclusion in decision-making and implementation, without good indicators, any indicator is not necessarily better than no indicator at all. Note in this regard that different indicators for the same objective reflect different perspectives, convey different pictures of a given situation, and importantly, have different implications for policy choices and outcomes (as in the case of, for example, pedestrian fatalities per million vehicle-kilometres versus per million pedestrian trips, versus per million pedestrian-kilometres, versus per capita).

Lastly, measures should be easily operationalizable, given available institutional resources; also, the ability of measures or indicators to communicate desired policy objectives and outcomes to decision makers and the general public is vitally important. A more complex

and data-intensive measure is to be preferred to a simple one, only if the relative benefits of the former, in terms of capturing and conveying the meaning of an objective, justify its costs.

The process of eliciting, clarifying and structuring objectives and measures as discussed above typically involves intensive interactions with decision makers and representatives of various groups in specific contexts, and is therefore beyond the scope of this paper. However, I discuss, based on "value focused thinking", some considerations for generating objectives and measures for better integrating social equity into urban transportation plans (note that Litman (2007) also presents indicators for social, environmental and economic goals in transport policy).

First of all, it is important that these objectives and indicators, taken together, capture the multiple dimensions of social equity, in terms of the various policy impacts that differentially affect various groups, such as accessibility, safety, traffic noise, and transportation expenditure. Further, as I discussed, these impacts should ideally be measured in a disaggregated manner, for various disadvantaged individuals, groups, and communities, stratified by, for example, income, age, gender, race and ethnicity, disability, mode(s) used, and location; as well, it is important to consider the issue of regional equity. Of course, while such disaggregation is desirable for a nuanced understanding of, and to measure progress toward, social equity in urban transport—and indeed, many of the plans I evaluated fare well in this regard—the benefits of doing so should be weighed against the associated costs, as just discussed.

For the purposes of our discussion, let us start by considering the goal of improving the situation for pedestrians, one could, for example, use the total length of sidewalks (perhaps in comparison to the length of roads) as a measure; or perhaps one could assess, either through some objective means or through surveys, "walkability", in terms of the quality of the pedestrian environment. But if pedestrians have to walk great distances or spend inordinate amounts of time to get to where they wish to go, this measure would not be particularly useful; besides, the bulk

of the high quality and “walkable” sidewalks might be concentrated in a few neighbourhoods. Or perhaps, as is common, one could use mode shares for pedestrian trips as a measure. While this measure might be indicative of a favourable situation for pedestrians, it could also simply be a reflection of a population which cannot afford to own cars or to use transit. Besides, even if mode shares were high, pedestrians might feel insecure, and there might be a high level of pedestrian injuries and fatalities. It is therefore a challenge to fully capture the multiple dimensions of the situation for pedestrians, in urban transport policy and decision making.

Similarly, in the case of public transit, one could use as a measure of the quality of service, the fleet size, or the daily fleet-kilometres; but these are merely a means to an end, not the end itself. One could, on the other hand, approach the problem from the vantage point of transit commuters, and measure proximity to bus stops (as is sometimes done), and/or the frequency of service. But these measures say very little about the service, if buses do not go from where most people who wish to use them live, to where they wish to go. Transit mode shares, whether in terms of passenger trips, or passenger-kilometres, may be a better measure, but as in the case of walk shares, they might be reflective of a lack of other options, more than a choice on the part of car owners; besides, they say nothing about the comfort and convenience of transit service.

Accessibility, which is essentially the ease and convenience of reaching desired destinations, on the other hand, is a very good measure of a desired outcome, or fundamental objective; because it combines in itself a measure of how well essential services are spatially distributed, and how well people are located relative to those services (namely urban form and land use), along with (in the case of public transit and pedestrian commuting, for example) the quality of transit service, the quality of the pedestrian environment, the effectiveness of traffic system management, the lack of physical barriers, and so on. Indeed, while accessibility measures

can be tailored to capture multiple dimensions of transport system effectiveness, livability and equity at multiple scales, few transportation plans adequately conceptualize or measure this concept in planning documents.[9]

Accessibility, measured in terms of journey time to desired destinations, can be determined and compared for different modes over time, for example, in order to assess how various modes are being provided for and prioritized in urban transport policy and decision-making. Accessibility can also be assessed separately for different trip purposes and destination types (work, education, shopping, health, recreation, etc.); for different groups (men, women, old, young, low income, ethnic minority, the handicapped, etc.), and for different neighbourhoods and regions. Effective comparisons of accessibility in these terms can be made at the neighbourhood or census boundary level, either by way of differences or ratios.

Such a disaggregated assessment of accessibility might show, for example: that while, on average, journey times to work are improving over time for cars, they are becoming longer by transit (because of, among other factors, poor pedestrian accessibility, declining transit service, lack of priority for transit); higher journey times to work for women relative to men, perhaps because women do not have as much access to household cars, and therefore have to rely on transit, above average journey times to retail for women or the elderly, because of poor transit service during off-peak hours, when they typically travel; higher accessibility to schools and health facilities in high income relative to low income neighbourhoods, perhaps because of better provision of quality schools and health care, along with the fact that children are driven to school, in the former, and barriers due to highways in the latter; high pedestrian accessibility in high

[9] Note that two of the present authors have used disaggregated accessibility measures to assess social equity related to the provision of transit services and pedestrian infrastructure (Manaugh & El-Geneidy, in press; Manaugh & El-Geneidy, 2011).

income neighbourhoods even though walk shares are low, and the reverse in poor neighbourhoods, and so on.

Of course, while accessibility is a good measure of social equity in urban transport, there need to be others as well, since after all, as I discussed, social equity is a multi-dimensional issue. Some other measures to this end might include the difference between top and bottom income quintiles in percentage share of household expenditure devoted to transport (an impact San Francisco measures), and the difference between traffic fatalities and injuries per passenger trip for cars, non-motorized modes, and public transit.

2.9 CONCLUSION

Throughout most of the 20th century, transportation planning goals were almost entirely *mobility*-based, with a focus on speed and congestion reduction, but as Agyeman and Evans (2003) note, there has been significant progress since the early 2000's in acknowledging social equity issues as being important, and articulating social equity in addition to environmental goals and objectives. This study echoes this finding; indeed, I find that a particularly strong case is made in some plans, such as Chicago's and New Orleans's, for considering justice and fairness in transportation policy. In general, however, most plans have an overwhelmingly stronger focus on environmental (and congestion reduction) rather than social equity goals; besides, local issues outweigh global, and even regional concerns.

While the plans, taken together, have goals and objectives related to the various policy impacts that differentially affect different groups, such as accessibility, safety, and transportation expenditure, and which therefore have a bearing on equity, only few plans do so in a somewhat comprehensive manner. Further, social equity goals are in many cases not translated into clearly specified objectives; and even in the case of such objectives, appropriate measures for assessing

achievement of these objectives, meaningfully and in the disaggregated manner, are often lacking. While the relative weighting of objectives is indicated in a few plans, it is unclear how the extent to which policies perform on each objective is assessed. While some plans appear not to focus on equity on first reading, I find, on closer examination—and echoing work by Berke and Conroy (2000)—that they in fact have reasonably well-developed objectives and performance measures to cover this issue. Finally, several plans make virtually no explicit mention of social justice goals. But of course, this does not signify that the concerned cities do not consider social equity in policy-making; a plan cannot be criticized for not emphasizing social equity if transport benefits and costs are in fact distributed in a relatively equitable manner.

Nonetheless, clear value focused thinking about and clear specification of objectives and measures that capture the multiple dimensions of social equity, in terms of the various policy impacts that differentially affect various disadvantaged individuals, groups, and communities, and regions, along the lines already discussed, will go a long way to better understanding social equity impacts, and making progress toward achieving social equity goals in urban transport. As well, the important communicative and educational value of objectives and measures in transport plans must be recognized.

CHAPTER 3: WHO BENEFITS FROM NEW TRANSPORTATION INFRASTRUCTURE? USING ACCESSIBILITY MEASURES TO EVALUATE SOCIAL EQUITY IN TRANSIT PROVISION

3.1 OVERVIEW OF CHAPTER

While Chapter 2 dealt primarily with broad goals and objectives and was concerned primarily with how various—often conflicting—transportation planning goals are traded-off and prioritized in planning documents, this chapter examines possible results using a quantitative methodology. By examining who could benefit, and to what extent, from proposed public transit infrastructure in the Montreal area, this study offers insight into how the value of transportation projects can be measured and conceptualized. This chapter makes explicit that transportation benefits should prioritize social justice goals—herein defined as neighbourhoods characterized by low income, and minority households having better public transit access and travel times to desired destinations. A novel methodology is developed which accounts for both regional job accessibility—how many employment opportunities can be reached in a given time threshold—and travel time to observed work locations. The latter made possible with a detailed data-set of home and work locations at the census tract level made available by Statistics Canada. A GIS analysis allows for a travel time matrix to be generated for the current system as well as a transportation system that includes the proposed public transit infrastructure in the 2007 Montreal Transportation Master Plan.

3.2 INTRODUCTION

A principal function of public transit is to provide accessibility to all members of society, particularly to those with limited mobility choices. As issues of equity and fairness gain importance in transportation planning, understanding who benefits from new and existing transit services has become an increasingly important topic.

This paper examines the extent to which proposed transit infrastructure projects in the City of Montreal, Canada transportation plan (MTP) benefit disadvantaged populations. First, I identify neighbourhoods with both high levels of social disadvantage (based on income, immigration status, and education levels) and transportation disadvantage (low levels of current job access). Then, accessibility to employment opportunities are modeled using both existing and new transit networks. A before and after comparison of the level of access and change in travel time will allow us to identify neighbourhoods that will benefit the most from the new plan. Benefits from new transit projects are quantified as an increase in access to opportunities and decline in travel time to desired destinations. Accessibility measures concentrate on quantifying the benefits at the regional scale, while the travel time measures concentrate on the personal scale. In short, this study tries to develop a methodology that can answer three research questions using readily available data and simple measures of land use and transportation interaction. 1) Are increases in accessibility to jobs due to the implementation of transportation plans reasonably distributed throughout the socio-economic gradient? 2) Do these jobs match with the labor market for socially disadvantaged populations? And 3) Are decreases in travel time equitably distributed in the region?

3.3 LITERATURE REVIEW

In recent decades, urban transportation planning has shifted in focus from increasing infrastructure capacity for automobile traffic to broader policies with environmental and social dimensions (Carmona and Sieh 2008; Banister and Gallent 1999; Hall 1997; Jabareen 2006; Lindquist 1998; Marsden et al. 2007). Plans now include goals that express principles of sustainable development such as improving air quality, reducing automobile dependency, and promoting active modes of transportation and public transit. However, while performance indicators and goals have become somewhat codified for environmental and economic goals of transit systems, equity goals lack clear appropriate indicators for measuring progress. If no measures exist to monitor progress toward certain goals, planners may prioritize other goals or be led away from them in the planning or evaluation process (Handy 2008; Briassoulis 2001; Meyer and Miller 2000). Urban planners and engineers are in need of tools with which to evaluate plans and projects for goals that are less easily quantified. In addition these measures should be applicable at various scales, individual and regional.

The role that public transit plays in providing access to job locations for those with limited mobility options has long been argued as a key goal in transit planning (Horner and Mefford 2005; Sanchez, Shen, and Peng 2004; Currie 2010). Recent transportation plan goals have more explicitly addressed this, in addition to economic and environmental goals. However, the difficulty is that these goals are not always complementary.

Much of the work concerning levels of access to employment opportunities among socio-economic gradients is based on spatial mismatch theory (Kain 2004). Recent work has shown that the issue may be characterized as “modal mismatch”, where the locations are not necessarily separated by geographic space as much as by difficulty of getting to a desired location by transit

or active means. In other words, with a car, such job locations would be easily accessible (Grengs 2010). Pickup and Giuliano (2005) describe a cycle where those without access to a vehicle are isolated from jobs and other services. This leads to further "area-based" social exclusion. In particular, many newcomers to cities first locate in areas with low job access and near existing newcomers. Apart from access to an individual's employment, transit also offers a poor substitute to the automobile in finding and interviewing for potential job opportunities (Sanchez, Shen, and Peng 2004).

In perhaps an extreme example of favoring equity over environmental and economic goals, Grengs (2010) argues that offering subsidies to the poor in order to purchase automobiles is potentially a viable solution. He is careful to point out that this may only be true in certain circumstances. For example when transit system is underdeveloped and providing these subsidies could be a cheaper and more efficient solution. In conclusion, there is clearly a healthy debate over the extent to which transportation goals should focus on economic factors and issues of social welfare and equity.

3.4 METHODOLOGY, DATA, AND CONTEXT

The following sections introduce the data, context, and methodology of the study.

3.4.1 Methodology

In order to measure changes in accessibility levels and travel time brought about by the projects proposed in the Montreal Transportation Plan (MTP), existing and proposed transit infrastructure are modeled in a Geographic Information System (GIS). The transit projects include the new Light Rail Transit system (LRT or Tram) lines, the rail link to the airport, extensions of the commuter rail and metro systems, the new Bus Rapid Transit (BRT) lines, and increased

reliability and travel speeds for existing bus lines thanks to signal-priority measures and/or reserved lanes (Figure 3.1). I am conceptualizing transit in this research as primarily a mode to connect workers to their place of employment, particularly for those without other viable options. The other important roles that transit may play in connecting people to shopping and social activities are not included in our analysis. This research will involve two phases of data preparation prior to the analysis phase. The first is identifying areas with high concentrations of social and transportation disadvantaged population. The second is generation of before and after MTP accessibility measures and travel time change matrixes.

The measure of accessibility used in quantifying the impact of the MTP is the cumulative opportunities measure. It is a simple measure to calculate and uses readily available data. In addition it is easily understood and communicated. It counts the number of opportunities that can be reached within a predefined travel distance or time (El-Geneidy and Levinson 2007), for example the number of jobs that can be reached by public transit within 30 minutes of travel time. A major advantage of this measure, beside the simplicity in explanation, is the high level of correlation with other complex measures like gravity based measures of accessibility (El-Geneidy and Levinson 2006). This measure is generated for both before and after periods for every project in the MTP. These measures of accessibility will enable the understanding of changes at the regional scale. However, I did use a more involved accessibility measure for identifying socially disadvantaged areas; this is explained below.

On average, in Canada, a one way transit trip is around 52 minutes (Turcotte 2005) . The 52 minutes comprise access time, waiting time, in-vehicle time, egress time and transfer time if a transfer was present. In our analysis I use 30 minutes of in vehicle as the standard for the measures of accessibility, which is a reasonable approximation of what users are willing to spend on in-vehicle-time.

Finally, information related to home and work location of every person residing in the Montreal metropolitan region is obtained from Statistics Canada. Travel time using public transit is calculated for each individual before and after the implementation of the MTP. This is done by linking each zonal pair back to individuals. In this way, changes in travel times associated to every project in the MTP are calculated for each individual. This will enable a better understanding of the effect of changes at the individual level and create a bridge between more data-intensive individual accessibility measures and zonal-based approaches.

Three indicators are explored to evaluate the extent to which the proposed projects in the MTP provide equitable access.

1. The impact of each transit project in the plan on areas shown to be socially disadvantaged in terms of accessibility to jobs with trips of 30 minutes in-vehicle time or less. This analysis will focus on jobs requiring a high school education or less.
2. The change in travel time to Montreal's 6 employment centers by transit from the identified disadvantaged areas.
3. The potential time savings based on actual current job locations (from detailed home and work location data from Statistics Canada).

Mapping, tables, and statistical analysis are used to highlight the benefits and differences among neighbourhoods and projects.

3.4.2 Data

The unit of analysis is the Traffic Analysis Zone (TAZ) which was provided by the Québec Ministère des Transports (MTQ). The MTQ also provided the research team with travel time information for transit that was generated by a travel demand modeling software. Employment and demographic information was extracted from the 2006 Census conducted by Statistics

Canada, while the transit network information was received from the Société de Transport de Montreal (STM). Access to aggregated home and work location data was provided by the MTQ *Services des affaires socio-economiques*.

Simulated congested A.M. peak travel times were obtained from two different government agencies for transit travel times. In order to model the proposed projects, new travel time matrices were generated. A transit travel time matrix was generated in a GIS environment using each of the transit stops closest to each TAZ centroid as both origins and destinations. Travel times on the transit network were estimated on the basis of the average operating speed of each individual transit line using the prepared GIS transit network. This method assumes that there is no delay at a transfer between lines. To correct this, a linear regression model was built to compare the simulated travel times to the travel times provided by the MTQ.

3.4.3 The Montreal Study Context

Montreal is located on an island in the St-Lawrence River. Comparatively speaking, Montreal has developed in a rather sustainable fashion, with an average metropolitan population density of about 6,000 persons per square mile of urbanized territory and with a modal share of 22% for public transit in the morning commute to work (Communauté métropolitaine de Montréal 2010). The city has a subway system which extends into two off-island suburbs and a suburban train system which reaches far into the metropolitan periphery. Both systems are focused on the CBD, where the majority of jobs are located. The other two largest employment centers are located elsewhere on the Island of Montreal; employment is growing in off-island suburbs as well (Shearmur 2006). Figure 3.1 shows the Montreal metropolitan region, along with the existing and proposed transit lines and the location of the 6 major job centers.

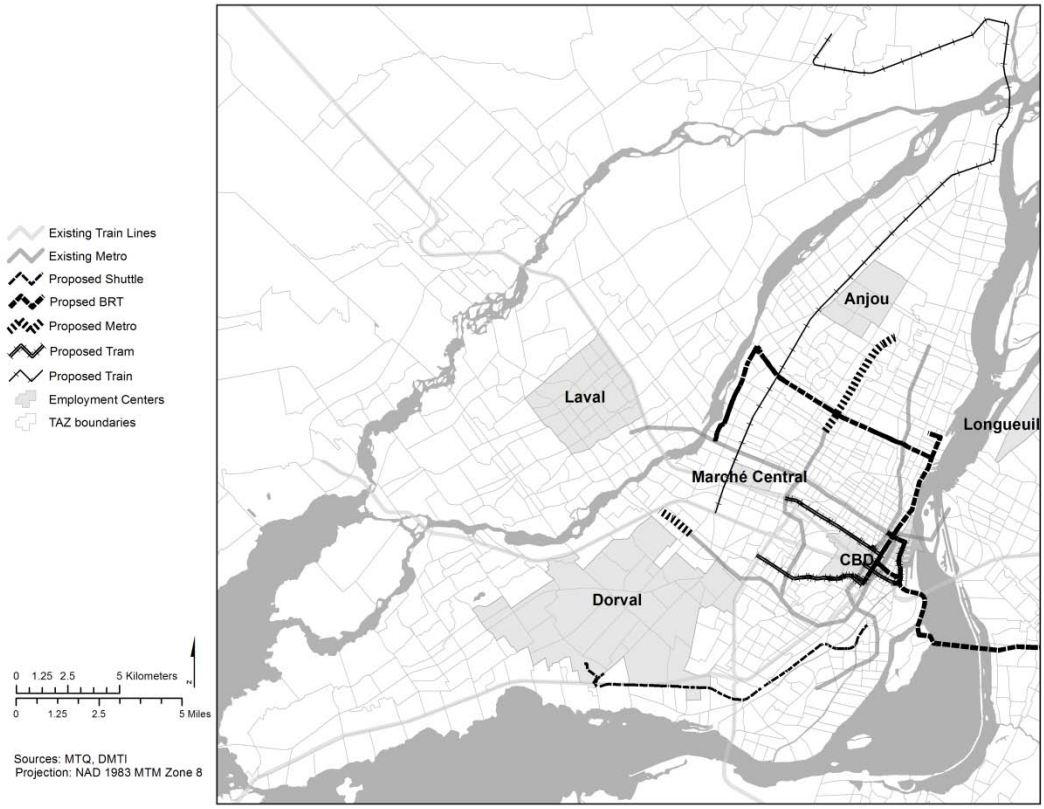


Figure 3.1: Proposed Infrastructure

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 contains no performance measures or indicators to assess if projects will help make transit the preferred modes of travel. The plan presents 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: change in the volume of greenhouse-gas emissions, reduction in accident rates, and total transit-service hours (Ville de Montréal 2008). Equity issues are not explicitly addressed in the plan. Moreover, none of these measures can effectively help prioritize the various projects contained in the plan.

3.5 ANALYSIS

3.5.1 Socially Disadvantaged Population

I first identified those neighbourhoods most in need by using a composite index made up of four indicators plus an employment accessibility measure. The indicators are: median household income, percentage of residents that are foreign-born, percentage of adults with high school education as the highest educational attainment, and percentage of residents who use transit for work trips. In addition to these four factors, I included a measure of accessibility to low-skill jobs requiring only a High School education accounting for competition from those of a similar education levels. This measure is known as the inverse balancing factors of the doubly constrained spatial interaction model measure of accessibility (Wilson 1971). The scores from all five indicators were standardized (Z-score), a measure which determines how far (plus or minus) a given value is from the mean. These scores were then summed, giving a simple social disadvantage index. I then took the highest (worst) decile neighbourhoods as the socially disadvantaged neighbourhoods. This index has precedence in the literature on social disadvantage (Bauman, Silver, and Stein 2006).

In this manner, the identified socially disadvantaged areas are predominantly characterized by low income, transit dependent, immigrant households with low educational levels, who, in addition to these linguistic and material constraints, also have poor accessibility to employment positions that they are likely to be seeking. Figure 3.2 shows a map of socially disadvantaged areas as well as mean values to highlight how these particular neighbourhoods differ from the regional average in these key indicators of social disadvantage and exclusion.

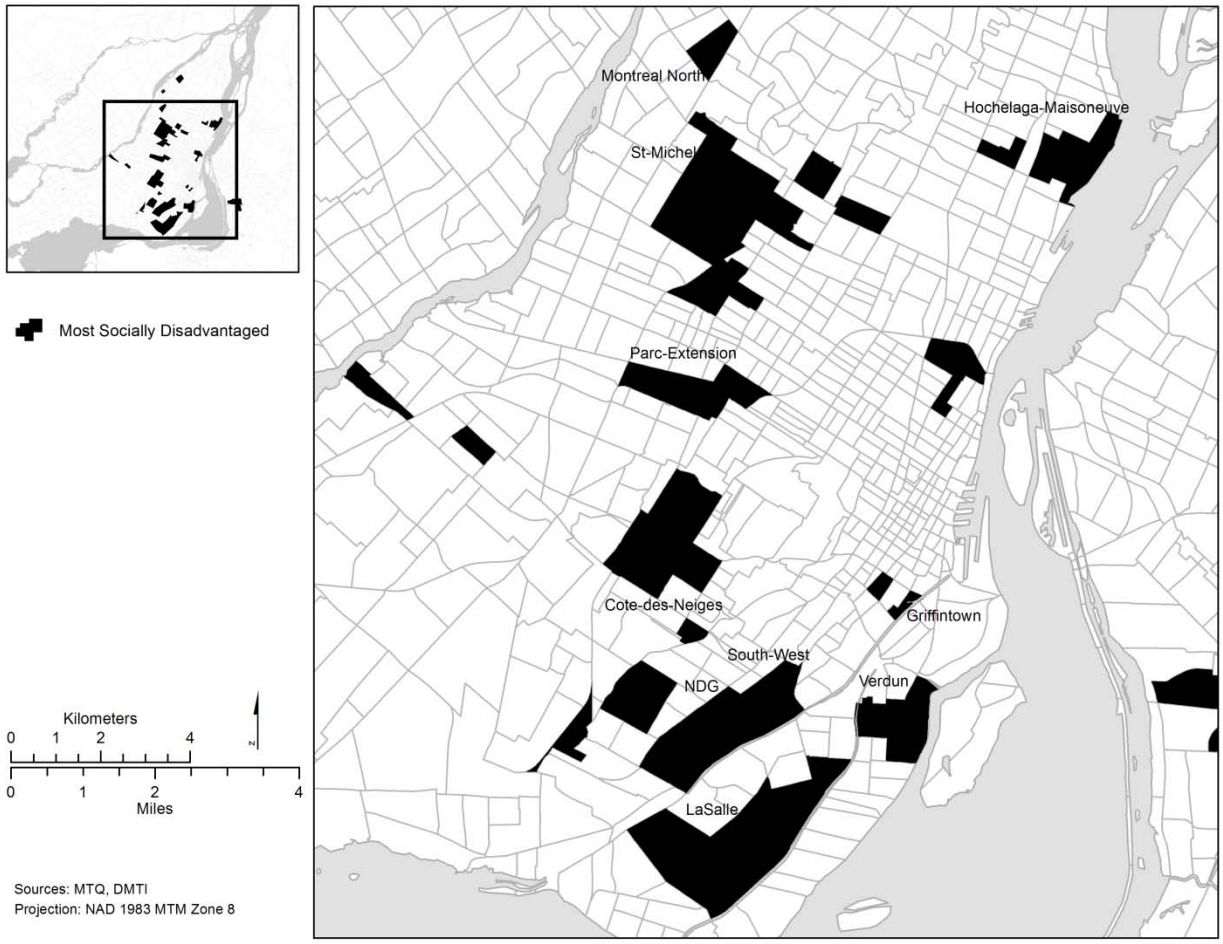


Figure 3.2 Socially Disadvantaged Neighbourhoods

Some indicators such as visible minorities and income are quite different; all differ significantly ($p<0.001$) using a two sample t test with unequal variance. As transit equity goals include increasing human interaction, increasing access to destinations and reducing social isolation, these neighbourhoods are arguably the most important to prioritize in giving increased choice and accessibility.

Table 3.1: Comparison of Socially Disadvantaged Neighbourhoods

Indicator	Socially Disadvantaged	Overall
High school educational attainment as highest level	13.0%	10.8%
Visible minority	32.0%	16.7%
Median Household Income (CAD)	32,803	52,392
Transit Modal Split	44.3%	23.2%
All variables are significantly different P<0.001, two sample t test with unequal variance		

3.5.2 Accessibility Impacts of Projects

A first step to understand the effects of the new projects is to observe a map with the changes in accessibility to low skilled jobs. The initial examination of accessibility change maps would seem to suggest that the MTP is indeed equitable. In fact, a two sample t-test of the most and least socially disadvantaged neighbourhoods shows that the most socially disadvantaged (highest quartile) areas benefit from a higher increase in accessibility to low-wage jobs than the least disadvantaged (lowest quartile). Due to the configuration of Montreal's transit system and the clustering of these low-income neighbourhoods relatively close to downtown, this is not entirely surprising. Figure 3.3 shows the changes in cumulative accessibility to jobs, with the most socially disadvantaged areas outlined in black. This allows a better visualization of how specific transit improvements help particular areas. In particular, we see how the BRT, metro and commuter rail line have significant effects on Montreal-North. In contrast, the airport shuttle has almost no effect on socially disadvantaged neighbourhoods, or, for that matter, on the region as a whole.

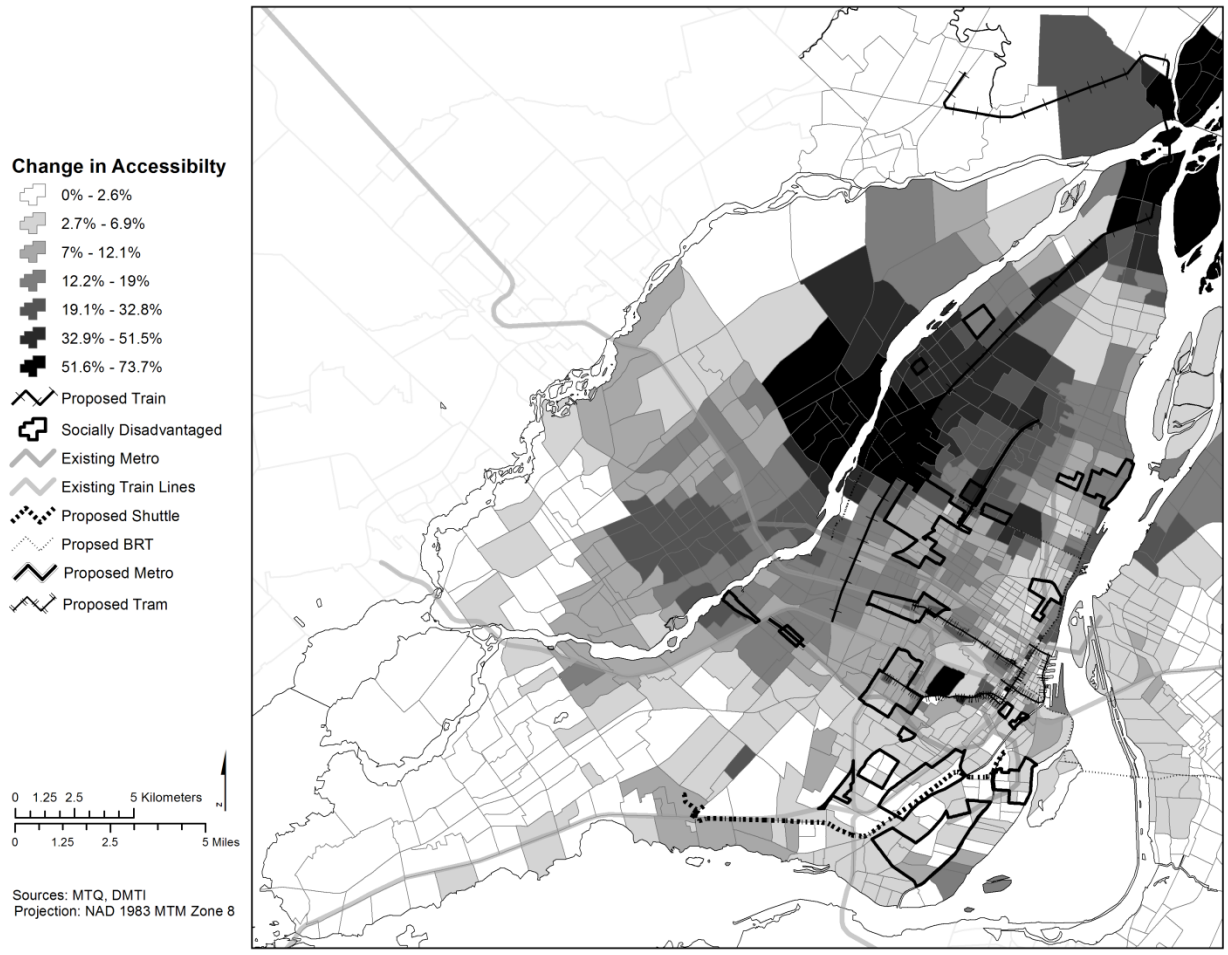


Figure 3.3: Changes in Gravity-based Job Accessibility

Table 3.2 shows increase in accessibility to all jobs and to low-skilled jobs in particular. In a "best-case scenario", we would hope to see that the percentage increase to low-skilled jobs is higher or equal to the overall increase in access, implying that the transportation plan takes into account the needs of the current residents of the given neighbourhoods. In fact, this is the case in many neighbourhoods, Hochelaga-Maisoneuve and Parc-Extension in particular. However, particularly in Montreal-North and St-Michel, the overall increase is extremely large, yet the increase to appropriate jobs is much smaller. Focusing on all jobs could easily misrepresent which jobs are truly accessible and which are not based on skills, knowledge and experience.

This focus on residents' current needs is also the principal reason why travel time to current jobs will be the focus of the next section of the study.

Table 3.2: Job Accessibility Changes by Project by Neighbourhood

		ALL	METRO	TRAIN	TRAM	BRT	Shuttle
Cote-des-Neiges	Low skilled jobs	11.1%	4.2%	1.0%	2.9%	1.3%	0.0%
	All jobs	10.9%	3.8%	0.6%	3.0%	1.7%	0.0%
Hochelaga-Maisonneuve	Low skilled jobs	13.7%	10.5%	0.5%	2.1%	5.1%	0.0%
	All jobs	13.2%	7.8%	0.2%	3.7%	3.3%	0.0%
Montreal-North	Low skilled jobs	49.8%	6.4%	45.5%	0.9%	24.1%	0.0%
	All jobs	161.7%	7.9%	124.4%	0.7%	40.3%	0.0%
NDG	Low skilled jobs	3.4%	1.6%	0.0%	0.3%	0.8%	0.2%
	All jobs	3.4%	1.5%	0.0%	0.6%	1.0%	0.1%
Parc-Extension	Low skilled jobs	14.7%	7.4%	7.2%	3.2%	3.1%	0.0%
	All jobs	10.8%	4.5%	4.3%	2.7%	2.3%	0.0%
Saint-Michel	Low skilled jobs	22.8%	8.5%	10.5%	0.7%	12.2%	0.0%
	All jobs	59.0%	7.6%	11.2%	1.3%	36.1%	0.0%
South-West	Low skilled jobs	2.4%	0.3%	0.0%	1.1%	1.1%	0.0%
	All jobs	3.4%	0.1%	0.1%	1.5%	1.7%	0.0%
Verdun	Low skilled jobs	2.9%	0.6%	0.7%	0.3%	1.3%	0.0%
	All jobs	3.1%	0.4%	0.8%	0.8%	1.5%	0.0%
Regional Average	Low skilled jobs	8.9%	2.4%	4.2%	1.0%	2.9%	0.2%
	All jobs	15.0%	2.4%	6.3%	1.4%	4.5%	0.1%

In order to give a fair sense of each neighbourhood's improvements in accessibility, standardized (z) scores were calculated before and after the improvements. This allows us to see how each neighbourhood fares relative to the regional average and therefore does not "credit" or "penalize" a neighbourhood based on its current accessibility. This can be seen in Figure 3.4 showing the z-score before and after the improvements. The zero line represents the regional average both before and after. Thus, for example, St-Michel scores roughly 0.5 and 0.75 above the regional average before and after the changes respectively. What is perhaps most interesting is that no neighbourhood crosses the line; the areas stay either above or below average. On one

hand, Montreal-North, which sees dramatic improvement is still only at roughly the mean point after all changes. On the other hand, neighbourhoods such as the South-West, Verdun, or NDG, while not benefitting from certain aspects of the plan are still well above average in their accessibility to employment. Comparing Table 3.2 and Figure 3.4, we can see the contrast in findings based on the terms of measurement used. While Table 3.2 might imply that certain areas suffer from lack of increased access, Figure 3.4 gives a slightly more nuanced analysis. That is, from a vertical equity standpoint, it could be argued that Montreal-North "deserves" more accessibility improvements than Parc-Extension or Cote-des-Neiges.

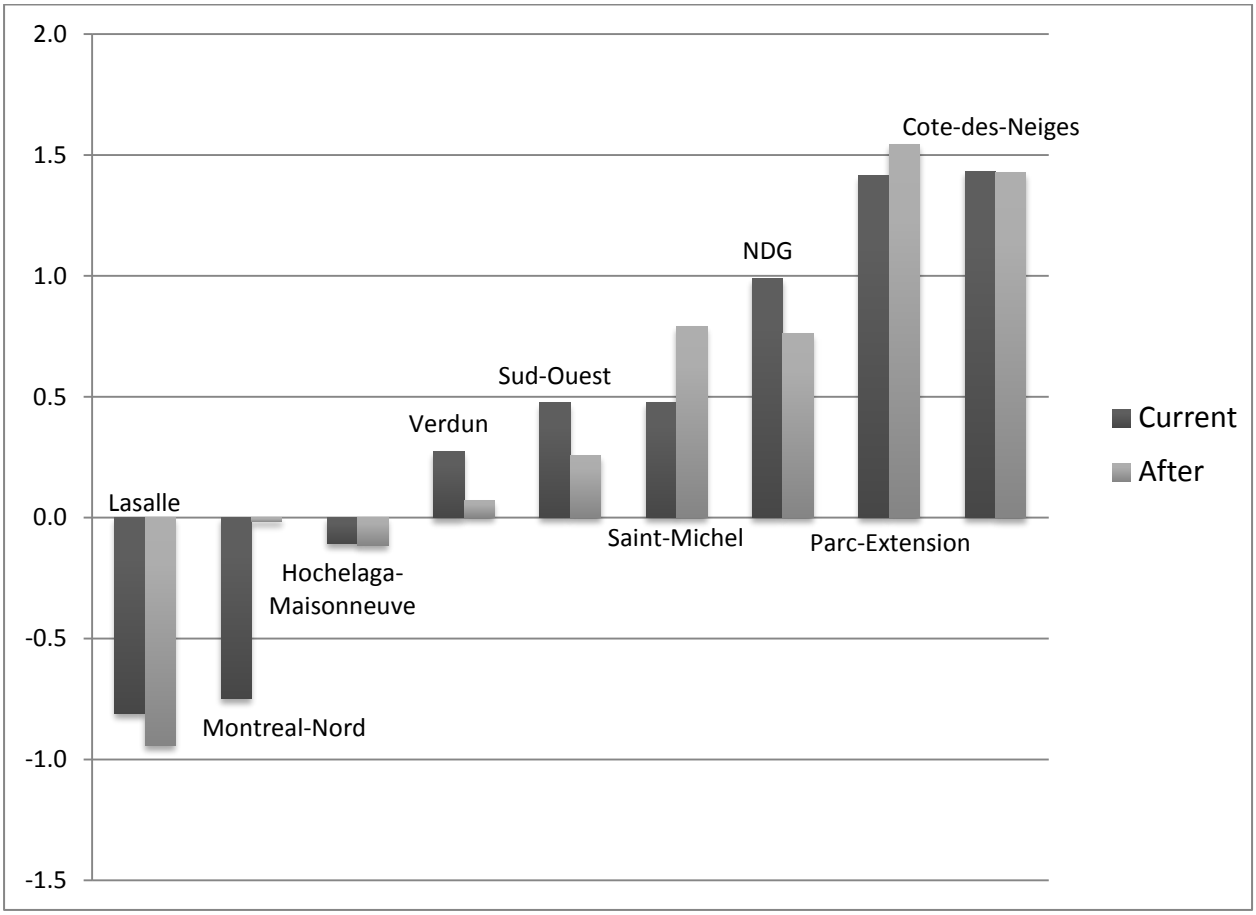


Figure 3.4: Relative standing of neighbourhoods before and after changes

Figure 3.5: Travel Times impacts of Changes

3.5.3 Travel Time Impacts of Projects

Accessibility to jobs was seen as not necessarily the only manner to measure equitable outcomes of the plan. Accessibility provided a global picture of the effects of each project. The estimated travel time to each of Montreal's six employment centers was calculated from each of the most disadvantaged neighbourhoods. This allows for two separate analyses, determining which neighbourhoods are most benefitting in terms of faster access to employment centers, and by which project. It is interesting to see that Hochelaga-Maisoneuve sees little travel time improvement to any of the major job centers, while Parc-Extension and St-Michel see marked

improvement to all job centers. Another striking finding is that access to Anjou and the CBD seem to be the most improved, all neighbourhoods show at least minor improvements to these areas.

Table 3.3: Job Accessibility Change by Neighbourhood

	Anjou	CBD	Dorval	Laval	Longueuil	Marché Centrale
Notre-Dame-de-Graces	13.1%	9.2%	0.0%	0.0%	2.7%	0.0%
Cote-des-Neiges South	25.6%	2.2%	0.8%	4.4%	5.6%	4.1%
Lasalle	4.7%	6.6%	0.0%	0.0%	2.6%	0.0%
Hochelaga-Maisonneuve	0.6%	5.8%	0.7%	9.5%	0.0%	12.6%
Montreal-North	7.1%	24.6%	23.9%	31.6%	7.0%	36.6%
Parc-Extension	31.8%	10.6%	2.6%	4.5%	8.7%	2.9%
Saint-Michel	23.3%	12.6%	7.9%	11.4%	11.6%	18.8%
South-West	2.9%	14.0%	0.0%	0.0%	3.6%	0.0%
Verdun	2.8%	13.5%	0.0%	0.0%	4.0%	0.0%
Villeray	30.2%	9.0%	0.0%	0.0%	10.3%	0.0%
Overall in Region	**11.9%**	**3.2%**	**5.5%**	**3.8%**	**1.3%**	**0.2%**

The final stage of the analysis concerns travel-time reductions based on actual home and work locations. For this, I mapped the current home-work commute for all workers in the region. I was able to estimate travel time savings for individuals as well as analyze and the number of people from a given neighbourhood who will benefit from such improvements. The results are summarized in Table 3.4 and mapped in Figure 3.5. If an area is gaining in accessibility to either unsuitable job opportunities or showing decreases in travel time to undesired locations, we could claim that the plan is not taking this neighbourhood's needs into account. While I do not want to suggest reverting to focusing on mobility at the expense of accessibility, in the case of examining the equitable outcomes of the plan, it seems that this travel-time savings is a key factor.

We see that certain neighbourhoods are better served. The South-west borough, parts of NDG and Griffintown are shown to have the least benefits in terms of travel-time reduction to current jobs. On the other hand, particularly due to the BRT, train and Metro lines, Montreal

North, St-Michel and Cote-des-Neiges show very high levels of benefit. This time-savings was examined as average time per person. Montreal-North again stands out as an area with high benefit to current residents. The last column shows estimated travel time savings in person-hours for a one-way commute. Comparing Table 3.2 and 3.4, we see that the South-West, for example, does not benefit much in terms of increased accessibility to jobs, however, a large percentage of residents are seeing real, albeit minor, travel time savings on their commute.

Table 3.4: Time savings by Neighbourhood

	Total Workers	% who would see a reduction in their current commute	% who would see a reduction of 5 minutes or more	Avg. time saved (minutes/ person)	Total Hours saved
Cote-des-Neiges	18120	51.1%	7.1%	1.3	37.6
Griffintown	1265	29.6%	0.0%	0.2	0.8
Lasalle	9795	13.2%	1.1%	0.3	4.1
Hochelaga-Maisonneuve	4090	33.7%	3.3%	0.8	7.9
Montreal-North	2135	66.3%	52.0%	6.7	25.8
NDG	14575	9.0%	1.6%	0.2	8.7
Parc-Extension	9685	41.7%	15.0%	1.6	25.9
Saint-Laurent	1420	96.8%	8.8%	2.7	6.6
Saint-Michel	9195	50.4%	28.2%	2.9	51.2
South-West	3415	20.9%	1.6%	0.4	1.7
Verdun	7610	22.5%	1.9%	0.5	6.0
Villeray	5145	30.7%	10.6%	1.4	15.4
Overall Region	1031150	34.5%	11.2%	0.7	2776.8

Based on the assumption that residents will keep their current jobs, Table 3.4 suggests that those near the train, metro and BRT benefit the most in terms of travel time to their current jobs. Surprisingly, the airport shuttle seems to do little to improve commuting time. The map seems to show an east/west divide with those in the western part of the island seeing much less direct benefits from the plan. However, some may argue that this actually shows the equitable aspect of the plan. The vast majority of the “low-change” areas to the west of the island are

wealthy suburban-style developments, while most of the areas more affected are likely to be poor, with more recent immigrants and higher rates of unemployment.

3.6 CONCLUSION

This research explores several issues related to accessibility, mobility and equity and adds to the burgeoning discussion on these topics. Among other findings, it would suggest the importance of scale, definition and appropriateness of measurement. From a regional standpoint, the plan seems to succeed. Many people who presently lack good accessibility and connections to employment centers will see increased benefits. Due to the geographic location of many disadvantaged neighbourhoods, and the focus of most new transit infrastructure near the CBD, the plan does provide quite well to many poorer neighbourhoods. However, on a micro-scale we see that certain neighbourhoods fare much better than others.

The measures of accessibility generated here allow for a long term vision. Having access to more jobs within the labor market increases the number of opportunities available to the disadvantaged population in the long term. On the other hand, the travel time analysis shows the short term impact on individual mobility, since each person is only concerned with how to access her existing job and to what extent the new plan will help her in doing so. Meanwhile the analysis of travel time to job centers concentrates on the long term aspect and flexibility that the plan can offer to the socially disadvantaged population in terms of job search in the future.

This paper set out to answer a relatively straightforward question; how well do currently socially isolated and disadvantaged neighbourhoods benefit from transit improvements and how is this quantified as time-savings to job locations. As sustainability goals continue to grow in importance for transit providers, it is important that easier-to-measure goals such as ridership and environmental impact do not become prioritized at the expense of considerations of equity. It is

not my intention, however to take the discussion completely away from these important considerations. For example, the proposed commuter train has the potential to be both an economic force in a relatively undeveloped region as well as being a possible solution to limiting GHG emissions for both current and future residents. In fact, this could be the most beneficial project from an environmental standpoint, if the potential time savings translate into mode shift. Interestingly, while the rail line has been primarily designed to serve residents at the periphery, the planned route and station placement may very well have a "spillover" effect and aid those in low-income neighbourhoods. The accessibility benefits provided by the train neither prioritize disadvantaged populations or other better-off groups. A focus on suburban mode shift is not necessarily misguided, and only becomes a concern if it leads to neglect of transit-dependent riders elsewhere. However, while it is beyond the scope of this paper to do a full cost/benefit analysis which weighs equity issues in some manner, this would be highly recommended before the city embarks on a costly and lengthy rail construction project. BRT and other bus improvements have great potential to meet the needs of disadvantaged populations at a fraction of the cost and time of rail projects.

Regional transit agencies interested in providing service in an equitable manner would be encouraged to understand important characteristics of underserved populations by asking three questions. Firstly, where are the under-served populations located? Secondly, where are their places of employment? Lastly, how can they be better served? Answering these questions might allow for more appropriate transit solutions for the needs of these populations. Faster connections, more reliable service, new areas of access, or entirely new routes might be considered. Relatively straight-forward GIS techniques can aid greatly in answering these questions at both the regional and personal scales.

This research is not without limitations. Further research might utilize census micro-data for a more accurate exploration of who lives in certain neighbourhoods. The aggregate approach misses socially disadvantaged individuals living in other neighbourhoods. Accessibility *to* transit was not examined thoroughly; neighbourhood-scale walkability factors play an important role in the attractiveness and comfort of using transit. Also, a fairly narrow view of the role of transit—connecting workers to jobs —is utilized; however, the approach is backed up theoretically and by previous research. Modeling transit presents its own unique challenges. Different individuals might have dramatically differing attitudes and preferences towards waiting times, frequencies of stops, number of transfers, as well as type of transit mode. So, for some, one minute on a train may not equal one minute on a bus. This, however, is a subtlety that I was not able to bring into the analysis.

This chapter leaves many questions unanswered. How decision-makers will adapt to changing goals of transit remains to be seen. These results highlight the importance of multi-criteria evaluation as the findings would suggest that potential environmental benefits of some projects are not necessarily aligned with issues of equity or need. It is hoped that policy-makers bear in mind these subtleties when prioritizing among projects. The approach outlined here shows how accessibility measures can be utilized to indicate the extent to which the benefits of transit projects are equitably distributed among those with the most need.

CHAPTER 4: WHAT MAKES TRAVEL "LOCAL": DEFINING AND UNDERSTANDING LOCAL TRAVEL BEHAVIOUR

4.1 OVERVIEW OF CHAPTER

In recent years, land use and transportation planning priorities have shifted away from issues of mobility to focus on the capacity of a neighbourhood to provide opportunities to live, work and socialize at the local scale. As planning for accessibility is seen to have more sustainable outcomes, measures of accessibility are gaining popularity as comprehensive performance measures of the interaction between land use and transportation systems (El-Geneidy and Levinson 2006; Grengs et al. 2010). By favouring shorter travel distances and active modes of transportation and influencing household location choices, accessibility can also be used as a sustainability indicator and a goal in land-use planning. Rather than emphasizing increased road capacity and travel speeds, transportation planners are looking for solutions to increase localized and short distance travel. However, there is a potential downside to this framework. Often those whose travel patterns are confined to their local area display this behaviour not by choice but due to mobility limitations. In fact, many other reasons may exist to limit individual and household travel patterns including: fear or lack of knowledge about certain areas or destinations and poor or unreliable transit service. Given identical levels of neighbourhood and regional accessibility, I hypothesize that households of differing socio-economic, attitudinal and personal preferences might display vastly dissimilar activity spaces. Furthermore, much previous research to understand "local" travel has focused too heavily on either distance travelled or an over-simplified measurement of household activity space. To explore these issues, this study introduces a new measure of the localization of household activity space to help understand the degree to which a household is engaged in local travel. This is done through a new travel

behaviour index that accounts for the dispersal of household destinations and total distance travelled. The proposed measure provides insight into household activity patterns to help in understanding the relationship between household activity space and local and regional accessibility while controlling for socio-demographic factors.

Therefore, the two main objectives of this chapter are 1) to introduce a new measure of the localization of the observed household activity space, and 2) to understand the effects of neighbourhood and regional accessibility on this new measure and how these effects vary with socio-economic and household characteristics. Reaching these objectives is expected to help transportation professionals who are aiming to develop policies to localize household travel patterns through land use and transportation coordination at the neighbourhood and regional scale. The paper commences with a brief literature review on the concept of accessibility and household activity space, and then continues with a discussion of the methodology and data used in the study. The results of the models are then summarized, followed by a discussion and a conclusion with policy recommendations for city and regional planners.

4.2 LITERATURE REVIEW

Previous research has explored the relationship between accessibility and travel behaviour. Examples include Levinson (1998) who looked at effects of accessibility on the journey to work. Kockelman (1998) studied the effect of various factors on total kilometres traveled and on travel behaviour including accessibility, which she found to have a statistically significant effect on both outcomes. Hanson and Schwab (1987) linked accessibility to characteristics of activity space finding a significant yet small relationship between the area of activity space and levels of accessibility. Finally, a recent paper examined the dispersal of activities throughout time and space in relation to access to information and communication technologies (ICTs) (Alexander,

Ettema, and Dijst 2010). Accordingly including accessibility measures at various scales to help in understanding travel behaviour and activity space is not new, yet understanding the effects of accessibility at these two levels on the localization of activities is new in the transportation planning literature. The following section outlines in more detail how regional and local accessibility has been measured and their use in travel behaviour research.

4.3 REGIONAL ACCESSIBILITY

Accessibility is defined as the potential of opportunities for interaction (Hansen 1959) and is often contrasted with mobility (Handy 2002). Accessibility considers the interaction between the land-use and transportation systems and can be used to measure their coordination. Many approaches exist to measure accessibility, cumulative opportunities and gravity-based approaches being the most common. This research utilizes an approach which accounts for competition for jobs, arguably giving a more accurate and nuanced picture of job accessibility. The inverse balancing factors of the doubly constrained spatial interaction model (Wilson 1971) is one of the most commonly used measures that accounts for both the supply and demand side of accessibility. This measure indicates the level of imbalance between the amount of opportunities and opportunity seekers(Geurs and Ritsema van Eck 2003). With this measure the supply and demand potential for all the zones is calculated iteratively, ensuring that the amount of trips to and from each zone is equal to the number of opportunities (Geurs and Ritsema van Eck 2003). In other words, it calculates all the potential opportunity-seekers (E_i) for the area as well as all the potential opportunities available (O_j) and balances the numbers until the model is stable. Using accessibility to jobs and number of potential job seekers, this model can be explained as:

$$A_{im} = \sum_{j=1}^{n} \frac{1}{B_j} O_j f(C_{ijm}), \quad (1) \qquad B_{jm} = \sum_{i=1}^{m} \frac{1}{A_i} E_i f(C_{ijm}) \quad (2)$$

A_{im} is the accessibility to jobs for people living in location *i*, using mode *m*. While, B_{jm} accessibility to workers at zone *j* using mode *m*. O_j is the number of opportunities (jobs) in zone *j*, E_i the number of opportunity-seekers (people) in location *i*, and $f(C_{ijm})$ the impedance function measuring the spatial separation between *i* and *j* using mode *m*.

The first step to operationalizing the measure is to calculate the accessibility to jobs for all zones, making the balancing factor B_{jm} equal to 1 (1). This amounts to calculating a gravity measure for all zones. The result of this A_{im} is incorporated to the calculation of the second factor B_{jm} (2). That result is then incorporated back into to the first factor A_{im} (1) and so on until a balance is reached. The model has converged when the results of two consecutive A_{im} factors are identical. This study used the 1500 TAZ of the Montreal region to generate the regional accessibility measures.

4.4 LOCAL ACCESSIBILITY

Handy (1993), explored issues of local and regional accessibility, identifying neighbourhoods in California that display high local but low regional accessibility and vice versa. While the results were somewhat ambiguous, this early study highlights the fact that local accessibility may lead to short local walking but may not effect overall distances travelled to other destinations. Crane and Crepeau (1998) found that neighbourhood-level characteristics such as street connectivity led to fewer car trips. Surprisingly, land use mix (measured by the area of commercial land use in the census tract) was seen to lead to more automobile trips in one model and not to be significantly associated with mode choice in another model. Dieleman, Dijst et al (2002) found that residents of mixed-use urban areas travel shorter distances and make fewer car trips, yet they utilized a rather over-simplified urban versus suburban categorization. Interestingly, their study showed personal and household characteristics and built form characteristics have roughly the same

explanatory power in the models. Therefore, both small scale and large-scale measures of accessibility need to be considered when studying travel behaviour in urban regions.

Accounting for local accessibility can be done through various methods. This research uses results obtained from walkscore.com (walkscore.com 2010). Recent work has both confirmed the accuracy of results from walkscore.com (Carr, Dunsiger, and Marcus 2010) as well as shown its usefulness in predicting walking behaviour for shopping trips (Manaugh and El-Geneidy 2011). Walkscore grants a score between 0-100 based on the presence of nearby amenities in thirteen separate categories (such as food, cafes, libraries, parks, and cinemas). It uses a simple gravity-based measure to weight nearby locations higher than those more distant. While walkscore has certain issues (use of straight-line distances for example), it has been shown to be a reliable manner in which to capture the proximity, variety, and ease of access for "everyday" destinations.

4.5 ACTIVITY SPACE

Over the past few decades, the concept of activity space has entered the literature as a manner in which to understand personal and household travel behaviour. Activity space has been defined as the geographical area containing all locations an individual has direct contact with as a result of his daily activities (Horton and Reynolds 1971). Several studies used data acquired from travel behaviour surveys to analyse the spatial representation of individual travel behaviour (Newsome, Walcott, and Smith 1998; Dijst 1999). Activity space has been used in the literature as a measure of travel behaviour to better understand travel demand (Newsome, Walcott, and Smith 1998), and as an indicator of social exclusion (Axhausen and Garling 1992).

Sherman et al. (2005) compared five measures of activity space in a study of healthcare accessibility; the Standard Deviation Ellipse at both 1 and 2 standard deviations, a road network

buffer approach, standard time polygon and relative time polygon. They found that the road network buffer approach is the most accurate and realistic representation of accessibility to healthcare as opposed to the more abstract nature of the standard deviation ellipses. Buiiung and Kanaroglou (2006) presented a thorough overview of such approaches, as well as introduced the idea of using convex hull polygons to operationalize activity space.

Activity space can be generated at the individual or household level of analysis. Previous research has shown the importance of examining the household as the main decision maker entity (Buiiung and Kanaroglou 2006). A prior study suggested that individual travel outcomes are heavily influenced by household-level characteristics (Bhat 1996). For these reasons, this study focuses on household-level behaviour using the convex hull approach.

Debate exists over the meaning of the activity space. Some theories suggest that the size of an activity space can proxy for the social inclusion of a household. Kenyon, along with colleagues has explored these issues in relating the size of activity spaces to measures of social exclusion (Kenyon, Lyons, and Rafferty 2002). However, the prevailing view from an energy/environmental perspective is that smaller, less dispersed travel behaviour is preferable. Accordingly studying activity space to recommend policies that encourage localized travel pattern requires a distinction between households that travel locally as a result of an amenable local environment and those that travel locally due to a lack of mobility options or time constraints.

4.6 STUDY CONTEXT

Montréal is among the largest cities in North America. The region covers an area of 4,360 square kilometres and had a population of 3.6 million in 2007 with 1.4 million private dwellings, 1.84 million automobiles and 1.86 million jobs (Communauté Metropolitan de Montréal 2009). The

population density in the urbanized area was 1805.1/km² in 2006 (TAC 2010). Although the city has a vibrant core, the growth at the centre has slowed recently in relation to outlying areas (Collin, Dagenais, and Poitras 2003). The region has several employment sub centers (Coffey and Shearmur 2001) meaning that daily travel to the downtown core is not a must for many households. Figure 4.1 is a map showing the study context. Montreal has a transit modal split above most of North America. The AM peak modal split to the CBD was 59% transit, 36% automobile and 4% non-motorized in 2006. Overall modal split was 21%, 66%, and 12 % for transit, car, and non-motorized respectively. Average vehicle km per capita was 15.1 and the median trip-to-work distance was 8.1 km in 2006 (TAC 2010).

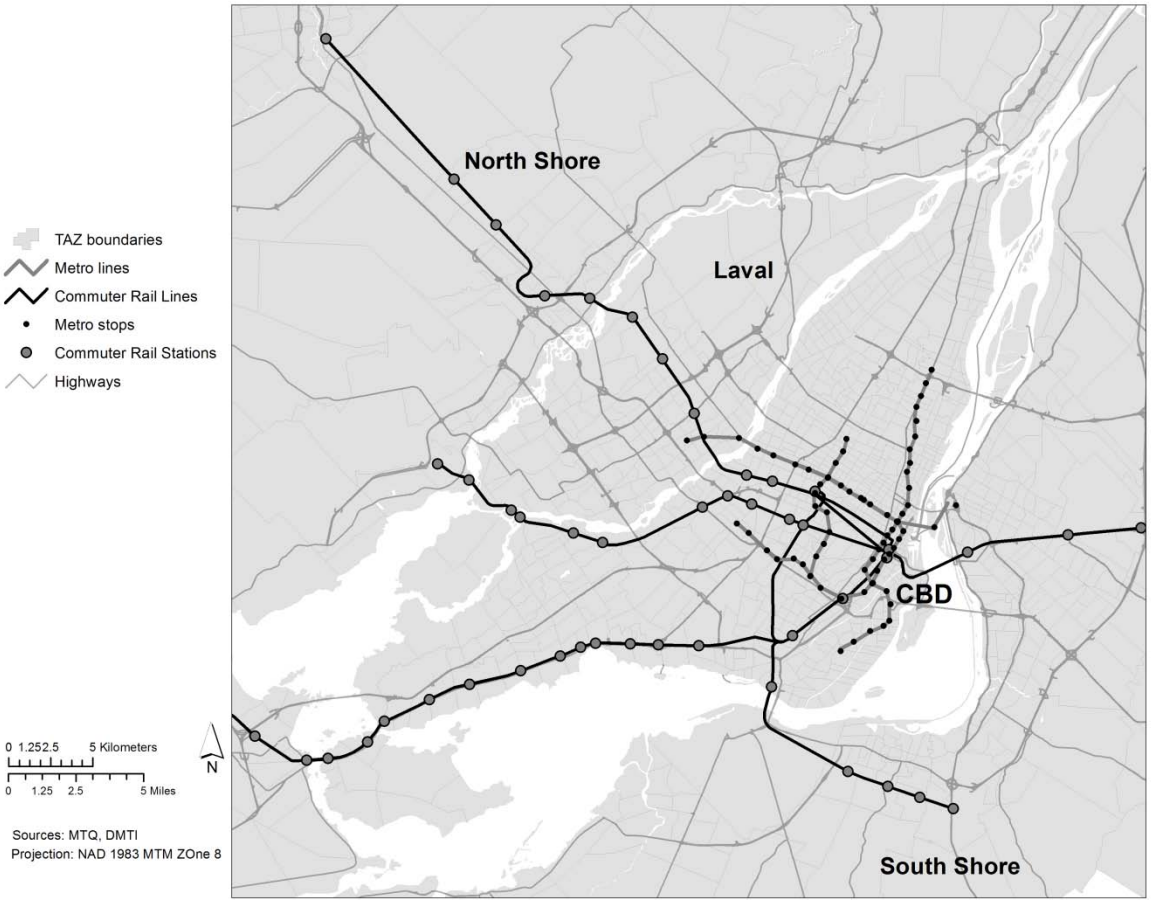


Figure 4.1: Montreal Regional Context

4.7 METHODOLOGY

The main goal of this paper is to measure the effects of the regional and local accessibility on local travel among households throughout the socio-economic spectrum. Accordingly, the first step is to generate accessibility measures that are theoretically sound at both scales. Regional accessibility is here captured by the inverse balancing factors of the doubly constrained spatial interaction model competition measure (explained above), while local accessibility is measured by the walkscore value. The index is calculated at every postal code in the region. In the Canadian context, a postal code represents a single block-face making it more appropriate than the zonal-based system used for the regional measure (Iacono, Krizek, and El-Geneidy 2010).

The second step is to generate activity space and other measures that can be used in measuring the localization of household travel behaviour, such as total distance traveled by household and the spatial dispersal of household's activity space. A sub-sample of households from the 2003 Montreal Origin-Destination survey who made both "mandatory" (i.e. work, school) and "non-mandatory" (i.e. leisure, visiting friends, shopping) trips in the same day are analysed for this purpose (Agence métropolitaine de transport 2003). A new measure of travel behaviour that accounts for dispersal of activity space as well as distance traveled is designed.

Elements of household structure play a large role in household travel behaviour. Households with more members would be expected to make more trips, travel more total distance and have a larger activity space. The presence of children in the household is expected to lead to more trips and more spatial dispersion in the travel pattern of the household. To account for variation in household structure a cluster analysis is conducted. This cluster analysis included basic household characteristics to account for the variation in households and how their activity spaces vary. Several statistical models are built to explore the relationships between travel

behaviour of a household while controlling for accessibility measures. Trip purpose dummies are included in the models to control for differences in the types of trips conducted by the household, household income is included as it is hypothesized that higher incomes could lead to more discretionary travel (Builiung and Kanaroglou 2006).

4.8 DATA SOURCES

The regional accessibility measure is calculated directly from employment, demographic and travel time data obtained from the 2006 census conducted by Statistics Canada and Ministère des transports du Québec (MTQ) respectively. This measure is generated at the traffic analysis zone (TAZ) level of analysis. MTQ provided the research team with a congested travel time matrix between the TAZs during the morning peak. Yet generating this measure requires calculating gravity based measures of accessibility to jobs and workers. Calculating the gravity based measure necessitates a travel time decay curve, which can be generated from combining the travel behaviour surveys with travel time obtained from MTQ. The 2003 Origin-Destination survey (Agence métropolitaine de transport 2003) is used for this purpose. The OD survey is conducted every 5 years and records completely disaggregated data on each trip made in the respondent's household on the previous workday. The survey is conducted in the autumn where travel patterns are less affected by either weather conditions or summer school holidays. The precise X and Y coordinates of each trip origin and destination are collected along with purpose, mode, and time of each trip, in addition several socio-economic variables of both the individual and household are recorded, including age, gender, work status, household income, and number of household members. The postal code of the home address of each household is used to define its level of local accessibility represented by the walkscore obtained from walkscore.com (walkscore.com 2010). A database containing the walkscore of over 100,000 postal codes in the

Montreal region was purchased for use in this study. A spatial join in GIS allowed for the determination of each household's local accessibility with a high degree of accuracy and disaggregation.

The same OD data is used to generate the activity space for household who were involved in several trip purposes during the day in addition to work trips. This resulted in a large sample of 31,333 individuals in 11,633 households making 93,902 trips. First household trips are mapped using the origin and destination coordinates in a GIS environment. Then the Convex Hull application in GIS is used. The convex hull application defines the smallest possible polygon that includes all the household activity points. This polygon corresponds to the household's activity space. The distance travelled used in the analysis is generated through measuring the network distance between every origin and every destination a household member was involved in solving for shortest travel time based on posted speed limit. This data is obtained from the Montreal OD survey and the calculations are conducted using the network analyst tools in Esri's ArcGIS 9.3.

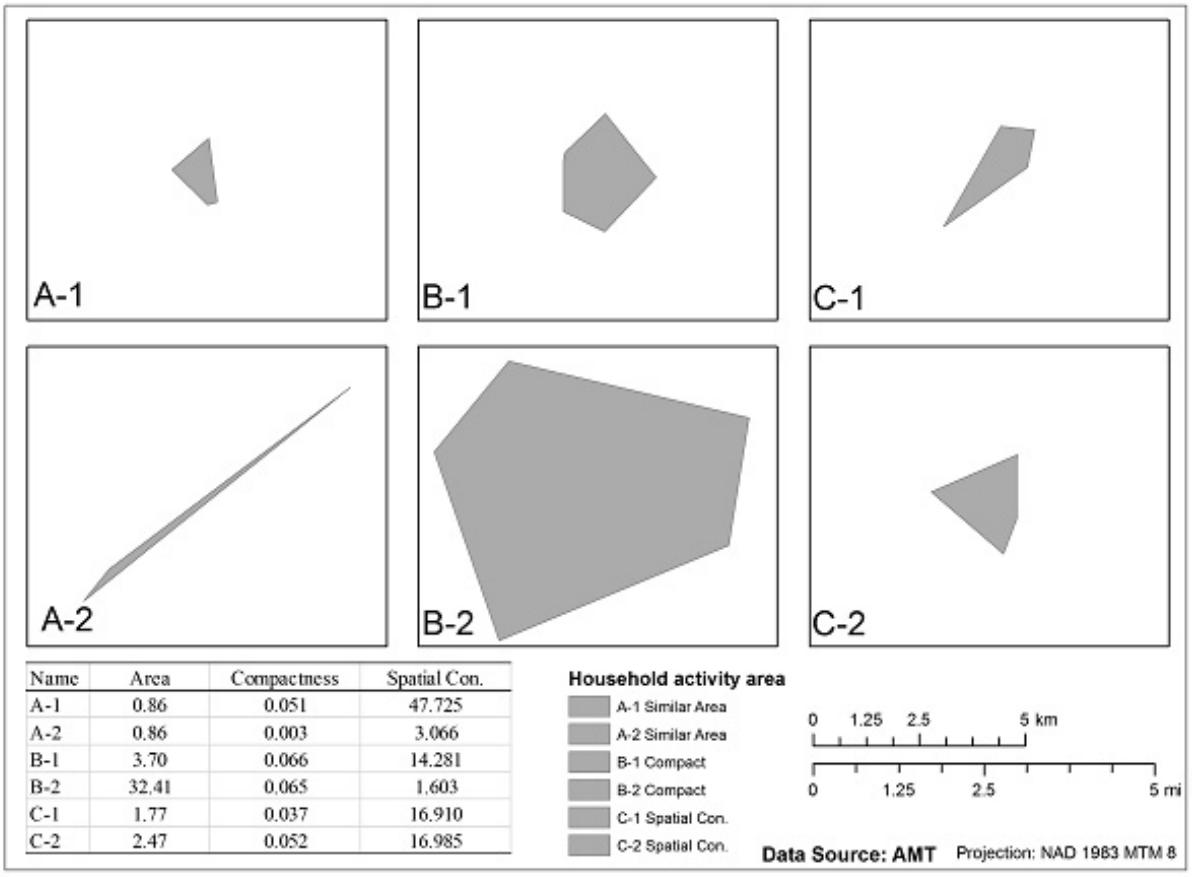
4.9 MEASURING THE ACTIVITY SPACE

Previous studies used the absolute area of activity space and total distance traveled to estimate how these travel behaviour indicators are affected by urban form and neighbourhood characteristics (Fan and Khattak 2009; Newsome, Walcott, and Smith 1998). However, these measures can be deficient to explain compact, local travel behaviour. The total distance traveled by a household does not account for direction of travel or the resulting use of space. The area of the polygon can be misleading, since having a small area does not necessarily mean having local travel behaviour. Figure 4.2 shows a comparison between various polygons. Polygons A-1 and A-2 have the same area but correspond to two different travel behaviours, A-1 has more trips close to the origin point, while A-2 has a very long trip, but only in one direction. A measure of

compactness is used to separate these two travel behaviours (Selkirk 1982). Compactness is the ratio between the area of the polygon and the area of the circle that can include this polygon. The measure of compactness is defined as :

$$\mathrm{Comp} = \frac{\mathrm{A_r}}{\mathrm{p}^2}$$

Where *Comp* is the compactness of the polygon, A_r is the area of the polygon and *P* is the perimeter of the polygon. This measure defines a circle around the polygon, and generates a ratio between the area of the circle and the area of the activity space. This separates households having similar areas with long travel distances from those with short ones, but as shown by polygons B-1 and B-2, this measure does not differentiate between a household with very local activity patterns and ones with more distant ones.



Name	Area	Compactness	Spatial Con.
A-1	0.86	0.051	47.725
A-2	0.86	0.003	3.066
B-1	3.70	0.066	14.281
B-2	32.41	0.065	1.603
C-1	1.77	0.037	16.910
C-2	2.47	0.052	16.985

Figure 4.2: Comparisons between different measures of household activity

Building on previous work (Parthasarathi, Hochmair, and Levinson 2011) which utilized the conception of local travel developed by Cerda and El-Geneidy (2010), this study includes both a spatial component of localization along with a network distance travelled to further refine this concept. In order to obtain a reliable measure of individual travel activity the measure of compactness is modified to account for spatial dispersal. The measure of spatial dispersal utilizes area ratios and compactness, generating a bridge between the above mentioned measures. The spatial dispersal of the activity space can be defined as:

$$\frac{A_r}{A_{max}} * \frac{A_r}{p^2}$$

Where A_r is the area of the activity space of a household, $A_{max,}$ is the area of the largest polygon in the sample, and A_r/p^2 is the compactness of the polygon measured earlier. As seen in Figure 4.2 polygons C-1 and C-2 have the same level of spatial dispersal as well as a similar area and compactness. A person with a low value of spatial dispersal is expected to live in an area with high levels of regional accessibility. However, this would still not fully describe a household's localized travel as it does not take into account network distances. Therefore, by generating a simple index of the standardized score for dispersal and total distance travelled; a more complete picture is provided. This index is named Local Travel Index (LTI) and can be expressed as:

$$\text{LTI} = \text{Z score}\left(\frac{A_r}{A_{max}} * \frac{A_r}{p^2}\right) + \text{inverse Z score (total distance traveled by household)}$$

Standardized scores (distance from mean (plus or minus) for a given value) for both dispersal and distance travelled are summed. This composite index is represented by a unit-less number where higher values represent household activity spaces that are both spatially concentrated and require short travel distances to generate. In Figure 4.3 we can see that similar spatial dispersal values can be generated by drastically different travel behaviour. In the first case (A1 and A2) this is as result of differences in the underlying road network that obligates a traveler to make indirect connections to destinations. In the second case (B1 and B2) the underlying road network is similar in terms of connectivity; however, the observed travel behaviour in B2 included many internal trips. While the LTI is a somewhat abstract measurement, I feel that it captures both of the desired inputs to local travel, a measure of total distance travelled and spatial dispersal of destinations. As illustrated in Figure 4.3, a focus on one or the other could lead to misleading results, street network characteristics or behaviour within the activity space could greatly

influence total distance travelled. It is also important to note that this measurement is unique to the sample from which the observation is drawn, in other words, these values are relative to all other households in the sample, and could not be used across samples.

	A1	A2	B1	B2
Dispersal (z-score)	0.141	0.142	-0.106	-0.100
Distance ((z-score)	-1.195	-1.055	-0.511	-0.247
Index	-1.337	-1.197	-0.405	-0.146

Projection: NAD 1983 MTM 8
Source: AMT, DMTI

Figure 4.3: Variation in LTI and spatial dispersal

4.10 CLUSTER ANALYSIS

In order to gain a better understanding of how socio-economic factors may influence travel behaviour, particularly localization of activity space, a cluster analysis was completed at the household level. Basic household characteristics were included in the clustering process. These include: income (a categorical variable with a $20,000 range), number of cars per licensed driver in household, number of children (under 18 years), number of full-time workers, number of students, and number of seniors. Figure 4.4 shows the variation from the mean for each of the inputted variables.

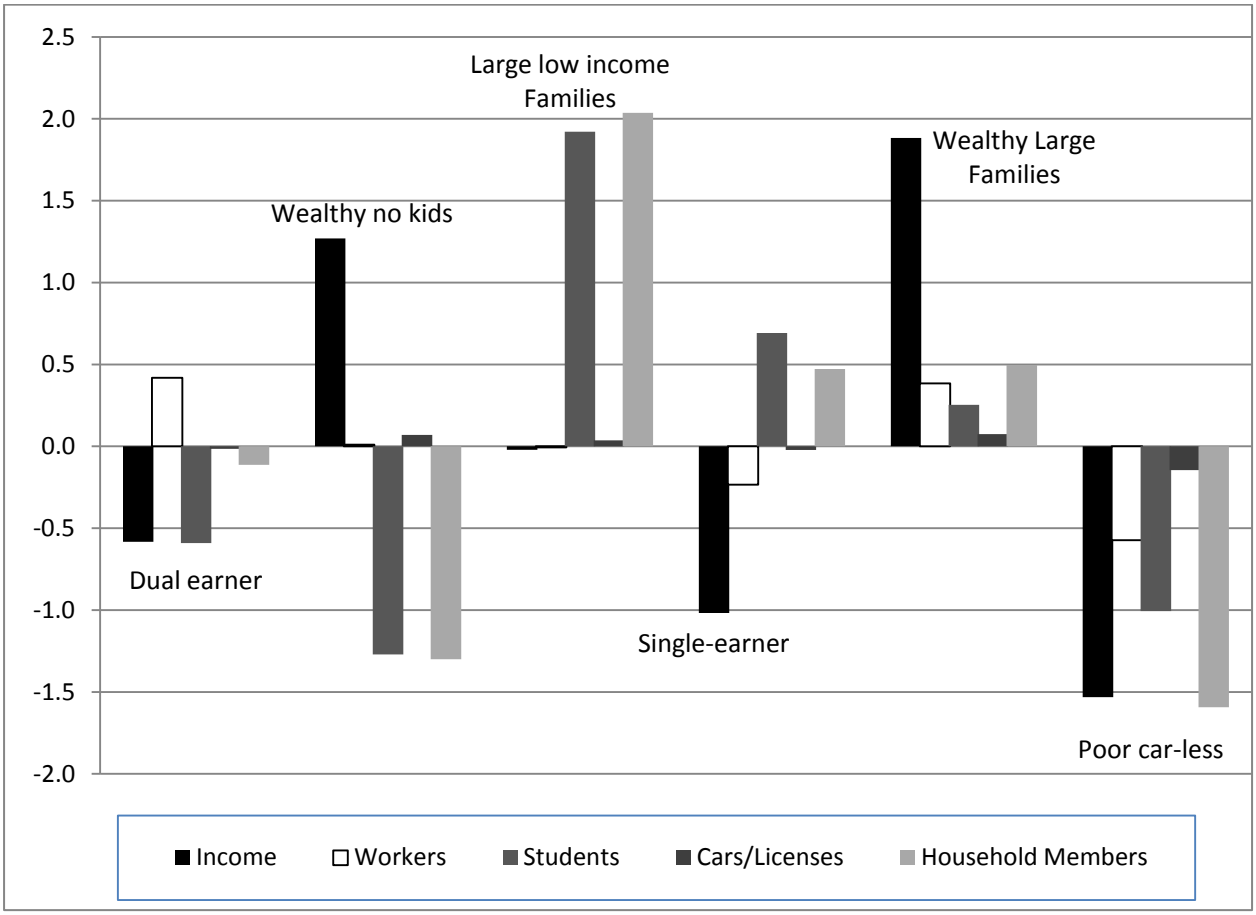


Figure 4.4: Variation from mean and number of observations for each cluster

To highlight some of the differences, we can look more closely at the *wealthy no kids* and *wealthy large family* clusters. Both clusters display household income and car ownership rates above the mean value, yet the number of total household members and number of students is quite different. It is important to note that the O-D survey does not collect information on several important socio-demographic factors. For example, no information on race, immigrant status or marital/relationship status of households is provided.

4.11 STATISTICAL ANALYSIS

A set of statistical models were developed to explore the relationship between small, localised activity spaces and accessibility to jobs, workers and retail. The dependent variable is the LTI explained earlier. Table 4.1 includes a list and description of the variables used in the analysis as well as summary statistics.

The independent variables have been chosen to explain household characteristics, mobility status, and regional and local accessibility. Several other location and accessibility variables were experimented with and subsequently dropped from the analysis due to correlation with other explanatory variables. The models presented in this paper do not include these correlated variables. Interestingly, the local and regional accessibility measures were not shown to be highly correlated (spearman rho=0.4). I hypothesize that the effect of regional and local accessibility will vary by socio-economic factors. Furthermore, some factors could have complex effects, for example, presence of school-age children may lead to increased travel distance, though many, if not most, households would try to minimize the dispersal of these trips. Along the same reasoning, picking up and dropping off children or other family members may lead to a decreased time budget so that other trips are simply not possible or must be minimized. Likewise

high accessibility would likely lead to less distance travelled but could generate many shorter trips in different directions, i.e. more dispersed travel.

Table 4.1: Descriptive statistics for all variables in model

Variable	Mean	Std. Dev.	Min	Max
Number of different trip purposes	2.77	0.94	2	8
Number of trips	8.07	4.09	3	42
Work trip dummy	0.92	0.27	0	1
Shopping trip dummy	0.35	0.48	0	1
School trip dummy	0.57	0.49	0	1
Leisure dummy	0.29	0.46	0	1
Social dummy	0.15	0.36	0	1
Pick up or drop someone off dummy	0.55	1.11	0	16
Percentage of trips by walking	11.34	21.74	0	100
Regional Accessibility *	0	1	-1.25	3.07
Local Accessibility	0	1	-2.51	2.29
Spatial Dispersal	12.21	111.37	0	5229
Total Distance travelled	51208.80	42077.42	533.75	478794.0
LTI	0.00	1.50	-48.20	8.05

*The accessibility measures have been standardized (z-scores) in order to more accurately measure the difference in magnitude and explanatory power of these variables.

Table 4.2, includes the results of an ordinary least square regression model for the LTI measured for households. The local and regional accessibility measures were standardized in order to be able to compare the effects of each relative to the other. Both local and regional accessibility measures have a statistically significant positive effect on LTI, with the local having more explanatory power in the model. The types of daily trips made by the household are also noteworthy and have a statistically significant effect in the model. Households that make at least one work trip are seen to have a lower LTI. While households that include trips to pick up and drop people off have a “better” LTI than households who do not. Perhaps this is due to these household types being restricted in their daily mobility by obligations to either other family members or individuals outside the household. These findings are interesting in that they show that accessibility measures and socio-demographic factors do not alone account for travel

behaviour, two households with identical accessibility will have varying travel behaviour based on what they actually chose to access.

Table 4.2: Regression results, LTI is dependent variable

Variable	Coefficient	t-stat
Dual earner households	0.090	0.250
Large low income	1.262**	2.140
Single earner households	2.740***	6.820
Wealthy large families	-1.871***	-4.490
Poor Car-less	2.921***	10.830
Percentage of trips by walking	11.310***	25.200
Regional accessibility	1.137***	11.470
Local Accessibility	3.399***	32.420
Number of different trip purposes	0.179	0.750
Number of trips	-1.209***	-30.040
Work trip dummy	-2.004***	-4.810
Shopping trip dummy	1.761***	6.100
School trip dummy	-0.504	-1.550
Social dummy	-0.785**	-2.320
Leisure dummy	-0.864***	-2.970
Pick up or drop someone off dummy	1.412***	4.490
Constant	-1.373	-2.420

N=11,633 Reference cluster is “wealthy no kids”
*** represents significance at 99%, ** = 95%, * = 90%
Adjusted R-square = 0.416

Table 4.3 presents the coefficients associated with each cluster and the two accessibility measures. As hypothesized, both local and regional measures of accessibility are shown to affect different types of households in drastically different ways. To further explore our hypothesis, a Chow test was performed. This allows for the determination of whether the coefficients in the overall model differ from the coefficients in separate models. In this case, I test the null hypothesis that the coefficients for local and regional accessibility found in the overall model (see Table 4.2) are identical to the coefficients found by stratifying the sample into 6 sub-samples. A new regression model was specified that generates a separate coefficient for local and regional accessibility for each group. The “test” function in STATA allows for the determination of

whether there is a statistically significant difference between each group's response to local and regional accessibility.

Table 4.3: Focus on local and regional accessibility effects on activity space.

Cluster Type	Walkscore β(t-value)	Regional Accessibility β (t-value)	N
Dual earner	4.385 (15.47)***	1.348 (4.84)***	1520
Wealthy no kids	3.438 (15.98) ***	1.268 (5.8)***	2141
Large low-income	5.054 (10.87)***	1.848 (3.88)***	548
Single earner	4.175 (15.77)***	0.945 (3.56)***	1733
Large wealthy	5.740 (18.89)***	1.973 (6.84)***	1368
Poor Car-less	1.677 (9.67)***	0.854 (5.42)***	4322

*** represents significance at 99%, ** = 95%, * = 90%
Only coefficients and significance for the variables of interest are shown, the fully specified model controls for trip purposes, total number of trips, and percentage of trips by foot. t-values are shown in parentheses.

As seen in Table 4.3, the coefficients and corresponding t-values are much higher for wealthy households compared to less-wealthy households. I interpret this as showing that household with a high degree of mobility choices (disposable income and car access) are more sensitive to their environment than those with fewer choices. Past work has found similar results; however, research that only controls for these socio-economic factors may miss much of the subtlety. The Chow test confirms that the coefficient for local accessibility is significantly different for most pairs, most interestingly, the two extremes "poor car-less" and "large wealthy" are statistically different than all other groups. More striking however, the pattern is not as clear for regional accessibility where we see no significant difference between "dual earner", "wealthy no kids", and "large low-income" nor for "poor car-less" and "single earner". The expected difference is found between "poor car-less" and most other groups. Examining Tables 4.2 and 4.3, it appears that wealthy large households are both more likely to have larger dispersal of activity space and be more affected by local and regional accessibility factors. Conversely, less affluent households will tend to exhibit smaller activity spaces and be less sensitive to changes in

their environment. These findings point towards the idea that these issues must be handled delicately; as many poorer households are shown to exhibit smaller activity spaces regardless of local or regional accessibility, perhaps this is not necessarily by choice. In addition, local accessibility is not only more strongly correlated with behaviour, it also varies in its magnitude across groups much more so than regional accessibility.

To further illustrate the relationships among accessibility, household types and activity space, Figure 4.5 shows how this generally upward trend is stratified by household type. X-axis shows the regional and local accessibility decile, the Y-axis is the mean LTI of households observed in this category.

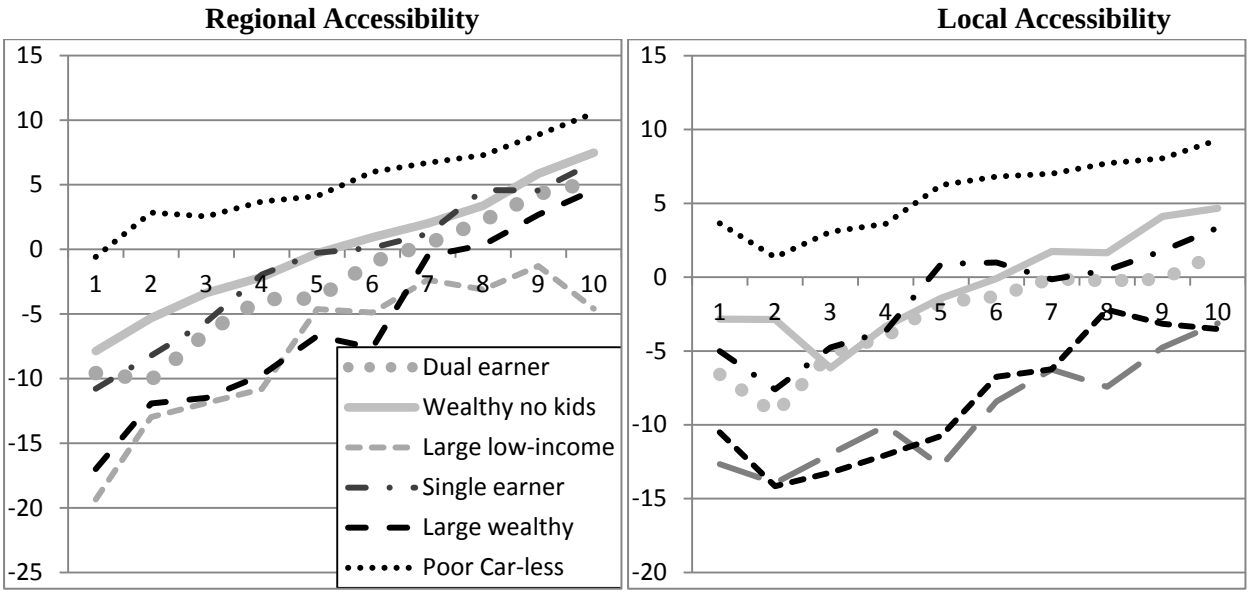


Figure 4.5: The relationship between regional and local accessibility and LTI

These findings support our hypothesis that levels of local and regional accessibility might impact different types of households with varying degrees of magnitude. While we see that there is an upward trend in LTI as levels of accessibility increase, socio-economic factors, reflected in the household typologies, play a key role. In fact, poorer households show higher LTI values than the "wealthy no kids cluster" in all but the highest deciles of accessibility. Interestingly, lower

income large households seem to have much more dispersed patterns than other clusters. The contrast between poor car-less households and these large households could be attributable to the high proportion of students in household; according to the regression results, school trips contribute to a higher dispersal of travel behaviour. In addition, there may be a downward bias in terms of income in households made up of students, who may enjoy parental support or student loans that may not be accounted for in the survey.

4.12 CONCLUSION

This study explored the relationships among local and regional accessibility, household characteristics and travel behaviour. In order to study household travel behaviour, a new measure of the actual activity space is introduced, LTI. The LTI accounts for the compactness and the scale of the activity space as well as the total distance traveled by a household. This measure has shown to be an effective way of measuring the extent to which travel is localized accounting for network structure.

Regional accessibility is found to have a statistically significant effect on the LTI. This suggests that policies favouring regional accessibility to jobs and workers can lead to more compact and sustainable travel patterns. Higher levels of accessibility at the regional levels favours more sustainable outcomes such as higher densities, shorter travel distances and more local, less spatially dispersed travel patterns. Local accessibility measured through the walkscore is found to have a greater impact on LTI compared to regional measures of accessibility. The variation of the explanatory powers of these two measures across household types raises several questions in regards to social equity and exclusion. These measures are shown to have much lower power on the LTI of poor car-less households. This can be explained as poor car-less household travel locally even if they experience low levels of accessibility to jobs and

neighbourhood amenities. On the other hand, local and regional accessibility have a statistically significant effect on “dual earners” and “wealthy with no kids” households leading to more localized travel.

These findings suggest that efforts to encourage local travel behaviour will ultimately depend on the attitudes and preferences of individuals and households. Wealthier households with high car access are seen to be more dispersed and travelling longer distances than poorer households while controlling for number of trips, and, more importantly, local and regional accessibility. This has important implications for both the measurement and understanding of local and regional accessibility factors. Much research, at least implicitly, assumes that most individuals in a region, neighbourhood, or household will respond in a similar manner to elements of accessibility. This research shows that household characteristics explain much of the variation in the localization of travel. For example, even at the highest decile of local accessibility, the large wealthy cluster exhibits a wider dispersal of travel behaviour than the poor car-less cluster at the lowest decile of local accessibility. This would imply that policy-makers should take into account local socio-demographic factors when deciding on land-use solutions to minimizing long-distance trips.

The primary limitation of this research is the use of a single-day travel survey. A multi-day survey, particularly one that includes weekends could add much to the findings presented here. Single-day travel diaries miss many important nuances in household travel behaviour, there is no way to ascertain whether the travel exhibited on a given day is “routine” or out of the ordinary. However, the large sample and consistent results lead us to accept the usefulness of the approach presented here.

The focus of the study is to understand—and make an initial attempt to separate—the effects of household characteristics and both local and regional accessibility on local travel

behaviour. By raising important issues of social equity and justice, it is hoped that this research may direct future research towards these essential elements.

4.13 ACKNOWLEDGMENTS

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CHAPTER 5: VALIDATING WALKABILITY INDICES: HOW DO DIFFERENT HOUSEHOLDS RESPOND TO THE WALKABILITY OF THEIR NEIGHBOURHOOD?

5.1 OVERVIEW OF CHAPTER

This chapter examines the ideas related to neighbourhood-level walkability introduced in Section 1.5. Recent years have seen a continued shift in land use and transportation planning priorities towards issues of neighbourhood walkability. An inviting pedestrian environment with access to commercial, leisure and school destinations is seen as a key component of walkability. Walkability indices have grown in popularity, due in part to their potential to measure qualities of livability. However, it is not clear how well these indices predict actual pedestrian behaviour. Many studies have not been able to adequately analyze the effects of these walkability indices across trip purposes and for households with varying characteristics. This study analyzes 44,266 home-based trips obtained from the 2003 Montréal Origin-Destination survey. Several statistical models are built to examine the correlation of different walkability scores and household travel behaviour while controlling for individual, household and trip characteristics. Further clustering of households allows the calculation of elasticities across household types. Our findings show that the examined walkability indices are highly correlated with walking trips for most non-work trip purposes; however, socio-demographic characteristics also play a key role. Most importantly, the results show that households with more mobility choices are more sensitive to their surroundings than those with less choice. Our findings highlight the fact that a walkability index will not have the same correlation with travel behaviour for all individuals or households. Therefore, solutions to encourage non-walkers to start walking need to vary depending on the socioeconomic characteristics of the neighbourhood.

5.2 INTRODUCTION

Recent years have seen a rise in popularity and use of walkability indices. By measuring both form and content of neighbourhoods, walkability indices are expected to measure the degree to which an area can provide opportunities to walk to various destinations. Many cities and regions include walkability goals in their land use and transportation plans. However, many of these goals are quite general and vague and difficult to quantify.

Walkability indices have been successful in describing the walking environment in many cities. However, due to small samples or lack of data, many previous studies have not been able to adequately analyze how different households with varying mobility needs and financial and time budgets might be affected by the walkability of their neighbourhood. Few studies have compared differing measures of walkability on the same sample. Most studies have used one measure across trip purposes and socio-demographic types.

My hypothesis is that walkability measures are not “one size fits all” and will vary by trip purpose and socio-economic characteristics of residents. In this view, walkability can be understood as a “match” between residents’ desires and expectations for certain types of destinations, their willingness to walk a given distance and the quality of the required path. Neighbourhoods that find this match between built form and residents’ needs will likely have more people walking in them. However, research that focuses solely on built environment and land use characteristics will miss this sense of neighbourhood/individual interaction. Furthermore, the equity implications of walkability are both important and delicate; it is vital to understand the difference between an individual who chooses to walk as a result of living in a “walkable” neighbourhood and someone who, for financial constraints or other reasons, has no choice but to walk in a neighbourhood that may or may not be conducive to walking.

This chapter aims to address two main issues 1) how well do existing walkability indices explain observed walking behaviour? And 2) how do they vary across trip purposes and socio-demographic factors? To address these questions, this chapter commences with a description of various walkability measurements and how they are calculated in this research. Then several statistical models are developed to explore the factors associated with the decision to make a particular trip by walking for shopping and school trips and to compare the various walkability indices that are commonly used in the transportation literature. This is followed by a modelling approach that takes into account socio-economic factors (instead of merely "controlling" for them) examining how different household types might respond to the walkability of their neighbourhood. Finally, policy relevance in Montréal and the wider North American context is presented.

5.3 DATA PREPARATION

As the first objective of this research is to compare measures of walkability at different geographic scales, the initial step is generating the walkability indices. For the purpose of this study I have chosen four commonly used indices in the academic literature to compare. The walkability index developed by Frank, Schmid, et al (2005) is the first index tested in this study. This well-known index has been used at various geographical scales: census divisions, and network buffers around specific households or commercial centers (Cerin et al. 2007; Saelens et al. 2003). I generated this index at 4 scales: 400, 800 and 1200 meter network buffers, as well as at the census tract level. While I hypothesized that the buffer-based approach would perform better, previous research has looked at neighbourhoods and census geography; therefore, I wanted to test this geographical level as well. Due to its ubiquity, this particular walkability index will be referred to as the "walkability index" (WI), in contrast to the approaches described below.

The second measure used was a simplified walk opportunities index that is similar to the measure used by Kuzmyack, Baber, and Savory (2005). Retail information was obtained from the Dun and Bradstreet business database. This was combined with a weighted intersection index. Possible destinations are weighted based on three key variables, distance, size and importance. The importance and desirability of a set of possible destinations was based on previous research (Banerjee and Baer 1984) that ranked residents' views of given destinations. For example, "everyday" destinations such as post offices, pharmacies and food stores rank higher than sports arenas or night clubs. The sum of the weighted intersection z-score and "everyday" retail z-score represents the walk opportunities index. As the walk opportunities index takes into account different types of individual businesses as well as intersection types, it is hypothesized that it will explain more walking behaviour than the WI.

The third measure uses the pedshed method (Porta and Renne 2005), which is simply the area of the pedestrian network buffer over a straight-line buffer of the same distance. In order to generate the network buffers used in the measures, highways and highway entrance ramps were removed from the street centerline files and a GIS network was built. This measure was chosen as it differs from the methods used in the other indices.

For the fourth and final measure of walkability, the research team purchased a database of over 100,000 postal code points from Walkscore for use in the analysis (walkscore.com 2010). In order to link this information to each household, a spatial join was performed in GIS to relate each household to the Walkscore of its postal code of residence. The process uses a simple gravity-based measure to weight nearby locations higher than those more distant.

The indices were chosen to represent a variety of measurements. Two of the indices are well-known and often used in research (walkscore and the WI), the walk opportunities was chosen as it represents a slightly more nuanced approach to either of these two approaches.

Finally, the pedshed was chosen as it offers a highly intuitive way of measuring connectivity that is also quite different than the other measures.

The maps in Figure 5.1 show the scores of the four measures aggregated at the census tract level. All of the measures are standardized using the z-score value for ease of comparison. This allows visualizing the differences between the measures at the census tract level of analysis. The z-score is a unit-less measurement; the lighter areas are much lower than the mean, the darker areas are much higher (in this case, better) while areas shaded in the middle of the spectrum straddle the mean value. This is primarily for illustrative purposes as most of the measures used in the statistical models are at the household level not the census tract level. However, the maps clearly show patterns of the distribution of quality walking environments throughout the region. Interestingly, the four maps are remarkably similar. Only the WI map stands out, this could be due to the index's inclusion of general land use mixing instead of the more specific destination characteristics of the walk opportunity and walkscore measures.

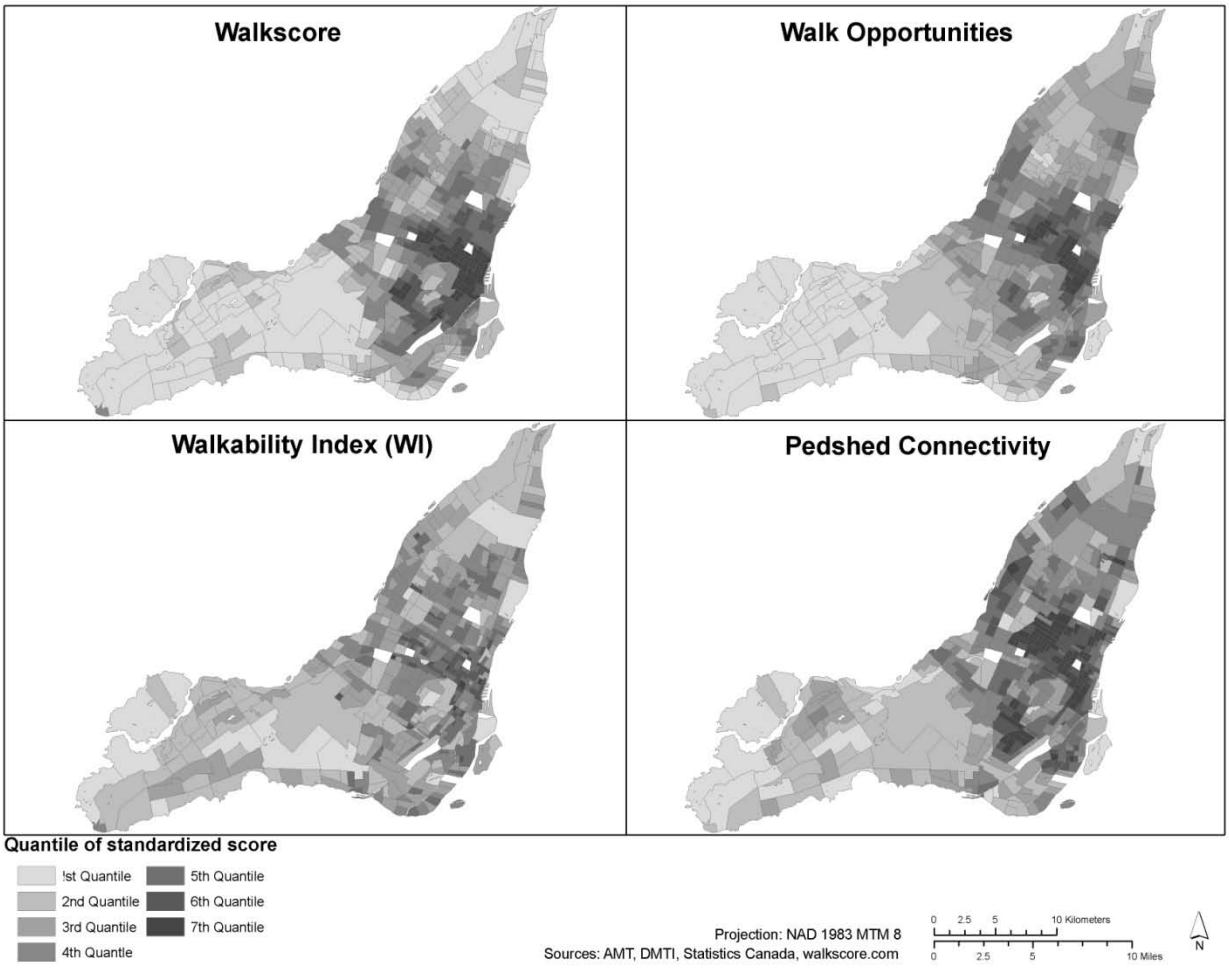

Figure 5.1: Visual comparison of walkability indices

Household level data and travel behaviour characteristics are obtained from the 2003 Montreal Origin-Destination survey (AMT 2003). The O-D survey collects detailed travel behaviour data from 5% of the households residing in the Montréal region. The survey contains disaggregate data on each trip made in the respondent's household on the previous workday. The precise X and Y coordinates of each trip's origin and destination are collected, along with purpose, mode and time of each trip. In addition, several socio-economic characteristics of both the individual and household are recorded, including age, gender, work status, household income, number of household members and length of time at current residence. For the purposes of this

research, a sample of 17,394 households on the island of Montréal was extracted; households with incomplete socio-demographic data were excluded from the analysis. After mapping the home location of each respondent household, the measures of walkability were generated using land use data and street centerline files from DMTI Inc. as well as census tract level demographic data from Statistics Canada. Circular and network buffers are generated around each household using 400, 800 and 1200 meter thresholds. From these households, 44,263 home-based trips were examined. Home based trips were chosen to better isolate walkability factors at the place of residence. Of these, 6,575 of the recorded trips were by foot for all purposes. Non-work trips are the focus of the research due to their likelihood to be more affected by local conditions than work trips.

In the following section the extent to which each walkability index increases the odds of walking to non-work destinations is examined. This section adds to the current state of knowledge by introducing a comparison of the various walkability indices that is not present in the current literature. It is important to note that, while I attempted to replicate the published indices as accurately as possible, studies in other cities or regions (or with different data sources) could, of course, show different results.

5.4 STATISTICAL COMPARISON OF WALKABILITY INDICES

Several discrete choice models were designed and tested. The decision to make a particular home-based trip was made by foot was modeled as a dichotomous variable in a binary logistic model. The independent variables included trip length, age, gender, income, car ownership and a single walkability measure. As I had access to a large sample of trips, I separated the models by trip purpose; each subsample had several thousand observations. This approach takes into account that not all individuals will evaluate a choice the same way; notably, the utility of a

particular mode of transport will vary not only by the time, distance and convenience (or lack thereof), but also by the characteristics of the decision maker (Handy 1996) and the type of trip. Accordingly, nine different statistical models were generated for each trip purpose using a different walkability measure in every run (walkscore, walk opportunities, the WI at four scales and three sizes for the pedshed connectivity measure), while keeping the other variables in the model specification constant. In other words, a different walkability measure was used for each of nine models. The findings from these models for shopping and school trips are reported in Table 5.1 showing the odds ratio associated with the walkability measure as well as the log-likelihood value to explain the model output. Log-likelihood values are used to compare model fit within trip purposes, the higher (closer to zero) value corresponds to better model fit. This value cannot be used to compare model fit amongst trip purposes, however. The base model includes only the control variables for comparison.

Table 5.1: Comparison of models

Shopping		
Index	**OR**	**LL**
Walkscore	2.132	-1276.97
Walk Opportunities	1.713	-1290.92
WI 400 buffer	1.910	-1293.83
WI 800 buffer	1.912	-1294.46
WI 1200 buffer	1.813	-1303.9
WI Census Tract	1.645	-1311.78
Pedshed 800	1.497	-1335.53
Pedshed 400	1.464	-1336.27
Pedshed 1200	1.488	-1337.41
Base	--	-1359.88

School		
Index	**OR**	**LL**
Pedshed 400	1.321	-1469.32
Pedshed 800	1.311	-1470.53
Pedshed 1200	1.243	-1475.32
WI 800 buffer	1.297	-1473.13
WI 1200 buffer	1.104	-1475.49
WI 400 buffer	1.196	-1478.89
Walkscore	1.140	-1480.69
WI Census Tract	1.115	-1482.04
Walk Opportunities	1.113	-1482.03
Base	--	-1484.08

Note: Each walkability measure was inputted into a separate model controlling for age, gender, income, car availability and length of trip. Minimum pseudo R square (McFadden) .418; max= 0.471. Bold indicates p< .01, * p< .05, **p<0.1. "Base" is model with no walkability measure included.

These nine models concentrating on shopping trips used a subsample of 5481 trips and control for age, gender, income, car availability (number of cars in household per licensed driver) and length of trip. Using a subsample of individuals who made home-based shopping trips, as opposed to using all of the observations, ensures that a fair comparison is being made. In this way, the model does not try to understand why a person did or did not make a shopping trip, but rather whether a particular home-based trip, that did in fact occur, was by foot. Furthermore, the approach deliberately excludes trip chains as an individual's decision to shop on her way home from work might have only a tenuous link to the walkability of her home neighbourhood. In addition, issues of work location and time budgets are beyond the scope of this paper.

Each model was consistent with regards to the control variables. Lower household income (defined as household income less than $40,000 is significantly (p<.05) and positively associated with walking trips. Vehicle availability is significantly (p<.001) and negatively associated with

pedestrian behaviour. Finally, age and being female have a respective negative and positive association with walking; however neither variable is statistically significant.

Examining, the results in Table 5.1, we see that Walkscore shows the best model fit. However, the differences amongst the indices are actually surprisingly small. The odds ratio here refers to the odds of a particular trip being by foot for each one-unit increase in the z-score of the given measure. Alternative model specifications, including quartile-based models yielded similar results and are not presented due to space constraints, however, this idea is explored further in the elasticities section. It should be noted that the WI is less data-intensive than the walk opportunities and is therefore perhaps preferable in some cases. Both the walkscore and walk opportunities index measure specific types of commercial and retail development as opposed to the WI that relies on more general land use categories. This could explain why these measures are seen to perform better in the shopping models. In addition, the WI uses an entropy measure of land use that has been criticized in the literature as being a somewhat arbitrary measure of land use mix (Hess, Moudon, and Logsdon 2001). However, another strength of the WI is its malleability to be able to be measured at multiple scales; this is not the case for either walkscore or walk opportunities.

In order to test the factors leading to walking-to-school trips, a subsample of 6,433 home-based school trips was analyzed. This research concentrated on children walking to school and excluded adults (University, continuing education).The results show that the factors influencing school trips differ from shopping. We see that pedshed connectivity measure better explains variance in mode choice for elementary trips than the walkscore, walk opportunities, or the walkability index. This is not entirely surprising, given that these walkability measures examine factors that capture commercial and retail destinations. However, this does have important implications for understanding this important trip purpose. A high walkscore might not translate

to more children walking to school. It is this subtlety that can be easily missed by focusing on only one measure of walkability. The model fit is almost entirely reversed from the shopping analysis. This suggests that these indices should be handled carefully depending on the type of trip being analyzed. One unexplored issue is the fact that the data does not record whether a parent accompanied their children; knowing what factors influence the frequency of unaccompanied school trips could deepen this analysis.

As a way to visualize these relationships, Figure 5.2 plots the percentage of actual shopping or school walking trips made on the y-axis and the decile of each walkability index on the x-axis. For example, in the shopping graph, in the lowest decile of households, as determined by the walkscore index, only 2.8% of all shopping trips are on foot, however, over 50% in the highest decile of the Walkscore are walking trips. This is instructive for several reasons, first the graphs show a clear trend between walkability and behaviour, secondly, the four indices have very similar results, and third, the indices perform differently across trip purposes. While shopping trips seem to be more highly correlated with walkscore values, school trips have alternate findings; not only are different indices associated more strongly with school trips, but the overall fit seems slightly less obvious. For school trips made in locations with the highest decile walkscore or connectivity measures, only 33% are made by foot. The less conclusive findings for elementary school trips could be related to unobserved factors such as safety concerns, traffic levels or parental preferences. These two figures suggest that walkability indices explain the probability of walking for trip purposes quite differently.

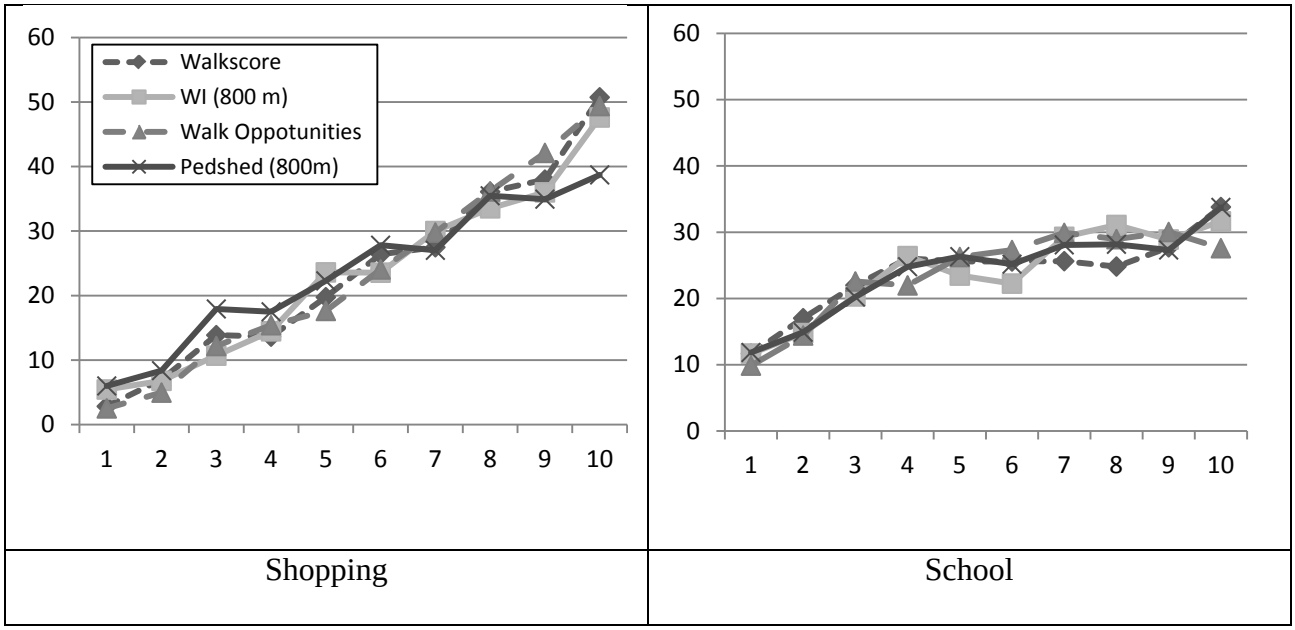

Figure 5.2: Percentage of home based shopping and school trips by deciles of walkscore

5.5 HOUSEHOLD CHARACTERISTICS

In order to understand how these various measures of walkability vary across different household types, a clustering analysis at the household level is performed. My hypothesis was that the degree to which various households react could vary dramatically with household characteristics and mobility needs. The logistic regression models presented above, which control for socio-demographic factors at the individual level, were not able to measure the required nuances. By simply "controlling for" socio-economic factors, researchers can miss important distinctions (Adler et al. 1994). Therefore, a two-step clustering analysis is undertaken; this is followed by generating a new set of statistical models, after which, elasticities are calculated to understand how different households differ in their response to increasing walkability levels in the area surrounding their home location.

5.5.1 Two-step clustering

Two step clustering is a well-known method used when dealing with a large data-set with both categorical and continuous variables (Norusis 2010). The goal of the clustering analysis performed here is to group household into distinct types with the maximum differences amongst groups and minimum variation within each group. A set of household-level variables were included in this analysis. These variables included income, number of people in household in various age categories, employment status, length of residence and vehicle ownership. These variables were chosen to capture factors that would explain preferences and demand for various trips purposes. The last step in the clustering analysis involves an examination, and naming, of each cluster. Figure 5.3 shows the variation from the mean value for each cluster. Income is represented by ranges of $20,000, while all other variables are continuous. The large family cluster, for example, has 2.1 more members – on average, than the overall sample mean, while the wealthy no kids cluster has 0.7 less children and 0.4 more full time employed household members than the overall average.

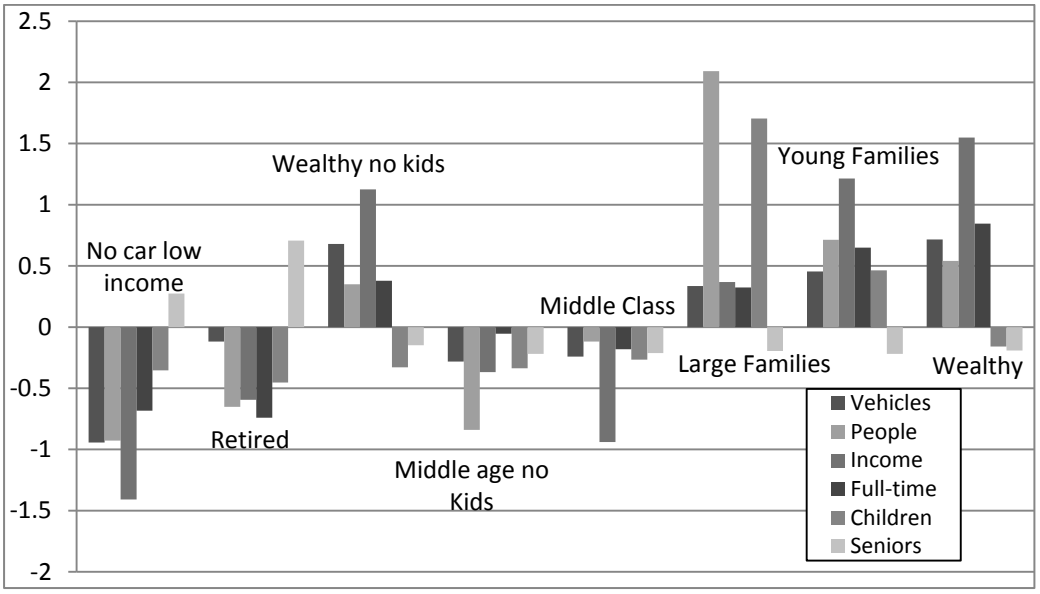

Figure 5.3: Variation of mean cluster values

In order to get a sense of how these clusters differed in their walking rates, a basic frequency analysis was performed based on the percentage of trips in each purpose that were by foot. Figure 5.4 shows, for example, that the "large families" cluster makes 20% more of their school trips on foot compared to the average, whereas "wealthy" households make almost 60% less school trips by walking. As no school trips were recorded in the retired seniors cluster, there are missing values in this category.

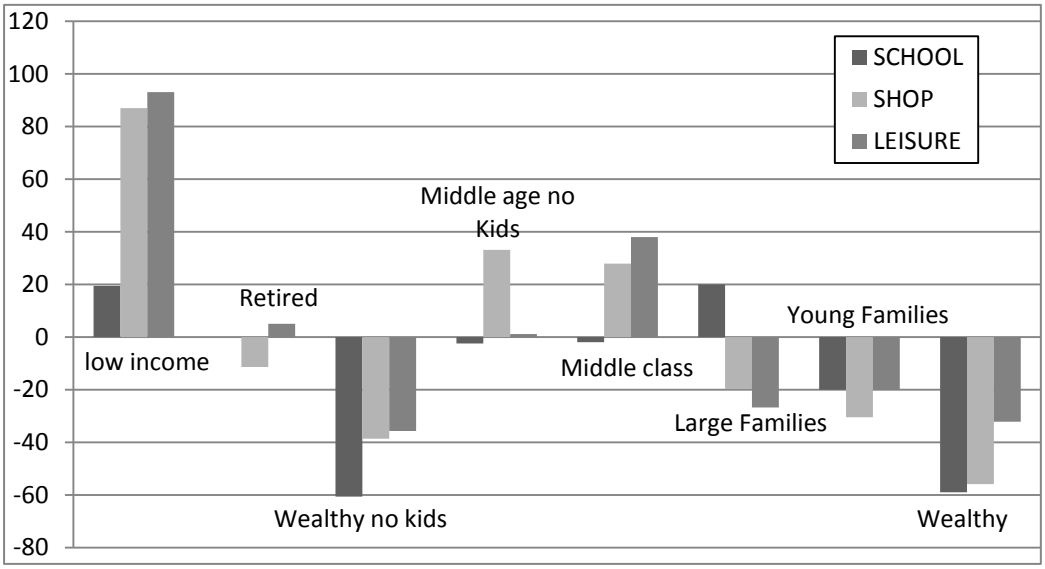

Figure 5.4: Variation from the mean frequency by mode and household type

However, to statistically validate this basic analysis, additional logistic regressions were specified. The decision whether or not to make a home-based shopping trip was modeled as a dichotomous variable in a binary logit model. A different walkability measure was inputted into each model. The definition of the sample depends on the household type identified in the two-step cluster. Based on the earlier findings (Table 5.1), only the Walkscore, WI at the 800 meter buffer, and the walk opportunities index is presented as these performed best for home-based shopping trips. I generated 24 different models with the same model specifications, with a different walkability measure as the independent variable of interest. Table 5.2 shows the odds ratio of the walkability indices, the pseudo R^2 and the sample size information.

Table 5.2: Comparisons of model outputs using samples identified in two-step cluster process

	WI 800 buffer		Walkscore		Opportunities		
Household Type	**OR**	**R^2**	**OR**	**R^2**	**OR**	**R^2**	**N**
No car low income	1.2	0.42	1.11	0.42	1.14	0.42	**638**
Retired	**2.04**	0.44	**2.41**	0.45	**1.81**	0.45	**1,329**
Wealthy no kids	**2.38**	0.40	**2.68**	0.41	**2.57**	0.42	**581**
Single	**1.65**	0.45	**1.93**	0.46	**1.37**	0.45	**732**
Middle Class	1.21	0.47	1.21	0.47	1.17	0.47	**373**
Large Families	1.32*	0.42	**1.62**	0.43	1.37**	0.42	**714**
Young Families	**1.78**	0.43	1.54*	0.42	**1.41**	0.42	**583**
Wealthy	**2.79**	0.51	**3.46**	0.53	**4.22**	0.57	**531**

Note: Each walkability measure was inputted into a separate model controlling for age, gender, and length of trip. The reported pseudo r-square (McFadden) is for the fully specified model. Bold indicates p< .01, * p< .05, **p<0.1.

In the subsample of low income and "middle class" families, the three walkability indices are seen to not be statistically significant in regards to explaining the variation in walking behaviour. However, in wealthy households and households with children the walkability indices play a major role as judged by both the odds ratio and p values. This supports the hypothesis that households differ in their response to the walkability levels in deciding to make a home-based shopping trip by foot or not. The differences in the response to walkability by household type will be explored in greater detail in the next section.

In general, the control variables performed as expected; however, some interesting findings were discovered in regards to gender. In both the large family cluster and young family cluster, being female is significantly ($p<0.01$) and positively associated with walking (OR=2.03 and 1.79 respectively). Wealthy families, however, show a significant and negative correlation ($p< .10$; OR=.48). In the other clusters gender is not significant.

5.6 ELASTICITIES

In order to simplify the findings from the above models a sensitivity analysis was performed to calculate the likelihood that a home-based shopping trip would be by foot. The goal was to determine the effect of moving to a higher decile in the walkability index for each of the identified household clusters. The mean values for age and trip length were inputted, the 'base case" for gender is female. Other socio-demographic data at the household level, such as income and vehicle ownership was not inputted as it is already imbedded in the clusters. The model predicts the likelihood that a 36 year female will make a home-based shopping trip at each decile of the Walkscore measure of walkability.

Of interest is the relative sensitivity of each group to changes in its surroundings. Examining Table 5.3, we see that a 36 year old female residing in a household in the low income cluster has a 72% chance of walking for a shopping trip of 734 meters (the average length of all home-based walking shop trips) in an area with poor walkability. This is contrasted by the likelihood of 3.3% in the wealthy cluster. However, what is arguably more instructive is the fact that the increase in likelihood from the lowest-to-highest decile varies greatly between groups. For the wealthy no kids cluster, the increase is almost fivefold compared to a mere 7.5% in the lower income cluster. Table 5.3 shows the probabilities at the first, fifth and tenth deciles. This analysis was also run for the other indices resulting in similar findings. This has implications for equity issues as people without a choice might be walking in areas with a low quality walking environment. In fact, the results suggest that a higher percentage of trips will be by foot in an area with a low-quality walking environment with a poor population than in the highest quality environment with predominantly wealthy residents. Given identical urban form factors a neighbourhood of predominantly poor car-less households and another with wealthy households

would show drastically different behaviour according to the model results. This also suggests the importance of accurately assessing the goals of pedestrian improvements in a neighbourhood as the results could vary by the population characteristics of the area.

Table 5.3: Sensitivity analysis

	Low income	Retired	Wealthy no kids	Middle age no Kids	Middle Class	Large Families	Young Families	Wealthy Families
First Decile	72.1%	36.1%	12.6%	21.4%	30.6%	29.7%	18.5%	3.3%
Fifth Decile	74.8%	65.2%	38.4%	43.6%	43.6%	49.7%	35.8%	16.2%
Tenth Decile	78.0%	89.4%	79.5%	74.1%	61.0%	74.1%	63.1%	63.2%

Elasticities calculated at the mean (average length shopping trip)

5.7 CONCLUSION

This study examined several existing walkability measures and indices at multiple geographic scales in order to understand how these measures are related to actual observed travel behaviour. All examined walkability indices and individual measures perform quite well in describing pedestrian behaviour on the island of Montréal. The highest level of correlation can be seen with home-based shopping trips. Our findings suggest that the online Walkscore index explains as much, if not more, of the variance in walking trips to shopping than other walkability indices used in the literature. However, it is important to note that the difference in the explanatory power amongst the examined indices is quite negligible. The simple pedshed (Porta and Renne 2005) method was found to be the best walkability index when it comes to explaining the odds of walking to school. Accordingly, different walkability indices should be used when trying to understand the level to which the built environment encourages walking to various destinations.

Clear patterns were seen in both frequencies of trips across various household types and in how these households were affected by their environment. Wealthy, car owning households are

much more sensitive to elements of walkability compared to retired or low-income households. While it might be somewhat obvious that households without a car are more likely to walk, our findings suggest that improvements in walkability indicators of a given neighbourhood will have drastically varying results in modal shift depending on the residents characteristics. Moreover, while wealthier households might be more responsive to improvements in the walkability of their neighbourhood, our results (Table 5.3) suggest that the number of people walking in more affluent neighbourhoods might never equal the number of people walking in neighbourhoods made up of individuals with less income and low car access, regardless of the quality of the pedestrian environment. Recent planning initiatives in the City of Montréal are concerned with ameliorating the pedestrian realm as well as prioritizing the development of neighbourhoods that offer a mix of residences, shops and leisure destinations within close proximity of one another (Montreal 2007). Yet it is clear from this research that understanding more than just land-use and street connectivity factors is required if the goal is to increase the livability of streets that can lead to increased presence of people on the streets. These findings highlight the importance of differentiating the walkability intervention at the neighbourhood scale depending on the type of residents in the neighbourhood, their current travel behaviour, and not only the current built environment.

CHAPTER SIX: SUMMARY, DISCUSSION, AND CONCLUSION

6.1 SUMMARY OF CHAPTERS

The preceding chapters examine how issues of equity and social justice are being addressed in current transportation planning and travel behaviour research. The chapters are arranged in order of scale—from large-scale policy comparison across North America, to local policy and infrastructure in Montreal, to how households and individuals benefit and respond to infrastructure changes and variance in neighbourhood context. This research had four primary research questions:

- How do municipalities and transit agencies balance economic, social, and environmental goals and objectives in transportation plans?
- How do these decisions affect outcomes, particularly with regards to social equity?
- How can current methods of measuring and understanding active transportation and neighbourhood walkability be improved to better capture these wide ranging objectives?
- How can these findings be used to improve decision-making in the future?

These questions were answered using mixed methods of research design. These included content analysis and several forms of quantitative research. The first three of these questions were addressed in the preceding chapters; this chapter will first summarize these findings and then address the final question above concerning policy lessons that could be taken from this research. The chapter will finish with some thoughts on future research.

The overarching finding of this research is that much work is needed to ensure that issues of social justice and equity are adequately accounted for in the decision-making process. Most

planning contexts place a much higher emphasis on environmental and economic benefits of transportation networks than on equity impacts. While the importance of environmental concerns should not be underestimated, many of the issues raised in this document point toward the fact that a focus on narrowly-defined environmental goals may in fact exacerbate problems for those with low income and few travel choices. The methodological advances presented here could be an important step toward a more nuanced view of how the determinants of travel vary by socio-economic factors. Transportation planning can address a wide range of societal goals apart from movement of people and goods, however, current ways of presenting and measuring these benefits may be "part of the problem".

Chapter 2 presents compelling evidence from 18 North American transportation planning documents that issues of social equity are not being adequately defined, measured, or presented in many regions. I argue that this may be connected to issues of problem definition. If decision-makers understand their major problem to be congestion or pollution, for example, implications for social and environmental justice may be compromised. The chapter offers some ideas for inclusive performance measures that may better capture more subtle differences among projects and outcomes.

The third chapter takes these concerns further by modeling network changes proposed in the Montreal Master Plan and determining who stands to benefit (in job accessibility and travel time savings) from this new infrastructure. The focus of the study is on neighbourhoods with a high level of social disadvantage. Interestingly, the study finds that the benefits of the plan are relatively equitable (no income group is under or over represented in the potential benefits), however, this may be in part to a "spillover" effect whereby a commuter rail line and a downtown tram line originally conceived to serve suburban commuters and tourists respectively also passes through low income areas that may benefit from its presence. This study offers a strong and

relatively-easily replicable methodology for measuring the degree to which infrastructure changes serve those most in need.

Chapter 4 makes two important contributions. It introduces a new way to measure household activity space that takes into account both the spatial dispersal of activity locations and the total distance traveled. Furthermore, it explores how this measure is related to local and regional accessibility measures as well as household-level socio-economic factors. However, the overall takeaway lesson from this study is the explicit acknowledgement that many travel behaviours seen as "good" or desirable from an environmental or energy-saving perspective may potentially have quite negative underlying motivations or consequences. The findings show that the effect that the availability of local amenities has on household travel behaviour varies greatly by socio-economic factors. Wealthier car-owning households, for example, are more likely to display large dispersed travel patterns regardless of local and regional accessibility measures. On the other hand, households with more financial means and mobility choices are much more responsive to the availability of local amenities; these factors explain much more of the variance in behaviour for this subgroup.

The final empirical work explores an area that has garnered much attention in the past few decades with a fresh perspective. Chapter 5 examines how the response to neighbourhood-level walkability varies by trip purpose and, more interestingly, by individual and household-level socio-economic factors. While most studies—implicitly or explicitly—assume that the response to built environment factors will be uniform for most people, this study presents strong evidence that this is not the case. The study has two important implications for wider social justice concerns. People with less income and limited access to vehicles are more likely to walk in neighbourhoods with low objectively-measured walkability than rich people are in areas of high walkability. Furthermore, the variance in behaviour is explained much more for wealthier

households. This highlights the importance of policy clarity around walkability goals. Is a proposed intervention meant to increase walking or augment the enjoyment, safety, and convenience of those already walking? How planners respond to this question can have important implications. However, the key point of this study in the context of this thesis is that it provides empirical evidence of many of the issues explored in Chapter 2. As the response varies so greatly by socio-economic factors, performance measures based solely on mode split or built form targets or indices do not capture vital issues of social justice.

This research points out the need to improve decision-making by improving measurement tools to include explicit social justice factors. Planners should strive to find indicators that encompass elements of accessibility stratified by group. These could include age, income, and racial immigrant categories. Furthermore, understanding temporal changes of how benefits vary by groups would be an important improvement to current evaluation methods. Chapters 3 and 4 of this dissertation show how some of these elements can be measured using readily-available data collected by most large cities and regional transportation authorities. These will be highlighted in the policy implications section below.

6.2 THEORETICAL AND METHODOLOGICAL CONTRIBUTIONS

Much research in recent years has focused on relatively easily-measured aspects of sustainability in a transportation planning context. A major objective of this research was to uncover more subtlety and nuance by understanding how plans balance, prioritize and trade-off environmental and social equity goals. This approach allows for an important distinction to be made between transportation goals that prioritize greenhouse gas reduction initiatives and goals that aim to address issues of justice.

A major contribution of this research is challenging the widely-held belief that individuals perceive and respond to elements of the built environment in a relatively consistent manner. The use of stratified regressions captured much variance in this response. It is hoped that the techniques and methods described here could be used further to better capture these difficult to measure elements. Traditional utility-maximizing frameworks, for example, may benefit greatly from a more explicit recognition that individual beliefs, values, preconceptions, and past experiences play an absolutely central role in travel behaviour. These issues are most often only included in the error term in regression analysis. While I acknowledge the difficulty of capturing these psychological factors in travel surveys, I would encourage researchers to explore ways in which these elements can be better integrated into travel behaviour research. The vast majority of travel behaviour research "controls for" personal characteristics, a key aspect of the research presented herein is the shift of focus to these key variables. In other words, instead of controlling for income, for example, and reporting the effect of land use mix on a travel outcome, this research makes the socio-economic characteristics of a respondent the key variable.

Mixed methods were used to explore the research questions. These included quantitative as well as qualitative methods. The scale and unit of analysis varied greatly throughout the chapters. Chapter 2 looked at transportation planning documents from 18 large North American cities. Chapter 3 examined one metropolitan region (with individual census tracts as the unit of analysis) to understand the benefits of proposed transit infrastructure. Chapter 4 used household travel behaviour as the unit of analysis with two scales of accessibility (local and regional). Chapter 5 looked at individual home-based trips with individuals nested in households.

6.3 POLICY IMPLICATIONS

Recurrent throughout the work is the notion that many current goals, objectives, and performance measure may miss vital implications of social justice. This is also true in many research contexts that fail to differentiate between travel behaviour that is motivated by constraints with that which is motivated and supported by appropriate, fast, and comfortable transit options and an inviting pedestrian realm for example. The research in Chapter 2 leads to the following recommendations concerning the use of performance measures and indicators to better capture elements of social justice.:

- Changes in accessibility over time: are certain groups given more/less access to desired destinations;
- Difference between car and public transit in journey time;
- Difference between top and bottom income quintile in % share of household expenditure on transport;
- Difference between car users and NMV users in deaths and injuries;
- Mode share: are certain groups over-represented on certain modes?; and
- Difference between top and bottom income quintile in journey time.

These indicators capture elements of social justice in an easily-understood manner. This research explores how some of these indicators can be measured and analyzed using data and skills that should be available in most governments or planning departments.

6.4 FURTHER RESEARCH

The research presented in this dissertation offer fertile ground for further expansion into areas not directly covered by the research questions. This will be elaborated in this section. The plan evaluation chapter examined only large North American cities; the geographic scope could be expanded to explore how regions in different areas balance these priorities. The rate of infrastructure expansion continues to grow internationally, particularly in countries such as India and China. Understanding how economic growth goals are balanced with social equity considerations is of paramount importance as these countries embark on costly investments to improve and expand transportation systems.

Similarly, most of the empirical work presented here was in Montreal, Canada. This city has a higher than average use of active modes and public transit as well as a unique geography and climate. Much could be learned from taking a similar approach in other cities. More importantly, the research presented in Chapter 4 and 5 could benefit greatly from more in-depth qualitative interviews or survey methods that explore more explicitly how individual and households make travel decisions. This could investigate, among other issues, whether respondents are satisfied with their observed travel and options, how preferences and desires play into their decision-making processes, whether there are destinations or areas of the city that they would like to visit more regularly but do not due to constraints. These constraints could be fear, lack of knowledge of other neighbourhoods, lack of financial means of using transit or owning a car, or a disability for example. Future survey design could benefit from collecting data on these issues and perceptions. Additionally, recent work has been able to take advantage of “real-time” and crowd-sourced data via cell phones or GPS devices to get a better sense of where exactly trips are taking place. Lastly, it is important to acknowledge that residential “self-selection” was

not fully accounted for in the studies concerning travel behaviour. Residential self-selection refers to the fact that people make residential choices at least in part to maximize the match between desired travel behaviour and neighbourhood characteristics. That is, people who prefer to walk, take transit, or drive will locate in areas that allow them to do so. Future work will take into account more detailed information concerning residential choices and past travel behaviour which can help to separate effects of accessibility and the built environment and travel preferences.

6.5 CONCLUSION

Planners, policy makers and transportation engineers have multiple goals to strive toward and multiple stakeholders to appease. However, ensuring that benefits of transportation systems are fairly distributed should surely be at the top of the list. The work presented here helps to bring these issues to the forefront though a series of qualitative and quantitative studies.

Balancing often-conflicting goals and priorities is not an easy or straight-forward task. However, for planners and policy-makers to begin to address the wider societal benefits that transportation systems can provide, a deeper understanding of who benefits and pays for transportation externalities is absolutely necessary.

On a more philosophical level, I would recommend that transportation planners continue to explore and rethink what role transportation systems play in society. How this role is conceptualized by decision makers may play a role in how elements of social justice and other, oftentimes “intangible”, goals can be incorporated into policy. Transportation decisions, particularly road and rail infrastructure, have lasting long-term effects not just on the growth and form of urban areas, but on who benefits and suffers, what neighbourhoods are connected and what neighbourhoods are isolated and torn apart. In short, these decisions impact people, they

impact neighbourhoods. While road capacity and efficiency are obviously important elements that will always play a major role in transportation planning, this thesis argues that thinking of the bigger picture could result in better policy outcomes that could stand to benefit more people for generations. Asking the “right” questions and using the most meaningful indicators is a step in the right direction to ensure that the benefits of transport systems are equitably distributed.

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