THE SOCIAL COSTS OF AUTOMOBILITY

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By

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ABSTRACT

The automobile is truly the most dominant mode of transport in Canada; a car is used by nearly 75% of the Canadian adult population each day. Under the auspices of sustainable development and practices, the impacts of automobile driving and its associated land-uses need be investigated using a triple bottom-line approach. This necessitates an understanding of the associated economic, environmental and social costs. Whereas much research attention has been drawn to external economic and environmental costs, the quantification of social costs, especially those related to social interaction and activity participation, has been far less studied. Despite calls from sociologists warning of the role of automobility in diminishing levels of social interaction, community cohesion, and social inclusion, there has been no response from the research community in the form of empirical investigation. The three studies comprising this dissertation seek to rectify the current state of neglect and fill this gap.

The modelling efforts in this dissertation lead to the discovery of a complex, nonlinear, and heterogeneous relationship between automobile use and social participation. For many individuals, particularly those who are not traditionally constrained by mobility and time limitations, automobile use is found to limit the likelihood of participation in a slew of social, discretionary, and out-of-home activities. Moreover, non-drivers who still participate in a spatially

dispersed lifestyle designed for automobility are at risk of exclusion from various forms of activities.

The research findings make significant contributions to the study of automobility, the measurement of socially sustainability transportation systems, and the role of transport in social exclusion. The findings also have broader implications for cities in terms of creating competitive social environments in a highly mobile and well-informed labour market, fostering equity between social groups, and promoting the participation in activities with positive social outcomes.

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The accomplishment of successfully researching, writing and defending this PhD dissertation will forever be recognized as the result of my labour. It thus inherently, and unfairly, ignores the contributions, both professional and personal, made by those guiding, supporting, and surrounding me throughout the process. I would like to thank all those who made this work possible, pleasurable, and not least, memorable.

Antonio, your contribution to my education, research, and professional development as an academic has been immense. At some point in my first year working with you, you recognized my research potential and made it clear to me that you planned on working me like a dog, but also promised great success and outstanding research results as a reward. Well, you were certainly true to your words. You opened my eyes to the importance of this research agenda, pushed me at all times to carry each research effort through to publication, sharpened my argumentation skills, and found the resources to send me around the world to increase my professional profile. For all of this, I sincerely thank you.

Darren and Pavlos, as the members of my supervisorial committee, your guidance and encouragement was confidence building. Your trust in my abilities implicitly reassured me to progress through the various stages of the PhD program. As course instructors, you were instrumental in challenging me to reach my potential and inspired me to immerse myself in the transportation, land-use, and activity analysis literature.

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Throughout the four years I spent in the department, I was privileged to have associated with a revolving cast of graduate students that formed the base of my personal and collegiate life in Hamilton. Dave, Justin, Antoine, Gloria, Kostas, the CSpA contingent, and all my other friends and associates from the department, thank you for the interesting conversations and wonderful distractions from the hard work.

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PREFACE

This dissertation can be read as a complete and coherent presentation of the research conducted in fulfillment of the Ph.D. requirements. The three middle chapters however were originally prepared as stand-alone articles for publication in peer-reviewed journals. As a result, there exists a slight overlap between the contents of the chapters, particularly in their introductions, literature reviews and descriptions of data sources. The first chapter of the thesis serves as an introduction to the broader research area and the research objectives of each of the three substantive papers are put forward. The fifth chapter contains a thorough discussion of the conclusions drawn from the work, how the work contributes to several broader bodies of literature, and the policy relevance of the findings. It is not a regurgitation and summary of the research findings.

The reader will notice that my supervisor, Dr. Antonio Páez, is co-author on all three of the papers. His contributions included guidance on research ideas and literary resources, critical appraisal of manuscripts, and editorial reviews. The co-authors on the third paper were co-investigators on a Human Resources and Social Development Canada funded research contract, and thus are included as authors by right. Their contribution to this particular piece of work however was limited to editorial review. As primary author of all the papers, I performed all of the substantial research activities including the literature review, data preparation, statistical analysis, model interpretation, and writing. The research papers included in the dissertation are as follows:

Chapter 2:

Farber, S., Páez, A. (2010). Running to stay in place: the time use implications of automobile oriented land-use and travel. *Journal of Transport Geography* (Submitted March 2010).

Chapter 3:

Farber, S., Páez, A. (2009). My car, my friends and me: a preliminary analysis of automobility and social activity participation. *Journal of Transport Geography, 17*(3), 216-225.

Chapter 4:

Farber, S., Páez, A., Mercado, R., Roorda, M., & Morency, C. (2010). A time-use investigation of shopping participation in three Canadian cities: Is there evidence of social exclusion? *Transportation* (In Press).

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1 Introduction

At the 2008 annual meeting of the Association of American Geographers, in a special session devoted to his life and career, noted regional scientist Manfred Fischer, prognosticated that the most meaningful and interesting research in the social sciences will occur at the overlapping boundaries between its disparate sub-disciplines. Like so many academic advancements in the past that rely on new applications of existing theories and methods, this dissertation draws upon and combines theoretical constructs and analytical methods from regional science, transport geography, sociology, and travel behaviour, to solidify our understanding of one of the most salient social challenges of our time: the supposed emaciation of the public sphere and the erosion of social capital wrought by the reliance of our urban regions on the automobile (Putnam, 2000; Sheller & Urry, 2000).

This research assesses, decomposes, and quantifies how automobile use influences our ability to perform essential daily activities. Conventional wisdom dictates that the influence is positive for drivers and negative for those lacking automobile access. For drivers however, the modern-era “freedom of the road” ethos has been challenged by stifling congestion and the need to travel between sparsely distributed activity locations; those without access to private vehicles fare even worse, left to cope with automobile-oriented urban spaces using inadequate public transit systems. In both cases, the social implications of automobility, social exclusion and diminished levels of social interaction, are thought to be significant but remain largely unsubstantiated by empirical evidence. This research contributes by substantiating, using traditional and state-of-the-art approaches, current debates concerning the social implications of our insatiable appetite for private mobility.

1.1 Background

Forty years after his ground-breaking address to the European Congress of the Regional Science Association, Hägerstrand's manifesto, *What about People in Regional Science?*, remains a pillar of regional thinking and philosophy (Hägerstrand, 1970). The ideas laid out in this work helped to situate regional activity within the human contextual environment, namely that of time and space, and helped to create the groundwork for the quantitative revolution in geography.

A measure of the ongoing relevance of Hägerstrand's work is the power of his time-space paradigm to illuminate many salient problems in the social sciences. Notably, this work provides the framework that inspires and informs state-of-the-art disaggregate quantitative research concerning human activities and time-space behaviour in the regional sciences[1]. Continued interest in time-space notions is better understood within the context of developmental trends that bring time and space to the forefront of our efforts to comprehend human activities. In the decades since the principles of time-geography were laid out by Hägerstrand's breakthrough work, urban regions around the world have experienced

[1] Indeed, according to the ISI Web of Knowledge, Hägerstrand's seminal publication in 1970 received 26 citations in 2007, 38 in 2008, and 47 in 2009; evidently, time-geographic methods remain at the cutting edge of today's research frontier.

unprecedented and unabated spatial expansion that has created urban, suburban, and even exurban environments of ever more scattered opportunities. These forms of spatial development have been accompanied, or rather facilitated and sustained, by a growth in automobile ownership and usage. Thus, modern life is characterized, to a degree never before seen in history, by spatially dispersed opportunities that can be reached mainly, or in some cases exclusively, by means of private transportation. Vehicle ownership, far from being a luxury, has now become a necessity – and one that seems to impose a previously unremarked cost, as people find themselves spending more time in their vehicles, often on congested roads, traveling between far flung destinations to accomplish the most essential activities of daily life.

The relevance of vehicle ownership for positive employment outcomes is well documented (Raphael & Rice, 2002; Ong, 2002; Gurley & Bruce, 2005). However, despite the welcome and often essential enhancement to personal mobility, increasingly researchers are concerned by the paradoxical effect of automobile-related *hypermobility* on social exclusion and declining levels of social interaction.

Concurrently, there have been substantive efforts to demonstrate the negative effects of accessibility deprivation, including an increased risk of social exclusion, that is, the inability to participate in the normatively defined usual activities of society.

At a theoretical and conceptual level, both aspects of this problem have been extensively discussed (Sheller & Urry, 2000; e.g. Church, Frost, & Sullivan, 2000). Despite this however, there is a lack of empirical studies on this subject. Using the activity analysis paradigm of transportation research, firmly rooted in Hägerstrand's time-geography framework, the objective of this dissertation is to fill this knowledge gap by investigating the social costs of automobility.

1.2 Chapter Objectives and Contents

This research aims to investigate costs originating with the system of automobility and accrued to members of society. The social benefit of mobility afforded to drivers, being able to travel long distances to activity locations, is posited to be associated with the yet unmeasured costs of social exclusion, isolation, and eroded social capital. In principle, these social costs can be experienced by both those who drive, in the form of reduced social interaction, and those who do not, by means of transport-related exclusion. At the onset of this dissertation, neither phenomenon has received empirical proofing. This research strives to correct this by providing testimony to these claims. Measuring, modelling, and quantifying how drivers and non-drivers allocate their time to transportation and other daily activities is seen as the key to understanding transport related exclusion and a decline in social interaction.

In the first substantive paper (Chapter 2), a theoretical rationale for why automobility may limit participation in discretionary and social activities is put forward. The argument is illustrated with time-geography constructs, and several models of urban development and mobility are compared with time-space metrics such as potential path areas and time-space prisms. Following this, time-use data drawn from a sample of Canadians living within metropolitan areas is used to substantiate the theoretical claims. The empirical work confirms the hypothesis by showing that those living non-automobile oriented lives, by living locally and travelling by active or public transport modes, on average have higher levels of participation in out-of-home discretionary activities than drivers. Furthermore, the data-analysis identifies a trend over the past 13 years of declining levels of social interaction and participation in discretionary out-of-home activities, and a corresponding increase in the amount of travel devoted to each journey.

The third chapter expands on the themes of the second, first by reviewing the literature on social interaction and then in a modelling exercise whereby automobile reliant survey respondents are compared to the rest of the sample for evidence of limited social activity participation. The models estimate the influence of automobile-reliance on both participation and duration, with the effect being far more pronounced on the former. The negative effect of automobile reliance is shown to exist for residents of urban and suburban contexts of the physical environment, highlighting the importance of studying daily mobility patterns, not just urban form, when investigating the relationship between the built-environment and activity participation.

Whereas the second and third chapters deal primarily with social and discretionary activity participation, the objective of the fourth chapter is to determine whether or not the auto-oriented transportation system acts to inhibit or enable participation in normal daily activities. Shopping participation, due to the activity's vital role in subsistence as well as leisure, is used as a cursory indicator of social inclusion, and a three-stage least squares model is used to identify the relationship between transportation access, mobility, and shopping outcomes for three populations at risk of exclusion: the elderly, lone-parents, and low-income households.

Finally, in the fifth chapter, the research contributions of the dissertation are summarized into three main themes: automobility, socially sustainable transportation, and social exclusion. Following this, the broader implications of the research findings are discussed from a policy perspective, and directions for future research are put forward.

Each of the substantive chapters in this dissertation (Chapters 2-4) contains a thorough literature and contextual review that quite succinctly prepares the reader for the ensuing analysis. A substantial literature review for the entire dissertation is therefore omitted from this introduction in order to avoid undue repetition. Furthermore, the conclusions in Chapter 5 are focussed on illustrating the importance of this research to a selection of pertinent broader theoretical frameworks. Thus if the reader pleases, a brief scan of the conclusions chapter before continuing would provide a glimpse of the broader context of which this research is a part.

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2 Running to stay in place: the time-use implications of automobile oriented land-use and travel

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2.1 Introduction

Land-use and transportation systems have a profound impact on the nature of individual activity patterns in time and space. On the one hand, there is the spatial separation between place of residence, work, school, public spaces, stores, etc. On the other, there is the ability of individuals to move about their environment to reach distant places. In turn, the relationship between the spatial pattern of activity locales and the mobility of individuals governs accessibility, the potential to reach opportunities.

In historical terms, land-use and transportation systems have dramatically changed life in cities. The single most influential factor affecting individual mobility in many societies during the twentieth century was without doubt widespread access to private means of transportation. Urban mobility in Canada, as an example, is dominated by daily automobile use, with 74% of adults travelling by car each day. Conventional wisdom has it that automobility, by greatly enhancing the natural limitations of human mobility, confers substantial accessibility benefits (Handy, 2006), for instance, access to jobs (Fol, Dupuy, & Coutard, 2007), leisure (Hjorthol & Fyhri, 2009), food outlets (Coveney and

O'Dwyer, 2009; Páez et al., 2010), and many other types of activities. Some of these gains, however, can potentially be negated by the kind of sprawling, low-density development that automobility has enabled and even encouraged in many urban areas. Sprawling development has led to an increased separation between activity locales, with a consequent increase in the distances that need to be overcome to reach activities. It has been suggested that cars in this setting have become a necessity to maintain even minimal levels of accessibility (Páez, Mercado, Farber, Morency, & Roorda, 2009, p. 118). Traffic congestion, an increasingly common experience in many urban areas, can further erode any accessibility gains accrued by the use of private cars by reducing travel speeds and therefore the distance that can be covered with a given time budget.

The often deleterious impacts of car use on the environment, human health, and the economy have been carefully researched. In addition to these dimensions of automobility, scholars have recently folded the issue of social sustainability of our auto-dependent regions into the discussion (Boschmann & Kwan, 2008), with the warning that automobile use might be responsible for a number of social ills (Lucas, 2004). For example, research published across the social sciences describes the privatization of space within personal vehicles, the atomization and fragmentation of social life, and the decline of community cohesion and social capital as a result of suburbia and automobile-dependent lifestyles (Larsen et al., 2006; Putnam, 2000; Urry, 2002). Despite the importance of these claims, most of this work has remained conceptual and, unlike research on congestion and the environment, relatively limited quantitative empirical evidence to support these hypotheses exists. There exists a tradition of investigating the links between geography, urban form and social contact in the literature, but the mechanism through which automobile-use affects higher-order social outcomes such as cohesion and capital remains unidentified (Forrest and Kearns, 2001; Grannis, 2009).

Theoretically, automobility could affect social well-being intermediately by modifying time-use and activity participation patterns. It is generally agreed that participation in an activity is desirable only if the utility gained from doing so exceeds the disutility associated with travel and the opportunity cost of missed participation in a different activity during that time (Miller, 1999). Within this context, it is possible to envision a hierarchy of activities, each with competing demands for consumption of time and space. Some activities, by having more obvious opportunity costs (e.g. employment) may trump other activities that have a less evident, but nonetheless important cost at a different level (e.g. meeting with friends). Given the unalterable nature of time budgets (there are only twenty four hours in the day), it is possible that competing demands may operate against participation in activities of a more social character that do not satisfy immediate utilitarian goals. Furthermore, social activity participation may impose more difficult conditions as these activities often require coupling constraints with activity partners.

The objective of this paper is to investigate the implications of automobility for spatio-temporal individual behavior and activity participation. In particular, in this paper we hypothesize that dispersion of activities facilitated by auto-oriented development, and traffic congestion caused by mass motorization, affect spatial and time-use behaviours in a way that tends to constrain the ability of individuals to participate in social activities. This idea is supported conceptually by making reference to the principles of time-geography (Hägerstrand, 1970), and is empirically examined by means of an extensive investigation of time-use patterns of the Canadian population using the Canadian General Social Surveys on time use. In the first two parts of the empirical exercise, patterns of time-use and travel are analyzed descriptively. Following this, the relationship between participation in a wide array of activities and time spent commuting to and from work is investigated with a sensitivity analysis. The paper ends with a summary of results, and a discussion of future research directions.

2.2 Theoretical Development

2.2.1 Time-Geography

Time-geography is the analysis of people's activities in space and time (Hägerstrand, 1970). Transportation demand, from this perspective, is considered to be derived from the participation in activities at disjoint locations in space. These activities can be mandatory, such as paid-work and child-care, or discretionary, such as watching a film or attending a dinner-party. Invoking Maslow's theory of human motivation (Maslow, 1943), people are thought to participate first in activities that help to secure physiological needs, for example by working to produce income, before securing love and belonging needs, for instance by meeting a friend for dinner. The hierarchy ensures that activities geared towards meeting more pressing needs are more likely to be performed despite the costs of participation. Thus travel-time, a cost associated with participation in an activity, is less likely to dissuade people from participating in mandatory activities than discretionary ones. One illustrative manifestation of this axiom is that people travel much further on a daily basis to get to work, than they do for any other regular activity (see Table 2-8 below).

There are several time-geography concepts that must be defined at this point, as they are needed to understand the role of the automobile in constraining activity participation (see Miller, 2004 for a complete review of time-geography concepts). Any activity location, L_i, in space and time can be represented by the triplet (x_i,y_i,t_i), where the first two terms correspond to geographic coordinates, and the third term is an instant in time. A *space-time path* is the series of triplets describing the spatial location of an individual from one instant to the next.

When considering space-time paths of individuals, it is quite plausible to imagine that a large portion of each day is devoted to mandatory activities at fixed locations in space in time. For example, a worker with young children at home spends eight hours each day at the workplace, and several hours at home in the morning and evening participating in child-care activities. These activities are called *anchors* as they serve to glue individuals to specific locations in time and space. Discretionary activities higher up in Maslow's pyramid of needs, can be slotted into a daily schedule when there is enough free time between anchors. Thus between any two anchors there is a *prism* in space and time where discretionary activities can potentially be performed. The size and shape of the space-time prism depends on the distance between anchors in space-time, and the speed at which a person can travel. Faster travelling speeds, reduced spatial separation, and increased temporal separation between anchors, result in larger space-time prisms, which has classically been interpreted to coincide with increased opportunity to participate in discretionary activities (Lenntorp, 1976; Burns, 1979; Miller, 1991).

2.2.2 Space-Time Impacts of the Automobile

According to a classical interpretation of car-use on space-time behaviour, the driver's increased travel-speed and autonomy over route choice leads to increased levels of mobility, and thus greater accessibility and the potential for activity participation. At the same time however, land-use systems that have been re-oriented for the automobile are typified by dispersed activity locations. There is therefore a tension between the increased travel velocities afforded by the automobile, and the increased separation between land-uses caused by automobile oriented development; the net effect of this balance on activity participation remains to be determined.

The volume of a space-time prism is a proxy for opportunity to participate in an activity, since larger prisms are representative of more spatial choice, more free time, or both. Posed in the constructs of time-geography, the automobile is a mobility tool that provides drivers with faster travel speeds, and therefore leads to an increased capability to reach locations farther away from anchor points and to an expansion of a driver's space-time prism. On the other hand, in response to faster travel speeds cities over time have expanded, creating greater distances between anchor points. This dispersion of activity locations limits the accessibility benefits accrued from the larger prism. The combined effect of city size and velocity on space-time prisms is illustrated below through a series of simulated scenarios.

Formally, the impact of velocity and anchor separation on prism volume can be computed mathematically. Assume a constant maximum travel speed, V. Let $A_1=(x_1,y_1,t_1)$ be the endpoint of a fixed activity such as work. Let $A_2=(x_2,y_2,t_2)$ be the beginning point of the next anchor such as being at home to cook dinner for the family, and let

$$(t_2 - t_1) < \frac{\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}}{V}.$$

This last assumption guarantees the existence of non-zero space-time prisms.

The space-time prism in this case is the union of two oblique cones with apexes at the anchor locations as in Figure 2-1. The cones share a common base formed by a slanted ellipse with foci at (x_1,y_1) and (x_2,y_2). Lentorpp (1976) obtained formulae for the Potential Path Area (PPA) and Potential Path Space (PPS) of such a prism, with the latter being the volume of the space-time prism, and the former being the projection of the prism onto the geographic plane. They are expressed as:

$$PPA = \frac{\pi}{4} T V^2 \sqrt{\left(T^2 - \left(\frac{ds}{V}\right)^2\right)}$$ Eq. 2-1

$$PPS = \frac{T}{3}\left(1 - \left(\frac{ds}{VT}\right)^2\right) \times PPA$$ Eq. 2-2

where V is the travel velocity, and T and ds are the temporal and geographic distances between two anchor points respectively.

In the following example, consider two notional cities, one where people walk at 5km/h, and one where people drive at 50km/h. The radius of each city is defined by how far people can travel in 30 minutes: 2.5km for the walking city, and 25km for the driving city. In this case, the maximum distance between two anchors is 5km and 50km respectively. Assume that the cities contain the same number of activity locations, and that the residences, workplaces, and locations of activities are evenly dispersed. This suggests that distances between anchor locations increase in proportion to travel speed and city size.

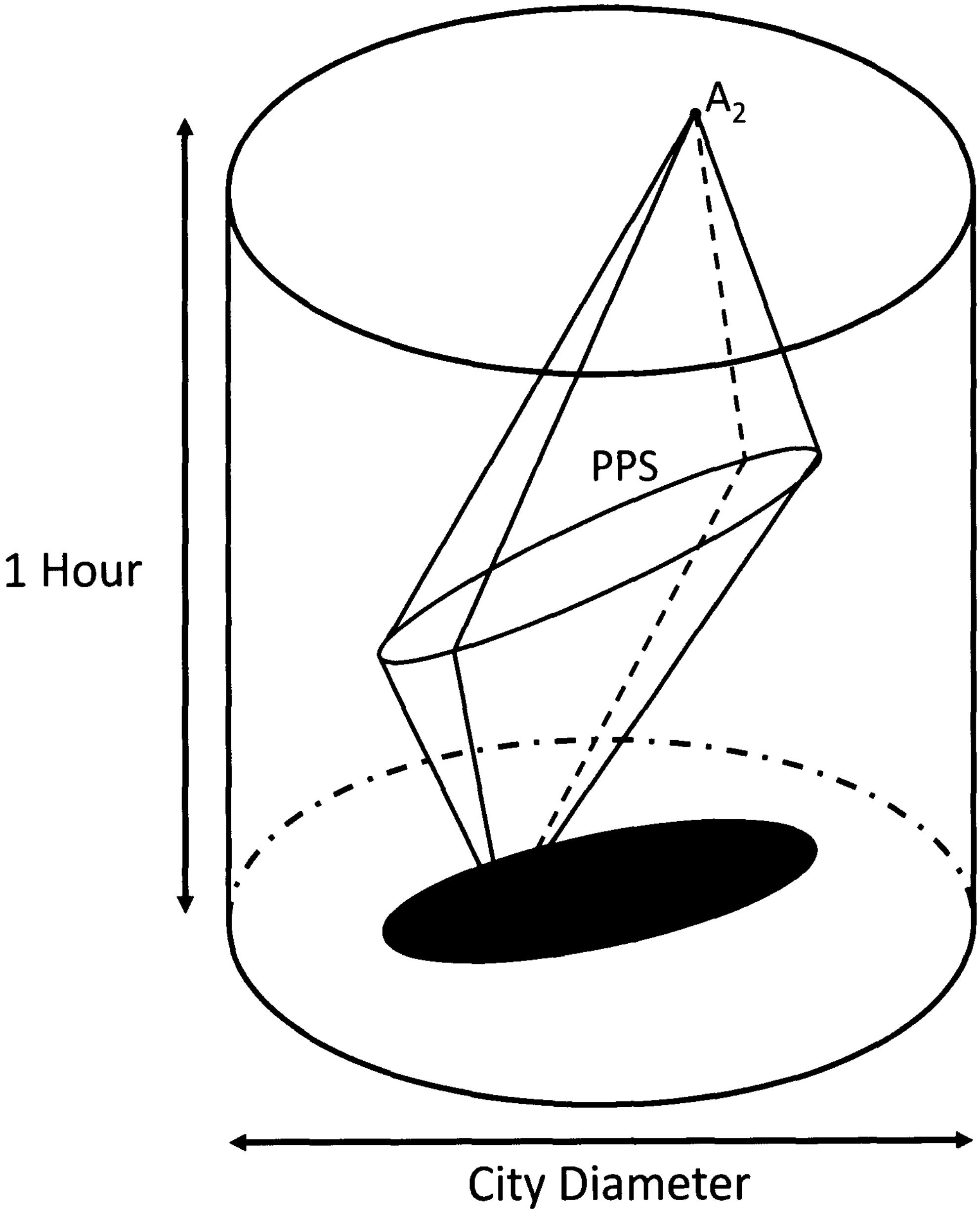

Figure 2-1 Time-Geography Concepts

Table 2-1 Space-time prisms in walking and driving cities

	Anchor Separation (km)	PPA (km^2)	PPS (hkm^2)	Free Time (min)	Spatial Coverage	Volume Coverage
Walking	0	19.6	6.5	60	100%	33%
Velocity = 5 km/h	1	19.2	6.2	48	98%	31%
Size = 19.6 km²	2	18.0	5.0	36	92%	26%
	3	15.7	3.4	24	80%	17%
	4	11.8	1.4	12	60%	7%
	5	0.0	0.0	0	0%	0%
Driving	0	1963.5	654.5	60	100%	33%
Velocity = 50 km/h	10	1923.8	615.6	48	98%	31%
Size = 1963.5 km²	20	1799.6	503.9	36	92%	26%
	30	1570.8	335.1	24	80%	17%
	40	1178.1	141.4	12	60%	7%
	50	0.0	0.0	0	0%	0%

Table 2-1 contains calculated PPAs and PPSs for individuals in these two cities given a 1 hour time interval between anchors at various geographic distances from each other. As the theory suggests, within each scenario, PPAs and PPSs decrease with respect to increasing spatial separation between anchors. Also, PPAs and PPSs are much larger for drivers due to increased travel velocities despite the proportionate increase to anchor separation. This increase in PPA and PPS for drivers could be misinterpreted as evidence of increased space-time accessibility to activity locations. The following arguments describe why larger prisms do not necessarily result in more access.

First, consider that space-time accessibility is composed of spatial access, as well as temporal access. In order to participate in an activity, one not only needs to reach the activity location, one also needs an appropriate amount of time available to perform it. In the context of our illustrative cities, free-time for participation can be approximated as the difference between the total amount of time and the amount of time needed to travel directly from one anchor to the next. Observe that despite faster velocities and larger PPAs and PPSs for drivers, the amount of free time available to participate in an activity remains constant for anchor separations of equivalent relative distances. Thus drivers obtain a greater spatial extent of possible activity participation, but they do not have more free time than walkers to actually stop and perform an activity.

Next, the impact of spatial extent on activity accessibility must be evaluated. For each city the total area possibly covered by PPAs and the total volume possibly filled by PPSs of its residents are computable. The total area possibly covered is simply the size of the city, which is 19.6 km^2 for the walking city, and 1963.5 km^2 for the driving city. The total volume potentially filled by prisms in each city is represented by a cylinder with base equal to the city area, and height equal to the 1 hour time difference between anchors. Thus, they are 19.6 $h{\cdot}km^2$ and 1963.5 $h{\cdot}km^2$ for the walking and driving cities respectively.

PPA sizes in the driving city are 100 times the size of those in the walking city, but as a percentage of the total city size covered (in the Spatial Coverage column of Table 2-1) the two sets of PPAs are equivalent. Thus, for a given relative anchor separation, the walker and the driver can access the same relative portion of their city and the same number of activity locations. In this case as before, under the assumption of a uniform distribution of activity locations, being a driver in a car-oriented city does not increase the number of available opportunities, despite increased absolute PPA sizes.

As an illustration of the above notions, consider the use of prism metrics as accessibility measures. Setting the anchor separation in the driving city to 49.167 km allows for precisely one minute of free time to participate in an additional activity. The PPA for an individual facing such conditions is equal to 356.9 km^2, more than eighteen times the size as the entire walking city! The size of the Potential Path Area potentially obscures the fact that greater spatial accessibility (a propounded benefit of driving) may in fact not be accompanied by a sufficient amount of free time to make participation in various activities desirable or even possible.

Finally, it is important not just to consider the locations of possible activities, but also the ability for space-time prisms to intersect (i.e. coupling constraints), as this is a necessary condition for physical interaction between human beings (Miller, 2005). As the size of space-time prisms increase with car use, so too should the likelihood of intersection between two prisms in a given volume. However, in large, car-oriented metropolises, despite people possessing large space-time prisms, the anchor locations belonging to interaction peers can be so dispersed that little opportunity for interaction is gained despite large increases to velocity.

This phenomenon is only realized when controlling prism volume as a ratio of total available space in which one's peers are active (last column of Table 2-1). Indeed, if one considers the percentage of the total volume of a city occupied by a space-time prism to be a proxy for interaction likelihood, then as before, there is no benefit associated with driving. Table 2-1 shows that the prism volumes for drivers are always larger than the volumes for walkers, but the portions of the total volume occupied are equivalent. Therefore, two randomly positioned PPSs of equivalent volume in the walking city are just as likely to intersect as their proportionately sized counterparts in the driving city.

Figure 2-2 further illustrates the relationship between mobility, physical separation, and social interaction. In this diagram, the space-time prisms associated with drivers are much larger than the dark-grey walking prisms. As a result, social interaction is only possible if both people drive. If however, the distance between activity partners increases, the potential for interaction diminishes, eventually reaching a point when the opportunity no longer exists or lies below a minimum threshold for making the trip worthwhile. So, if on a normal working day an individual is faced with a very long travel-time to meet a friend for a social arrangement, a likely outcome is simply that the individual will opt out of participation and return home. In this case, data measuring an individual's time-space behaviour would actually indicate a *decrease* in travel time, and analyzing travel times without taking into consideration activity participation rates is a pitfall that must be avoided.

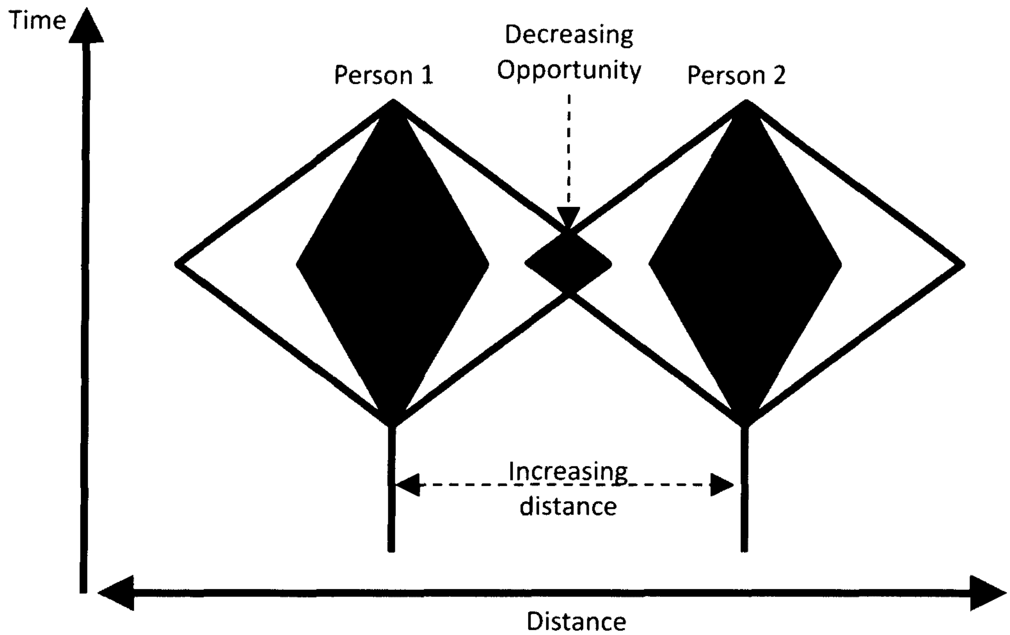

Figure 2-2 Opportunity for Social Interaction

The simple examples above illustrate that under the assumption of constant and proportionate increases in urban spatial extent and anchor dispersion, the mobility afforded to car drivers does not result in increased free-time, increased access to activity locations, or increased propensity to physically interact with others. In reality, while cities have grown dramatically since the advent of the automobile, congestion has also increased, and travel speeds, particularly during peak hours have slowed (Lee, Gordon, Richardson, & Moore, 2009). By adjusting the initial conditions of the experiment, one can explore the effect of excessive dispersion and congested travel speeds on accessibility outcomes.

Three scenarios are shown:

- *Scenario 1*: Travel speeds are 10% slower.
- *Scenario 2*: Activity anchors are 10% more dispersed.
- *Scenario 3*: Activities are 10% more dispersed and travel speeds are 10% slower.

For each case the associated reductions to free time, spatial coverage, and volume coverage compared to the original driving city scenario are reported in Table 2-2.

According to the calculations, congestion and dispersion cause nearly equivalent reductions to free-time, but for spatial and volume coverage, the effect of congested travel speeds is far more drastic than the somewhat benign impact of anchor dispersion. This finding is particularly salient to this paper's empirical focus on time-use, suggesting that time lost to congestion and long commutes may have detrimental impacts on discretionary activity participation. This is the topic investigated in the empirical analysis section below.

Table 2-2 Accessibility Impacts of Dispersion and Congestion in a Driving City

Scenario 1 (Congestion)	Anchor Separation (km)	Free Time	Space Coverage	Volume Coverage
	0	0%	-19%	-19%
	10	-3%	-19%	-20%
	20	-7%	-21%	-24%
	30	-17%	-25%	-34%
	40	-44%	-38%	-64%
	50	N/A	N/A	N/A
Scenario 2 (Dispersion)	**Anchor Separation (km)**	**Free Time**	**Space Coverage**	**Volume Coverage**
	0	0.0%	0%	0%
	11	-2.5%	0%	-1%
	22	-6.7%	-2%	-6%
	33	-15.0%	-6%	-17%
	44	-40.0%	-21%	-50%
	55	N/A	N/A	N/A
Scenario 3 (Combined)	**Anchor Separation (km)**	**Free Time**	**Space Coverage**	**Volume Coverage**
	0	0.0%	-19%	-19%
	11	-5.6%	-20%	-21%
	22	-14.8%	-23%	-30%
	33	-33.3%	-31%	-50%
	44	-88.9%	-72%	-97%
	55	N/A	N/A	N/A

2.3 Empirical Analysis and Discussion

The discussion above describes how mobility and dispersion interact to enhance or limit the opportunities for activity participation in several hypothetical settings. The objective of the empirical analysis in this section is to address whether longer travel times, due to congested travel speeds or activity location dispersion, can be linked to reduced participation in discretionary and social activities in Canadian metropolitan areas.

2.3.1 Data and Method

The data used in the analysis are drawn from three waves of the General Social Survey (1992, 1998 and 2005). This is an annual survey conducted with the primary objectives of: "gather[ing] data on social trends in order to monitor changes in the living conditions and well being of Canadians over time; and to provide information on specific social policy issues of current or emerging interest" (Statistics Canada, 2006 p.7). For the purposes of this investigation, only those records that pertain to individuals over 15 years of age and living within Census Metropolitan Areas (CMAs) are used. Also, the respondents are only drawn from Ontario, Quebec, Alberta, British Columbia, and Saskatchewan since CMA identifiers only exist for these provinces within the GSS. The data are weighted by the inverse probability of having been selected into the sample, and these weights are used throughout the analysis to correct for sampling bias. Table 2-3 contains some basic information about the three cycles used.

Table 2-3 Summary of GSS Cycles Used in the Analysis

	Cycle 7: 1992	Cycle 12: 1998	Cycle 18: 2005
Number of respondents in CMAs	3,853	4,906	11,885
Weighted number of respondents	11,628,857	14,172,606	19,239,987
Provinces with CMAs	QC ON SK AB BC	QC ON SK AB BC	QC ON SK AB BC

The GSS cycles for the years herein under investigation consist of detailed one-day time-use diaries coupled with socioeconomic questionnaires. Each time-use diary is composed of data entries pertaining to individual activity episodes greater than or equal to 1 minute in length. In addition to start time and duration, the activity episode records contain contextual characteristics such as the activity type, its location (categorized, not geocoded), and the social context in which the activity was performed. These characteristics are used in the ensuing descriptive analysis to find shifts in the types and characteristics of activities being performed by Canadians over time.

Between 1992 and 2005, the Canadian CMA adult population grew at an annual rate of 3.9%, approximately 2.5 times the growth rate for the entire country, signifying a considerable level of urbanization. This growth in population has primarily been associated with sprawling land-use patterns on the fringes of existing urban development and around highway infrastructure (Maoh, Koronius, & Kanaroglou, 2010). While Canadian cities became dominated by the automobile during the middle of the last century, automobile-dependent sprawl remains the dominant growth trend even to this day. The City of Toronto, for example, grew by 117,859 people between 1996 and 2006 while the census divisions comprising the suburban lands of the Greater Toronto Area (York Region, Durham Region, and Peel Region) grew by 709,788 residents, a 6:1 ratio in favour of decentralized expansion. Surely this population growth is indicative of strong economic development in the GTA, but several recent policy documents about the city cite traffic congestion and commute times as one of the region's most critical policy concerns. A November 2009 OECD report estimates that traffic congestion in the GTA is responsible for $5 billion in lost productivity annually at the national level, largely due to high rates of automobile use and a lack of investment in transportation infrastructure (OECD, 2010). This finding is corroborated in the March 2010 Toronto Board of Trade Scorecard which finds that Torontonians have the longest average commute amongst a group of 19 global cities including L.A., London and New York (Toronto Board of Trade, 2010). And Toronto is simply the best-known example of a trend that can be observed in most urban areas in Canada and North America.

The primary objective of the empirical analysis is to explore the data for shifting time-use allocation to different types of activities, locations of activity participation, and social contexts. The analysis is split into three parts. In the first, time use trends are investigated in terms of three important questions: what activities are Canadians doing; where are Canadians doing activities; and with whom are Canadians doing activities. The second part of the analysis focuses on trends in travel purpose, and the third consists of an exploration of the time-use trade-offs associated with daily commute trip durations.

2.3.2 What, Where and With Whom

In this section, changes in the average amount of time Canadians allocate to different activity types, locations and social contexts are investigated. The average daily durations of broad activity types for 1992 and 2005 are found Table 2-4. These averages are calculated with non-participants counted as zero-length durations, so they do not reflect the average duration of actual activity episodes. Rather, they are a combined measure of the allocation of time to an activity as well as the frequency of participation across the population. The fourth and fifth columns contain the duration differences in absolute and relative forms, and the final column contains the p-value of a two-tailed difference of means t-test assuming unequal variances between samples.

Table 2-4 Mean activity durations for 1992 and 2005

	1992 (mins)	2005 (mins)	Diff. (mins)	% Diff.	p(t)
Paid Work	216	221	+5	2.1%	0.3468
Domestic	109	110	+1	1.0%	0.6589
Childcare	24	23	-1	-1.3%	0.8076
Shopping	32	31	-1	-3.1%	0.3945
Personal	627	632	+5	0.8%	**0.0733**
Education	36	35	-1	-2.1%	0.7453
Organizational & Volunteering	20	16	-4	-17.2%	**0.0084**
Entertainment	70	73	+3	4.7%	0.1508
Sports, Hobbies and Computer	47	60	+13	28.7%	**0.0000**
Media	182	162	-20	-10.8%	**0.0000**
Travel	77	74	-3	-3.5%	**0.0490**

The most prominent finding is that mean durations have not changed much over time for the majority of mandatory activities such as paid work, domestic work and childcare. Observe, however, that there are significant decreases in organizational and media activities and significant increases in personal activities and sports, hobbies and computer usage. Organizational and volunteering activities include professional, union, political, fraternal, social and religious meetings, volunteering, and unpaid child and house care outside one's household. According to social capital scholars, these are important activities for developing and maintaining social capital, civic engagement, and cohesion (Putnam, 2000). Media activities include reading newspapers, magazines and books and watching television, and it appears that these traditional forms of staying tuned in are being replaced by large increases in computer usage.

Another significant finding from Table 2-4 is that mean travel durations have significantly decreased on average from 1992 to 2005. Drawing from the time-geography axioms, such a decrease in travel could be caused by three factors: activity locations are nearer together than they were in the past; travel speeds have increased; or people are performing fewer activities that require travel than in the past. Urban sprawl with choking congestion was the dominant pattern of urban growth in this time-period, so it is unlikely that activity spaces became more compact or that travelling became faster. Rather, this reduction in time spent travelling is due, as will be shown below, to a reduction of participation in out-of-home activities, one of the hypothesized outcomes of a combination of increased travel times for work and other mandatory activities, and spatial dispersion of activity locations.

Evidence in support of the claim that travel reductions are actually due to a shift in the number of activities taking place out of the home is found in Table 2-5. This table contains the mean daily duration of activities taking place at home, work, another person's home, and at other locations such as restaurants, bars, parks, museums and so forth. The table clearly shows a significant shift from out-of-home to in-home activity participation. Most striking is a 17% decrease in the amount of time spent visiting other homes, an indication that Canadians are visiting social contacts less than they did in the past.

Table 2-5 Mean activity durations for 1992 and 2005 by location

	1992 (mins)	2005 (mins)	Diff. (mins)	% Diff.	p(t)
Respondent's Home	968	989	+21	2.2%	**0.0003**
Work	194	197	+3	1.1%	0.6589
Other Homes	57	47	-10	-17.3%	**0.0004**
Other Places	140	133	-7	-5.0%	**0.0402**

Table 2-6 Mean activity durations for 1992-2005 by social contact

	1992 (mins)	1998 (mins)	2005 (mins)	Diff. (mins)	% Diff.	p(t)
Alone	328	364	390	26	7.2%	**0.0000**
Spouse	183	174	194	20	11.4%	**0.0000**
Hhd. Children <15		88	82	-6	-7.1%	**0.0494**
Hhd. Parents		16	18	2	9.4%	0.2373
Other HHd. Members		42	27	-15	-36.5%	**0.0000**
Non Hhd. Children <15		3	5	2	47.4%	**0.0217**
Non Hhd. Children >=15		7	7	0	-8.1%	0.4702
Non Hhd. Parents		14	12	-2	-11.3%	0.1798
Non Hhd. Other Family		31	33	2	8.6%	0.1434
Friends		104	89	-25	-14.8%	**0.0000**
Other		191	150	-41	-21.5%	**0.0000**

Table 2-6 contains activity durations broken down by whom the activities are participated with. The coding mechanism for "with whom" characteristics of activities significantly changed between 1992 and 1998 and only two of the codes from 1992, alone and with spouse, are commensurate with the later vintages of the data. Fortunately, the data are coded identically in 1998 and 2005 and the last three columns in Table 2-4 pertain to the differences between these years.

The social interaction statistics show a striking pattern of increasing isolation and decreased physical socialization with friends and other non-family contacts over the time-period. The only types of social contact that significantly increased in the period were joint activities with one's spouse and with non-household children under the age of 15. The latter presumably is due to increasing numbers of non-nuclear family arrangements, and the former, taken in conjunction with the large increase in time spent at home during the same period, is due to reduced out-of-home discretionary activity participation. The period is also characterized by a large reduction in socialization with one's friends and with non-family household members.

During the time period under investigation, the computer has become a major time-sink amongst Canadians of all ages. There is now a plethora of research investigating the socio-psychological impacts of internet usage, and the relationships between internet usage and social capital development. Wellman et al. found that on-line communication substitutes for conventional forms of social interaction, and may in fact lead to enhanced civic engagement (Wellman et al., 2001). On the other hand, work by Caplan finds that a preference for on-line versus conventional forms of interaction is indicative of negative psychosocial health outcomes (Caplan, 2003). In Canada, it appears that increased computer use (excluding work, school and gaming uses) corresponds with decreases in telephone and television usage as well as the duration of reading books, magazines and newspapers. The extent to which it is directly responsible for the decreased time spent with friends is impossible to determine using a descriptive analysis.

2.3.3 Mode, Purpose and Trip Duration

The changes from 1992 to 2005 in travel times by mode and trip purpose are investigated in this section. Table 2-4 indicates that travel times in general have decreased, and Table 2-7 confirms that the reduction applies to all modes. The biggest changes occurred for car-passengers, walkers and bicyclists. The change in car-passenger travel might have a demographic cause since the elderly female population in 2005 are more likely to be drivers than those in 1992 (Scott et al., 2009). Keep in mind that these averages are for all trip purposes; one-way commute durations for drivers increased 25% to 25 minutes in the same period, while commute durations for walkers stayed constant at 10 minutes (not shown). An examination of travel times by trip purpose follows.

Table 2-7 Mean Travel Durations for 1992 and 2005 by Mode of Transportation

	1992 (mins)	2005 (mins)	Diff. (mins)	% Diff.	p(t)
Driver	48	46	-2	-5.0%	**0.0314**
Passenger	14	11	-3	-22.7%	**0.0000**
Active	8	6	-2	-31.5%	**0.0000**
Bus/Subway	10	9	-1	-3.4%	0.5738
Other	2	2	0	-10.9%	0.6603

In Figure 2-3, we display the relationship between trip durations and participation rates for a variety of activities. The horizontal axis of the plot measures the percentage change in trip duration from 1992 to 2005 while the vertical axis measures the percentage change in participation rates.

Observe that the majority of activities are found in the lower-right quadrant of the graph, indicating the existence of a negative relationship between trip-duration and activity participation. Also, there are no entries in the top-right quadrant, meaning that in not a single case did participation rates increase when trip durations increased too. It is not clear at this moment why several activities can be found in the lower-left quadrant. One hypothesis is that if travel durations for so many other types of activities have increased, then one might expect those increased time-expenditures to spill over and affect participation in other, unrelated activities.

In confirmation of the initial hypothesis that anchors have become more dispersed or that congested travel speeds have lengthened trip durations, we observe that work, shopping, and childcare travel durations increased significantly between 1992 and 2005 despite an overall decrease in travel. In fact, it is easily observed that the total reduction in travel time seen in Table 2-4 is due mainly to reduced participation in a wide variety of activities that require travel.

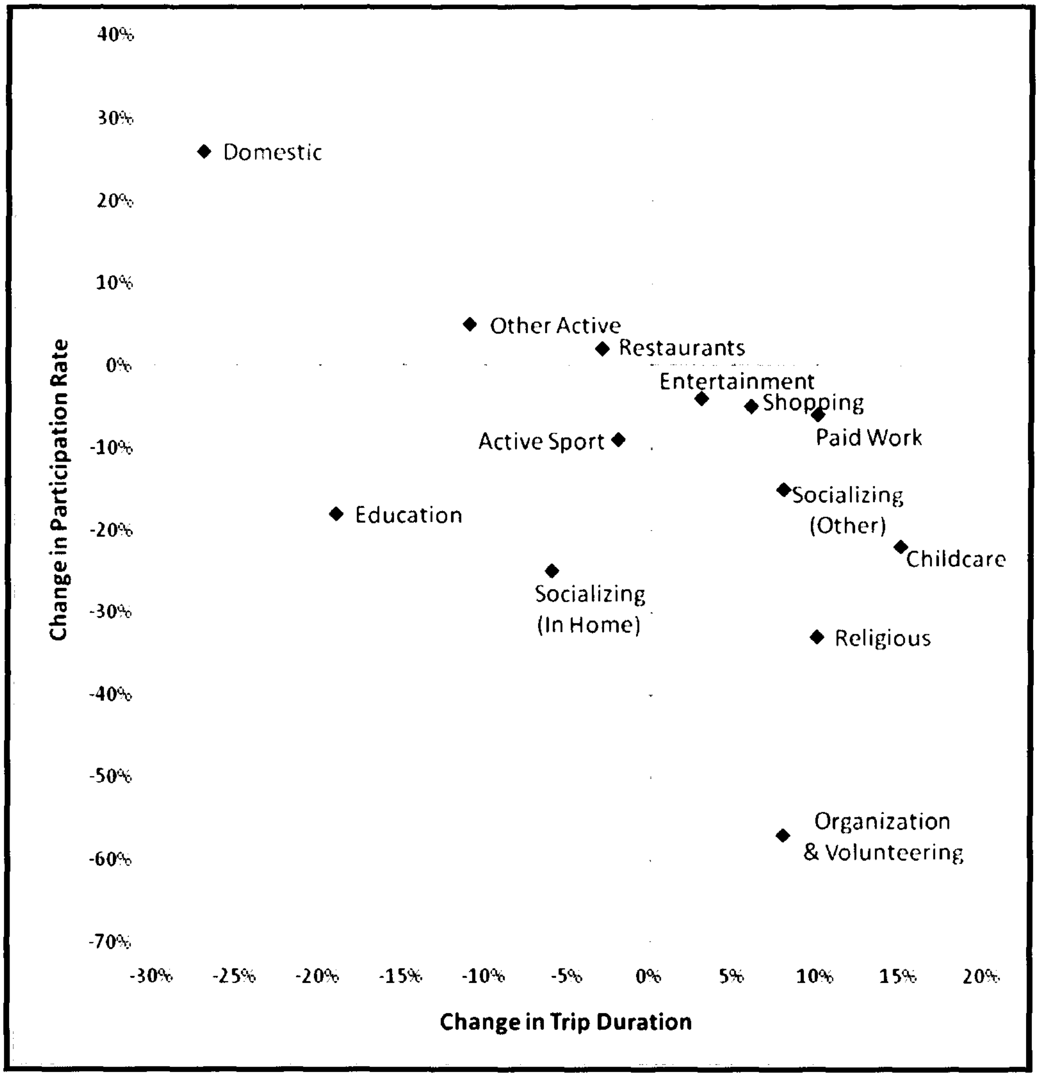

Figure 2-3 Change in Activity Participation and Trip Duration (1992 to 2005)

Finally, to determine if mandatory trip durations have grown at the expense of participation in other types of activities, one can assess the share of the daily travel budget devoted to each trip purpose. As seen in Table 2-8, work travel accounted for nearly 34% of all travel time in 2005, a significant increase (14%) from its 1992 share. The significant increase in work travel share is met by significant decreases in travelling for social visits and organizational and volunteering activities, both activities having positive social benefits. At this point it is important to note that the empirical results match very closely with the initial hypotheses suggested in the theoretical development section above, even if the analysis does not establish the causality of these relationships.

Table 2-8 Travel purpose share of all travel 1992-2005

	Share % (1992)	**Share % (2005)**	**Diff. Share**	**Diff. %**	**p(t)**
Work	29.7%	33.8%	+4.1	+13.8	**0.0027**
Goods & Services	20.8%	21.2%	+0.3	+1.4	0.6712
Socializing (in homes)	13.5%	10.1%	-3.4	-25.2	**0.0000**
Education	6.2%	5.1%	-1.1	-17.6	0.1400
Restaurants	5.0%	5.5%	+0.5	+10.1	0.4075
Active Sports	4.6%	4.1%	-0.5	-11.0	0.1515
Childcare	4.5%	4.7%	+0.2	+4.5	0.8815
Organizational / Volunteering	3.9%	1.8%	-2.1	-53.7	**0.0000**
Socializing (other)	3.9%	3.4%	-0.4	-10.3	0.1183
Other Active	3.0%	2.9%	-0.1	-3.3	0.7436
Sports & Entertainment	2.4%	2.6%	+0.2	+8.4	0.6812
Religious Services	1.6%	1.2%	-0.4	-24.7	0.0541
Domestic	0.6%	0.6%	+0.1	+17.8	0.8472
Media	0.2%	0.3%	+0.1	+50.2	0.1772
Other Personal	0.2%	2.4%	+2.2	-	**0.0000**
Coaching	0.0%	0.2%	+0.2	-	**0.0011**
Hobbies	0.0%	0.1%	+0.1	-	**0.0001**

2.3.4 Commuter Trade-Offs

The descriptive investigation of travel purpose above indicates that going to and from work is the most dominant travel purpose in terms of time commitment and participation frequency. Its importance has also increased significantly from 1992 to 2005. When considering a worker's day, the amount of time devoted to their commute has a significant bearing on their lifestyle. Suburban workers who are often stuck in traffic jams face a very different set of space-time opportunities and constraints compared to an inner-city bicycle commuter. The suburban driver not only has to devote much more time to travel than the inner-city bicyclist for example, but it may also be far more inconvenient for the driver to chain activities together given the spatial structure of suburban activity locations and their interface with the transport network. They may have to struggle through long delays at highway on- and off-ramps, when turning at busy intersections, and when looking for parking. In total, these additional costs of travel may limit the attractiveness of performing additional activities even if commute times between modes are equivalent. In the next series of tables, the relationship between commute mode, duration and activity participation is investigated.

The data required to perform this analysis are drawn from the 2005 cycle of the GSS. 4,398 respondents living in CMA's and performing at least one work trip on the survey day (up to a daily work-trip duration of 4 hours) are included in the analysis. These respondents were further categorized as car-commuters or commuters by other modes of transport, and placed into 20 minute intervals up to 2 hours long. These intervals were chosen to maintain sufficiently large within-group sample sizes for significance testing (Table 2-9). Observe that much higher percentages of automobile drivers appear in the lower commute-time intervals, but within each interval, drivers and other mode users have roughly equivalent mean commute durations.

Table 2-9 Frequency of workers by commute interval with mean commute duration in brackets

Quantiles	Range	Car (duration)	Other (duration)	Combined
Q1	1 - 20	900 (14)	253 (14)	1153
Q2	21 - 40	928 (33)	210 (33)	1138
Q3	41 - 60	771 (54)	211 (55)	982
Q4	61 - 80	268 (73)	82 (74)	350
Q5	81 - 100	188 (92)	98 (91)	286
Q6	101 - 120	139 (113)	113 (117)	252
Q7	121 - 240	116 (165)	121 (162)	237
ALL	1 - 240 Minutes	3310	1088	4398

An investigation of the durations of activities, social characteristics and activity locations for members of the different groups in Table 2-9 can be found in Table 2-10, Table 2-11 and Table 2-12. In each case, the joint impact of mode choice and commute duration is determined by a series of hypothesis tests. A one-way ANOVA test is used to determine if commute duration by mode is a significant factor in explaining the variation in other activity durations, and a difference of means t-test is used to determine if mode used, given a certain commute time, impacts the duration of other activities.

Table 2-10 Commute Mode, Commute Duration and Activity Durations

	Paid Work			**Domestic**			**Childcare**		
	Car††	Other††	Diff.	Car††	Other	Diff.	Car	Other††	Diff.
Q1	485	443	42**	68	49	19**	22	10	12**
Q2	512	445	67**	61	62	-1	18	14	4
Q3	532	486	46**	60	59	1	18	15	3
Q4	535	520	15	63	52	11	20	30	-10
Q5	525	508	17	52	48	4	18	17	1
Q6	549	492	57**	41	57	-16**	14	13	1
Q7	523	487	36*	45	44	1	16	16	0

	Shopping			**Personal**			**Education**		
	Car††	Other††	Diff.	Car††	Other††	Diff.	Car††	Other††	Diff.
Q1	19	16	3	574	581	-7	13	57	-44**
Q2	15	19	-4	577	577	0	7	52	-45**
Q3	9	10	-1	566	593	-27**	4	14	-10**
Q4	8	9	-1	556	560	-4	3	14	-11
Q5	6	7	-1	560	543	17	10	22	-12
Q6	6	9	-3	537	565	-28**	6	16	-10
Q7	6	8	-2	519	548	-29**	4	17	-13*

	Organizational & Volunteering			**Entertainment**			**Sports and Hobbies**		
	Car	Other	Diff.	Car††	Other††	Diff.	Car††	Other††	Diff.
Q1	9	10	-1	55	62	-7	43	50	-7
Q2	6	11	-5	38	51	-13*	30	48	-18**
Q3	6	9	-3	30	27	3	34	34	0
Q4	8	2	6**	23	35	-12	25	27	-2
Q5	11	2	9**	23	50	-27**	21	38	-17*
Q6	12	6	6	29	28	1	26	26	0
Q7	8	6	2	24	17	7	25	27	-2

	Media and Communication		
	Car††	Other††	Diff.
Q1	103	110	-7
Q2	112	93	19**
Q3	103	111	-8
Q4	103	90	13
Q5	96	87	9
Q6	84	89	-5
Q7	86	88	-2

ANOVA test for data in that column is significant at 0.10 (†) or 0.05 (††).

Asterisks in the "Diff." columns indicate the significance of difference of means t-tests between modal groups at the given commute duration for that row at 0.10(*) or 0.05(**).

Table 2-11 The effect of commute mode and duration on activity locations

	Home			**Work**		
	Car††	Other††	Diff.	Car††	Other††	Diff.
Q1	820	780	40**	456	419	37**
Q2	815	790	25	482	425	57**
Q3	802	810	-8	488	453	35**
Q4	798	783	15	495	474	21
Q5	773	723	50**	487	499	-12
Q6	719	784	-65**	526	459	67**
Q7	699	742	-43*	493	460	33
	Other's Home			**Other Location (not in transit)**		
	Car††	Other††	Diff.	Car††	Other††	Diff.
Q1	31	41	-10	81	147	-66**
Q2	18	42	-24**	60	118	-58**
Q3	14	28	-14*	57	67	-10
Q4	9	18	-9	43	69	-26
Q5	9	45	-36**	54	57	-3
Q6	9	6	3	50	52	-2
Q7	11	12	-1	54	45	9

ANOVA test for data in that column is significant at 0.10 (†) or 0.05 (††).

Asterisks in the "Diff." columns indicate the significance of difference of means t-tests between modal groups at the given commute duration for that row at 0.10(*) or 0.05(**).

Table 2-12 The effect of commute mode and duration on joint activity durations

	Alone			Spouse/Partner			Household Children (<15)		
	Car	Other††	Diff.	Car	Other	Diff.	Car†	Other†	Diff.
Q1	423	370	53**	131	95	36**	75	34	41**
Q2	403	370	33	128	102	26**	67	58	9
Q3	438	398	40*	115	98	17**	62	46	16*
Q4	411	400	11	123	102	21**	65	61	4
Q5	403	422	-19	117	82	35**	50	48	2
Q6	415	477	-62*	109	96	13**	47	29	18*
Q7	433	456	-23	107	94	13**	67	58	9
	Friends			**Other Non-Family & Non-Household**			**Household Member**		
	Car††	Other††	Diff.	Car††	Other	Diff.	Car††	Other	Diff.
Q1	58	109	-51**	270	284	-14	181	158	23*
Q2	45	112	-67**	300	292	8	176	159	17
Q3	57	72	-15	285	289	-4	156	150	6
Q4	40	50	-10	315	334	-19	170	136	34*
Q5	50	71	-21	320	308	12	163	119	44**
Q6	79	55	24	328	259	69**	140	138	2
Q7	64	46	18	335	312	23	158	142	16
	Non-Household Member								
	Car†	Other††	Diff.						
Q1	348	414	-66**						
Q2	364	423	-59**						
Q3	353	367	-14						
Q4	371	401	-30						
Q5	383	415	-32						
Q6	413	328	85**						
Q7	402	356	46						

ANOVA test for data in that column is significant at 0.10 (†) or 0.05 (††).

Asterisks in the "Diff." columns indicate the significance of difference of means t-tests between modal groups at the given commute duration for that row at 0.10(*) or 0.05(**).

Table 2-10 details the results concerning activity types. Given the natural constraint that time spent in one activity (commuting) determines how much time remains to be spent in other activities, it is not surprising to see that the ANOVA tests indicate that commute time explains a significant amount of variation in the duration of many activities. Notably, the mandatory responsibilities of domestic and childcare activity durations are not affected by commute duration for other mode users and car drivers respectively, evidence that as commutes increase, mandatory activities are less likely than discretionary activities to be traded off.

Durations of all non-work activities are expected to decrease with respect to commute duration but we are interested in which activities are more likely to be traded off with higher levels of commuting. To investigate this, the percentage change in activity duration between respondents in the longer commute intervals versus the shorter ones is investigated. The activities that decrease the most are those which are most elastic with respect to commuting. The mean duration of the first two and last two intervals is used in the calculation to avoid excessive variability. The order of activities for car drivers is: Shopping (-75%), Education (-50%), Entertainment (-43%), Domestic (-33%), Sports & Hobbies (-30%), Childcare (-25%), Personal (-8%), Work (+8%), Organization & Volunteering (+33%). For other mode users the order is: Education (-70%), Entertainment (-60%), Shopping (-51%), Sports & Hobbies (-46%), Organization & Volunteering (-43%), Domestic (-9%), Work (+10%), and Childcare (+21%). For both categories, discretionary activities are more severely impacted than mandatory ones. The higher percentage changes for non-car commuters suggest that car-users are more able to participate in discretionary activities in light of increased commutes compared to other types of commuters.

Despite the differences in elasticity of activity duration to commute time, there are also many significant absolute differences between activity durations for car-commuters and other mode users. The t-tests show that car-commuters have significantly longer work durations, and significantly shorter Personal, Educational, Entertainment and Sports & Hobbies durations for most commute-time intervals. Thus, car-commuters in general participate less that other commuters in discretionary activities, but discretionary activity duration is less elastic to commuting duration for drivers.

All together, the findings from Table 2-10 lead to an important conclusion: the lifestyle of drivers includes less discretionary activity participation despite it being easier for them (compared to non-car commuters) to participate in these activities in the face of increasing commuting times. This finding is mirrored below with respect to activity location and social context.

Table 2-11 is schematically equivalent to Table 2-10, except that it pertains to activity locations rather than activity type classifications. The four location classes are Home, Work, Other's Home, and Other Location (not including travel). According to the ANOVA tests, the amount of time spent in each type of location differs by commute duration. The location durations, furthermore, are all negatively impacted by commute duration, except for time spent at one's place of work. This indicates that automobility potentially has a positive economic impact (more time spent in paid work), at the cost of a decrease in time spent at discretionary locations.

The percentage-change analysis reveals the following order of activity locations most impacted by increasing car commute durations: Other's Home (-59%), Other Location (-26%), Home (-13%) and Work (+9%). For other mode users the order is: Other's Home (-78%), Other Location (-63%), Home (-3%), and Work (+9%). According to these calculations, participation in out-of-home non-work activities is less severely impacted by increasing commute durations amongst car drivers. However, the t-tests indicate that car-commuters on average spend more time at work, and far less time at Other's Homes and Other Locations. These results corroborate the findings derived from Table 2-10, that automobile commuters spend less time in discretionary activity locations despite a less elastic relationship between commute and location durations. Presumably, the mobility afforded by driving causes this observed relative inelasticity, but the lifestyles belonging to drivers, as judged by activity participation, are clearly different to those that commute by other means.

The social contexts of activities are investigated in Table 2-12. These categories, unlike those in the previous two tables, could not be made mutually exclusive and they include travelling activities. For this reason, the findings should be interpreted with caution. The ANOVA results suggest that commute duration is a significant predictor of joint activity participation in only a handful of cases and the percentage-change analysis leads to the following ordering for car commuters: Child (-20%), Spouse (-17%), Household Members (-17%), Alone (+3%), Non-Household Members (+14%), Other Non-Family & Non-

Household (+16%), and Friends (+39%). These results are quite striking, and they indicate that time spent with household members is traded off for time spent with others as commute times increase. Presumably, much of this increase is associated with increased time spent with work-mates, some of which might be classified as friends. For non-driving commuters, the order of elasticities is quite different: Friends (-54%), Non-Household Members (-18%), Household Members (-12%), Children (-5%), Spouse (-4%), Other Non-Family & Non-Household (-1%), and Alone (+26%). These elasticities tell a completely different story; time spent alone increases and time spent with friends decreases very rapidly as commute durations increase.

Because of the steeper elasticities associated with non-automobile travel, the t-tests are most significant at the two extremes of the duration spectrum. Drivers tend to spend more time with spouses, children, and other household members, but this is probably due to automobile ownership being higher amongst adults living with families. For other types of social contacts, the effect of mode differs for short and long-duration commuters. In particular, for short-duration commuters, drivers are more likely to spend time Alone, and less likely to spend time with Friends and Non-Household Members. As commute duration increases, the relationships reverse; drivers tend to spend less time Alone and more time with Friends and Other Non-household Members. These findings correspond with those from above. The mobility afforded to drivers with long commutes puts them at a *social* advantage over their non-driving counterparts. However, under less extreme commuting conditions, non-drivers have higher levels of social interaction.

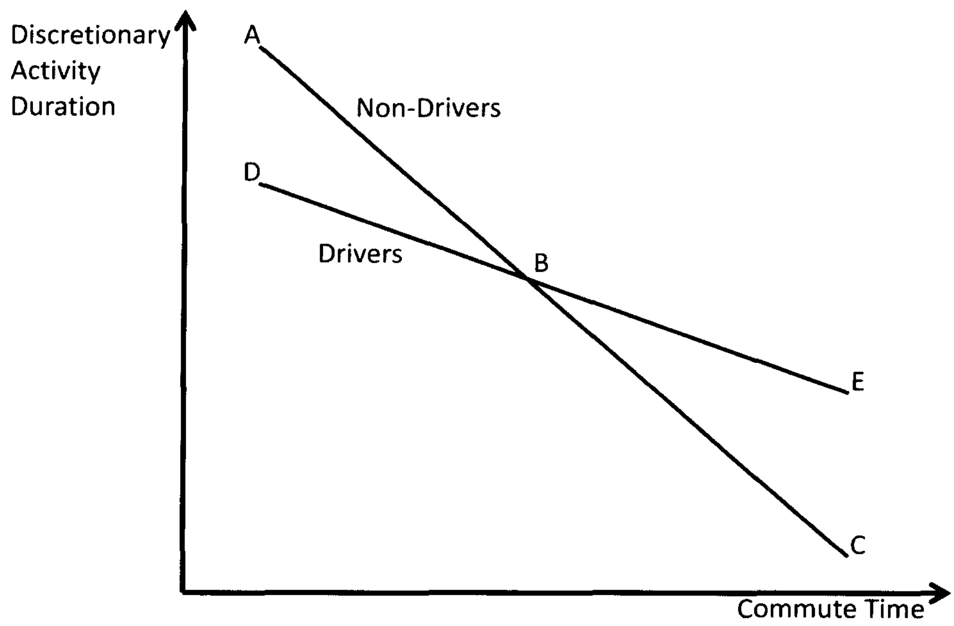

Figure 2-4 Commute Time vs. Discretionary Activity Duration

The analysis in this section illustrates the role of commute mode and duration on participation in activity types, locations, and social contexts. The results indicate that discretionary, out-of-home activities are more likely to be traded off with commuting than in-home, mandatory activities. Figure 2-4 contains a schematic representation of the trade-offs between discretionary activities and commute trips for drivers and non-drivers as distilled from the data found in the previously discussed tables. The figure shows that non-drivers participate in more discretionary activities than drivers so long as commutes stay relatively small (segments AB and DB), but as commute times get sufficiently large, non-drivers lose the ability to participate (segments BC and BE). This could be evidence of the added flexibility the car provides over other alternatives, but it may also be indicative of extra hardships experienced by non-drivers in cities with urban form supporting automobility (Farber, Páez, Mercado, Roorda, & Morency, 2009). Quite strikingly, the results suggest that walking and public transit commuters with reasonably short commutes manage to devote more time to discretionary activities in comparison to drivers, evidence that congestion and dispersion make automobile-oriented development less attractive than living locally.

2.4 Conclusions

This paper addresses the issue of urban form, automobile use, and activity participation, through a series of theoretical and empirical investigations. The work is motivated by a growing body of literature concerned with the unforeseen social costs of automobility, the present system of land-use and transportation that dominates the Canadian urban form. The oft assumed accessibility benefits gained by increased mobility are brought into question. And through simulated space-time geometries, it is shown that the automobile does not increase accessibility if activity dispersion, commonly associated with automobile oriented development, accompanies the increased travel velocities. Furthermore, if activities become overly-dispersed, or if travel-speeds are reduced by road-congestion, drivers may suffer considerable accessibility losses in comparison to residents of theoretically walkable cities.

The empirical component of the paper seeks to confirm the theoretical advancements through an investigation of several dimensions of time-use behaviour. In the first part of the analysis, general trends concerning activity types, locations, and social settings, are revealed. The findings suggest quite stable activity patterns over-all, however a significant decline in social, out-of-home, and discretionary activities was discovered. In the second part of the analysis, the changing activity patterns were shown to be related to actual trip-lengths for each activity purpose. The analysis discovered that most types of trips have increased in duration, while participation in those same activities has declined. This evidence supports the hypotheses that time-spent travelling reduces the propensity to participate in discretionary activities. Finally, in the third component of the analysis, the impact of commute mode and duration on the participation in other types of activities is investigated. Corroborating previous research (Farber & Páez, 2009), it is revealed that drivers have quite distinct time-use patterns to other types of commuters, and that despite being less likely to participate in a broad range of discretionary social activities in general, participation is less elastic for this group than for non-drivers. This evidence does not refute the initial hypotheses, but it certainly raises concerns over equitable distribution of accessibility benefits (Martens, 2010), since non-drivers might be excluded from participating in an automobile oriented land-use and transportation system (Farber et al., 2009).

These descriptive findings do not prove causality, however the trends are in support of the initial hypothesis that automobility has led to increased travel for mandatory activities and a reduction in social interaction and participation in discretionary activities.

One useful way to consider the findings is with respect to the daily time-use budget. Each day is composed of the same number of minutes and the daily budget of time can be partitioned into an array of activities. Over the time period of investigation, the average allocation of time for some activities has increased, for some decreased, and for some it has remained somewhat constant. In this paper, these changes have been accounted for aggregately but it is only the first step in determining and understanding the dynamics controlling these shifts in allocations. Examples of balancing time use budgets exist in the literature (Farber et al., 2009; Kockelman, 2001), and in future work these disaggregated methodologies could be adapted to deal with the pseudo-panel data.

One of the interesting aspects of this work is that it represents a departure from the normal hypothesis that transportation is a derived demand from needing to participate in activities. We accept that in the short-run, travel is a derived demand from the need to participate in activities, but in the long-run, due to its interaction with time-use constraints, it plays a significant role in determining activity outcomes. Obtaining an automobile, especially for employment purposes, is unfortunately a crucial step toward inclusion in the automobile society we have created and it has fuelled a movement toward decentralization. For the past half century, norms have shifted and people have become accustomed to trading the short-run pecuniary travel-costs, such as gasoline and parking, for discounted developments on the fringe. They have decided to locate farther and farther away from their places of employment, recreation, and shopping. Sixty years after the post-war boom and the beginning of mass suburbanization and automobile ownership, the hidden travel-cost, the impact of spatial dispersion and time-loss on individual social capital, organizational engagement, and society at large, remains largely unmeasured. This paper represents the first steps in the discovery of significant trade-offs between daily mandatory travel and participation in a host of discretionary, socially positive activities, a precursor to having healthy and socially sustainable cities.

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3 My car, my friends, and me: A preliminary analysis of automobility and social activity participation

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3.1 Introduction and Brief Literature Review

The prevailing popular perception of the automobile is that it confers freedom to its users. Freedom to move about one's environment; to reach more and better economic opportunities; to utilize service opportunities; and if one is to believe the predominant representations of automobility in the print and electronic media, freedom as well to be adventurous, to travel the open road, to climb a mountain, and to make it back in time to pick the kids up from school. Without doubt, the automobile is a great enabler of mobility and thus serves to increase personal accessibility to the necessities of daily life. This is a theme that has been studied fairly extensively from the perspective of employment outcomes, including job concentration and access to places of employment (Blumenberg & Ong, 1998), and the welfare-to-work transition (Cervero, Sandoval, & Landis, 2002; Ong, 2002; Shen & Sanchez, 2005). As reported by Gurley and Bruce (2005) the evidence consistently is of a positive relationship between car ownership or access, and employment outcomes. Indeed, this relationship between automobile use and employment achievement has spawned policies designed to increase the private mobility of the urban poor in some areas (Fol, Dupuy, & Coutard, 2007; Lucas & Nicholson, 2003).

As the research cited above illustrates, the economic benefits of increased mobility in the form of automobility have been well researched in the past. On the other hand, relatively little is known about the effect of automobility on activity participation for other classes of activities. For example, despite recent interest in the social sphere from the perspective of travel behaviour research, almost no research focuses on the relationship between automobile use and non-economic, primarily social activities. Due to this, it is unclear whether or not the freedom, or at least increased access to opportunities, that the automobile confers on drivers when it comes to participation in economic activities, holds in a similar way with respect to participation in a variety of activities of a more social, not necessarily economic nature.

From a travel perspective, the enhanced potential for mobility afforded by the private vehicle that allows auto users to reach more and better economic opportunities, should in principle also allow people to access geographically dispersed social contacts (relatives, friends, acquaintances, people with like interests, etc.) Moreover, the effect of mobility on social participation rates could be even stronger than the effect on economic activities when considering that individuals may have more control over the spatiality of the locales where they interact in social terms, as opposed to sites of employment and services. Accordingly, it could be posited that automobility, in addition to the economic and employment benefits previously identified, may also operate by increasing social activity participation, in many settings a highly desirable goal. Two counter-arguments can be formulated to oppose this view. First, from a time use perspective, given fixed time budgets, it is possible that the ability to reach better but more distant economic and employment opportunities may reduce the time available for other activities. In relation to this, a sociological argument is that automobility "subordinates other 'public' mobilities of walking, cycling, travelling by rail and so on; and it reorganizes how people negotiate the opportunities for, and constraints upon, work, family life, leisure and pleasure" (Sheller & Urry, 2000, pg. 739). From this perspective, it is claimed that the car at first brings great personal freedom to drivers but results in coercing "almost everyone to juggle tiny fragments of time in order to put together complex, fragile and contingent patterns of social life" (Sheller & Urry, 2000, pg. 744). A potential outcome of this process of private motorization could be geographically disparate social networks (Urry, 2002) that may be detrimental to social capital building (Putnam, 2000). These arguments are important and have generated a lively discussion about some of the societal costs of automobility. However, despite an abundance of theoretical work on this topic, there is scant empirical evidence to verify many claims about the social impacts of automobility. The objective of this article is to fill this gap and provide evidence, using as a case study the Portland Household Activity and Travel Survey, of the extent to which people who depend on their automobiles for all of their mobility needs are socially active (i.e.

frequency of participation), and to quantify their level of social activity (i.e. duration of activities).

In order to achieve this objective, we adopt the tools of the activity-based approach (Axhausen & Garling, 1992; Scott, 2006), in particular the use of multivariate statistical models for activity participation and duration analysis. Parting from the recognition that transport-mode choices may feed into the activity generation process we investigate the possibility that the hypermobility generated by the automobile (which allows drivers to pursue highly individualized and spatially dispersed daily activity patterns) may reduce the likelihood of impromptu and planned social interactions.

It is important to be clear at the outset that the scope of this paper is to investigate the relationship between automobile use and social activity participation, which is but a small fragment of the relationship between the system of automobility and social well-being. At a different scale, the impact of automobility on society can be conceptualized using a general framework of social theory developed by Coleman (1990). Coleman's framework suggests that social change arises from direct systematic stimuli as well as through stimuli affecting individual actors within the system which when accumulated have an impact at the system-level. Relatively little is known about the effect of automobile dependence on the levels of social interaction at the individual level. However, if these individual effects are extant and measurable, they are of interest for their potential influence on aggregate outcomes, such as the level of social capital. Given the current state of research, the paper aims to provide evidence of the existence of some of these effects, and is therefore inductive in nature.

With this caveat in mind, the remainder of the paper is structured as follows. The next section contains a discussion of the dataset used in the analysis. The third section contains a description of the models and methods used to explore the relationship between automobile use and social interaction. The fourth section contains a discussion of the model results, and the fifth section contains conclusions and identifies several current discourses in transportation geography to which this and future research on this theme applies.

3.2 Data considerations

Activity analyses require as input large quantities of disaggregated travel and activity behaviour data. Over the years, many rich surveys have been collected and made available to the research community. One such survey, the 1994 Household Activity and Travel Behavior Survey, was completed by 4,451 complete households containing 10,048 individuals in and around Portland, Oregon. Data pertaining to households, individuals, activities, travel, and vehicles were collected via a two-day diary instrument followed by a CATI enabled telephone interview (Cambridge Systematics, 1996). The data sampling was stratified by season (spring, fall, winter), day of the week, and residential location. The vast and detailed information in the Portland dataset lends itself to this type of analysis (with some limitations discussed below). However, it must be noted that Portland is distinguished by its urban growth boundary and forward-looking public transportation planning, which may not be completely representative of the broader North American urban context.

For the analysis in this paper, each personal record was split by day thereby creating 20,096 unique individual/day combinations. Further, in an effort to reduce the risk of results being unduly affected by the dependence of youths' activity patterns on adult household members, records pertaining to respondents younger than 19 years of age were filtered from the dataset leaving 15,396 person-days in the analysis.

Several activity classifications in the dataset have been highlighted as being social in nature, or having a social potential. They are: in-home visiting, in-home amusements and out-of-home amusements. The in-home visiting classification includes the in-home casual entertaining and in-home formal entertaining categories. "In-home" implies that the activity took place within the home of the respondent or someone else's home, whereas "out-of-home" implies that the activity location was not inside the respondent's or anyone else's home. The visiting activities by their nature imply some level of social interaction whereas the amusement activities may or may not have been performed in a social setting. The in-home amusements activity classification includes television watching, and may even be somewhat asocial in nature. Consequently, factors related to increased participation in this activity may be interpreted as having a negative impact on social contact. The out-of-home amusements category is very broad, encompassing activities such as going to the movies, a bar or cafe that may be performed in both social and asocial contexts. While these activity categories are quite specific, we prefer this to more general categories which may confound the results through activity aggregation. Given the absence of "with-whom" characteristics of trips and activities in the database (a common feature of all but a handful of existing datasets), we have selected those activities most likely associated with social behaviour even though some ambiguity with respect to the presence of others remains.

3.3 Methods

The production of the dataset was fairly straightforward and consisted of simple database queries and variable transformations performed in Microsoft Access and SPSS. First, respondents had to be classified in terms of their degree of reliance on a car for their mobility. Since traditional definitions of automobile dependence pertain to urban areas, and not the individuals within, an appropriate method of categorization was not obvious (Kenworthy & Laube, 1999). Interestingly, recent work by Zhang (Zhang, 2006) supports the idea that individuals themselves can become automobile dependent through his formulation of the captured driver, especially when they have no other feasible transportation choices. Keeping in mind that the objective of the analysis is not to investigate why people use different transport modes, auto-reliance can be thought of as a 'revealed preference'. The reason for using the automobile – being captive, or plainly having a strong preference – is not of primary concern, but rather the impacts of effectively being auto-reliant on activity participation. For the exploratory analysis to follow, the percentage of all trips by mode for each record was computed, and those individuals which use personal automobiles as a driver or as a passenger for 100% of their daily trips were coded as 'auto-reliant'. All other respondents are deemed 'mixed-mode'.

Both descriptive and multivariate methods are used to study the impact of automobility on social activities. In the first phase of analysis, mean daily durations amongst auto-reliant and mixed-mode respondents are tested for significant differences using a *t*-test while crudely controlling for the urban/suburban dichotomy. The statistical significance level associated with this *t* value is the probability that under the null hypothesis of equal means the difference observed could occur by chance.

In the second stage of analysis, ordered probit and multivariate regression is used to simultaneously control for the impacts of many factors and covariates while predicting frequency and duration of activities respectively. Factors are transformed into a series of binary indicator variables and then entered into ordered probit and multivariate regression models. In the case of the duration model, factors are multiplied by the auto-reliant indicator to produce a set of interaction variables. These interaction terms are designed to capture non-uniform impacts of automobile reliance amongst different types of sampled respondents.

3.4 Results and discussion

3.4.1 Descriptive and Inferential Statistics

Figure 3-1 shows the distribution of the automobile share variable. The database contains 15,396 person/day records of which 8,870 (58%) use their automobile as an exclusive means of travel on the sampled day. The dominance of the auto-reliant mode is clearly depicted and it drives our decision to consider the 100% auto-reliant respondents as a categorical factor. Even if we extended this group to include all individuals who used the car more than 51% of the time, it would only add an additional 18% of the population to the group. Essentially, the bar-chart shows 3 different types of automobile users: the automobile-reliant, the automobile-free, and the mixed-auto users. For the analysis to follow, the automobile-free and mixed-auto groups have been collapsed and are referred to as the mixed-mode group below.

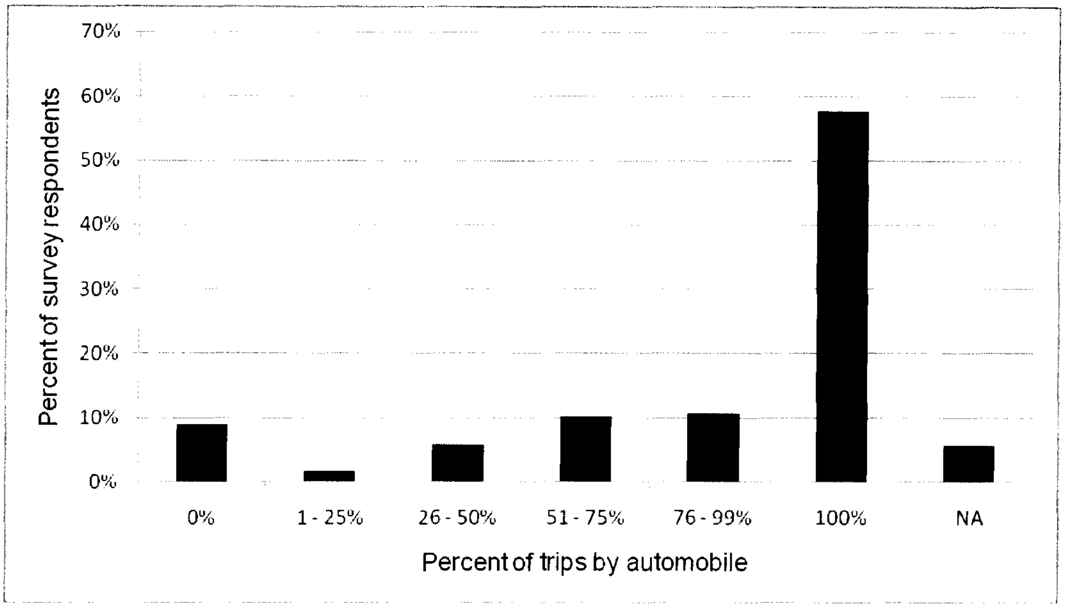

Figure 3-1 Percent of Trips by Automobile by Percent of Respondents

Descriptions of demographic and activity behaviour characteristics (in Table 3-1 and Table 3-2) can be used to characterize differences between the two automobile-use groups. Although there are several statistically significant differences, in general the two groups have quite similar socio-economic characteristics. Along demographic dimensions, the automobile reliant group contains lower percentages of females, young adults and the elderly as compared to the mixed-mode respondents. They are also less likely to live in apartment buildings, to live in the core metropolitan area, and belong to households with shorter tenures than mixed-mode respondents. Economically, automobile reliant respondents are more likely to be employed and have higher household incomes. These differences are unsurprising since automobile use is certainly related to automobile ownership, a more common characteristic of more affluent suburban households. However, the two groups are actually quite similar socio-economically which supports the notion that automobile use, not its demographic determinants, is responsible for the observed discrepancies in activity behaviour between the two groups seen in Table 3-2.

Table 3-1 Demographic characteristics of mixed mode and auto-reliant respondents

	Mixed Mode (n=6525)	Auto Reliant (n=8870)	t-score
Age			
19-24 years	8.6%	5.2%	8.39***
25-64 years	72.6%	78.6%	8.75***
65 or more years	18.8%	16.2%	4.35***
Gender			
Female	52.9%	51.2%	2.08**
Household income			
$60,000 or more	18.1%	21.2%	4.85***
$40,000 - $59,999	19.9%	24.8%	7.22***
$20,000 - $39,999	27.6%	25.6%	2.77***
$0 - $19,999	16.0%	9.4%	12.37***
Don't Know/Refusal	18.4%	18.9%	0.76
Employment status			
Full-time worker	55.8%	61.2%	6.72***
Part-time worker	10.3%	11.0%	1.31
Full-time homemaker	5.2%	6.9%	4.17***
Retired	19.4%	15.7%	6.03***
Not employed	7.2%	4.1%	8.34***
Don't Know/Refusal	2.0%	1.1%	4.51***
Race			
White/Caucasian	94.0%	94.9%	2.25**
Black/African American	1.4%	1.1%	1.8*
Hispanic/Mexican or Native American	1.7%	1.4%	1.44
Some other race	2.9%	2.7%	0.85
Dwelling type			
Single family	72.9%	85.0%	18.63***
Apartment	22.9%	11.2%	19.85***
Some other type	4.2%	3.9%	0.91
Household size			
Less than 5 members	98.5%	97.2%	5.38***
More than 5 members	1.5%	2.8%	5.06***
Years in home			
More than 1 year	86.7%	90.5%	7.45***
6 months to 1 year	6.7%	5.0%	4.64***
Less than 6 months	6.6%	4.5%	5.58***
Geographic Stratum			
Not Multnomah County	27.2%	41.3%	18.32***
Multnomah County	66.1%	54.0%	15.15***
Sample Enrichment (Park-n-ride users)	6.7%	4.6%	5.55***
½ mile to light rail			
Yes	4.9%	5.4%	1.38

*$p<0.1$, **$p<0.05$, ***$p<0.01$

Table 3-2 Activity durations and participation rates of mixed mode and auto reliant respondents

Activity	**Mixed Mode[a] (n=6523)**	**Auto Reliant[a] (n=8870)**	**B**	**C**
1.1 Meals	110 (84.15%)	103 (85.67%)	1.8%	-6.5%
1.2 Work	448 (42.1%)	475 (50.41%)	**19.7%**	6.2%
1.3 Work-related	264 (8.99%)	185 (7.83%)	**-12.9%**	**-29.8%**
1.4 Shopping (general)	66 (30.84%)	68 (33.1%)	7.3%	3.1%
1.5 Shopping (major)	66 (1.17%)	89 (1.1%)	-6.4%	**35.3%**
1.6 Personal Services	55 (4.5%)	55 (3.38%)	**-25.0%**	-1.1%
1.7 Medical care	107 (4.09%)	82 (4.74%)	**16.0%**	**-23.3%**
1.8 Professional services	99 (0.76%)	41 (0.69%)	-8.8%	**-58.1%**
1.9 Household or personal business	75 (10.41%)	70 (10.64%)	2.1%	-6.1%
2.0 Household maintenance	183 (38.99%)	193 (40%)	2.5%	5.5%
2.1 Household obligations	132 (8.16%)	147 (9.49%)	**16.2%**	**11.7%**
2.2 Pick-up/Drop-off passengers	17 (11.24%)	19 (16.43%)	**46.1%**	6.0%
3.1 Visiting	175 (24.8%)	155 (20.4%)	**-17.8%**	**-11.8%**
3.2 Casual entertaining	173 (1.45%)	197 (1.01%)	**-30.3%**	**13.9%**
3.3 Formal entertaining	182 (0.99%)	184 (0.83%)	**-16.3%**	0.9%
4.1 School	294 (7.35%)	280 (4.88%)	**-33.7%**	-4.8%
4.2 Culture	141 (1.59%)	155 (1.04%)	**-34.2%**	**10.2%**
4.3 Religion/Civil Services	138 (4.48%)	141 (5.18%)	**15.5%**	2.7%
4.4 Civic	152 (2.62%)	174 (2.11%)	**-19.1%**	**13.9%**
4.5 Volunteer work	163 (1.19%)	153 (1.44%)	**20.7%**	-6.0%
5.1 Amusements (in-home)	221 (71.74%)	212 (75.42%)	5.1%	-3.9%
5.2 Amusements (out-of-home)	190 (12.18%)	178 (8.73%)	**-28.3%**	-6.2%
5.3 Hobbies	170 (9.8%)	186 (9.28%)	-5.3%	8.9%
5.4 Exercise/Athletics	108 (13.65%)	124 (9.31%)	**-31.8%**	**15.1%**
5.5 Rest and relaxation	175 (28.83%)	172 (22.61%)	**-21.6%**	-1.9%
5.6 Spectator athletic events	162 (1.04%)	161 (1.3%)	**25.5%**	-0.2%
9.0 Incidental trip	31 (18.23%)	36 (13.23%)	**-27.4%**	**15.9%**
9.1 Tag along trip	81 (0.44%)	63 (0.29%)	**-34.1%**	**-22.7%**
9.2 Commute	33 (42.17%)	28 (50.14%)	**18.9%**	**-15.2%**

[a] Average daily duration in minutes for those respondents that participated. The percentage of respondents that participated is in parenthesise.
B Percentage participation difference between Mixed-Mode and Auto Reliant respondents.
C Percentage duration difference between Mixed-Mode and Auto Reliant respondents.

The second and third columns of Table 3-2 contain the average daily durations in minutes and participation rates (in brackets) of mixed mode and auto reliant respondents respectively. The fourth and fifth columns show percentage difference between the two groups. Differences greater than ±10% are in bold. With few exceptions, differences between participation rates are far more pronounced than those in average durations. Interestingly, participation rates for the auto reliant group for activities such as visiting & entertaining (20.4%), cultural (1.0%), civic (2.1%), out-of-home amusements (8.7%), exercise (9.3%), and rest and relaxation (22.6%) are between 15% and 35% smaller than those for the mixed mode respondents. This is complemented by increased rates in work activities (50.4%), household obligations (9.5%), religious/civil services (5.2%) and volunteer work (1.4%). Given a finite amount of time in a day, time spent on one activity necessarily reduces the amount of time available for another. However, lacking further investigation it is unclear whether (a) the two groups differ in how they value the relative utilities of each activity, evidence of heterogeneous preferences; (b) mobility and accessibility constraints affect activity choices; or (c) automobile use is acting as a proxy for a life-style or a life-cycle stage.

As alluded to above, one potential question raised by this classification concerns whether or not automobile reliance acts as a proxy for other socio-economic or spatial factors. For example, we know that automobile use is associated with higher incomes and suburban living, and it may be that these factors and not automobile use are associated with reduced social interaction. The descriptive statistics in Table 3-3 show that the auto-reliant respondents engage in less in-home visiting and out-of-home amusement activities, and are more likely to participate in in-home amusements compared to the mixed mode respondents. It is possible that automobile use is acting as a proxy for a suburban lifestyle, and one way to dispel this hypothesis is to further divide the sample population into urban and suburban dwellers. Doing so essentially holds the impact of general meso-scale location constant, and the results illustrate that within a given development context, the automobile reliance factor still has a strong impact on both activity participation rates and durations. The *t*-tests indicate that automobile reliance has a significant and negative impact on in-home visiting and out-of-home amusement participation rates for suburban and urban respondents. Auto-reliance seems also to reduce the average duration of visiting and in-home amusement durations for all respondents, and out-of-home amusements for the suburban respondents. This variation in strength and direction of impact with respect to urban form begs the question of how the effects of automobile reliance on social behaviour interact with other socio-economic and contextual factors.

Table 3-3 Activity participation rates and durations by automobile reliance and urban context

	Activity Participation Rate (activities per day)			Activity Duration (minutes per day)		
	Mixed Mode	Auto Reliant	Difference of means P(t)	Mixed Mode	Auto Reliant	Difference of means P(t)
In-home Visiting						
All Respondents	0.352	0.273	< 0.001	180.3	161.3	0.001
Suburban Respondents	0.354	0.265	< 0.001	186.4	164.5	0.002
Urban Respondents	0.352	0.3	0.009	169.4	151.7	0.042
In-home Amusements						
All Respondents	1.186	1.156	0.069	220.7	212.1	0.001
Suburban Respondents	1.181	1.153	0.153	221.7	212.6	0.005
Urban Respondents	1.193	1.164	0.345	219	210.4	0.083
Out-of-home Amusements						
All Respondents	0.14	0.099	0.041	189.7	177.9	0.208
Suburban Respondents	0.13	0.097	< 0.001	206.4	179.7	0.033
Urban Respondents	0.158	0.106	< 0.001	165.1	172.4	0.581

3.4.2 Multivariate Analysis

As illustrated above, a difference of means test can be used to determine if exclusive use of automobile significantly impacts the activity rates and durations within specific factorial subgroups. Multivariate models are used to simultaneously investigate the impact of automobile use while accounting for the simultaneous impacts of a large number of factors. Ordered probit models are used to explore activity participation and then ordinary least squares regression models with interaction terms are used to explore activity durations amongst those who participated. Since this work intends to explore the process and assist in hypothesis building, a large selection of variables are entered into the models in the anticipation that lack of significance in the coefficients will be as revealing as its presence.

Table 3-4 Ordered probit results for visiting and amusement episode counts

	In-Home Visiting	In-Home Amusement	Out-of-Home Amusement
Summary Statistics			
N	15396	15396	15396
L*(c)	-8391.9	-16149.6	-4140.5
L*(β)	-7884.7	-15346.2	-3781.8
-2[L*(c) -L*(β)] (chi-square, 30 df)	1014.4*	1607.0*	717.5*
Nagelkerke-R^2	0.086	0.108	0.094
Coefficients	**Beta (P)**	**Beta (P)**	**Beta (P)**
Auto Reliant (Yes = 1)	-0.10 (0.000)	0.06 (0.001)	-0.14 (0.000)
Covariates			
Commute duration (mins)	0.001 (0.209)	-0.002 (0.000)	0.002 (0.068)
Work duration (mins)	-0.001 (0.000)	-0.001 (0.000)	-0.001 (0.000)
Day of week			
Monday to Thursday (base)			
Friday	0.15 (0.000)	-0.06 (0.014)	0.30 (0.000)
Weekend	0.19 (0.000)	0.03 (0.243)	0.24 (0.000)
Employment status			
Full-time worker (base)			
Part-time worker	0.02 (0.567)	-0.03 (0.360)	-0.08 (0.118)
Full-time homemaker	0.04 (0.395)	0.06 (0.167)	-0.23 (0.000)
Retired	0.02 (0.611)	0.24 (0.000)	-0.28 (0.000)
Not employed	-0.06 (0.216)	0.04 (0.398)	-0.09 (0.151)
Don't Know/Refusal	-0.22 (0.018)	-0.17 (0.025)	0.11 (0.281)
Age			
24-64 years (base)			
19-24 years	0.23 (0.000)	-0.19 (0.000)	0.21 (0.000)
65 or more years	-0.03 (0.394)	0.22 (0.000)	-0.09 (0.089)
Gender			
Male (base)			
Female	0.07 (0.002)	-0.14 (0.000)	-0.07 (0.015)
Race			
White/Caucasian (base)			
Black/African American	0.06 (0.575)	0.06 (0.458)	-0.05 (0.677)
Hispanic/Mexican or Native American	0.06 (0.481)	0.06 (0.423)	0.19 (0.072)
Some other race	0.03 (0.704)	0.00 (0.945)	-0.09 (0.330)
Season			
Spring (base)			
Fall	-0.06 (0.085)	0.17 (0.000)	-0.38 (0.000)
Winter	-0.05 (0.064)	0.24 (0.000)	-0.26 (0.000)
Geographic Stratum			
Not Multnomah County (base)			
Multnomah County	0.05 (0.055)	-0.02 (0.338)	0.13 (0.000)
Sample Enrichment (Park-n-ride users)	-0.03 (0.584)	0.00 (0.910)	0.11 (0.110)

Table 3-4 Continued

Coefficients	Beta (P)	Beta (P)	Beta (P)
Household size			
Less than 6 members (base)			
More than 5 members	-0.07 (0.337)	-0.02 (0.779)	-0.25 (0.027)
Household income			
$60,000 or more (base)			
$40,000 - $59,999	0.08 (0.020)	0.07 (0.009)	0.00 (0.977)
$20,000 - $39,999	0.15 (0.000)	0.06 (0.020)	0.00 (0.944)
$0 - $19,999	0.14 (0.001)	0.20 (0.000)	-0.12 (0.037)
Don't Know/Refusal	0.03 (0.418)	0.01 (0.766)	0.06 (0.225)
Years in home			
More than 1 year (base)			
6 months to 1 year	-0.04 (0.386)	-0.05 (0.179)	0.09 (0.131)
Less than 6 months	-0.04 (0.448)	0.05 (0.247)	0.15 (0.016)
½ mile to light rail			
No (base)			
Yes	0.06 (0.217)	0.07 (0.099)	-0.08 (0.235)
Dwelling type			
Single family (base)			
Apartment	0.05 (0.155)	0.09 (0.001)	0.10 (0.014)
Some other type	-0.01 (0.906)	0.14 (0.003)	0.11 (0.119)
*Threshold***			
0	0.64 (0.000)	-0.67 (0.000)	0.97 (0.000)
1	1.60 (0.000)	0.56 (0.000)	
2		1.42 (0.000)	

* Significant at p<0.01;
** Episode classes: visiting 0, 1, 2 or more episodes; in-home amusements 0, 1, 2, 3 or more episodes; out-of home amusements 0, 1 or more episodes

3.4.2.1 Automobile Reliance and Social Activity Generation

Ordered probit regression is appropriate for estimating ordinal, limited dependent data, and is used within transportation research for activity and trip generation models (Scott & Kanaroglou, 2002; Paez, Scott, Potoglou, Kanaroglou, & Newbold, 2007). To ensure a healthy number of observations in each activity episode interval, the number of daily activity episodes per respondent is regrouped into more suitable classes. The results of the probit analysis are reported in

Table 3-4. Likelihood ratio tests reject with significance the null-hypothesis that all parameters other than the constants equal zero.

The set of variables used in the probit regressions can be found in the first column of Table 3-4. In addition to the indicator variables, two continuous covariates, work duration and commute duration, were included in the model. Work duration in particular is a time constraint that will likely impact the participation in and duration of social activities (Golob & McNally, 1997; Srinivasan & Bhat, 2005). Commute duration is included to differentiate between the impacts of automobile reliance and longer commute times. Finally, preliminary data analysis, excluded here for the sake of brevity, led us to aggregate factors with similar characteristics, such as in the race and household size categories. It is worth noting that since most of the independent variables are binary, their coefficients can be directly compared in terms of their magnitude and polarity. Likewise, the coefficients of the two duration variables can be compared since they are both measured in minutes.

Auto reliance. The main result of this analysis is the coefficient for automobile reliance. After controlling for other important confounding variables, in particular commute and work time, the effect of this indicator variable seems to support the hypothesis that respondents who use a car for all their mobility needs in the timeframe analyzed are less likely to perform the activities analyzed. According to the model results, automobile reliance has a strong negative impact on the probability to participate in more in-home visiting and out-of-home amusement activities, but a positive effect on in-home, and potentially asocial, amusements. Given the ambiguity of the precise social nature of these activities it is not possible to draw more conclusive inferences. However, if truly social, these results support the notion that automobility is associated with more asocial and sedentary lifestyles.

Time constraints and day of week. There are a couple surprises in the results with respect to the signs of the remaining coefficients. For example, whereas work duration uniformly decreases the propensity to participate in all three activities, longer commute duration increases the tendency for out-of-home amusements but makes in-home amusements less likely. Visiting and out-of-home amusements are more likely to occur on Fridays and over weekends, while the effect on in-home amusements is more ambiguous.

Employment. Interestingly, the employment status variables are amongst the least significant factors in the model. Being retired has a significant positive effect on in-home amusements and a negative effect on out-of-home amusements. While retirement is associated with having more free time, it is also associated with having less mobility, at least amongst the elderly, and the effect of this mobility constraint is apparent in the sign of the coefficient. Contrastingly, automobile reliance is conventionally associated with increased mobility, however, this increased mobility fails to positively impact the likelihood to socialize.

Age. Similar to the findings with retirement, we find that the elderly (and less mobile) are less likely to perform social activities, while the young (and more mobile) are more likely.

Season. Socializing is significantly less likely in the fall and winter, as compared to spring. The coefficients, while significant, are very small for visiting, but are quite strong for the amusement categories. Consistent with common sense perceptions of the impact of colder weather, fall and winter have a strong positive impact on in-home amusements, and a negative effect on out-of-home amusements.

Geographic Stratum. We find that respondents living in Multnomah County, which contains the urban core of Portland, are significantly more likely to socialize than those in the satellite counties, thus confirming conventional theories concerning urban form and reduced social contact.

Household Income. The results show that respondents from lower income families are more likely to perform in-home activities (visiting and amusements) and less likely to perform out-of-home amusements. If we assume that in-home activities cost less than out-of-home activities, then it would make sense that lower-income individuals perform more of them.

Other findings.

- Individuals who are new to their homes are more likely to perform out-of-home amusements.

- Apartment dwellers have increased tendencies to perform all three classes of activities compared to those in houses.
- Females are more likely to visit or be visited, and less likely to participate in amusement activities.
- Race, household size and proximity to light-rail do not seem to impact activity participation significantly.

3.4.2.2 Automobile Reliance and Activity Durations

Linear regression is the modelling framework selected for this analysis. Through the use of indicator variables and interactions, the modifying effect of automobile reliance on each factor level can be determined. Despite issues of heteroskedasticity and non-normality of the error terms, a linear equation is deemed sufficient at this early stage of inquiry for exploring the multivariate relationships that exist between the independent variables and the daily durations of the three activities under analysis. Violating the normality assumption leads to consistent but non-efficient estimates so we must heed caution when drawing conclusions regarding statistical confidence. Furthermore, in order to avoid the confounding effect of zero measures on the dependent variables each of these models is based on the sub-sample of the population that participated at least once in the respective activity. Thus the estimates of the coefficients pertain solely to those that do participate.

The results of the regression analyses are in Table 3-5. The main coefficient and the interaction coefficient for each factor as well as their associated significance levels are reported. Interpretation of the dummy variable coefficients is straightforward; they simply represent a change from the constant in minutes. For the continuous covariates, the standard interpretation of a regression coefficient applies.

Despite similarities amongst the processes being modelled, goodness-of-fit varies quite drastically with adjusted R^2's ranging from 0.44 to 0.09 for in-home and out-of-home amusements respectively. The R^2 for in-home visiting is 0.15, which may suggest that these models are more appropriate for predicting asocial versus social behaviour. In any event, all the models pass the F-test, indicating that the data used are significant covariates, and thus appropriate for inference regarding activity duration.

Table 3-5 Results of linear regression for activity durations

	In-Home Visiting		**In-Home Amusement**		**Out-of-Home Amusement**	
Summary Statistics						
N	3665		11372		1570	
Adjusted R^2	0.145		0.438		0.097	
S.E.E.	156.2		106.2		176.7	
ANOVA F-test	11.2 (p<0.0001)		146.5 (p<0.0001)		3.8 (p<0.0001)	
	Main Coefficient (*p*)	**Auto Reliance. Interaction (*p*)**	**Main Coefficient (*p*)**	**Auto Reliance Interaction (*p*)**	**Main Coefficient (*p*)**	**Auto Reliance Interaction (*p*)**
Constant	**191.2 (0.000)**	**-103.5 (0.000)**	**68.9 (0.000)**	11.7 (0.198)	**197.7 (0.000)**	-69.4 (0.116)
Covariates						
Count of episodes*	**54.0 (0.000)**	17.9 (0.042)	**91.1 (0.000)**	0.6 (0.795)	**48.1 (0.001)**	6.9 (0.742)
Commute duration (mins)	-0.19 (0.208)	0.03 (0.926)	**-0.17 (0.010)**	0.09 (0.350)	-0.27 (0.546)	0.17 (0.786)
Work duration (mins)	**-0.22 (0.000)**	**0.10 (0.003)**	**-0.10 (0.000)**	0.01 (0.466)	**-0.21 (0.000)**	0.04 (0.548)
Day of week						
Monday to Thursday (base)						
Friday	1.8 (0.859)	19.4 (0.171)	**8.6 (0.044)**	-2.3 (0.686)	-6.7 (0.696)	28.0 (0.248)
Weekend	-3.9 (0.671)	**42.3 (0.001)**	**9.5 (0.021)**	-1.0 (0.851)	-26.6 (0.091)	**50.9 (0.028)**
Employment status						
Full-time worker						
Part-time worker	**-36.1 (0.005)**	20.1 (0.257)	**-20.3 (0.000)**	10.2 (0.165)	**-44.7 (0.032)**	39.2 (0.213)
Full-time homemaker	**-56.9 (0.001)**	**50.5 (0.023)**	**-19.5 (0.011)**	10.7 (0.273)	-46.5 (0.185)	-6.0 (0.893)
Retired	**-49.2 (0.001)**	16.5 (0.414)	-0.1 (0.992)	11.1 (0.197)	**-102.5 (0.000)**	55.3 (0.152)
Not employed	**-66.2 (0.000)**	**72.8 (0.001)**	**17.8 (0.009)**	**-24.8 (0.012)**	-18.7 (0.422)	5.8 (0.878)
Don't Know/Refusal	**-55.5 (0.044)**	60.8 (0.165)	**-26.5 (0.033)**	17.5 (0.340)	**85.9 (0.026)**	-21.9 (0.693)
Age						
24-64 years (base)						
19-24 years	**95.9 (0.000)**	**-55.5 (0.005)**	**12.1 (0.055)**	-7.3 (0.417)	**41.3 (0.034)**	-44.0 (0.188)
65 or more years	-13.1 (0.336)	15.8 (0.387)	8.1 (0.154)	-1.7 (0.818)	**105.3 (0.000)**	-44.2 (0.220)

Table 3-5 Continued

	In-Home Visiting		In-Home Amusement		Out-of-Home Amusement	
	Main Coefficient (p)	**Auto Reliance. Interaction (p)**	**Main Coefficient (p)**	**Auto Reliance Interaction (p)**	**Main Coefficient (p)**	**Auto Reliance Interaction (p)**
Gender						
Male (base)						
Female	**-16.4 (0.041)**	3.8 (0.734)	**-15.8 (0.000)**	3.0 (0.483)	**-26.6 (0.045)**	1.4 (0.942)
Race						
White/Caucasian (base)						
Black/African American	-3.6 (0.899)	-59.3 (0.223)	1.9 (0.881)	-36.5 (0.044)	-54.6 (0.400)	**148.1 (0.083)**
Hispanic/Mexican or Native American	**-54.9 (0.086)**	**92.8 (0.025)**	**44.3 (0.000)**	**-39.4 (0.015)**	24.2 (0.548)	3.5 (0.955)
Some other race	34.0 (0.124)	-23.4 (0.465)	2.3 (0.810)	-5.9 (0.638)	-19.9 (0.608)	-28.3 (0.626)
Season						
Spring (base)						
Fall	**60.2 (0.000)**	**-49.8 (0.002)**	**22.2 (0.000)**	-5.9 (0.345)	**62.6 (0.008)**	-43.1 (0.202)
Winter	**26.7 (0.002)**	-18.9 (0.116)	**28.2 (0.000)**	-2.8 (0.542)	8.1 (0.599)	13.9 (0.522)
Geographic Stratum						
Not Multnomah County (base)						
Multnomah County	**-17.0 (0.053)**	14.3 (0.224)	-0.2 (0.964)	-5.9 (0.203)	**-27.0 (0.090)**	**44.0 (0.039)**
Sample Enrichment (Park-n-ride users)	-8.5 (0.646)	26.9 (0.298)	5.4 (0.428)	-0.3 (0.971)	-30.2 (0.304)	46.0 (0.288)
Household size						
Less than 6 members (base)						
More than 5 members	**-96.2 (0.005)**	59.0 (0.152)	1.6 (0.906)	-7.4 (0.639)	**110.6 (0.085)**	-59.8 (0.463)

Table 3-5 Continued

	In-Home Visiting		**In-Home Amusement**		**Out-of-Home Amusement**	
	Main Coefficient (p)	**Auto Reliance. Interaction (p)**	**Main Coefficient (p)**	**Auto Reliance Interaction (p)**	**Main Coefficient (p)**	**Auto Reliance Interaction (p)**
Household income						
$60,000 or more (base)						
$40,000 - $59,999	**-42.7 (0.001)**	**44.5 (0.011)**	7.3 (0.158)	-6.1 (0.346)	-11.4 (0.599)	-6.4 (0.827)
$20,000 - $39,999	**-30.4 (0.012)**	**31.8 (0.054)**	**14.5 (0.003)**	-7.3 (0.246)	-4.4 (0.828)	-7.8 (0.781)
$0 - $19,999	-22.8 (0.102)	1.2 (0.953)	**27.1 (0.000)**	**-18.5 (0.019)**	0.8 (0.974)	-40.8 (0.292)
Don't Know/Refusal	**-31.6 (0.023)**	17.3 (0.351)	**14.9 (0.006)**	0.9 (0.899)	32.3 (0.146)	-26.0 (0.391)
Years in home						
More than 1 year (base)						
6 months to 1 year	**-36.7 (0.028)**	**62.7 (0.007)**	-5.9 (0.383)	-0.5 (0.954)	3.4 (0.880)	-21.7 (0.575)
Less than 6 months	15.7 (0.328)	-13.8 (0.560)	0.7 (0.921)	-2.9 (0.755)	-15.1 (0.562)	26.3 (0.474)
½ mile to light rail						
No (base)						
Yes	-14.7 (0.378)	-2.5 (0.913)	-9.7 (0.195)	**23.3 (0.013)**	33.0 (0.265)	-54.6 (0.207)
Dwelling type						
Single family (base)						
Apartment	0.6 (0.950)	3.0 (0.848)	-0.3 (0.943)	**10.0 (0.096)**	-1.4 (0.934)	28.7 (0.281)
Some other type	2.9 (0.870)	-8.7 (0.742)	**15.8 (0.041)**	-6.1 (0.545)	2.5 (0.932)	-23.2 (0.621)

* Count of the number episodes in the activity class pertaining to the model

According to the models, the respondents with baseline characteristics on average spend 190 minutes visiting, 70 minutes on in-home amusements and 200 minutes on out-of-home amusements on days when they participate in said activities. The baseline respondents are those who filled out surveys from Monday to Thursday during the spring, are full-time workers, are aged 24 to 65 years, are Caucasian males, are living outside of Multnomah County and not within half a mile from a rail station, and live in single-detached high-income households with 5 or fewer members for longer than a year. Departures from this configuration of factors results in estimated durations that can be computed simply by summing the coefficients corresponding to the appropriate factors. The following interpretation of parameters follows the order of the factors in Table 3-5.

Automobile reliance. Contrary to the findings in the participation models, this variable has a less pronounced impact (in terms of significance) on durations of the amusement activities. This suggests that automobile use is a more reliable predictor of whether or not an individual participates, but amongst those that do participate, it has a muted impact on duration. Automobile reliance does however significantly reduce the duration of in-home visiting. Given that visiting is always done in a social setting, this lends credence to the theoretical impact of automobility on time spent socializing. In addition to the main effects, the phenomenon is explored through its interaction effects on the remaining independent variables to tease out the variable impact of automobile reliance according to the characteristics of the trip-maker and her activity profile.

Covariates. Durations of all social activities are negatively impacted by longer work duration. This is consistent with the time budget constraint theory. Interestingly however, the negative effect of work duration on visiting duration is significantly lessened for automobile-reliant respondents.

Day of week. Automobile reliance inflates visiting and out-of-home amusement durations on weekends. This may suggest that automobile-reliant respondents are more likely than mixed-mode respondents to perform social activities on the weekend, ostensibly due to the difficulty of reaching dispersed social contacts during busier weekdays.

Employment status. Compared to full-time workers, all other employment statuses exert significant negative impacts on visiting durations. This result is puzzling since full-time workers have less free time than the other groups to socialize. We do observe that automobile reliance has a significantly positive effect on visiting times for home-makers and those otherwise not employed. Taken together with the first result, we may be observing a tendency for people anchored at home to socialize less than those anchored at work during the day. Moreover, for those anchored at home, automobile use is associated with more in-house visiting.

Age. The younger respondents, aged 19 to 25, spend more time on all three activities as compared to the other age groups. Automobile-enabled youth however spend one hour less time visiting. Interestingly, there does not seem to be an effect of automobile reliance on the other age groups or activity categories.

Race. Quite unexpectedly automobile reliance increases visiting durations for Hispanic and Native-Americans and decreases durations of in-home amusements. It also significantly increases durations of out-of-home amusements for African-Americans.

Season. Fall and winter activity durations are significantly larger than those recorded in the spring stratum but less so for automobile reliant respondents. The modifying effect of automobile reliance may indicate the drivers' relative indifference to seasonal weather fluctuations compared to mixed-mode respondents.

Geographic stratum. Automobile reliance has a significant positive impact on out-of-home amusements for those living in Multnomah County, the county containing Portland's city center.

Household income. Automobile reliance has a significantly positive influence on visiting durations for middle-income households, and a negative (but statistically insignificant) influence on both amusement categories for all households as compared to the high-income reference group.

Years in home. Except for a negative influence of shortened tenure (6 months to 1 year) on visiting durations, the factors in this category are insignificant. Interestingly, the automobile reliance for this group significantly increases visiting durations, perhaps indicative of their need to travel to their previous neighbourhoods to meet with their social contacts.

Gender. Females have shorter durations in all three classes of activities, and automobile reliance seems not to influence this trend.

The preceding passages provide a rich contextual description of the variations in durations across many socio-economic factors with specific attention being paid to the modifying impact of automobility. The strongest negative impact of automobile reliance is on in-home visiting durations, but it has secondarily been shown to interact positively and negatively with many other factors, and the existence of this variation is indicative of a complex relationship between automobile use and duration of social activities.

One possible source of variation is the complex system of constraints exhibited by the independent variables in the model. Some factors, such as work duration, are indicative of increased time constraints and we see that automobile use plays a positive role in extending interaction times. Other factors are indicative of mobility constraints, such as the youth and elderly factors. Again, the model confirms expectations, and automobile use enhances the duration capabilities of the elderly, and decreases those of the youths. Still other factors, such as those in the race category, are affected to a surprisingly large degree by automobile use, and lacking further research no reasonable explanation for this variability can be put forward.

3.5 Conclusions

The objective of this paper has been to investigate the impact of automobile use on participation in and duration of activities with the potential for a social dimension, using the 1994 Household Activity and Travel Behavior Survey for Portland, Oregon. This research provides evidence to inform ongoing discourses in transport geography, travel behaviour, sociology of mobility, and social capital, regarding the impacts of automobility on social interaction. Using simple hypothesis testing procedures, the automobile reliant respondents with both urban and suburban locations of residence are found to participate in significantly fewer social activities. These results were confirmed by a series of multivariate regression models that control for a variety of demographic factors and time-use constraints. Ordinal probit analysis suggests that automobile reliant respondents tend to participate in fewer activities, while linear regression models indicate that automobile respondents have on average shorter activity durations. Furthermore, the effect of automobile reliance is moderated by a number of socio-economic factors.

Some limitations of the analysis that provide opportunities for further research must be discussed. First, this study represents a snapshot inquiry into the relationship between automobility and participation in activities with social components or potential thereof. The characteristics of the data constrain to some extent the breadth of our findings. Since our automobile reliance classification is based on Portland's two-day travel and time-use survey, an avenue for future work is the use of data covering a more extended time frame to allow the identification of car reliance or even car dependency with increased confidence. A second limitation of the data used is that social interactions are not explicitly captured in the questionnaire, and so our classification can at best identify activities likely to be social. To be fair though it should be noted that these data predate emerging focal interests in travel behaviour on social contact, networks, and influence (Axhausen, 2005; Carrasco & Miller, 2006; Dugundji & Walker, 2005; Páez, Scott, & Volz, 2008; Páez & Scott, 2007), and newer datasets, mindful of these emerging interests, are more likely to include richer descriptions of the social dimension of activities. The newest release of the General Social Survey of Canada for example, will offer some interesting possibilities in this regard since in addition to containing a far more detailed activity classification scheme it also has a special focus on social contacts and social networks. Given suitable data, additional measures of social well-being such as social capital and social network characteristics could be investigated.

With regards to future research, the following are possibilities for extending the investigation presented in this paper. First, more subtle ways to capture varying degrees of automobile dependency, including a multi-criteria classification scheme or a continuous measure of reliance could be devised. The bigger issue of endogeneity resulting from the same factors simultaneously influencing automobile reliance and social participation could be mitigated by estimating the likelihood of automobile use and activity participation simultaneously. Taking a systematic approach to studying the relationships between the social activities, through structural equation modelling or some other simultaneous equation approach would broaden the scope of the work by representing the trade-offs between time spent on various kinds of social activities. This would bring the research in line with econometric time-budget interpretations of activity behaviour (Kockelman, 2001). Other avenues to increase the technical sophistication of the analysis include the use of a discrete-continuous modeling approach to account for correlations between participation and duration outcomes. Multilevel models surface as an attractive alternative, especially to account for individual correlations across multiple day records. In general, a more sophisticated and theoretically succinct modelling framework, and models which exclude some variables shown here to be ineffectual, can be expected to improve the interpretability of the results.

In addition to providing evidence of hitherto unmeasured social costs of automobility, this research may further the agendas of other current discourses in transportation geography; namely socially sustainable transportation and social exclusion. Recently, scholars have recognized the need to develop a better understanding of the social impacts of transportation systems and individual's transportation choices. This argument is constructed under the directive of developing sustainable transportation systems, which by definition include social considerations, even if these considerations have often been secondary to the economic and environmental factors that are more frequently the focus of the literature (Boschmann & Kwan, 2008). In an effort to spark research interests, Boschmann and Kwan categorize socially sustainable transportation in terms of *social equity*, *social exclusion*, and *quality of life* (QoL). One unifying feature of Boschmann and Kwan's model of socially sustainable transport is that in order to quantify and analyze the impact of transportation on the three dimensions of social sustainability, transportation behaviour must be hypothesized to constrain activity patterns and the achievement of normative social goals. The research in this paper is therefore a tangible example of how quantitative socially sustainable transportation research can proceed.

Recent work has examined the policy implications derived by linking traditional geographic concepts of accessibility to the current fields of social sustainability and new mobilities (Farrington, 2007). In particular, social exclusion is a current policy issue tightly coupled to accurate portrayals of changing levels of accessibility and mobility. Kenyon's research on the follies of increasing personal mobility to achieve social inclusion is bolstered by the findings reported herein (Kenyon, 2003). While automobility augmented social activity participation amongst the elderly and low-income households, the broader impact was exclusionary. This corresponds with Kenyon's call for a more holistic approach to measuring the impacts of increasing levels of personal mobility.

While the scope of this paper is narrow by necessity - merely an investigation into the impact of automobile use on levels of participation in activities with a plausible potential for social interaction – it is applicable to broader research concerning sociological perspectives on automobility, social sustainability, and social exclusion. Whereas Sheller and Urry's theories of automobility provide a reasonable narrative for the occurrence of the measured phenomena, sustainability and social exclusion are sources of policy-oriented demand for continued research in this area.

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4 Transport and social exclusion: A time-use investigation of shopping participation in three Canadian cities

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4.1 Introduction

In recent years there has been an increased concern for the status of various groups in society thought to face mobility challenges. In some cases, interest has been triggered by broader changes in the demographic, economic, and social outlook of countries, which may impact the ability of some groups to fully satisfy their mobility needs. In particular, there is now a greater recognition of the possibility that some segments of the population, including the old, the disabled, as well as low-income and/or single parent households, may find themselves at disadvantage from a mobility perspective, and that this could negatively impact their ability to fully participate in all aspects of society (Páez & Scott, 2007; Mohammadian & Bekhor, 2008). In other words, there is a concern that transportation and mobility limitations can lead to the risk of social exclusion (Social Exclusion Unit, 2003).

While a precise and concise definition of social exclusion remains somewhat elusive, it broadly refers to the inability for people to participate fully in society. From an operational viewpoint – that is, a mobility and accessibility perspective – one quantifiable aspect of social inclusion is when people actually participate in the normal activities of daily life. Complete lack or even limited participation could be a matter of taste, or could be indicative of exclusionary patterns – especially if systematic trends are observed for various groups perceived to be at risk of poor (labor, education, cultural, etc.) participation outcomes. Early research into the transportation relevance for social exclusion in fact was motivated by the need to address specific social issues. For example, Church et al. (2000) note that in the case of London the information needs of policy makers led to a more explicit identification of the potential connection between transportation, accessibility, and social exclusion.

The Social Exclusion Unit in the UK (2003) further highlights the policy-making relevance of the issue in a report that identifies the links between transportation and social exclusion. This early work has provided useful information about the potential mechanisms of operation between mobility and social exclusion, and the role of transportation in enabling or constraining the facility with which individuals can partake of economic activities (e.g. employment and training opportunities), and daily life needs (e.g. access to food stores, financial, recreational, health, and other social services).

Conceptually, it is now recognized that social exclusion is a multifaceted concept. Kenyon for instance, identifies nine pertinent dimensions that affect exclusion: *economic, living space, mobility, organized political, personal, personal political, social networks, societal,* and *temporal* (see Kenyon 2003, Table 4-1); all aspects that interact in important ways with individual mobility, accessibility, and activity participation as the realization of accessibility. These dimensions and outcomes have been incorporated as key elements in analytical frameworks for the study of activity participation/inclusion for example by Páez et al. (Páez, Mercado, Farber, Morency, & Roorda, 2009), and other works over the past decade. In particular, compelled by the preliminary evidence provided by these and related works, a number of efforts have been directed at creating a broader empirical knowledge base to document the connections between transportation and exclusion (Hine, 2003). A secondary goal of many of these research efforts is to generate a better understanding of the implications of said connections, and inform decision makers about the role of policy to mitigate, reduce, or eliminate the negative effects of transportation-related exclusion (Preston & Raje, 2007).

Empirically and methodologically, recent studies have begun to fill the knowledge gap, both in terms of providing evidence of exclusion, and of producing indicators useful for policy analysis. Clarke et al. (2002) for example, investigate access to food retail provision, and derive accessibility indicators to identify the existence of food deserts in three British cities. Their findings illustrate the multi-dimensional nature of exclusion, and that competition between service providers is an important factor to consider when planning policy for increased accessibility. Casas (2007) applies the concept of accessibility to the case of individuals with disabilities in the Buffalo-Niagara region. Her research identifies a number of potential factors leading to reduced accessibility including disability type, income, and age, but she is cognizant that her method ignores time-budget and space-time constraints, issues to be addressed in this paper. Another more recent example is the method proposed by Páez et al. (2010) to calculate measures of relative accessibility deprivation. In an application to retail and fast food accessibility they highlight the fact that exclusion occurs at the intersection between mobility and the spatial patterns of activity locations, thus pure supply-side spatial constructs such as food desserts must be coupled with personal mobility measures in order to provide more sophisticated estimates of accessibility.

Along these lines, Church and Marston (2003) propose and implement a measure to evaluate the relative accessibility of individuals facing mobility challenges. Taking a relativistic approach, they reinforce the subjective and internalized nature of exclusion, requiring policy to be targeted toward and planned for specific sub-groups of the population. Schönfelder and Axhausen (2003) suggest employing activity spaces as measures of social exclusion and find that the number of unique locations at which activities take place is a more important measure of activity space than socio-economic factors. However, they failed to find significant differences between the activity spaces of at-risk subgroups and normal members of the population, suggesting both the importance of locality in exclusion studies, and that new measures of social exclusion, perhaps time-based, may be more telling than activity spaces. Rajé (2004) uses a case study from Oxford to demonstrate how social exclusion can be engineered, for example when transportation projects sever connections with the wider community. This reinforces the notion that barriers to inclusion may be physical, for example if they manifest themselves as dangerous pedestrian routes through car-oriented transport infrastructure. In addition, it is quite possible that some impacts are subjective, if these routes are unsightly or if there is a sense of loss on the part of the individuals affected. Investigating the subjective, McCray and Brais (2007) use a mixture of GIS and small-sample qualitative data to explore the reasons why low income women in a Canadian city are prevented from making desired trips. Their work attempts to map out the unmeasured subjective attitudes toward trip-making often missing from exclusion and accessibility papers.

An important characteristic of much of the research in the literature to date, including the papers cited above, is a central concern with the *spatial* aspects of transportation and accessibility. Bittman (2002) brings a different perspective to the problem when he states, in the context of participation in leisure activities, that "the ability to participate in leisure is the product of both access to leisure goods and services, and a sufficient amount of leisure time". This insight, of course, applies to a host of other activities besides leisure, and while research on the topic in the field of transportation has generated valuable information regarding access to opportunities, there have only been glimpses so far regarding the potential of more in depth investigations of the temporal dimension of mobility and exclusion. This is the case of Lyons (2003), who mirrors the views of Bittman when reflecting, in a paper that forms part of a special issue on

Transportation and Social Exclusion (Hine, 2003), that the combined effect of time use, management, and constraints, is one of five factors that govern the understanding and influences of exclusion. Likewise, Kenyon (2003) identifies time poverty as a one of nine dimensions of exclusion. These early pointers towards the relevance of time use perspectives notwithstanding, there are still very few examples of time use pattern analysis applied to social exclusion. This seems to be the case of the broader scientific literature (Garhammer, 1998; Bittman, 2002), and is certainly true in the specific case of transportation research, despite the increasingly central role that time use research has claimed in the study of travel behavior (Pendyala & Goulias, 2002; Bhat & Koppelman, 1999). To the best of our knowledge, the few examples of time use analysis applied to social exclusion in the transportation literature are, in addition to the more conceptual explorations of Jain and Guiver (2001), Kenyon and Lyons (2007) and Farber and Páez (2009).

In this paper, we adopt a time use perspective, and apply it to the analysis of shopping activities and the social exclusionary implications of time use patterns. In other words, in this paper we turn to the question of what are the temporal constraints that may affect activity participation. The time use perspective provides a valuable conceptual and analytical framework to discover possible barriers to inclusion by quantifying and comparing activity levels while controlling for socioeconomic and locational differences in the population (Harvey & Taylor, 2000; Goulias, 2002; Farber & Páez, 2009). There are several reasons why shopping activities for goods and services are germane to social exclusion research. First, shopping for groceries, pharmaceutical needs, and everyday items such as clothing are essential activities for sustaining life. Second, shopping is a primary social and leisure activity. Third, access to medical, financial, and government services is essential to the entire population but perhaps even more so to populations at risk. Finally, travel pertaining to shopping for goods and services represents a growing fraction of overall travel demand indicating the growing significance of this activity to the members of society.

4.2 Time Use Approaches

There is a growing awareness that the subtleties of accessibility, mobility and time constraints must be brought into the equation in order to derive a more complete representation of exclusion (Lucas & Nicholson, 2003; Cass, Shove, & Urry, 2005; Lyons, 2003). This necessitates an integrated approach to recognizing the individual constraints on mobility and accessibility with respect to activity patterns, socioeconomic status, demographics and time use. While previous research has made significant progress in terms of identifying the spatial characteristics of at-risk individuals, in other words, their location and surrounding opportunity landscape (Schönfelder & Axhausen, 2003; Casas, 2007; Páez et al., 2010), a time use approach can provide the complementary perspective of the temporal context of at-risk population segments.

Time use approaches have been used in sociological research for many decades to produce general indicators of living conditions (Dagfinn, 1978); to study gender and age inequalities (Frederick, 1995); economic outcomes and development (Minge-Klevana, 1980) and in comparisons over time and across nations (Robinson & Godbey, 1999).The link between time-use and transportation analysis was first hypothesized by Javeau (1972) who theorized a direct relationship between traffic density and the time constraint associated with compulsory travel. Since then, time-use approaches (often coupled with spatial approaches and deemed activity analysis) have been heralded by travel behavior researchers for their potential to modeling traffic demand management strategies in the post "model-it and build-it" era (Bhat & Koppelman, 1999; Pendyala & Goulias, 2002).

Proponents of behavioral travel analysis and models frequently state that the traditional Urban Transportation Modeling System (UTMS), due to its aggregate, trip-based nature, is no longer the best alternative to deal with the management and policy demands of contemporary transportation systems (McNally, 2000a; McNally, 2000b), or that UTMS fails to capture a required level of complexity such as household interactions (Scott & Kanaroglou, 2002), tours and trip chaining (Carrasco, Hogan, Wellman, & Miller, 2008; Ye, Pendyala, & Gottardi, 2007; Frank, Bradley, Kavage, Chapman, & Lawton, 2008), social influence and interaction (Dugundji & Walker, 2005; Páez & Scott, 2007), and full-day or multi-day travel patterns (Axhausen, Zimmermann, Schonfelder, Rindsfuser, & Haupt, 2002). A reason why the time use approach is appealing is that the individual or activity episode is the unit of analysis, which greatly facilitates the inclusion of any relevant contextual information.

Time use approaches share a vital connection with the activity-based approach to transportation analysis. This conceptual system of activity analysis in turn draws heavily from models of temporal-spatial behavior, notably time-geography (Hägerstrand, 1970; Miller, 2005; Neutens, Van de Weghe, Witlox, & De Maeyer, 2008), which part from the observation that space-time behaviour is conditioned by time budget constraints and the necessity to participate in activities at fixed locations. Thus much of the literature in this field focuses on modeling behaviour pertaining to activity generation and scheduling. Modeling activity patterns often necessitates simultaneous estimation of multiple dependent and interdependent variables such as participation rates and durations in various classes of activities and thus often represents or exploits the latest innovations in econometric modeling. Harvey (2004) provides an excellent introduction to the time-use approach to transportation behavior modeling, and Buliung and Kanaroglou (2007) comprehensively review the state of the art and practice in activity analysis.

Given the strength of the time-use approach in investigating a variety of transportation and behavior issues, it is quite surprising that more examples of its use in the exclusion literature are not existent. From an activity analysis viewpoint, there is a succinct rationale to support the notion that time-use is an integral part of the exclusion process, and that in turn, specific time-use outcomes can be indicative of exclusion. Of course, the true time-use indicator of exclusion (with respect to shopping) is the amount of unfulfilled shopping demand, the difference between the observed shopping duration and one's fulfillment threshold: the desired but not necessarily achieved shopping duration. Unfortunately this metric cannot be gauged from diary data alone; this data limitation among others is discussed in section 4.5.3 below. Making the simple assumption that time spent shopping (not the amount of time spent travelling for shopping activities) is a benefit, in that it provides enjoyment for some and utility for all, we hypothesize that activity patterns characterized by low shopping durations are more likely to be indicative of socially excluded individuals since they are less likely to meet one's fulfillment threshold.

Over and above using time-use patterns as indicators of exclusion, the time-use and activity theory of transportation also provides an appropriate paradigm for explaining the interactions between mobility levels, spatial configuration of activity locations, and activity participation rates. For each of the subgroups investigated in this paper, we can hypothesize a system of constraints, of mobility, and of accessibility, that plays a role in leading to exclusionary time-use patterns. For single-parents, we imagine that earning income and providing home- and child-care, without a partner on either front, results in a time-burden such that there is simply not enough time left-over to meet one's shopping threshold. For the elderly, physical constraints leading to reduced mobility (either through lack of vehicle licensing or inability to walk longer distances) may result in reduced shopping activity participation. And finally, for low income families, over and above their lower levels of disposable income, we posit that the costs of transportation, the lack of flexibility and unusual timing of shift-work, and home- and child-care responsibilities that cannot be outsourced, may similarly lead to reduced shopping participation. For these reasons the time-use approach shows much potential for studying social exclusion. It is also possible to imagine now how the spatial distribution of potential activity destinations, the so-called supply-side of the equation, fits into the overall picture. In each example, the provision of conveniently located and accessible service providers would greatly alleviate outstanding time constraints. Due to data limitations in our analysis, the spatial distribution of activities is unfortunately unknown, but time spent travelling is considered a partial proxy for the separation between activity locations in general.

4.3 Data

The empirical research reported in this paper uses Cycle 19 of the Statistics Canada General Social Survey (GSS). This is an annual survey conducted with the primary objectives of: "gather[ing] data on social trends in order to monitor changes in the living conditions and well being of Canadians over time; and to provide information on specific social policy issues of current or emerging interest" (Statistics Canada, 2006, p. 7). Collected over a twelve-month period in 2005, the GSS contains a detailed one-day time-use survey, a socioeconomic questionnaire, data pertaining to transportation and vehicle ownership, and data on other topics not used in this research such as self-rated well-being, sport and physical activity participation, and questions pertaining to social values and social networks.

The time-use questionnaire is composed of data entries pertaining to individual activity episodes greater than or equal to 1 minute in length. In this analysis, the duration and classification of each episode is used to construct daily duration variables for 4 broad activity classes and their associated trips (seen in Table 4-1). These are the dependent variables in the model. The independent variables are drawn from the other components of the survey and are meant to control for differences in activity patterns that arise due to socioeconomic status and transportation accessibility. Two additional groups of variables pertain to: a) the respondents' home location with respect to the central business district of their respective city of residence (Montreal, Toronto or Hamilton); and b) a stated enjoyment factor associated with various types of activities. These are used to account for geographic trends and heterogeneous tastes, respectively.

The entire GSS survey contains more than 19,000 respondents over the age of 15 from across the country, however, only half of the respondents were asked questions pertaining to transportation, accessibility and social networks. Of these, 2,108 resided in our study area: Toronto, Montreal and Hamilton. After removing respondents with extreme valued durations (greater than 3 standard deviations from the mean) and selecting those that performed shopping activities and shopping trips (see 4.4), a final sample for analysis was obtained consisting of 685 respondents.

Numerical descriptions of the categorical control variables and the continuous variables used in the analysis appear in Table 4-2 and Table 4-3. The average activity durations in Table 4-3 pertain to the mean daily duration of all activities in a given category across all respondents. For example, if a respondent went grocery shopping for 30 minutes and spent 30 minutes at a bank, their daily duration for shopping for goods and services would be 60 minutes, and this 60 would contribute toward the sample mean for the first variable in Table 4-3. Furthermore, if the respondent did not work at all, the respondent would contribute a 0 toward the sample mean of daily work and education activities duration.

Table 4-1 Activity Classification

Work and Education (WKEDU)	work for pay at main job, work for pay at other job(s), overtime work, looking for work, unpaid work in a family business/farm, travel during work, waiting/delays at work during work hours, meals/snacks at work, idle time before/after work hours, coffee/other breaks at work, other work activities, full-time classes, other classes (part-time), credit courses on television, special lectures (occasional outside regular work or school), homework, meals/snacks/coffee at school, breaks/waiting for class, leisure and special interest classes, other education related activities.
Household and Personal Maintenance and Care (DOMCARE)	meal preparation, baking, preserving food, food/meal cleanup, indoor cleaning, outdoor cleaning, laundry, ironing, folding and drying, mending clothes/shoe care, dressmaking and sewing, interior maintenance and repair, exterior maintenance and repair, vehicle maintenance, other home improvements, gardening/grounds maintenance, pet care, care of plants, household management, stacking and cutting firewood, other domestic/household work, unpacking groceries, packing and unpacking luggage and/or car, packing and unpacking for a move of the household, child care (infant to 4 years old), child care - Putting children to bed, child care - Getting children ready for school, child care - Personal care for children of the household, helping, teaching, reprimanding, reading to/talking/conversation with children, playing with children, medical care - household children, unpaid babysitting - household children, personal care - household adults, medical care - household adults, help and other child care - household children, help and other care - household adults, washing, dressing, personal medical care at home, private prayer, mediation and other informal spiritual activities, meals/snacks/coffee at home, other meals/snacks/coffee: non-socializing, meals at restaurant, night sleep/essential sleep, naps/lying down, relaxing, thinking, resting, smoking, other personal care/private activities.
Social, Entertainment and Community (SOCIAL)	professional/union/general meetings, political, civic activities, child/youth/family organizations, religious meetings/organizations, religious services/prayer/Bible reading, meals/snacks/coffee at religious services, fraternal and social organizations, support groups, volunteer organizational work, meals/snacks/coffee at place of volunteer work, housework, cooking assistance, house maintenance/repair assistance, unpaid babysitting, transportation assistance to someone other than a household member, care for disabled or ill person, correspondence assistance, unpaid help for farm/business, other unpaid work/help, other civic, voluntary or religious activities, professional sports events, amateur sports events, pop music concerts, fairs, circuses, parades, amusement parks, ice follies, zoos, botanical gardens, planetarium, observatory, movies/films at a theatre/cinema, art films, drive-in movies, classical music concerts, opera, ballet, theatre, museums (excluding art museums), art galleries (art exhibition), heritage sites, socializing at a private residence (no meals), socializing at a private residence (with meals, excluding restaurant meals), other socializing with friends/relatives at a non-private and non-institutional residence, socializing with friends/relatives at an institutional residence, socializing at bars, clubs (no meals), attendance at casinos, bingo or arcades, other social gatherings.
Shopping for goods and services (SS)	grocery store, market, convenience store, shopping for every day goods and products, take-out food, rental of videos, shopping for durable household goods, personal care services, financial services, government services, adult medical and dental care, including having prescriptions filled, other professional services, car maintenance and repair, other repair and cleaning services, waiting for purchases or services, other shopping and services.

The analysis sample provides a reasonable representation of the population at large, with a few exceptions, including an under-sampling of teenagers and an oversampling of women. One reasonable explanation for these discrepancies is that although each survey participant was randomly selected from the members of a telephoned household, the analysis sample only contains those respondents who performed a shopping activity. Another issue worth noting is that approximately 25% of the sample population does not know or refused to state their personal and/or household income levels, perhaps due to privacy concerns of the individual respondents. Finally, it is worth noting that approximately 50% of the analysis sample resides in the Toronto Census Metropolitan Area (CMA), 43% in the Montreal CMA and 7% in the Hamilton CMA.

A final note regarding the dataset is that in order to georeference the observations with high locational fidelity (in this case the postal code was used), we worked with the master data file containing sensitive information that is subject to the privacy policies of Statistics Canada. This policy restricts the publication of data pertaining to individuals or groups of individuals containing 5 or fewer respondents, and requires that all descriptive statistics be reweighted using the survey weights provided in the dataset by Statistics Canada. These weights represent the number of Canadians each respondent represents from the entire Canadian population aged 15 years or more, not residing in an institution, and excluding the population of the Yukon, Northwest Territories and Nunavut.

Table 4-2 Descriptive statistics for categorical variables

	n	%		n	%
Age			$40K-$60K	96	14.0%
15-20 years	14	2.0%	$60K-$80K	55	8.0%
20-35 year	171	25.0%	$80K-$100K	9	1.3%
36-50 years	221	32.3%	Greater than $100K	33	4.8%
51-64 years	164	23.9%	Unknown	178	26.0%
65-74 years	76	11.1%	Family Status		
over 75 years	39	5.7%	Single	144	21.0%
Female	415	60.6%	Couple	191	27.9%
Employment			Couple with kids	220	32.1%
Full time	317	46.3%	Child with parents	51	7.4%
Part time	55	8.0%	Single parent	60	8.8%
Student	44	6.4%	Child with only 1 parent	18	2.6%
Not employed	259	37.8%	City		
Unknown	10	1.5%	Toronto	341	49.8%
Household Income			Montreal	299	43.6%
less than $20K	51	7.4%	Hamilton	45	6.6%
$20K-$40K	72	10.5%	Survey day		
$40K-$60K	103	15.0%	Monday-Friday	433	63.2%
$60K-$80K	104	15.2%	Saturday	149	21.8%
$80K-$100K	58	8.5%	Sunday	103	15.0%
Greater than $100K	123	18.0%	Has drivers license	561	81.9%
Unknown	174	25.4%	Access to vehicle		
Personal Income			all the time	453	66.1%
less than $20K	150	21.9%	part of the time	88	12.8%
$20K-$40K	164	23.9%	Access to public transport	600	87.6%

Table 4-3 Descriptive statistics for continuous variables

	Mean	SD	p25	p50	p75
SS duration (mins)	98.6	83.0	35	75	130
SS trip duration (mins)	38.5	27.1	20	30	50
WKEDU duration (mins)	138.5	218.7	0	0	285
WKEDU trip duration (mins)	13.5	29.2	0	0	10
SOCIAL duration (mins)	143.0	150.9	0	90	230
SOCIAL trip duration (mins)	18.0	36.9	0	0	20
DOMCARE duration (mins)	792.5	190.6	650	790	930
DOMCARE trip duration (mins)	11.5	27.8	0	0	10
Driver duration (mins)	51.5	58.4	0	35	80
Passenger duration (mins)	12.5	28.7	0	0	10
Public transportation duration (mins)	10.5	31.5	0	0	0
Other mode duration (mins)	1.6	14.6	0	0	0
Walking and bicycling duration (mins)	8.9	22.9	0	0	5
Driver percent	0.6	0.5	0	1	1
Passenger percent	0.2	0.3	0	0	0.1
Public transportation percent	0.1	0.3	0	0	0
Other mode percent	0.0	0.1	0	0	0
Walking and bicycling percent	0.1	0.3	0	0	0.0
Distance to Toronto CBD[a] (km)	10.9	14.7	0	0	18.9
Distance to Montreal CBD[b] (km)	7.2	11.3	0	0	10.8
Distance to Hamilton CBD[c] (km)	0.6	2.6	0	0	0
Factor: Social Enjoyment	0.0	1.0	-0.8	-0.2	0.7
Factor: Domestic Enjoyment	0.0	1.0	-0.7	0.1	0.7
Factor: Entertainment Enjoyment	0.1	1.0	-0.5	0.3	0.9
Factor: Shopping Enjoyment	0.0	1.0	-0.8	-0.2	0.7
Factor: Work Enjoyment	-0.1	0.9	-0.9	-0.5	0.4
Number of children 0-4 years at home	0.1	0.3	0	0	0
Number of children 5-12 years at home	0.2	0.6	0	0	0
Number of children 13-18 years at home	0.2	0.4	0	0	0

a. equals zero if respondent does not reside in Toronto
b. equals zero if respondent does not reside in Montreal
c. equals zero if respondent does not reside in Hamilton

4.4 Methods

Drawing from the time- and budget-constrained framework for modeling activity demand, activities are conceptualized as goods from which the participant receives utility in accordance with the activity type and duration (Kockelman, 2001). Given that the allocation of one's time to an activity impacts the duration of participation in a second activity due to the daily time-budget constraint, the activities are inherently in competition with each other. If each activity's duration is modeled by a linear equation, then the set of activities can be modeled using a system of linear equations such as:

$$\begin{aligned} \boldsymbol{y}_{t1} &= \boldsymbol{\gamma}_1 \boldsymbol{y}_t + \boldsymbol{\beta}_1 \boldsymbol{X}_t + \varepsilon_{t1}, \\ \boldsymbol{y}_{t2} &= \boldsymbol{\gamma}_2 \boldsymbol{y}_t + \boldsymbol{\beta}_2 \boldsymbol{X}_t + \varepsilon_{t2}, \\ &\vdots \\ \boldsymbol{y}_{tM} &= \boldsymbol{\gamma}_M \boldsymbol{y}_t + \boldsymbol{\beta}_M \boldsymbol{X}_t + \varepsilon_{tM} \end{aligned} \qquad \text{Eq. 4-1}$$

In this formulation, for a given observation *t*, and activity *m*=1..*M*, the duration $\boldsymbol{y}_{tm}$, is modeled as a linear and additive function of the other durations, $\boldsymbol{y}_t$, a set of exogenous variables, $\boldsymbol{X}_t$ and a random disturbance denoted by $\boldsymbol{\varepsilon}_{tm}$. Some of the regression parameters in $\boldsymbol{\gamma}_m$ and $\boldsymbol{\beta}_m$ are often constrained to simplify the model, or to better represent a priori knowledge of the system. Estimation may proceed in a variety of ways including: ordinary least squares (OLS); seemingly unrelated regression (SUR); instrumental variable regression (IV); three-stage least squares (Greene, 2002) ; or via a structural equations approach Golob (Golob, 2000). The set of simultaneous equations can be rewritten in matrix form as:

$$\mathbf{Y} = \mathbf{\Gamma Y} + \mathbf{BX} + \mathbf{E} \qquad \text{Eq. 4-2}$$

where:

$$[\mathbf{Y} \quad \mathbf{X} \quad \mathbf{E}] = \begin{bmatrix} y_1' & x_1' & \varepsilon_1' \\ y_2' & x_2' & \varepsilon_2' \\ & \vdots & \\ y_T' & x_T' & \varepsilon_T' \end{bmatrix}, \qquad \text{Eq. 4-3}$$

$$\mathbf{\Gamma} = \begin{bmatrix} \gamma_{11} & \cdots & \gamma_{1M} \\ \vdots & \ddots & \vdots \\ \gamma_{M1} & \cdots & \gamma_{MM} \end{bmatrix}, \qquad \text{Eq. 4-4}$$

$$\mathbf{B} = \begin{bmatrix} \beta_{11} & \cdots & \beta_{1M} \\ \vdots & \ddots & \vdots \\ \beta_{K1} & \cdots & \beta_{KM} \end{bmatrix} \qquad \text{Eq. 4-5}$$

with T observations and K exogenous variables in the dataset.

Ordinary least squares estimates of the coefficients are inconsistent and biased since endogenous variables appear on the right hand side of the equation. A two-stage instrumental variables regression can be used to make the estimates consistent. Additionally if the disturbances are correlated between equations then the estimates are inefficient. In the case of activity durations, we can safely assume that the residuals are correlated across equations since there likely exist unmeasured factors which simultaneously impact the durations of multiple activities. A seemingly unrelated regression incorporates an estimated residual covariance matrix into a generalized least squares (GLS) estimation of the coefficients in order to make the estimates efficient. When endogeneity and residual covariance need to be treated simultaneously, the three-stage regression method can be used to combine IV and SUR estimation into a single estimator.

Very simply, the three stages of the estimator consist of: (1) computing the intermediate forms of the endogenous variables using the instruments as predictors; (2) retrieving an estimate of the covariance matrix of the residuals arising from a regression of the endogenous factors on the exogenous factors and the intermediate form endogenous factors; and (3) estimating the coefficients of the model with a GLS regression using the estimated covariance matrix from the second step and the intermediate forms from the first (Zellner & Theil, 1962; Greene, 2002). The eight endogenous variables in this analysis are the daily durations of four broad activity classes and their associated trips: *shopping for goods and services* (SS); *work and education* (WKEDU); *household and personal maintenance and care* (DOMCARE); and *socializing and entertainment* (SOCIAL). The variables were log transformed in order to reduce the positive skew apparent in all of the durations and to achieve a more normal distribution of the dependent variables.

The model as implemented incorporates two types of endogeneity: trip/activity and activity/activity. The first pertains to the hypothesis that people decide their trip and activity durations simultaneously. For example, if one spends a great amount of time travelling to a shopping destination, it is likely that they would decide to spend more time shopping; in a sense to make the trip more worthwhile. Alternatively, the contrapositive argument is that people are not likely to spend a lot of time travelling when their desired shopping duration is small. This hypothesis is tested via the introduction of the shopping trip duration term on the right hand side of the shopping activity duration equation. The trip duration terms for the other three activity classes were similarly included on the right hand sides of their associated activity duration equations. The second type of endogeneity, activity/activity, is a result of the daily time budget constraint. Self-evidently, any time spent on one activity necessarily reduces the amount of time available to spend on another, but depending on whether or not two activities can be thought of as compliments or substitutes will affect the size of the effect of one's duration on another. For example, a home-keeper may have long durations of grocery shopping and child-care relative to the primary income earner in a household who has more prolonged working durations. In this scenario, grocery shopping and child-care may be considered to be complimentary activities, while grocery shopping and working are substitutes. Over and above the fact that activity durations vary from person to person due to tastes, constraints, and socio-economic characteristics, the complimentary or substitute nature of sets of activities adds another layer of variation to be explored in the model.

4.5 Results and Discussion

The fact that the regression model can determine the impact of a factor while holding constant and separating out the impacts of other factors is its greatest advantage over simple descriptive statistics, and is especially useful in testing theories relating accessibility, mobility and socioeconomic conditions to measures of social exclusion in terms of time spent participating in a variety of daily activities. So, from a policy perspective, examining the individual impacts of factors should inform the policy design process. However, at this early stage of examination of social exclusion in Canadian cities, simply documenting the level of participation in a variety of activities for a variety of population subgroups and then acknowledging that the phenomenon exists, represents a significant step towards a more complete understanding of the underlying issues. To this end, what follows is a series of simple figures depicting the mean durations and participation rates of activities related to shopping for goods and services broken out by age (Figure 4-1 and Figure 4-2), household income (Figure 4-3 and Figure 4-4), and single-parent status (Figure 4-5 and Figure 4-6). Figure 4-1, Figure 4-3, and Figure 4-5, show mean activity durations for all persons in each socio-economic class that participated in the given activity. For example, in Figure 4-1, the bar-chart for *Shopping for Goods and Services* (SS) shows average daily durations of total shopping activities amongst those that went shopping for each age group. Since the analysis sample only includes those that went shopping, all 685 respondents were used to calculate the mean SS durations. The 2nd bar-chart shows average daily durations of Grocery, Market and Convenience shopping activities amongst those that went grocery, market and convenience shopping for each age group.

4.5.1 Descriptive Statistics

In general, an item for exploration is whether those seen at risk of social exclusion due to mobility and accessibility have lower participation rates, shorter activity durations and longer trip durations in comparison to the rest of the population. For Figure 4-1 and Figure 4-2, we would then focus our attention to the two age cohorts over the age of 65; for Figure 4-3 and Figure 4-4, we focus on the lowest two income groups; and for Figure 4-5 and Figure 4-6, we focus on single parents. A tabulation with sample sizes appears in Appendix I.

Across the board, there is a great difference between seniors younger than 75 years and those aged over 75, but not necessarily a great difference between seniors in general and the remainder of the population. Quite importantly, with one exception, participation rates for seniors in all three categories of activities are on par with the rest of the population. However, those aged over 75 years have much higher participation rates in the services compared to all other age groups, perhaps partially as a function of increased demand for health services. There seems to be a greater variety in durations in comparison to participation rates. For example, we see in Figure 4-1 Duration (minutes) of shopping activities by age group that the oldest cohort has long shopping durations when compared to the younger group of seniors and the rest of the population. This is not so in the services category where the oldest cohort has very low durations while the younger seniors, those aged 65-74 years, have durations on par with the rest of the population. Interestingly, the figure for SS travel duration is parabolic shaped, indicating that the oldest and youngest groups travel the longest for goods and services, while those middle aged have shorter travelling durations. This parabolic shape can be linked to Hägerstrand's theory of constraints which suggests that teens and seniors, both presumably with ample free time, are able to spend more time travelling to their destinations. In this light, longer travel durations are likely innocuous; besides the systems view of transportation efficiency, there is no normative directive stating that travel is per se a bad thing. However, if these longer travel times arise from a bias in the transportation system against those with mobility constraints, such as the elderly, then these longer travel durations can be interpreted as a barrier to inclusion.

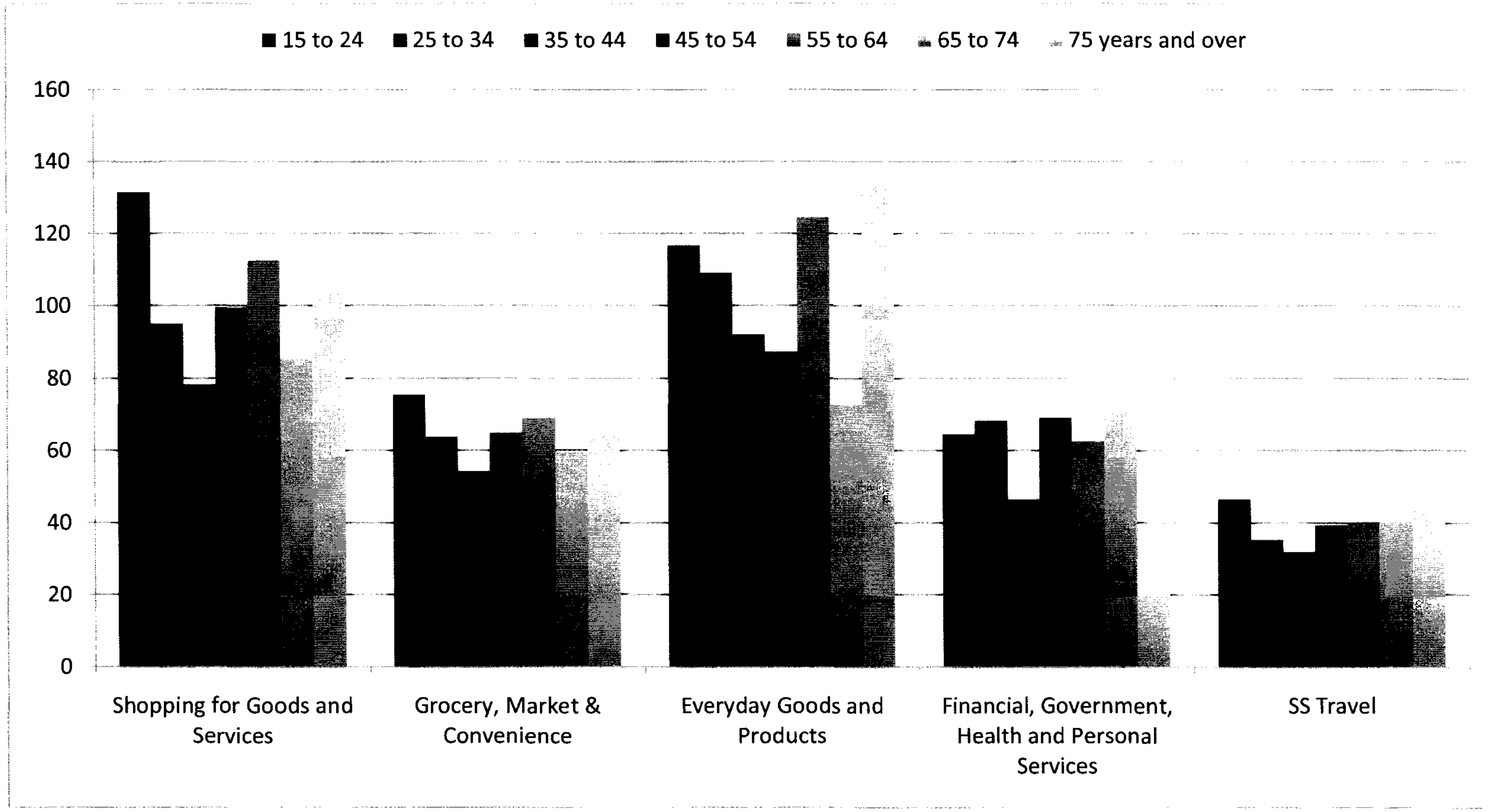

Figure 4-1 Duration (minutes) of shopping activities by age group

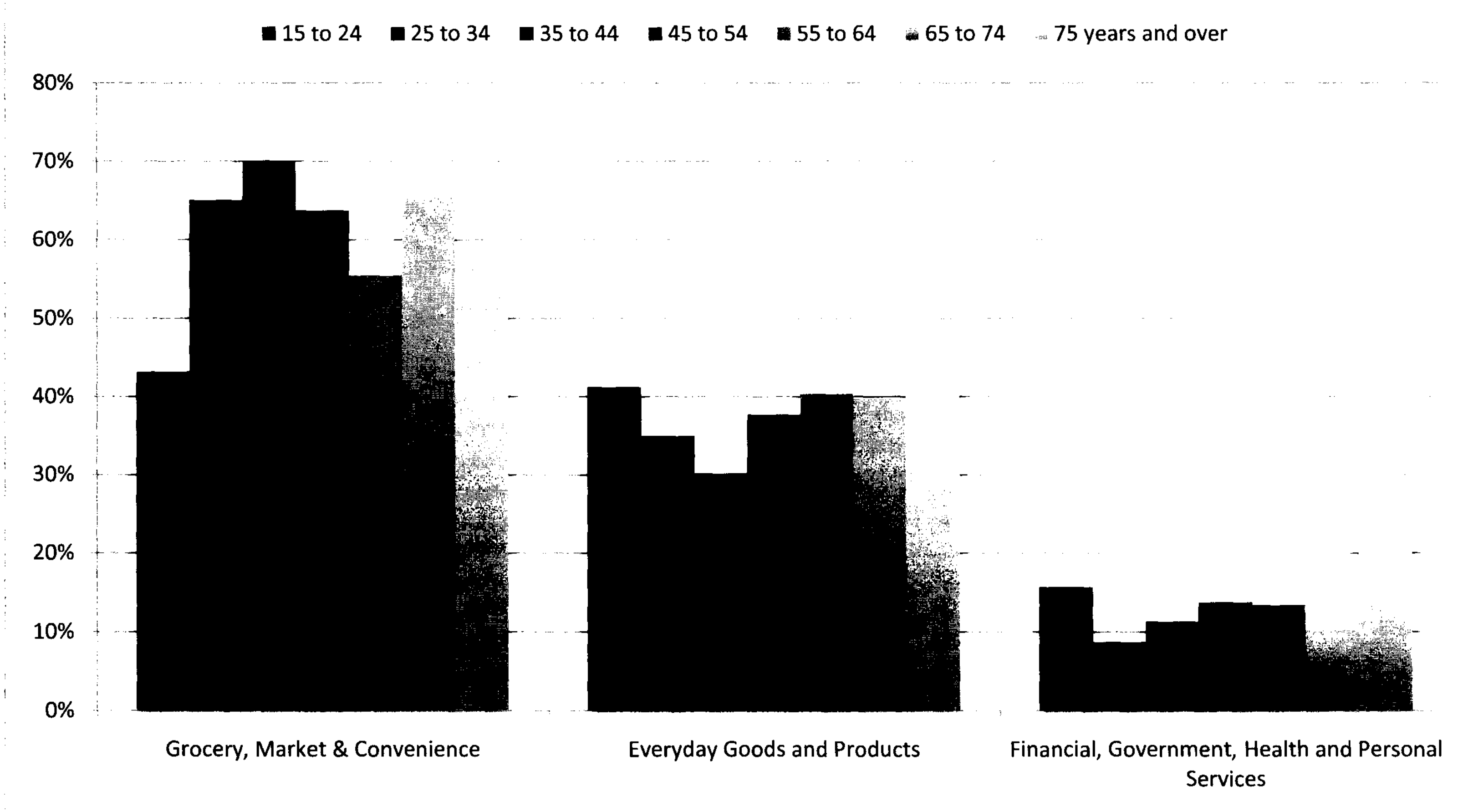

Figure 4-2 Participation in shopping activities by age group

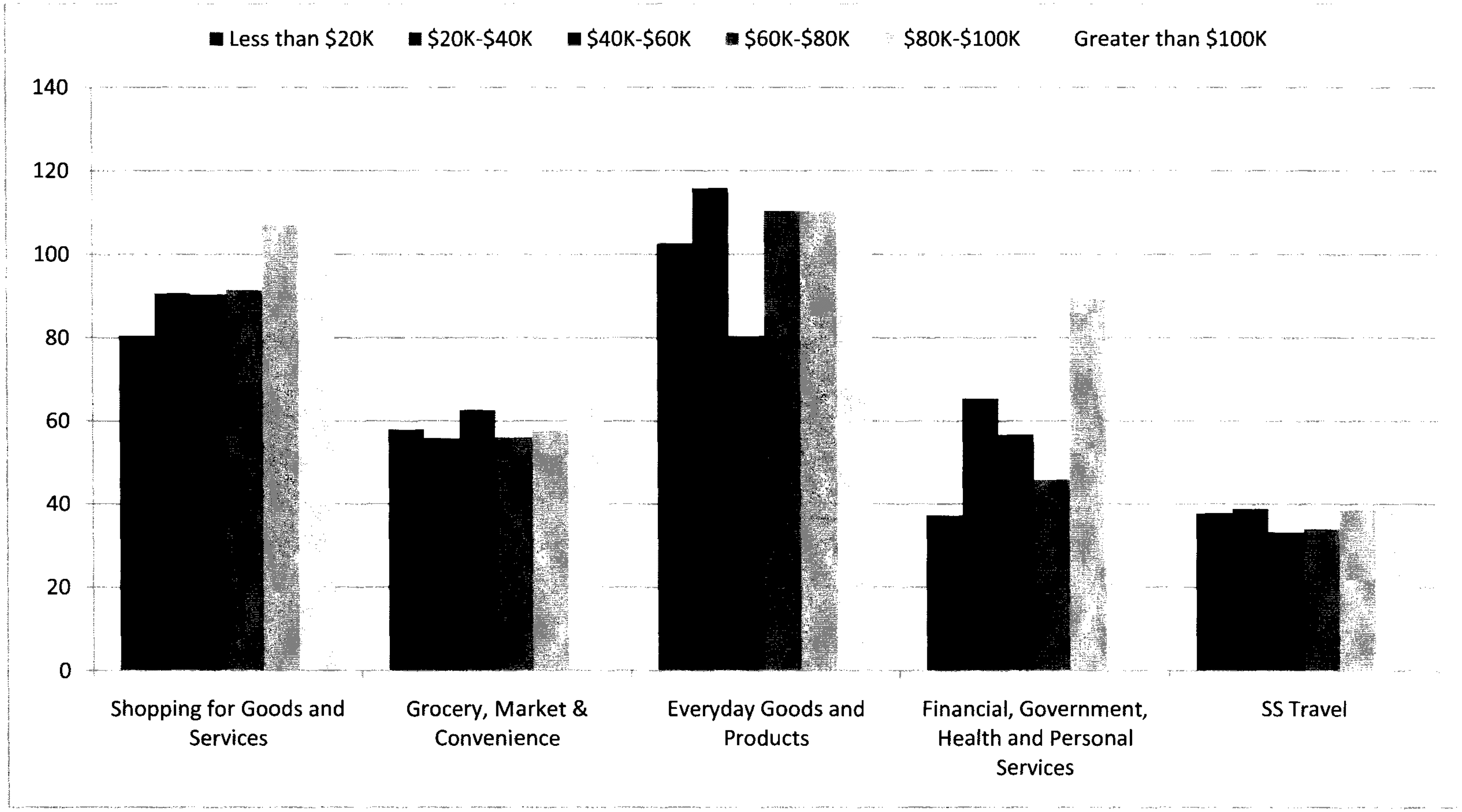

Figure 4-3 Duration (minutes) of shopping activities by household income group

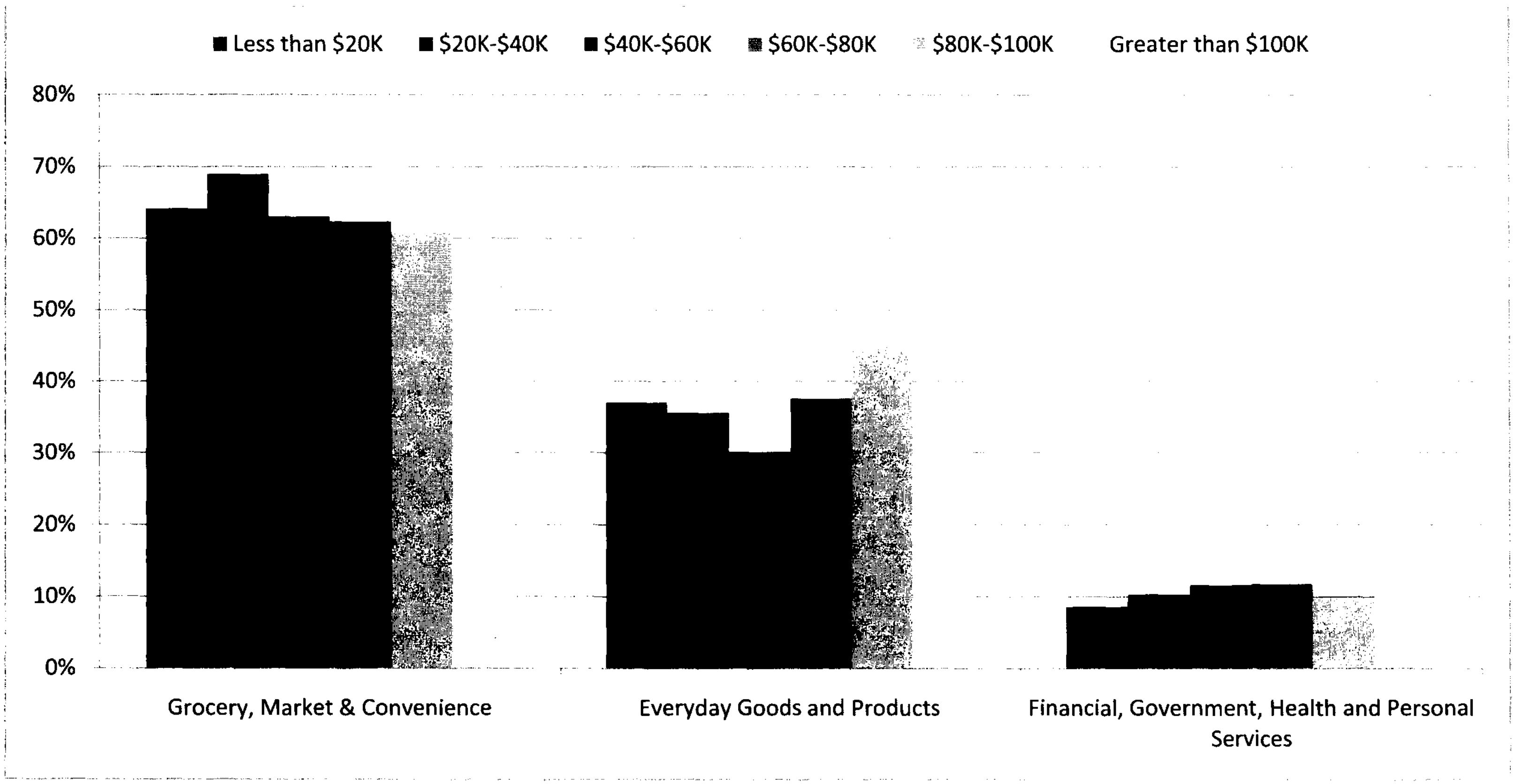

Figure 4-4 Participation in shopping activities by household income group

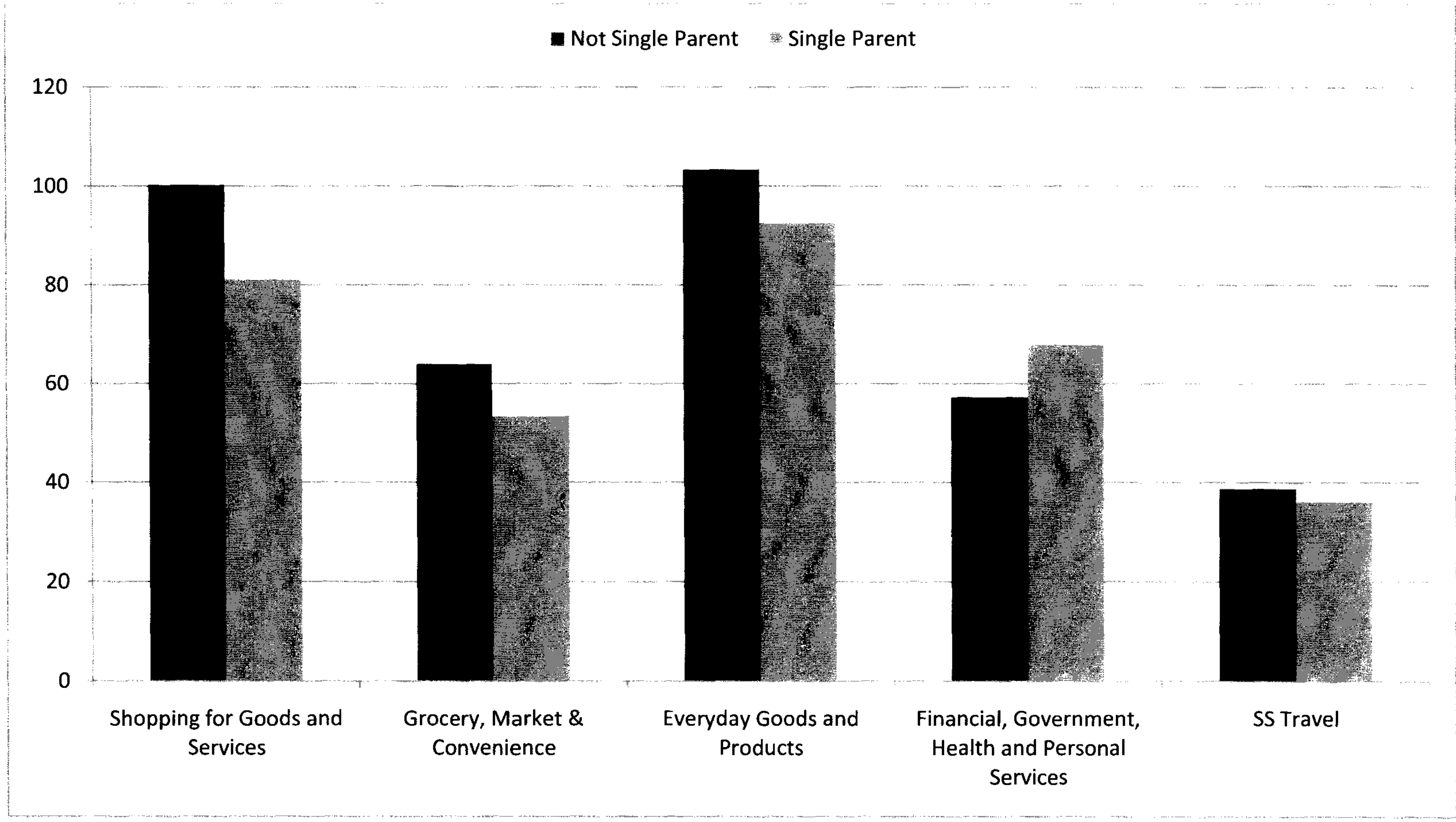

Figure 4-5 Duration (minutes) of shopping activities by lone-parent status

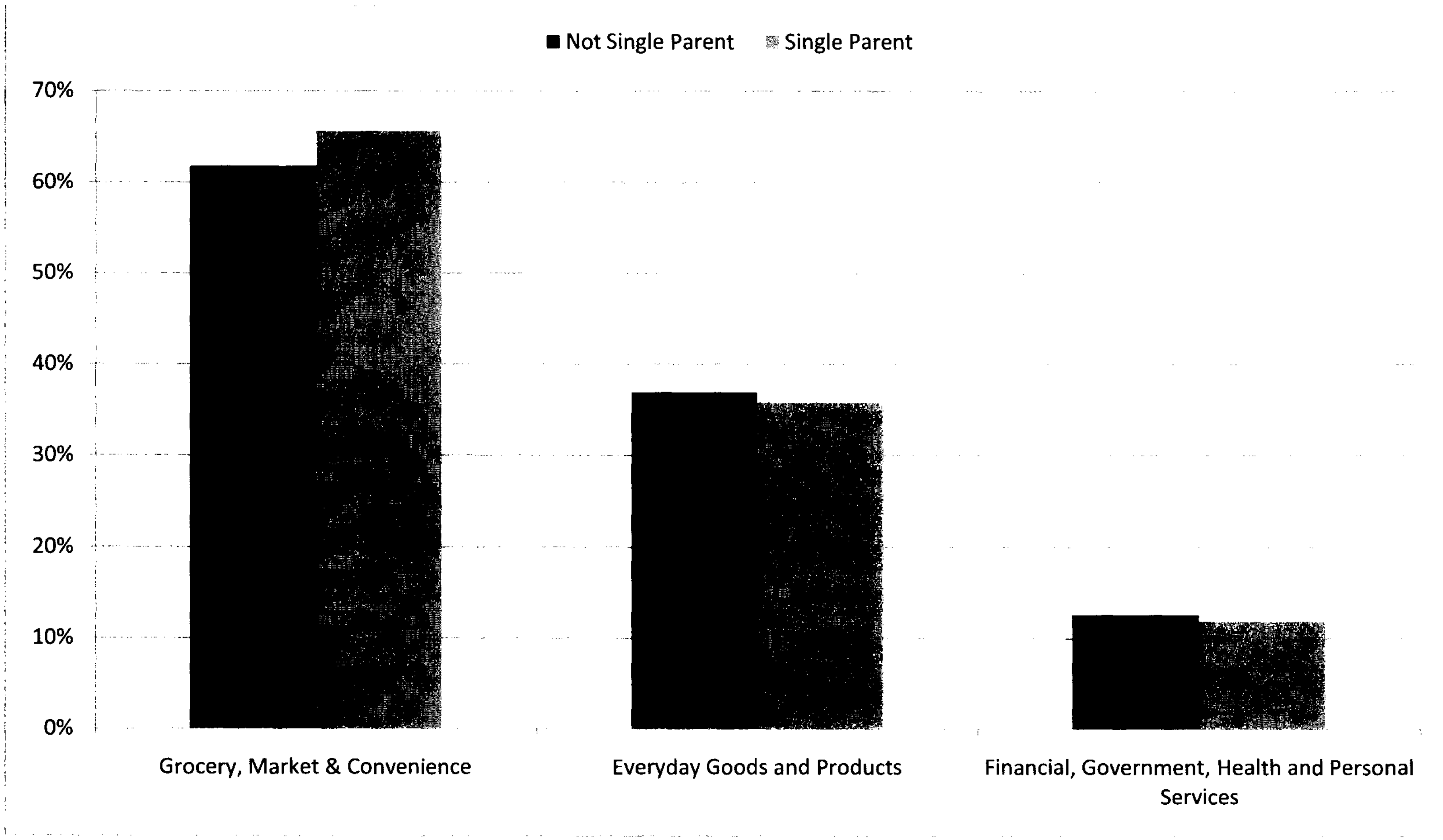

Figure 4-6 Participation in shopping activities by lone-parent status

Similarly, a set of possible constraints can be deduced from Figure 4-3 and Figure 4-4, pertaining to activity durations and household income. First of all, we see the same pattern for travel durations in Figure 4-3 as we did in Figure 4-1; indicating that both the poorest and the wealthiest households travel longer for goods and services. We are yet to determine how income affects this process. However, whereas the wealthy may travel longer due to cheaper relative travel costs (for gas, parking, insurance etc.), the impoverished may be travelling longer because they do not have access to mobility tools, they tend to travel by public transit rather than by automobile, they live in underserviced parts of the city forcing them to travel further, or simply because they choose to travel further since their value of time is lower than for those with higher incomes.

In terms of shopping activities, the charts indicate that respondents from poorer households typically spend less time shopping for goods and services, and in particular spend far less time on financial, government, health and personal services. Interestingly, the poorest households have high participation rates for grocery shopping but lower grocery shopping durations. This may be indicative of a more precarious live-one-day-at-a-time situation, in which more frequent trips to the stores for shorter shopping episodes are associated with limitations to afford, carry, or store larger quantities of purchased items. This provides preliminary evidence of distinct activity patterns associated with the poorest households, and the causes and outcomes of this must be further studied.

The third and final subgroup of the population for which we investigate time use patterns is single-parent households. Approximately 10% of respondents in the survey are single-parents living at home with one or more children in the household; nearly all are female and many have low incomes. Single parents face increased time constraints as the sole provider for income and child-care, and as can be seen in Figure 4-5 and Figure 4-6, they also differ greatly from the rest of the population in terms of durations and participation rates for shopping activities. The single parents on average spent approximately 20% less time shopping and 20% more time on services activities. Despite the reduced grocery shopping durations, single parents, like the low-income households, have higher grocery shopping rates, but no discernible participation difference in the other activities.

4.5.2 Regression Results

In the preceding section, durations of a variety of activities are investigated for various population subgroups. Accordingly, in the regression that follows, we try to determine if these sub-setting factors, namely age, income, and single parent status, remain significant predictors of activity patterns while controlling for a wide range of socioeconomic factors, transportation accessibility, personal mobility and the daily time budget constraint.

Obtaining a parsimonious and accurate model specification for eight simultaneous regressions with more than 60 exogenous variables is quite a large task that calls for the use of a supervised specification search algorithm. Given that forward stepwise regression is controversial due to omitted variable bias and path dependencies (Greene, 2002), it was deemed more appropriate to proceed with an equation by equation backward stepwise regression. The modeling starts by including all of the exogenous variables and a selection of endogenous variables in each equation and proceeds by removing the variable with the highest p-value greater than 0.1 at each iteration. Note that the trip duration variables were only included on the right hand side of the equation that relates to its activity class. Furthermore, since the focus of this analysis is on the *shopping for goods and services* activity, the time spent on each of the other activities is included on the right hand side of the SS duration equation.

The model summary and fit statistics of the stepwise simultaneous equation regressions are in Table 4-4. Notice that the number of significant factors and the R^2 values vary greatly from equation to equation. Most importantly, the equations for the focal SS duration and SS trip duration achieve a level of fit commensurate with, if not slightly higher than, other models in the literature (Bhat, 1996; Rosen, Shankar, & Ulfarsson, 2004). All of the models are significantly more powerful predictors than their means as indicated by the χ^2 test results. In addition, as seen in Table 4-5, the residuals show a high albeit varied amount of between-equation correlation, indicating that the selected three-stage method of estimation is indeed appropriate and required to increase efficiency of the estimators. It is interesting to note that the models are generally more accurate predictors of the activity durations themselves in comparison to their associated trip durations. This indicates that the spatiality of the activity locations, which in turn induces travel times, is not captured very well by these models. Of course, it is very difficult to model travel times without understanding the landscape of activity opportunities available to each respondent. Alas, a more complete spatial analysis is not feasible due to the data sparseness for individual urban areas.

Table 4-4 Summary of Models

Equation	Obs.	k	RMSE	R^2	Adj. R^2	χ^2	p-value
SS duration	685	16	0.88	0.1531	0.1328	206.3	0.0000
SS trip	685	14	0.72	0.1252	0.1069	108.1	0.0000
WKEDU duration	685	9	3.16	0.7285	0.7249	1233.9	0.0000
WKEDU trip	685	16	3.64	0.4036	0.3893	469.1	0.0000
DOMCARE duration	685	25	0.22	0.2598	0.2317	278.8	0.0000
DOMCARE TRIP	685	10	4.42	0.1115	0.0983	87.3	0.0000
SOCIAL duration	685	14	4.56	0.2462	0.2304	132.4	0.0000
SOCIAL trip	685	15	4.88	0.0609	0.0398	54.3	0.0000

Table 4-5 Bivariate correlation matrix of SEM residuals

	SS Duration	**SS Trip Duration**	**WKEDU Duration**	**WKEDU Trip Duration**	**DOMCARE Duration**	**DOMCARE Trip Duration**	**SOCIAL Duration**	**SOCIAL Trip Duration**
SS Duration	1.00							
SS Trip Duration	[redacted]	1.00						
WKEDU Duration	0.07	-0.04	1.00					
WKEDU Trip Duration	[redacted]	[redacted]	-0.03	1.00				
DOMCARE Duration	0.01	0.03	-0.09	[redacted]	1.00			
DOMCARE Trip Duration	-0.07	0.00	-0.05	-0.02	0.05	1.00		
SOCIAL Duration	[redacted]	0.01	-0.01	[redacted]	[redacted]	-0.03	1.00	
SOCIAL Trip Duration	[redacted]	[redacted]	[redacted]	-0.09	[redacted]	0.09	-0.02	1.00

Shading indicates absolute correlation greater than or equal to 0.10

Table 4-6 Coefficients for the SS and SS trip duration models

Variable	Coef.	Std. Err.	|z|	P>|z|
SS duration Equation				
Constant	8.038	1.900	4.23	0.0000
SS trip duration	0.669	0.079	8.51	0.0000
WKEDU duration	-0.055	0.012	4.67	0.0000
SOCIAL duration	-0.091	0.014	6.45	0.0000
DOMCARE duration	-0.943	0.267	3.53	0.0000
Age: 15-20 years	0.750	0.232	3.23	0.0010
Age: over 65 years	-0.788	0.179	4.41	0.0000
*Distance to Hamilton CBD	0.073	0.034	2.19	0.0290
Employment: Full time	-0.186	0.087	2.14	0.0320
Survey day: Saturday	0.238	0.085	2.80	0.0050
Hamilton	-0.289	0.135	2.15	0.0320
Has drivers license	-	-	-	-
*Age: over 65 years	0.372	0.188	1.98	0.0480
*Household income: less than $20K	-0.598	0.169	3.54	0.0000
*Personal income: less than $20K	0.383	0.103	3.72	0.0000
*Distance to Toronto CBD	0.011	0.004	2.73	0.0060
Access to public transport	0.321	0.114	2.83	0.0050
*Distance to Toronto CBD	-0.012	0.005	2.70	0.0070
SS trip duration Equation				
Constant	3.934	0.093	42.35	0.0000
Factor: Shopping Enjoyment	-0.079	0.027	2.87	0.0040
Age: 15-20 years	-1.107	0.214	5.17	0.0000
Age: over 65 years	0.165	0.100	1.65	0.0990
*Distance to Toronto CBD	-0.011	0.005	2.32	0.0200
Employment: Full time	-0.174	0.065	2.69	0.0070
Employment: Student	0.336	0.130	2.58	0.0100
Number of children 0-4 years at home	-0.199	0.096	2.08	0.0380
Montreal	-0.121	0.058	2.07	0.0380
Has drivers license	-0.422	0.081	5.18	0.0000
*Distance to Hamilton CBD	0.060	0.024	2.45	0.0140
Access to public transport	-	-	-	-
*Distance to Hamilton CBD	-0.092	0.025	3.62	0.0000
Access to vehicle: part of the time	0.162	0.082	1.98	0.0470
Walking and bicycling percent	-0.367	0.098	3.73	0.0000
Personal income: less than $20K	-	-	-	-
*Family status: Single parent	-0.611	0.211	2.90	0.0040

The coefficients retrieved by the final stepwise regression for the SS equations are listed in Table 4-6. The top half of the table pertains to the SS activity duration equation while the bottom contains the results for shopping trip durations. Notice the coefficients for the endogenous variables appearing on the right hand side of the equation. First, the SS trip duration variable is positive and significant, indicating that longer shopping trips result in longer shopping durations. Conversely, the coefficients for the other endogenous factors indicate that time spent working or at school, time spent socializing and time spent on domestic and personal care all reduce the amount of time spent shopping. Keeping in mind that the logarithms of all duration variables have been used in the models and not the raw times themselves, the coefficients are considered elasticities and can be interpreted as follows: a 10% increase in SS travel duration will result in a 6.7% increase in SS duration; a 10% increase in WKEDU duration results in a 0.6% decrease in SS duration; a 10% increase in SOCIAL duration results in a 1% decrease in SS duration; and a 10% increase in DOMCARE duration results in a 9% decrease in SS duration. The fact that these elasticities largely reflect the relative lengths of the durations with respect to the total daily time budget is an important observation. To illustrate this point, observe in Table 4-3 that the median DOMCARE duration is nearly 13 hours, so a 10% change is likely to have a big effect on the amount of free time for other activities. Conversely, the median SOCIAL duration is 90 minutes, so a 10% change would not have a large impact on the amount of free time for other activities. With this in mind, let us examine the impact of working 4 hours versus 8 hours, the standard half- and full-time working day in Canada. The jump from 4 hours to 8 hours represents a 100% increase in WKEDU duration which according to the elasticity will result in a 5.5% decrease in SS duration, quite a small change given the very large change in time commitment. Since the elasticity of SS with respect to WKEDU is nearly zero, we can argue that the two activities are weak substitutes.

Interpretation of the remaining coefficients, those for solely exogenous factors, is similar to that for ordinary least squares with a logged dependent variable. For the binary variables in the model, this means that the coefficients are simply a prediction of percentage change in duration with respect to a one unit change in the independent variable. For example, the coefficient for *Age: over 65 years* suggests that being a senior, holding all else equal, decreases daily SS duration by 79%. Furthermore, the interaction of being a senior and distance from the Hamilton CBD indicates that for seniors in Hamilton, SS durations increase at a rate of 7% per kilometre as respondents reside further and further away from the centre of the city.

Overall, the coefficients for the exogenous factors paint an interesting portrait of how shopping behaviour varies with lifestyle and lifecycle stage. According to the models, we find that being a senior significantly reduces the amount of time spent shopping for goods and services, and at the same time, increases the length of trips associated with said activities. It is not in the scope of the model to determine if the increased travel times seniors face are due to accessibility and mobility restrictions or if simply they choose to travel further to reach their desired destinations. Further, the fact that being a senior tends to decrease SS durations is not necessarily indicative of a social issue but rather may just be an indication that seniors have different time-use preferences that include shorter SS durations. It is even more critical however to note that this model does not imply causation between longer SS travel times and shorter SS durations for seniors. Further follow-up studies should be used to determine the extent to which these hypotheses can be confirmed or denied.

The interaction between *Has drivers license* and *Age: over 65 years* suggests that the negative impact of being a senior on SS durations is moderated by the possession of a drivers license. In particular, whereas the effect of having a driver's license in general is insignificant, we find that seniors without licenses tend to have 79% shorter SS durations and seniors with licenses only have 42% shorter durations. Curiously, we find that possession of a drivers license significantly interacts with a number of other relevant socioeconomic factors. For example, amongst licensed drivers, low personal income results in increased SS durations, whereas low household income results in greatly reduced SS durations. The income effect suggests that low-income members of households, presumably charged with shopping responsibilities for the household, have longer durations, while the effect of low income status at the household level is strong and negative. Why these effects are only significant for those respondents with driver licenses is unclear at this time, however this points to the notion that accessibility and mobility play important albeit somewhat complex roles in the duration of shopping and services activities.

Importantly, the coefficient for the single parent status indicator never achieved significance in the model for SS duration and was thus removed in the backward stepwise procedure. This suggests that upon explicitly controlling for socioeconomic factors, mobility, and time-use patterns, single-parent status by itself does not directly impact shopping durations.

As with SS duration, socioeconomic factors also significantly impact how long people spend travelling for goods and services. Holding all else equal, we see that teenagers spend significantly less time travelling for goods and services in comparison to the mean, while seniors spend significantly more time. The impact of being a senior, however, declines for Toronto residents as they live farther from the centre. This suggests that downtown seniors travel longer for goods and services compared to those in the suburbs. This is quite puzzling since it opposes the prevailing logic that activity dense downtowns require shorter trip times compared to the sparsely populated suburbs. It is important to remember when interpreting these results that there is no a priori reason to consider longer or shorter trip times as a positive or negative outcome, as this outcome may reflect a preference for suburban retail locations. At this point, the results merely serve to support the assertion that seniors in general have longer trip times, and this effect is strongest in the centre of Toronto.

Perhaps even more striking than the impact of age on travel times is the impact of low income single parent households. According to the model, being a low-income single parent reduces trip times by more than 60%. Similarly, for each child at home below the age of four, a parent's travel time is reduced by nearly 20%. A plausible explanation for this is that parents, especially single parents, cannot afford to spend much time travelling for goods and services given their extra demand for spending time on child and household care. We may use the contrary argument now to suggest that seniors have longer travel times merely because they have lots of free time, and so, they can afford to spend more time travelling for goods and services. Again, to be certain of this claim, more theory must be developed, ideally supported through additional qualitative research.

Finally, as expected, the general trend for mobility variables is that travel times decrease as mobility increases. This is evident in the 42% reduction in travel times afforded by having a driver's license, or the 16% increase for those who only have partial access to an automobile. Interestingly, we see that the effect of having a drivers license tapers off with distance to the CBD for Hamilton residents, indicating that being a licensed driver is a more significant factor for suburban dwellers compared to those in the centre of the city where public transit and walking are more viable modes of transport. Interestingly, we also see that as the percentage of time travelling by foot or bicycle increases, the amount of time spent travelling for goods and services decreases. This indicates that increased mobility afforded by the automobile, and decreased mobility afforded by foot and bicycle, both *reduce* the amount of time spent travelling for goods and services. Presumably, this can be explained by the spatial configuration of walkers and bikers, concentrated in urban areas, and within shorter distances to shopping opportunities. It is doubtful that walking and biking leads to shorter travel times for those living in the suburbs, but not surprising to find that it has a negative regression coefficient.

4.5.3 Interpretation and Caveats

The research presented in this paper represents a significant effort towards obtaining a model to account for the endogeneity and cross-equation correlations in time use analysis. It is important however at this point to delimit the scope and limitations of the results presented in this paper. One important caveat is related to the fact that when it comes to travel and activity times, each variable's distribution is naturally truncated at zero minutes. In addition, since respondents did not necessarily participate in all four activity-types on the surveyed day, a large number of the observed durations have values of zero minutes. Our experience suggests that regressions on these types of distributions give rise to coefficients that merely differentiate between the dichotomous choice of participating or not participating, and models do not have the fidelity to accurately predict the continuous duration variable. In situations such as these, non-participants cannot be simply dropped from the analysis without introducing a positive selection bias. A Heckman selection regression can be used to remedy this in the univariate case (Heckman, 1979). In the case of multivariate regression, state of the art solutions include Bhat's Multiple Discrete-Continuous Extreme Value (MDCEV) model and Fang's recent work that uses an ordinal instead of a categorical discrete model of selection (Bhat, 2005; Fang, 2008). For the reasons outlined above and since the focus of this work is on the *shopping for goods and services* activity, only the respondents that performed both a shopping activity and a shopping trip were selected into the analysis sample. The technical challenge to implement the complex discrete-continuous methods limits our ability to deal with the selection bias at this time. Future work should proceed with the implementation of a two-stage process.

Another limiting factor is due to the cross-sectional nature of the GSS data. Evidence in the literature suggests that activity participation is partially constrained by household interactions. Discretionary activities such as shopping need not be undertaken by all household members. To this end, our model of activity schedules for solitary household members implicitly assumes independence between household members. The literature suggests that modeling activities jointly amongst household heads improves estimation and is theoretically more suitable (Gliebe & Koppelman, 2002; Scott & Kanaroglou, 2002; Golob & McNally, 1997). Other surveys, such as the 1994 Portland Activity-Based Travel Survey contain diary data on entire households and thus analyses using household interactions are possible. Unfortunately the GSS only contains very limited data on household composition, let alone the time-use of other household members. A second and similar drawback of the GSS is that it only contains diary data for a single day. Clearly, the activity schedule of the captured day must be considered conditioned on previously performed activities and future, planned activities, something that was shown many decades ago in early empirical work (Cullen & Godson, 1975). More recently, long term travel surveys have been conducted to investigate the dynamic aspects of activity and time-use (Axhausen et al., 2002). Bhat et al. (2004) specifically investigate the rhythmic and irregular qualities of shopping episodes.

Another interesting discussion point concerns activity chaining, and the potential for distinct activity/trip chaining patterns to be associated with the at-risk groups investigated in the paper. Being an aggregate study, with durations being modelled as day-sums, the question of chaining is not directly addressed in the paper, and we feel in fact that it is beyond the paper's scope. It is possible however that some sort of measure of observed chaining behaviour could be used to predict daily total duration of different activity types (ie. chaining might result in shorter travel times since there will be fewer home-based trips). A very interesting avenue for future research is to investigate how mode-use and time-constraints interact in the determination of chaining behaviour. For example, concurrently having a car and lots of free time might result in more single-purpose trips, because time can be 'wasted' on extra home-based trips. Comparatively, those who are more time-crunched may be forced to compress their activities into longer chains. This remains an open and very interesting question, and we could explore this in the future using the existing data at hand. Of course, no dataset can capture every relevant factor, nor can any model account for all sources of variation. Given the present data availability in Canada, and the emphasis of this work on intra-day time-use dependencies, the methodological caveats described here do not negate the contribution of this research to the literature, but should be considered potential areas for future research.

To summarize, several directions for future research can be identified. From a data-needs perspective, obtaining multi-day or weeklong diaries for complete households should be made a priority to better understand how individual needs are met throughout the week and as part of a family unit. From a methodological perspective, with the appropriate data, multiple-discreet/continuous models that can account for household interactions as well as time-dependencies will greatly serve to reduce potential inconsistencies of parameter estimates. Another interesting methodological direction is in stochastic frontier analysis, a model that assumes that observed travel time is a function of an unobserved frontier, in our case, the desired shopping duration. And finally, from a theoretical or paradigmatic perspective, there is a clear need to collect and incorporate qualitative data in a movement toward a mixed-methods approach. By joining observed time-use patterns with attitudinal data concerning time-use and transport barriers to activity participation, a purer interpretation of model-based indicators of exclusion should be made possible.

4.6 Conclusions

A recent surge in interest in transport related social exclusion has sparked a number of quantification attempts in the literature. In order to inform the social exclusion debate in Canadian cities, the objective of this paper was to use the methods of time use and activity analysis to uncover the existence of significant variations in the patterns of time spent shopping for goods and services. In addition to exploratory analysis of time use data from the Canadian GSS, a three-stage regression approach was undertaken to allow for the simultaneous estimation of multiple activity durations thereby increasing efficiency and reducing endogeneity bias. The model results, coupled with a simple series of descriptive charts, outlines an interesting and complex story of mobility, accessibility and time-use constraints that ultimately brings us closer to discovering the extent of the role that these factors play in causing social exclusion.

The key findings from the descriptive analysis are:

- Shopping participation rates amongst senior citizens are similar to those of the rest of the population. Seniors over 75 have higher shopping participation rates for government, financial and personal services.
- Seniors and teens have longer trip durations for shopping activities.
- Respondents living in high-income and low-income households have longer shopping trip durations than the mean.
- Respondents living in low-income households have shorter shopping durations but higher shopping participation rates.
- Single parents spent 20% less time shopping and 20% more time on services activities.
- Single parents have higher grocery shopping rates.

The key findings from the regression analysis are:

- Duration in all other activities have a significant and negative impact on shopping duration.
- Being a senior significantly shortens shopping durations while lengthening trip durations.
- Low-household income decreases shopping durations, but low personal income seems to increase shopping duration.
- Being a low-income single parent has a negative effect on trip length.
- When holding other factors constant, being a single parent does not impact shopping duration.
- Having a drivers license decreases trip times for everyone, and increases shopping durations for seniors.
- Those who walk and bike more frequently, typically travel less time for goods and services.

One of the most interesting findings is that trip length has a positive impact on activity duration. This is not a new finding (Rosen et al., 2004; Schwanen, 2004), but deserves more discussion given that this study is trying to find a link between mobility, accessibility and exclusion. In particular, if we assume that longer trip durations are indicative of lower levels of access, and longer activity durations are indicative of less exclusion, then the positive coefficient suggests that lower accessibility is in fact associated with less exclusion. On its face, this is a contradiction of logic and theory, and serves as a reminder of how we should be interpreting the variables in our model. Lacking more in depth qualitative information, it is best to assume that trip duration is simply a complementary time-constraint and not an indicator of accessibility.

Finally, it is important to note that the nature of our models is simply to highlight inequalities in activity patterns amongst three marginalized subgroups: the elderly; low-income households; and single-parents. We must caution that while low duration and participation rates amongst certain segments of the population may be indicative of barriers to inclusion, typically models cannot identify the discrepancy between the required (or demanded) and achieved (or consumed) activity pattern. For example, longer travel times for shopping may indicate a willingness to travel further for specialty items rather than a lack of personal mobility and accessibility to activity locations. For this reason, while this work draws attention to potential areas for further study, we feel it is not appropriate to draw stronger conclusions about exclusion based on the analysis presented here. In this light, the contribution of this paper is to determine the extent to which different marginalizing factors such as age, income, and family status cause reduced levels of participation in shopping activities for goods and services. In order to determine whether the patterns we have discovered truly represent exclusionary processes or if they are merely a realization of varying tastes and preferences for activities and travel, we contend that further qualitatively orientated research is warranted. McCray and Brais (2007) perhaps offer the best direction for future qualitative research, one which joins locality with subjective attitudes toward travelling to various shopping destinations. In an approach such as this however, what one gains in understanding and clarity, one loses in quantification, abstraction, and generalization, benefits derived from quantitative modeling approaches, and important to supporting policy recommendations.

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5 Conclusions

This dissertation draws on methods and theoretical frameworks from time-geography and activity analysis to contribute to several bodies of literature: socially sustainable transportation, transport and social exclusion, and automobility. The first substantive paper contributes to socially sustainable transport and social exclusion through an analysis of time-use diary data and a theoretical exposition making use of key time-geographic concepts. In the second paper, modelling techniques drawn from the activity-analyst's toolbox are used to further investigate time-use patterns while controlling for confounding factors. Together, these papers contribute to the automobility literature by providing evidence of reduced social interaction and out-of-home activity participation resulting from automobile-oriented land-use and transportation systems. The third paper's focus differs somewhat by contributing evidence of social exclusion amongst populations at risk resulting from limited mobility levels and time-use constraints.

In the remainder of this chapter these aforementioned contributions are discussed in more detail, the broader implications of the research to policy making are put forward, and several directions for future research are identified.

5.1 Research Contributions

Let there be no confusion, the primary aim of this body of work is to provide quantifiable evidence of social costs of automobility, primarily in the form of reduced participation in discretionary and social activities. Be that as it may, the work tangentially draws on and contributes to a growing body of literature concerning the sustainability of our land-use and transportation systems, the system of automobility, and the risk of exclusion as a result of having limited access to the transportation system.

5.1.1 Automobility

This research contributes to the understanding of automobility by rooting the hypotheses of diminishing social interaction and participation in discretionary activities in formal time-geographic constructs. According to Urry (2004), the system of automobility is composed of six elements: *the manufactured object*; *individual consumption*; *complex socio-economic interactions*; *culture identity*; *resource-use*; and *mobility*. The *mobility* dimension in particular is associated with the automobile's power over the driver's daily schedule, and the long term impact of driving on how people negotiate complex time-space structures largely due to the spatial dispersion of social networks (Wellman, 2001).

The results of this dissertation indicate that a seventh dimension should be added to this list, *land-use* and *urban spatial structure*. It is clear from the land-use and transportation literature that these two systems are intimately linked in a cycle of reinforced urban expansion and development of automobile-oriented transport and land-use infrastructure. Automobility makes far-off places reachable, attractive, and therefore developable. These areas are then only feasibly reached by automobiles, therefore enticing, or rather, inducing the adoption of the automobile by residents, and the promotion of automobile infrastructure by interest groups and policy makers (Wegener, 2004). Any city with motorization rates as high as they are in North America but lacking the proper transport infrastructure and low density urban spatial structure to amenably accommodate the automobiles would be strangled by congestion. Thus the perpetuation of automobility as a system requires the land-use response.

Land-use is clearly influenced by – and influences – the perpetuation of automobility, but this thesis shows that the impact of automobility on activity outcomes is dependent on urban spatial structure and the dispersion of activity locations. The work in Chapter Two illustrates this effect theoretically (using time-space volumes) and empirically (using commute duration as a proxy for dispersion). It is shown that automobility may result in reduced participation if mobility is hampered by congestion or excessive spatial expansion. Furthermore, the empirical analyses in Chapters 2 and 3 illustrate that living locally results in more social participation, even for those who are automobile-bound.

Interestingly, in Urry's 'System' of Automobility (Urry, 2004), the relationship between time-space and automobility is thoroughly explored without couching the theory in time-geography. The exposition touches on many time-geographic concepts: increased spatio-temporal flexibility, expanded activity spaces, fragmentation over space and time of daily activities, and heterogeneous time-space paths. In this dissertation, many of these concepts are formalized in a time-geographic framework which certainly is beneficial to operationalizing the empirical quantitative analysis.

Finally, the time-geographic analyses in this dissertation services the automobility literature by linking its basic theories to two operational evaluative frameworks, socially sustainable transportation and social exclusion. This is given in more detail below.

5.1.2 Socially Sustainable Transportation

The evaluation of the land-use and transportation systems is a primary concern of transport-geographers. Sustainability is a lens through which to distinguish and examine the long-run impacts of transportation policy. The current system of automobility faces increasing criticism for its unsustainable consumption of resources, energy, and public space; its deleterious impact on local and global environmental systems; and a wide array of social externalities such as health, pedestrian fatalities, equity and justice, and social capital development. This last category of externalities partly constitutes the focus of the Socially Sustainable Transportation literature (Boschmann & Kwan, 2008), and it is the area of sustainability to which this research most significantly contributes.

All definitions of sustainability encompass the shared notion that in reaching our greatest potential in the present, we should not jeopardize the future generation's ability to reach theirs. From the perspective of socially sustainable transportation, we must ask whether or not our current practice of automobility will inhibit tomorrow's society from reaching its desired goals. To do this, activity behaviour modellers must turn the camera around and examine how transport systems affect social outcomes; a reversal of the traditional task of modelling activities for the sake of better understanding transportation outcomes. The three substantive chapters of this dissertation do exactly this.

The impacts of automobility on discretionary and social activity behaviour have been made clear in this dissertation. To transfer the discussion to sustainability, we must take these results and hypothesise what they might mean to the adoptive generation of our current system of automobility. This exact task lies outside the scope of this research, but surely urban areas in which people spend a greater number of hours in traffic, fewer hours doing discretionary activities, and have less time to be with friends and family, will be less desirable than competing locations ceteris paribus. There is a growing popular awareness that city-choice has a tremendous impact on overall life-outcomes (Florida, 2008). This recognition may lead people in large numbers to avoid cities that suffer from these types of ailments, thus reducing the competitiveness of certain cities in the labour market. To this end, improving the social aspects of today's transportation system will surely increase the viability of the city that the next generation inherits.

5.1.3 Transport and Social Exclusion

Transport and Social Exclusion is the third body of literature to which these research findings contribute. The broader question of interest is whether or not the existing transport system acts to inhibit or enable participation in the normal activities of daily life. This question is specifically addressed in Chapter 4 through an analysis of shopping participation for three sub-groups at risk of exclusion. To our knowledge, this is the first time that time-use measures have been used to address the issue of social exclusion, and the lessons learned will likely be very valuable to future researchers examining exclusion from a time-use perspective.

In particular, we discovered that drawing strong conclusions regarding the presence of exclusion is extremely difficult in the absence of data measuring the desired level of participation. While the methods used in this study use recorded participation levels, exclusion, by definition, would be identified as the difference between these two quantities. Furthermore, the role of transportation should be assessed by measuring its impact on this difference. While it does not enter into this dissertation, I am pleased to report that we have applied this idea in a report prepared for Human Resources and Skills Development Canada (Páez & Farber, 2010). In that study, Canadians with conditions that potentially limit activity participation are asked whether or not they desire to participate in more leisure activities. Variables measuring transportation access and prevention are used to explain this binary outcome, and those with better access to transport were less likely to feel desire for more leisure participation.

While the difference between revealed and desired preferences for shopping consumption cannot be determined from the GSS data used in Chapter 4, several findings do lend credence to the existence of exclusionary processes related to transportation. First, the model finds that the possession of a driver's license induces seniors to spend less time on shopping trips, and more time on shopping. This corresponds to the results of Chapter 3, that senior citizens, typically a demographic group with more severe physical mobility constraints, are able to participate more in social activities if they are automobile users. If we take the inverse, we could conclude that due to the current system of transportation and land-use in place, those with limited physical mobility are unable to participate as fully in social and shopping activities if they do not have access to a vehicle.

The implications of this research to social exclusion are not limited to the results specific to Chapter 4. Rather, the broader question of participation in social and discretionary activities can be viewed through a social exclusion lens. Typically, transport related exclusion is thought to apply to those who do not have access to the dominant mode of transport, namely the automobile. In addition to providing evidence of this classical form of exclusion, this research expands the possibilities of social exclusion to those who do drive. We've seen that those who do not depend on the car by living locally actually participate in more discretionary, social, and out-of-home activities; thus, using a car while attempting to live locally may actually cause social isolation. It is only when individuals participate in physically dispersed lifestyles that having a car enables more participation.

5.2 Policy Implications

The implications of this work, for the most part, follow from the above discussion of the research contributions. In addition to contributing to the academic discourses of Automobility, Sustainable Transportation, and Social Exclusion, some practical policy implications are evident. Transportation and land-use policies can and should be used to achieve societal goals, and understanding the social effects of a transport policy are a key input in the policy debate. This is especially true when the estimated effects are the result of a model with known inputs, methods, and caveats (King & Kraemer, 1993). The models found in this dissertation could form the basis of a new family of policy-oriented models of transport-related social outcomes.

By using a suite of social-outcome models, planners could discuss transport policies in the context of hypothesized impacts on time-use and social interaction. This provides for a holistic and comprehensive cost-benefit analysis that should result in a more valuable allocation of public resources. It specifically could foster the realization of positive social outcomes, such as community cohesion, participation in "pro-social" activities, and an increase in equity.

5.2.1 Community Cohesion

Cohesion is hypothesized to increase human happiness by fostering trusting relationships between neighbours (Litman, 2009). In trying to understand the development and formation of trusting social relationships, urban sociologist

Rick Grannis (2009), identifies the importance of repetitive, casual encounters between neighbours as a precursor to formal trusting friendship. The models in this dissertation show that promoting the ability to live locally, perhaps through land-use mixing, higher densities, and the fostering of active transport, will result in more out-of-home discretionary activities, more social interaction, and less time lost to isolative automobile travel. The models therefore provide a quantitative evidential link between transportation/land-use policies and the development of more cohesive societies.

Of course, I am not contending that this research *discovered* the link between transport and cohesion. Forty years ago, residents of the Annex in Toronto opposed the construction of the Spadina Expressway south of Eglinton Avenue precisely because of the deleterious social impacts it would have at the local, neighbourhood, or community level. Marshall McLuhan, a contemporary of the Toronto intelligentsia, famously stated that "Toronto will commit suicide if it plunges the Spadina Expressway into its heart... [planners] haven't the faintest interest in the values of neighbourhoods or community" (Nowlan & Nowlan, 1970, inside cover). So clearly this link is not new. The novel aspect of this work is that we can now begin to quantify the impact of planning decisions in terms of estimates of human social behaviour, a precursor to measuring community quality.

5.2.2 Fostering Pro-social Activity Participation

Time use analysis provides planners the opportunity to observe, predict, and *influence* the type, time, location, and social context of activities that people participate in. As we've shown in Chapter 2, by ignoring this power land-use and transportation policy likely caused reduced participation in a slew of activities with positive social benefit in Canadian cities over the last two decades. Cataloguing and monitoring activity participation could be made a requirement for judging the efficacy of a transportation and land-use policy. Community cohesion is one specific planning goal that can be monitored using the types of models calibrated in this thesis, but by changing the outcome variable of interest, other pertinent social problems related to transport policies can be investigated.

By matching a social issue with an appropriate activity outcome the possibilities for using activity analysis to discover transport-related social problems are plentiful. Political and civic engagement is matched to participation rates in organization and community meetings. The current obesity epidemic is monitored with rates of physical activity participation, grocery shopping, and time spent cooking. Declining levels of social capital could be linked to volunteering for neighbours, family, and the greater community. All of these activities are theoretically linked to transportation access, neighbourhood urban form, and the spatial arrangement of residential, work, and leisure opportunities at the metropolitan scale; time use analysis is able to provide planners with an operational framework to quantify these relationships, and judge the efficacy of their growth policies.

5.2.3 Equity between Social Groups

One potential goal of a transportation system in a democracy is to provide equitable opportunity to participate in activities for all citizens. In Chapter 4, the realization of this goal was investigated with time use analysis by modelling the impact of transportation access amongst three population subgroups (elderly, low -income, and lone-parents) on shopping participation. This analytical format could be extended to different types of activities (such as unpaid labour, the use of government services, and commute duration) and to different forms of potential marginalization (such as minority status, gender, and disability).

This research framework recognizes that transportation and land-use policies not-only affect the accessibility of locations in heterogenous ways, but they also impact the mobility and personal accessibility of individuals at all locations according to complex sets of personal constraints and capabilities. This recognition for a long time was ignored by transport policies dominated by generalized and system-level goals of increasing transport system efficiency for the daily commute trip. The research in this dissertation views transport policy through a lens of equitable inclusion and participation in a slew of non-work activities and it provides a framework for analyzing the impact of policy on equity.

5.3 Directions for Future Research

This investigation of the impact of automobility on time use and activity participation made several advancements to theory and has several policy implications. From this work it is possible to identify several directions for future research in terms of methodology and the need for new substantive research questions. These research directions are discussed in more detail in the following sections.

5.3.1 Methodological Needs

Human behaviour is extraordinarily complex. Any abstraction of behavioural processes in the form of a model will most certainly illuminate one process while casting a shadow on another. The strategy adopted in this research is to represent with more detail the parts of the process that are closest to the research foci, and to understand the potential drawbacks of leaving some processes as black-boxes, stochastic patterns, or economic assumptions. Methodological caveats and solutions are discussed at the end of each research chapter of the thesis, but three ideas stand out as being the most interesting and potentially fruitful: simulations in time-space geometries; multiple discrete-continuous model formulations; and stochastic frontier analysis.

5.3.1.1 Time-Space Simulations

The theoretical time-space metrics at the onset of Chapter 2 succinctly illustrate the relationships between mobility, activity dispersion, and accessibility.

They do however make very strong assumptions regarding the distribution of activity locations, velocities, and the locations of potential activity partners. The relaxation of these assumptions creates the possibility for far more realistic simulations in time-space.

In particular, the processes of land-use and modal velocity could and should be replaced by surfaces and fields better representing reality (Miller & Bridwell, 2009). Land-use data are readily available, as are data to produce a network representation of free-flow or congested link velocities. In addition to this, journey-to-work data provides a population of origin-destination pairs from which activity paths could be sampled. It is then a simple matter to repetitively sample pairs of activity paths to determine how much time-space opportunity there is for social interaction. The results of thousands of such simulations could be aggregated by origins and destinations resulting in maps of social interaction potential. These can be analyzed for relationships to urban form and mode use, and the lessons learned could surely be inputted into a comprehensive activity-based transportation/land-use model as these are in need of more evidence and theory to support the modelling of social activity patterns.

5.3.1.2 Multiple Discrete/Continuous Models

Discrete/Continuous models arose in the econometrics literature as a solution to the selection bias problem. That is, a continuous measurement is only observed if it is already large enough to exist, so any estimated relationship between that measurement and an exogenous factor is potentially biased.

Translated to the activity analysis framework, activity duration is observed only in the event that an activity episode took place, which might be a function of the desired duration. This in turn is a function of the number and duration of other competing and complementing activities performed in the day. Keeping in mind that activity participation is measured on an ordered nominal scale, and duration is most appropriately modelled using time-dependent hazard formulations, the task of simultaneously modelling multiple ordered/time-dependent processes is nearly untenable. Indeed, a modeller must pick and choose which relationships to assume away, and which to account for.

The family of discrete/continuous models have recently been expanded in a number of ways by transportation modellers. It is now known how to model multiple discrete/continuous variables simultaneously (Bhat, 2005), how to model the discrete process in an ordinal manner (Habib, Páez, & Bonin, 2010), and how to model the continuous process using a time-dependent hazard formulation (Habib, Carrasco, & Miller, 2008). What remains however is to link these three formulations together, therefore achieving a multiple, ordered-discrete/continuous-time-dependant model of activity participation and duration. Such a model fits closer to the nature of the statistical relationships. And, it allows for the simultaneous estimation of efficient and consistent coefficients for parameters across many competing activity types.

5.3.1.3 Stochastic Frontier Analysis

In Chapter 4, shopping activity durations were investigated for evidence of social exclusion. Interpretation of the model results was confounded by the assumption that the observed activity durations were optimal realizations of each individual's desire; exclusion is more likely evinced as a difference between desired and observed durations. No dataset containing desired durations exists to our knowledge. Despite this, the econometric method of stochastic frontier analysis may aid the investigation of exclusion (Aigner, Lovell, & Schmidt, 1977; Kumbhakar & Lovell, 2000).

Stochastic frontier analysis can be used to condition the estimation of an activity duration on an unobserved, stochastic frontier, interpreted as the desired level of duration. Applications of stochastic frontier models do exist in the transportation literature (Banerjee, Ye, & Pendyala, 2007; Kitamura, Yamamoto, Kishizawa, & Pendyala, 2000), but the hypothesized purpose proposed here differs significantly to what has been attempted in the past.

5.3.2 Subjective Well-Being

In contemplation of these conclusions, one new research question can be differentiated as an important extension of this dissertation research. This research has taken, for the most part, a normative approach to activity analysis. It is implicit in each of the chapters that doing more social, discretionary, and shopping activities is somehow better than doing less. This stems from the theoretical backdrop borrowed from the sociological automobility literature.

However, this normative assumption should be questioned. From an economic perspective, the changes in activity participation patterns from 1992 to 2005 observed in Chapter 2 may simply represent a shift in preferences Therefore utility, or well-being, may not have decreased as a result of these changes. With the advent of sophisticated home-entertainment, in-car entertainment, and portable listening devices, the comparative utility of social interaction and out-of-home discretionary activity participation may simply be declining with no net-loss to utility.

Of course, utility is an unobserved latent construct, useful in understanding the economic behaviour of agents, but impossible to know directly. One way to determine whether or not utility has been declining as a result of these time-use changes is to investigate proxy variables such as subjective measures of well-being. Variables measuring well-being, life-satisfaction, stress, and health already are collected in Cycle 19 of the GSS. It will be quite reasonable to investigate this data for the relationships between well-being, automobile use, and social interaction. Thus the hypothesis that reduced social participation affects utility can be tested.

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6 Appendix

Appendix I Average Duration and Participation of Shopping Activities

		Shopping Related Travel			Shopping for Goods and Services			Grocery, Market & Convenience			Everyday Goods and Products			Services		
		Dur.	n	Part.	Dur.	n	Part.	Dur.	n	Part.	Dur.	n	Part.	Dur.	n	Part.
Age	15 to 24	46.4	51	100%	131.4	51	100%	75.4	22	43%	116.7	21	41%	64.6	8	16%
	25 to 34	35.3	103	100%	95.0	103	100%	63.9	67	65%	109.1	36	35%	68.3	9	9%
	35 to 44	31.9	159	100%	78.3	159	100%	54.3	111	70%	92.0	48	30%	46.5	18	11%
	45 to 54	39.4	138	100%	99.6	138	100%	64.9	88	64%	87.3	52	38%	69.1	19	14%
	55 to 64	39.9	119	100%	112.6	119	100%	68.9	66	55%	124.5	48	40%	62.6	16	13%
	65 to 74	40.2	78	100%	85.2	78	100%	59.4	51	65%	72.6	31	40%	70.6	8	10%
	75 years plus	46.7	37	100%	104.3	37	100%	64.6	21	57%	133.9	16	43%	25.7	8	22%
Hhd. Income	Less than $20K	37.9	81	100%	80.5	81	100%	58.0	52	64%	102.7	30	37%	37.3	7	9%
	$20K-$40K	38.9	87	100%	90.8	87	100%	55.9	60	69%	115.8	31	36%	65.4	9	10%
	$40K-$60K	33.3	103	100%	90.4	103	100%	62.6	65	63%	80.4	31	30%	56.8	12	12%
	$60K-$80K	34.1	93	100%	91.5	93	100%	56.1	58	62%	110.4	35	38%	45.8	11	12%
	$80K-$100K	38.6	51	100%	107.1	51	100%	57.7	31	61%	110.3	23	45%	89.4	5	10%
	$100K plus	40.0	107	100%	105.5	107	100%	65.9	63	59%	101.8	37	35%	27.1	14	13%
	Unknown	43.2	163	100%	108.6	163	100%	72.9	97	60%	100.3	65	40%	76.8	28	17%
Lone-Parent Status	Not Single Parent	38.8	618	100%	100.3	618	100%	64.0	382	62%	103.4	228	37%	57.3	78	13%
	Single Parent	36.1	67	100%	81.1	67	100%	53.4	44	66%	92.5	24	36%	67.9	8	12%