TELECOMMUTING TRAVEL BEHAVIOR

TELECOMMUTING TRAVEL BEHAVIOR: EXAMINING THE INFLUENCE OF WORK STATUS ON DISTANCE AND MODE CHOICE IN THE NATIONAL CAPITAL REGION

By

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ABSTRACT

This study explores telecommuter travel behaviour by examining discretionary travel distance and mode choice. The study utilizes data obtained from the 2005 origin-destination survey conducted by TRANS, a joint transportation planning committee serving the National Capital Region of Canada. The study compares and explains the discretionary travel behavior of teleworkers relative to other population groups and identifies that the average teleworker travels 3 times farther than regular workers and 1.7 times farther than non-workers for discretionary purposes. Regression indicates that dependent children, vehicle accessibility, housing type, residential distance to the urban core, land-use mix, residence within a Greenbelt region and day of the week all positively affect travel distance. Conversely, age, proximity to shopping centers and inclement weather demonstrate significant negative effects. Then, through binary logistic regression, the study confirms that work status significantly influences mode choice. Similarly, the following predictor variables demonstrate a significant positive effect towards active mode choice: teleworker work status, larger household size, greater income, warmer temperature, closer proximity to shopping centers, apartment housing type, trips for recreational and restaurant purposes, taking subsequent trips in a day, and travel between 8:00 A.M. and 4:00 P.M. On the contrary, increased entropy, trips within the Greenbelt region, dependent children under 16 years old, increased vehicle accessibility and trips for transporting someone or for shopping purposes all reduce the probability of active travel mode choice.

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"It is the mark of an educated mind to be able to
entertain a thought without accepting it."
– Aristotle

"I have never let my schooling interfere with my education"
– Mark Twain

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LIST OF ABBREVIATIONS

CMA	Census metropolitan area
DA	Dissemination area
NCC	National Capital Commission
NCR	National Capital Region
PKT	Person Kilometers Traveled
OC Transpo	Ottawa-Carlton Regional Transportation
STO	Société de transportation de l'Outaouais
TAZ	Traffic Analysis Zone
TDM	Travel demand management (also transportation demand management)

CHAPTER ONE

INTRODUCTION

A sustainable transportation system is an integral component for a prosperous urban society. With the majority of the world's population now living in urbanized environments, urbanization has become a global trend (Central Intelligence Agency 2012). Cities offer the incentives of employment opportunity, education, health care and other sought after amenities, however, rapid and unplanned urban expansion is often associated with population demands surpassing service capacity, especially in the context of the transportation system (Moore et al. 2004). The negative effects of an overly congested network are often identified in academic literature through health impacts, environmental degradation and perhaps the most easily quantifiable, the negative economic costs of traffic (Downs 2004; iTRANS 2006; Turcotte 2011; Rabl and de Nazelle 2012).

In a Canadian context, the economic cost of traffic congestion has grown considerably over the past two decades across all major census metropolitan areas (CMAs) (iTRANS 2006; Turcotte 2011). Thus, in attempts to improve congested travel conditions, various travel demand management (TDM) strategies have been implemented over recent years. Although once considered a speculative concept, TDMs are now fairly widespread and incorporated into planning processes as a method to adhere to budgetary constraints while addressing critical transportation issues (Orski 1990; Ferguson 1999). Among the available traffic mitigation tools, telecommuting offers the potential to alleviate congested roadway conditions, particularly during peak rush hour travel (Salomon 1998).In 2009, 40% of Canadian public and private sector firms offered employees the opportunity to telework, an increase from the 25% in 2007 (Canadian Telework Association 2012). The Canadian Telework Association estimates that as of 2009 roughly 10% of the Canadian workforce or 2.5 million employees work through a teleworking arrangement at least once a week (Transport Canada 2010; Canadian Telework Association 2012).

Conceptually, telecommuting is a flexible working arrangement which dramatically increases the virtual accessibility of the worker, allowing them to work from home or satellite office location. This flexibility reduces the need for a worker to be physically transported through the transportation network on a daily basis, unlike a typical commuter. For Canadians, the national average daily commute time continues to increase, while the vast majority of workers perceive their commute as a waste of time and a significant source of stress (Turcotte 2011). To explore the application of telework as a TDM, literature has examined a range of aspects including social influences, environmental costs, health impacts and the friction of workplace implementation (Kitou and Horvath 2003; Kossek et al. 2006; Walls et al. 2007; Kitou and Horvath 2008; Páez 2008; Maruyama et al. 2009; Morganson et al. 2010; Turetken et al. 2011; Wilton et al. 2011; Scott et al. 2012).However, this study examines the relatively unexplored influence of work status on travel behaviour; specifically, the effects on discretionary travel distance and active travel mode choice.

1.2 OBJECTIVES

The goal of the study is to advance the current knowledge of telecommuter travel behaviour. This is necessary to gain a sense of relative impact that teleworkers have on the transportation system as compared to individuals of other work statuses. For this study, work status divides the population into three categories, namely, teleworkers, regular workers (commuters) and non-workers. Literature identifies that relative impact is often studied through the examination of two key characteristics, namely, travel distance and modal choice (Habib et al. 2012). Thus, the examination of these two components forms the two main objectives of the study:

(1) To descriptively compare the discretionary travel distance of teleworkers to those of other work statuses, and explain the observed differences for teleworkers specifically.

(2)To explore the influence of work status on active travel mode choice to identify whether work status is a significant factor.

The first objective places teleworker travel behaviour into context among other work statuses. Once a sense of travel distance is established, the second objective examines mode choice to gain a sense of the relative impact that teleworkers have on the transportation system in relation to other work statuses. Understandably, an increase in travel does not necessarily possess the same level of impact if all travel is performed through non-impactful physically active modes in comparison to automotive modes (Cosgrove and Holahan 2012; Habib 2012).

1.3 OVERVIEW

Following this section are two capsulated chapters, each addressing a thesis objective. Each chapter contains an abstract, introduction, background, data& methods, results and discussion specific to the objective. Although the background literature in both chapters pertains to telework and travel behaviour, each chapter contains relevant and unique information themed specific to the study objectives. Following these two chapters, is a conclusion, discussion on study limitations and areas for future research.

CHAPTER TWO

TELEWORKERS IN MOTION:
AN INVESTIGATION OF DISTANCE TRAVELED
FOR DISCRETIONARY PURPOSES

2.1 ABSTRACT

This paper compares and explains the discretionary travel behavior of teleworkers relative to other population groups. The study utilizes data obtained from the 2005 origin-destination survey conducted by TRANS, a joint transportation planning committee serving the National Capital Region of Canada. Considering total daily travel, the comparison reveals that the average teleworker travels 3 times farther than regular workers and 1.7 times farther than non-workers for discretionary purposes. Regression indicates that dependent children, vehicle accessibility of the household, housing type, distance to the urban core, land-use mix, residence within a Greenbelt region and day of the work week are all associated with increased travel distance. Conversely, proximity to shopping centers and inclement weather have significant negative effects on discretionary travel distance.

2.2 INTRODUCTION

Traffic congestion has worsened in all major Canadian census metropolitan areas over the past two decades (Turcotte 2011). The cost of traffic congestion is realized through the measurable increase in travel time through a congested system. From the result of early research done by Jack Nilles, it has been established that the flow of traffic through a system behaves much more like blood than water, in that when it reaches a congestion threshold it can clot (Nilles 1996). This analogy speaks to the increase in the number of private automobiles on roadways, which can lead to a network disruption at a non-linear rate (Lighthill and Whitham 1955;

Richards 1956; Vickrey 1969).As a means to mitigate congested travel conditions, several travel demand management (TDM) strategies have been designed to address the core issues of overcrowded roadways. Telecommuting is a single example that conceptually eliminates the need to commute on a daily basis, which ultimately reduces the number of vehicles on the road and alleviates the severity of peak hour travel conditions.

Thus far, several studies are identified in literature to have examined the travel patterns of workers who alternate commuting days with telework days. The results show that there is a greater preference to reserve discretionary travel for regular commuting days, so that trips can be completed as part of the work trip, forming trip chains (Nilles 1996; Mokhtarian 1998; Mokhtarian et al. 2004; Primerano et al. 2008). The utility of trip chaining is well supported due to increases inefficiency and maximization of leisure time. However, this study focuses on the empirical evidence that teleworkers travel greater distances to complete common discretionary trips in comparison to non-teleworkers.

To examine this unique behavior, this study begins with a descriptive comparison of the person kilometers travelled (PKT) of teleworkers to regular workers (commuters) and non-workers. A regression model is presented to better explain the socio-demographic, built environment and meteorological characteristics that influence discretionary PKT by teleworkers. In so doing, this study compliments previous research efforts by advancing knowledge on teleworker travel behavior and provides additional Canadian context to the current body of telecommuter research. The remainder of this paper is separated into four sections following the introduction: a background review of research focusing on telework and travel behavior, data and methodology, results, and finally the conclusion.

2.3 BACKGROUND

The terms telecommuting or teleworking represent a wide range of flexible working arrangements, from a limited range of periodic work once a week to entirely virtual forms for weeks at a time (Mokhtarian 1991). Its sustainability and resilience have been made possible through incredible growth in telecommunications over the past three decades and is often seen as an attractive public policy measure to reduce daily commuting and associated externalities. The telecommuter concept represents a shift from the traditional working arrangement, perhaps best explained by researcher Jack Nilles, as moving work to the workers, in exchange for moving workers to work (Nilles 1998). This shift has been further facilitated through rapid advances in telematics and the integration of these technologies into workers' homes. Rapid advancements in telephone communication, the fax machine, forms of wireless communications and most recently, the internet, have all improved the efficiency and reliability of data transmission (Nagae et al. 2012). Perhaps the largest driving force has been the advent of powerful and inexpensive computers, which are readily available in the commercial market (Nagae et al. 2012).

Through telecommuting, workers have the ability to complete tasks by means of a virtual presence, eliminating the necessity to physically travel. As past research identifies, it is crucial to understand the existing relationship between an individual's time and travel behavior, particularly, the demand placed on wage-earning time and the resulting demand of leisure time. This is an underlying econometric concept that helps explain the variations in travel behavior for individuals of differing employment status, e.g. full-time employment, part-time employment or unemployed. Past efforts to combine economics and travel demand concepts identify that the allocation of time between wage-earning and leisure is measurable by PKT and trip chaining (Anas 2007).This is a relatively simple concept in that a work commute is usually perceived as a mandatory allocation of time and therefore, by chaining smaller trips, e.g. grocery shopping, to the required work commute, the burden of allocating leisure time is reduced. By chaining trips, the individual travels from one destination to another as a substitute for traveling home between each destination, resulting in a reduction of the overall daily PKT. However, given this relation of time and efficiency, the perception differs for teleworkers in that most, if not all, trips exist solely on leisure time. A study conducted in 2001 observed the travel behaviors of regular workers given the option to telecommute certain days of the week while commuting on other days. The study concluded that when individuals are presented with the choice of completing tasks on a regular working day or on a teleworking day, the majority restricted self-travel until a regular working day, completing tasks on the return home commute from work (Wells et al. 2001). This type of behavior indicates travel efficiency and suggests that by removing the work commute entirely, teleworkers experience an additional increase in leisure time each day. This surplus of time reduces the demand placed on efficient travel, and it is hypothesized that teleworkers possess a different travel behavior, tested through increased activity levels, as compared to regular workers and non-workers.

The importance of understanding the differences in population travel behavior resides in the direct application to public policy and congestion management strategies. Throughout the telework literature, several metrics are often used to describe the travel behavior of teleworkers. These include the strong relationships between telework status and occupation type, socio-demographic status, psychological perception, work productivity and energy consumption, trip frequency and travel distance (Mokhtarian and Salomon 1997; Tonn and Hernick 2004; Walls et al. 2007; Kitou and Horvath 2008; Cao et al. 2009). Several more recent studies have investigated the interaction of variables with the teleworking environment by exploring factors such as perception, and telework adoption (Ory and Mokhtarian 2009). To date, research indicates that work experience, task interdependence and exposure to communications technology are all critical in modeling teleworking occurrence (Tonn and Hernick 2004; Turetken et al. 2011). Furthermore, the desire to telecommute has been explained though the introduction of attitudinal factors, varying measures of perception, and social influence (Hamer et al. 1991; Mokhtarian 1991; Mokhtarian and Salomon 1997; Mokhtarian 1998; Mokhtarian and Bagley 2000; Ellen and Hempstead 2002; Ory and Mokhtarian 2009; Wilton et al. 2011; Scott et al. 2012).

Other studies discuss the effects telecommuting on residential location choice and resultant changes in commute distances. Several studies indicate that there is a positive relationship between residential proximity and the urban core, that is, teleworkers tend to live farther from the urban core (Nilles 1991; Mokhtarian et al. 2004). In more recent research, case studies have provided insight towards travel behavior through discrete choice modeling and multivariate regression (Wells et al. 2001; Cao et al. 2009). Through modeling efforts, built environment variables have proven influential in travel behavior for the general populace, and therefore should be explored for teleworker specific activities (Cao et al. 2009; Cao et al. 2009). However, what remains an area of limited research coverage are the quantifiable impacts of meteorological conditions on travel. To explore these effects, this study incorporates several weather and atmospheric variables to identify their significance in explaining PKT. For an accurate representation of weather during individual trips, atmospheric conditions, as reported by Environment Canada, are linked to trips based on trip starting times.

2.4 DATA AND METHODOLOGY

2.4.1 Data and Study Area

The data were obtained from the 2005 origin-destination survey conducted by TRANS, a joint transportation planning committee serving the National Capital Region (NCR) of Canada. The survey collected information at the household, personal, and trip level for a random sample of 23,868 households over the months of September, October and November of 2005. Expansion factors were assigned to households to allow for an accurate estimation of the true population size. As part of the survey, respondents indicated their work status as one of a teleworker, regular worker (commuter), or non-worker. To ensure a comparable population of non-workers with workers, only respondents aged 16 to 64 years were included in the analysis. This range abides with the parameters governing the Minimum Age Laws in Canada outlined by the Canadian Labour Congress (Canadian Labour Congress 2012). Respondents under the age of 16 do not meet the minimum required age to work in all employment locations and conditions in Canada, and similarly respondents over and including the age of 65 have the greatest tendency to be retired and beyond the scope of the analysis.

The study area is the National Capital Region of Canada, which consists of Ottawa, Ontario (amalgamation of Ottawa, Nepean, Kanata, Gloucester, Vanier, Cumberland, West Carleton, Goulburn, Rideau, Osgoode and Rockcliffe Park) and Gatineau, Quebec (amalgamation of Aylmer, Buckingham, Gatineau, Hull and Masson-Angers). The region is separated by the Ottawa River, which serves as the provincial boundary between the provinces of Ontario and Quebec. However, despite the river separating the study area, there remain five bridges available for transport across the river which provides regional access. Furthermore, Ottawa's public transportation, OC Transpo, operates in both the Ottawa, ON and Gatineau, QC regions connecting to the Quebec public STO transit service. For the purpose of this study, the location of the urban core is defined as Parliament Hill, as indicated in Figure 2.1. The figure also shows the distribution of teleworkers in the region, as a percent of the population within each traffic analysis zone (TAZ) for reference. Initially from this map, it is evident that there are several areas of greater teleworker concentration in the study region, in other words they are not evenly distributed throughout the region.

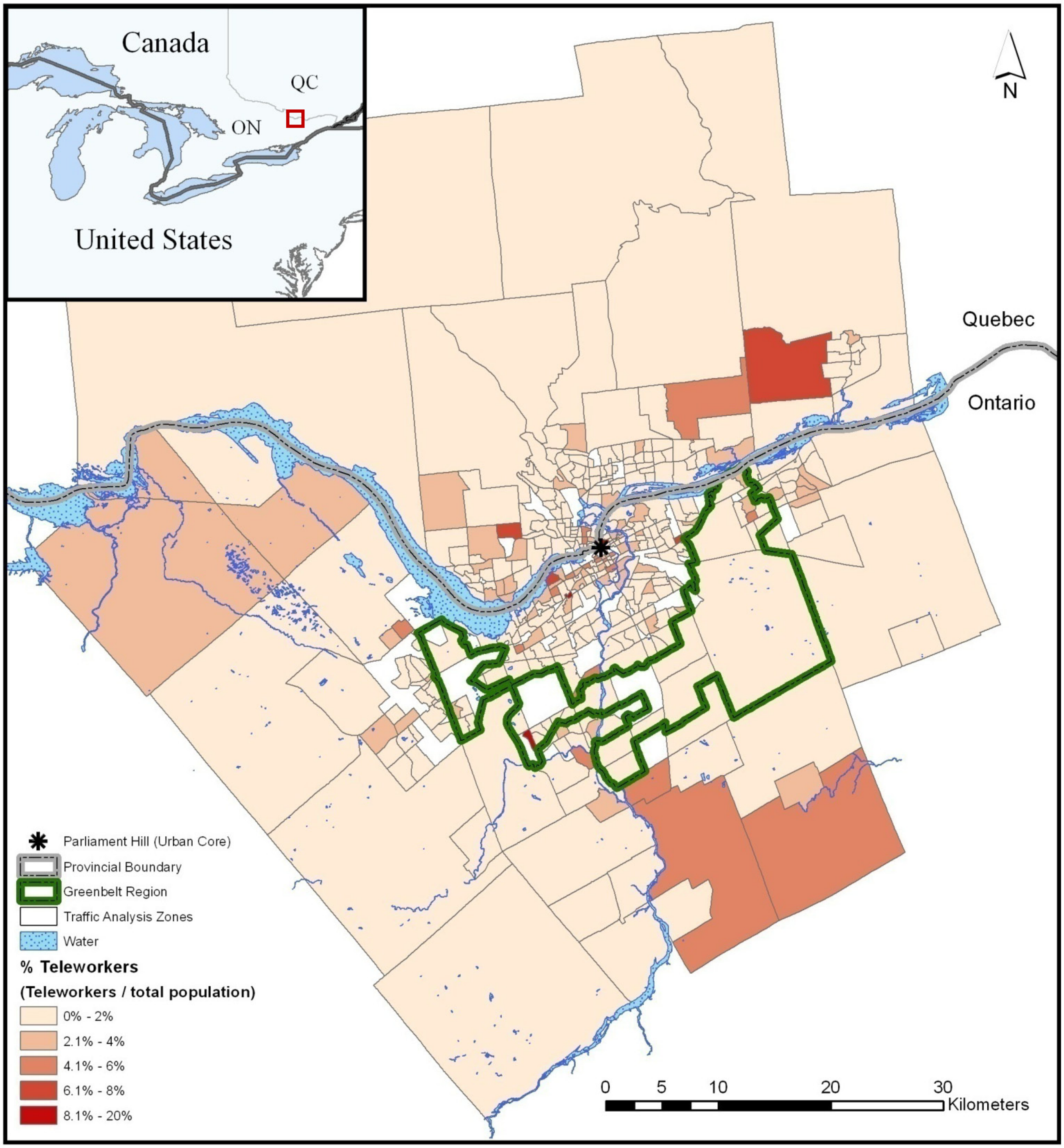

Figure 2.1. Study area showing teleworker population percentage per traffic analysis zone.

This study focuses on discretionary trips, and therefore all work, school, and return home trips are excluded from the analysis. Focusing solely on discretionary travel provides a more robust comparison between population groups, since this type of travel is shared among all three population groups. Through initial data exploration, it was found that all trips used the same mode of travel to return home as their outbound counterpart, apart from a negligible percentage (0.18%).It is for this reason and to prevent overrepresentation in the data, that all return home trips were removed from the analysis. These criteria resulted in only discretionary travel, which can be further categorized into one of multiple trip purposes: shopping (stores, big boxes, grocery shopping), recreation, restaurant (take-out), restaurant (eating in), visiting friends or family, medical, dropping someone off, picking someone up, and other (if the trip does not fall into one of the aforementioned purposes).

Trip origins and destinations were collected at the traffic analysis zone level of geography. Given the geographic location with a dense downtown core and sprawling rural regions, the TAZs vary in size from a minimum of 0.1 km^2 to a maximum of 616.3 km^2, with a standard deviation of 46 km^2. To minimize error, respondents' exact locations were estimated within the TAZ by using a population-weighted position calculated based on population density at the dissemination area (DA) level. The result is a single population-weighted position for each TAZ based on the unique population density pattern at the local level within each region. Among other methods explored, this process achieved the most representative spatial distribution of respondents, particularly for larger TAZ regions in the periphery of the NCR.

2.4.2 Dependent Variable

For this study, all trip distances are computed as Euclidean distances (or "as the crow flies") between geocoded origins and destinations. The dependent variable for this analysis is the natural logarithm of the total PKT for the day - that is, the natural logarithm of the sum of all discretionary travel distance for a teleworker on the day surveyed. As it is a fundamental assumption in linear regression that the values of the dependent variable be normally distributed, a natural logarithmic transformation was performed to teleworker PKT to obtain the desired normal distribution. Originally, teleworker PKT exhibited a positive skew, and thus the transformation compresses the variable's long tail, which arises due to the well-known effect of distance decay on spatial interaction intensity (Axisa et al. 2012).

For this study, the focus is on modeling the discretionary PKT of teleworkers. Here, teleworkers are defined as individuals who work either full-time, or part-time from home through a telecommuting arrangement with their employer. In this study, the focus is on teleworkers who do not perform work-related trips, including trips for itinerant work, on the survey day. In other words, the teleworkers identified are those who are teleworking from home on the survey day. There are 6,891 Teleworkers which represents1.8% of the expanded sample population. Conversely, regular workers are either full-time or part-time employees who commute to work. In this definition, self-employed individuals who travel to work, fall under this category. In other words, on the survey day these individuals either commute to work or have itinerant work trips. The expanded sample of regular workers includes 224,441 individuals which equates to approximately 57.5% of the population. Finally, there are 158,642 non-workers who are individuals that are not employed: this includes students, retirees and homemakers. Non-workers represent the remaining 40.7% of the population.

Preliminary data analysis identifies that teleworkers are the most active population group among all work statuses. Table 2.1 summarizes the average discretionary PKT for each work status with the inclusion of regular commuter work trips for reference. Conceptually, teleworkers share numerous similarities with both regular workers and non-workers. For instance, both teleworkers and regular workers are either part-time or full-time employees, where a large portion of hours in a day are considered work hours. However, teleworkers diverge from the commuter paradigm as they do not travel to work, thus receiving extra leisure time in place of the time otherwise spent commuting in traffic. Similarly, teleworkers and non-workers share similarities in travel patterns as trips can be completed throughout the day rather than during fixed morning or evening time windows coinciding with peak rush hour times. On the other hand, teleworkers are uniquely different from non-workers in that hours during the day are still work hours and not leisure time.

First, considering only discretionary travel, teleworkers' total PKT is approximately 3 times greater than regular workers and 1.7 times greater than non-workers. Consequently, teleworkers travel farther than others for common discretionary trips. Therefore, it appears the mixture of home or satellite office based employment promotes greater travel throughout the day. To gain a better understanding of the overall system impact of teleworkers compared to regular workers, Table 2.1 also summarizes the average PKT (including work travel) of regular workers. From this, it is observed that an average teleworker's discretionary PKT is approximately 92.6%

of a regular commuter's total daily travel (including all work related trips). Thus, from a system impact perspective, implementing telework does reduce overall daily PKT, despite the large increase in discretionary travel.

Table 2.1.Comparing discretionary travel distance (km) by work status.

	Classification	**Regular Worker** *Work trips included*	**Regular Worker** *Discretionary travel only*	**Teleworkers** *Discretionary travel only*	**Non-Worker** *Discretionary travel only*
	Total Population	24.6	6.1	12.8	9.9
	Active Participants*	**27.2**	**8.3**	**25.2**	**14.7**
Age group	16 to 19	23.4	9.7	19.4	11.0
	20 to 24	23.7	8.6	27.9	11.9
	25 to 34	26.1	8.0	27.0	13.5
	35 to 44	28.3	8.1	25.6	18.4
	45 to 49	28.5	8.7	25.7	19.3
	50 to 54	27.7	8.7	21.4	17.9
	55 to 64	26.6	8.4	24.2	19.1
Sex	Male	28.2	8.5	24.3	14.4
	Female	26.2	8.2	26.0	14.9

Note: All values are expressed in kilometers.
*Active participants are defined as individuals who perform a trip on the survey day as opposed to individuals who remain at home and do not take trips.

2.4.3 Independent Variables

Among a comprehensive list of explanatory variables, work status is used to distinguish between three distinct population groups in the study, labeled as: teleworkers, regular workers, and non-workers. For the model presented in this paper, only the PKT of teleworkers is considered. Initial exploration identified that teleworkers traveled more for discretionary purposes than others, and therefore interest is placed on explaining teleworker PKT. To achieve this, a suite of socio-demographic, built environment and meteorological variables were tested. Descriptions for all variables tested are summarized in Table 2.2. Although not all of these variables proved statistically significant in the final model, they were all explored to determine their potential explanatory capabilities.

Table 2.2. Independent variables tested in the empirical analysis.

Variable	Definition	Sample percent (weighted)	Mean discretionary PKT (km) (weighted)	Mean	Std.
Employment					
Teleworker	1 if respondent telecommuted on the day surveyed; 0 otherwise	1.7	12.8		
Regular worker	1 if respondent commuted on the day surveyed; 0 otherwise	57.5	6.1		
Non-worker	1 if respondent does not work; 0 otherwise	40.7	9.9		
Full time	1 if respondent works full-time hours; 0 otherwise	53.7	7.9		
Part time	1 if respondent works part-time hours; 0 otherwise	5.6	11.0		
Built Environment					
Single-detached house	1 if respondent resides in a single-detached house; 0 otherwise	60.1	10.8		
Semi-detached house	1 if respondent resides in a semi-detached house; 0 otherwise	9.0	8.8		
Row or townhouse	1 if respondent resides in a row or townhouse; 0 otherwise	13.6	8.8		
Apartment	1 if respondent resides in an apartment; 0 otherwise	15.5	6.2		
Other (trailer, cottage,	1 if respondent resides in other form of residence; 0 otherwise	1.8	10.0		
X coordinate	X coordinate of respondent's place of residence			-75.7	0.1
Y coordinate	Y coordinate of respondent's place of residence			45.4	0.1
X*Y	X coordinate multiplied by Y coordinate			-3437.0	7.4
X coordinate squared	X coordinate squared			5731.3	19.8
Y coordinate squared	Y coordinate squared			2061.2	7.9
Distance to Parliament Hill	Straight-line distance (km) from residence to Parliament Hill (urban core)			11.7	8.3
Intersections	Number of intersections in traffic analysis zone (TAZ)			110.9	137.8
Entropy	Land-use mix score: 1 signifies maximally heterogeneous; 0			0.1	0.1
Shopping center gravity	Inverse distance weighting of shopping centers; weight by number of			17.1	10.0
Greenbelt location	1 if respondent lives within a Greenbelt location, 0 otherwise	25.5	10.0		
Meteorological					
Maximum temperature	Maximum recorded temperature (°C) on the day surveyed			24.0	1.4
Mean temperature	Average temperature (°C) on the day surveyed			21.1	1.4
Minimum temperature	Minimum recorded temperature (°C) on the day surveyed			15.6	1.8
Speed of maximum gust	Maximum wind speed recorded (km/h) on the day surveyed			65.8	5.3
Total rainfall	Total amount of rainfall (mm)			30.9	4.3
Total snowfall	Total amount of snowfall (mm)			7.7	3.1
Total precipitation	Total amount of combined precipitation (mm)			30.9	4.3

Snow on ground	1 if snow is present on the ground; 0 otherwise	8.8	68.8		
Demographic and household					
Age	Age in years			38.4	13.0
ln Age	Natural logarithm of Age			3.6	0.4
Female	1 if respondent is female; 0 male	49.5	10.2		
Median Income	Median household income in dollars for TAZ of residence			55719.0	5519.7
Average Income	Average household income in dollars for TAZ of residence			83033.7	17961.
Children (under 16 years)	1 if there is a child in the respondent's household; 0 otherwise	35.1	11.3		
Age of youngest child	Age (years) of the youngest child in respondent's household			7.5	4.9
License	1 if respondent has a driver's license; 0 otherwise	87.9	10.5		
Registered driver	1 if respondent is a registered driver; 0 otherwise	44.6	9.1		
Transit pass	1 if respondent owns a transit pass; 0 otherwise	20.3	7.0		
Household size	Number of people in who reside at the respondent's place of residence			3.1	0.3
Number of vehicles	Number of vehicles at the respondent's home			1.7	0.9
Household car share	Number of licensed drivers divided by number of household vehicles			0.6	0.4
Survey Information					
Monday	1 if respondent completed survey on a Monday; 0 otherwise	20.1	10.5		
Tuesday	1 if respondent completed survey on a Tuesday; 0 otherwise	20.4	9.3		
Wednesday	1 if respondent completed survey on a Wednesday; 0 otherwise	19.8	9.8		
Thursday	1 if respondent completed survey on a Thursday; 0 otherwise	19.5	9.3		
Friday	1 if respondent completed survey on a Friday; 0 otherwise	20.3	11.6		
Expansion factor	Weight assigned to each respondent for representation in total population			20.7	6.1
Number of trips	Number of trips reported on the day surveyed			3.3	1.8

Notes: Except for household income, variable definitions are in reference to the months September, October, and November of 2005. Household income was obtained from the 2006 Census of Canada. The weighted sample population was calculated based on a weight provided by TRANS, Ottawa, Canada. The percentages shown may not sum to 100 due to rounding.

2.4.4 Model Specification

Multiple regression is used to quantify the relationship between discretionary PKT and a number of socio-demographic, built environment and meteorological variables. The model is specified as:

$$\boldsymbol{T} = \boldsymbol{X\beta} + \varepsilon \tag{1}$$

where $\boldsymbol{T}$ represents the natural logarithm of discretionary PKT for a teleworker *i* on a typical day. $\boldsymbol{X}$ is a matrix of variables that reflect socio-demographic, built environment and meteorological characteristics for teleworker *i*. $\boldsymbol{\beta}$ is a vector of parameters to be estimated by the model. Since the modeled dependent variable is based on a natural logarithmic transformation, parameters are interpreted as follows: when multiplied by 100, a parameter indicates the percentage change in discretionary PKT associated with a unit change in an independent variable. As for categorical variables, the coefficient is interpreted as a percentage change in the dependent variable when the categorical variable occurs. Finally, $\boldsymbol{\varepsilon}$ represents the unobserved error in *i*. As a result, the above model can be estimated using the Ordinary Least Squares (OLS) method.

Variables such as inclement weather and closer proximity to shopping centers are expected to have a negative relationship with travel distance. On the other hand, greater accessibility to a private vehicle, having children in the household, built environment, and housing type are expected to have a positive relationship on distance travelled. Although all variables in Table 2.2 were tested, only those that were statistically significant at p> 0.05are retained in the final model.

2.5 RESULTS

A regression model is used to better understand the socio-demographic, built environment and meteorological characteristics that result in greater discretionary travel distances by teleworkers. Table 2.3 shows the results of the regression model. The results show a series of independent variables, which demonstrate strong and statistically significant effects on the dependant variable. For ease of interpretation, variables significant at p>0.05 significance level and model fit were all considered in the final selection of the model. The model demonstrates an adjusted coefficient of determination of 0.151 and the observed effects of the variables coincide with findings from related literature. The observed effects are further discussed throughout this section.

Table 2.3.Regression model of the natural logarithm of person kilometers traveled (km) for teleworkers.

Variable	Coefficient	*t*-statistic
Constant	2.408	20.080
Child under 16 years of age	0.185	5.830
Household car share index	0.332	8.530
Semi-detached house	0.314	5.970
Apartment	0.135	2.720
Other (trailer or cottage)	0.279	3.010
Distance to Parliament Hill	0.034	15.880
Entropy	0.599	4.850
Shopping center proximity	-0.004	-2.630
Greenbelt	0.173	5.260
Wednesday	0.199	5.640
Friday	0.266	-8.110
Total Precipitation (mm)	-0.023	-6.450
Summary Statistics		
r^2	0.153	
Adjusted r^2	0.151	
n	366	
N	6891	

Note: all coefficients are significant at the 0.05 significance level.

For socio-demographic variables, the model indicates that the presence of dependent children under 16 years of age in the household demonstrates a fairly strong positive effect on teleworker travel distance. More specifically, a teleworker who has dependent children increases daily PKT by approximately 18.5% as compared to those without. The household car share index represents the ratio of vehicles available in the teleworker's household to the number of registered drivers at the residence. It is apparent that the effect of the coefficient is a strong positive predictor for travel distance. In other words, as vehicle accessibility increases, so does a teleworker's PKT. This is an expected relationship which indicates a positive link between vehicle accessibility and the freedom to travel. Housing type was explored to identify any trends that may occur as housing parcels become more detached. The reference variable for this suite is the single detached housing type as it was the least significant. In reference to this housing type, the model indicates that other types are associated with an increase in discretionary PKT. For instance, a teleworker residing in a semi-detached house exhibits a 31.4% increase in PKT as compared to a teleworker of a single detached house. Apartments are associated with a 13.5% increase, and Other (trailer, cottage etc.) are associated with a 27.9% increase. It is most likely that the observed effects of housing type are closely related to other built environment factors which are further discussed in this section. Although all socio-demographic variables were tested, age, gender, average income and household size proved to be not statistically significant in the final model.

In terms of built environment variables, mixed effects are to be expected as past research indicates that similar variables in multiple studies may report opposing effects (Mitra and Buliung 2012). The model indicates that as residential distance from the urban core increased, overall discretionary PKT increases as well. The results show that with a one kilometer increase in distance from the urban core, a 3.3% increase in travel distance is expected, a similar positive trend reported in literature where teleworkers were observed to live in more suburban environments (Nilles 1991; Mokhtarian et al. 2004).It is probable that this trend is the result of teleworkers who both reside in suburban environments and therefore must complete trips which require greater travel given the fixed spatial allocation of amenities. This finding reinforces the current understanding of teleworker residential location and its relationship with daily travel (Mokhtarian et al. 2004). Although it is still not fully understood if it is a causal relationship, it is well accepted that a strong positive relationship exists between residential location and telework (Mokhtarian et al. 2004). It has been thought that perhaps the act of relocating farther from the urban core is facilitated by the ability to telecommute, or perhaps workers in these regions seek telework arrangements to reduce their daily travel requirements (Mokhtarian et al. 2004). In either of the proposed cases, the conclusions of previous studies are further confirmed here that due to the telecommuter arrangement, overall PKT is reduced as compared to a typical commuter taking work trips, further highlighting the benefits of telework (Mokhtarian et al. 2004).The model demonstrates as land-use becomes more heterogeneous (increased entropy) in terms of land-use mix, greater travel distance is to be expected. This coincides well with the observed effects of residence within a Greenbelt region. As an area of restricted commercial development, the variable demonstrates a relatively strong positive relationship, interpreted as a 17.3% increase in PKT. The Greenbelt exists to prevent continued urban sprawl commercial development around the Ottawa region, but leads to the well known “leapfrogging” phenomenon (City of Ottawa 2008; NCC 2012). This phenomenon in part captured by the model and explains the observed increase in PKT as teleworkers must travel further to complete discretionary trips due to limited local accessibility. The Greenbelt region is identified in Figure 2.1 for further spatial reference in the study area. Trips originating within or on either side are often extended to reach commercial amenities on opposing sides. Although other built environment variables were tested, they did not prove statistically significant.

To observe the effects of the work day, a variable representative of each day of the week was tested. This suite of variables is in reference to Thursday, the least statistically significant. The results show that PKT is more heavily influenced by Wednesday and Friday. The effects show an increase of 19.9% and a reduction of 26.5%% respectably in comparison to travel on Thursdays. Discretionary travel on Mondays and Tuesdays proved statistically non-significant in the final model. These results are interesting as statistically the number of teleworkers is relatively equal for all days of the work week, suggesting that daily travel does truly vary per work day.

The effects of meteorological variables coincide well with findings in literature, particularly, the recent study by Saneinejad (2012), where inclement weather has been reported to negatively impact the decision to travel via physically active modes. Although this study considers all modes for discretionary PKT, the results show the expected negative relationship between rain and travel. More specifically, with every millimeter of increased precipitation, daily PKT is expected to decrease by 2.2%. It understandable that this decrease is not experienced uniform across all modes, as physically active forms would be negatively impacted more so than automotive. Furthermore, it is probable that the effects of meteorology are linked through additional and more complex processes beyond the scope of this study, such as road safety, perception of inclement weather and others. Still this result contributes to the existing literature on biometeorology and research which focuses on how inclement weather impacts travel distance.

2.6 DISCUSSION

This paper has explored the determinants of discretionary PKT for teleworkers in attempts to further advance the knowledge surrounding teleworker travel behavior and its application towards the mitigation of traffic congestion. At first glance, the potential benefit from telework replacing the work commute is profound; however, through greater exploration, it is realized that the benefits are less than expected due to an apparent compensation of increased discretionary travel throughout the day. Still, the net reduction proves beneficial for the transportation system, in addition to the flexibility of trips occurring outside of the peak morning and evening travel times. Through the comparison of teleworkers to regular workers and non-workers, it is evident that teleworkers are the most active group in the study's population. Empirically, teleworkers travel approximately 3 times farther than regular workers (commuters) and 1.7 times farther than non-workers for discretionary travel. However, despite the observed increase in discretionary travel, the results of this study conclude that teleworkers still contribute approximately 7.4%fewer kilometers daily as compared to regular commuters (including their work travel) signifying a net reduction on the transportation system. To explore this behavior, further examination into the determinants of teleworker discretionary PKT was performed. This was achieved through regression modeling to observe the effects of various socio-demographic, built environment and meteorological influences on travel distance. In so doing, this study extends the literature through examination of teleworker travel behavior at a municipal scale in a Canadian context. The results show that the significant determinants are age, presence of children younger than 16 years of age, vehicle accessibility (household car share index), housing type, residential distance to the urban core, land-use mix, proximity to shopping centers, residence within the Greenbelt region and day of the week. Finally, this study confirms the results of previous work in the areas of biometeorology with regards to the negative effects that inclement weather have on travel amounts. The findings of this study compliment previous research in the area of telecommuter travel behavior research and contribute towards the ongoing exploration of positive impacts of telework on the transportation system.

2.7 ACKNOWLEDGEMENTS

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CHAPTER THREE

TELEWORKER IMPACT:
EXPLORING THE DETERMINANTS OF
ACTIVE TRAVEL

3.1 ABSTRACT

This paper examines the determinants of active travel mode choice to determine the influence of work status. The study utilizes data obtained from the 2005 origin-destination survey conducted by TRANS, a joint transportation planning committee serving the National Capital Region of Canada. Binary logistic regression indicates that the following predictor variables demonstrate a significant positive effect on active travel mode choice: larger household size, greater income, warmer temperature, closer proximity to shopping centers, apartment housing type, trips for recreational and restaurant purposes, taking subsequent trips in a day, and travel between 8:00 A.M. and 4:00 P.M. Conversely, increased entropy, trips within the Greenbelt region, dependent children under 16 years old, increased vehicle accessibility, trips for transporting someone or for shopping purposes all reduce the probability of active travel mode choice. Finally, the model indicates that the work status teleworker is a significant predictor of active travel mode choice in reference to regular workers.

3.2 INTRODUCTION

The economic cost of traffic congestion has grown considerably over time in all major census metropolitan areas (CMAs) across Canada (iTRANS 2006; Turcotte 2011).It has long been understood that overcrowded transportation networks restrict the possibility for urban expansion and potential future economic development (Stopher 2004; Meng and Liu 2012).A recent report by Statistics Canada revealed that the average commute time for Canadians was 65 minutes per day in 2010;this is a 3% increase from 2005 and a substantial 20% increase from the

1992 commute time (Turcotte 2011).Trends indicate that not only has congestion increased over the past two decades, but that 88% of commuters perceive their travel to work as a waste of time and a substantial source of stress and anxiety (Turcotte 2011).Among a vast body of academic literature, the fundamental source of daily congestion remains to be the heightened demands during peak morning and evening rush hour times (Downs 2004). Therefore, among other travel demand management (TDM) strategies, telecommuting has the potential to mitigate congestion by reducing the severity of peak rush hour travel conditions.

As an alternative working arrangement, telework eliminates the need to commute on a daily basis. Instead, the more flexible working arrangement allows people to work from home or a satellite office location, while maintaining a virtual presence wherever necessary (Haddad et al. 2009).With tremendous growth in telecommunications technology, a wealth of academic literature discusses telework and its relation to energy impact, work productivity, quality of life, societal perception, workplace adoption, and social influence to name a few (Kitou and Horvath 2003; Mokhtarian et al. 2005; Walls et al. 2007; Kitou and Horvath 2008; Páez 2008; Haddad et al. 2009; Hislop and Axtell 2009; Cooke 2010; Wilton et al. 2011; Scott et al. 2012). Still, little is known about the teleworker's discretionary travel behavior, particularly as it pertains to mode choice on telework days. Initial data analysis indicates that teleworkers have the greatest propensity to choose physically active modes as compared to individuals of other work statuses, i.e. regular workers and non-workers. Therefore, in addition to the elimination of work commutes in the transportation system, teleworkers also demonstrate an affinity to choose more active modes of travel, which directly assists in the reduction of daily traffic congestion.

The aforementioned active travel behavior warrants further examination, and therefore, this paper explores the determinants of active travel mode choice and whether work status, i.e. teleworker, regular worker or non-worker, statistically influences the decision. The findings provide insight into two key areas; first, the study explains and compares mode choice between work statuses to provide a sense of relative impact on the transportation system, and second, it provides Canadian context for teleworker travel behavior research. This examination is accomplished through a binary logistic regression model designed to explain how various predictor variables including socio-demographic, built environment, time-of-day, and meteorology affect mode choice. The remainder of this paper is separated into four sections: a background review of existing literature pertaining to telework and travel behavior, data and methods, results, and finally the conclusion.

3.3 BACKGROUND

Telework, or telecommuting, leverages cutting-edge technology in the field of telecommunications to increase the virtual accessibility of employees. Through telecommuting, workers can complete tasks by means of a virtual presence, successfully eliminating the need to travel to work. The term telework covers a flexible range of working arrangements; for instance, an employee may choose to work from home every day of the week or merely telework a half-day once a week. Nonetheless, all forms of telework share the common aspect of the absence of a work commute, which ultimately returns leisure time back to the teleworker; time which otherwise would be lost commuting in traffic. Research indicates that the introduction of leisure time into a day results in a measurable change in travel behavior (Anas 2007).To fully understand this concept, it is essential to mention the fundamental relationship between time and travel behavior, particularly, the demand placed on wage-earning time and the resulting demand of leisure time (Anas 2007). This concept is well founded in econometrics and helps to explain the variations in travel behavior between individuals of different employment statuses, e.g. full-time employment, part-time employment, or unemployed. Since workers perceive their commute as a mandatory allocation of time, trip chaining occurs to maximize efficiency (Anas 2007; Turcotte 2011). Trip chains are instances when smaller discretionary trips are included into the primary trip purpose, e.g. completing errands on the way home from work. Through trip chaining, the return home trips between stops are removed since the individual travels directly to the next destination instead of returning home. These trip chains are also referred to as tours. A tour results in less overall travel time and distance compared to taking individual trips where a return home trip is included for each destination. To generalize the observed behavior, the less leisure time that is available, the more trip chaining will occur, as it is a result of efforts to increase efficiency. Thus, given this relation of time and efficiency, the perception of time is uniquely different for teleworkers, as compared to regular workers since all trips on a teleworking day exist on leisure time.

This concept was observed in a study conducted in 2001, where the travel behaviors of regular workers were observed on alternating telework days. The study concluded that with the option of completing errands on a regular commute day or telework day, the majority of respondents restricted travel until a regular commute day. More specifically, errands were completed on the return home trip from work (Wells et al. 2001). This phenomenon falls directly into the expected trip chaining behavior, to maximize efficiency of time and travel. From the results, it is hypothesized that when the work commute is removed entirely, teleworkers would receive an additional increase of leisure time on the telecommuting day, a surplus of time which effectively reduces the demand placed on efficient travel. However, in addition to travel amounts, modal choice is also a key component to accessing system impacts (Habib 2012). For instance, a recent study has demonstrated quite a significant range of impact when examining the external congestion costs for differential vehicle sizes (Cosgrove and Holahan 2012). More so, when comparing physically active modes, such as walking or bicycling, the impact is negligible. These forms of active travel are tremendously desirable from a sustainability perspective and have positive health benefits as well (Badland and Schofield 2008; Samimi and Mohammadian 2010; Bopp et al. 2011; Panter et al. 2011).

To gain a better understanding of an individual's decision to travel actively, several studies have examined a range of factors and discuss their influence on mode choice. They conclude that a host of factors including, perception, weather, built environment, and accessibility all affect the decision to walk or bicycle (Samimi and Mohammadian 2010; Panter et al. 2011; Spinney and Millward 2011; Saneinejad et al. 2012; Sener and Bhat 2012; Spinney et al. 2012).In particular, a recent study reports that workers perceive sustainable active travel as an attractive mode choice primarily due to its eco-friendly attitudes (Bopp et al. 2011).Recent literature examined the mode choice of commuters based on weather conditions and confirmed that meteorological effects are significant enough to warrant attention at the research, data collection, and planning levels of travel behavior research (Spinney and Millward 2011; Saneinejad et al. 2012; Spinney et al. 2012). A growing body of literature in public health, planning and transportation has specifically documented the relationship between built environment and physical activity (Leslie et al. 2010; Samimi and Mohammadian 2010; McCormack et al. 2011; Panter et al. 2011; Larco et al. 2012; Mitra and Buliung 2012; Saneinejad et al. 2012; Sener and Bhat 2012). Specifically, proximity to shopping centers, housing development, housing structure and other socio-demographic factors all influence the level of physical activity in society (Larco et al. 2012). Based on the findings of previous research, the aforementioned considerations were taken into consideration in the variable selection process of this study to incorporate a mixture of tested and newly untested variables to produce an informative model.

3.4 DATA AND METHODS

3.4.1 Data and Study Area

The data were obtained from the 2005 origin-destination survey conducted by TRANS, a joint transportation planning committee serving the National Capital Region (NCR) of Canada. The survey collected household, personal, and trip information for a random sample of 23,868 householdscontaining184,088 persons who took a total of 942,662 trips over 24 hours. The survey collected information for the months of September, October and November of 2005. Expansion factors were assigned to households to allow for an accurate estimation of the true population size. As part of the survey, respondents indicated their work status as a teleworker, regular worker (commuter), or non-worker. For the analysis, only respondents aged 16 to 64 years were included to ensure a comparable population of non-workers with workers. Respondents under the age of 16 do not meet the minimum required age to work in all employment locations and conditions in Canada, and similarly respondents over and including the age of 65 have the greatest tendency to be retired (Canadian Labour Congress 2012).

The study area is the National Capital Region of Canada, which consists of Ottawa, Ontario (amalgamation of Ottawa, Nepean, Kanata, Gloucester, Vanier, Cumberland, West Carleton, Goulburn, Rideau, Osgoode and Rockcliffe Park) and Gatineau, Quebec (amalgamation of Aylmer, Buckingham, Gatineau, Hull and Masson-Angers). The region is bisected by the Ottawa River, which serves as the provincial boundary between the provinces of Ontario and Quebec. Although the Ottawa River flows through the center of the study area, it is not a major obstruction restricting travel as there are five bridges available throughout the region. Furthermore, Ottawa's public transportation, OC Transpo, operates in both Ottawa, ON and Gatineau, QC regions connecting to the Quebec STO transit service. A key feature of the study area is the Greenbelt, indicated in Figure 3.1, a substantial crescent of land where real estate development is stringently controlled by the National Capital Commission (NCC). While the majority of the land is both owned and managed by the NCC, the remainder is partially owned by other smaller federal government departments and some private interests. The initiative was established in the mid-1950s, as a component of Ottawa's master plan for the prevention of urban sprawl and to provide potential growth of future farms, natural areas and government campuses (City of Ottawa 2008). Due to the Greenbelt's location, it is associated with a phenomenon known as "leapfrogging", where urban development is forced to occur in rural farm land beyond the Greenbelt barrier, rather than in more suitable urban environments, such as closer to the urban core (City of Ottawa 2008).For this study, the location of the urban core is defined as Parliament Hill, also indicated on the location map. The figure also shows the distribution of teleworkers in the region, as percent of the population within the traffic analysis zones (TAZ). It is evident that there are several areas of greater teleworker concentration in the study region.

This study focuses on trips for discretionary purposes, therefore work, school, and return home trips are excluded from the analysis. Focusing solely on discretionary travel provides a more robust comparison between population groups, as these are the types of trips all groups can make. Furthermore, through data exploration, it was determined that all but a negligible percentage of trips used the same mode of travel to return home as their outbound counterpart. To prevent overrepresentation in the data, all return home trips were removed from the analysis. These criteria resulted in only discretionary travel, which can be further categorized into one of multiple trip purposes: shopping (stores, big boxes, grocery shopping), recreation, restaurant (take-out), restaurant (eating in), visiting friends or family, medical, dropping someone off, picking someone up, and other.

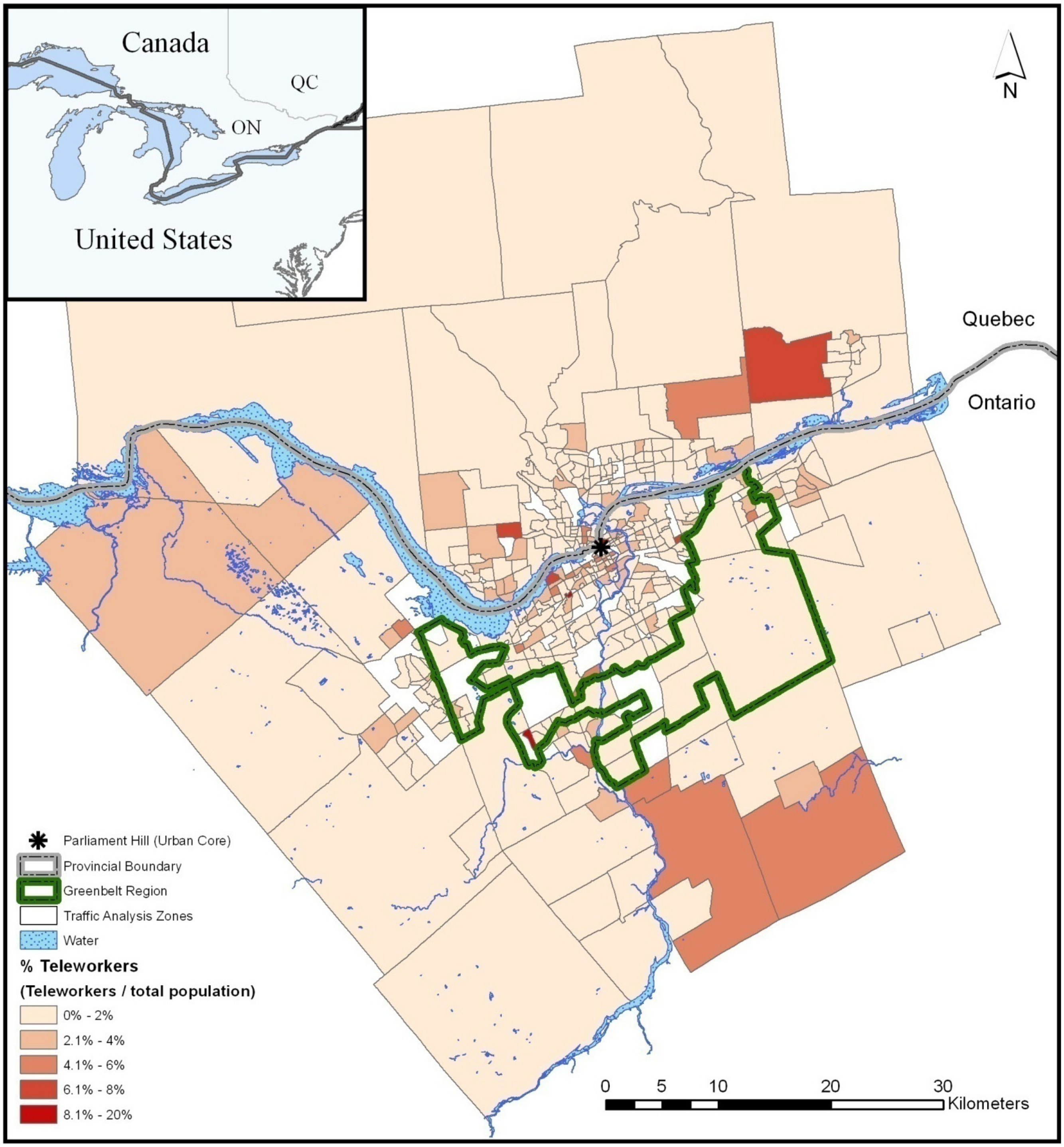

Figure 3.1. Study area showing teleworker population percentage per traffic analysis zone.

Trip origins and destinations were collected at the TAZ level of geography. Given the geographic region with a dense downtown core and sprawling rural regions, the TAZs vary in size from a minimum of 0.1 km^2 to a maximum of 616.3 km^2, with a standard deviation of 46 km^2. To minimize error, respondents' locations were estimated within the TAZ by using a population-weighted position calculated based on population density at the dissemination area (DA) level. The result is a single population-weighted position for each TAZ based on the unique population density pattern at the local level within each region. This process achieved the most representative spatial distribution of respondents, particularly for larger TAZ regions in the periphery of the NCR.

3.4.2 Dependent Variable

As part of the travel diary, respondents indicated mode choice to complete each trip. A variety of physically active and automotive alternatives were considered in the survey: car driver (light truck or small van), car passenger (light truck or small van), OC Transpo (public transit system serving Ottawa and Gatineau regions), STO (public transit system serving the Gatineau urban area), other transit (excluding intercity, e.g. Greyhound/Voyager), school bus, O-train (train service serving the Ottawa region), ferry, taxi, paratransit, bicycle, walk, motorcycle and other. For this study, active travel encompasses walking and bicycling only. The remaining modes identified before are considered non-active (automotive). Trip mode is the dependent variable in this study. The variable is expressed dichotomously and indicates whether a trip was taken using a physically active mode (1 = active), or not (0 = automotive).

3.4.3 Independent Variables

Among a comprehensive list of explanatory variables, work status is used to distinguish between three distinct population groups in the study, labeled as: teleworkers, regular workers, and non-workers. Teleworkers are defined as individuals who work either full-time or part-time from home through a telecommuting arrangement with their employer. In this study, the focus is on teleworkers who do not perform work-related trips, including trips for itinerant work, on the survey day. In other words, the teleworkers identified are those who are teleworking from home on the survey day. Such teleworkers are responsible for approximately 2.5% of all discretionary trips in the study area. Conversely, regular workers are either full-time or part-time employees who commute to work. In this definition, self-employed individuals who travel to work, fall under this category. In other words, on the survey day these individuals either commute to work or have itinerant work trips. Regular workers contribute approximately 59% of discretionary trips, and are the largest group in the study. Finally, non-workers are classified as individuals who are not employed: students, retirees and homemakers. In addition to work status, a suite of socio-demographic, built environment, time-of-day, meteorological, and other variables were tested. The variables tested are summarized in Table 3.1. Although not all of these variables proved statistically significant in the final model, they were all tested for their potential explanatory capabilities. The table includes the variable description, and some descriptive statistics, namely, the representative sample percentage (weighted based on household expansion factor), the percent of active travel (weighted by household expansion factor), the mean and the standard deviation values. The variables are categorized into six groups: employment, built environment, meteorology, demographics/household, and survey information. All variables were derived from data provided by TRANS, except the suite of household income variables which were obtained from the 2006 Census of Canada, meteorological data obtained from Environment Canada, and built environment data obtained from Open Data Ottawa and DMTI Spatial.

Table 3.1. Independent variables tested in the empirical analysis.

Variable	Definition	Percent of sample trips (weighted)	Percent active travel (weighted)	Mean	Std.
Employment					
Teleworker	1 if respondent telecommuted on the day surveyed; 0 otherwise	1.3	15.7		
Regular worker	1 if respondent commuted on the day surveyed; 0 otherwise	67.1	10.8		
Non-worker	1 if respondent does not work; 0 otherwise	31.6	16.5		
Full time	1 if respondent works full-time hours; 0 otherwise	40.1	10.4		
Part time	1 if respondent works part-time hours; 0 otherwise	5.4	15.3		
Built Environment					
Single-detached house	1 if respondent resides in a single-detached house; 0 otherwise	62.4	9.5		
Semi-detached house	1 if respondent resides in a semi-detached house; 0 otherwise	9.0	14.1		
Row or townhouse	1 if respondent resides in a row or townhouse; 0 otherwise	12.3	13.7		
Apartment	1 if respondent resides in an apartment; 0 otherwise	14.2	28.0		
Other (trailer, cottage, etc.)	1 if respondent resides in other form of residence; 0 otherwise	2.0	15.7		
X coordinate	X coordinate of trip starting location			-75.7	0.1
Y coordinate	Y coordinate of trip starting location			45.4	0.1
X*Y	X coordinate multiplied by Y coordinate of trip starting location			-3436.9	6.3
X coordinate squared	X coordinate squared (trip starting location)			5731.0	17.9
Y coordinate squared	Y coordinate squared (trip starting location)			2061.1	7.3
Distance to Parliament Hill	Straight-line distance (km) from trip starting location to Parliament Hill			10.4	8.0
Intersections	Number of intersections in traffic analysis zone of trip starting location			92.4	115.7
Entropy	Land-use mix score (value of 1 signifies maximally heterogeneous; 0			0.1	0.1
Shopping center gravity	Inverse distance weighting of shopping centers; weighted by number of			19.2	12.6
Greenbelt location	1 if trip starts within a Greenbelt location; 0 otherwise	24.1	8.9		
Meteorological					
Speed of maximum gust	Wind speed (km/h) at trip starting time			13.9	7.2
Rain	1 if it is raining at trip starting time; 0 otherwise	41.2	13.2		

Snow	1 if it is snowing at trip starting time; 0 otherwise	7.3	14.9		
-11 to -20°C	1 if temperature is between -11 and -20°C at trip starting time; 0 otherwise	0.4	11.2		
-0.9 to -10.9°C	1 if temperature is between -1 and -10°C at trip starting time; 0 otherwise	14.9	13.3		
0 to 9.9°C	1 if temperature is between 0 and 9°C at trip starting time; 0 otherwise	54.9	13.2		
10 to 19.9°C	1 if temperature is between 11 and 20°C at trip starting time; 0 otherwise	23.5	12.7		
22 to 30°C	1 if temperature is between 21 and 30°C at trip starting time; 0 otherwise	6.3	16.2		
Relative humidity	Percent relative humidity measured at the trip start time			83.5	15.0
Wind chill	1 if there is a wind chill factor at the trip starting time; 0 otherwise	15.6	13.5		
Demographic and household					
Age	Age in years			46.4	24.4
ln Age	Natural logarithm of Age			3.7	0.6
Female	1 if respondent is female; 0 male	54.2	54.0		
Income $39,999 or less	1 if respondent's household income is $39,999 or less; 0 otherwise	4.1	18.1		
Income $40,000-59,000	1 if respondent's household income is $40,000 to 59,000; 0 otherwise	9.3	11.2		
Income $60,000-79,000	1 if respondent's household income is $60,000 to79,000; 0 otherwise	61.2	13.1		
Income $80,000-99,000	1 if respondent's household income is $80,000 to 99,000; 0 otherwise	10.2	10.7		
Income $100,000 or more	1 if respondent's household income is $100,000 or more; 0 otherwise	15.1	15.4		
Children (under 16 years)	1 if there is a child under 16 years old in the respondent's household; 0	40.3	10.7		
License	1 if respondent has a driver's license; 0 otherwise	81.0	11.2		
Registered driver	1 if respondent is a registered driver; 0 otherwise	29.0	4.6		
Transit pass	1 if respondent owns a transit pass; 0 otherwise	14.4	13.3		
Household: 1 person	1 if respondent's household size is 1 person; 0 otherwise	12.7	23.9		
Household: 2 people	1 if respondent's household size is 2 people; 0 otherwise	30.1	14.3		
Household: 3 people	1 if respondent's household size is 3 people; 0 otherwise	19.5	11.5		
Household: 4 people	1 if respondent's household size is 4 people; 0 otherwise	24.8	10.7		
Household: 5+ people	1 if respondent's household size is 5 or more people; 0 otherwise	12.9	10.6		
Household car share	Number of licensed drivers divided by number of household vehicles			0.59	0.38
Survey Information					
Monday	1 if respondent completed survey on a Monday; 0 otherwise	19.2	15.3		
Tuesday	1 if respondent completed survey on a Tuesday; 0 otherwise	19.6	13.6		
Wednesday	1 if respondent completed survey on a Wednesday; 0 otherwise	19.6	13.0		
Thursday	1 if respondent completed survey on a Thursday; 0 otherwise	19.0	13.4		
Friday	1 if respondent completed survey on a Friday; 0 otherwise	23.1	11.4		
Expansion factor	Weight assigned to each respondent for representation in total population			21.2	6.7

Number of trips	Number of trips reported on the day surveyed			3.1	2.0
Trip Information					
Recreation	1 if trip purpose was for recreation; 0 otherwise	10.2	19.3		
Shopping	1 if trip purpose was for shopping; 0 otherwise	16.7	11.8		
Restaurant eat out	1 if trip purpose was for restaurant take-out; 0 otherwise	0.8	16.8		
Restaurant eat in	1 if trip purpose was for restaurant eat in; 0 otherwise	2.7	16.7		
Visit someone	1 if trip purpose was to visit someone; 0 otherwise	4.6	12.5		
Medical	1 if trip purpose was for medical; 0 otherwise	2.9	4.8		
Drop someone off	1 if trip purpose was to drop someone off; 0 otherwise	6.7	3.9		
Pick someone up	1 if trip purpose was to pick someone up; 0 otherwise	4.8	7.1		
Other	1 if trip purpose was for other reason; 0 otherwise	7.1	16.6		
1st trip	1 if trip was the first made in the day; 0 otherwise	21.0	11.2		
2nd trip	1 if trip was the second trip made in the day; 0 otherwise	25.5	16.0		
3rd trip	1 if trip was the third trip made in the day; 0 otherwise	19.7	11.4		
4th+ trip	1 if trip was the fourth or more trip made in the day; 0 otherwise	33.8	13.8		
4:00-4:59 A.M.	1 if trip starting time was between 4:00-4:59 A.M.; 0 otherwise	0.0	0.0		
5:00-5:59 A.M.	1 if trip starting time was between 5:00-5:59 A.M.; 0 otherwise	0.9	9.6		
6:00-6:59 A.M.	1 if trip starting time was between 6:00-4:59 A.M.; 0 otherwise	3.1	10.2		
7:00-7:59 A.M.	1 if trip starting time was between 7:00-6:59 A.M.; 0 otherwise	3.1	8.1		
8:00-8:59 A.M.	1 if trip starting time was between 8:00-8:59 A.M.; 0 otherwise	4.6	12.1		
9:00-9:59 A.M.	1 if trip starting time was between 9:00-9:59 A.M.; 0 otherwise	4.1	14.7		
10:00-10:59 A.M.	1 if trip starting time was between 10:00-10:59 A.M.; 0 otherwise	4.9	13.9		
11:00-11:59 A.M.	1 if trip starting time was between 11:00-11:59 A.M.; 0 otherwise	4.9	17.1		
12:00-12:59 P.M.	1 if trip starting time was between 12:00-12:59 P.M.; 0 otherwise	5.2	19.4		
13:00-13:59 P.M.	1 if trip starting time was between 13:00-13:59 P.M.; 0 otherwise	4.8	14.1		
14:00-14:59 P.M.	1 if trip starting time was between 14:00-14:59 P.M.; 0 otherwise	6.9	16.3		
15:00-15:59 P.M.	1 if trip starting time was between 15:00-15:59 P.M.; 0 otherwise	10.3	16.3		
16:00-16:59 P.M.	1 if trip starting time was between 16:00-16:59 P.M.; 0 otherwise	9.6	11.8		
17:00-17:59 P.M.	1 if trip starting time was between 17:00-17:59 P.M.; 0 otherwise	8.6	11.3		
18:00-18:59 P.M.	1 if trip starting time was between 18:00-18:59 P.M.; 0 otherwise	8.7	10.6		
19:00-19:59 P.M.	1 if trip starting time was between 19:00-19:59 P.M.; 0 otherwise	7.9	12.7		
20:00-20:59 P.M.	1 if trip starting time was between 20:00-20:59 P.M.; 0 otherwise	5.5	13.3		
21:00-21:59 P.M.	1 if trip starting time was between 21:00-21:59 P.M.; 0 otherwise	4.5	11.1		
22:00-22:59 P.M.	1 if trip starting time was between 22:00-22:59 P.M.; 0 otherwise	2.8	14.0		

23:00-23:59 P.M.	1 if trip starting time was between 23:00-23:59 P.M.; 0 otherwise	1.3	12.6
24:00-24:59 A.M.	1 if trip starting time was between 24:00-24:59 A.M.; 0 otherwise	0.7	11.6
25:00-25:59 A.M.	1 if trip starting time was between 25:00-25:59 A.M.; 0 otherwise	0.3	13.8
26:00-26:59 A.M.	1 if trip starting time was between 26:00-26:59 A.M.; 0 otherwise	0.2	7.0
27:00-27:59 A.M.	1 if trip starting time was between 27:00-27:59 A.M.; 0 otherwise	0.1	2.4
28:00-28:59 A.M.	1 if trip starting time was between 28:00-28:59 A.M.; 0 otherwise	0.0	6.3
Morning peak	1 if trip starting time is during morning peak period; 0 otherwise	13.7	11.5
Evening peak	1 if trip starting time is during evening peak period; 0 otherwise	51.8	12.5
Peak hour	1 if trip starting time is during peak period; 0 otherwise	65.5	12.3

Notes: Except for household income, variable definitions are in reference to the months September, October, and November of 2005. Household income was obtained from the 2006 Census of Canada. The weighted sample population was calculated based on a weight provided by TRANS, Ottawa, Canada. The percentages shown may not sum to 100 due to rounding.

3.4.4 Model Specification

A binary logistic regression model was designed to explore the determinants of active travel mode choice. Although the logistic regression belongs to a larger family of statistical models known as general linear regression, it differs in that it predicts the probability outcome of a categorical variable based on one or more explanatory variables modeled using the logistic function. For this analysis the dependant variable, trip mode, takes a binary form, "1" denoting a physically active mode of travel, and "0" denoting an automotive mode. The binary logistic regression equation is specified as follows:

$$\mathrm{P} = e^{(\alpha+\boldsymbol{\beta}\boldsymbol{X}+\varepsilon)} \quad (1)$$

where, P is the probability of active travel, base e represents the exponential function, α is the intercept from the logistic regression equation (which is the resulting value when all predictor variables equal zero), and $\boldsymbol{\beta}$ is a vector of parameters to be estimated by the model. $\boldsymbol{X}$ represents a matrix of predictor variables, in this case, explaining the propensity to choose an active travel mode through socio-demographics, built environment, time-of-day, meteorological, and other factors. Finally, ε denotes the error term.

Due to respondents taking multiple trips within a survey day, it was necessary to control for the multiple observations per respondent. Thus, a robust cluster variance estimator was used to control for shared variables measured. This was achieved through the use of STATA Data Analysis and Statistical Software version 12. With this technique, model robustness was improved as the variance within a cluster, i.e. the trips made by the same respondent, were moderately self-canceling. The difference between treating each recorded trip as an independent observation and clustering trips based on the actual surveyed respondents was the identification of some variables no longer showing strong statistical significance, assisting in the identification of key predictor variables of active travel mode choice. This robust variance is known under different names, but is often referred to as the Huber/White/sandwich estimate of variance named accordingly after Huber (1967) and White (1980). The term “sandwich” in the name refers to the mathematical structure of the estimate as it is the product of three matrices. The first matrix formed by taking the outer product of the observation-level. The second matrix is the likelihood/pseudo-likelihood score vectors which are used as the middle of these matrices. Finally, this matrix is in turn pre- and post-multiplied by the usual model-based variance matrix (Froot 1989; Rogers 1993; Williams 2000; Wooldridge 2002; StataCorp 2011)

The robust cluster variance estimator is specified as follows:

$$V_{\text{cluster}} = (X'X)^{-1} * \sum_{j=1}^{n_c} u_j * u_j * (X'X)^{-1} \tag{2}$$

where,

$$u_j = \sum_{j\,\text{cluster}} e_j * x_i$$

and $\mathbf{n_c}$ are the total number of clusters, $\mathbf{e_i}$ is the residual for the i^{th} observation, $\mathbf{x_i}$ is a row vector of predictors including the constant (Rogers 1993; StataCorp 2009; StataCorp 2011). As noted in literature, this estimator is unbiased for both cluster-correlated data and specifications of the setting (Froot 1989; Williams 2000).

Variable selection for the model was based on ease of interpretation and best model fit. Reference variables were chosen for series of categorical variables, e.g. time-of-day series, where one-hour intervals are included to demonstrate the trend throughout the day. This is particularly effective since the 24-hour interval is not only useful for identifying sharp peak hour travel, but also for observing peak spreading, a phenomena where the narrow time window of rush hour travel is known to be much wider and spread out (Mayer 2001). Reference variables were also used for socio-demographic as well, namely household income, household size, household type, trip purpose and the propensity to undertake subsequent trips throughout the day. In most cases, the least significant variable within a category was removed as the reference to allow for a comprehensible interpretation of the results. All reference variables are identified in the model results seen in Table 3.2 of the next section. Certain variables, such as a smaller household (household size), reduced proximity to shopping centers (built environment), increased heterogeneous land-use mix (entropy) and reduced accessibility to a vehicle are all expected to have positive influences on active travel mode choice (McCormack et al. 2011; Larco et al. 2012; Twells et al. 2012). On the other hand, rain, snow and other inclement weather conditions (meteorology), colder temperatures and starting a trip farther from the urban core (built environment) are all expected to have a negative influence (Samimi and Mohammadian 2010; Panter et al. 2011; Spinney and Millward 2011; Saneinejad et al. 2012). In addition to the regression model, variable interaction terms were explored to observe the resulting effects between telework work status and other independent variables, although ultimately the interactions proved not statistically significant.

3.5 RESULTS

All variables which were statistically significant at the $p > 0.05$ level of significance were included in the final model, shown in Table 3.2. It is determined that the determinants of active mode choice are a mixture of socio-demographic, built environment, time-of-day and meteorological influences. The model's adjusted coefficient of determination value is 0.139.

Socio-demographics demonstrate a mix of positive and negative effects in the model. Specifically, age demonstrates a negative effect – that is, as the age of the respondent increases, there is a reduced tendency to choose either walking or bicycling as a mode of transportation. On the contrary, household income is a strong positive predictor, where in this suite of categorical variables, the average household income $60,000-79,999 was used as the reference variable for ease of interpretation as it was the most common. As income increases from less than $30,000 (strong negative effect on active travel) to an income of over $100,000 (strong positive effect) there is evidence of an increasing probability to choose a physically active mode. The trend is reversed for household size, whereas the number of people in the household increases, the probability of active mode choice decreases. In this case, individuals living alone had the highest propensity to walk or bicycle.

Table 3.2.Binary logistic regression model of active travel mode choice.

Category	Variable	Coefficient	*p*-value
Age	Age	-0.015	0.000
Household Income	$39,999 or less	-0.460	0.000
	$40,000-59,999	-0.438	0.000
	$60,000-79,999	Ref.	Ref.
	$80,000-99,999	0.166	0.030
	$100,000+	0.259	0.000
Household size	1 Person	0.910	0.000
	2 Person	0.376	0.000
	3 People	0.247	0.021
	4 People	0.150	0.011
	5 People or more	Ref.	Ref.
Meteorological	Rain	-0.314	0.000
	Snow	0.142	0.000
	21 to 30 ^{0}C	0.340	0.008
Built Environment	Distance to Parliament Hill	-0.032	0.000
	Entropy	-1.514	0.022
	Shopping center gravity index	0.010	0.000
	Greenbelt location	-0.162	0.000
Household type	Single-detached house	Ref.	Ref.
	Semi-detached house	0.231	0.009
	Row or townhouse	0.110	0.001
	Apartment	0.307	0.000
	Other (trailer, cottage, etc.)	0.235	0.000
Household Structure	Children (under 16 years)	-0.119	0.000
	Household car share	-1.587	0.010
Trip Purpose	Recreation	0.634	0.004
	Shopping	-0.099	0.003
	Restaurant eat out	0.324	0.002
	Restaurant eat in	0.239	0.002
	Visit someone	-0.087	0.004
	Drop someone off	-1.093	0.002

	Pick someone up	-0.561	0.002
	Medical	Ref.	Ref.
	Other	0.301	0.006
Trip starting time	5:00-5:59 A.M.	2.948	0.010
	6:00-6:59 A.M.	3.128	0.005
	7:00-7:59 A.M.	3.210	0.003
	8:00-8:59 A.M.	3.345	0.002
	9:00-9:59 A.M.	3.285	0.002
	10:00-10:59 A.M.	3.053	0.094
	11:00-11:59 A.M.	3.292	0.002
	12:00-12:59 P.M.	3.332	0.002
	13:00-13:59 P.M.	2.929	0.006
	14:00-14:59 P.M.	3.051	0.004
	15:00-15:59 P.M.	3.008	0.005
	16:00-16:59 P.M.	2.638	0.013
	17:00-17:59 P.M.	2.528	0.018
	18:00-18:59 P.M.	2.450	0.021
	19:00-19:59 P.M.	2.581	0.016
	20:00-20:59 P.M.	2.705	0.011
	21:00-21:59 P.M.	2.403	0.023
	22:00-22:59 P.M.	2.512	0.018
	23:00-23:59 P.M.	2.271	0.034
	24:00-24:59 A.M.	2.330	0.030
	25:00-25:59 A.M.	2.142	0.053
	26:00-26:59 A.M.	2.987	0.006
	27:00-27:59 A.M.	Ref.	Ref.
	28:00-28:59 A.M.	2.874	0.023
Trip frequency	1st trip made	Ref.	Ref.
	2ndtrip made	0.416	0.000
	3rd trip made	0.283	0.000
	4thor more trips made	0.713	0.000
Work status	Regular worker	Ref.	Ref.
	Teleworker	0.383	0.021
	Non-worker	0.276	0.000

Constant		-4.027	0.000
Summary Statistics			
	Adjusted r^2	0.139	
	Pseudolog-likelihood	-309645.89	
	n	13752	
	N	917996	

Built environment variables also demonstrate mixed effects, which were expected. In particular, as distance from the urban core increases the likelihood of active mode choice decreases. This spatial trend likely reflects the density of opportunities in the urban core relative to locations at greater distances. A similar effect is shown by trips which start closer to shopping centers, as this was a major trip purpose for discretionary travel. With regards to land-use mix (entropy), a negative effect on walking and bicycling is observed. The model indicates that as land-use mix became more heterogeneous, individuals chose to walk or bicycle less. Entropy has been an interesting factor in travel research over recent years as both positive and negative relationships have been reported by a variety of studies (Mitra and Buliung 2012).Similarly, trips which originate from within the Greenbelt region demonstrate a reduced probability for active mode choice. This can be explained by the stringently controlled development influencing individuals to travel greater distances beyond its boundaries to complete discretionary travel purposes. The term "leapfrogging" applies to this case, in addition to trips beginning and ending on either side of the Greenbelt region (City of Ottawa 2008).Finally, the model reveals that respondents who live in different household types exhibit a range of effects. The strongest negative predictor for active travel is observed from respondents who reside in a single-detached house, and for ease of interpretation, is the reference variable for household types. As a result, semi-detached houses, townhouses, apartments and others (trailers, cottages, etc…) all have positive effects. The strongest positive effect on active mode choice is shown by residents of apartments due to the higher land-use density often associated with this housing type.

Examining meteorological effects yields a mix of both positive and negative effects. Similar to previous research results (Saneinejad 2012), this study concludes that inclement weather reduces the probability of physically active modes. Although the model encompasses the effects of both rain and snow, rain in particular demonstrates a strong negative impact on one's decision to walk or bicycle. On the other hand, snow increases the probability of active travel, a result which coincides with literature (Saneinejad et al. 2012). This phenomenon is explained by severe and snowy road conditions restricting some automotive modes in addition to forcing bicyclists to walk (Saneinejad et al. 2012). Thus, the effects of meteorology are complex and potentially involve several additional factors such as safety, ease of travel, and road conditions.

Although the various trip purposes demonstrate a range of effects, several strong predictors are identified from the model results. Since preliminary research identified that three trip purposes (shopping, eating at a restaurant and recreation) had a much greater frequency of occurrence, it was important to examine the effects of these trips on active mode choice. For this category, medical trips are used as the reference variable for ease of interpretation. In reference to these, trips to restaurants (for eating in and take-out) and those for recreational purposes both had a tendency to increase the probability of walking and bicycling. This is in stark contrast to trips for shopping, visiting someone, dropping someone off and picking someone up which all demonstrate relatively negative effects. The results are somewhat intuitive as trip purpose often has additional requirements for mode choice, e.g. picking someone up or dropping someone off demonstrates a greater probability of the respondent using an automotive mode, a much more practical mode of travel for multiple occupants than a bicycle.

As for time-of-day, peak and non-peak hour travel exhibit a distinctive influence on mode choice. For this series, 3:00 A.M. - 3:59 A.M. is the reference variable for ease of interpretation.

As a general trend, there is a tendency for physically active modes earlier in the day during typical work hours (between 6:00 A.M. and 4:00 P.M). Specifically within this time range, there are three spikes of increased active travel. These times are the morning peak period of 6:00 A.M. - 9:59 A.M., around noon (11:00 A.M. to 1:00 P.M.) and finally 2:00 P.M. - 4:00 P.M. After the evening peak period, there is a steady decrease of active mode choice for the remainder of the day. To examine this trend further, work status was interacted with the time-of-day variables to observe the results. The outcome proved not statistically significant at the desired $p > 0.05$ level and therefore was not included in the final model.

The effects of subsequent trips taken in the same day exhibit an increase in the probability of active mode choice with each additional trip taken in the day. Here, the first trip of the day was used as the reference variable as it had demonstrated the greatest tendency to be an automotive trip. The results show that subsequent trips exhibit a strong positive effect on active mode choice, particularly as 4 or more trips are performed in a day. In other words, the decision to travel via walking or bicycling increases dramatically with each additional trip taken. This result is beneficial for the transportation system as increased trip frequency would normally cause additional traffic and environmental impact; however, the effects are lessened as there is a modal shift towards more active forms (Samimi and Mohammadian 2010; Rabl and de Nazelle 2012). To explore further potential relationships, these variables were interacted with work status, which demonstrated positive results, particularly with teleworkers; however, they did not prove to be as statistically significant.

Finally, work status was included in the model to explore the effects of teleworkers and non-workers in reference to regular workers. It is evident from the model that both telework and non-worker status are statistically significant, and improve the probability of choosing active modes. More so, that teleworkers have a greater influence than non-workers in this context. It was for this reason that teleworker and non-worker work status was interacted with several of the independent variables. Although this avenue was fully explored, ultimately it proved not to be statistically significant in the final model. Thus, the role of work status in active mode choice reveals that telework status is a significant predictor in reference to regular workers, although not entirely different from non-workers. This result adds to the ongoing discussion weighing the benefits and disadvantages of implementing telework as a sustainable working arrangement.

3.6 DISCUSSION

This paper has explored the determinants of active travel mode choice, in particular the role of work status, to further advance the knowledge surrounding teleworker travel behavior. Preliminary data exploration identified differences in mode preferences between work status groups, where teleworkers demonstrate a greater propensity to travel via physically active modes more so than regular workers and non-workers; a finding not adequately reported in current academic research. This behavior was further explored through binary logistic regression to identify statistically significant predictor variables. From these modeling results, it is concluded that numerous socio-demographic, built environment, time-of-day and meteorological factors contribute to active mode choice. In particular, the strong positive predictors were identified as household income, household size, trip purpose (recreational trips), and trips taking place between 6:00 A.M. – 4:00 P.M. Conversely, inclement weather, increased vehicle accessibility in the household and trips taken to transport someone all exhibited a strong negative relationship. Finally with regards to work status, working under teleworking conditions is identified as a strong positive predictor for active travel, in reference to regular workers (commuters). Thus, a positive relationship is established between telework and a modal shift towards physically active forms of travel (walking and bicycling). As for the continued discussion of telework and its role among other TDM strategies to reduce congestion, the results of this study suggest that it positively influences a modal shift towards more sustainable and physically active modes, effectively reducing impact. The affinity for active travel is beneficial for several reasons, namely the direct mitigation of congested roadway conditions, as well as to the reduced environmental impacts and improved health benefits associated with being physically active (Rabl and de Nazelle 2012; Twells et al. 2012). The knowledge gained from this study compliments previous efforts in travel behavior research, and contributes towards the ongoing discussion regarding telework implementation, its cost benefit exploration, and application towards traffic congestion mitigation.

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CHAPTER FOUR

CONCLUSION

The goal of this study is to advance the knowledge of telecommuter travel behaviour, specifically through examination of the determinants of travel distance and mode choice. From the comparison of travel distance by work status, it is identified that the average teleworker travels significantly farther than those of other work statuses. Specifically, teleworkers travel 3 times farther than regular workers and 1.7 times farther than non-workers for discretionary purposes. Through regression the determinants of discretionary travel distance are identified and shown to demonstrate significant effects. The results explain that dependent children, vehicle accessibility, housing type, distance to the urban core, land-use mix, residence within a Greenbelt region and day of the work week all heavily influence the behavior to travel greater distances to complete discretionary tasks. These findings confirm the effects of several factors reported in literature, particularly in the areas of telecommuter residential location and travel amounts (Mokhtarian et al. 2004).The significant influence of vehicle accessibility suggests a strong link to mode choice, an additional source of motivation to further explore this aspect. For this reason, the third chapter of the study explores, in further detail, the determinants of active travel mode choice. This is accomplished through binary logistic regression and identifies a series of variables which influence the decision to travel by walking or bicycling as opposed to an automotive form. The results agree with existing literature and extend the knowledge of relatively untested meteorological factors, such as, those recently discussed in the areas of biometeorology (Saneinejad et al. 2012).It is concluded that teleworkers, as compared to regular workers and non-workers, are unique with regards to discretionary travel patterns. Those who telework, have the propensity to travel greater distances to complete discretionary tasks and demonstrate an affinity for physically active travel over automotive modes.

The results of this study contribute towards the continued discussion of implementing telework as an effective TDM to mitigate traffic congestion. This study compliments existing research in the areas of telecommuter travel behaviour and the cost-benefit comparison of implementing telework while providing a Canadian context for telework. It demonstrates that implementing telework generates a net reduction in daily commute, although increases the discretionary travel distance. Furthermore, a strong link has been established between telework and physically active travel mode choice. The identification of this link is relatively unreported in academic literature and introduces new insight surrounding the benefits of this working arrangement. In addition to other congestion reducing effects, telework may have other physical health benefits that accompany greater physical activity. The twofold potential to reduce economic burden through traffic mitigation and the improved physical activity of workers demonstrates future potential for telecommuting.

4.2 LIMITATIONS AND FUTURE RESEARCH

Although suitable for the purposes of this study, potential limitations are inherent due to the level of detail retained in the data. For instance, respondent location was estimated based on a population weighted position within each TAZ. This position is used to calculate the proximity of teleworkers to shopping centers, the urban core or residence within a Greenbelt region. Even though exact coordinates would improve accuracy for these variables, such sensitive information was removed from the data to comply with ethical and privacy issues. Another source of error, beyond the control of this study, is the reporting of trips in the trip diary in the data collection phase. It is expected that full disclosure of all activity, whether a major or minor trip, is reported, however this is not always guaranteed. Still, despite these limitations, the study conforms to the merits of academic research and contributes towards the ongoing examination of telework.

As for potential future research, given the established framework that teleworkers travel more for discretionary purposes as compared to regular commuters and non-workers, two key areas warrant further investigation. The first, to further quantify the system impact teleworkers would have, simulation, traffic assignment and environmental impact estimations could be performed in a switch case scenario measuring a hypothetical scenario, one in which teleworkers become commuters in the existing system. Such a study would identify local benefits unique for the study region, given the unique transportation network available. The second area of potential research is to further explore the division of trips in a household unit. This can be done by observing the division of trips by parents with dependent children. From this study, the model shows the strong positive effect that dependent children have on a teleworker's discretionary PKT. This aspect could be further examined to identify whether this is due to the second parent commuting to work, leaving the responsibility of child transport to the teleworker or another unanticipated scenario entirely.

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