Modeling of Commuters' Mode Choice and Office Location/Relocation Preferences of Business Firms for Informed Decision-making and Planning: Applications of Stated Preference Methodology

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ABSTRACT

This study makes use of a stated preference (SP) methodology to examine the mode choice preferences of commuters who commute to the central business district of Ottawa taking into account the addition of a Light Rail Transit (LRT) system that is currently non-existent. As part of a planning perspective, the study also seeks to investigate how telecommuting may influence the location/relocation of offices within a multinucleated region such as the City of Ottawa. Two separate surveys were carried out: A survey on commuters' mode choice within the central business district of Ottawa; and a survey on office location/relocation preferences within the Ottawa municipal area. Each survey elicited SP responses to a number of hypothetical scenarios defined according to the principles of SP experimental design. In addition, information about the characteristics of commuters as well as the profile of companies was also obtained. These surveys yielded the data for the model estimation. A discrete choice modeling approach framework was used to estimate the parameters of the utility function. The innovation in this research is the use of these SP methodologies to understand the role of certain important factors in commuters' mode preferences and the location/relocation preferences of office space within the Ottawa municipal area. Results are presented and discussed in the study.

ACKNOWLEDGEMENT

This research was carried out under the supervision of Professor A.M. Khan, whose advice, guidance and continuous encouragement during the course of this study is greatly appreciated. His hospitality, ability to delegate responsibility and relentless effort to seek for knowledge gave me the zeal to continuously work towards achieving my career objectives.

I would also like to acknowledge the time and effort set aside by Professor Scott Bennett for providing comments on my Stated Preference survey design methodology used to collect data for this study.

DEDICATION

This piece of work is dedicated to my parents ***Dr. Andrew Ngome Eneme*** and ***Mrs. Elizabeth Tanyi*** as well as to all members of my family.

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Acronyms

CA	Conjoint Analysis
CBD	Central Business District
CV	Contingent Valuation
IIA	Independent of Irrelevant Alternative
IID	Independent and Identically Distributed
IT	Information Technology
ITS	Intelligent Transportation System
MLE	Maximum Likelihood Estimation
MNL	Multinomial Logit
NMM	Non-motorized Mode
NL	Nested Logit
ROC	Receiver Operating Characteristics
SC	Stated Choice
SP	Stated Preference

PART I: INTRODUCTION AND LITERATURE REVIEW

1. INTRODUCTION

1.1. Purpose

This research makes use of a Stated Preference (SP) methodology to examine the mode of transport preferences of commuters and also to evaluate the role of telecommuting in the decision-making process regarding how business firms locate/relocate their offices within an urban area, using the City of Ottawa municipality as a case study. Findings made from this research contribute knowledge towards understanding the role of public transit in achieving sustainable development and sustainable transportation. There are also land-use implications and transportation benefits that may be associated with the research findings.

1.2. Problem Definition

For the first time ever, majority of the world's population live in cities, and this proportion continues to grow (Global Health Observatory [GHO], 2013), stretching the limits of cities around the world to become less sustainable. Amongst several other aspects that are being stretched beyond their sustainable limits, the transportation network system within these cities are being subjected to intense pressure from daily use as a result of their limited capacity. Evidence in the growth of cities is clearly visible in the failure of the operational capacity of their transport systems particularly during morning and afternoon peak hours. With the continuous provision of roads not being the most viable option for solving this gridlock problem, other sustainable options need to be evaluated in order to manage the current available urban transportation infrastructure. Possible options could range from implementing travel demand management (TDM) measures to changing land-use activities in order to reshape transport demand and optimize the operational capacity of the current infrastructure.

The role of modern cities can be divided into two functions: (1) places for work and (2) places to live and carry out recreational activities (Tayyarran, 2000). In the midst of this division, residents tend to demand for transportation services to meet their daily schedules such as commute to work, go out for shopping/leisure activities, etc. Amongst many reasons why people demand transportation services, commuting to and from work turns out to be the activity with the most demand. The presence of office space away from the immediate surroundings of residents alongside the requirement for them to be physically present at these office locations by most corporations create an imbalance between residential and employment locations within cities. This implies that there is bound to be constant traffic movement between office and home for majority of the residents on a weekly basis. This constant traffic movement alongside the limited capacity of the current urban transportation infrastructure results in traffic congestion and gridlock due to the following reasons:

- High dependence and excessive overuse of the automobile as the primary mode of transportation;
- Most commutes occur within specific time frames during the morning and afternoon periods resulting in excessively high travel demand relative to supply;
- Poorly developed alternative transport systems such as mass transit;
- Continuous growth in population and employment.

Consequences of a poor urban transportation facility include: high levels of congestion, increase in land prices, and other possible social problems. At the moment, the current urban transportation infrastructure within most cities cannot continuously sustain the high levels of automobile dependency resulting from continuous growth. Hence, in order to avoid the inevitability of the above consequences, the incorporation of growth management strategies of some sort at the planning and design stages of transportation facilities within cities is of utmost importance in order to limit reckless growth and promote sustainable development.

So far, there have been several travel demand management strategies developed and implemented within some cities around the world in order to limit automobile dependency. For example, the Cities of London, Rome, Stockholm, Milan, and Valetta have successfully implemented a congestion price schemes to limit the number of private vehicles accessing their downtown area (Wood, 2012). Other viable options that have also been implemented include: the use of electronic road pricing (e.g. HWY 407 in Toronto), parking charges, implementation of High Occupancy Toll/High Occupancy Vehicle (HOT/HOV) lanes, etc. So far, although these options have been tested and research carried out shows that they could be good at limiting the use of automobiles to access areas with high congestion levels, they may however not necessarily be a solution towards attaining a change in the character of travelers from being too dependent on automobile to being somewhat less dependent on the automobile especially for commuting trips.

As part of a solution towards promoting sustainable development in urban transportation, this research study seeks to investigate the role two travel demand management aspects that could help cut down congestion. This research investigates: (1) the role of mass public transit as a viable transportation option for commuters and (2) the role of telecommuting and its influence in the decision-making process regarding where corporate managers choose to locate/relocate their office space within a city. In terms of mass transit, the research seeks to investigate how improvements to public transit can change the mode preferences of commuters from being dependent on the automobile to using a more sustainable form of transportation. On the other hand, with telecommuting fast gaining the attention of researchers, transport engineers and policy experts as a potentially very sustainable, effective and useful tool applicable for reducing traffic congestion experienced during peak hours (see Habib *et al.* 2012; Robert *et al.,* 2006; York Region Transportation Master Plan [YRTMP], 2000), this research also seeks to investigate the role telecommuting on the location/relocation of offices within an urban environment. From a transportation and sustainability point of view, finding a link between telecommuting and office location/relocation may have implications on the land-use patterns as well as the transportation network within a city. On the assumption that telecommuting may have some decentralization effects within an urban area (see Tayyaran & Khan, 2003; Khan, 2010), this could result in the location/relocation of offices away from central to suburban areas of a city, thereby fostering the development of a multinucleated city structure. A multinucleated urban form can be perceived as a form of growth whereby the central business district of a major urban center remains the dominant focal point yet at the same time develops surrounding suburban centers (satellite communities) over the course of time resulting from growth in residential locations and some employment opportunities making them become local focal points within these suburban centers (Ibrahim, 1997; Khan, 2010). In theory, this form of 'compact city' growth has the potential to eradicate the negative social and economic impacts of uncontrolled urban expansion that often results in the misuse of natural surrounding land. In addition, the provision of a good mass transit system that links the various suburban centers to the main urban center could help reduce automobile dependency. In the following section, the overall objectives of this research are presented.

1.3. Research Objectives

As part of an effort to achieve sustainable transport development, this research aims at modeling the mode choices preferences of commuters and the office location/relocation preferences of business firms for informed decision-making and planning. The two main objectives of this study are as follows:

- To find out the effect of public transit improvement on commuters' mode choice preferences;

- To examine the trade-off made by corporate level management with regards to their office location/relocation preferences as influenced by the adoption of a telecommuting program.

1.4. Research Questions

I. To evaluate the effect of transit improvement on commuters' mode choice preferences;

- What factors influence commuters' choice of mode of transport?
- Where would the sample population be collected (i.e., study area)?
- What would be the modal split following improvements made to the transit system?
- What percentage of commuters would switch from their current mode to the newly improved transit mode?

II. To examine the trade-off made by corporate level management with regards to their office location/relocation preferences as influenced by the adoption of a telecommuting program.

- What factors contribute in the decision-making process with regards to where office managers choose to locate/relocate an office within a city?
- How does the adoption of a telecommuting program influence the location/relocation of office space within an urban center?
- What are the potential land-use and transportation implications of the outcome of this study?

1.5. Conceptual Framework

In a research study, a conceptual framework explains, either graphically or in narrative form, the main things to be studied—the key factors, concepts, or variables—and the presumed relationships among them (Miles & Huberman, 1994 p. 18). This research aims at modeling the mode choice preferences of commuters as well as office location/relocation preferences of business firms within an urban area for informed decision-making and planning purposes. The research contributes knowledge towards achieving sustainable urban transportation mobility as well as the implications of telecommuting on land use development. The conceptual framework of this research required the execution of two studies: (1) a study on commuters' mode choice preferences and (2) a study on office location/relocation preferences as influenced by telecommuting. Figure 1.1 below presents an overall conceptual framework for this study.

The overall conceptual framework is defined by four phases. The problem identification phase identified the source of the problem and the purpose of the research. The survey design and data collection phase outlined the methodology used to collect data from the sample population. A literature review of previous related research work and findings was also presented at this phase. The statistical analysis and model development phase involved analyzing and modeling the collected data using appropriate modeling techniques. Finally, the results obtained from statistical analysis were interpreted and related to society in the conclusion phase.

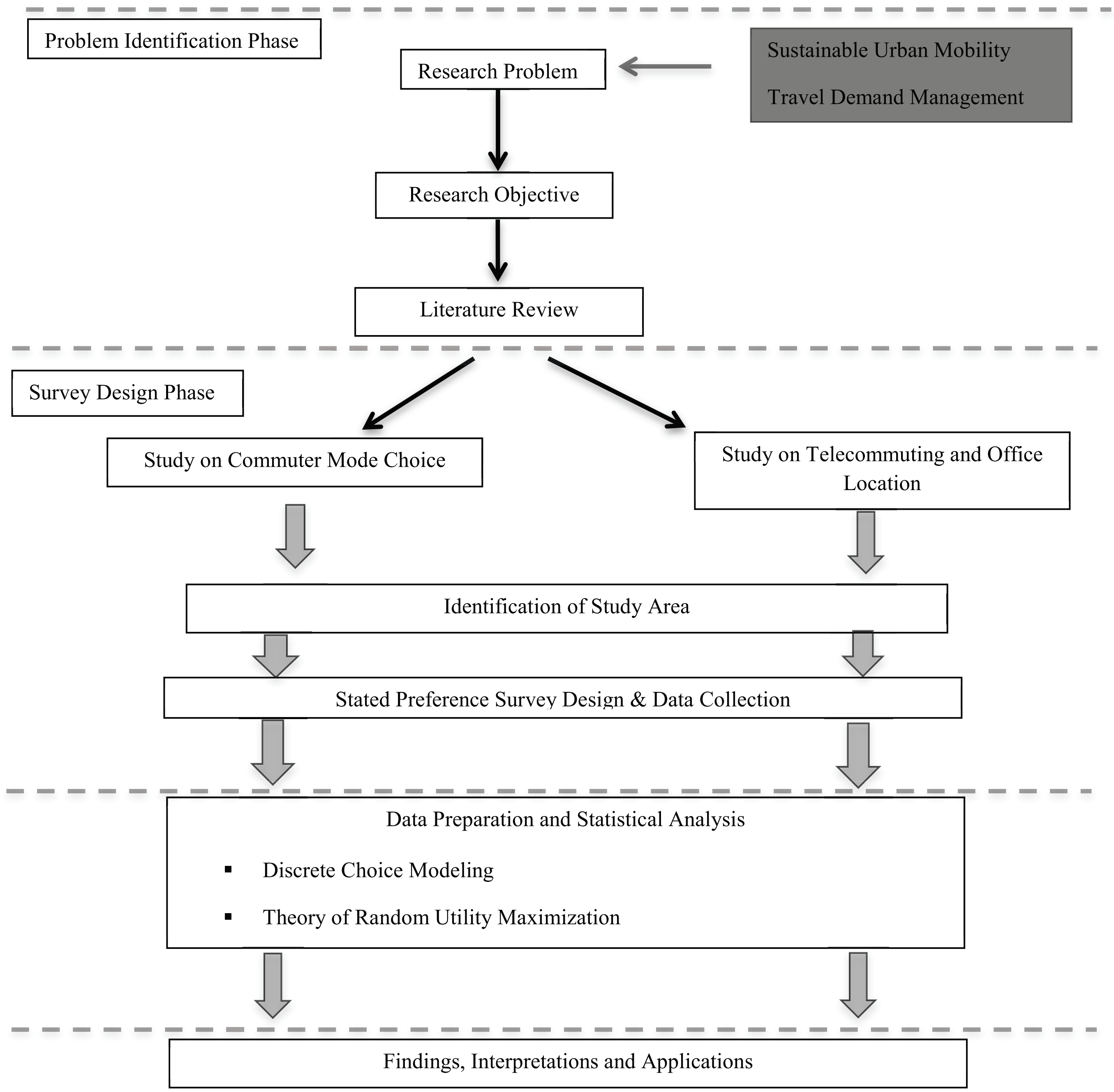


Figure 1.1: Overall Conceptual Framework

1.6. Research Methodology

The methodology used to achieve the above objectives of this study was centered upon the design and implementation of two separate stated preference (SP) surveys: one for collecting data related to commuter mode choices while a second one was aimed at collecting data from business firms on office location/relocation preferences. The SP survey on mode choice was characterized by attributes and attribute-levels that described ground modes of transport while the SP survey on office location/relocation was characterized by attributes and attribute-levels that described hypothetical office location/relocation alternatives. The methodology included;

- Selection of a study area;
- An estimation of a representative sample size of the entire population within the study area;
- Application of discrete choice analysis to develop mode choice and office location/relocation models using the theory of random utility maximization;
- Interpretation and application of research findings/observations to society.

Figure 1.2 below depicts a flow of the methodology used in this research study.

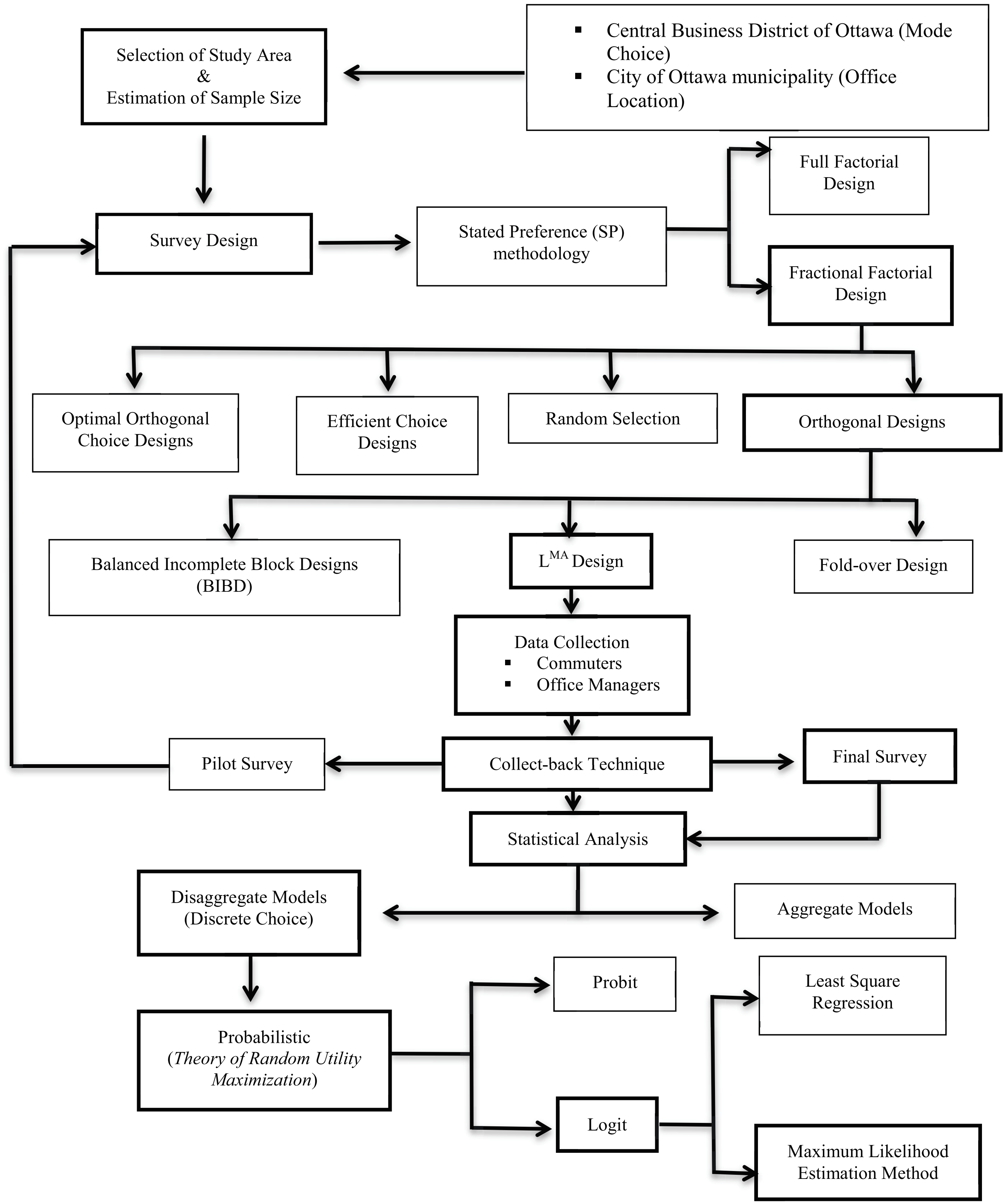


Figure 1.2: Research Methodology

1.7. Thesis Organization

The flowchart in Figure 1.3 below presents an overall picture of the organization of this thesis.

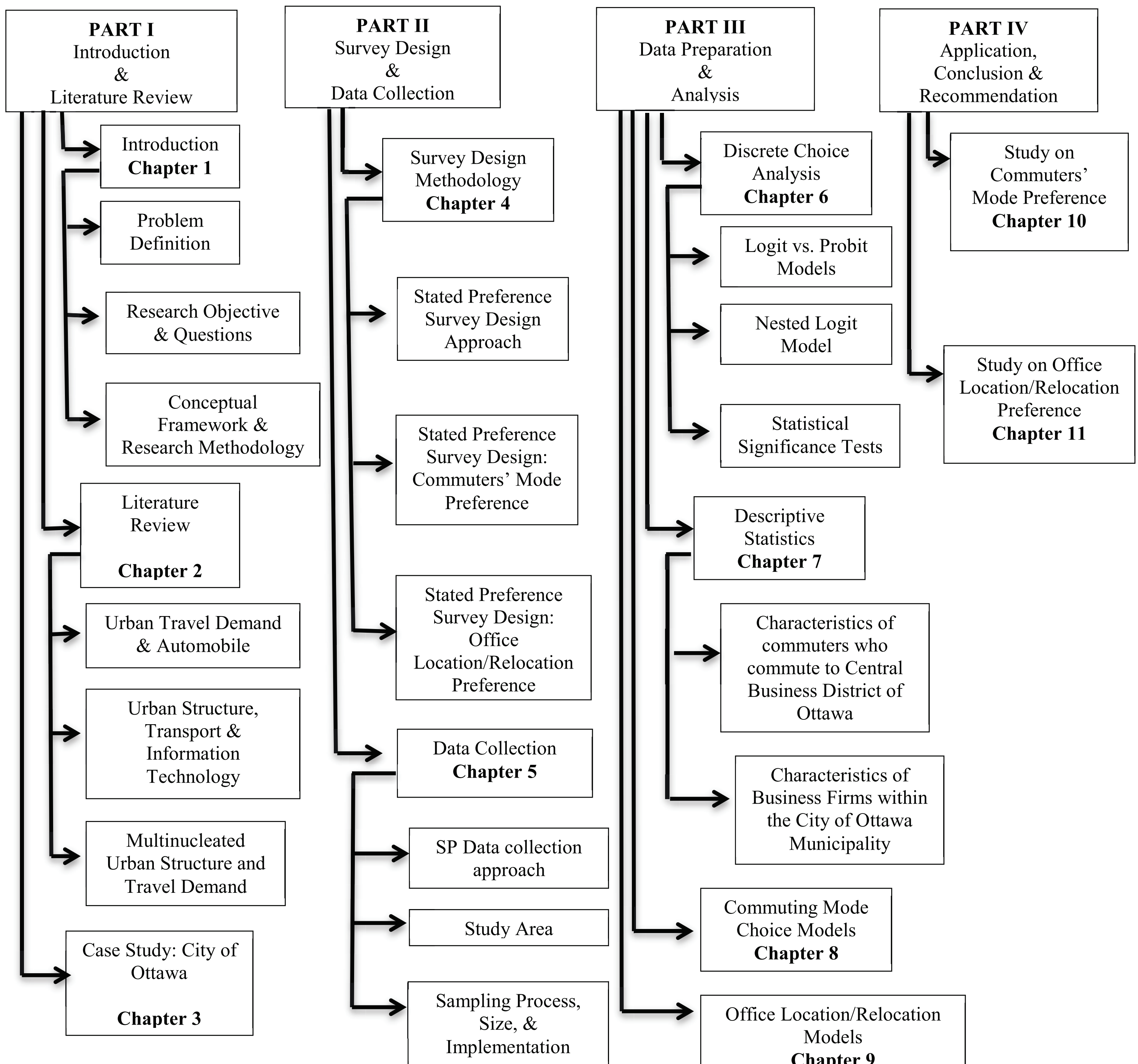


Figure 1.3: Thesis Outline

2. LITERATURE REVIEW

This chapter provides a theoretical background related to the objectives outlined in this research study. It sheds light on concepts related to the urban transportation systems, land use and the influence of information technology on cities.

2.1. Urban Travel Demand and Automobile

Local authorities within urban areas are continuously challenged with the problem of traffic congestion resulting from excessive use of automobile [1] (Van der Heijden *et al.,* 2006). High dependency on automobile also increases the amount of land paved for roads and parking which has economic, social and environmental repercussions (Arnold & Gibbons, 1996). In addition, automobiles require more road space per passenger compared to any other mode of transport. They also reduce opportunities for social interaction, spontaneous exchange between residents and contribute significantly to the deterioration of the urban living climate (Engwicht, 1993; Van der Heijden *et al.,* 2006).

Although high automobile usage has some negative impacts to the urban environment, completely forbidding their use does not necessarily provide a solution. Some benefits of the automobile include: they offer accessibility to a wider range of destinations; they offer flexibility, comfort, and convenience and possess other qualitative factors when compared to other ground modes of transport. Hence, given their pros and cons, there's a need to identify those trips for which their use is optimum.

[1] "Automobile" refers to cars, vans, light trucks and SUVs for personal use.

Modern urban centers are locations with high levels of accumulation of economic activities and complex spatial structures supported by transport systems (Rodrique *et al.,* 2009). Every major urban area experiences the ills of high automobile dependency at peak commute times during which its transport systems, for a variety of reasons, fail to supply the required service for efficient urban mobility. Consequences of this include: high levels of traffic congestion, environmental degradation alongside economic and social repercussions. Within a country like Canada, approximately 82% of workers commute by automobile while 12 % and 6% commute by public transit and non-motorized modes, respectively (Statistics Canada, 2012). So far, there have been several policies and strategies evaluated to cut down on high automobile usage especially for the purpose of commuting within densely congested urban areas. For example, some authorities within urban areas make use of parking regulation measures to discourage the use of automobile within certain areas. Others make use of vehicle restriction measures and/or traffic flow regulation using speed control and guided routing to improve throughput within road networks and limit traffic flow in congestion-sensitive areas (Van der Heijden *et al.,* 2006). Amongst these measures, the design of urban transport systems to support other alternative modes of transportation represents a viable option to help reduce automobile dependency in general, especially for commuting. For example the addition of a special urban bicycle network or development of a variety of public transport services could provide residents within an urban area with alternative modes of transportation as opposed to being solely dependent on the automobile. Nonetheless, according to Van der Heijden *et al.* (2006), switching from one mode of transport to another is not usually an easy process. Hence, the success of transport and road traffic management within urban areas depends upon the integration of several different measures, which have to work together in a synergetic manner to cause a significant impact on limiting urban automobile use. Cities such as London and Rome have successfully designed and implemented congestion-pricing schemes alongside provided an extended network of high-quality public transportation service to serve as an alternative travel mode for residents (Van der Heijden *et al.,* 2006). Most cities, however, are not equivalent in terms of size when compared to London, Paris, Rome or New York. Although smaller in size, many of them nevertheless do struggle with severe traffic problems and their city authorities continuously search for alternatives to handle the ever-growing number of automobiles moving on the ground.

The City of Ottawa, Canada is an example of a city currently experiencing growth and continuous traffic congestion within its urban transportation network. Despite there being measures in place such as; parking restrictions, traffic flow optimization, provision of multiple bicycle paths and a dedicated transit-way for bus rapid transit, these measures have not been spectacular at attaining a modal shift from automobile use to other modes of transport. Consequently, the congestion problems experienced during the morning and afternoon peak hours are becoming worse. In an effort to deal with this inevitable traffic congestion problem resulting from traffic growth, the city plans to improve its public transit system by adding a light rail transit (LRT) system to its already existing transit network in order to achieve a 30% public transit modal split by the year 2031 (TMP, 2008). Given that the new public transit mode (LRT) is yet to come into existence, this research study seeks to make use of a stated preference methodology to collect data required to model the mode choice preferences of commuters who commute to the central business district of Ottawa. It also models which commuters are more likely to shift from using their current modes of transport for commuting to using the LRT system.

Prior to understanding the nature of the automobile and travel demand within the City of Ottawa alongside the challenges faced by its public transportation in particular, it would be imperative to discuss how the urban form and urban spatial structure of a city may influence its urban transportation system.

2.1.1. Urban Form, Urban Spatial Structure and Transportation

Land use has an important impact over travel demand as well as the type of transport systems required to satisfy the needs of this demand (Zegras, 2004). At the urban level, urban transport infrastructures such as roads, transit systems or simple sidewalks shape demographic and mobility growth. Consequently, this leads to wide varieties of urban forms, spatial structures and associated urban transportation systems within different urban areas (Rodrigue *et al.* 2009). Bourne (1982) defined *urban form* as the spatial arrangement of individual elements such as buildings and uses, as well as social groups of economic activities, public institutions and transportation networks within an urban area. Alternatively, *form* is the physical pattern of land use activities, population distribution and the networks that link them. These features jointly bestow a level of spatial arrangement within cities. According to Rodrigue *et al.* (2009), elements of an urban transport system, namely transport modes, infrastructure and users, have spatial imprints, which shape the urban form of a city (see Figure 2.1). These spatial imprints are often a function of a city's socioeconomic and geographic characteristics. Large variations of urban transportation spatial imprints are observed between different cities as well as between different parts within the same city (e.g. between central and peripheral areas). In addition, urban transport systems are also composed of spatial interactions, which are a set of relationships that result from a city's urban form and the flow of people, freight, services or information among places, in response to localized travel demand and supply (Rodrigue *et al.* 2009; Lucas, n.d.) forming what is known as the urban spatial structure (an evaluation of the extent to which an urban structure can be achieved from specific urban transport systems. See Figure 2.1.

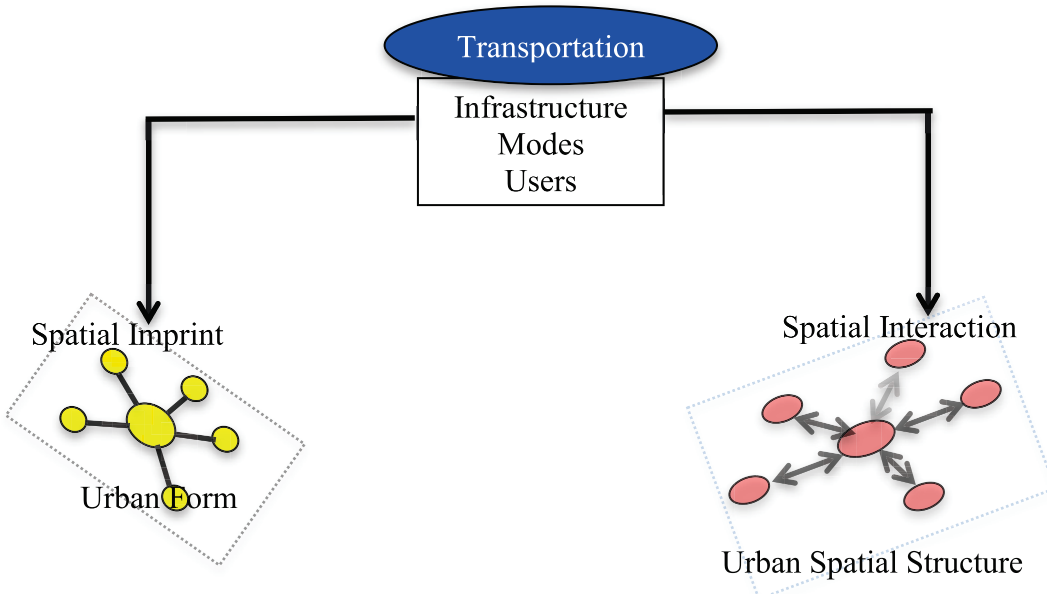


Figure 2.1: The Urban Transport System
Note. Modified from Rodrique *et al.* (2009). *The Geography of Transportation Systems*. New York.

Transportation systems play an important role in shaping the form of city. For example, transit-oriented cities have different housing types, high density settlement, on street shopping, different interaction patterns and behavior thus giving them a different urban form compared to those that are dependent entirely on the automobile.

In this age of urbanization, major cities around the world are challenged with the increased number of trips within their urban areas. In Canada, about 80% of the population is centered within nine major urban areas with the Ottawa-Gatineau metropolitan area being amongst them (Statistics Canada, 2008). Cities have generally responded to growth in mobility by expanding their transport supply through the construction of new highways or roads. The spatial structure of most North American cities (including the City of Ottawa) were developed in a manner that led to an increased reliance on automobile, unlike those encountered in most European or Japanese cities (Rodrigue *et al.* 2009). Given the current nature of the transportation system within the City of Ottawa, a major goal has been set to improve its current public transportation facilities through the addition of a light rail transit

(LRT) to its current bus rapid transit system in order to reduce the reliance on automobile and increase the use of public transit as a sustainable mode of transport especially within its central area.

2.1.2. Urban Transportation Problems

Cities are locations with high levels of accumulation of economic activities alongside complex spatial structures supported by transport systems. Urban productivity is highly dependent on the efficiency of its transport system to move labor, consumers and freight between multiple origins and destinations. The larger the city, the more complex it gets to effectively manage its transport system. Urban transport problems often occur when transport systems, for a variety of reasons, fail to satisfy the demand for urban mobility (Rodrigue *et al.,* 2009). Some problems such as congestion are ancient, while others such as environmental impacts and energy consumption are relatively recent. The following are amongst the most notable urban transportation problems (Rodrigue *et al.,* 2009):

- Traffic congestion and parking difficulties
- Longer commuting
- Public transport inadequacy
- Difficulties faced by non-motorized transport
- Loss of public space
- Environmental impacts and energy consumption
- Safety (traffic accidents)
- Land consumption
- Freight distribution

In the course of this study, some of the urban transport problems to be addressed pertain to the likes of public transport inadequacy and traffic congestion. Other notable mentions include land scarcity and environmental impacts.

2.1.3. Urban Transportation and Sustainability

The form of a city has a major impact on the lifestyles of its residents. As urban centers grow and transportation demand increases, strategies are required in place to ensure that the quality of life is not adversely affected by this growth. Hence, the overall goal of any urban transportation objective should be geared towards providing efficient and sustainable solutions to its current existing transportation problems.

As underlined in the 1987 Brundtland Commission, sustainable development can be defined as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In today's society where environmental impact alongside energy consumption have become major problems in addition to already existing problems posed by transportation systems, setting up goals to achieve an efficient urban transport system with minimum degradation on the environment is paramount. So far, majority of North American cities inherited urban forms that are highly dependent on the automobile linked with high levels of mobility (Rodrigue *et al.,* 2009). However, as studies have shown, this mode of transportation represents a major cause of traffic and environmental impact within cities (Kenworthy & Laube, 1996). Taking into consideration the limited availability of land, Kenworthy & Laube (1996) carried out a study to explore some of the underlying land use, transport and economic reasons for different transport patterns within cities. They found urban density to be a key explanatory variable in the role of automobile versus transit use (i.e., transit use decreases with decrease in urban density and vice versa). In this regard, Kenworthy & Laube (1996) suggested the following series of directions for land use and transport developments in cities if the goal of increased sustainability is to be met:

- Establish land use objectives geared towards more transit-oriented, high density and mixed land uses in order to help halt growth in automobile based development;
- Design an urban structure such that it stabilizes or lower the use of private automobiles and also place less emphasis on infrastructure needed for cars;
- Improve urban structure to support public transit systems especially rail, which are more competitive with cars;
- Improve facilities to support safer use of non-motorized modes such as cycling and walking in order to increase the use of these modes;
- Reduce encroachment onto agriculture land;
- Make use of technology to reduce energy consumption.

Through a concerted set of actions, all these above factors amongst others can contribute towards attaining an efficient and sustainable urban transportation system.

2.1.4. Urban Transportation Modes

Transport modes are an essential component of transport systems through which mobility is supported. As defined by the European Community Transport Research, Development and Demonstration (ECTRDD) Program (2001), they provide access and mobility for people and goods, linking origins to destinations within the inner part and periphery of the urban area. Conceptually, the urban transport system is intricately linked with urban form and spatial structure. In this age of motorization and personal mobility, a number of cities (including Ottawa) have developed spatial structures resulting from an increased reliance on automobile. According to Rodrigue *et al.* (2009), urban transportation is organized into the following three broad categories: collective transport; individual transport and freight transport.

2.1.4.1. Collective Transportation (Public transit)

The purpose of collective transportation is to provide publicly accessible mobility over specific parts of a city. It provides important dimension of mobility, notably within high-density areas. Its efficiency is based upon transporting large numbers of people and achieving economies of scale. It includes modes such as tramways, buses, trains, subways and ferryboats.

2.1.4.2. Individual Transportation (Private modes)

These modes include any mode where the demand for mobility is as a result of personal choice using modes such as the automobile, walking, cycling and the motorcycle. Benefits of any form of private transport include: privacy, reliance, comfort and flexibility. However, given the growth experienced within most urban centers recently, excessive use of automobile poses severe challenges to the transport network and environment.

2.1.4.3. Freight Transportation

As cities are dominant centers of production and consumption, large movements of freight accompany urban activities. These movements are mostly characterized by delivery trucks moving between industries, distribution centers, warehouses and retail activities as well as from major terminals such as ports, railyards, distribution centers and airports. The mobility of freight within cities tends to be overlooked. Nonetheless, it is an important component of the urban transport system.

The three above categories of transportation cover a range of important social and economic activities within urban areas. Overall, their objectives should aim at fulfilling the demand for accessibility in an efficient and sustainable manner.

2.1.5. Importance of Public Transportation

Continuous increase in demand for transport within major urban centers calls for the need of more sustainable modes of transport. In this regard, the use of public transport becomes a very essential mode to achieve a sustainable urban transportation system.

Public transportation provides residents with mobility and access to employment, community resources, medical care, and recreational opportunities within communities throughout an urban area. According to the Federal Highway Administration [FHWA], over 90 percent of public transport users do not own an automobile and must therefore rely on public transportation (FHWA, 2008). Hence, it provides a basic mobility service to these persons and to all others who do not have access to an automobile.

Successful public transport systems pose as competitors to private modes of travel given that they have the ability to retain customers from all social classes, not just the poor and it can be used for a wide range of trips for most part of the day. Nonetheless, achieving this objective would require a well-planned, affordable and attractive public transport system to all groups of people.

The adoption of public transportation into economic and land use planning can also help a community expand business opportunities, reduce sprawl, and create a sense of community (Lavoie, 2012). By creating a locus for public activities, transit-oriented developments could contribute to a sense of community and can enhance neighborhood safety and security. For these reasons, areas with good public transit systems have thrived economically and offer location advantages to businesses and individuals who choose to work or live within them. And in times of emergency, public transportation could also be used to safely and efficiently evacuate residents, providing the resiliency a city needs in its emergency transportation network.

Public transportation also helps to reduce road congestion and travel times, air pollution, and energy and oil consumption, all of which benefit both riders and non-riders alike.

2.2. Urban Structure, Transport and Information Technology

The dawn of information technology has made it possible for countless amount of information to be generated, routed and transmitted anywhere cheaply, nearly instantaneously and at high volumes. Although urban scholars speculate about the impacts of this “information superhighway” on society, surprisingly little is known about the potential effects of this revolution on the structure of an urban area (see Atkinson, 1998).

Information technology would definitely have an impact on the spatial structure of an urban area (see Giuliano, 1998; Audirac, 2005) but the question that remains to be answered is: to what extent would this impact have towards attaining sustainable urban growth? Some hypotheses have been put forth stating that advances made in information technology (IT) would likely promote urban sprawl characterized by spatially dispersed, less densely populated footloose growth patterns, resulting from uncontrolled development within metropolitan areas. However, research carried out by Nilles (1991) shows that telecommuting (the use of technology to replace commuting) does not, as yet, exacerbate urban sprawl. Nonetheless, advances made in IT could possibly bring about job growth within suburban centers driven by relocation from out of the central city (Atkinson, 1998). Stough & Paelinck (1996) also revealed that the role of technology on urban development could lead to a spatial leap-frogging pattern with significant growth occurring within existing satellite communities turning them into primary growth "nodes" within a metropolitan area.

Advancement in information technology has changed the distribution pattern of jobs irrespective of its impact on urban spatial structure. The presence of devices that facilitate telecommunications such as video conferencing, emails, telephone, fax, and many others have changed the dynamics of the working environment within most business firms making it possible for employees to work wherever they have access to these facilities as oppose to working only within the conventional office environment. Hence, IT is likely to diminish current office location constraints encountered by companies (Horan, Chinitz, and Hackler, 1996). The following section presents an insight into telecommuting and its impact on transport demand, job and residential location.

2.2.1. Telecommuting: What is it?

Telecommuting refers to the partial or complete substitution of an employee's normal working hours in a traditional office work place for working at home or at an alternative workplace such as a neighborhood telecommuting center. The overall goal of telecommuting is to reduce the time and number of trips spent commuting to and from work (Nilles, 1975; Tayyaran & Khan, 2003).

While the subject of the use of telecommunications to substitute physical transport has been of interest since the early 1940s, telecommuting was never pursued seriously because of the inadequacies of the technologies and the relative ease of commuting at the time. Notwithstanding, energy supply problems in the 1970s alongside difficulties in commuting revived interest in telecommuting (Reymers, 1996; Nayab & Scheid, 2011). Nonetheless, telecommuting wasn't still taken into full effect given the lack of sufficient technical support offered by computer hardware and software as well as telecommunications systems. By the 1990s, advances in information technology as well as concerns over traffic congestion, energy consumption, and air pollution brought discussions of telecommuting to the fore once again. With the passage of the Clean Air Act of 1990, many companies have turned to telecommuting in order to comply with this mandate (Reymers, 1996). By November 1994, the U.S. government required "thousands of businesses employing more than 100 people to submit detailed proposals outlining a program deemed by the employer as a way to reduce their employees' commute time by 25 percent through carpooling, public transportation incentives, condensed workweeks, or the most practical, cost-effective and popular option, telecommuting" (Zelinsky, 1994).

Telecommuting has so far found a niche in transportation policies in some countries. In recent years, it has been widely recognized as a transportation demand management (TDM) tool because of its potential to relieve traffic congestion, conserve fuel, reduce greenhouse gases, and improve air quality in urban areas (Hamer, *et al.,* 1991; Mokhtarian, *et al.,* 1995; Dearborn, 2002; Khan, 2010). It has the potential to reduce the number of peak-hour trips generated by reducing the need for commuting. At the individual level, studies have shown that it offers many benefits for employees as well. These include greater productivity, less stress, more flexibility to balance work with family commitments, greater job satisfaction, and lower costs on travel (Peters *et al.,* 2004; Topi, 2004). Amongst several benefits offered by telecommuting to employers, the most significant one is that it has the potential to reduce the overall overhead cost (e.g. excess office and parking space). It has also been proven to increase company productivity by reducing absenteeism, tardiness, and employee turnover (Office of Personnel Management, 2009). In this regard, policy makers have begun incorporation telecommuting alternatives into law. The United States Public Law 106-346 (Sec. 359, 2001), for example, states, "each executive agency (of the Federal government) shall establish a policy under which eligible employees of the agency may telecommute to the maximum extent possible without diminished employee performance" (Ory & Mokhtarian, 2005; Sikes *et al.* 2011). Some cities such as Ottawa and the Region of York have included telecommuting as a transport demand management tool in their transportation master plan (York Regional Transportation Master Plan [YRTMP], 2000; Ottawa Transportation Master Plan [TMP], 2008).

According to the 2011 American Community Survey, approximately 2.5% of the U.S. employee workforce (3.1 million people, not including the self-employed or unpaid volunteers) telecommuted between the year 2010 and 2011. This number was up by 0.64% compared to the number of employees who telecommuted between the 2005 and 2006 (Global Workplace Analytics, 2011). Although the availability and use of computers is not a prerequisite for telecommuting, majority of the tasks carried out by telecommuters make use of computers and telecommunication systems to exchange information between the telecommuter and the main office.

2.2.2. Impact of Telecommuting on travel demand, job and residential location

> "Cities are greatly shaped by business and household location decisions, and urban form can be seen as an aggregate consequence of these locational preferences… If information technology alters locational decisions to some extent, the resultant urban form may also change."
>
> *Horan et al., 1996*

Several different scholars and researchers hold very similar views about the impact telecommuting has on travel demand, job and residential location. In investigating the impact of telecommuting and intelligent transportation systems (ITS) on urban development patterns Tayyaran, Khan & Anderson (2003) used a discrete choice modeling approach framework and stated preference methods and revealed that telecommuting and ITS may have an influence on the choice of residential location amongst other factors such as housing cost, size, outdoor amenities, etc. within a multinucleated urban region. Muhammad *et al.* (2007) also found that telecommuters are more likely to relocate their residences to a more peripheral area with higher quality surroundings as opposed to regular commuters leading to changes in residential patterns. In most instances, telecommuting usually follows when individuals relocate their residence farther away from their work place rather than commencing before the residential relocation (Mokhtarian & Ory, 2005).

In terms of the impact of telecommuting on travel demand, many hypotheses have been formulated and tested by several different scholars and researchers. Although studies have shown that telecommuting has the potential to reduce the number of commuting trips made, the overall distance covered by telecommuters is relatively higher than those covered by non-telecommuters based on their residential location (Mokhtarian & Ory, 2005; Muhammad *et al*, 2007). In particular, individuals who tend to move upon adopting a telecommuting program generally move farther away from their office locations compared to individuals who already telecommute prior to moving their residential location (Mokhtarian & Ory, 2005). Hence, telecommuting could be viewed as either a "friend" or "foe" to travel reduction policies. In the friend scenario, telecommuting allows those who live in distant locations to commute less frequently to work, thus reducing travel demands. In the foe scenario, telecommuting motivates those who would have otherwise lived closer to their offices to locate to the peripheries of urban areas, resulting in more vehicle-miles traveled than there would have been without the option of telecommuting.

In terms of job relocation, research and studies have shown that advances made in information technology in general alongside telecommuting in particular plays a role in the relocation of employment and job opportunities across urban areas as well as across different regions (Atkinson, 1998; Mokhtarian & Ory, 2005). From a firm's point of view, advances in information technology give them the ability to outsource work to outlying communities where real estate and labor cost is relatively cheaper. Furthermore, Kumar (1990) reveals that advances in telecommunication technology could result in the dispersal of information-based firms into different parts of a city thereby changing the structure of urban areas towards a multinucleated form.

Overall, telecommuting could lead to a more decentralized land-use development pattern and promote suburbanization based on the assumption that it may have an influence on residential and job location preferences (Kumar, 1990; Tayyaran & Khan, 2003; Tayyaran, Khan & Anderson, 2003). The assumption of its decentralization effect on land-use could bring about an increase in job-housing balance within urban and suburban areas. This could potentially lead to a reduction in travel demand and vehicle-kilometers-traveled (Nilles, 1991). Although the potential impact of telecommuting on the overall urban travel demand is difficult to quantify, telecommuting could be an effective tool for achieving sustainable urban transport systems and in mitigating the spread of traffic congestion during peak hours (Olszewski & Lam 1996; Vana, Bhat, & Mokhtarian, 2007). However, this may be possible if applied within a well-structured urban form. With knowledge about the trend caused by telecommuting on travel demand, residential and job locations, this research study seeks to quantify as part of its objective, the influence telecommuting on the physical location of office space within an urban area.

2.3. Multinucleated Urban Structure and Travel Demand

The structure of a city is a subject of the events, technological changes, policies and preferences that have occurred over its history. All these in turn have an inevitable influence on its associated travel patterns and spatial configuration (Anderson, Kanaroglou & Miller, 1996). The relationship between urban structure, which is a function of land-use and transportation, has become a matter of considerable concern among planners, transportation engineers and policy-makers who are concerned with issues of sustainable urban development (Ibrahim, 1997; Khan 2010). In recent years, attention has been focused on the reduction of travel demand within urban areas by encouraging more efficient land-use patterns and the development of sustainable and efficient means of transportation.

In light of the above concern, several planners, transportation engineers and policy makers have turned to the adoption of a ‘smart growth’ concept into the structure and land-use patterns of several cities in an attempt to avoid unstructured/uncontrolled growth (Ziegler, 2003; Godschalk, 2004).

Fostering the idea of a 'smart growth' has led to the adoption of a multinucleated urban structure as a model structure for most urban areas that are currently at risk of being subjected to unstructured/uncontrolled growth. A multinucleated urban region can be perceived as an emerging urban form characterized by outward development directed towards a number of well-defined nodes (suburban centers) located within the immediate surrounding of the main downtown central business district (CBD) of an urban center (Ibrahim, 1997;Khan, 2010). In theory, each suburban center within a multinucleated urban region should develop into a self-sustained entity capable of providing the basic needs for majority of its residents. In the long run, this would in turn be beneficial to the overall land-use and transport system within the urban area.

Nonetheless, although the multinucleated urban region concept is welcomed with much delight by most urban centers around the world, jurisdictional constraints and/or the lack of planning foresight has limited the number of job opportunities located within the suburban communities of numerous urban regions to match their population growth. In this regard, imbalance between employment opportunities and population growth within these suburban centers has led to continuous increase in commuting between the central business districts within the main urban center and the suburban centers by majority of suburban residents thereby leading to continuous increase in traffic congestion.

According to notions put forth by Khan & Zargari (2010), the development of a multinucleated urban region through the establishment of land-use plans that support the relocation of jobs to suburban centers away from the main urban center could be enormously beneficial to an urban transportation network. In other words, the creation of mixed land-use development characterized by high density settlement that offer both employment and residential opportunities for residence within suburban centers alongside a well developed public transportation system linking these suburban communities to the main urban center is likely to become attractive model for sustainable growth. This kind of urban structure will not only benefit residents to live, work and play within their immediate surroundings but it will also create a sustainable transport network given that it will result in a reduction in vehicle-kilometer traveled as a result of less commuting. It may also induce the use of non-motorized modes of transport for local transport and enable the development of a mass transit for local and regional trips. In theory, a multinucleated urban form can be used to achieve road traffic flow improvement, enhance modal split for public transit, reduce of vehicle-kilometers traveled and reduce energy consumption and emissions (Young, 1990; Tayyaran & Khan, 1996 a,b).

Success in the development of a multinucleated urban structure depends on a number of outlined policies some of which include: striving for a balance of employment opportunities and residential location; development of mixed land uses supported by sustainable modes for local transport; implementation of a rapid transit to link suburban centers to the main urban center and defining demand management measures that can potentially lead to sustainable travel along multimodal corridors within multinucleated urban region. This research seeks to investigate how changes in transportation technology through telecommuting may influence office location/relocation. Research findings may have implications on land-use and transportation development.

2.4. Summary

This chapter presented an insight on the complex relationship between transportation and land use. Implications of having an urban transportation system that is highly dependent on the automobile were discussed. Some repercussions of such a system includes: high levels of traffic congestion, alongside environmental, economic and social degradation. It is suggested by studies that high urban density and mixed land-use developments contribute towards achieving a sustainable transportation system supported by public transit.

Furthermore, the chapter also presented an insight of the role of information technology (IT) on travel demand and land-use with metropolitan urban centers. More attention was placed on telecommuting (use of information and communication technology to substitute work related travel) and its associated travel demand management benefits. Studies show that the adoption of telecommuting may likely have a decentralization effect on land-use given its potential to relax constraints placed on choice of residential location and employment distribution within urban area.

Considering the role of public transit as a sustainable mode of transport as well as the ability of telecommuting to serve as a travel demand management strategy with possible effects on decentralization within urban centers, this study seeks to investigate how improvements in public transit could bring about changes in commuters' mode choices as well as the role of telecommuting in the office location/relocation decision-making process within the City of Ottawa. Findings made from the study could have land-use and transportation demand management implications. The following chapter sheds light on the structure and nature of the transportation system within the City of Ottawa, which was used as the case study for this research.

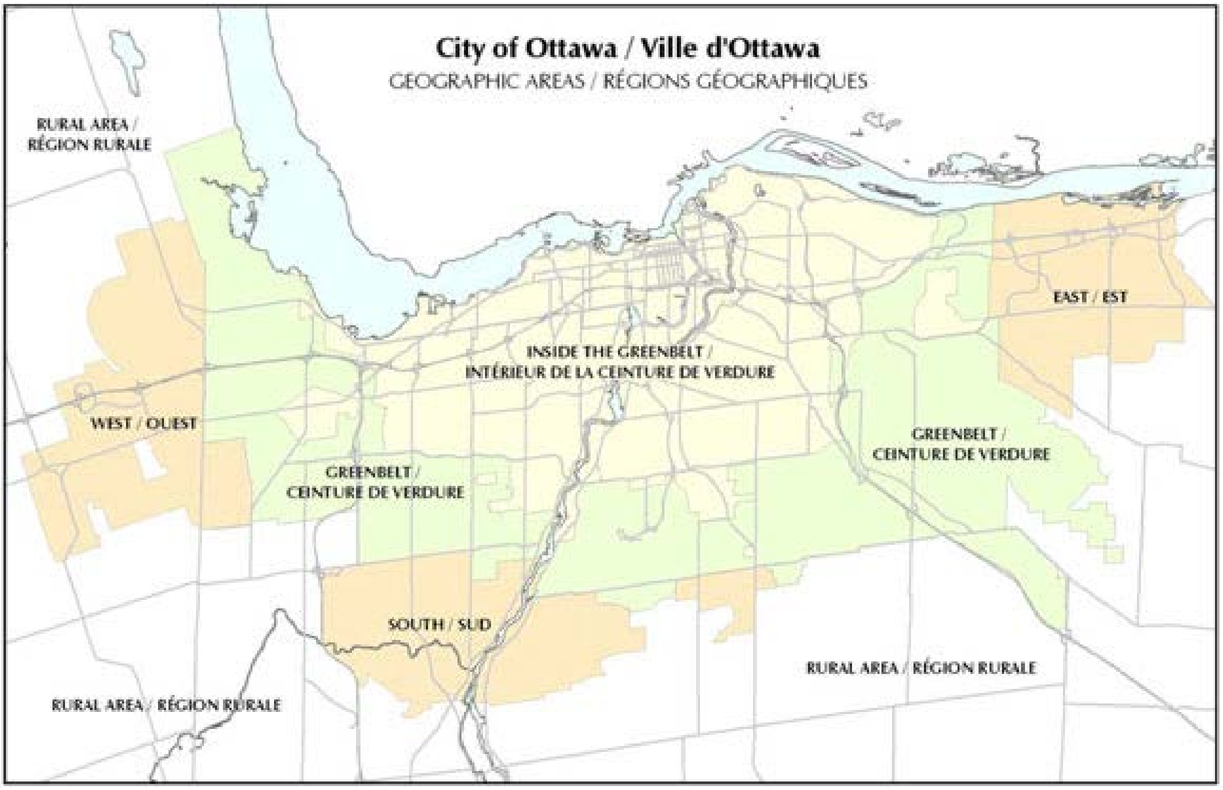
3. CASE STUDY: CITY OF OTTAWA

This chapter presents a *status quo* of the transport system within the city of Ottawa as influenced by its surrounding communities, urban form, population and employment growth. It discusses aspects such as its access and mobility issues alongside its long-term plan for developing an integrated land use pattern supported by public transit.

3.1. Population and Urban Form

The City of Ottawa municipality is located within Canada's National Capital Region (NCR). It is currently home to approximately 900,000 residents and covers a land area of about 2,790 square-kilometers (Statistics Canada, 2012a). Approximately 10% of this land area is urban while 90% is composed of agricultural land, villages, marginal and forested land and wetlands (Transportation Master Plan [TMP], 2008). Together with the City of Gatineau, they both form the fourth largest metropolitan area in Canada in terms of population after Toronto, Montreal and Vancouver.

In terms of urban form, the city of Ottawa is composed of a central urban area surrounded by first tier and second tier suburban communities around its peripheries. It has a greenbelt that separates its central urban area from its surrounding suburban communities. First tier communities include the suburban centers of Kanata (West), Orleans (East) and Barrhaven (South) while its second tier/rural communities include Stittsville, Manotick and Osgoode. These suburban communities alongside central Ottawa form the Ottawa municipal area (See Figure 3.1).



Note. From *Transportation Master Plan, November 2008,* City of Ottawa

Figure 3.1: City of Ottawa Municipality

In terms of future growth, the city of Ottawa municipality is projected to grow by 30% in population by the year 2031 while employment levels are projected to increase by about 35% (TMPIRS, 2008; TMP, 2008). Table 3.1 summarizes these growth projections between 2006 and 2031.

Out of the 265,000 new residents expected by 2031, 20% are expected to live within central Ottawa; 68% are expected to live within the first tier suburban communities; while the remaining 12% are expected to live within the second tier/rural communities. However, in terms of employment, 42% of the forecasted employment growth is expected to be within central Ottawa while 50% of this growth will be distributed amongst the first-tier suburban communities. The remaining 8% employment growth will be distributed within the second-tier/rural communities.

Table 3.1: Projected Population and Employment Growth

Population	Inside Greenbelt	West Urban Centre	South Urban Centre	East Urban Centre	Rural Area	Total
2006	533,100	88,400	64,500	99,000	85,700	870,700
2031	585,800	162,200	147,600	123,500	116,600	1,135,700
Growth	52,700	73,800	83,100	24,500	30,900	265,000
Distribution	20%	28%	31%	9%	12%	100%

Employment	Inside Greenbelt	West Urban Centre	South Urban Centre	East Urban Centre	Rural Area	Total
2006	428,600	43,600	9,800	17,900	21,800	521,700
2031	505,500	77,000	49,300	35,000	36,200	703,000
Growth	76,900	33,400	39,500	17,100	14,400	181,300
Distribution	42%	18%	22%	10%	8%	100%

Source: *Transportation Master Plan, November 2008,* City of Ottawa

Based on the above population and employment forecast, there will be an imbalance between population growth and employment opportunities between central Ottawa and its surrounding satellite communities that may cause an upset in the city's current transportation system. Such a trend is bound to create more travel demands in future considering that there will be an increase in commuting trips made to central Ottawa. This therefore implies that a redistribution in employment and population growth between the city's urban and suburban communities alongside improvement on its public transportation network would be necessary towards attaining a sustainable growth pattern that would be beneficial for its transportation system and land use.

3.2. The City of Ottawa Transportation System

The nature and location of economic activities in relation to residential areas determine the travel demand in a city. This section describes certain aspects that influence the urban transportation system within the city of Ottawa.

3.2.1. Economic Activity

The city of Ottawa is the current political capital of Canada. Over the years, it has evolved to become a political and technological center within Canada (Ottawa, 2013). Two sectors that provide strength to its economy include the federal government and the high technology sector. Both these sectors account for 37% of the city's total GDP with the federal government employing over 110,000 people and the high technological sector employing approximately 80,000 people. The federal government has most of its offices located within the central and inner areas of Ottawa while most offices belonging to high technology firms are located within the suburban center of Kanata. Its densely populated central business district serves as the heart of majority of its economic activities. Its proximity to the city of Gatineau (Quebec) also contributes vitality to its economic strength.

The City of Ottawa also benefits from a vital rural sector. Its rural economy contributes over $1 billion to the GDP. Agriculture alone accounts for $400 million, $136.7 million of which is farm-gate sales. Rural economic activity includes such things as agriculture, retail sales, construction, forestry and mining (aggregates), tourism, manufacturing, personal and business services, and transportation, to name a few. Rural employment expanded by a healthy 18% from 1996 to 2001 (Ottawa, 2013).

The city is the fourth largest in Canada in terms of population, has more than 25,000 employers and currently offers more than 500,000 jobs.

3.2.2. Vehicle Composition

The city of Ottawa had a total number of 479,844 motor vehicles registered in the year 2006[2]. Out of this total, 85% were private passenger vehicles. While the number of registered private vehicles within the city grew at an approximate rate of 1.24 % annually between the year 2000 and 2006, the number of registered transit buses remained constant throughout this period. Although the automobile growth rate within Ottawa was less than the national average set at 1.89 % per year[3], the lesser number of registered transit buses within this same time period implies that not enough emphasis was placed on promoting the use of public transit as a viable mode for transportation. Possible reasons for the continuous growth in automobile ownership within the city of Ottawa may be due to the following:

- The presence of its sparsely populated suburbs;
- Most residents live at a significant distance from the city center;
- The presence of low-density neighborhoods especially within its suburban centers.

[2] Vehicle Licensing and Control System, Ministry of Transportation, Province of Ontario, 2000-2006 (*2003 data is unavailable), and City of Ottawa.

[3] Canadian Vehicle Survey 2007 Summary Report

3.2.3. Traffic Volume

The central business district of Ottawa serves as a major destination for most trips attracting about 23% of the total average daily trips made within Ottawa (TMP, 2008). A significant greater number of these trips are generated from the suburban centers with 57% of them coming from the suburban communities located in the East (Orleans) compared to 43% that come from the suburban communities located in the West (Kanata/Stittsville). Hence, irrespective of a high significant number of viable transportation options available within the central business district of Ottawa, continuous increase in the number of trips made to the downtown central business district have rendered the streets to become less amenable to sustain the current traffic generated by all modes of transport such as automobiles, transit buses, cyclists and pedestrians. Tables 3.2 and 3.3 below represent the percentage of trips made by purpose and the modal split within the city of Ottawa as contained in the most recent 2011 origin – destination survey.

Table 3.2: Trip Purpose – City of Ottawa

Trip Purpose	2011 Percentage
Work	19%
Education	6%
Shopping	12%
Pick up /Drop off	7%
Personal and Other	16%
Return Home	41%
Total	100%

Source: 2011 National Capital Region Household Origin-Destination Survey

Table 3.3: Modal Split for all Trips – City of Ottawa

Mode	Modal Split (%)
Auto Driver	54%
Auto Passenger	15%
Transit	13%
Bicycle	2%
Walk	11%
Other	5%

Source: 2011 National Capital Region Household Origin-Destination Survey

3.2.4. Public Transport

According to Transportation Master Plan Infrastructure Requirement Study [TMPIRS], the city of Ottawa's current public transport system is rated amongst the best when compared to other cities of its size within North America (TMPIRS, 2008). OC Transpo contracted through the city council provides public transportation service within Ottawa. The facilities of the current public transit include: 31 km of dedicated bus rapid transitway with 34 stations, 16 km of arterial road bus lanes, 23 km of freeway shoulder bus lanes, 11 Park & Ride lots with 5370 parking spaces and light rail train known as the O-train that runs for 8 km from North to South with five stations. It also operates 91 lift-equipped vans and 37 cars providing specialized transit service for persons with disabilities (TMP, 2008). At the time of writing this report, work was being done to add an additional station along the O-Train line in order to increase its service frequency from 15 minutes to 8 minutes. The OC Transpo fleet currently has over 1,000 buses and three sets of train serving our nearly 370,000 daily riders (OC Transpo, 2013).

Regardless of the fact that it currently operates one of the world's best and most successful Bus Rapid Transit (BRT) systems, the city of Ottawa still exists today as a largely automobile-oriented city that accounted for at least 54% of all trips made according to the 2011 National Capital Region (NCR) origin-destination survey while the public transit accounted for just 13% of the trips. In addition, its public transit operation within the downtown central business district has reached its capacity making it unable to meet with the current ridership levels. Continuous dependency on automobile for commuting adds more pressure to its current transportation infrastructure for which there is limited land available for any further expansion. As a result, Ottawa is currently facing problems of inefficient mobility and congestion resulting from the above factors especially within its downtown core.

Consequences of these problems range from increase in travel time to the creation of environmental, economic and social problems.

Figure 3.2: OCTranspo O-Train

Figure 3.3: Bus Rapid Transit

3.3. Future of Public Transit Planning and Development

The city of Ottawa is currently working towards achieving a sustainable urban transportation system that would support public transit and be less dependent on the use of automobile. The city has therefore set guidelines to encourage mixed land use developments supported by a strong transit system. This section discusses these guidelines alongside planned improvements to the city's public transportation system.

3.3.1. Land Use

The right kind of land use and the intensity of activities have a direct relationship on the efficiency of transit (Polzin, 1999). Mixed land use developments close to transit offer people a chance to perform multiple tasks at one location. This would generate or attract a high percentage of riders, enhance the level and frequency of service that can be provided and the efficiency of the transit system. Additional functional efficiencies can be obtained if these developments are built in medium to high-density areas as greater concentrations of people justify higher levels of transit service. Based on this, the city of Ottawa has set the following guidelines aimed at achieving an efficient public transport system through the development of mixed land use patterns.

a) The city plans to provide transit supportive land uses such that they are within a 600-meter walking distance of a rapid transit stop or station. Transit-supportive land uses encourage transit use and transportation network efficiency as they:
    - Establish high residential and/or employee densities,
    - Create travel outside of the am/pm peak periods,
    - Promote reverse-flow travel,
    - Attract and generate pedestrian and cycling traffic,
    - Provide extended hours of activity, throughout the day and week.

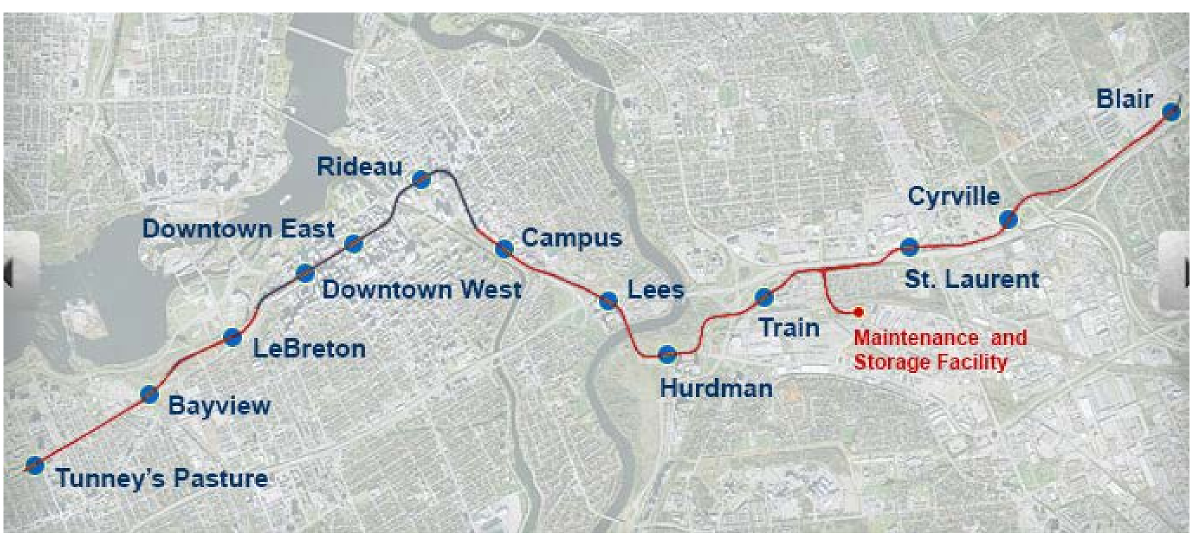
b) Discourage non transit-supportive land use development that would favor automobile use as opposed to the use of other sustainable modes of transport. Non transit-supportive land uses are those that:
    - Generate exclusively high levels of vehicle activity,
    - Use large amounts of land with low-density development.

c) Create a multi-purpose destination for both transit users and local residents by providing a mix of different land uses such as house types, employment opportunities, local services and other amenities that support a vibrant community and enable people to meet many of their daily needs locally, thereby reducing the need to travel.

The city of Ottawa is so far a step closer toward achieving its sustainable urban transportation development plans following its above guidelines. For example, it has set to achieve a 30% public transit modal split by the year 2031. Attaining this objective would require a redesign of its current public transportation system that would see the addition of a light rail transit (LRT) system. The section below discusses the proposed LRT system alongside some of it features.

3.3.2. The Light Rail Transit System

In light of the current problems faced by its current transit system, the City of Ottawa in an effort to promote sustainable mobility and enhance accessibility to its residents adopted a plan to construct a light rail transit (LRT) that would run along its East-West corridor as part of its modification to its existing rapid transit system. The LRT line to be known as the Confederation Line upon construction would consist of 13 stations between Tunney's Pasture (West) and Blair Station (East) (see Figure 3.4).



Source: Ottawa Light Rail website

Figure 3.4: Light Rail Transit (LRT) Route

3.3.3. Some Features of the Proposed LRT

The LRT is expected to become operational by the year 2018. Based on information obtained from the City of Ottawa (2012), some notable features of the proposed LRT confederation line are presented below:

Operational Capacity:

- 300 passengers per train, up to 18,000 passengers per hour per direction by 2031, downtown LRT stations predicted to handle more than 50 million annual trips in 2031.
- Will account for more than 40% of the trips taken within Ottawa
- Peak service frequency: every 45 to 60 seconds
- Average speed: 37 km/h
- Maximum speed: 100km/h
- Travel time from Tunney's Pasture to Blair: less than 24 minutes

Transit Route:

- Length: 12.5 km with 2.5 km tunnel underneath the downtown core.
- Number of Stations: 13
- Part of current transitway to be converted into rail route

Source: CBC News (2012, Dec)

Figure 3.5: Light Rail Transit – Concept

Source: Butler (2013, February)

Figure 3.6: Light Rail Transit Station – Concept

3.4. Summary

This chapter presented the *status quo* of the transport system within the city of Ottawa as influenced by its surrounding communities, urban form, population and employment growth. The structure of the city is made up of an urban area surrounded by suburban communities. A current imbalance between employment opportunities and population settlement between its urban and suburban communities has resulted in an increase in travel demand, as residents tend to commute from its suburban centers to its urban center thereby leading to an increase in traffic congestion accompanied by other detrimental effects. In an effort to reduce the dependency on automobile and reduce congestion, the City of Ottawa aims at achieving an efficient public transport system through the development of mixed land use patterns. As part of this objective, it plans to redesign its public transit system that would see the implementation of a Light Rail Transit (LRT) system. This improvement is expected to achieve a 30% public transit modal split by the year 2031.

PART II – SURVEY DESIGN AND DATA COLLECTION

This part of the report discusses the methodology used in the survey design as well as the technique used in collecting data for this research study.

4. SURVEY DESIGN

Two separate surveys were designed using the stated preference (SP) methodology (see Figure 4.1.1):

- The first SP survey was designed to collect data from commuters on their mode of transport preference;
- The second SP survey was designed to collect data from office managers on their office location/relocation preferences.

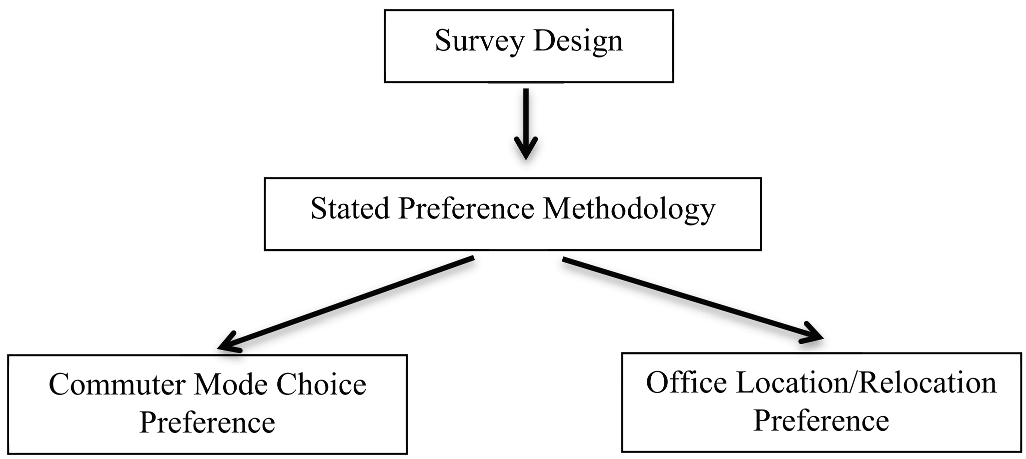


Figure 4.1.1: Survey Design Process

In general, there is a logical sequence of tasks required to design a stated preference choice experiment. These tasks, though distinguished from the issue of statistical design complexity, should however be undertaken with some broad awareness of the downstream implications of decisions made at each stage (Hensher, 1994). There are generally seven recommended steps involved in the design of a successful stated preference survey and an effective statistical model (Kocur *et al.*, 1982). These include:

1. Identification of the scope of study of the research;

2. Preparation of initial versions of hypothetical scenarios and draft questionnaire;
3. Execution of a focus group meeting consisting of members of the population to be studied in order to determine factors that influence the scope of study of the research;
4. Evaluation of results obtained from focus groups;
5. Redrafting of hypothetical scenarios and questionnaire;
6. Launching of pilot survey to a small portion of the sample population;
7. Final evaluation and changes prior to launching of main survey;

However, steps 3, 4 and 5 were omitted in the SP survey design process of this research study due to the inability to organize focus group meetings as a result of lack of time and financial constraints. Hence, the derivation of attributes used in the design of the SP survey was heavily dependent on relevant information obtained from previous related studies. Aside from the design of stated preference (SP) hypothetical choice sets, the survey questionnaire also contained other general questions addressed to obtain relevant descriptive information about the specific characteristics of the sampled respondents. Figure 4.1.2 below outlines steps involved in the design of each of the SP surveys in this research study.

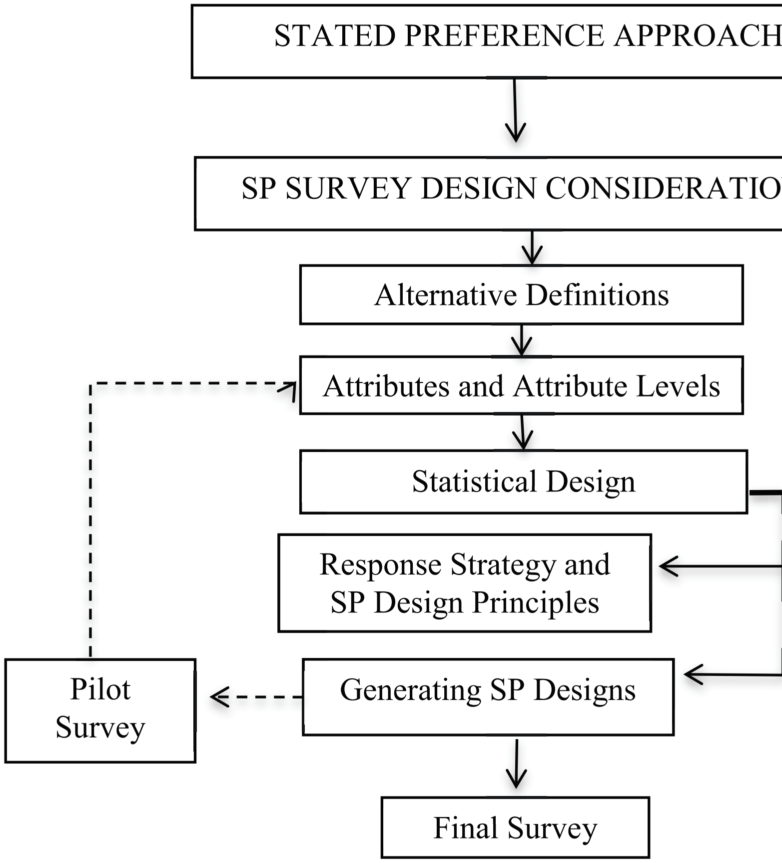


Figure 4.1.2: Factors Considered in the design of the Stated Preference Experiment

Prior to discussing the details of the survey design, an insight into the stated preference approach and applications is presented below.

4.1. Stated Preference Approach and Applications

There are two main approaches to study the preferences of individuals based on the manner in which data is collected. When the data is based on the individual's actual choices and behaviors, it is commonly known as "Revealed Preference" method, while when the data is based on the individual's responses to hypothetical scenarios, it is commonly referred to as "stated preference" method. Given that overall goal for this research study aims at evaluating concepts that are not currently in existence, the use of revealed preference survey methodology as a technique for obtaining data for this study is completely out of context. Hence, this research adopted a stated preference methodology as favorable technique for designing the survey questionnaire for this study. This section presents an insight into stated preference approach. A comparison between the stated versus the revealed preference approach is also discussed. Some limitations of the stated preference approach are also mentioned.

4.1.1. What are Stated Preference Methods?

Without trying to give a rigorous definition, stated preference methods can be said to be a range of techniques that involve the collection of data about respondents' preferences in hypothetical settings as opposed to their actual actions as observed in real markets. Their selected preferences are based on a set of alternatives (Kroes, *et al.* 1988; Ortúzar, *et al.*, 2011). Each alternative is typically characterized by a set of attributes and attribute levels constructed by the researcher that are subsequently used to estimate utility functions.

Stated preference methods have been in existence for a long time and were originally developed in marketing research in the early 1970s. They became widely used in the field of transportation by 1979. Since then, there has been rapid growth in their popularity and application to many different fields of research including transportation (Hensher, 1994). The three most common stated preference (SP) methods include: *contingent valuation* (CV); *conjoint analysis* (CA) and *stated choice* (SC) techniques (Ortúzar, *et al.*, 2011). An overview of these methods is provided in Ortúzar and Willumsen (2011, pp.95-97). The definitions of the three SP methods are stated below:

- *Contingent valuation* (CV) primarily involves a situation whereby respondents are presented with detailed information about a situation or problem with possible alternative solutions applicable to solve the problem. They are then asked if they would vote to accept the changes and pay a certain amount of money or vote against the suggested initiatives. The overall goal of this method is to evaluate the *willingness-to-pay* (WTP) of a sample of individuals for various policy or product options (Louviere *et al.,* 2000; Ortúzar *et al.* 2011). This method is similar to methods used in marketing to evaluate new concepts for goods or products. A concern with this method is that it does not allow researchers to examine the individual characteristics of the product or policy under study (i.e., it cannot be used to evaluate separate components of a product). For more details on contingent valuation, see Mitchell and Carson, (1989).
- *Conjoint Analysis* (CA) involves any decompositional method that estimates the structure of a consumer's preference given his/her overall evaluation of a set of alternatives that are pre-specified in terms of levels of different attributes (Green & Srinivasan, 1978). Here, respondents are presented with a number of alternative policies or products and are asked to either rate or rank them. The levels of the attributes of the various policies or products could be systematically varied and form the independent variables which are regressed against the rated or ranked data. Nonetheless, CA methods are accepted with limitations within the field of transportation for the following two reasons (Ortúzar *et al.* 2011): (1) lack of appropriate statistical methods available to analyze collected CA data; (2) the use of ranking/rating systems could be approached by respondents in various different manners as each individual may have different psychological interpretations.
- *Stated Choice* (SC) methods are similar to CA methods insofar as respondents are presented with a number of hypothetical alternatives; however, the two methods differ in terms of their

response metric. Respondents undertaking a SC survey are required to choose their preferred alternative from amongst a subset of the total number of hypothetical alternatives constructed by the researcher (Ortúzar *et al.* 2011). This method tends to be the dominant method used in most transportation related studies. In asking respondents to make a choice from amongst a set of alternative, rather than rating or ranking them, this method avoids the two criticisms leveled against the CA method.

4.1.2. Stated Preference versus Revealed Preference Methods

Revealed preference (RP) methods are based on actual information obtained from respondents in regard to a particular situation. Despite being a favorable technique applicable for deriving utility models and estimating models of travel demand, there are some factors that restrict their general suitability (Kroes *et al.* 1988, Ortúzar *et al.* 2011):

- The use of such an approach makes it impossible to evaluate policy options and/or situations that do not currently exist. For example, with respect to this study, such approach cannot be used to determine the impact of new transportation facilities (such as the addition of the light rail transit) and/or planning and policy related aspects such as the influence of telecommuting on office location;
- It is difficult to obtain sufficient variation from using a revealed preference approach to examine all variables of interest. For example, it is difficult to incorporate intangible attributes such as reliability, flexibility and comfort in the design of a RP survey;
- Revealed preference approaches cannot avoid correlation problems (particularly between transport times and costs) and statistical inefficiencies due to insufficient variation in real-world data. For example, only a small proportion of businesses locate/relocate their offices

within any reasonable time period, implying the use of the RP approach would require a large dataset to minimize correlations between attributes.

The above limitations would be surmounted if it was possible to undertake real-life controlled experiments within cities or transport systems, but the opportunities for doing this in practice are very limited. Thus, where data from real markets is not available for predicting behavior or eliciting reliable preference functions, researchers have turned to the use of *stated preference* (SP) methods.

The stated preference approach is attractive in that it provides approximate laboratory conditions, where respondents make choices among hypothetical alternatives presented in an experiment based around real world scenarios (Kim *et al.,* 2005; Ortúzar, *et al.*, 2011). As suggested by Hensher (1994), the stated preference approach provides a means through which a series of survey questions elicit a respondent to respond to a series of alternatives characterized by a combination of levels of attributes in a controlled manner. A good experiment should have sufficiently understandable and realistic attributes and discernible choice contexts, together with enough variation in the attribute levels necessary to produce meaningful behavioral responses in the context of the strategies under study. The main features of a stated preference methodology may be summarized as follows:

- It is based on the elicitation of respondents' statements of how they would respond to different non-existing hypothetical alternatives.
- SP methods are easier to control (because the researcher defines the conditions which are being evaluated by the respondents). Typically, the researcher constructs a set of hypothetical alternatives using *experimental design* techniques so that the individual effect of each attribute can be estimated with the smallest standard errors and correlations as much as possible;

- They are more flexible (being capable of dealing with a wider variety of variables). Each alternative is represented as a 'package' characterized by different attributes and attribute levels;
- They are cheaper to apply (as each respondent provides multiple observations for variations in the explanatory variables which are of interest to the researcher);

SP methodology makes it possible to quantitatively analyze the responses of respondents using disaggregate models.

4.1.3. Limitation of Stated Preference Methods

Aside from the advantages of using the SP method for collecting data needed for calibrating disaggregate models, the question of how good they are at capturing 'real' preferences often arises in both academic and commercial applications (Louviere *et al.,* 2000). A significant disadvantage of this method is: respondents' preferences to hypothetical choice sets may not necessarily be the actual choices they would make in real-life situations. This is a major criticism leveled against the use of stated preference methods. Nonetheless, this only becomes a major issue when the experimental design of the stated preference survey is poorly carried out.

4.2. Stated Preference Survey Design Considerations

Generating an efficient design is paramount in every SP experiment since there exist several possible ways in which they can be constructed. Hence, the aim of any analyst/researcher is to choose a particular method that best suits the purpose of the experiment. How to best do this depends on a number of many different considerations.

Firstly, the researcher needs to determine whether the experiment should be treated as *labelled* or *unlabelled*. In general, the decision to treat an experiment as *labelled* (i.e., the experiment uses alternatives with names that have substantive meaning to the respondent other than indicating their relative order of appearance, (e.g., Central Ottawa, West Ottawa, East Ottawa, etc.) or as *unlabelled* (i.e., the names of the alternatives only convey their relative order of appearance, e.g. Alternative 1, Alternative 2, Alternative 3) typically impacts upon the number and type of parameters that will be estimated as part of the study and will depend on the problem under study (Rose *et al.* 2009; Ortúzar *et al.* 2011). For example, mode choice studies will generally require a labelled experiment, whereas route choice problems are in general amenable to unlabelled SP experiments.

Maintaining attribute *level balance* such that the levels of each attribute occur with equal frequency is another consideration typically associated with SP experimental designs (*see* Huber *et al.* 1996). This is generally considered a desirable property, although it may impact the statistical efficiency of the design (Rose *et al.* 2009;Ortuzar *et al.* 2011). If present, it ensures that each point in preference space is equally represented, so that the parameters can be estimated equally well on a whole range of levels, instead of having more or less data points at some of the attribute levels (which may affect how the design performs in practice). Nevertheless, it is worth nothing that attribute *level balance* may require larger designs than dictated by the number of parameter estimate requirement.

Determining the *number of attribute levels* to reflect the relationship each level has to the overall contribution to utility and whether the relationship is expected to be linear or non-linear from one level to the next is another useful aspect to consider (Ortúzar *et al.* 2011). If non-linear effects are expected for a certain attribute, then more than two levels need to be used for this attribute in order to be able to estimate these non-linearities. However, dummy coded attributes require only two attribute levels. The more levels used, the higher the number of choice tasks will be. Also, mixing the number of attribute levels for different attributes may yield a higher number of choice situations (due to attribute level balance). For example, if there are three attributes with two, three and five levels, respectively, then the minimum number of choice sets will be 30 (since this is divisible by two, three and five). On the other hand, if one would use two, four and six levels, then only a minimum of 12 choice sets would be enough. Therefore, it is wise not to mix too many different numbers of attribute levels, or at least have all even or all odd numbers of attribute levels (Rose *et al.,* 2009).

Aiming at maintaining a reasonable *attribute level range is useful*. With regard to this, researchers suggest that using a wider range (e.g. \$1 - \$6) is statistically preferable to a using narrower range (e.g. \$3 - \$4) as this will theoretically lead to better parameter estimates (i.e., with smaller error), although using a very wide range may also be problematic (see Rose *et al.*, 2009). The reason for this is that the *attribute level range* will impact upon the likely choice probabilities obtained from the design, which is reflected on the expected standard errors obtained from that design. Having a very wide range will likely result in choice tasks with dominated alternatives (at least for some attributes) whereas a very narrow range will result in largely indistinguishable alternatives (Rose *et al*. 2009). Notwithstanding, such considerations are purely statistical in nature and analysts should also consider practical limitations upon the possible range that the attribute levels can take i.e., the attribute levels shown to the respondents must appear to be realistic to them (Ortúzar *et al.* 2011). Hence, there will be often a trade-off between the statistical preference for a wider attribute level range and practical considerations that may limit this range.

Selection of an appropriate *design type* between a *full factorial design* and a *fractional factorial design* is of great importance. Full factorial designs are more practical because they consist of all possible different choice situations and are capable of estimating all possible effects (main and interaction effects). However, due to the large number of choice sets associated with *full factorial designs*, *fractional factorial designs* are more preferred by researchers. There exist many different types of designs within this class. *Fractional factorial designs* could be achieved either through random selection of choice situations from a *full factorial design* or by following a structured approach, such that the best data from the SP experiment would be produced from estimating the model (Rose *et al.*, 2009).

Ensure that the design preserves its orthogonal properties. *Orthogonality* is satisfied when the joint occurrence of any two levels of different attributes appear in profiles with frequencies equal to the product of their marginal frequencies (Addelman 1962).

Develop designs that minimize the number of zero attribute difference i.e., with *minimal overlap* such that the probability of an attribute level repeating itself in each choice set remains as small as possible (*see* Huber *et al.* 1996; Louviere *et al.* 2000).

Lastly, the design of a fractional factorial SP experiment requires accurate estimation of the number of *choice sets* that can be presented to each respondent for optimum results. This is bounded from below by the number of degrees of freedom, as well as typically by the number of choice sets required to achieve attribute level balance (Louviere *et al.*, 2000; Rose *et al.,* 2009). Also, the design type may restrict the number of possible choice sets.

4.3. Stated Preference Survey Design

This section presents a discussion on the design of the two surveys carried out in this study using the stated preference methodology. An outline of the survey design process is presented in Figure 4.1.3 below.

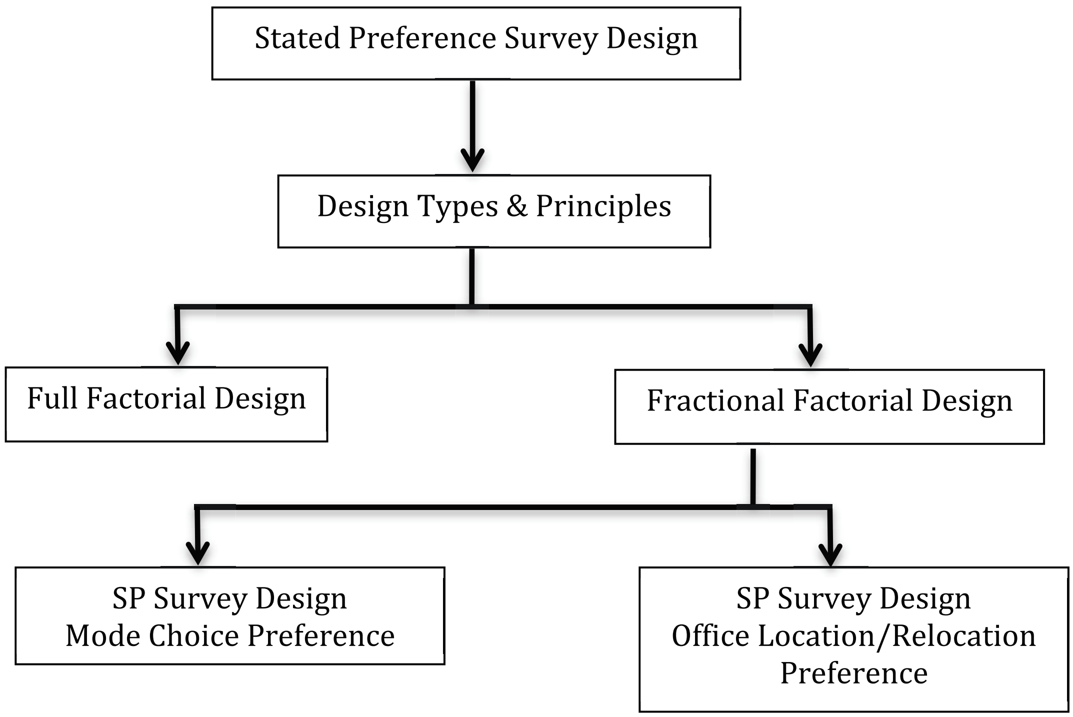


Figure 4.1.3: Survey Design Outline

4.3.1. Design Types and Principles

A stated preference (SP) survey can be designed and presented to respondents following either a full factorial design or a fractional factorial design. With a full factorial design, all levels of each attribute are utilized in the design of the hypothetical choice sets, while for a fractional factorial design, only a fraction of the levels of each of attribute are utilized in the design of the hypothetical choice sets. With the exception of small experiments with fewer numbers of attributes and attribute levels that favor the application of full factorial designs, fractional factorial designs turn out to be the most practical approach to follow when designing SP experiments. With a fractional factorial design, it is possible to derive subsets from an entire set of possible combinations of the various attribute levels as opposed to having one large set of all possible combinations of the attribute levels. By representing each subset as choice set matrices, multiple different questionnaires can be developed and presented to respondents covering different possible combinations of the attributes and attribute levels. In this manner, the respondents would be subjected to lesser burden, as each respondent would have a lesser number of hypothetical scenarios for which they need to provide responses (Louviere *et al.,* 2000). Figure 4.1.4 below outlines the two main methods (*full factorial vs. fractional factorial)* applicable for obtaining an SP survey design.

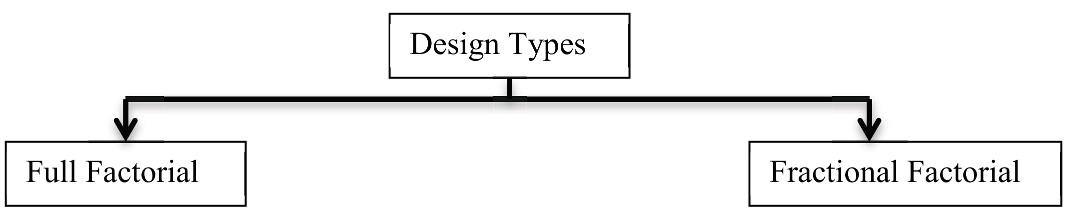


Figure 4.1.4: SP Design Types

4.3.2. Fractional Factorial Design

4.3.2.1. Types

A full factorial design estimates all main effects, two-way interactions and higher-order interactions. However, they tend to produce an unbearable number of choice sets thus making them less favorable to be selected as the preferred method for designing SP experiments with numerous attributes and attribute levels. In addition, should an SP experiment be designed following a full factorial design, the generation of too many choice sets may induce fatigue on the respondents and subsequently, increase the response error (Pearmain *et al.* 1991). For this reason, researchers often use fractional factorial designs that consist of fewer choice sets than full-factorial designs (SAS Institute, 1993).

The SP survey design for this experiment called for the reduction of the full factorial design into a fractional factorial design in order to make it more manageable for the respondents to respond. Four applicable methods to obtain a fractional factorial design include: Optimal Orthogonal Choice Designs, Efficient Choice Designs, Random Selection and Orthogonal Designs (Rose *et al.,* 2009). See Figure 4.1.5 below.

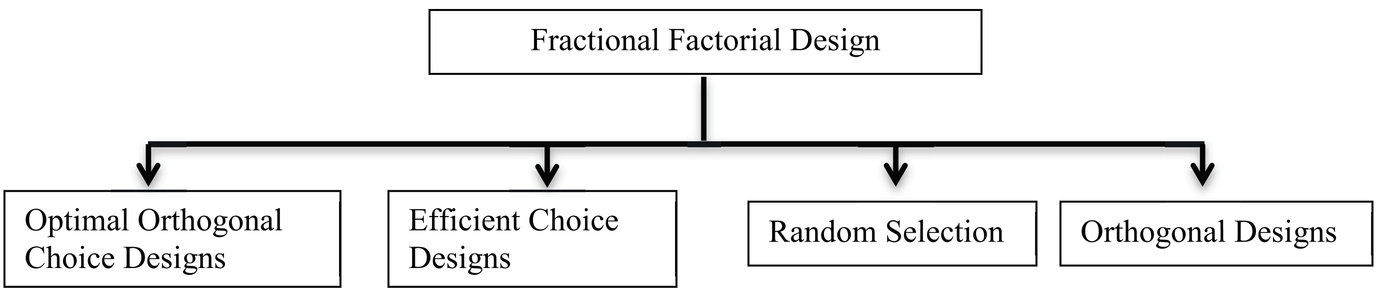


Figure 4.1.5: Fractional Factorial Designs

Optimal orthogonal choice designs can be distinguished into D-*optimal* and D-*efficient* designs and research suggests that they should be constructed in a manner such that attributes common across alternatives should never take the same level over the SP experiment (see, e.g. Street *et al*., 2001; Street and Burgees, 2004; Street *et al.*, 2005). However, this design method is not suitable for obtaining the fractional-factorial SP designs for this experiment for the following reasons: Firstly, *Optimal orthogonal choice designs* may only be constructed for unlabelled SP experiments. Labelled choice experiments, where attributes may not be common across alternatives or where attribute levels may differ for common attributes, are not possible for such designs, given that such designs are not covered by the definition of optimality offered. Secondly, these designs may promote certain forms of behavioural response, such as lexicographic choice behaviour. By forcing each attribute to be different across alternative, a particularly dominant attribute level may govern the entire experiment (Rose et al., 2009).

Efficient choice designs aim at deriving possible statistically efficient designs in terms of predicting standard errors of the parameter estimates instead of merely looking at correlations between attribute levels (Rose et al., 2009). Essentially, these designs try to maximize the information from each choice situation.

Random selection involves the selection of scenario choice sets from the full factorial design at random in order to obtain a fractional factorial design. *Random selection* is the most unfavourable methods applicable to achieve a fractional factorial SP design amongst all methods.

Orthogonal designs are constructed with the sole criteria being that the correlations of the design attributes (and possibly interaction terms) are all zero. They have the following characteristics that make them favourable to be used to obtain fractional factorial designs (Rose et al., 2009):

a) Orthogonal designs allow for an independent determination of each attribute's contribution on the dependent variable.
b) Orthogonal designs maximize the power of the design to detect statistically significant relationships.
c) Orthogonal designs are easy to construct and obtain (either from software packages or academic papers).

Orthogonality is only preserved in a situation whereby respondents are presented with a complete orthogonal matrix. However, orthogonality will generally be lost if the subset of the design are not replicated evenly throughout the survey i.e., one cannot add or remove rows from an orthogonal design and/or replicate unevenly rows of the design over multiple respondents and retain orthogonality within the dataset. Thus, it is the duty of the researcher to ensure that in allocating the choice task to respondents, each choice task is equally represented in the final data.

For the purpose of this SP survey design, an orthogonal design was used to achieve the fractional-factorial designs. There exist several methods for constructing an orthogonal design, some of which are shown in Figure 4.1.6 below.

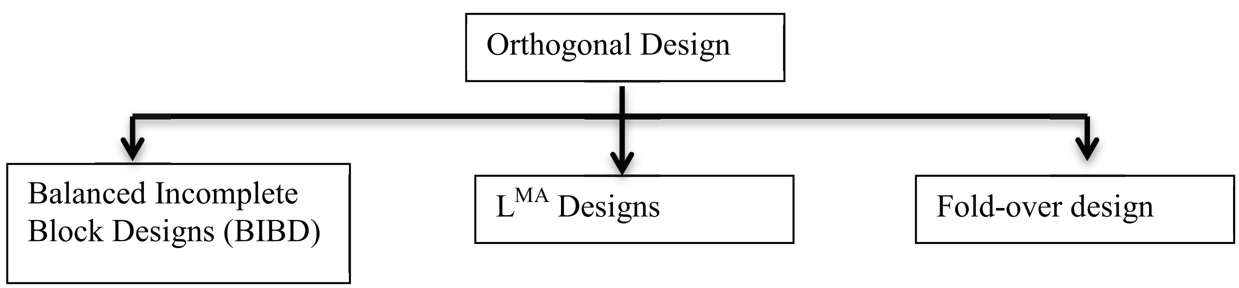


Figure 4.1.6: Orthogonal Designs

The L^{MA} design method was implemented to obtain the orthogonal design given that it is the most common form of orthogonal design.

4.3.2.2. L^{MA} Fractional Factorial Design

In an L^{MA} orthogonal design, *M* represents the number of alternatives under consideration, *A* represents the number of attributes and *L* represents the number of attribute levels. Given the large number of choice sets that can be obtained from a full factorial of this orthogonal design, a fractional factorial orthogonal design was developed in order to reduce the number of possible choice sets presented to respondents. The implementation of L^{MA} fractional factorial designs can be done in two ways: (1) by splitting the choice sets obtained from a full factorial design into multiple subsets in different survey questionnaires followed by administering to an equal number of respondents or (2) by making assumptions to ignore the effects of higher order interaction terms and using predesigned orthogonal fractional factorial design codes. One pitfall of associated with fractional factorial design is that some effects become confounded[4] as a result of a reduction in the number of choice scenarios (SAS Institute, 1993). This is because some degrees of freedom are given up compared to the possible number of relationships between the attributes that can be examined.

An orthogonal fractional factorial design seeks to minimize the correlation between the attribute levels in the choice sets. The design strategy for this experiment called for the selection of the smallest orthogonal main effect design from the full factorial that satisfied desired identification properties (Louviere *et al.,* 2000). Considering only main effects, the smallest possible orthogonal design was determined from the degrees of freedom (d.f.) in order to estimate all implied main effects where each main effect (attribute) had exactly $L - 1$ degrees of freedom (d.f.), and *L* represents the attribute levels of each attribute. In addition, a 'constant' in the form of a 'no choice' option may be added to each

[4] Two effects are said to be confounded or aliased when their effects cannot be distinguished from each other because the levels they take in the design yield identical partitions of the runs (SAS institute, 1993).

choice set as an alternative in order to limit bias selection in choice sets with dominant alternatives (Louviere *et al.,* 2000).

With the goal behind the design of an SP experiment set at defining alternatives within each choice set with more equal choice probabilities (Huber, J. and Zwerina, K., 1996), this experimental design made use of a two-strength[5] *orthogonal main effect plan (OMEP)*, a special type of orthogonal fractional-factorial design in which all estimable effects are uncorrelated (see Abdelman 1962; Kuhfeld, 2004). An orthogonal main effect plan that accounts only for main effects was used in the design. Hence, all two-factor and higher order interactions were assumed to have an overall negligible effect on the experiment.

4.3.2.3. Orthogonal Main Effect Design Codes

This section presents the general procedure for developing an orthogonal main effect plan (code) required for the design of choice sets using the attributes and attribute-levels. The steps are outlined in Figure 4.1.7 below.

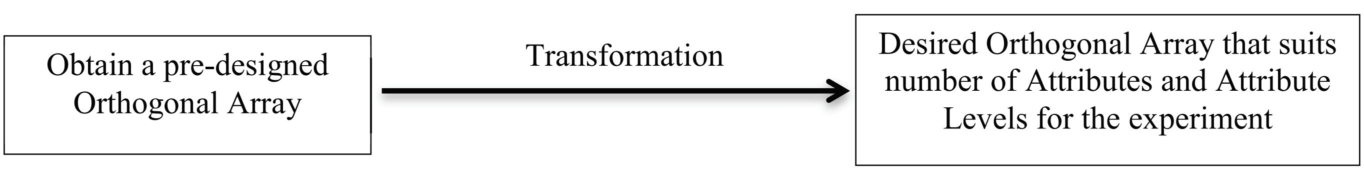


Figure 4.1.7: Generating an Orthogonal Main Effect Plan (OMEP)

[5] Strength is the number of columns where one is guaranteed to see all the possibilities an equal number of times. By basing the experiment on an orthogonal array of t-strength, we ensure that all possible combinations of up to t of the variables occur together equally often (Kuhfeld, 2004). For example, orthogonal arrays with a two-strength main effects design implies that all level pairs occur equally often within every pair of columns.

A two-strength pre-designed mixed orthogonal array with N runs, k-factors, s-levels represented generally as **MA.N.s1.k1.s2.k2....**[6] was obtained from a library of orthogonal arrays (Sloane, 2003). Following procedures for transforming an orthogonal array from one form to another as contained in Street and Burgees (2007, pp. 41-53), the selected pre-designed orthogonal array was transformed to suit the purpose of the design of the number of choice sets required for the design of the SP survey. However, although the goal of the fractional factorial orthogonal main effect plan is to achieve a reduction of the number of possible choice sets that can be presented to the respondents without losing orthoganality, in most cases, most of the derived OMEP tend to have quite a number of cases that may be too many to present as choice sets to the respondents. Hence, further reduction of the number of choices sets required for the survey design was needed.

Although many researchers have proposed several techniques applicable to obtain optimum results from a reduced number of choice sets without sacrificing the quality of the data obtained (e.g. Kroes *et al.*, 1988; Kuhfeld *et al.,* 1994), there is however little rigorous empirical research to guide us on this matter given that existing results are somewhat contradictory. Some research has shown that uncertainty in preferences associated with SP choice experiments are further exacerbated by high task demands such as decision complexity and cumulative cognitive burden which, tend to result in less consistency in choice made, leading to higher variance in statistical models that affect the overall efficiency (see Swait and Louviere, 1993; Swait and Adamowicz, 1996). To further support this finding, Caussade *et al.* (2005) investigated effects of learning and fatigue while simultaneously investigating the impact of design complexity and cognitive burden in a heteroskedastic logit framework on a route choice data. It was observed that learning effects were prevalent during the first nine choice sets, followed by fatigue effects. The notion of learning effects being followed by fatigue

[6] The name **MA.N.s1.k1.s2.k2....** indicates a mixed-level (or asymmetrical) orthogonal array with N runs, k1 factors at s1 levels, k2 factors at s2 levels... and with strength 2

effects is also consistent with the findings by Hu (2006) who interacted the scale parameter with the number of choice sets in a mixed logit model and found learning effects to be prevalent over the first six choice sets, followed by fatigue effects. In general, the longer it takes to complete an SP choice survey, the more bored and less interested the respondent tends to become leading to lesser attention paid to the survey. The outcome of this is an increase in the variance of error (Hess *et al.* 2012). Thus, the design of SP choice sets should aim for a complexity level for which the variance is minimized given that variance is a convex function of decision complexity and cumulative cognitive load. Notwithstanding, some researchers have shown that survey response rates and model parameters are essentially equivalent irrespective of the number of choice sets (twelve, twenty-four, forty-eight and ninety-six) presented to different groups respondents compared in a particular decision task (see Brazell and Louviere, 1997). In addition, Hanley *et al*. (2002) found no significant differences between the results obtained from respondents who were presented with four choice scenarios versus the results from respondents who were presented with eight choice scenarios in a five-attribute, two-alternative experiment. Nonetheless, Carson *et al.*, (1994) were able to determine that respondents of most SP studies evaluate between one and sixteen choice sets with the average being somewhere around eight choice set per respondent.

Given the mixed views and opinions presented by various different authors regarding the number of choice scenarios deemed appropriate, there isn't so far any form of recommended guidelines as to the number of choice scenarios that should be assigned to each respondent in an SP choice experiment. However, the nature of the SP experiment may help determine the number of choice sets deemed necessary for each respondent. According to Louviere *et al.* (2000), the number of choice sets assigned to respondents is a function of choice tasks complexity (number of attributes and alternative), incentives, mode of elicitation (mail survey, personal interview, computerized interview, etc.), types of respondents and many more. Kuhfeld, Tobias and Garratt (1994) also report that the total number of choice sets can be further reduced at the expense of sacrificing some design orthogonality. However, any reduction is subjected to the restriction that the minimum number of choice sets by number of choice alternatives must equal or exceed the total degrees of freedom to be estimated. In addition, Kroes and Sheldon (1988) suggest that fractional factorial designs should be composed typically of some 9 to 16 choices sets for an optimum result. Meanwhile, Carson *et al.* (1994) also suggest that there are usually between 1 and 16 choice sets presented to each respondent with the average being 8 choice sets for each SP experimental design.

4.3.2.4. Design of Orthogonal Combination Codes for Choice Sets

In this section, the method used for developing the orthogonal fractional factorial design codes to design the hypothetical SP choices sets considering all alternatives is presented. The orthogonal design codes obtained from the orthogonal main effect plan (OMEP) in section 4.3.2.3 above can be used to establish a choice set composed of attributes and attribute levels representing one alternative. A *cyclic or shifted design* technique first developed by Bunch, Louviere, and Anderson (1994) was implemented to generate a design code that would represent the combination of the attributes and attribute levels for subsequent alternatives considered in the design of each SP survey.

Following the cyclic (shifted) design technique, orthogonal design codes for subsequent alternatives were constructed by adding cyclically generated design codes to the obtained orthogonal main effect codes. This was obtained by adding one additional level on to each subsequent code that represented the attribute level for the previous alternative until the highest level for that attribute was attained, at which point the reassignment re-cycles to the lowest level. In this manner, the same number of alternatives as the maximum number of levels could be generated easily (Huber, J. and Zwerina, K., 1996). Cyclically generated alternatives are usually beneficial for the following reasons (Huber, J. and Zwerina, K., 1996):

- They mirror the perfect level balance and orthogonality of the seed (original) array (i.e., the frequency of occurrence of each pair of attribute levels is equivalent to the product of their marginal frequencies).
- They are easily generated and maintain minimal overlap – each level occurs only once for each attribute within a choice set.

The following requirements should be checked when a cyclic design technique is used to obtain an orthogonal main effect design code for all the alternatives:

1. The frequency of occurrence for each code representing the levels of each attribute to ensure that attribute level balance is maintained.
2. Orthogonality
3. Minimal level overlap

Following the generation of the orthogonal design codes from the above procedures, the attributes and the attribute levels were substituted for the generated design codes in order to obtain the hypothetical choice sets that would be presented to the respondents. A 'no choice' alternative may be added to each choice set to minimize selection bias.

4.4. Stated Preference Survey Design: Commuters' Mode Preference

With an explanation of the survey design process for this study presented in section 4.3 above, this section describes the process involved in the design of the stated preference survey needed for collecting data required for studying commuters' mode preference.

4.4.1. Response Strategy

The design of the experimental choice sets made use of a combination of *Stated Choice* (SC) and *Conjoint Analysis* (CA) as the favorable response strategies to examine commuter's choice of mode of transport amongst all four alternative modes of transport presented alongside, the commuter's perception for the newly proposed LRT mode of travel. The stated choice and conjoint analysis response methods differ in terms of the response metric (see section 4.1.1). Although the conjoint analysis method has been criticized for their use in transportation studies, a blend of both methods was deemed necessary for designing the hypothetical scenario choice sets needed to gather information for this mode choice study. In so doing, one can obtain an in-depth information required to achieve the overall objective for which this research study is being carried out – which is: to understand how the forthcoming LRT will bring changes in the modal split of commuters to the central business district of Ottawa; to obtain a picture of choice behaviour in the transition zone where respondents start to convert from other modes of transport to LRT mode and to obtain knowledge of how commuters perceive the LRT system.

The choice matrix for each hypothetical choice set was divided into two parts: In the first part, respondents were requested to select their preferred mode of transport for commuting amongst the four alternative modes considered based on the attributes presented for each mode in each scenario. Upon selecting their preferred mode of transport for commuting, the second part of the choice matrix required respondents who did not select the LRT mode as their preferred mode of transport in part one to indicate on a five-point rating system their affinity towards using the LRT mode should their preferred mode becomes unavailable (1 – '***definitely not using LRT***' to 5 '***definitely using LRT'***). Hence, a combination of both conjoint analysis and stated choice response strategies together allows respondents to express their preferences in a more precise manner (Hensher, 1994), thereby allowing the analyst reviewing the results to determine the consistency in the pattern of answers and gauge the perception of the respondents towards the new mode of travel compared to already existing modes.

4.4.2. Alternative Definition

The current modes of transport available for use to commute to the CBD precincts of Ottawa include: (1) automobile (car-pool/drive alone); (2) bus transit; (3) non-motorized modes. In addition to these currently available alternatives, the implementation of the Light Rail Transit (LRT) within the future will add onto the number of alternative modes available to commuters. Hence, this research study considered the following four alternative mode of transport (see Figure 4.1.8).

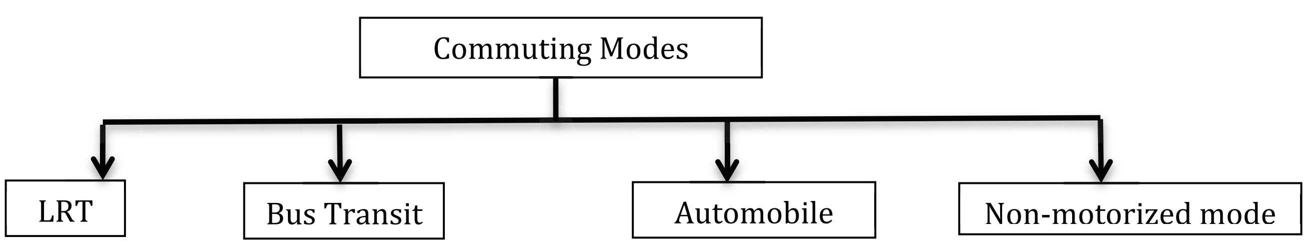


Figure 4.1.8: Structure of Modal Choice for Commuters

4.4.3. Attributes and Attribute Levels

The process of selecting attributes and attribute levels for most SP survey design experiments implement the use of a focus group in order to obtain relevant information regarding how the sample population would perceive the utility of the product. In the case of a mode choice study, the purpose of a focus group discussion would be: (1) to determine what characteristics attract users to particular modes of transport; (2) to identify important attributes that make up the characteristics of new services such as the LRT; (3) and to identify potential attitudinal factors that could be included in the SP survey. However, the lack of sufficient funds and time allocated for this study made it impossible to carry out a focus group discussion. Nonetheless, results obtained from a similar mode choice focus group discussion carried out in Lisbon, Portugal revealed that local residents consider the following attributes important when deciding what mode of transport to use: travel time, travel time variability, travel cost, frequency, access/egress time etc., alongside attitudinal factors such as comfort, privacy, flexibility, convenience, environmental friendliness and security (Yang et *al.,* 2009). Some of these attributes were taken into consideration in the development of the attributes and attribute-levels for the SP experiment. The attribute levels were made to be realistic, reasonable and to cover as much as possible all factors with significant effect on modal choice for commuting. Also, levels for each attribute were selected such that respondents would be able to see the critical difference in utility offered by the different modes of transport available for commuting. In the pilot and final survey design, the attribute levels across each alternative were made to balance (i.e., same number of levels across each alternative) in order to make the design more efficient and reordered such that: (1) the dominance of some alternatives is reduced and (2) zero attribute level differences within each choice set is minimized (Huber & Zwerina, 1996). The attributes and attribute levels that were considered in the pilot survey are described below. Following comments received from the pilot survey, modifications were made to some attributes and their levels prior to launching the final survey.

4.4.3.1. Attributes and Attribute Levels – Pilot Survey

The attributes and attribute levels of this experimental design were selected in a manner to reflect the characteristics of each travel mode alternative. Table 4.1 shows the levels in each attribute for all four alternatives considered in the pilot survey. These attribute levels represent one-way travel characteristics.

Table 4.1: Attributes and Attribute Levels – Pilot Survey: Commuters' travel mode preference

Attributes	LRT	Bus transit	Automobile	Non-motorized mode
Commuting/Traveling time (minutes)	3 4 7 12 14 15	4 6 8 16 18 20	3 4 6 11 12 14	13 18 23 25 26 30
Cost/Fare ($)	3.50 4.50 5.50	2.00 3.00 4.00	11.00 12.00 13.00	Free 1.00 2.00
Delay /(Travel time Variability) (minutes)	(0) (+/- 1) (+/- 2)	(+/- 6) (+/- 8) (+/- 10)	4 6 9	0 1 2
Accessibility (Walking distance to and from transit station or parking garage)	Lesser than 500 meters Greater than 501 meters	Lesser than 500 meters Greater than 501 meters	Lesser than 500 meters Greater than 501 meters	Lesser than 500 meters Greater than 501 meters
Frequency of service (minutes)	3 8	7 15	N/A N/A	N/A N/A
Level of Convenience	Excellent Very Good	Very Good Poor	Good Poor	Good Poor

The definition of each of the attributes alongside the rationale behind the selection of their attribute levels are explained below.

Commuting/Traveling time (minutes) is an estimate of the time spent commuting starting from the moment a commuter boards his/her mode of transport to the moment when he/she gets off upon arriving his/her final destination. It includes the time spent while waiting for a transfer from one mode to another if need be. This attribute contained six attribute levels. The commuting/travel times were derived based on the assumption that all modes of transport used by commuters cover the same distance. Although the average commuting distance for the Ottawa region stands at 7.8 km with approximately one-third and 5.4% of commuters travelling less than 5 km and above 30 km respectively (Ottawa counts, 2004), the 12.5 km distance to be covered by the LRT was used as the reference commuting distance. Six numbers that fall within the range of 2 km and 12.5 km were randomly generated using Microsoft Excel to represent six possible different range of commuting distances. According to the 2008 transportation master plan and infrastructure requirement study report and the 2008 Transportation Master Plan for the City of Ottawa, the following speeds representing the average commuting speeds for the different motorized modes were obtained: 35 km/h (LRT), 27 km/h (Bus), 40 km/h (Car), and 18 km/h (cycling/rollerblading/skating). Bohannon (1997) provides an average walking speed of 1.76 m/s for commuters. Using these speeds and the distances generated randomly between the range of 2 km and 12.5 km, the commuting times for the various modes of transport were estimated at six levels in Table 4.1 above.

Cost/Fare is the cost in monetary terms incurred by each commuter for using a particular mode of transport for commuting. Considering that the LRT is yet to be implemented in Ottawa, the derived fares were based on information obtained from other municipalities within Canada (such as the cities of Calgary and Edmonton) whose sizes are generally similar to that of Ottawa. However, the fares were adjusted to reflect a better sense of pricing for the Ottawa region given that it has a higher population. Meanwhile, the fare for bus transit was estimated based on current bus transit fares set by

OC Transpo (*OC Transpo Transit Fares*). The different fare levels were calculated taking into consideration commuters who may use monthly pass or pay cash to use the bus service on regular routes and express routes. The fare levels for LRT is slightly higher than those for bus transit given that it is supposed to offer a better service than bus transit. The costs of commuting by automobile were estimated based on monthly parking rates within the range of $180.00 to $210.00 for the downtown area (*see Parking in Ottawa*). These rates were factored to daily rates and a flat fee of $2.00 was added to cover for fuel expenses. Other expenses incurred for using a car such as insurance, maintenance, etc. were omitted from the estimation. In terms of cost for the non-motorized mode alternative, the idea behind selecting three levels was done such that commuters who use this mode would incur zero costs (e.g. walking) or could incur minimal costs for up to an amount of $2.00 (e.g., those who commute by cycling and may decide to store their bicycles in a secured place).

Delay is an estimate of the variability in travel time that a commuter may experience while commuting with a particular mode. Delay may result from accidents, road repairs, unexpected congestion, poor weather, etc. or variability in arrival/departure time of transit vehicles. Given that the LRT is meant to offer a high level of service alongside make use of the latest forms of technology to keep travellers informed about the status of their trips, the levels of time variability for this mode were chosen to vary between 0 and +/- 2 minutes. However, according to the [TMPIRS, 2008], the current time variability for buses ranges between 5 – 10 minutes. Random numbers generated from Microsoft Excel within the range of 5 – 10 were used to represent the time variability for the bus transit in minutes. Similarly, the travel time variability experienced by automobile commuters' ranges between 2 – 9 minutes (TMP, 2008). Using random number generation as above, the travel time variability for the automobile were estimated as contained in Table 4.1 above. Lastly, the levels of delay for the non-motorized mode users were assumed to be in the range between +/- 2 minutes.

Accessibility is defined as the commuter's total walking distance in meters to and from the transit station or parking garage relative to his/her final destination (home/office). The accessibility criteria considered for all modes of travel was set at two levels: less than 500 m (≤ 500 m) or greater than 500 m (> 500 m). These levels were selected following requirements set-forth by the City of Ottawa's transportation master plan in which it defines an area as accessible if it is less that 500 meters from major transit routes, roads and streets are less accessible if otherwise.

Service Frequency is defined as how often the service mode is provided/made available to users. Arrival frequencies for the LRT alternative were estimated based on the rush hours arrival frequencies obtained from LRT services in the cities of Calgary and Edmonton (*see LRT in Other Cities*). Meanwhile, the arrival frequencies for the bus transit alternative were based on the arrival frequencies of the 94, 95,96,97,98 & 99 express bus routes (OC Transpo).

Level of Convenience was defined as the relative ease of using a particular mode of transport for commuting taking into consideration factors such as flexibility, reliability, ability to do work on board mode of transport, availability of traveller information systems, number of transfers made, comfort, etc. Table 4.2 was used to define the level of convenience offered by each mode of transport.

Table 4.2: Qualitative Level of Convenience Attribute

Attitudinal Factors	Qualitative level of Convenience			
	Excellent	Very Good	Good	Poor
Reliability	✔	✔	✔	✖
Flexibility	✔	✖	✔	✔
Comfort	✔	✔	✔	✖
Availability of traveler information systems	✔	✔	✖	✖
Ability to do work while commuting	✔	✔	✖	✖
Transfer required	No	No	No	Yes

From the Table 4.2 above, a mode of transport that offers an ***excellent*** level of convenience for commuting implies that the mode is reliable, flexible, comfortable, has traveller information systems that enable commuters to plan their trip, offers commuters the ability to do work on board while commuting, and lastly, it offers a direct connection between the commuter's origin and his/her destination without need to transfer from one mode of transport to another. Meanwhile, if a mode of transport is designated with ***poor*** level of convenience rating, this would imply that the mode is flexible yet unreliable, uncomfortable, lacks advanced traveller information systems to enable commuters plan their trip, does not offer commuters the ability to do work on board while commuting and lastly, the commuter would require to change from one mode to another while commuting from home to work and vice versa.

4.4.4. Fractional Factorial Design – Pilot Survey

The attributes and attribute levels contained in Table 4.1 (section 4.4.3.1) above were used in the design of the pilot survey for the study on commuters' mode preference. The Table contains one six-level attribute, two three-level attributes and three two-level attributes. A full factorial L^{MA} orthogonal design would have required the generation of 3.483 x 10^{10} [$(6^1 \times 3^2 \times 2^3)^4$] possible choice sets taking into consideration all these attributes, attribute levels and alternatives (Louviere *et al.* 2000). However, a fractional factorial design was implemented to reduce the overall design to a manageable quantity.

Accounting for main effects only, the attributes, attribute-levels and alternatives considered for the design of the pilot survey were found to have a total of 48 degrees of freedom[7]. Therefore, the smallest possible orthogonal main effects plan for this survey design required a minimum of 49 choices sets as determined by the total degrees of freedom (48 d.f.) in order to estimate all implied main effects. The section below describes the development of the fractional factorial orthogonal main effect design codes that suits the number of attributes, attribute levels and alternatives considered in the pilot survey design.

4.4.4.1. Orthogonal Main Effect Design Codes – Pilot Survey

The construction of an orthogonal array code to suit the purpose of this experiment originated from a strength-two *mixed orthogonal array* with 12 runs, *MA.12.2.2.6.1* [8] (Sloane, 2003). Following procedures outlined in Street and Burgees (2007) that demonstrate various methods on how to obtain new orthogonal arrays (symmetric or asymmetric) from pre-designed orthogonal arrays, a more suitable orthogonal array for the design of the choice sets for the pilot survey was obtained without losing their orthogonal characteristics. This was done by adding one more factor to the pre-designed orthogonal array (*MA.12.2.2.6.1*) leading to the formation of the following orthogonal array: MA.24.2.2.2.6.1. The most suitable orthogonal array was obtained from subsequent addition of factors to each newly formed array leading to the formation of the following array: MA.216.2.2.2.3.3.6. The overall goal was to generate an array with all possible combinations that suits the 2^3 x 3^2 x 6^1 design without losing orthogonality. The final orthogonal array obtained by adding one more factor to existing arrays is one with 216 runs and composed of three 2-level attributes, two 3-level attributes

[7] [(1 attribute x 5) + (2 attributes x 2) + (3 attributes x 1)] x 4alternatives = 48 d.f

[8] The name **MA.N.s1.k1.s2.k2....** indicates a mixed-level (or asymmetrical) orthogonal array with N runs, k1 factors at s1 levels, k2 factors at s2 levels... and with strength 2.

and one 6-level attribute. A snap-shot of the final orthogonal array obtained is shown in Table 4.3 below. A complete Table of this orthogonal array is shown in Appendix A (Table 1-A).

Table 4.3: Orthogonal Main Effect Design Codes for commuters' mode preferences – Pilot Survey

Treatment combination	**Attributes**					
	Level of Convenience	**Accessibility (meters)**	**Service Frequency**	**Delay (minutes)**	**Cost/Fare ($)**	**Commute Time (mins)**
1	0	0	0	0	0	0
2	0	0	0	0	1	2
3	0	0	1	0	2	4
4	0	1	1	1	0	1
5	0	1	0	1	1	3
6	0	1	0	1	2	5
7	1	0	1	2	0	1
8	1	0	1	2	1	3
9	1	0	0	2	2	5
10	1	1	0	0	0	0
11	1	1	1	0	1	2
12	1	1	1	0	2	4
13	0	0	0	1	0	0
14	0	0	0	1	1	2
15	0	0	1	1	2	4
16	0	1	1	2	0	1
17	0	1	0	2	1	3
18	0	1	0	2	2	5
19	1	0	1	0	0	1
20	1	0	1	0	1	3
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
205	0	0	0	2	0	0
206	0	0	0	2	1	2
207	0	0	1	2	2	4
208	0	1	1	0	0	1
209	0	1	0	0	1	3
210	0	1	0	0	2	5
211	1	0	1	1	0	1
212	1	0	1	1	1	3
213	1	0	0	1	2	5
214	1	1	0	2	0	0
215	1	1	1	2	1	2
216	1	1	1	2	2	4

Numbers 0, 1,…, 6 indicate the various levels of each attribute.

The orthogonal design codes in Table 4.3 above represents the codes for a fraction of the full factorial design with 216 runs. In other words, the above orthogonal array has reduced the number of possible choice sets that can be generated from a full factorial design from 3.483 x 10^{10} choice sets to 216 choice sets for one alternative considering only main effect. However, although 216 choice sets seem somewhat to be a reduction compared to the number of choice sets encountered in a full factorial survey design, it will be almost impossible to present a total of 216 choice sets for evaluation to each respondent given the time and budget limitations allocated to this research study. In addition, too many choice sets per respondent would tend to increase the burden on the respondents and induce fatigue thereby leading to low quality responses and inaccurate results (Pearmain *et al.* 1991). Hence, further reduction of the number of choices sets required for the pilot survey was needed.

Taking findings from previous studies into consideration (see Kroes et *al.,* 1988; Carson *et al.,* 1994; Kuhfeld *et al.,* 1994), the fractional factorial design for the pilot survey was set to compose of twelve choice sets. Twelve was chosen as the favorable number because it is divisible by two, three and six (the levels of the attributes in consideration, see Rose *et al.,* 2009); it is within the range of nine to sixteen; and lastly, it meets the minimum number by which the number of choice sets can be further reduced at the expense of sacrificing some orthogonality as suggested by Kuhfeld *et al.,* (1994). The following section presents a description of the derivation of the fractional factorial orthogonal design codes for the twelve choice sets taking into account the attributes, attribute levels and alternatives for the pilot survey.

4.4.4.2. Orthogonal Combination Codes for Choice Sets

The process of selecting twelve choices sets from the developed mixed orthogonal array with 216 runs in Table 4.3 above was as follows: An algebraic sum of the codes for each of the 216 runs was obtained. Following this procedure, twelve rows with the highest sums were selected from amongst the 216 runs. Each row represented the orthogonal codes for the attributes of one alternative for each of the twelve choice sets (Huber & Zwerina, 1996). A *cyclic (Shifted)* design technique (see Bunch *et al.* 1994) explained in section 4.3.2.4 above was used to obtain the orthogonal main effect design codes for the subsequent alternatives for each of the twelve choice sets (see Tables 4.4 (a & b). The codes in the orthogonal array is denoted by [6^1 x 3^2 x 2^3/4/12] and read as orthogonal main effect combination codes composed of one 6-level attribute, two 3-level attributes, three 2-level attributes, four alternatives and twelve choice sets.

Table 4.4 (a): SP Treatment Combination Design Codes: Commuters' Mode Preference – Pilot Survey

Choice Set	Alternative	Service Frequency	Level of Convenience	Accessibility	Delay	Cost/Fare	Commuting Time
	LRT	0	0	1	0	2	4
	Bus	1	1	0	1	0	5
1	Auto	0	0	1	2	1	0
	Non-Motorized	1	1	0	0	2	1
	LRT	0	1	0	1	2	5
	Bus	1	0	1	2	0	0
2	Auto	0	1	0	0	1	1
	Non-Motorized	1	0	1	1	2	2
	LRT	1	1	1	0	1	2
	Bus	0	0	0	1	2	3
3	Auto	1	1	1	2	0	4
	Non-Motorized	0	0	0	0	1	5
	LRT	0	1	0	2	1	3
	Bus	1	0	1	0	2	4
4	Auto	0	1	0	1	0	5
	Non-Motorized	1	0	1	2	1	0
	LRT	1	1	1	1	2	4
	Bus	0	0	0	2	0	5
5	Auto	1	1	1	0	1	0
	Non-Motorized	0	0	0	1	2	1
	LRT	1	1	0	0	0	0
	Bus	0	0	1	1	1	1
6	Auto	1	1	0	2	2	2
	Non-Motorized	0	0	1	0	0	3

Numbers 0, 1,…, 6 indicate the various levels of each attribute.

Table 4.4(b): SP Treatment Combination Design Codes: Commuters' Mode Preference – Pilot Survey

Choice Set	Alternative	Service Frequency	Level of Convenience	Accessibility	Delay	Cost/Fare	Commuting Time
	LRT	0	0	0	2	1	2
	Bus	1	1	1	0	2	3
7	Auto	0	0	0	1	0	4
	Non-Motorized	1	1	1	2	1	5
	LRT	1	0	1	2	0	1
	Bus	0	1	0	0	1	2
8	Auto	1	0	1	1	2	3
	Non-Motorized	0	1	0	2	0	4
	LRT	1	0	0	1	2	5
	Bus	0	1	1	2	0	0
9	Auto	1	0	0	0	1	1
	Non-Motorized	0	1	1	1	2	2
	LRT	1	0	1	0	1	3
	Bus	0	1	0	1	2	4
10	Auto	1	0	1	2	0	5
	Non-Motorized	0	1	0	0	1	0
	LRT	0	1	1	2	0	1
	Bus	1	0	0	0	1	2
11	Auto	0	1	1	1	2	3
	Non-Motorized	1	0	0	2	0	4
	LRT	0	0	0	1	0	0
	Bus	1	1	1	2	1	1
12	Auto	0	0	0	0	2	2
	Non-Motorized	1	1	1	1	0	3

Numbers 0, 1,…, 6 indicate the various levels of each attribute.

As observed in Tables 4.4 (a&b), it is seen that the levels of each attribute occur with equal frequency. For example, each 2-level attribute occurs precisely in half of all cases for each alternative while the 6-level attribute occurs precisely in one-sixth of all cases for each alternative. This therefore implies that the design maintains a level balance. In addition, orthogonality is also maintained. Given that the marginal frequency of the 2-level attribute is half and that of the 6-level attribute is one-sixth, the joint occurrence of any combination of a 2-level attribute and a 6-level attribute occurs in exactly one-twelfth of all cases. However, the above design does not meet the minimal overlap requirement for all alternatives in each choice set given that some levels occur more than once in each choice set. The cost of violating the minimal overlap criterion can be seen most clearly when the levels of one attribute remain the same across all alternatives within a choice set. Nonetheless, given that there is attribute level differences in each alternative, this factor does not really affect the design as opposed to the situation were all attributes in each alternative were the same.

With the generated orthogonal combination codes in Table 4.4 (a&b) above alongside the attributes and the attribute levels in Table 4.1 (section 4.4.3.1) the twelve hypothetical stated preference choice sets for the pilot survey were obtained by substituting the codes with the various levels in each attribute. Table 4.5 below represents an example of the hypothetical mode choice matrix presented to respondents considered in the pilot survey. A full version of the pilot survey questionnaire for this study is presented in Appendix B.

A calibrated mode choice logit model using data collected from the pilot survey is shown in Appendix E. Following results and comments obtained from the pilot survey, some modifications were made to the SP experimental design prior to launching the final survey. A major complaint received from most respondents who completed the pilot stated that the survey was long and that the hypothetical choice scenarios were too many to process. These complaints were taken into consideration in the design of the final SP survey.

Table 4.5: Example Hypothetical Choice Scenario Matrix – Commuters' Mode Preference: *Pilot Survey*

<table>
<tr><td colspan="5">Example Choice Scenario Matrix</td></tr>
<tr><td colspan="5">Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="2">Attributes (Features)</td><td colspan="4">Modes of Transport</td></tr>
<tr><td>LRT</td><td>Bus transit</td><td>Automobile</td><td>Non-motorized mode</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Commuting/Traveling time (minutes)</td><td>12</td><td>18</td><td>3</td><td>18</td></tr>
<tr><td>Cost/Fare ($)</td><td>5.50</td><td>2.00</td><td>12.00</td><td>2</td></tr>
<tr><td>Delay /(Travel time variability) (minutes)</td><td>0</td><td>(+/- 8)</td><td>9</td><td>0</td></tr>
<tr><td>Accessibility (Walking distance to and from transit station or parking garage)</td><td>Greater than 501 meters</td><td>Lesser than 500 meters</td><td>Greater than 501 meters</td><td>Lesser than 500 meters</td></tr>
<tr><td>Frequency of service (minutes)</td><td>3</td><td>15</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Level of convenience</td><td>Excellent</td><td>Poor</td><td>Good</td><td>Poor</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>1). Please, select your preferred mode of transport for commuting (☑ only)</td><td>☐LRT</td><td>☐Bus</td><td>☐Automobile</td><td>☐Non-motorized mode</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>2). If your preferred mode of transport is not the LRT alternative, please indicate on the scale of 1 to 5 your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ one only)</td><td colspan="4">Will definitely Use LRT 1 ☐
May use LRT 2 ☐
Not Sure 3 ☐
May not use LRT 4 ☐
Will definitely not use LRT 5 ☐</td></tr>
</table>

4.4.5. Attributes and Attribute Levels – Final Survey

Comments and reviews provided by the sampled respondents following the launching of the pilot survey questionnaire led to modification in the survey design. Some attributes that were considered in the pilot survey questionnaire were completely omitted while the levels of some attributes were changed. A major reason for omitting the attributes and attribute levels was in order to reduce the overall size of the survey design. The attributes on *level of convenience* and *delay* contained in the pilot survey were omitted in the final survey design while changes were made to the attributes on commuting time and accessibility.

The attribute on *level of convenience* contained in the pilot survey was omitted because respondents who completed the pilot survey found it too cumbersome to interpret. Given the complexity involved in the design, interpretation and collection of SP survey data, it is of utmost importance that the SP questionnaire be designed with the minimum amount of complexity so as to encourage responses from the masses without compromising the quality of the response. Also, some respondents mentioned that costs/fare and travel time are the most important factors they consider when deciding what mode of transport to use for commuting. Hence, taking the above into consideration, the attribute on *level of convenience* was not considered in the final survey design.

Secondly, for attributes considered in the final survey design, *delay (minutes)* and *commuting time* where merged to form one attribute. The number of attribute levels representing commuting time was reduced from six levels to three levels in order to reduce the size of the SP design. In addition, it was also done in order to make the difference between one attribute level and the other to be more significant. The commuting times were derived following the same procedure presented in the derivation of commuting time contained in the pilot survey attribute levels in section 4.4.3.1 above.

Lastly, the attribute on *accessibility (meters)* used in the design of the SP pilot survey was changed to *Access/Egress time (minutes)* in the design of the final SP survey. However, it still remained defined as the cumulative time spent walking to and from transit station or parking garage to access one's mode of transport. Its unit of measurement was changed from distance (meters) to time (minutes) in order to give a better perception of the attribute to the respondents considering that people tend to associate the accessibility to an area better if described as a function of the time as opposed to the distance covered. Table 4.6 represents the attributes and attribute-levels considered in the design of the final SP survey. The definitions of the attributes and the rationale surrounding the selection of their attribute levels remain the same as with the case for the attributes in the pilot survey with the exception of minor changes explained above.

Table 4.6: Attributes and Attribute Levels – Final Survey: Commuters' travel mode preference

Attributes	LRT	Bus transit	Automobile	Non-motorized mode
One-way commuting time (minutes) (Includes delay and travel time variability)	7 mins (± 1 mins) 13 mins (± 2 mins) 15 mins (± 1 mins)	8 mins (± 6 mins) 17 mins (± 8 mins) 20 mins (± 5 mins)	6 mins (± 4 mins) 12 mins (± 5 mins) 14 mins (± 8 mins)	23 mins (± 0 min) 26 mins (± 0 min) 30 mins (±1 mins)
Cost/Fare ($)	$3.50 $4.50 $5.50	$2.00 $3.00 $4.00	$11.00 $12.00 $13.00	Free $1.00 $2.00
Access and Egress time (minutes) (Cumulative Time spent walking to and from transit station or parking garage)	**Less than or equal to** 5 mins **Greater than** 5 mins	**Less than or equal to** 5 mins **Greater than** 5 mins	**Less than or equal to** 5 mins **Greater than** 5 mins	**Less than or equal to** 5 mins **Greater than** 5 mins
Frequency of service (minutes)	3 mins 8 mins	7 mins 15 mins	N/A N/A	N/A N/A

4.4.6. Fractional Factorial Design – Final Survey

The attributes and attribute levels contained in Table 4.6 above were used in the design of the final survey for the study on commuters' mode preference. A full factorial design would lead to the generation of 1,679,616 ($[3^2 \text{ x } 2^2]^4$) possible choice sets for the final survey *(*Louviere *et al*. 2000). Accounting for main effects only, the attributes, attribute-levels and alternatives considered for the design of the final survey were found to have 6 degrees of freedom per alternative generating a total of 24 degrees of freedom[9]. Therefore, the smallest possible orthogonal main effects plan for this survey design required a minimum of 25 choices sets as determined by the total degrees of freedom (24 d.f.) in order to estimate all implied main effects. The section below describes the development of the fractional factorial orthogonal main effect design codes that suits the number of attributes, attribute levels and alternatives considered for the final survey.

4.4.6.1. Orthogonal Main Effect Design Codes – Final Survey

The construction of an orthogonal array code to suit the $3^2 \times 2^2$ design originated from a strength-two *mixed orthogonal array* with 9 runs, *OA.9.4.3.2*[10] (Sloane, 2003). See Table 4.7 below.

Table 4.7: Fractional Factorial Design for Four 3-level attributes (*OA.9.4.3.2*)

Treatment combination	Attribute A	Attribute B	Attribute C	Attribute D
1	0	0	0	0
2	0	1	1	2
3	0	2	2	1
4	1	0	1	1
5	1	1	2	0
6	1	2	0	2
7	2	0	2	2
8	2	1	0	1
9	2	2	1	0

Street and Burgees (2007) demonstrate various methods through which several different forms of orthogonal arrays (symmetric or asymmetric) can be obtained from already existing orthogonal arrays

[9] (2 attributes x 1 + 2 attribute x 2) x 4 alternatives = 24 d.f
[10] The file name **OA.N.k.s.t** indicates an orthogonal array with N runs, k factors, s levels, and strength t.

without losing their orthogonal characteristics. By *collapsing*[11] the last two levels of the orthogonal array (*OA.9.4.3.2*) from 3-level to 2-level attributes, a final orthogonal array was obtained that suited the number of attribute and attribute-levels (see Table 4.8). Although collapsing ensures that an Orthogonal Main Effect Plan (OMEP) is obtained (i.e., orthogonality is preserved), it however violates level balance (Huber *et al.,* 1996).

Table 4.8: Fractional Factorial Design for two 3-level attributes and two 2-level attributes

Treatment combination	Commuting Time (minutes)	Cost/Fare ($)	Access/Egress time (minutes)	Service Frequency (minutes)
1	0	0	0	0
2	0	1	1	0
3	0	2	0	1
4	1	0	1	1
5	1	1	0	0
6	1	2	0	0
7	2	0	0	0
8	2	1	0	1
9	2	2	1	0

The treatment combination codes in Table 4.8 represent the combination codes for one alternative. Taking into consideration research carried out to determine the number of choice sets to consider for optimum results, a total of six hypothetical choice set scenarios was chosen as the ideal number of scenarios to be presented to each respondent. Six was chosen because: (1) it conforms with the degrees of freedom required to estimate only main effects for each alternative; (2) it meets the minimum requirement set by Kuhfeld *et al.,* (1994) for reducing the total number of scenarios at the expense of losing some orthogonality; it meets requirement as suggested by Carson *et al.* (1994); (3) it reduces the burden on the respondent. The section that follows presents a description of how the fractional factorial orthogonal design codes for the six hypothetical choice sets were derived for the attributes, attribute levels and alternatives in the final survey.

[11] Collapsing is used to obtained new orthogonal arrays from an already existing one by reducing the levels of one or more attributes (l_q) to obtain new attributes with lower levels (l_s) (i.e., $l_s < l_q$).

4.4.6.2. *Orthogonal Combination Codes for Choice Sets*

The process of selecting six choices sets from the above developed mixed orthogonal array with nine runs (Table 4.8) was similar to that carried out in the pilot survey design (see section 4.4.4.2): A *cyclic (Shifted)* design technique (see Bunch *et al.* 1994) explained in section 4.3.2.4 above was used to obtain the orthogonal codes for all the alternative. The orthogonal main effect design codes for all four alternative modes of transport for each of the six choice sets developed following the *cyclic (Shifted)* design technique is shown in Table 4.9. The codes in the orthogonal array is denoted by 3^2 x 2^2/4/6 and read as orthogonal main effect combination codes composed of two 3-level attributes, two 2-level attributes and six choice sets.

As observed in Table 4.9, it is seen that the levels of each attribute occur with equal frequency. For example, each 3-level attribute occurs precisely in one-third of all cases for each alternative while the 2-level attributes occurs precisely in half of all cases for each alternative. This therefore implies the design maintained a level balance. In addition, orthogonality was also maintained. Given that the marginal frequency of the 2-level attribute is half and that of the 3-level attribute is one-third, the joint occurrence of any combination of a 2-level attribute and a 3-level attribute occurs in exactly one-sixth of all cases. However, the above design does not meet the minimal overlap requirement for all alternatives in each choice set given that some levels occur more than once for each attribute across the different alternatives in each choice set. The cost of violating the minimal overlap criterion can be seen most clearly when the levels of one attribute is the same across all alternatives within a choice set. Nonetheless, given that there are attribute level differences in each alternative, this factor does not really affect the design as oppose to the situation where all attributes in each alternative were the same.

Table 4.9: SP Treatment Combination Design Codes – Final Survey: Commuters' Mode Preference

Choice Set	Attributes (Features)				
	Alternative	**Commuting or Travel Time**	**Cost/Fare**	**Access and Egress Time**	**Service Frequency**
1	LRT	2	1	0	1
	Bus	0	2	1	0
	Auto	1	0	0	1
	Non-Motorized	2	1	1	0
2	LRT	1	2	0	0
	Bus	2	0	1	1
	Auto	0	1	0	0
	Non-Motorized	1	2	1	1
3	LRT	0	2	0	1
	Bus	1	0	1	0
	Auto	2	1	0	1
	Non-Motorized	0	2	1	0
4	LRT	1	0	1	1
	Bus	2	1	0	0
	Auto	0	2	1	1
	Non-Motorized	1	0	0	0
5	LRT	0	1	1	0
	Bus	1	2	0	1
	Auto	2	0	1	0
	Non-Motorized	0	1	0	1
6	LRT	2	0	1	0
	Bus	0	1	0	1
	Auto	1	2	1	0
	Non-Motorized	2	0	0	1

Notes: Numbers 0,1, and 2 indicate the various levels of each attribute.

With the generated orthogonal combination codes in Table 4.9 above alongside the attributes and the attribute levels in Table 4.6 (section 4.4.5) the six hypothetical stated preference choice sets for the final survey were obtained by substituting the codes with the various levels in each attribute. Table 4.9.1 below represents an example of the hypothetical mode choice matrix presented to respondents considered in the final survey. A full version of the final survey questionnaire for this study is presented in Appendix C.

Table 4.9.1: Example Hypothetical Choice Scenario Matrix – Commuters' Mode Preference *Final Survey*

Example Scenario Choice Set				
Given that you work in the downtown area of Ottawa, please indicate which mode of transport you will prefer to use most for commuting and state your perception about the LRT mode of transport assuming that the following attributes (features) are the only factors that influence your choice of mode of transport.				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	15 mins (± 1 min)	8 mins (± 6 mins)	12 mins (± 5 mins)	30 mins (±1 min)
Cost/Fare ($)	$4.50	$4.00	$11.00	$1.00
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	Less than or equal to 5 mins	Greater than 5 mins	Less than or equal to 5 mins	Greater than 5 mins
Frequency of service (minutes)	8 mins	7 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ only)	☐LRT	☐Bus	☐Automobile	☐Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ one only)	Will definitely Use LRT 1 ☐ May use LRT 2 ☐ Not Sure 3 ☐ May not use LRT 4 ☐ Will definitely not use LRT 5 ☐			

4.5. Stated Preference Survey Design: Office Location/Relocation Preference

4.5.1. Response Strategy

The experimental design made use of *Stated Choice* (SC) method as a favourable SP approach to examine the preferences of respondents in order to determine the influence of telecommuting on office location/relocation preferences within the Ottawa municipality. The hypothetical choice set matrix was designed and presented to respondents such that they were required to make a discrete selection between alternatives. A 'None' option was also included amongst the alternatives to reduce selection bias. By presenting the respondents with discrete alternatives in the choice matrix, the response obtained from the SP survey questionnaire would be a measure of the preference of their chosen alternative relative to the other non-chosen alternatives. The principles behind the design of the both the pilot survey and the final survey are presented in the following sections.

4.5.2. Alternative Definition

This section describes the various alternatives considered for this survey design. Two alternatives were considered as possible location/relocation alternatives in which business firms could consider when deciding where to locate/relocate their office within the city of Ottawa municipal region. The two alternatives considered are shown in Figure 4.1.9.

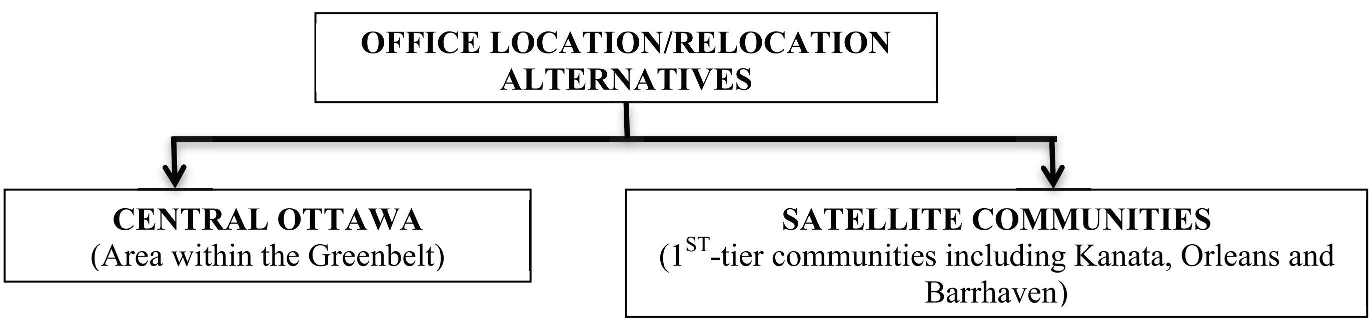


Figure 4.1.9: Office location/relocation alternatives

The office location/relocation alternatives were selected as above because of the following reasons:

1. The satellite communities surrounding central Ottawa have grown in terms of population to become major suburban centers with the potential to provide the basic necessities to support the needs of their residents similar to central Ottawa;

2. There is an imbalance in employment and population growth between central Ottawa and its surrounding satellite communities;
3. To investigate the possibility of developing a mixed land use whereby residential and office locations will be within the same community offering residence the opportunity to live, work and play within their immediate environment.

Figure 4.2.0 below represents a schematic of the above location/relocation alternatives relative to each other. These alternatives remained the same for both the pilot survey study and the final survey study.

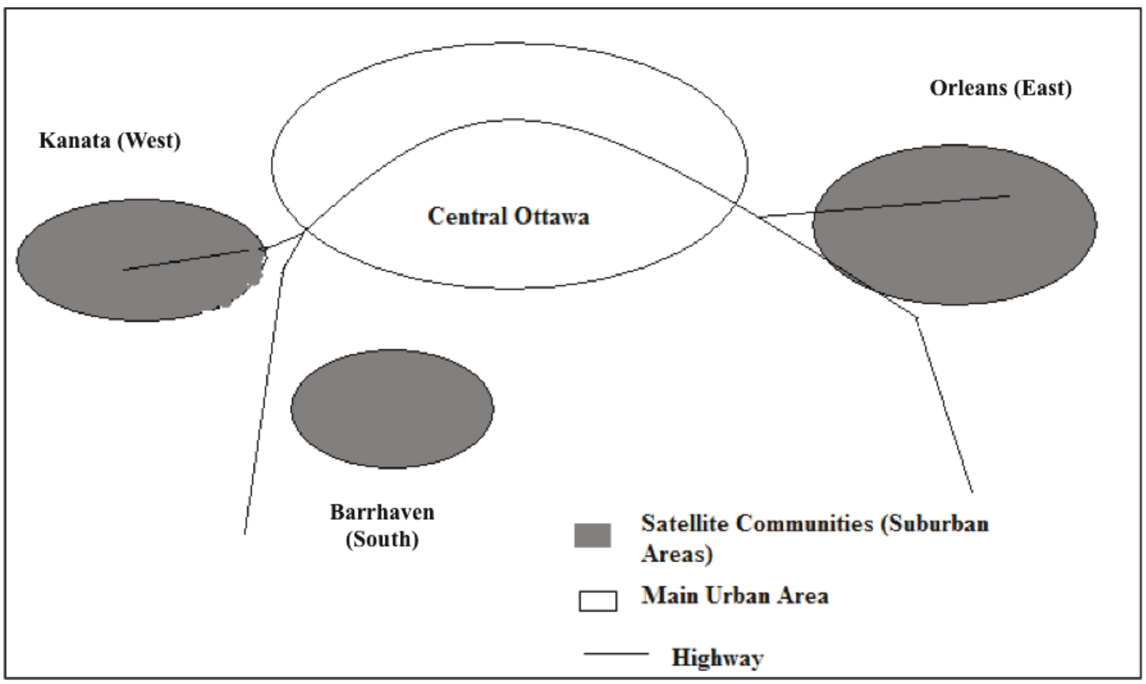


Figure 4.2.0: Schematic Diagram of Office Location Alternatives

4.5.3. Attributes and Attribute Levels

This section describes the attributes and attribute-levels used to describe each alternative. A focus group discussion was not carried out in the design of this SP experiment as required due to lack of sufficient funds and time. Nonetheless, upon consulting several past studies on aspects related to telecommuting and/or trends in office siting (see DeSanctis, 1984; Onishi, 1994; Tayyaran & Khan, 2003, pp.91; Argiolu *et al.* 2008) an overall idea of possible attributes that are likely to affect office location decisions within the City of Ottawa municipality were devised. These attributes were chosen in a manner such that prominent factors that affect managerial decision to locate/relocate an office within a specific area were represented. The levels of the attributes were assigned in a balanced manner in order to make the design more efficient (Huber & Zwerina, 1996). The attributes and attribute levels that were considered in the pilot survey are described below. Following the launching of the pilot survey and comments received, modifications were made to these attributes and their levels prior to launching the final survey.

4.5.3.1. Attributes and Attribute Levels – Pilot Survey

Table 4.9.2 shows the attributes and attribute-levels considered for each of the two office location/relocation alternatives in the design of the pilot survey.

Table 4.9.2: List of Attributes and their levels for the Stated Preference Experiment – Office Location/Relocation: Pilot Survey

Attributes	**Attribute Levels**	
	Central Ottawa	**Satellite Communities**
Employee Telecommuting Level	1 – 3 days/week 0 days/week	1 – 3 days/week 0 days/week
Monthly Rental Cost	No Change 1 % Increase 2 % Increase	2 % Decrease 1 % Decrease No Change
Office and Parking Space	Reduces No Change Increases	Reduces No Change Increases
Proximity to related businesses	Excellent Poor	Excellent Poor
Office Accessibility	Office located less than 500 meters from major transit hubs/ streets or roads Office located more than 500 meters from major transit hubs/ streets or roads	Office located less than 500 meters from major transit hubs/ streets or roads Office located more than 500 meters from major transit hubs/ streets or roads
Employee Productivity	Remains the same Increases	Remains the same Increases

The definition of each of the above attributes alongside the rationale behind the selection of their attribute levels are explained below:

Employee Telecommuting Level represents the average number of days per week an employee chooses to telecommute assuming that his/her company adopts a telecommuting program. Two attribute levels were assigned to this attribute because there wasn't enough evidence to expect the existence of non-linearities with this attribute. There are only two possible outcomes should a business firm choose to adopt a telecommuting program: Its employees may decide to telecommute (approximately say between 1 to 3days/week) or may choose not to telecommute at all (0 day/week).

Monthly Rental Cost is the monthly cost paid out for renting an office space. It is expressed in three levels of change, relative to the cost currently incurred by the business firm. The percentage change in monthly rental costs were based on numbers approximated around those contained in the Commercial Rents Service Price Index (CRSPI) (see Statistics Canada, 2012 b).

Office and Parking Space represents the size of the office in terms of number of cubicles or desks and the number of parking spaces expressed as a relative change with respect to the current office size of the business firm. The idea behind choosing three levels to represent the office space attribute was that the size of an office is non-linear and it may increase, remain the same or decrease depending on the preferences of the company.

Proximity to related businesses is a measure of the importance a company associates with locating/relocating its office within a strategic area so as to be in close proximity to its resources, clients, other businesses of similar type, personnel, etc. Two levels where selected to represent this attribute. Proximity could either be *Excellent* – i.e., a location would offer great benefits to the company or it could be *Poor* – i.e., a location would be disadvantageous for the company`s growth.

Office Accessibility is the relative ease at which the office building can be accessed. Two levels were assigned to this attribute. These levels were based on guidelines contained in the 2008 City of Ottawa Transportation Master Plan. According to these guidelines, an area could be classified as having good accessibility if it is located within 500 meters of major bus routes or roadways and poor accessibility if it is located beyond 500 meters from majors bus routes and roadways.

Employment Productivity is a measure of the employee`s performance based on where a business firm chooses to locate/relocate its office. Two levels were assigned to this attribute. It was assumed that the benefits of telecommuting to employees could result to either an increase in their overall productivity level or result in the productivity level remaining the same.

4.5.4. Fractional Factorial Design – Pilot Survey

Table 4.9.2 in section 4.5.3.1 shows two attributes at three levels, four attributes at two levels and two alternatives that were considered for the design of the choice set for the pilot survey. A full factorial L^{MA} orthogonal design would have required the generation of 20,736 ($[3^2 \times 2^4]^2$) possible choice sets if all these attributes, attribute levels and alternatives were taken into consideration (Louviere *et al.* 2000). However, a fractional factorial design was implemented to reduce the overall design to a manageable quantity.

Taking into account only main effects, the attributes, attribute-levels and alternatives considered for the design of the pilot survey were found to have a total of 16 degrees of freedom[12]. Therefore, the smallest possible orthogonal main effects plan for this survey design required a minimum of 17 choices sets as determined by the total degrees of freedom (16 d.f.) in order to estimate all implied main effects. The section below describes the development of the fractional factorial orthogonal main

[12] (4 attributes x 1 + 2 attributes x 2) x 2 alternatives = 16 d.f

effect design codes that best suits the number of attributes, attribute levels and alternatives considered for the pilot survey.

4.5.4.1. Orthogonal Main Effect Design Codes – Pilot Survey

The construction of an orthogonal main effect design code to suit the purpose of this experiment started with the selection of a strength-two pre-designed *mixed orthogonal array* with 12 runs, *MA.12.2.4.3.1* [13] (Sloane, 2003). Following procedures outlined in Street and Burgees (2007) demonstrating various methods on obtaining new orthogonal arrays (symmetric or asymmetric) from pre-designed orthogonal arrays, a more suitable orthogonal array for the design of the choice sets for the pilot survey was obtained without losing their orthogonal characteristics. This derived mixed orthogonal array was obtained by adding one more level to the pre-designed *MA.12.2.4.3.1* orthogonal array and is represented as M.A.36.2.4.3.2. The overall goal was to generate orthogonal main effect design codes with all possible combinations that suited the 2^4 x 3^2 design representing the attributes and attribute levels of the pilot survey without losing orthogonality. The final orthogonal array obtained is shown in Table 4.9.3 below.

The orthogonal design codes in Table 4.9.3 below represents the codes for a fraction of the full factorial design with 36 runs considering one alternative. In other words, the orthogonal array has reduced the number of possible choice sets that can be generated from a full factorial design from 20,736 choice sets to 36 choice sets for one alternative considering only main effect. However, although 36 choice sets seem somewhat to be a reduced number of choice sets compared to the

[13] The name **MA.N.s1.k1.s2.k2....** indicates a mixed-level (or asymmetrical) orthogonal array with N runs, k1 factors at s1 levels, k2 factors at s2 levels... and with strength 2.

number required for a full factorial survey design, presenting a total of 36 choice sets to each respondent for evaluation would tend to increase the burden on the respondents and induce fatigue thereby leading to inaccurate results (Pearmain *et al.* 1991). Hence, further reduction of the number of choices sets required for the pilot survey was needed.

Table 4.9.3: Orthogonal Main Effect Design Codes – Office Location/Relocation Preference Pilot Survey

Treatment combination	Employee Telecommuting Level	Office Proximity	Office Access	Employee Productivity	Monthly Rental Cost	Office Space
1	0	0	0	0	0	0
2	0	1	0	1	0	1
3	1	0	1	0	0	2
4	1	1	1	1	0	0
5	0	0	1	1	1	1
6	0	1	1	0	1	2
7	1	0	0	0	1	0
8	1	1	0	1	1	1
9	0	0	1	1	2	2
10	0	1	0	0	2	0
11	1	0	0	1	2	1
12	1	1	1	0	2	2
13	0	0	0	0	0	0
14	0	1	0	1	0	1
15	1	0	1	0	0	2
16	1	1	1	1	0	0
17	0	0	1	1	1	1
18	0	1	1	0	1	2
19	1	0	0	0	1	0
20	1	1	0	1	1	1
21	0	0	1	1	2	2
22	0	1	0	0	2	0
23	1	0	0	1	2	1
24	1	1	1	0	2	2
25	0	0	0	0	0	0
26	0	1	0	1	0	1
27	1	0	1	0	0	2
28	1	1	1	1	0	0
29	0	0	1	1	1	1
30	0	1	1	0	1	2
31	1	0	0	0	1	0
32	1	1	0	1	1	1
33	0	0	1	1	2	2
34	0	1	0	0	2	0
35	1	0	0	1	2	1
36	1	1	1	0	2	2

Numbers 0,1, and 2 indicate the various levels of each attribute.

Taking all these findings from previous studies into consideration (see Kroes et *al.,* 1988; Carson *et al.,* 1994; Kuhfeld *et al.,* 1994), the fractional factorial design for the pilot survey was set to compose of twelve choice sets. Twelve was chosen as the favorable number because it is divisible by two and three (the levels of the attributes in consideration, see Rose *et al.,* 2009); it is within the range of 9 to 16; and lastly, it meets the minimum number by which the number of choice sets can be further reduced at the expense of sacrificing some orthogonality as suggested by Kuhfeld *et al.,* (1994). The section that follows presents a description of the derivation of the fractional factorial orthogonal design codes for the twelve choice sets considering the attributes, attribute levels and alternatives for the pilot survey.

4.5.4.2. Orthogonal Combination Codes for Choice Sets

The process of selecting twelve choices sets from the above developed mixed orthogonal array with 36 runs was similar to that described in section 4.4.4.2 using a *cyclic (shifted)* design technique. The orthogonal main effect design codes for both alternatives I and II in each of the 12 choice sets developed following the *cyclic (Shifted)* design technique is shown in Table 4.9.4. The codes in the orthogonal array is denoted by 3^2 x 2^4/2/12 and read as orthogonal main effect combination codes composed of two 3-level attributes, four 2-level attributes, two alternatives and 12 choice sets.

As observed in Table 4.9.4, it is seen that the levels of each attribute occur with equal frequency. For example, each 2-level attribute occurs precisely in half of all cases for each alternative while the 3-level attribute occurs precisely in one-third of all cases for each alternative. This therefore implies the design maintains a level balance. In addition, orthogonality is also maintained. Given that the marginal frequency of the 2-level attribute is half and that of the 3-level attribute is one-third, the joint occurrence of any combination of a 2-level attribute and a 3-level attribute occurs in exactly one-sixth of all cases. The design also meets the minimal overlap requirement for all alternatives in each choice set. The cost of violating the minimal overlap criterion can be seen most clearly when the levels of one attribute are the same across all alternatives within a choice set. Nonetheless, although this is the case with the attributes in this experiment (i.e., the attributes levels are the same for each alternative), this is not going to have an effect on the choice matrix since the minimal overlap requirement is met.

Table 4.9.4: SP Treatment Combination Design Codes – Office Location/Relocation Preference Pilot Survey

Choice Set	Alternative	Attribute A	Attribute B	Attribute C	Attribute D	Attribute E	Attribute F
1	I	0	1	0	1	0	1
	II	1	0	1	0	1	2
2	I	0	0	1	1	1	1
	II	1	1	0	0	0	2
3	I	1	0	0	0	1	0
	II	0	1	1	1	0	1
4	I	0	0	1	1	2	2
	II	1	1	0	0	0	0
5	I	1	1	1	0	2	2
	II	0	0	0	1	0	0
6	I	1	0	0	0	1	0
	II	0	1	1	1	2	1
7	I	1	1	1	1	0	0
	II	0	0	0	0	1	1
8	I	0	1	0	0	2	0
	II	1	0	1	1	0	1
9	I	0	1	0	1	0	1
	II	1	0	1	0	1	2
10	I	1	1	0	1	1	1
	II	0	0	1	0	2	2
11	I	1	0	1	0	0	2
	II	0	1	0	1	1	0
12	I	0	0	1	0	2	2
	II	1	1	0	1	0	0

Notes:
Numbers 0,1, and 2 indicate the various levels of each attribute.
Letters A to D represent the two-level attributes while letters E and F represent the three-level attributes

With the generated orthogonal combination codes in Table 4.9.4 above alongside the attributes and the attribute levels in Table 4.9.2, the twelve hypothetical stated preference choice sets for the pilot survey were obtained by substituting the codes with the various levels in each attribute. Table 4.9.5 below represents an example of the hypothetical mode choice matrix presented to respondents considered in the pilot survey. A full version of the pilot survey questionnaire for this study is presented in Appendix B. A calibrated office location/relocation logit model using data collected from the pilot survey is shown in Appendix E.

Table 4.9.5: Example of Hypothetical Choice Scenario – Office Location/Relocation Pilot Survey

<table>
<tr><td colspan="4">Example Scenario</td></tr>
<tr><td colspan="4">Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="2">Features of Office Location/Relocation Area</td><td colspan="3">Office Location Alternatives</td></tr>
<tr><td>Central Ottawa</td><td>Satellite Communities</td><td>None</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Employee Telecommuting level</td><td>Between 1 - 3 days/week</td><td>0 days/week</td><td rowspan="6"></td></tr>
<tr><td>Monthly Rental Cost ($)</td><td>No Change</td><td>1 % Decrease</td></tr>
<tr><td>Office and Parking Space</td><td>No Change</td><td>Reduces</td></tr>
<tr><td>Proximity to related businesses</td><td>Excellent</td><td>Poor</td></tr>
<tr><td>Office Accessibility</td><td>Office located less than 500 meters away from major transit hubs/ streets or roads</td><td>Office located more than 500 meters away from major transit hubs/ streets or roads</td></tr>
<tr><td>Employee Productivity</td><td>Remains the same</td><td>Increases</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Please, select where you will choose to locate/relocate your office given the above conditions (✔only)</td><td>☐ Central Ottawa</td><td>☐ Satellite Communities</td><td>☐ None</td></tr>
</table>

4.5.5. Attributes and Attribute Levels – Final Survey

Comments and reviews provided by the sampled respondents following the launching of the pilot survey led to some modifications of the questionnaire. Some attributes that were considered in the pilot survey questionnaire were completely omitted while for others, their attribute-levels were changed.

The *Employee Productivity* attribute considered in the pilot survey was completely omitted in the final survey design, reason being the following: It is relatively difficult to measure the productivity of an employee and secondly, based on comments received, most respondents of the pilot survey did not perceive it as an attribute they would consider in their decision-making process regarding where to locate/relocate their office space.

Secondly, the attribute on *Monthly Rental Cost* contained in the pilot survey was replaced by a new attribute called *Change in Overhead Cost.* The reason for this attribute change also followed from comments provided by respondents on the pilot survey. Overhead cost is a much more applicable term in the context for which this study was being carried out taking into account the fact that business firms tend to incur several different costs besides their rents. In addition, considering that most office rental spaces are placed on long-term lease contracts (minimum of 5 years in most cases), it made more sense to replace the monthly rental cost attribute with an overhead cost in other to make the attribute more significant given that it reflects the language used in the business world when it comes to talking about costs incurred. Table 4.9.6 shows the attributes alongside each attribute-level for the office location/relocation alternatives considered in the design of the final survey.

The definitions of each attribute and the rationale behind the selection of the attribute levels remained the same as contained in the attributes used in the pilot survey with the exemption to the following modifications:

Change in Overhead Cost referred to yearly changes in ongoing expense incurred for operating a business, also known as an "operating expense" expressed as a percentage change of the current overhead cost. Overhead costs include accounting fees, advertising, depreciation, insurance, interest, legal fees, rent, repairs, supplies, taxes, telephone bills, travel expenditures, and utilities. Two attribute levels are assigned to this attribute because there isn't enough evidence to expect the existence of non-linearities (i.e., the overhead cost experienced by a company can either increase or decrease). The yearly percentage changes in overhead cost for running a business was estimated using random number generation in MS Excel based on values obtained from the yearly Producer Price Indexes (PPI) for service industries and the Consumer Price Index (CPI) (see Statistic Canada, 2012c). These changes in overhead costs were expressed slightly higher than the yearly changes in PPI and CPI to create a worst-case scenario and make them more significant.

Office Accessibility is the relative ease at which the office building can be accessed. This attribute was still maintained with two levels similar to that used in the pilot survey design. The only difference is that while the units for measurement for the attribute levels were in meters for the case of the pilot survey, the units of measurement for this attribute were changed to minutes in the final survey design. An average walking speed of 1.76 m/s was used in the calculation (see Bohannon 1997, Table 4) alongside the guidelines contained in the 2008 City of Ottawa Transportation Master Plan regarding minimum walking distance to determine the accessibility of an area.

Table 4.9.6: List of Attributes and their levels for the Stated Preference Experiment – Office Location/Relocation Final Survey

Attributes	Attribute Levels	
	Central Ottawa	**Satellite Communities**
Employee Telecommuting Level	1 – 3 days/week 0 days/week	1 – 3 days/week 0 days/week
Change in Overhead Cost	4 % Reduction per year 10 % Increase per year	9 % Reduction per year 5 % Increase per year
Office and Parking Space	Reduces No Change Increases	Reduces No Change Increases
Proximity to related businesses, clients and other amenities	Excellent Poor	Excellent Poor
Office Accessibility	Office located less than 5 minutes walk from major transit hubs/ streets or roads Office located more than 5 minutes walk from major transit hubs/ streets or roads	Office located less than 5 minutes walk from major transit hubs/ streets or roads Office located more than 5 minutes walk from major transit hubs/ streets or roads

4.5.6. Fractional Factorial Design – Final Survey

Table 4.9.6 in section 4.5.5 shows that one attribute at three levels, four attributes at two levels and two alternatives were considered for the SP experimental design that would lead to the generation of 2,304 ($[3^1 \times 2^4]^2$) possible choice sets for the final survey if the design was to follow a full factorial design (Louviere *et al. 2000)*.

Taking main effects into account only, the attributes, attribute-levels and alternatives considered for the design of the final survey were found to have a total of 12 degrees of freedom[14]. Therefore, the smallest possible orthogonal main effects plan for this survey design required a minimum of 13 choices sets as determined by the total degrees of freedom (12 d.f.) in order to estimate all implied main effects. The section below describes the development of the fractional factorial orthogonal main effect design codes that best suits the number of attributes, attribute levels and alternatives considered for the final survey.

4.5.6.1. Orthogonal Main Effect Design Codes – Final Survey

The orthogonal main effect design code for the 2^4 x 3^1 design was obtained from a two-strength pre-designed *mixed orthogonal array* with 12 runs, denoted as *MA.12.2.4.3.1*[15] (Sloane, 2003). There was no transformation carried out on the pre-designed orthogonal main effect array given that it provided a suitable fractional factorial design code for the 2^4 x 3^1 design. The pre-designed mixed orthogonal array code is shown in Table 4.9.7 below.

Although the design codes from Table 4.9.7 above provides a reduction from the generation of possibly 2,204 choice sets from a full factorial design to the generation of only twelve possible choice sets, comments received from the pilot survey revealed that respondents found the evaluation of twelve different SP choice sets to be too cumbersome and brain-draining. Hence, in order to reduce the burden on the respondents, minimize inaccurate responses and encourage a high response rate (Pearmain *et al.,* 1991), a further reduction of the number of choice sets was carried out. The fractional factorial design for the final SP experiment was composed of six hypothetical choice sets.

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[14] (4 attributes x 1 + 1 attribute x 2) x 2 alternatives = 12 d.f

[15] The name **MA.N.s1.k1.s2.k2....** indicates a mixed-level (or asymmetrical) orthogonal array with N runs, k1 factors at s1 levels, k2 factors at s2 levels... and with strength 2.

The section that follows presents a description of the derivation of the fractional factorial orthogonal design codes for the six choice sets considering the attributes, attribute levels and alternatives.

Table 4.9.7: Orthogonal Main Effect Design Codes – Office Location/Relocation Final Survey

Choice Set	Attributes (Features)				
	Employee Telecommuting Level	Overhead Cost	Proximity to Related Businesses	Office Accessibility	Office and Parking Space
1	0	0	0	0	0
2	0	1	0	1	0
3	1	0	1	0	0
4	1	1	1	1	0
5	0	0	1	1	1
6	0	1	1	0	1
7	1	0	0	0	1
8	1	1	0	1	1
9	0	0	1	1	2
10	0	1	0	0	2
11	1	0	0	1	2
12	1	1	1	0	2

Numbers 0,1, and 2 indicate the various levels of each attribute.

4.5.6.2. *Orthogonal Combination Codes for Choice Sets*

The process of selecting six choices sets from the above developed mixed orthogonal array with twelve runs was similar to that described in sections 4.3.2.4 and 4.4.4.2 using a *cyclic (shifted)* design technique using information contained in Table 4.9.7. The orthogonal main effect design codes for both alternatives I and II in each of the six choice sets were developed following the *cyclic (Shifted)* design technique is shown in Table 4.9.8. The codes in the orthogonal array is denoted by 3^1 x 2^4/2/6 and read as orthogonal main effect combination codes composed of one 3-level attributes, four 2-level attributes, two alternatives and six choice sets.

Table 4.9.8: SP Treatment Combination Design Codes - Office Location/Relocation Final Survey

Choice Set	Attributes (Features)					
	Alternative	**Employee Telecommuting Level**	**Overhead Cost**	**Proximity to Related Businesses**	**Office Accessibility**	**Office and Parking Space**
1	I	0	0	0	0	0
	II	1	1	1	1	1
2	I	1	1	1	1	0
	II	0	0	0	0	1
3	I	0	1	1	0	1
	II	1	0	0	1	2
4	I	1	0	0	0	1
	II	0	1	1	1	2
5	I	0	0	1	1	2
	II	1	1	0	0	0
6	I	1	1	0	1	2
	II	0	0	1	0	0

Notes: Numbers 0,1, and 2 indicate the various levels of each attribute.
Letters A to D represent the two-level attributes while letters E and F represent the three-level attributes

As observed in Table 4.9.8, it is seen that the levels of each attribute occur with equal frequency. For example, each 2-level attribute occurs precisely in half of all cases for each alternative while the 3-level attribute occurs precisely in one-third of all cases for each alternative. This therefore implies the design maintains a level balance. In addition, orthogonality is also maintained. Given that the marginal frequency of the 2-level attribute is half and that of the 3-level attribute is one-third, the joint occurrence of any combination of a 2-level attribute and a 3-level attribute occurs in exactly one-sixth of all cases. The design also meets the minimal overlap requirement for all alternatives in each choice set. The cost of violating the minimal overlap criterion can be seen most clearly when the levels of one attribute are the same across all alternatives within a choice set. Nonetheless, although this is the case with the attributes in this experiment (i.e., the attributes levels are the same for each alternative), this is not going to have an effect on the choice matrix since the minimal overlap requirement is met.

With the generated orthogonal combination codes in Table 4.9.8 above alongside the attributes and the attribute levels in Table 4.9.6, the six hypothetical stated preference choice sets for the final survey were obtained by substituting the codes with the various levels in each attribute. Table 4.9.9 below represents an example of the hypothetical mode choice matrix presented to respondents considered in the pilot survey. A full version of the final survey questionnaire for this study is presented in Appendix C.

Table 4.9.9: Example Hypothetical Choice Set – Office Location/Relocation Final Survey

Example Scenario			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	1 – 3 days/week	
Overhead Cost (%)	10 % ***increase*** per year	7 % ***reduction*** per year	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

4.6. Summary

The above chapter discussed the stated preference methodology used in the survey design of this research study. The rationale for using the stated preference method was because it makes it possible to evaluate policy and/or options that do not exist – such as those examined in this research study. The survey design for the study on commuters' mode preference and office location/relocation mode preference were also described. The following chapter discusses the method used to collect data.

5. DATA COLLECTION

Figure 5.1 below outlines the data collection process applied to this research study.

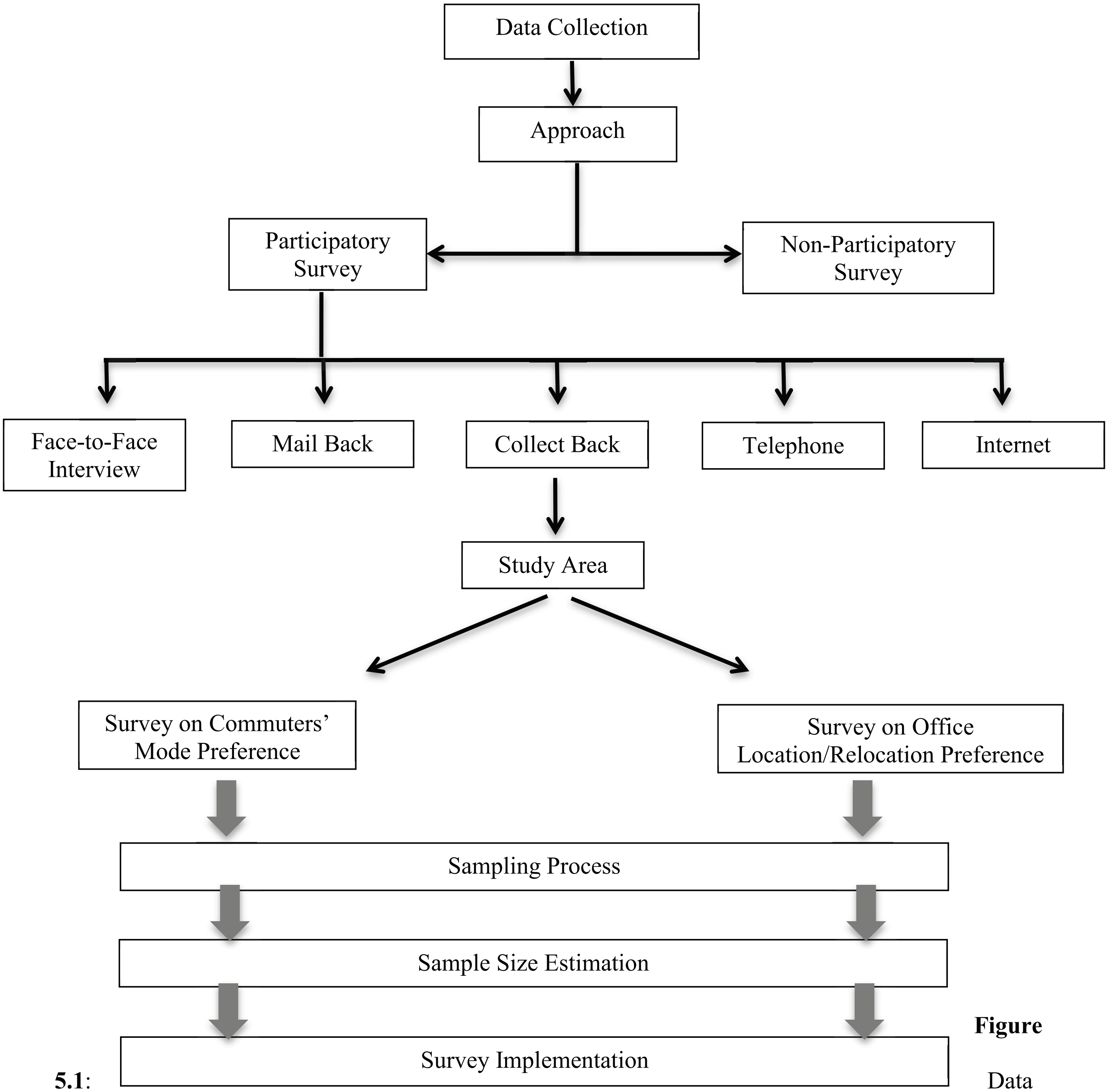


Figure 5.1: Data collection process

5.1. Approach

There are two approaches applicable for collecting data. These include: (1) through participatory surveys and (2) through non-participatory surveys (Stopher, in Hensher *et al.*, 2000). *Participatory* surveys require the active participation of the respondents by answering questions and/or providing data (e.g., completing a survey questionnaire) while *non-participatory* surveys are done usually without the knowledge of the participants (e.g., traffic counts). The participatory survey approach was used to collect data for this research study.

Participatory surveys could be implemented through either of the following methods: face-to-face interviews, mail-back techniques, collect-back techniques, telephone interviews, and most recent of all, through online methods. However, despite these several methods, an important aspect about the use of stated preference methodology is that the quality of the survey and the techniques used to collect information need to be of the highest possible quality considering the complexity involved with stated preference surveys (Kroes & Sheldon, 1988).

Face-to-face interview is the most preferred method applicable to collect data for a survey study designed following the stated preference methodology. According to Kroes & Sheldon (1988), a face-to-face interview ensures:

- A thorough understanding of the background of the respondent.
- Prevents respondents from making 'educated guesses' i.e., ensures that the respondent does not respond under the influence of preconceived ideas about the alternatives presented nor does he/she respond to an alternative based on "enticing" stimuli.

However, the costly nature required to carryout a face-to-face interview made it impossible to be used as the technique for collecting data for this study.

A mail-back collection technique is also applicable provided that the task for the respondents is fairly easy and well explained. For instance, for straightforward choice tasks, they appear to give good results (Kroes & Sheldon, 1988). However, a disadvantage with them is that their interpretation is subjected to the respondent's ability.

A collect-back technique is in a way similar to a mail-back technique in principle. However, instead of collecting responses with the help of the postal services, a collect-back technique involves initiating contact with respondents from the sample population, followed by the distribution of the survey questionnaire to those interested to take part in the survey. Survey responses are then picked-up at a later date following their distribution upon their completion.

Telephone interviews are rarely used for the collection of data for a stated preference survey simply because of the task difficulty encountered in explaining the process over the telephone (Kroes and Sheldon, 1988). However, a combination of telephone interviews and mail-back/collect-back techniques can be used to increase response rate. Nonetheless, executing this kind of survey collection method is not the most cost effective.

A more recent development is the use of computers to undertake computer-assisted interviews at the respondent's home (Computer-Assisted Survey Information Collection). Though this approach seems favorably accepted by respondents (Kroes and Sheldon, 1988), it is usually difficult to track who provides responses through online survey methods. Hence, there is a risk of the survey being completed by respondents who do not belong to the target group for which the survey is being carried out. Online technique could not be used to collect data needed for this study in order to limit the risk of the survey being completed by respondents who are not within the research study area.

5.2. SP Survey data collection method

Taking into account some of the participatory survey implementation methods presented above, a collect-back technique was used as the method to collect data for this study for the following reasons:

- Given that the hypothetical choice sets designed following the stated preference methodology may not be easy to understand by the respondent, an initial contact with the respondents was deemed necessary in order to brief them on what is expected of their responses although instructions on how to interpret the choice sets were provided in the questionnaire.
- Secondly, a collect-back survey technique helps establish a personal relationship between the researcher and the respondent, which leads to a generation of some degree of commitment and obligation on the part of the respondent upon agreeing to take part in the survey. Hence, with the notion of a deadline set to pick up the survey, respondents who commit to take part in the survey feel obliged to do so thereby, increasing the quality of the responses obtained from the survey given that the respondents know what is being asked from them.
- With respect to the reading speed, accuracy and comprehension of information, findings from research show that information contained on hard paper tends to be understood better compared to the same information presented online (Noyes *et al.,* 2008). In addition, studies have shown that survey responses provided on hard paper tend to produce overall results with better quality and higher response rate compared to those provided through online survey collection methods (Yang, L.Q. *et al.,* 2009).

Given that there was no incentive to urge the respondents to complete the survey, a collect-back survey collection technique was perceived as the only method to seek the participation of the respondents, considering that people generally tend to respond provided they have a well-informed knowledge of what is being asked of them.

5.3. Structure of Questionnaire

This section presents an overview of the structure of the survey questionnaire. In addition to the stated preference hypothetical choice sets, other general questions were asked to the respondents. This was done in order to categorize the various respondents. To better meet the objective of the pilot survey, the following additional questions aimed at obtaining feedback about the survey quality of the questionnaire were posed (Kocur *et al.,* 1982):

- Are the survey instructions clear?
- Is the experiment too lengthy or too complicated? How so?
- Do the attributes in the stated preference choice sets seem reasonable?
- Is there any ambiguity in the questions? If so, which ones?
- Are there any factors other than those mentioned in here that you think are important in your decision for selecting either of the alternatives?

5.3.1. Structure of Questionnaire – Commuters' Mode Preference Survey

The commuters' mode preference survey was composed of five parts. Part I was an introductory letter that explained the purpose of the survey and briefly described the benefits of an LRT system to commuters. Part II contained questions aimed at gathering information about the characteristics of the commuting trips made by commuters. Part III composed of the hypothetical SP choice sets characterized by the attributes of each alternative. In part IV, respondents were requested to rate on a seven-point-scale their perception on different attitudinal factors such as reliability, flexibility, etc. with respect to the public transit. Lastly, part V was structured to obtain some basic information about the socio-economic and demographic lifestyle of the various respondents.

5.3.2. Structure of Questionnaire – Office Location/Relocation Preference Survey

The office location/relocation questionnaire was composed of three parts. Part I was an introductory letter that explained the purpose of the survey and described briefly the concept of telecommuting. It explained the rationale and importance of the research to the respondent. Part II was composed of the stated preference hypothetical choice sets. Each choice set had two alternatives characterized by a combination of attributes. A ‘no choice’ option was also included as an alternative to limit selection bias. Respondents were asked to evaluate each alternative and indicate their preferred office location alternative. Part III contained questions posed to obtain information regarding the business orientation of the organization.

Full versions of the final survey questionnaire for this study are presented in Appendix C.

5.4. Study Area

Two separate study areas were considered in this research study. Both study areas were within the City of Ottawa municipality. These study areas alongside the target respondents for each survey are described in the following subsections.

5.4.1. Commuters' Mode Preference Survey

The proposed Light Rail Transit (LRT) system for the city of Ottawa will span from Tunney's Pasture Station in the West to Blair Road Station in the East including a 2.5-kilometer tunnel beneath the downtown core (See Figure 5.2). The overall length of the rail track will cover a distance of 12.5 kilometers.

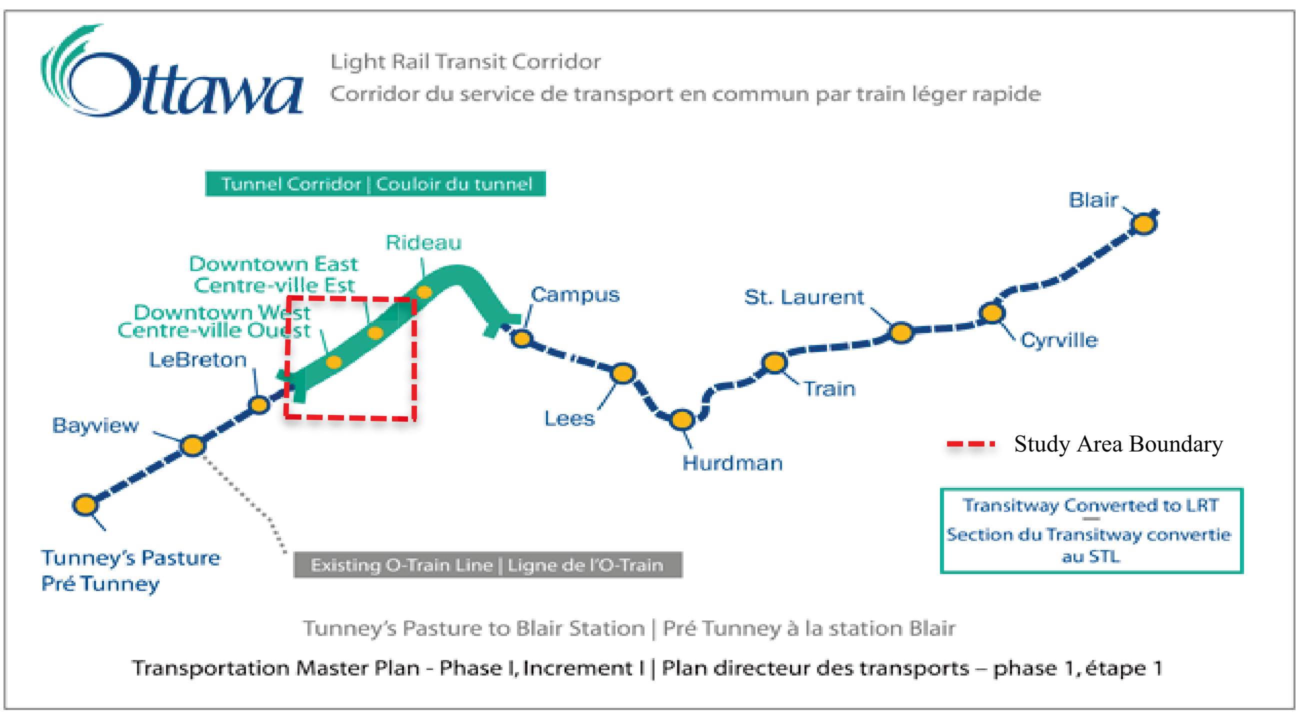
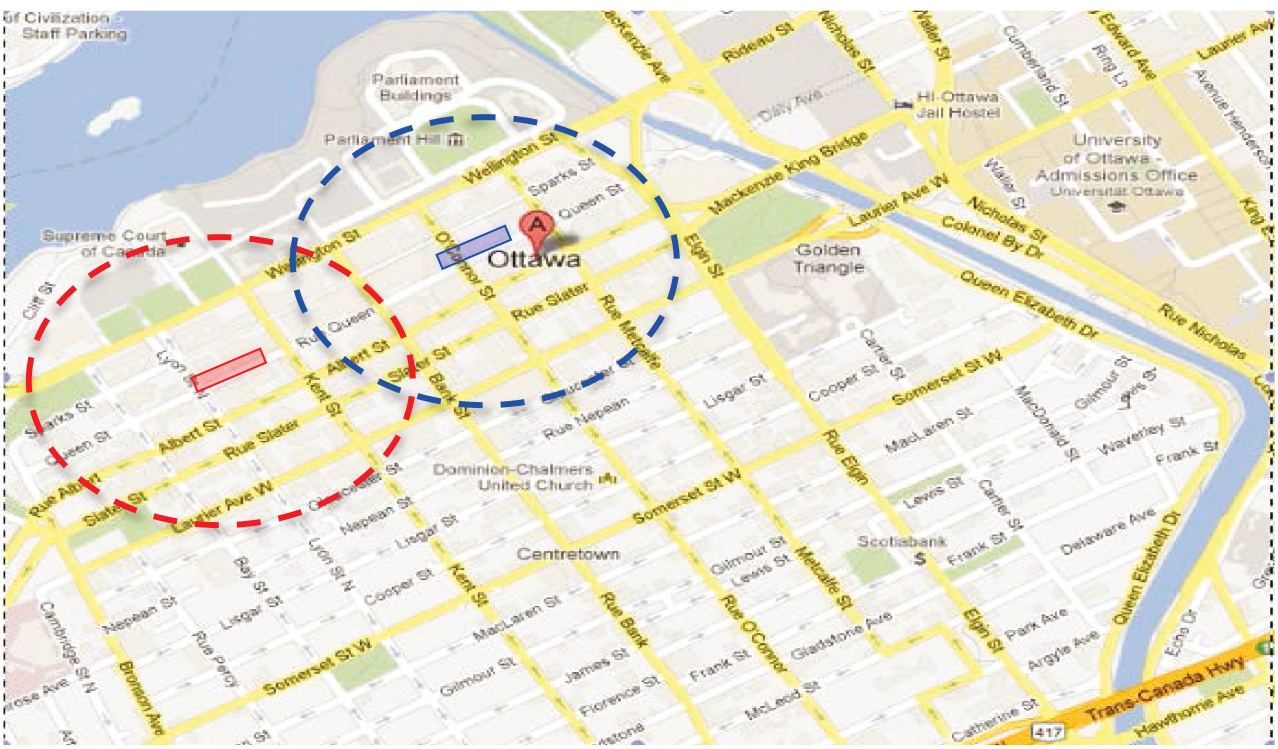


Figure 5.2: Proposed LRT Stations
Source: Light Rail Transit Corridor, (2012), *Ottawa Light Rail.* Retrieved September 14th, 2012, from: http://www.ottawalightrail.ca/en/routes-stations

With the current bus transitway operating near capacity especially through the downtown core where buses compete with other surface traffic, the study area for the commuters' mode of preference study was limited to boundaries within the central business district (CBD) of Ottawa. This area was chosen as the focus area for this study because it is the most affected by congestion especially during peak commute times. For the purpose of this study, the limits of the CBD were set to be bounded by the Ottawa River in the North; Bronson Avenue in the West; Rideau Canal in the East and Somerset Street in the South (See Figure 5.3). Major destinations (such as offices and other public places of interest) were selected within a 500-meter catchment radius of the two proposed LRT stations that are to be located along Queens Street within the study area. This catchment radius served as an area from where the sample for the survey was collected.



Downtown West Station

Downtown East Station

Figure 5.3: Study Area showing Approximate Locations of LRT Station within Ottawa CBD
Source: Google Map Images

5.4.2. Office Location/Relocation Survey

The city of Ottawa alongside its surrounding first-tier satellite communities was selected as the study area for the office location/relocation research study for the following reasons:

- The satellite communities surrounding central Ottawa which include: Kanata (West); Orleans (East); and Barrhaven (South) have grown to become major suburban centers with the potential to provide the basic necessities to support the needs of their residents similar to central Ottawa;
- Secondly, there's a high number of employment opportunities within the 'high-tech' sector as well as within other sectors that are favorable to support the adoption of a telecommuting program within the City of Ottawa municipality;
- Lastly, it is the current hometown of the researcher thus, making it easier when it comes to collecting data required for the study.

Figure 5.4 below is a schematic representation of the study area showing the central Ottawa as well as its surrounding suburban centers.

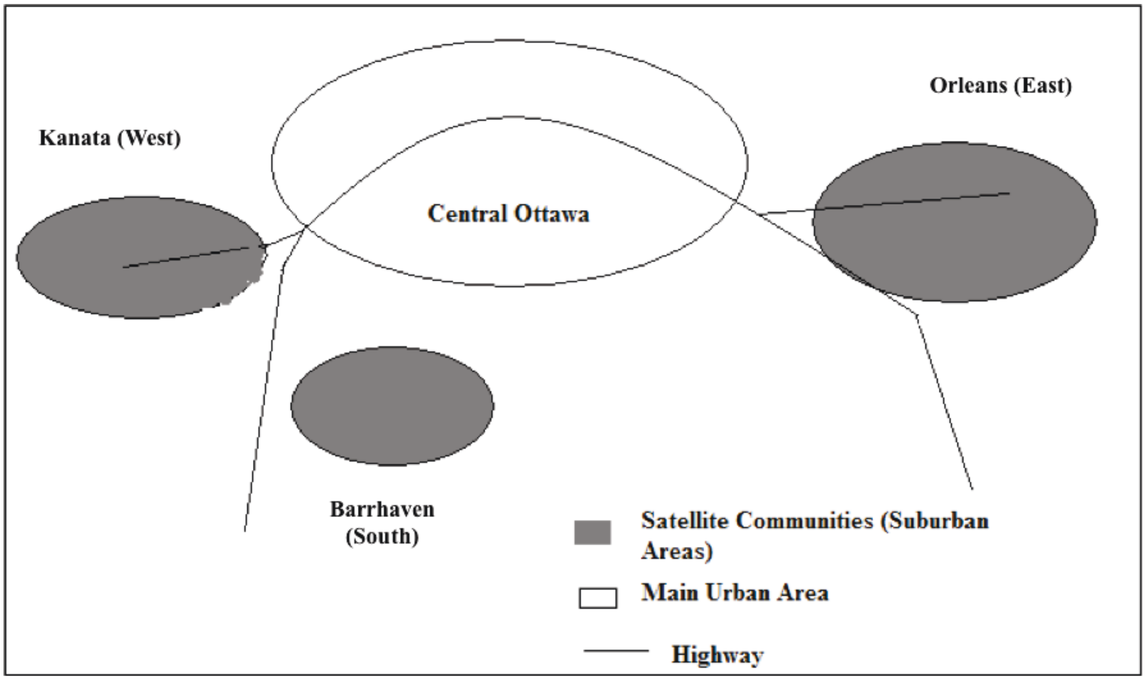


Figure 5.4: Schematic representation of the City of Ottawa multinucleated urban center

5.5. Sampling Process

The sampling process is the process that simply involves the selection of a subset of individuals from a population in order to estimate the characteristics of the entire population using statistical inference. This section describes the sampling process for each of the survey.

5.5.1. Sampling Process – Commuters' Mode Preference Survey

Considering that the planned LRT system would not extensively cover most neighbourhoods within the city of Ottawa, the sample population had to be selected from an area accessible by the four ground modes of transportation alternatives available for commuting. Under favourable circumstances, it would have been ideal to choose the sample population based on residential locations within the City of Ottawa. However, this would have required more resources and time, more than what was allocated for this project. In addition, given that the LRT would not be accessible in every community within Ottawa, sampling residents would have resulted in selection bias considering that those with no access to the LRT would automatically tend to prefer other transport modes. Moreover, people usually choose their mode of transport based on their activity (e.g., commuting to work versus recreational activities). Taking all these into consideration and also keeping the objective of this research study in mind, the target respondents for this research study were selected randomly from offices within a 500 meter catchment radius of the two proposed LRT stations to be located along Queens Street within the central business district (CBD) of Ottawa for the following reasons:

i. It is accessible by all ground modes of transport currently available for use in Ottawa;
ii. It attracts a lot of trips generated from other parts of the City of Ottawa especially during weekdays;
iii. It is a major destination point for most commuters due to the high density of office spaces within the area;

Hence for the above stated reasons, the sampling frame[16] for this survey was limited to commuters who work within a 500-meter catchment radius of the two proposed LRT stations along Queens Street within the CBD of the City of Ottawa. Mode choice preferences for other purposes other than for commuting were not included in this study. In the same vein, commuters who commute to areas outside the central business district of Ottawa were also left out of the survey sample.

[16] Sampling frame is the list of all those within a population from which a sample is drawn to administer the data collection instrument (Louviere, 2000).

5.5.2. Sampling Process – Office Location/Relocation Preference Survey

Although the adoption of a telecommuting program is perceived to be favorable for firms whose primary activities are in the sector of high technology, empirical evidence has shown that telecommuting could also be well adopted by firms whose primary activities are within the sectors of finance, consulting services, education and research, insurance and retail (Mokhtarian, 1992). In addition, research also reveals that there is no evidence in the differences between the public versus the private sector when it comes to adopting a telecommuting program (Mokhtarian, 1992; Moss & Carey, 1994). Hence, the sampling process for this study should ideally include samples from both the public and private sectors. However, for the purpose of this study, samples were only selected from firms within the private sector for the following reasons:

- The public sector was not considered because the location of a public office is more likely to be influenced by political decisions, rules and regulations. They less likely to be based on the decision of one person or a small group of corporate managers;
- The citing of office space for private firms is primarily influenced by strategic business decisions alongside private interest some of which may include (need to reduce overhead cost, need to be in proximity to resources/clientele, need to be close to employees, etc.).

Hence for the above reasons, the sampling frame[17] for this research study was limited to managers of business firms whose offices are currently located within the central and first-tier satellite communities of the city of Ottawa. Only those businesses that are likely to support a telecommuting program for their employees were included in the sampling frame.

[17] Sampling frame defines the universe of respondents from which a finite sample is drawn to administer the data collection instrument (Louviere, 2000).

5.6. Sampling Size

Estimating a sample size prior to launching a survey is a very important process especially if it is the goal of the study to make inferences about the general population from the sample. In addition, determining an appropriate sample size could help avoid the waste of time and money during the data collecting phase in a research study (Healey, 1999). The size of a sample depends on (1) the desired level of statistical significance and confidence interval required and (2) the expected response rate (Kocur *et al.,* 1982). Given that the value of the true population within each of the study area is unknown (i.e., the number of commuters within the CBD of Ottawa and the number of business firms within the City of Ottawa municipality), the sample size was estimated using the formula below:

$$N = \frac{(Z^2)(P_u)(1 - P_u)}{(C.I)^2} \qquad [5.1.1]$$

Where:

Z = the z-score at a confidence level (1.96 for 95% confidence, 1.6449 for 90% confidence and 2.5758 for 99% confidence);

P_u = estimated variance in the population (in decimal);

$C.I$ = the desired precision level (in decimal).

5.6.1. Estimated Sampling Size – Commuters' Mode Preference Survey

Taking into consideration the resources allocated for this study, the sample size for the commuters' mode preference survey was estimated using the following parameters: Z = 1.96 (95% confidence); P_u[18] = 0.5; C.I = 5%. With these parameters, a minimum sample size of 384 respondents was required.

5.6.2. Estimated Sampling Size – Office Location/Relocation Preference Survey

Taking into consideration the resources allocated for this study, the sample size for the commuters' mode preference survey was estimated using the following parameters: Z = 1.6449 (90% confidence); P_u = 0.5; C.I = 6%. With these parameters, a minimum sample size of 188 respondents was required.

5.7. Survey Implementation

With knowledge of the study area, sampling process, and sample size, this section describes how the stated preference surveys were implemented within their respective study areas. It discusses how respondents were selected randomly and the number of questionnaires distributed and collected.

[18] Setting P_u at 0.5 ensures that the expression $P_u(1-P_u)$ will be at its maximum possible value and consequently, the confidence interval will be at its maximum width (Healey, 1999).

5.7.1. Survey Implementation – Commuters' Mode Preference

5.7.1.1. Pilot Survey

The pilot survey for this study was carried out throughout the month of October 2012. Fifteen pilot survey questionnaires were handed-out. The sample size for the pilot survey composed of friends and professors within Carleton University, alongside some former colleagues who work within the central business district of Ottawa. Out of the fifteen distributed surveys, eight completed and usable questionnaires were returned.

5.7.1.2. Final Survey

The final survey for this research study was collected between November 1st, 2012 and December 21st, 2012. Given that the true population (i.e., number of commuters) within the research study area was unknown, an estimation of the sample size assuming an infinite population calculated from section 5.6.1 above showed that a minimum of 384 respondents were to be sampled for this study.

A total of 500 questionnaires were printed and distributed amongst commuters who work within the central business district (CBD) of Ottawa. A list of the offices randomly selected for the distribution of this survey is shown in Table 1-D of Appendix D. In order to ensure that the questionnaires were completed only by the target respondents (commuters), face-to-face contacts were made with office receptionists from randomly selected offices and their help was solicited to distribute and collect-back completed responses from their fellow colleagues. For those offices that limited direct public access into their buildings, people entering the building were randomly stopped and asked if they were interested in taking part in the survey. Interested participants who belonged to this category were given questionnaires with self-addressed return envelops to enable them return their completed survey by mail. Caution was exercised to make sure that these participants actually work within these office buildings. In the meantime, completed surveys dropped of at offices that were accessible through a receptionist were collected-back by December 21st.

By the approach of the deadline, a total of 157 surveys were returned (giving a response rate of 31.4%). Amongst these surveys returned, six respondents returned the questionnaires without completing the stated preference (SP) section (Part II). Nonetheless, all completed questionnaires were used in the calibration of the modal split model for the CBD area. However, in the calibration of the modal shift models, only questionnaires whose respondents completed the SP section were used (i.e., 151). The distribution of the survey questionnaire for this study did not go without encountering some challenges. Below are some problems encountered during the distribution of this survey:

- Most office receptionists refrained from assisting to distribute the survey questionnaires to their fellow colleagues citing to company policy and clauses that prevented soliciting of any form within their offices;
- The structure of some offices made it impossible to distribute the survey questionnaires to their employees. For example, offices within the public sector required that mails of any sort addressed to their employees must go through a centralized mailing system and then, distributed by their internal mailing system to their employees. This made it impossible to sample employees within such office buildings given the inability to trace the completed surveys.
- Most offices were inaccessible due to the inability to get through their highly secured doors.

5.7.2. Survey Implementation – Office Location/Relocation Preference

5.7.2.1. Pilot Survey

The pilot survey for this study was carried out throughout the month of October 2012. Seven pilot survey questionnaires were handed-out to randomly selected managers of private business firms whose primary activity were within the sectors of information technology, legal services and engineering while one copy of the pilot survey questionnaire was handed to the chair of the department of civil and environmental engineering at Carleton University. Out of a total of eight questionnaires distributed, six responses were picked-up. Amongst the six picked-up pilot surveys, one of them was returned with no response provided in the stated preference section that contained the scenario choice sets. Hence, the number of usable pilot surveys for analysis was reduced to five (120 observations in total).

5.7.2.2. Final Survey

The final survey for this research study was collected between November 1st, 2012 and December 21st, 2012. Given that the true population (i.e., number of business firms) within the study area of research was unknown, an estimation of the sample size from section 5.6.2 required the sampling of at least 188 respondents for this study.

A total of 200 questionnaires were printed and door-to-door contacts were made with various office managers of business firms within the study area. These business firms were selected randomly from the YellowPages business directory and they belonged to different company sectors whose primary activities are within the areas of high-tech, engineering, sales, marketing, finance, legal services, etc.

Out of the 200 visits made to these offices, a total of 120 managers agreed to take part in the survey. A list of all contacted offices contacted for the distribution of the office location/relocation survey is shown in Appendix D (Table 2-D). In some cases, the questionnaires were left with the receptionists addressed to their managers. For each successful questionnaire handed out, the business card of the manager was taken and follow-up email reminders were sent on weekly basis in an attempt to increase the response rate. By the approach of the survey pick-up deadline, a total of 52 responses were picked up out of the 120 handed-out (giving a response rate of 43.33%). Amongst all collect survey responses, only one was returned with no response provided in stated preference section with the hypothetical office location/relocation choice scenarios. Therefore, 51 of the responses were usable for analysis. This resulted to 612[19] total data points from the refined data. The following problems encountered during the distribution of the survey made it impossible for the successful distribution of the 200 printed survey questionnaires:

- Most companies have security doors restricting access to office space;
- On average, most office managers confronted refused to part-take in survey – citing breach of company confidentiality and lack of time as primary reason;
- Some office had outdated addresses as suggested by YellowPages while some didn't exist at all.

5.8. Summary

This chapter described the approach used to collect data required to carry out this research study. The survey distribution and implementation method, sampling process & sampling size applicable to each of the surveys were discussed. Problems encountered during the distribution and implementation of

[19] 51 responses x 6 choice set per respondent = 612 data points

the survey was also stated. Having described the survey design and data collection process within chapters 4 & 5 in this report, the next part of the report describes how the data was prepared for analysis and statistical techniques and tools used for analyzing the data.

PART III: DATA PREPARATION, MODEL CALIBRATION & ANALYSIS

This part of the report discusses the method used to calibrate and analyze the collected data. It also discusses the steps involved in the preparation of the collected data for model calibration required to understand the relationships between the factors being studied in this research as outlined in the research objective.

6. DISCRETE CHOICE ANALYSIS

6.1. Introduction

In general, the development of urban policies related to issues such as public transit improvements, route choice studies, planning studies often involves the aggregate sampling of the behavior from a large group of people or a specific market segment in the society. However, the calibration of aggregate choice models can be very costly and cumbersome. In addition, they tend to be subjected to serious biases and prediction errors owing to their reliance on a group as a whole as oppose to individual characteristics (Ben-Akiva & Lerman, 1985). Thus, considering that aggregate behavior is in essence the result of individual decisions, modeling of individual behavior is at the core of all predictive models of aggregate behavior (Ben-Akiva & Lerman, 1985). Hence, given that all data for this research study were collected at an individualistic level, discrete choice models (also known as disaggregate demand models) based on the theory of random utility maximization were used to analyze the data. The purpose of this chapter is to describe principles of the random utility theory upon which discrete choice models are developed. Techniques used to test the significance of these models are also presented.

6.2. Discrete Choice Models

A discrete choice analysis was used as the modeling framework for modeling decisions throughout this research study. Discrete choice models describe the choices of decision-makers among alternatives. The decision-makers can be people, households, firms, or any other decision-making unit, and the alternatives might represent competing products, courses of action, or any other options or items over which choices must be made. In essence, discrete choice models in general postulate that the probability of an individual choosing a given alternative is a function of their individual characteristics and the relative attractiveness of the alternative (Ortúzar *et al.* 2011). For a set of alternatives to fit within a discrete choice framework, they must possess the following characteristics (Train, 2002):

- The alternatives must be *mutually exclusive* from the perspective of the decision-maker
- The alternatives must be *exhaustive,* in that all possible alternatives should be included.
- Lastly, the number of alternatives has to be *finite.*

Discrete choice models are based on the theory of utility maximization. In other words, a decision maker faced with a set of alternatives chooses the one with the highest perceived utility. The most common theoretical framework for generating discrete-choice models is the random utility theory (Domencich and McFadden, 1975; Train, 2002). It is important to note that the analyst, who is an observer of the system, does not possess complete information about all the elements considered by the individual making the choice; therefore, the analyst assumes that the utility of an individual is probabilistic and composed of two components:

- A measurable, systematic or deterministic component (V_{iq}) that is a function of measured attributes; and
- An error (random) component ($\in_{iq}$) that reflects the idiosyncrasies and particular tastes of each individual, together with any measurement or observational errors made by the analyst.

Thus, since there are utility aspects of the individual not observed by the analyst, the analyst postulates that utility can be decomposed as:

$$U_{iq} = V_{iq} + \in_{iq} \qquad [6.1.1]$$

which allows two apparent 'irrationalities' to be explained: that two individuals with the same attributes and facing the same choice set may select different alternatives, and that some individuals may not always select what appears to be the best alternative (from the point of view of the attributes considered by the analyst). The above decomposition is fully general, since $\in_{iq}$ is defined simply as the difference between true utility U_{iq} and the part of utility that the analysts captures in V_{iq}. Given its definition, the characteristics of $\in_{iq}$, such as its distribution, depend critically on the analyst's specification of V_{iq}. In particular, $\in_{iq}$ is not defined for a choice situation *per se.* Rather, it is defined relative to an analyst's representation of that choice situation. This distinction becomes relevant when evaluating the appropriateness of various specific discrete choice models (e.g. using a multinomial logit model versus using a nested logit model). Considering that the analyst does not know $\in_{iq}$ $\forall\, i$ and treats them as random, probabilistic statements about the decision-maker's choices can be made provided the joint densities of the random vector $\in_{iq}= \langle \in_{1q},\ldots,\in_{nq} \rangle$ is known. From this perspective, the choice probability that decision-maker q chooses alternative *i* is (Train, 2002):

$$\begin{aligned} P_{iq} &= Prob(U_{iq} > U_{jq}\ \forall\, j \neq i) \\ &= Prob(V_{iq} + \epsilon_{iq} > V_{jq} + \epsilon_{jq}\ \forall\, j \neq i) \\ &= Prob(\epsilon_{jq} - \epsilon_{iq} < V_{iq} - V_{jq}\ \forall\, j \neq i) \end{aligned} \qquad [6.1.2]$$

The above probability is a cumulative distribution, namely, the probability that each random term $\epsilon_{jq} - \epsilon_{iq}$ is below the observed quantity $V_{iq} - V_{jq}$. Manski (1977) identified the following to be sources of uncertainty or randomness in the utility function:

- Unobserved alternative attributes;
- Unobserved individual attributes;
- Measurement errors;
- Proxy or instrumental variables.

For the purpose of this research study, a Logit Model was selected as the preferred model for calibration, although the Probit Model stands as another possible applicable model.

6.3. LOGIT versus PROBIT Models

The assumptions made about the error terms determine the form of model that is developed. The error terms could follow multivariate normal or independently and identically type I extreme value (gumbel) distribution (Johnson & Kotz, 1970). A multivariate normal assumption of the error terms leads to the development of a multinomial probit (MNP) model (Daganzo, 1979); while an assumption that the errors are independently and identically distributed with a Weibull distribution (also known as the extreme value type 1, Gumbel or double-exponential distribution) leads to the development of a multinomial logit (MNL) model (McFadden, 1973;Fowkes & Wardman, 1988). The probit model allows complete flexibility in the variance-covariance structure of the error terms, but its use requires numerical integration of a multidimensional normal distribution (Hensher and Button, 2000). Given the computational complexity associated with probit models, a logit model was implemented as the preferred model for calibrating data collected in this entire research study.

The deterministic component V_{iq} of the utility function in equation [6.1.1] is often commonly specified as linear in parameters and includes variables that represent the attributes of the alternatives, the decision context and the characteristics of the decision-maker. With the assumption that the error component of the utility follows a gumbel distribution, the general form of a logit model can be represented by:

$$P_{iq} = \frac{e^{V_{iq}}}{\sum_{j=1}^{j} e^{V_{jq}}} \qquad [6.1.3]$$

where j = the number of alternatives including the i^{th} alternative
e = the base of the natural logarithm

Equation [6.1.3] above represents the general case for of the logit model when there are more than two alternatives (also known as multinomial logit model). For a binary logit model where there are only two alternatives, the probability of individual q choosing alternative i is given by:

$$P_{iq} = \frac{e^{V_{iq}}}{e^{V_{iq}} + e^{V_{jq}}} \qquad [6.1.4]$$

The closed form of the above logit models makes it straightforward to estimate, interpret and use. However, the assumptions that the error terms are independently and identically distributed across alternatives places important limitations on the competitive relationships amongst the alternatives (Hensher & Button, 2000). The following section discusses the properties of the logit models.

6.3.1. Properties of the Logit Model

The Logit model has many desirable properties that make it to be used widely. These properties obtained from the Travel Model Improvement Program [Saiyed, 1999; Louviere *et al.* 2000 pp.15; Tayyaran, 2000] are listed below:

- It is fairly easy to use, as it requires a few simple calculations and can be applied to complex choice problems.

- The probability of choosing a particular alternative depends on the deterministic components of all other available alternatives such that the chosen alternative is that with the highest total utility.
- The probability of selecting a particular alternative increases when the deterministic component of that alternative increases. Likewise, it decreases when the deterministic component of the utility of any other alternative increases.
- The model should accommodate choice sets containing any number of alternatives and should be able to predict the effects of changes in alternatives.
- Lastly, the model assumes that the variance associated with the component of the random utility expression describing each alternative (i.e., capturing all the unobserved influences on choice) are independently and identically distributed (IID) amongst the alternatives in the choice set and that these unobserved effects are not correlated between all pairs of alternatives.

Despite the above properties of the Logit model that seem favorable from the standpoint of the analysts, there are some properties exhibited by the logit model that can be perceived as unfavorable. These include the 'independence from irrelevant alternatives' and the elasticity of the model variables. These properties are presented below.

6.3.2. Independent from Irrelevant Alternatives (IIA)

The IIA property states: "the ratio of the probabilities of choosing one alternative over another (given that both alternatives have a non-zero probability of choice) is unaffected by the presence or absence of any additional alternatives in the choice set" (Louviere *et al.* 2000). As can be seen in the case of a multinomial logit model:

$$\frac{P_{jq}}{P_{iq}} = e^{(P_{jq} - P_{iq})} \qquad [6.1.5]$$

The above ratio is indeed a constant independent of the rest of the options. The IIA property is both a strength and weakness of a choice model: its strength is that it provides a computational convenient choice model and permits the introduction and/or elimination of alternatives in choice sets without *re-estimation*. However, its weakness is that the observed and unobserved attributes of utility may not be independent of one another, and/or if the unobserved components of utility are correlated among alternatives, this leads to bias utility parameters and added errors in forecasts. The use of a 'nested logit' structure (where similar alternatives are grouped into nests) serves as a remedy in the case where some of the alternatives are suspected to have shared, unobserved effects. This eliminates the problem of correlation because the logit probabilities are based on differences in alternative utilities, therefore any shared (common) effects would cancel in the subtraction.

6.3.3. Elasticity of Logit

Another useful property of the logit model is that it is possible to derive fairly simple equations for the direct and cross-elasticities of the model (Ortúzar *et al.,* 2011). For example, the direct point elasticity, i.e., the percentage change in the probability of choosing alternative i with respect to a marginal change in a given attribute X_{kiq}, is simply given by (Louviere *et al.* 2000 pp.59; Ortúzar *et al.,* 2011 pp. 235):

$$E_{P_{iq},X_{kiq}} = \beta_{ik} X_{kiq} (1 - P_{iq}) \qquad [6.1.6]$$

while the cross-point elasticity i.e., the percentage change in the probability of choosing alternative i with respect to a marginal change in the value of the k^{th} attribute of alternative j for individual q is also simple given by:

$$E_{P_{iq},X_{kjq}} = -\beta_{jk} X_{kjq} P_{jq} \qquad [6.1.7]$$

It can be seen from equation [6.1.7] above that the cross-elasticities of any alternative i with respect to the attribute X_{kjq} of alternative j are equal and independent from alternative i. This seemingly peculiar result is also due to the IIA property, or more precisely, to the need for identical and independent distributed (IID) utility functions in the model generation.

Despite the range of desirable properties associated with the general logit model, its limitation and assumptions that the error terms are independently and identically distributed (IID) across alternatives made it less suitable for use for calibrating the commuters' mode preference model survey in this research study. Instead, a nested logit model was used to calibrate the data obtained for the commuters' mode preference survey.

6.4. The Nested Logit Model

6.4.1. Overview

With the IID limitation of the multinomial (MNL) model long been recognized, McFadden (1978, 1979, 1981) proposed a more generalized extreme value (GEV) model that can accommodate various degrees of cross-alternative substitution and remain consistent with utility maximization. The nested logit (NL) is the most widely used member of the GEV family of models. GEV models partially relax IIA assumption such that the random components (error terms) become correlated within a partition of a choice set but not across partitions (Louviere *et al.*, 2000; Heiss, 2002). Hence, NL models naturally lead to a consideration of partitioning choice sets so that richer substitution patterns can be accommodated to reflect differential degrees of similarity or dissimilarity. In this section, the nested logit model is discussed.

6.4.2. Nested Logit Model Description and Structure

Train (2007) notes that the nested logit model is appropriate when the choice set facing a decision-maker can be partitioned into subsets, known as nests, in such a way that the following properties hold:

- For any two alternatives in the same nest, the ratio of probabilities is independent of the attributes or existence of other alternatives in the nest. In other words, IIA holds within each nest;
- For any alternative in different nests, the ratio of probabilities can depend on the attributes of other alternatives in the two nests. In other words, IIA does not hold in general for alternatives in different nests.

Whereas the multinomial logit model treats all alternatives equally, the nested logit model includes intermediate branches that group alternatives into nests as shown in Figure 6.1 below.

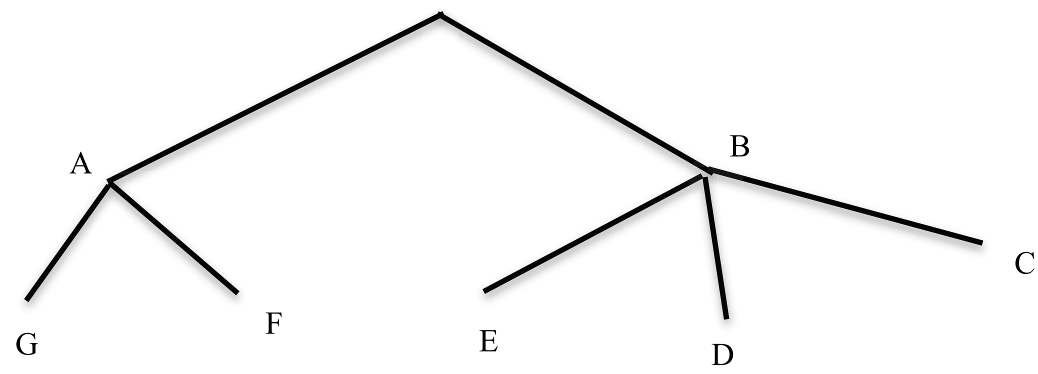


Figure 6.1: An Example of a Nested Logit Model with Two Levels

The above nested structure is composed of five alternatives (C, D, E, F & G) separated into two nests (A & B). By placing alternatives F & G within the same nest, this implies their probabilities would always change uniformly upon the exclusion of one of the alternatives. Likewise, the same holds for the alternatives in nest B (E, D & C). Nested logit models are often appropriate in situations where the respondent is faced with making a choice that can be separated in two or more levels (i.e., the nature of the choice problem is sequential). However, although decision trees in nested logit analyses such as that shown in Figure 6.1, are often interpreted as implying that the highest-level decisions are made first, followed by decisions at lower levels, no such temporal ordering is necessarily implied (Hensher, Rose & Greene 2005, Chapter 13). In fact, probably the best way to think about nested logit models is that they are appropriate when the researcher believes that there are unobserved similarities between group of alternatives; in other words, they are appropriate when there is correlation for unobserved reasons between the alternatives in each nest but no correlation between alternatives in different nests.

6.4.3. Estimation of the Nested Logit (NL) Model

6.4.3.1. General Approach

The choice probabilities of a nested logit model are estimated by first partitioning the choice set into M subsets ('nests') denoted as B_k, $k = 1, \ldots, K$ so that each alternative belongs to exactly one nest. For example, the nest to which alternative j belongs to can be represented as (Heiss, 2002).

$$B(j) = \{B_k : j \in B_k, \qquad k = 1, \ldots K\}$$

For a nested logit model, it is possible to decompose the observed portion of the utility function into two parts: (1) a part labeled W that is constant for all alternatives within a nest and (2) a part labeled Y that varies over alternatives within a nest thus, leading to:

$$U_{nj} = W_{nk} + Y_{nj} + \varepsilon_{nj} \qquad [6.1.8]$$

for $j \in B_k$, where

- W_{nk} depends only on variables that describe nest K. These variables differ over nests but not over alternatives within each nest.
- Y_{nj} depends on variables that describe alternative j. These variables vary over alternatives within nest K.

By decomposing the utility equation in the manner shown in equation [6.1.8] above, the nested logit probabilities can be written as the product of two standard logit probabilities (Train, 2007). In effect, for a two level nested logit model, the probability of choosing alternative $i \in B_k$ is equal to the probability that nest B_k is chosen multiplied by the probability that alternative i is chosen given that an alternative in B_k is chosen represented as:

$$P_{ni} = P_{nB_k} \times P_{ni|\,B_k} \qquad [6.1.9]$$

where $P_{ni|\,B_k}$ is the conditional probability of choosing i given that the alternative in nest B_k is chosen and P_{nB_k} is the marginal probability of choosing an alternative in nest B_k. These conditional and marginal probabilities take the form of logits and so can be written as follows (Train, 2007, pp.90):

$$P_{nB_k} = \frac{e^{W_{nk}+\lambda_k \Gamma_{nk}}}{\sum_{i=1}^{K} e^{W_{ni}+\lambda_i \Gamma_{ni}}} \qquad [6.2.0]$$

$$P_{ni|\,B_k} = \frac{e^{Y_{ni}/\lambda_k}}{\sum_{j \in B_k} e^{Y_{nj}/\lambda_k}} \qquad [6.2.1]$$

where

$$\Gamma_{nk} = \ln \sum_{j \in B_k} e^{Y_{nj}/\lambda_k} \qquad [6.2.2]$$

From equation [6.2.2] above, Γ_{nk} is called the inclusive value or inclusive utility for alternative k for nest B_k in the first level. It is calculated as the log of the denominator of the second level. The inclusive value links the two levels of the nested logit model, bringing information from the bottom level into the upper level.

Thus, we have:

$$P_{ni} = \frac{e^{W_{nk}+\lambda_k \Gamma_{nk}}}{\sum_{i=1}^{K} e^{W_{ni}+\lambda_i \Gamma_{ni}}} \times \frac{e^{Y_{ni}/\lambda_k}}{\sum_{j \in B_k} e^{Y_{nj}/\lambda_k}} \qquad [6.2.3]$$

Equation [6.2.3] essentially tells us the probability that alternative k in nest B_k is chosen in the first level and alternative i is chosen in the second level in the case of a two-level nested logit model. Assuming $W_{nk} = \omega_{nk}\gamma$ and $Y_{ni} = x_{ni}\beta$ and substituting in equation [6.2.3], we have:

$$P_{nB_k i} = \frac{e^{\omega_{nk}\gamma + \lambda_k \Gamma_{nk}}}{\sum_{i=1}^{K} e^{\omega_{ni}\gamma + \lambda_i \Gamma_{ni}}} \times \frac{e^{x_{ni}\beta/\lambda_k}}{\sum_{j \in B_k} e^{x_{ni}\beta/\lambda_k}} \qquad [6.2.4]$$

where $P_{nB_k i}$ is the probability that individual *n* chooses nest B_k in the first level and alternative *i* in the second level, *K* is the number of discrete choices or nests in the first level, ω_{nk} is a matrix of independent variables associated with nest B_k in the first level, x_{ni} is a matrix of independent variables associated with alternative *i* in the second level, and γ, λ, and β are vectors of coefficients[20]. Essentially, $\lambda_k \Gamma_{nk}$ captures the expected value or utility individual *n* derives from the alternatives available in nest B_k, where λ_k reflects the degree of independence amongst unobserved portions of utility for alternatives in nest B_k.

6.4.3.2. Testing the appropriateness of nests in NL models

Testing for the acceptability of a nested logit model involves testing the appropriateness of the nests formed. The parameter λ_k (known as the dissimilarity parameter) is used to test the nested structure. λ_k is a measure of the degree of independence in unobserved utility among the alternatives in nest, B_k. A high λ_k means greater independence and less correlation i.e. the alternatives in the nest are less similar for unobserved reasons. The parameter λ_k can differ over nests, reflecting different correlation among unobserved factors within each nest. Notwithstanding, it is possible for the analyst to constrain the λ_k's to be the same for all (or some) of the nests, indicating that the degree of correlation is the

[20] Note that the nested logit choice probability can be written without the coefficients in the second level being divided by λ_k. Should this be the case, then the choice probability would be said to be non-normalized and it would not be the same as that shown in Eq. [6.2.3]. The model shown above in which the coefficients in the bottom level are divided by λ_k is sometimes referred to as the normalized nested logit model and it is consistent with a random utility model (RUM) setup. By scaling the coefficients within each nest, the RUM-consistent model allows utilities to be compared across nests; without the rescaling, utilities in each nest would be scaled by a different factor and would therefore not be comparable across nest. For a further discussion of the differences between these two models, see Train (2007, pp. 88) and Heiss (2002).

same in each of these nests. For the nested logit model to be consistent with utility-maximizing behavior, λ_k must be within the following range.

$$0 < \lambda_k \leq 1$$

If $\lambda_k > 1$, then the model is consistent with utility-maximizing behavior for only some range of the independent variables. If $\lambda_k < 0$, then the model is inconsistent with utility maximization since it implies that improving the attributes of an alternative actually decreases the probability that it will be chosen. A value of $\lambda_k = 1$ means complete independence in nest B_k. Obviously, if $\lambda_k = 1$ for all nests, then the GEV distribution simply becomes the product of independent extreme value terms i.e. the nested logit reduces to the standard logit model.

6.4.3.3. Properties of Nested Logit Models

The following are properties of a nested logit model:

- It relaxes the Independence of Irrelevant Alternative (IIA) assumption assumed by the Multinomial Logit and Conditional Logit Models (Heiss, 2002)

- It is computationally straight forward and fast compared to the multinomial probit and mixed logit other even more flexible models due to the existence of a closed-form expression for the likelihood function (Heiss, 2002).

- The multinomial logit model assumes that the error terms $\varepsilon_{i1}, \ldots \varepsilon_{j1}$ are I.I.D. as Extreme Value Type I, whereas, the nested logit model assumes a generalized version of this distribution. This special form of the generalized extreme value (GEV) distribution extends the Extreme Value Type I distribution by allowing the alternatives within a nest to have mutually correlated error terms.

- The inclusive value (IV_m) corresponds to the expected value of the utility an individual i obtains from the alternatives in a nest m.

Following the above process, nested logit models with more than two levels can also be estimated. For example, a three-level nested logit can be obtained by partitioning the choice set into nests and then the nests into sub-nests. Following this, the choice probabilities can be expressed as a series of logits, whereby the top level describes the choice of nest; the second level describes the choice of sub-nest; and the bottom level describes the choice of alternative within each sub-nest. As expected, the top level includes an inclusive value for each nest and this captures the expected utility that the decision maker gets from the sub-nests within the nest; it is calculated as the log of the denominator of the second level model. Similarly, the second level models include an inclusive value for each sub-nest, which represents the expected utility of the alternatives in each sub-nest; it is calculated as the log of the denominator of the third level model.

Each layer of nesting introduces parameters that capture the degree of correlation among alternatives within the nests. With the full choice set partitioned into nests, the parameter λ_k is introduced for nest B_k. If the nests are partitioned into additional sub-nests, then a parameter σ_{mk} is introduced for sub-nest B_m in nest B_k. Using the decomposition of the probability into a series of logits, σ_{mk} is the coefficient of the inclusive value in the second level model and $\lambda_k\sigma_{mk}$ is the coefficient of the inclusive value in the first level model.

6.5. Statistical Significance Tests

This section summarizes the appropriate techniques used for testing the statistical significance of the parameter estimates contained in the discrete choice model alongside, the overall measure of the goodness-of-fit of the model.

6.5.1. Model Estimation Techniques

The calibration of parameters in a model in general (irrespective of the type) calls for the evaluation of its goodness of fit, i.e., finding a model that best fits the observed data (Myung, 2003). There are generally two methods applicable to estimate the parameters of a model. These are: Least-Square Estimation (LSE) and Maximum Likelihood Estimation (MLE).

Least Square Estimators (LSE) are the values that minimize the sum of the squared differences between the observed and the expected values of the observation (Ben-Akiva and Lerman, 1985). The coefficients of regression are estimated by the basic objective function *F* given by:

$$F = \min \sum (\beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k - Y)^2 \qquad [6.2.5]$$

The desired coefficients are estimated by taking (k+1) derivatives of equation [6.2.5] and solving for (k+1) unknowns. This method is usually called the *Ordinary Least-Squares (OLS)*. The least-square estimators are usually unbiased under general assumption. Nonetheless, it should be noted that the least square method is less likely to be the favorite method used for estimating the parameters in a model other than linear regression models.

On the other hand, the characteristics of a Maximum Likelihood Estimation (MLE) method (such as sufficiency, consistency, efficiency, asymptotic normality and parameterization invariance) make it favorable for its application in parameter calibration and inference in statistics (Myung, 2003). In addition, most of the inference methods such as: the chi-square test, the G-square test, Bayesian methods, inference with missing data, modeling of random effects, and many model selection criteria such as the Akaike information criterion (Akaike, 1973) and the Bayesian information criteria (Schwarz, 1978) are developed based on the MLE method.

The maximum likelihood estimation method is based on the idea that although a sample could originate from several populations, a particular sample has a higher probability of having been drawn from a certain population than from other (Ortúzar & Willumsen, 2011). Therefore, the maximum likelihood estimates are a set of parameters, which will generate the observed sample most often (i.e., maximizing the likelihood function with respect to the parameters). In general, the value of the likelihood function, *L(θ)*, is expressed in equation [6.2.6] below (Ortúzar and Willumsen, 2011).

$$L\,(\theta) = \prod_{q=1}^{Q} \prod_{A_j \epsilon\, A(q)} {P_{jq}}^{g_{jq}} \qquad \text{Equation [6.2.6]}$$

Where; $g_{jq} = \begin{cases} 1\; if\; A_j\; was\; chosen\; by\; q \\ 0\; otherwise \end{cases}$

$P_{jq} = the\; probability\; that\; individual\; q\; \epsilon\; Q\; will\; choose\; alternative\; j\; \epsilon\; A$

The procedure for estimating the set of parameters in a model following the MLE method involves maximizing the likelihood function in equation [6.2.6] by differentiating *L(θ)* partially with respect to the parameters θ and equating the derivatives to zero (Ben-Akiva and Lerman, 1985). Thus, the likelihood function is transformed into a log-likelihood function given as:

$$l(\theta) = \log L\,(\theta) = \sum_{q=1}^{Q} \sum_{A_j \in A_q} g_{jq} log P_{jq} \qquad [6.2.7]$$

At this stage, the determination of the parameters in the model is based on an iterative process. For the case of nested and standard logit models, the function in equation [6.2.7] is well behaved and always converges quickly to a unique maximum. The estimates are generally consistent as well as asymptotically efficient and normal. Therefore, the MLE method is the most commonly utilized parameter estimation method for logit models. Hence, due to its high application, the maximum likelihood estimation method was used as the favorable method for calibrating the logit models in this research study (StataCorp, 2011).

For in-depth, technically more rigorous knowledge of the MLE method, the reader is directed to other sources (e.g. Bickel and Doksum, 1977, Chap 3; Spanos, 1999, Chap 13; Louviere *et al.* 2000, Appendix A3; Casella and Berger, 2002, Chap. 7).

6.5.2. Goodness-of-fit Measures

There are several goodness-of-fit measures that can be applied to logit models to test how well the model fits the observed data. However, the following were used to test how good the logit models fit the observed data:

- Likelihood ratio test
- The overall test of fit

- The rho-squared index
- Hosmer-Lemeshow test (Binary Models only)
- ROC Curves (Binary Models only)
- The asymptotic t-test

6.5.2.1. Likelihood Ratio Test

The likelihood ratio (LR) test has the ability to test the significance of a subset of parameters (θ) generated following the MLE procedure i.e., it utilizes the log likelihood function *l(θ)* evaluated at the mean of the utility parameters as a criterion for assessing the overall goodness-of-fit of a discrete choice model in which the parameters of the model were calibrated according to the MLE procedure (Louviere *et al.*, 2000). According to the likelihood ratio (LR) test, the significance of a discrete choice model with a large sample size is tested by testing the null hypothesis that the probability of an individual q, choosing alternative *i,* P_{qi} is independent of the parameters contained in the discrete choice utility function. The generalized LR criterion takes the following form:

$$R = \frac{LL(0)}{LL\ (\theta)} \qquad [6.2.7]$$

where:
LL(0) = the log-likelihood when no parameter has been included in the model
$LL(\theta)$ = the maximized log-likelihood of the fitted model (i.e., log-likelihood at convergence when all the parameters are included in the model)

It has been shown that the product of the natural logarithm of R and -2 (i.e., -2lnR)[21] follows a chi-square distribution with M degrees of freedom provided the null hypothesis is true (Wilks, 1962). The LR tests expresses how many times more likely does an observe data fits one model than the other. It can be used to compute a p-value, or compared to a critical value to decide whether to reject a null model in favor of an alternative model. The interpretation of the value obtained from the LR test can be done in two ways: One seeks to maximize a value of R for a model with all unconstrained values (full model) and, subsequently for a model with constrained values (parameters set to zero) that will produce a lower "-2lnR" value, i.e., the lower the "-2lnR", the better the model fits the observed data[22]. The second method is based on examining if "-2lnR" is greater than χ^2_M (chi-square obtained for M degrees of freedom) at a preselected significance level (e.g. $\alpha = 0.05$). If the calculated value of χ^2_M exceeds the critical value for the specified level of confidence, one rejects the null hypothesis that the particular subset of θs being tested is equal to zero.

6.5.2.2. *The Overall Test for fit*

A special case of the LR test is to examine if the estimated model is better when compared to a model in which all the parameters (θ) are equal to zero (Ortúzar *et al.,* 2011). The test statistics can be expressed as follows:

$$LR = -2[LL(0) - LL(\theta)]^{23} \qquad [6.2.8]$$

LR compares the values predicted by the fitted model and those predicted by "the most complete model possible to fit" (Belloco & Algeri, 2011). Evidence of lack-of-fitness of a model occurs when

[21] "lnR" is the difference between two log likelihoods
[22] A small ratio of log likelihoods indicates that the full model is a far better fit than the intercept model.
[23] Since the log likelihood is always negative, this is simply two times the (magnitude of the) difference between the constrained and unconstrained maximums of the log likelihood function. If this value exceeds the critical value of chi-squared with the appropriate degrees of freedom, then the null hypothesis is rejected (Train, 2002).

the value of LR is large. LR follows a χ^2 (chi-square) distribution with k degrees of freedom (k = number of parameters). Therefore, if a significance level α is selected, and $LR \geq \chi^2_{(k,\alpha)}$, then we will reject the null hypothesis. Nonetheless, this test turns out not to be very useful in general because models with alternative-specific constants (ASC) tend to reproduce a much better data than those without (i.e., models with parameters will always be better than those without any parameters). A much better test will be to verify how well all the variables excluding the ASC in the model best fit the observed data. The LR test statistics can then be written as follows:

$$LR = -2[LL(C) - LL(\theta)]^{14} \qquad [6.2.9]$$

where:

LL(C) = the is log-likelihood at convergence when only the alternative-specific constants are included in the model

The test follows a χ^2 ((k-j+1), α) distribution with k-j+1 degrees of freedom (j = total number of alternatives in choice set). In general, an extra run of the estimation routine is required to calculate *LL(C)* except for models where individuals face the same choice set, in which case it can be obtained from the following formula:

$$LL(C) = \sum_{i=1}^{j} Q_i log \frac{Q_i}{Q} \qquad [6.3.1]$$

where:

Q_i is the number of individuals choosing alternative *i.* The notional relation for a set of parameters that maximize the values of the log-likelihood function is shown below:

$$LL(0) < LL(C) < LL(\theta) \qquad [6.3.2]$$

6.5.2.3. The rho-squared test

The rho-square index is the percent increase in the log-likelihood function *l(θ)* above the value it takes when there are zero parameters in the model (Train, 2002). Although it is analogous to the squared multiple correlation coefficient (R^2) in linear statistics models, there is no intuitive interpretable meaning for the values it produces (Ortuzar *et al.* 2011). Equation (6.3.3) represents the general expression of ρ^2 index:

$$\rho^2 = 1 - \frac{LL(\theta)}{LL\ (0)} \qquad [6.3.3]$$

Generally, the value of ρ^2 varies between 0 (no fit) to 1 (perfect fit) despite being meaningless. As a matter of fact, values of ρ^2 between 0.2 and 0.4 are usually considered to be an indication of an extremely good model fit (Louviere *et al*., 2000). Simulations by Domencich and McFadden (1975) postulated that this range is equivalent to R^2 within the range of 0.7 to 0.9 for a linear function. In a strict mathematical sense, the upper bound of ρ^2 will always be less than 1 (Judge *et al.*, 1985 and Tardiff, 1976). Nonetheless, it is important to choose an appropriate ρ^2 index computed relative to any null hypothesis considering that the minimum values obtained in (6.3.3) vary in proportion as individuals choose each alternative. For the case of a binary model, the minimum ρ^2 value for various relative frequencies can be selected from Table 6.1 below (Tardiff, 1976). Two conclusions were derived from Table 6.1 (Tardiff, 1976 pp.382):

- ρ^2 does not generally satisfy the lower bound obtained from equation [6.3.3];
- It will be meaningless to compare the ρ^2 statistic for different samples with different relative frequencies. For example, a model calibrated with a 0.9/0.1 sample yielding a ρ^2 of 0.55

would undoubtedly be much weaker than one yielding a ρ^2 of 0.25 from a sample with 0.5/0.5 split.

Table 6.1: Minimum ρ^2 for various relative frequencies

Sample Proportion selecting the first alternative	Proportion selecting second alternative	Minimum value of ρ^2
0.50	0.50	0.00
0.60	0.40	0.03
0.70	0.30	0.12
0.80	0.20	0.28
0.90	0.10	0.53
0.95	0.05	0.71

For other logit models, the minimum value for $\rho_{min}{}^2$ can be calculated using the general formula below:

$$\rho^2_{min} = 1 - \frac{\sum_{i=1}^{t}\left(\frac{N_i}{T}\right)\left[log\frac{N_i}{T}+log\frac{1}{k_i}\right]}{log\frac{1}{\sum_{i=1}^{t}k_i}} \quad [6.3.4]$$

where k_i is the number of distinct alternatives in set *i,* N_i be the number of sampled individuals selecting alternative *i,* and *T* be the total number of sampled individuals.

The minimum ρ^2 index can be modified into *corrected* ρ^2 ($\bar{\bar{\rho}}_c{}^2$), which contains all desired properties making it analogous to R^2 used in linear regression analysis (Tardiff, 1976):

$$\bar{\bar{\rho}}_c{}^2 = 1 - \frac{LL(\theta)}{LL\ (\mathrm{C})} \quad [6.3.5]$$

More so, ρ^2 index can be adjusted by taking into account the degrees of freedom (*k*), an adjustment that is useful if there is need to compare different models (Ben-Akiva and Lerman, 1985; Louviere *et al.,* 2000).

$$\rho^2_{adj} = 1 - \frac{LL(C)-K}{LL\ (0)} \quad [6.3.6]$$

Equation [6.3.6] takes into account the number of parameters estimated. However, it is still based on the likelihood of the equally likely model so it maintains the main problems of ρ^2. McFadden's adjusted (ρ^2_{adj}) mirrors the adjusted R-squared in OLS by penalizing a model for including too many predictors. If the predictors in the model are effective, then the penalty will be small relative to the added information of the predictors. However, if a model contains predictors that do not add sufficiently to the model, then the penalty becomes noticeable and the adjusted R-squared can decrease with the addition of a predictor, even if the R-squared increases slightly. Note that negative McFadden's adjusted R-squared are possible (IDRE, 2013).

In summary, we should note that different pseudo R-squares can give very different assessments of a model's fit, and that there is no one version of pseudo R-square that is preferred by most data analysts over other versions (IDRE, 2013).

6.5.2.4. Hosmer-Lemeshow test

To avoid problems associated with the asymptotic distribution Pearson's chi-squared test, Hosmer and Lemeshow (1980,1989) developed a set of formal goodness-of-fit tests whereby observations are grouped into *G* groups and a chi-squared test is then estimated using the amalgamated cells. Prior to the observations being partitioned into *G* equal-sized groups (G = 10 in most cases), they are first sorted in increasing order of their ordered estimated event probability (Shah *et al.* 2003, Archer & Lemeshow, 2006). Specifically, the Hosmer-Lemeshow goodness-of-fit test is obtained by calculating the Pearson chi-square statistics from a table *G*x2 of observed and expected frequencies for the *G* equal-sized groups (Shah *et al.,* 2003). The statistic for the case of a simple random sample is defined as:

$$H_L = \sum_{g=1}^{G} \frac{(O_g - N_g \overline{\Pi}_g)^2}{N_g \overline{\Pi}_g (1 - \overline{\Pi}_g)} \qquad [6.3.7]$$

where N_g is the total frequency of observations in the *G-th* group, O_g is the total frequency of event outcomes in the *G-th* group, and $\overline{\Pi}_g$ is the average estimated probability of an event outcome for the *G-th* group. H_L follows a chi-square distribution with G-2 degrees of freedom (χ^2_{G-2}). In a binary regression model, we fail to reject the null hypothesis (i.e., the independent variables actually predict the actual probabilities of the model) if the p-value of the H_L is greater than the set level of significance (α). In addition, a higher value of the chi-square (χ^2) statistic is an indication that the performance of the overall model is not by chance (i.e., that the results contained in the model are less likely to be as a result of chance compared to a model with a lower χ^2. It however does not tell how much better the model is.

However, just like any other goodness of fit measure, the Hosmer-Lemeshow (H-L) test does not tell us anything about the extent of fit of a model. In addition, it is strongly influenced by the sample size. As the sample size gets large, the H-L statistic can find smaller and smaller differences between observed and model-predicted values to be significant. More so, there isn't a theory that guides the choice of the ideal number of equal-sized groups required to partition the number of observations. Hence, given its limitations, researchers are skeptical and currently question the validity of this test as a measure of goodness-of-fit for a binary model (Allison, 2013). Nonetheless, calibrated binary logit models for this study were still tested for the H-L test given that there hasn't been any recent development to this day.

6.5.2.5. ROC Curve

Another intuitively appealing way to assess the goodness-of-fit of a binary logistic regression model is to see what proportion of true positives it classifies as being positive (the *sensitivity*) and what proportion of true negatives it classifies as being negative (the *specificity*). Unfortunately, the output of a logistic regression is not a classification as positive or negative, but a predicted probability of being positive or negative. When comparing two binary models, the area under the ROC curve can be used as a measure to determine which model best fits the observed data. The ROC value ranges between zero (poor fit) and one (good fit). As the value approaches 1, this implies the model fits the observed data perfectly.

6.5.2.6. The Asymptotic t-test

The asymptotic t-test is one of several tests used to test the statistical significance of different parameter values from a known value – zero often being the case. This test is valid only asymptotically (for large samples) when considering nonlinear models such as logit and probit (Ben-Akiva and Lerman, 1985). If $\hat{\beta}$ is an estimator of parameter β in a statistical model, then the *t*-statistics is obtained:

$$t = \frac{\widehat{\beta} - \beta_0}{s.e.(\widehat{\beta})} \qquad [6.3.8]$$

where β_0 is a non-random, known constant and $s.e.(\widehat{\beta})$ is the standard error of the estimator $\hat{\beta}$. By default, statistical packages report *t*-statistic with $\beta_0 = 0$. Results of the *t* values determine if the null hypothesis is rejected or not. For larger sample sizes, the *t* distribution tends to resemble the *Z* distribution more and more until the two become identical for sample sizes greater than 120. As *N* increases, the sample standard deviation (s) becomes a more and more adequate estimator of the population standard deviation (α), and the t distribution becomes more and more like the Z distribution (Healey, 1999). In this case, rather than computing the t-statistic, the z-score is computed and the z-test used instead of the t-test. Table 6.2 shows the z-score for different confidence levels.

Table 6.2: z-score and confidence levels

z-score (t-values)	Confidence Level (%)
± 3.00	99.73
± 2.58	99.00
± 1.96	95.00
± 1.64	90.00

The current practice recommends the inclusion of highly important or policy variables relevant to the calibrated model (such as travel time, cost, etc.) with the correct sign even if it fails any significance test (typically with a z-score (t-value) greater than 1 or less than -1). The reason being that the estimated coefficient is the best approximation for its true value. The lack of its significance may just be due to lack of enough data or lack of enough variability of the attribute in the sample (Ortúzar and Willumsen, 1994).

Aside from the above measures put in place to tests and determine the goodness of fit of a model, other minor and less prescribed measures that can be considered include:

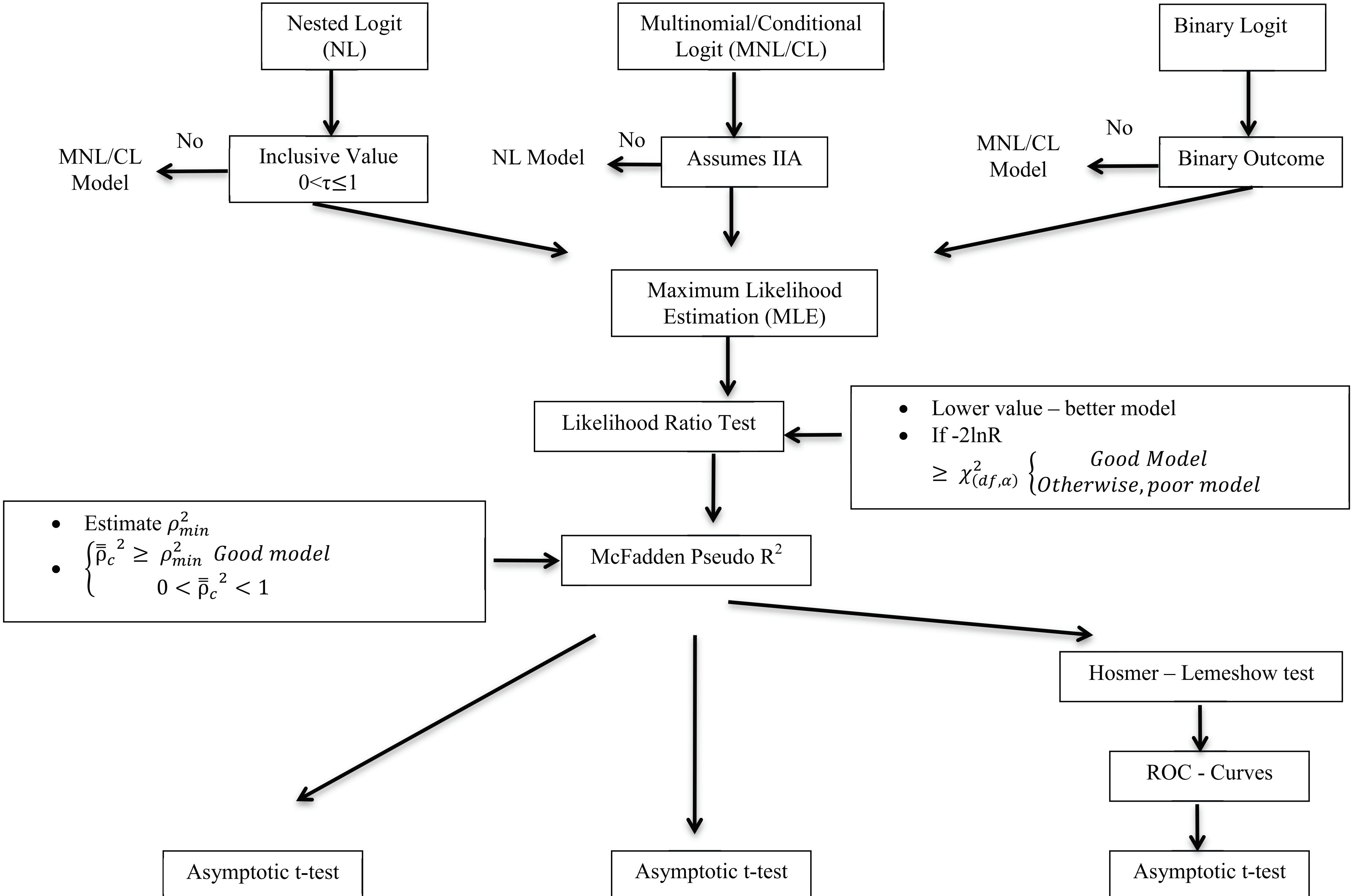
- Verifying that the signs of the coefficients are logical. For example, higher cost usually deter the use of a particular mode of transport, hence it should be negative. Important variables related to the course for which the study is being carried out should be maintained in the model regardless of whether they fail the significance test or not. However, less important variables related to the course of the study should be removed from the model if they are not significant at the 80% level or carry a wrong sign (Ortúzar & Willumsen, 1994).

- Including a constant in the model regardless of its magnitude or t-statistics. The constant accounts for the utility effects of miscellaneous factors not included in the model specification due to measurement and/or prediction difficulties. Though it should be zero under ideal circumstances, this is however not the case since it is impossible to explicitly address all decision-making factors in the model.
- Lastly, the value of the coefficients should be reasonably similar to those estimated for the same study in other studies especially those related to transportation. The assumption here is that individual travel behavior is fairly consistent irrespective of the area where the individual lives.

6.5.3. Summary

In this section, a discussion of the various measures of goodness of fit for a logit model was presented. Logit models are calibrated following the Maximum Likelihood Estimation (MLE) method. The likelihood ratio test that follows a chi-square distribution is ideal for testing the overall fitness of a model in the log likelihood function. The rho-square index is also used as an indicator of the fitness of a model though there is no adequate meaning of the values it produces. The asymptotic t-test is used to test the significance of the parameters contained in the model. Lastly, other less prescribed measures used include: verification of the coefficient signs, inclusion of a constant term and examination of similarity of coefficients with past similar studies. An overview of the steps involved in testing the goodness-of-fit of a model is shown in Figure 6.2 below.

Figure 6.2: GOODNESS-OF-FIT TESTS FOR DIFFERENT DISCRETE CHOICE MODELS



6.6. Applicable Software Packages

Microsoft (MS) Excel spreadsheet and STATA 12.0 were used throughout this research for data editing and model calibration. Microsoft excel was used primarily as the database for data entry and editing while STATA 12.0 was used for analyzing and calibrating the discrete choice utility models.

STATA 12.0 calibrates Logit models following the Maximum Likelihood Estimation (MLE) procedure. It has the capability to calibrate several different logit models such as binary logit, multinomial logit, conditional logit, and nested logit just to name a few. Data contained in MS excel spreadsheets where imported into STATA 12.0 and then calibrated using the appropriate logit commands. MS excel was used as a database entry/editing platform due to the ease and familiarity associated with the software. Given that the binary logit and the nested logit commands were used throughout this research for data analyses, a brief description of these commands is provided below.

6.6.1. Binary Logit Command

In STATA 12.0, the logit command is used to estimate the binary logit model. The command fits maximum likelihood models for which the dependent variables are dichotomously coded as 0/1 (StataCorp, 2011). STATA 12.0 interprets a value of 0 as a negative outcome (failure) and treats all other values (except missing) as positive outcomes (successes). Thus if your dependent variable takes on the values 0 and 1, then 0 is interpreted as failure and 1 as success. If your dependent variable takes on the values 0, 1, and 2, then 0 is still interpreted as failure, but both 1 and 2 are treated as successes. The general form of the binary logit command is as follows:

logit *dependent variable* [*independent variables*].

Below is an example of a binary logit command:

logit Y A B C

In the above command, Y represents the dependent variable while A B & C represent the various independent variables. These independent variables may be factor variables (categorical variables) or continuous variables. One additional feature possessed by the logit command in STATA 12.0 is that it automatically checks the model for identification and, if it is under-identified, it drops unwanted variables and observations not needed in the estimation procedure. The logit command in STATA 12.0 possess the following capabilities (StataCorp, 2011):

- It determines "one-way causation by dummy variables";
- It has the ability to identify "two-way causation" and give out warning messages in the event where this occurs;
- It has the ability to check for collinearity and produce warning messages of such situations;
- It has the ability to detect complex problems that can arise with continuous data;

6.6.2. Nested Logit Command

In STATA 12.0, the nested logit model is calibrated using the nlogit command. This command also calibrates models according to the maximum-likelihood estimation method. The command uses a parameterization that is consistent with the random utility maximization (RUM) theory. This permits it to calibrate models that reflect consumer behavior (StataCorp, 2011). The general form of the nested logit command is as follows:

nlogit *dependent variable* [*independent variables*] [|| *level 1 equation* [|| *level 2 equation…*]] || *alternative variable*: [*by alternative variable list*], case (*variable name*)

Below is an example of an nlogit command

nlogit A B C D || E: F G, base (H) || I:, case (J)

In the above command, letter A represents the dependent variable, letters B, C, D represent the independent variables at the base level of the nested tree, letter E represents the chosen alternative within the first level of the nested tree with variables F and G. Letter H represents the alternative set within the first level. Letter I represents the bottom level where the final decisions are made while J represents the various groups of cases.

7. DESCRIPTIVE STATISTICS

This chapter describes the characteristics of the sampled respondents collected from additional questions contained in each of the survey questionnaire. It begins with presenting characteristics of the sampled commuters followed by a presentation of the characteristics of the sampled business firms.

7.1. Characteristics of commuters who commute to the Central Business District of Ottawa

This section presents the demographic, socio-economic and commuting characteristics of the sampled respondents from a population of commuters who commute to the central business district of Ottawa. An overall description of the attitudes and perceptions with regards to some qualitative factors related to public transit as perceived by respondents is also presented.

7.1.1. Demographic Characteristics

Table 7.1 below represents the demographic characteristics of the sampled respondents from a population of commuters who commute to the central business district of Ottawa. Out of this sampled population, 59.2 % of the respondents were females while most of the respondents were aged between 35 years and 50 years (38.8%). Closely following this group were respondents between 20 and 34 years old. In terms of marital status, 56.7 % of the sampled population were either married or had a common-law partner. Lastly, 81.3% of respondents revealed that their households have at most two adults aged 16 and above while 35.7% of them stated that they had no kids aged 16 and under.

Majority of the respondents (57.1%) stated that they had at most two kids aged 16 and under within their households.

Table 7.1: Demographic Characteristics

Demographic Characteristics		
Variable	Variable Level	%
Gender	Male	40.8
	Female	59.2
Age Group	20 - 34 Years	36.8
	35 - 50 Years	38.8
	50 - 70 Years	24.3
Marital Status	Single/Divorced	43.2
	Married/Common-law	56.7
Household (HH)	At most 2 adults per HH aged above 16 years	81.3
	More than 2 adults per HH aged above 16 years	18.7
	No kids aged 16 and under	35.7
	At most 2 kids per HH aged 16 and under	57.1
	More than 2 kids per HH aged 16 and under	7.2

7.1.2. Socio-Economic Characteristics

Table 7.2 describes the socio-economic characteristics of the sampled population. Based on the data collected, 94.4% of the sampled respondents were full-time employees with 45.9% of them working within the public sector. Most respondents' occupations are within the classes of arts/social science/finance/administration (54.8%) according to the national occupation classification scheme[24]. In terms of individual income, 33.8% of the respondents earn between \$50,000 and \$75,000 per year with 22.6% and 21.1% of them earning between \$75,001 - \$100,000 and above \$100,000 per year respectively. 46.1% of the sampled population reported that they had access to at least two vehicles

[24] National Occupational Classification (http://www.hrsdc.gc.ca/eng/jobs/lmi/noc/index.shtml#tab2)

per household while 12.2% reported that they do not have access to any vehicle in their household. In the same vein, the households of 51.9% of the respondents have two other licensed drivers living with the respondent in the same household. Lastly, in terms of level of education, 42.5% of the respondents have achieved at least a bachelor's degree closely followed by a college diploma (23.5%). 1.3% of the sampled population did not complete high school.

Table 7.2: Socio-Economic Characteristics

Socio-economic Characteristics		
Variable	Variable Level	%
Employment Status	Full Time	94.4
	Part time	5.6
Employment Sector	Public	45.9
	Private	40.8
	Non-Profit	13.4
Respondent's Class of Occupation	Management/Executive	20.8
	Natural Science/Engineering	21.5
	Arts/Social Science/Finance/Administration	54.8
Access/Ownership of Vehicle	0 Vehicles	12.2
	1 Vehicle	41.7
	2 Vehicles or more	46.1
Number of Licensed Drivers per HH	None	2.6
	1	25.6
	2	51.9
	3 or more	19.9
Individual Income Level	Under $35,000	8.3
	$35,001 - $50,000	14.3
	$50,001 - $75,000	33.8
	$75,001 - $100,000	22.6
	Above - $100,000	21.1
Education Level	Did not complete High School	1.3
	High School Completion	10.5
	College Diploma	23.5
	Bachelor's Degree	42.5
	Master's Degree	19
	PhD or other Doctoral Level Degree	3.3

7.1.3. Commuting Characteristics

The commuting characteristics of the sampled population are shown in Table 7.3 below. Based on the data obtained, 51% of the sampled population commutes by public transit; 29.3% commute by automobile (18.5% drive alone; 10.8% carpool) and 19.7% of the commuters commute by non-motorized mode, which include either walking/cycling/skating/rollerblading. 24.5% of the respondents live within 6 – 10 km away from their offices on a one-way trip, with the second majority of respondents (19.9%) living within 0 – 5 km away from their offices. In terms of commuting cost, carpool commuters pay between \$0.00 - \$20.00 per week while 26.8% of single occupant vehicle commuters spend between \$61.00 to \$80.00 per week. 71.6% of commuters who commuted with public transit own a monthly bus pass. In terms of access/egress time, 64.5% of the respondents spend less than 5 minutes to access/egress their mode of transport. At the same time, majority of the respondents (54.3%) also spend less than 5 minutes at their bus stops/station while waiting for their bus. Lastly, 84% of the respondents have access to a direct mode of transport between their homes and their workplaces without the need to transfer from one mode to another while 16% of the respondents make at least one transfer from one mode of transport to another (e.g. from car/bicycle to bus or from bus to bus).

Table 7.3: Commuting Characteristics

Commuting Characteristics		
Variable	Variable Level	%
Current Mode used for Commuting	Auto (Drive Alone)	18.5
	Auto (Carpool)	10.8
	Bus Transit	51
	Non-Motorized Mode	19.7
One-way Commuting Distance	0 km – 5 km	19.9
	6 km - 10 km	24.3
	11 km - 15 km	17.8
	16 km - 20 km	17.8
	21 km - 25 km	11.8
	26 km - 30 km	5.9
	Above 30 km	2.6
Weekly Cost incurred (Auto)	$0.00 - $20.00[25]	29.3
	$21.00 - $40.00	12.2
	$41.00 - $60.00	9.8
	$61.00 - $80.00	26.8
	$81.00 - $100.00	19.5
	Above $100,000	2.4
Fare - Bus Transit Users	$2.60 - $3.30	18.5
	$3.31 - $4.65	8.6
	Day Pass ($7.75)	1.2
	Monthly Pass (Average $96.50	71.6
Access/Egress Time	0 mins - 4 mins	64.5
	5 mins - 9 mins	28.1
	10 mins - 15 mins	7.4
Current Bus Wait Time	1 min - 5 mins	54.3
	6 mins - 10 mins	39.5
	11 mins - 15 mins	4.9
	16 mins - 20 mins	1.2
Number of Transfer made from one Mode to another	0 Transfers	84
	At least 1 Transfer	16

[25] Carpool Commuters

7.1.4. Attitude and Perception of respondents towards public transit

A seven-point scale was used to measure respondents' attitudes and perceptions towards certain important qualitative attributes that were difficult to quantify such as the flexibility, reliability, comfort alongside other factors associated with the use of public transit for commuting. This was done in order to obtain an insight of what people think about certain qualitative aspects of public transit given that the forth-coming light rail transit (LRT) will also form part of a public transit system. Table 7.4 below shows the results obtained from the collected data.

Table 7.4: Perceptions and Attitudes of respondents regarding certain qualitative factors associated with public transit measured on a seven-point scale.

Factor	Mean	Median	Std. Dev. of Mean	*N*
Reliability of Public Transit	4.86	5.00	1.38	157
Flexibility of Public Transit	4.19	4.00	1.68	156
Degree of Comfort offered by Public Transit	3.25	3.00	1.51	157
Is Public Transit an Eco-Friendly mode for commuting?	5.49	6.00	1.49	156
Is Public Transit a Secure Mode for commuting?	3.92	4.00	1.56	156
Is Public Transit the cheapest mode available for commuting?	4.25	5.00	1.89	157
Does commuting by walking/cycling/Skating help in exercising?	5.97	6.00	1.54	155

Note: '1' denotes strongly disagree while '7' denotes strongly agree

From the results above, respondents find public transit to be somewhat reliable for use for commuting. However they are neutral about the flexibility offered by public transit when it comes to using it for commuting as well as using it to meet their other daily activities. The respondents find public transit to be somewhat uncomfortable when used for commuting. Nonetheless, they tend to agree that it is an eco-friendly mode when used for commuting. In terms of cost, respondents neither tend to agree nor disagree that public transit costs relatively less compared to other modes of transport. However, they tend to perceive public transit not to be the most secured mode of transport available for commuting. Lastly, respondents generally agree that they would benefit from the exercising gained in the process of commuting by non-motorized modes (walking/cycling/skating).

As shown in Table 7.5, majority of the commuters (54.3%) find the use of public transit for commuting to be somewhat to very uncomfortable.

Table 7.5: Comfort Level of Public Transit by In-vehicle Commute Time

Level of Comfort of Public Transit	Commute Time			
	0 - 25 mins.	26 - 50 mins.	51+ mins.	Total
Somewhat to very uncomfortable	52.2%	56.0%	57.2%	54.3%
Neutral	20.3%	25.3%	14.3%	22.5%
Somewhat to very Confortable	27.5%	18.6%	28.6%	23.3%
	100.0%	100.0%	100.0%	100.0%
	Gamma value = -0.037	*p = 0.097*		
	Pearson chi^2 = 138.13	*p = 0.00*		

A p-value < 0.1 indicates that there is a relationship between the length of commuting time and the degree of ride comfort offered by the current public transit system. The negative sign associated with the gamma value reveals that as commute time increases, people tend to find it very uncomfortable to commute using the current public transit.

In order to obtain an insight of how respondents perceive the reliability of the current public transit system, a cross-tabulation between their current modes used for commuting and their perception of the reliability of public transit measured on a seven-point scale was generated (see Table 7.6).

Table 7.6: Level of Reliability of Public Transit by Current Commute Mode

Level of Reliability of Public Transit	Current Commute Mode				
	Auto (Drive Alone)	Auto (Carpool)	Bus	Non-Motorized	Total
Somewhat to very Unreliable	20.6%	29.4%	11.2%	19.4%	16.5%
Neutral	13.8%	17.6%	13.8%	19.4%	15.3%
Somewhat to very Reliable	65.4%	52.9%	75.0%	61.4%	68.1%
	100.0%	100.0%	100.0%	100%	100.0%

Pearson $chi^2 = 384.49$ $p = 0.00$

Overall, 68.1% respondents tend to agree that the current public transit system is somewhat to very reliable with about 75% of them being current bus commuters. However, in terms of flexibility offered by public transit, Table 7.7 shows that respondents who commute by driving alone are 1.89 times (58.6/31) less likely to find public transit as a flexible mode useful for other activities other than commuting. Overall, in comparing the level of reliability and flexibility of the current public transit, most commuters would rely on public transit for commuting. However, they are less likely to rely on its use for carrying out other activities such as shopping, leisure, visit to the hospital, etc.

Table 7.7: Level of Flexibility of Public Transit by Current Commute Mode

Level of Flexibility of Public Transit	Current Commute Mode				
	Auto (Drive Alone)	Auto (Carpool)	Bus	NMM	Total
Somewhat to very Inflexible	58.6%	31.2%	25.1%	38.7%	34.6%
Neutral	10.3%	25%	12.5%	29%	16.7%
Somewhat to very Flexible	31%	43.7%	62.5%	32.3%	48.7%
	100.0%	100.0%	100.0%	100%	100.0%

Pearson $chi^2 = 949.08$ $p = 0.00$

7.2. Characteristics of Business Firms within the City of Ottawa Municipality

This section presents an overview of the characteristics of the sampled respondents from a population of office managers and their business firms within the City of Ottawa municipality.

7.2.1. Executive Characteristics

The characteristics of the sampled respondents from a population of office managers and their business firms within the City of Ottawa municipality are shown in Table 7.8 below. Out of all the respondents, 78.4% of them held the position of Manager/CEO/Partner/President within their business firms while the rest belonged to a group that held other high profile positions within the company such as assistant manager, financial adviser, engineering manager, chief operating officer, just to name a few. In terms of their role played in the decision-making process regarding the siting of their office space within the Ottawa municipal area, 54.9% of the managers tend to somewhat have very strong influence in the decision making process; 19.6% of them are neutral while 25.5 % of them somewhat have very little influence in the decision making process. Also, with regard to the role played by the respondents in the office location/relocation decision-making process, Table 7.9 shows a mean of 4.67 and a median of 5 based on a seven-point scale rating system. This implies that decisions made regarding where to locate/relocate an office are not be based solely on office managers, although they do have some influence over the decision-making process. Regarding the adoption of a telecommuting program, 35.4% of all sampled companies currently have an existing telecommuting program while 16.7% of executive managing companies without a telecommuting program have sometimes thought of introducing a telecommuting program. Amongst the total number of sampled companies, 10.4 % of the executive stated that it is impossible for their employees to telecommute (hence, impossible for them to introduce a telecommuting program), while 8.3 % of them stated that their companies are currently working towards developing and adopting a telecommuting program for its employees. Table 7.9.1 shows a mean of 4.79 and a median of 5 based on a seven-point scale rating system implying that office managers have sometimes thought of adopting a telecommuting program for their employees. However, making the final decision regarding its implementation is not dependent solely on their decisions.

Table 7.8: Executive Characteristics

Characteristic	**Categories**	**Relative Frequency (%)**
Post of Respondent	Manager/CEO/Partner/President	78.4
	Other (e.g. Assistant manager, COO, Financial Adviser, Engineering Manager, etc.)	21.6
Respondent's Influence on office location/relocation decision making process	Least Influence	25.5
	Neutral	19.6
	Most Influence	54.9
Introducing a telecommuting program for employees	It is impossible for my employees to telecommute	10.4
	Never thought of it	4.2
	Rarely thought of it	14.6
	Sometimes thought of it	16.7
	Definitely thought of it	10.4
	Working towards developing one	8.3
	Currently have an existing telecommuting program	35.4

Table 7.9: Respondent's influence on office location/relocation decision-making using a seven-point scale

Respondent's Influence on office location/relocation decision making	Median	Mean	Standard Deviation of Mean
	5	4.67	2

Note: '1' denotes least influence and '7' denotes most influence
N = 51

Table 7.9.1: Thoughts of adopting a telecommuting program for employees using a seven-point scale

	Median	Mean	Standard Deviation of Mean
Thoughts of Introducing a Telecommuting Program for Employees	5	4.79	2.1

Note: '1' denotes impossible to adopt a telecommuting program and '7' denotes working towards adopting a telecommuting program
N = 48

Table 7.9.2 shows the methods of supervision used by managers to supervise their employees measured on a seven-point scale. Amongst the methods considered, the method used frequently by managers to supervise their employees is by reviewing their assigned tasks upon completion. They also often use meeting reviews and on-site supervision to supervise their employees. Mangers less often review written reports as a means of supervising their employees. Drawing from this analysis, it seems as though managers tend to prefer using methods of supervision that would keep them in close contact with their employees as much as possible.

Table 7.9.2: Methods of supervision used by employers to supervise their employees using a seven-point scale

Methods of Supervision	Median	Mean	Standard Deviation of Mean	N
Review of completed task	6	5.32	1.6	50
Meeting Reviews	5	4.76	1.7	51
On-site Supervision	5	4.48	1.9	52
Timesheets	5	4.13	2.5	52
Activity logs	4	4.04	2.0	51
Written Report	4	3.57	1.9	51

Note: '1' denotes 'Never Used' and '7' denotes ' Used Very Often'

7.2.2. Organizational Characteristics

With respect to the composition of the employee work force within the sampled business firms, 48.1 % of the executives indicated that a greater percentage (above 60 %) of their employees are professionals (i.e., hold professional licenses in their field of practice) and 92.3% of them indicated that their employees rely on the use of telecommunications and information technology to facilitate their work. Face-to-face interaction was acknowledged by majority of the executives (59.6%) as an important factor in carrying out business transactions while 21.2% of them were neutral to the idea. 19.2% do not regard face-to-face interaction as an integral part of running a business on daily basis. In general, Table 7.9.3 shows that respondents found face-to-face interaction to be a very important factor in carrying out successful business transactions, although some managers may hold some discretion.

Table 7.9.3: Importance of face-to-face interaction in doing business measured on a five-point scale

Importance of face-to-face Interaction in doing business	Median	Mean	Standard Deviation of Mean	N
	4	3.63	1.2	52
1 denotes 'Not important at all' and 5 denotes 'Extremely Important'				

In order to get an understanding of the degree of flexibility of the working environment within most business firms, the survey sought to inquire if employees were allowed to access their office work from anywhere else other than from their office. 98% of the executives responded that their companies allow employees to access work from anywhere through telecommunication media such as email, video-conferencing, fax machines, telephones, etc. besides being in the office. In terms of amount paid out as monthly rental cost, 24.5% of the executives stated that their companies currently own their office building while for those companies that lease space, 24.4% of them pay under $3,000 per month for lease. The primary activity of 51% of the sampled companies fall within the categories of finance, accounting, sales, marketing, law, public relations and customer support while the rest fall within the category of information technology, high-tech and engineering. Most companies surveyed fall under the small to medium size categories in terms of number of employees with 66.7% of the executives indicating they supervise less than five employees.

Table 7.9.4: Organizational Characteristics

Characteristics	Categories	Relative Frequency (%)
Percent composition of Professional Employees within company	Less than 20%	15.4
	21 to 40 %	13.5
	41 to 60 %	23.1
	Above 60 %	48.1
Percent reliance on the use of telecommunication and technology to facility work	Less than 20% of the time	1.9
	41 - 60 % of the time	5.8
	Above 60 % of the time	92.3
Importance of Face-to-Face Interaction	Not Important	19.2
	Neutral	21.2
	Very Important	59.6
Are employees allowed to access work from other places other than office?	Yes	98.0
	No	2.0
Length of stay at current address	Less than 15 Years	51.9
	More than 15 Years	48.1
Current location of company	Central Ottawa	76.9
	Satellite Community	23.1
Monthly lease cost ($)	0 - 3000$	24.4
	3001 - 5000$	14.3
	5001 - 10000$	20.4
	Above $10000	16.3
	Company owns space	24.5
Primary Activity of Company	IT/High Tech/Engineering	49.0
	Other (Finance, Accounting, Sales, Marketing, Law, etc..)	51.0
Number of Employees	Under 10 employees	40.4
	11 - 50 employees	44.3
	Over 51 employees	15.4
Number of under manager's direct supervision	0 - 5 employees	66.7
	> 5 employees	33.3

To determine if the adoption of a telecommuting program had any impact on any office location choice within the Ottawa municipality, office managers who recently experienced a relocation of their office address within the last 15 years were asked to select from amongst a list of options, their primary reason for relocating. From Table 7.9.5 below, 42.5% of the offices relocated for strategic business reasons and not one of the surveyed offices (0%) reported to have moved following decisions made to introduce a telecommute program. In terms of their current location, 76.9% of the surveyed companies are currently located within central Ottawa. In the same vein, 51% of the executives indicated that their companies have been located at their current location for less than 15 years counting from the moment the company was established or ever since it carried out its last relocation.

Table 7.9.5: Reasons for Relocating Offices within the Ottawa Municipality within the past 15 years

Reasons	**Frequency**	**Valid Percent**
Thoughts of introducing and/or following the introduction of a Telecommuting Program	0	0
To be closer to where employees live	1	2.5
To reduce overhead cost	9	22.5
To be closer to clients	1	2.5
For strategic business reasons	17	42.5
Needed more room	4	10.0
Other needs (e.g, end of lease)	8	20.0
Total valid responses	**40**	**100.0**
No Response	**12**	

8. COMMUTING MODE CHOICE MODELS

Knowledge of the percentage of travelers/commuters that use a particular mode of transport is an integral part of transportation demand and supply management. It helps to provide information regarding what transportation services are in high demand and identifies areas where the supply of transportation services is required. In this chapter, a modal split for all modes of transport that access the central business district was estimated taking into account the forth-coming LRT mode. In addition, in order to determine what percentages of commuters are likely to shift from using their current mode of transport to the newly proposed LRT mode, a modal shift analysis was carried out. The models were calibrated using data collected from the commuters' mode stated preference (SP) survey. Both modal split and modal shift models were based on the theory of random utility. The modal split model was calibrated following a nested logit model while the modal shift model was calibrated following binary choice models.

8.1. Data Preparation and Coding

This section presents an overview of how the data collected following the launching of the final survey was prepared and coded for statistical analysis.

8.1.1. Dependent Variable

The dependent variable for the model was the preferred mode of transport chosen by the respondent presented in each SP hypothetical choice set scenario. In each scenario, the preferred mode of transport amongst all four alternatives selected by the respondent was coded as '1' and '0' otherwise.

8.1.2. Independent Variables

The independent variables considered included alternative-specific variables that described the characteristics of each alternative mode of transport contained in each hypothetical SP choice set alongside three individual specific variables. Table 8.1 below shows the alternative-specific as well as the individual-specific variables considered in the calibration of the modal split model.

Table 8.1: Independent Variables – Commuters' Mode Preference Survey

	Variables	Variable Type	Code
Alternative Specific Variables	In-vehicle Travel Time (minutes)	Continuous	-
	Cost/Fare ($)	Continuous	-
	Accessibility (minutes)	$\leq$ 5 mins	1
		> 5 mins	0
	Service Frequency (minutes)	Continuous	-
Individual Specific Variables	Income ($)	Under $ 50,000	0
		$50,001 - 100,000	1
		Over $ 100,000	2
	Car Ownership	Continuous	-
	Educational Level	High school or college diploma	0
		Bachelor's Degree	1
		Postgraduate Degree (Master's/Doctorate)	2
	Distance (km)	Continuous	-

The derivation of the in-vehicle travel time variable (minutes) took into account the commute time for each mode of transport alongside its associated delay/travel time variability component that were contained in each hypothetical SP choice scenario matrix. Using a Monte Carlo simulation based on random number generation, random numbers within the boundaries of each associated delay/travel time variability component were calculated and added to the commute time in order to come up with an estimate of the in-vehicle travel time. Equation [8.1.1] below was used to estimate the minimum sample size required in other to obtain accurate results with some level of precision.

$$n = \left(\frac{Z \times \alpha}{\varepsilon}\right)^2 \qquad [8.1.1]$$

Where:

n = Minimum sample size

Z = number of standard deviations corresponding to the required confidence level (± 1.96 for 95% confidence level)

α = Standard deviation

ε = limit (tolerance) of acceptable error in the estimation

At the start of the process, given that a value for the standard deviation (α) was unknown, a commuting time alongside its associated delay/travel time variability was selected at random from the hypothetical SP choice sets presented to the respondents. The randomly selected commuting time was 17 minutes (± 8 minutes). Using this randomly selected value with upper and lower limits set at ± 8 minutes, different values of the standard deviation (α) and the mean (μ) were calculated using a Monte Carlo simulation. Table 8.2 below shows the results obtained following a Monte Carlo simulation of 500 runs (100 simulations per run).

Table 8.2: Results of Monte Carlo Simulation – commuting time

Run Number	Number of Simulations	Standard Deviation (α)	Mean (μ)	Percentage (%) of α in μ
1	100	3.08	16.38	18.80
2	100	3.00	16.33	18.30
3	100	2.99	16.76	16.53
4	100	3.20	16.36	19.56
5	100	3.01	16.55	18.19
Average percentage of α in μ				18.276

The goal was to obtain an estimation of what percentage of the standard deviation (α) is contained in the mean (μ) of the commuting time. Knowing this percentage, the standard deviations (α) of the different commuting times describing each mode of transport were estimated. A value of 5% was assumed to be the tolerance (ε) for the value of each commuting time. Using equation [8.1.1] above, an estimate the minimum number of sample size needed to obtain a fairly accurate value of the commuting time with a 95% confidence level of precision for each mode of transport taking into account travel time variability and delay was calculated. Table 8.3 below shows various values of the parameters in equation [8.1.1] for each commuting travel time and the minimum number of runs required (rounded to two significant figures).

From Table 8.3 below, a sample of 52 random numbers was generated within the range of each travel time variability/delay associated with each commute travel time. An average was then taken following this sample generation. This average value represented the average delay/travel time variability for each travel time. This value was added on to the commute travel time in order to obtain the in-vehicle travel time. The values of the in-vehicle travel times are shown in Table 8.4 below and were used in the model calibration.

Table 8.3: Minimum Sample Size required for estimating the in-vehicle commuting time

Commute travel time with variability/delay (minutes)	Z	α	ε	n
6 mins (± 4 mins)	1.96	1.10	0.30	52
7 mins (± 1 min)	1.96	1.28	0.35	52
8 mins (± 6 mins)	1.96	1.46	0.40	52
12 mins (± 5 mins)	1.96	2.19	0.60	52
13 mins (± 2 mins)	1.96	2.38	0.65	52
14 mins (± 8 mins)	1.96	2.56	0.70	52
15 mins (± 1min)	1.96	2.74	0.75	52
17 mins (± 8 mins)	1.96	3.11	0.85	52
20 mins (± 5 mins)	1.96	3.66	1.00	52
23 mins (± 0 mins)	1.96	4.20	1.15	52
26 mins (± 0 mins)	1.96	4.75	1.30	52
30 mins (±1 min)	1.96	5.48	1.50	52

Table 8.4: Estimated In-vehicle Travel Time taking into account travel time variability and delay

Commute Travel Time with Variability and Delay	Estimated In-vehicle Travel Time (minutes)
6 mins (± 4 mins)	5.33
7 mins (± 1 min)	7.10
8 mins (± 6 mins)	8.00
12 mins (± 5 mins)	12.07
13 mins (± 2 mins)	13.36
14 mins (± 8 mins)	14.30
15 mins (± 1min)	14.93
17 mins (± 8 mins)	16.10
20 mins (± 5 mins)	19.41
23 mins (± 0 mins)	23.00
26 mins (± 0 mins)	26.00
30 mins (±1 min)	30.05

8.2. Modal Split Model

The proposed LRT system would bring about a change in the modal split within the CBD of Ottawa. Forecasting this modal shift is of great importance given that it would provide an insight into the assessment of the transportation system, travel planning, modeling and lastly, it would provide a new forum for more research to be carried out. A nested logit model was used to calibrate the modal split model using observed data collected from the SP surveys provided by the sampled respondents.

8.2.1. Rationale for choosing the Nested Logit Model

The Multinomial Logit Model (MNL) structure has been widely used for both urban and intercity mode choice models primarily due to its simple mathematical form, ease of estimation and interpretation, and the ability to add or remove choice alternatives. However, the MNL model has been widely criticized for its Independence of Irrelevant Alternatives (IIA) property (see section 6.3.2). The IIA property of the MNL restricts the ratio of the choice probabilities for any pair of alternatives to be independent of the existence and characteristics of other alternatives in the choice set. This restriction implies that introduction of a new mode of transport or improvements to any existing mode should reduce the probability of existing modes of transport in proportion to their probabilities before the change i.e., the IIA property associated with MNL models implies that their application in the calibration of modal split models takes into account the assumption that all ground modes of transportation are equal and compete with each other fairly. However, making such an assumption is inappropriate given that in reality, not all ground modes of transport compete with each other. For example, bus transit may compete with the LRT since they belong to the same group of public transit but it may be inappropriate to model bus transit and automobile as modes of transport that compete with one another given that both modes offer different service levels and have different characteristics.

Considering the four modes of transport included in the SP experiment of this study, the bus and light rail transit (LRT) alternatives are likely to be more similar to each other when compared to the other alternatives due to attributes they share in common. Examples of common attributes shared bus and light rail may include: the same fare structure and operating policies, they offer a means for mass transportation, they operate on a schedule, and so on. Omitting these similarities from the measured (systematic) portion of the utility function and grouping them together would lead to correlation between the random errors associated with these alternatives – a major violation of the assumptions which underlie the derivation of the MNL.

The IIA property of MNL models often results in inconsistent calibration of models according to the random utility maximization theory, most especially with models involving alternatives that often compete closely with each other and share common similarities. Hence, by making a different assumption about the behavior of the error component of the utility equation, the nested logit (NL) model described in section 6.4 was developed and used in the calibration of the modal split model for this study.

8.2.2. Structure of Modal Split Models

The selection of a preferred nesting structure requires a combination of judgment (about reasonable nesting structures) and statistical hypothesis testing. Considering the four alternative modes of transport included in this study, several different patterns could be tested to derive a nested tree structure applicable for calibrating the model. However, based on judgmental analysis, some unfeasible nesting structures (e.g. placing automobile and bus or non-motorized-mode and LRT in the same nest) were eliminated in order to test for a smaller number of more realistic structures. The nested structures tested were based on the perceived competitive relationships amongst the alternatives.

8.2.2.1. Formulation of Nested Structures

Structure I

The first nested structure considered in the calibration of the modal split model using the collected data is shown in Figure 8.1. The structure was a two-level nested structure and classified the various modes of transport considered into two nests: Public Transport versus Private Transport. The lower level composed of the mode choice alternatives (LRT, Bus, Automobile and Non-Motorized mode) while the upper level composed of public and private transport modes.

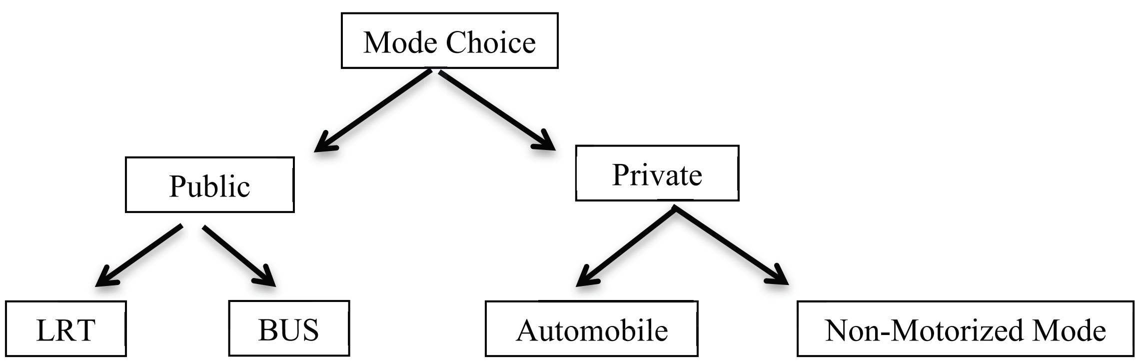


Figure 8.1: Nested Structure – I

The idea surrounding the classification of the nested logit structure in the above manner was based on the assumption that the LRT and bus are more likely to share common characteristics as well as automobile and Non-motorized mode. However, although the nested logit model calibrated the observed collected data with some satisfaction following the above structure, some variables in the calibrated model turned out to be insignificant (See Table 3 – F, Appendix F).

Structure II

A second nested structure tested for this study is shown in Figure 8.2 below. The structure was also a two-level nested structure. For this tree, the LRT and bus alternatives were grouped into one nest (public) while automobile and non-motorized mode alternatives were considered as degenerate nests[26].

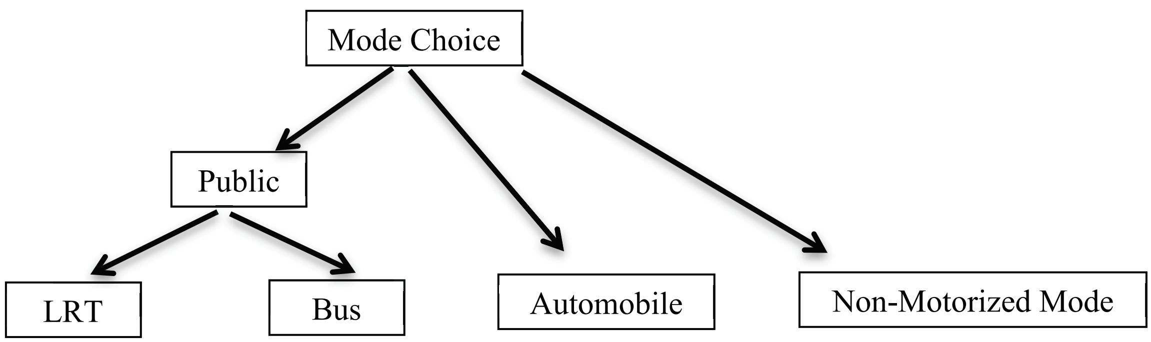


Figure 8.2: Nested Structure II

However, although the nested logit model calibrated the observed collected data with some satisfaction following the above structure, most of the variables in the calibrated model were insignificant (see Table 4 – F, Appendix F).

[26] A degenerate nest is one that contains only one alternative.

Structure III

The quest for a nested logit structure that fitted the observed data collected from the mode choice SP survey led to the consideration of a three-level nested logit tree structure shown in Figure 8.3.

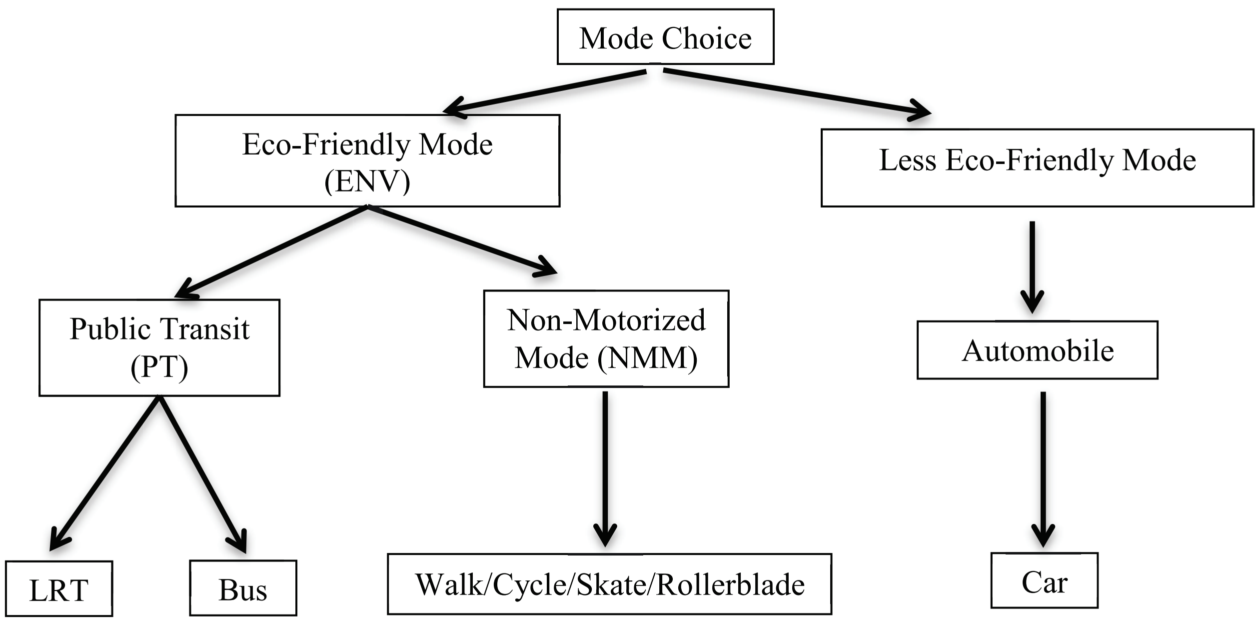


Figure 8.3: 3-level Nested Logit Mode Choice Model for Commuting Trips made to Central Ottawa

The idea surrounding the formulation of the above nested logit structure was as follows: considering we live today in a period of increasing environmental consciousness, it was reasonable to model the mode choices of commuters based on how environmentally conscious they are to the society. The nesting structure composed of three levels: At the first level of decision-making, commuters may choose between commuting by: (1) using an environmental (eco-friendly) mode or (2) using a less environmental (less eco-friendly) mode. This category formed the top-level nests of the nested structure and the modes within each category were assumed to share some similarities amongst them.

For example, some characteristics of an eco-friendly modes include: they transport more people per unit area, they result in an overall reduction in emissions per unit person transported and they may be cheaper compared to less eco-friendly modes. Hence, there is bound to be a correlation of the error terms within this nest. Meanwhile the less eco-friendly nest is a degenerate nest which contains only the automobile alternative. At the second level of the nested structure, the eco-friendly mode was divided into two categories: public transit and non-motorized modes. This implies, a commuter who decides to commute by an eco-friendly mode could choose between taking public transit or using a non-motorized mode (e.g walk, cycle, skate, or rollerblade). The public transit nest is a binary choice between Light Rail Transit and Bus while the non-motorized nest is a degenerate nest. The LRT and the bus share the same nest since they share common characteristics such as fare, mass transportation, similar policies, etc. In general, the nested tree was created in a manner such that elements within the same nests shared some level of similarity and therefore, were bound to somehow have correlated error terms.

In deciding amongst the three nested structures described above, the McFadden ρ^2 was used as a basis to measure how each of the above nested structures fitted the observed data. Equation (6.3.4) in section (6.5.2.3) was used to calculate the minimum ρ^2. The estimated ρ^2 obtained from the calibrated models for each of the above nested structures were then compared with reference made to the minimum calculated ρ^2. Table 8.5 below shows the results obtained.

From the results shown in Table 8.5 below, although none of the nested structures met the minimum ρ^2 required, the nested logit model described by structure III was the best structure that fitted the observed data given that it has the highest estimated ρ^2 value closest to the minimum ρ^2. Hence, the modal split model was calibrated following nested structure III.

Table 8.5: Comparison of Nested Structures based on McFadden ρ^2

Nested Structure	**Minimum ρ^2**	**Estimated ρ^2**
Structure I	0.2862	0.031
Structure II	0.2862	0.179
Structure III	0.2862	0.266

8.2.3. Modal Split Model Calibration

8.2.3.1. Probabilities of Mode of Transport Alternatives

The general approach for estimating the probability associated with each alternative in a two-level nested logit model is presented in section 6.4.3. However, considering that the nested tree used to calibrate the modal split for this study is composed of three levels, the probability associated with each mode were estimated through the application of an extension of the concepts presented in section 6.4.3. Once more, the general utility (U_{iq}) is represented as:

$$U_{iq} = V_{iq} + \in_{iq} \qquad [8.1.2]$$

In the specific case of a random utility maximization nested logit framework, the utility obtained by decision-maker q from consuming alternative i can be obtained by the following utility equation (Heiss, 2002):

$$U_{iq} = V_{iq} + \in_{iq} = \alpha_i + x_{iq}\beta_i + z_q\gamma_i + \in_{iq} \qquad [8.1.3]$$

where V_{iq} is the deterministic part of the utility and $\in_{iq}$ is the random part; x_{iq} represents the alternative-specific variables and z_q are individual/case specific variables. Lastly, γ and β are parameters. The utility equations for each of the four alternative transport modes in the nested logit structure (Figure 8.3) could be represented as follows:

$$\begin{aligned} U_{car} &= V_{car} + \in_{car} \\ U_{NMM} &= V_{ENV} + V_{NMM} + \in_{ENV} + \in_{NMM} \\ U_{Bus} &= V_{ENV} + V_{PT} + V_{Bus} + \in_{ENV} + \in_{PT} + \in_{Bus} \\ U_{LRT} &= V_{ENV} + V_{PT} + V_{LRT} + \in_{ENV} + \in_{PT} + \in_{LRT} \end{aligned} \quad [8.1.4]$$

The probabilities of the light rail transit (LRT) and the Bus, based on the choice of public transit (PT) are given by:

$$P_{Bus|\,PT} = \frac{e^{V_{Bus}/\lambda_{PT}}}{e^{V_{Bus}/\lambda_{PT}} + e^{V_{LRT}/\lambda_{PT}}} \quad [8.1.5]$$

$$P_{LRT|\,PT} = \frac{e^{V_{LRT}/\lambda_{PT}}}{e^{V_{Bus}/\lambda_{PT}} + e^{V_{LRT}/\lambda_{PT}}} \quad [8.1.6]$$

where λ_{PT} = is the dissimilarity parameter at the lowest (i.e., public transit) level.

The conditional probabilities of selecting between a non-motorized mode (NMM) ($P_{NMM|\,ENV}$) and public transit (PT) $\left(P_{PT|\,ENV}\right)$ at the second nested-level given that a commuter chooses an eco-friendly (ENV) mode are given by:

$$P_{NMM|\,ENV} = \frac{e^{V_{NMM}/\lambda_{ENV}}}{e^{V_{NMM}/\lambda_{ENV}} + e^{(V_{PT} + \lambda_{PT}\Gamma_{PT})/\lambda_{ENV}}} \qquad [8.1.7]$$

$$P_{PT|\,ENV} = \frac{e^{(V_{PT} + \lambda_{PT}\Gamma_{PT})/\lambda_{ENV}}}{e^{V_{NMM}/\lambda_{ENV}} + e^{(V_{PT} + \lambda_{PT}\Gamma_{PT})/\lambda_{ENV}}} \qquad [8.1.8]$$

where λ_{ENV} = the dissimilarity parameter for the intermediate level (i.e., for the eco-friendly modes)

Γ_{PT} = the dissimilarity parameter of the exponents of the nested utilities for the lower nest level.

$$\Gamma_{PT} = \ln\left[e^{V_{Bus}/\lambda_{PT}} + e^{V_{LRT}/\lambda_{PT}}\right] \qquad [8.1.9]$$

Finally, the probabilities of selecting between a less eco-friendly mode (car) and an enviro-friendly mode (ENV) nest are given by:

$$P(car) = \frac{e^{V_{car}}}{e^{V_{car}} + e^{(V_{ENV} + \lambda_{ENV}\Gamma_{ENV})}} \qquad [8.2.0]$$

$$P(ENV) = \frac{e^{(V_{ENV} + \lambda_{ENV}\Gamma_{ENV})}}{e^{V_{car}} + e^{(V_{ENV} + \lambda_{ENV}\Gamma_{ENV})}} \qquad [8.2.1]$$

where λ_{ENV} = the dissimilarity parameter for the intermediate level (i.e., for the enviro-friendly modes), and

Γ_{ENV} = the dissimilarity of the exponents of the nested utilities for the intermediate nest.

$$\Gamma_{ENV} = \ln\left[e^{V_{NMM}/\lambda_{ENV}} + e^{(V_{PT} + \lambda_{PT}\Gamma_{PT}/\lambda_{ENV}}\right] \qquad [8.2.2]$$

Hence, the marginal probabilities of non-motorized mode, light rail transit and bus are the product of the probabilities of each branch from the root (to the top of the tree) to the alternative:

$$P(NNM) = P_{NMM|\,ENV} \times P(ENV)$$

$$P(LRT) = P_{LRT|\,PT} \times P_{PT|\,ENV} \times P(ENV) \quad [8.2.3]$$

$$P(Bus) = P_{Bus|\,PT} \times P_{PT|\,ENV} \times P(ENV)$$

Based on data obtained from the SP commuter mode choice survey, deriving an estimate of each of the above probabilities would provide an insight (forecast) of what the modal split within the downtown central business region of Ottawa would be upon the implementation of the LRT.

8.2.3.2. Variance in Error Term

The lower one goes down the nested tree, the lower the value of the dissimilarity becomes. This follows from the requirement that the error variance at each level of the tree must be lower than the next higher level since the total variance for each alternative is fixed. At the same time, it must remain positive. As described in section 6.4.3.2, the dissimilarity parameter λ for each nest should be between the range of 0 and 1. However, for a multi-level nested tree structure such as the one considered in the calibration of the data for this study (see Figure 8.3), the dissimilarity parameter at each level is restricted to be between zero and the dissimilarity parameter at the next higher level of the nesting structure. Thus, for the nested structure in Figure 8.3, $0 < \Gamma_{ENV} \leq 1$ and $0 < \lambda_{PT} < \Gamma_{ENV} \leq 1$. This hierarchical restriction ensures that the variance of each error term remains positive as required (Koppelman *et al.* 2006).

8.2.3.3. Modal Split Model Calibration and Interpretation

With the use of the nlogit command in the STATA 12.0 statistical software, the parameters in the utility equation [8.1.3] were calibrated using data collected from the mode choice SP survey. Table 8.6 shows the three-level calibrated nested logit model for the CBD of Ottawa.

Table 8.6: Nested Logit Model – Modal Split

Variable	Coefficient	S.E	p> |z|
In-vehicle Travel Time (minutes)	-0.06	0.02	0.01
Cost/Fare ($)	-0.17	0.06	0.01
Time to Access Mode (minutes)	-0.48	0.22	0.03
Mode Frequency (minutes)	-0.02	0.01	0.06
INCOME ($)			
Less Eco-Friendly Mode (e.g. Car)		*Base*	
Eco-Friendly Modes	-0.57	0.17	0.00
CAR OWNERSHIP			
Less Eco-Friendly Mode (e.g. Car)		*Base*	
Eco-Friendly Modes	-0.34	0.12	0.01
EDUCATION LEVEL			
Less Eco-Friendly Mode (e.g. Car)		*Base*	
Eco-Friendly Modes	1.20	0.18	0.00
DISTANCE (km)			
Less Eco-Friendly Mode (e.g. Car)		*Base*	
Non-Motorize Mode (e.g. Walk/Cycle)	-0.25	0.09	0.01
Public Transit	-0.05	0.01	0.00
Constants			
Less Eco-Friendly Mode (e.g. Car)		*Base*	
Bus	1.69	0.71	0.02
LRT	1.79	0.66	0.01
Non-Motorized Mode	3.03	0.57	0.00
Dissimilarity Parameters			
Public Transit Nest (Γ_{PT})	0.42	0.18	
Eco-Friendly Nest (Γ_{ENV})	0.81	0.38	

Log-Likelihood at Constants = - 1068.24
Log-Likelihood at Convergence = - 784.58
Likelihood Ratio = 567.31
McFadden $\bar{\rho}^2$ = 0.27
Number of Obs. = 2868
Number of Cases = 717
LR test for IIA (Γ = 1): chi^2 (3) = 6.6 Prob > chi^2 = 0.0834

The calibrated nested logit model shown in Table 8.6 above describes the observed data with some fair amount of accuracy compared to other nested model structures tested to fit the observed data. All variables were found to be significant with appropriate signs. All alternative-specific modes of transport variables (in-vehicle travel time, cost, time to access mode and frequency of mode) had negative signs associated with them. This implies that commuters are more likely to use modes of transport that have the following characteristics:

- They are more likely to use modes of transport that would require them to spend the minimum in-vehicle time between their homes and their offices;
- They are more likely use a mode of transport that would require them to pay a minimum out of pocket cost per unit commuting distance traveled;
- They are more likely to use modes of transport that are accessible i.e., the longer the access time required to access a particular mode of transport, the less likely they are going to use that mode;
- Lastly, they are more likely to use modes of transport with a high service frequency i.e., the shorter the headway between vehicles (in the case of a transit system), they more likely they are to use that mode of transport.

Taking a look at the individual specific variables considered in the model calibration, the higher the income level of an individual, the less likely does he/she consider selecting any alternative belonging to the eco-friendly nest. In the same vein, the more cars accessible to each household, the less likely would its occupants consider the use of a mode of transport alternative from amongst the eco-friendly nest. This observation is rational given that the higher the personal income, the higher the chances of having access to a personal vehicle at home. However, in terms of level of education attained, the more educated people become, the more likely they would tend to prefer to commute by eco-friendly transport modes. This finding is also rational given that the higher the education level attained by an individual, the more informed he/she becomes with regards to making mode choices that are sustainable and environmentally friendly. The farther the one-way commuting distance between a commuter's home and the CBD, the less likely he/she would commute by public transit or by a non-motorized mode. Notwithstanding, commuters are more likely to commute by public transit compared to using a non-motorized mode for every 1 km increase in commuting distance. However, when compared overall to the automobile, they are less likely to commute by public transit or non-motorized mode for every 1 km increase in commute distance. This finding is also reasonable, given that people who live at distant areas away from the CBD are not served with efficient public transit systems that would entice them to consider it as a viable option for commuting.

To further confirm how well the nested structure fitted the observed data, it can be seen from Table 8.6 above that the value of each of the dissimilarity parameters within each of the sub-nests within the nested structure are within the acceptable range of 0 and 1 (with the exception of the less eco-friendly degenerate nest which has a dissimilarity parameter equals to 1). A lower value of the dissimilarity parameter associated with the public transit nest (Γ_{PT} = 0.42) implies that there is some correlation between the LRT and Bus mode of transport alternatives with similar unobserved error components as expected. Meanwhile, the dissimilarity parameter of the eco-friendly nest Γ_{ENV} was found to be equal to 0.81. In general, the dissimilarity parameters within the nested structure fall within the following range $0 < \Gamma_{PT} < \Gamma_{ENV} \leq 1$. The adjusted McFadden pseudo rho square $\bar{\rho}^2$ of 0.27 falls within a range of acceptable $\bar{\rho}^2$ values.

8.3. Modal Shift

The implementation of a LRT system within the city of Ottawa will be a major improvement to its existing transit system currently served by Bus Rapid Transit routes and a train route that runs along its North – South corridor from Bayview to Greenboro. Given this improvement to the public transit system, there is bound to be a modal shift from one mode to another.

A modal shift occurs when one mode (e.g. rail) has a comparative advantage in a similar market over another mode (e.g. road) (Rodrique *et al.*, 2013). Comparative advantages can take various forms, such as costs, capacity, time, flexibility or reliability and the importance of these factors may vary depending on the purpose for which the transportation is needed. For some, timesaving may be a factor when considering a modal shift following improvements made to one mode as oppose to another, while for others, cost savings may be a factor. Other qualitative factors such as privacy, comfort, reliability, flexibility and others may also play an important role. Nonetheless, the outcome is usually a series of decisions made by individuals (for passengers) or firms (for freight) to shift to other modes, provided that the comparative advantages for the new mode are significant enough.

In the case of the commuters' mode preference study, an analysis of the modal shift for commuters who commute to and from the CBD of Ottawa was carried out. The goal was to investigate what percentage of commuters would shift from using their current modes to using the LRT once it becomes operational. In order to obtain a clue of this potential modal shift, respondents were required to rate their preference for using the LRT mode of transport on a five-point scale following the selection of their preferred mode of transport from the alternatives presented in each hypothetical SP mode choice scenario matrix. In each hypothetical SP mode choice scenario matrix, the respondents were only required to rate the LRT provided it wasn't selected as their preferred mode of transport. The overall purpose here was to cross-examine how respondents perceived the LRT based on its characteristics and their affinity towards using the mode for commuting. A cross-tabulation between respondents who chose other modes of transport other than the LRT in each SP choice scenario versus their rating of the LRT mode is shown in Table 8.7 below. The rating was done on a five-point scale. However, for the sake of convenience, the two levels at the extreme of the five-point scale were collapsed to one level each.

Table 8.7: Preference for LRT Usage in the absence of Preferred Mode of Transport

Preference for LRT usage in absence of preferred choice	Stated Preference Mode of Transport			
	Bus	Auto	Non-Motorized	Total
May not/definitely wouldn't use LRT	18.9%	21.5%	28.4%	22.7%
Indecisive	17.2%	14.8%	9.1%	13.9%
May/definitely would use LRT	63.8%	63.7%	62.6%	63.4%
Total	**100%**	**100%**	**100%**	**100%**
	p-value = 0.00			

Using the content in Table 8.7 above, a ratio of respondents who 'may/ definitely would use LRT' to respondents who 'may not/ definitely wouldn't use LRT' in the absence of their preferred mode of transport was calculated for the bus, automobile and non-motorized modes of transport (see Figure 8.4 below).

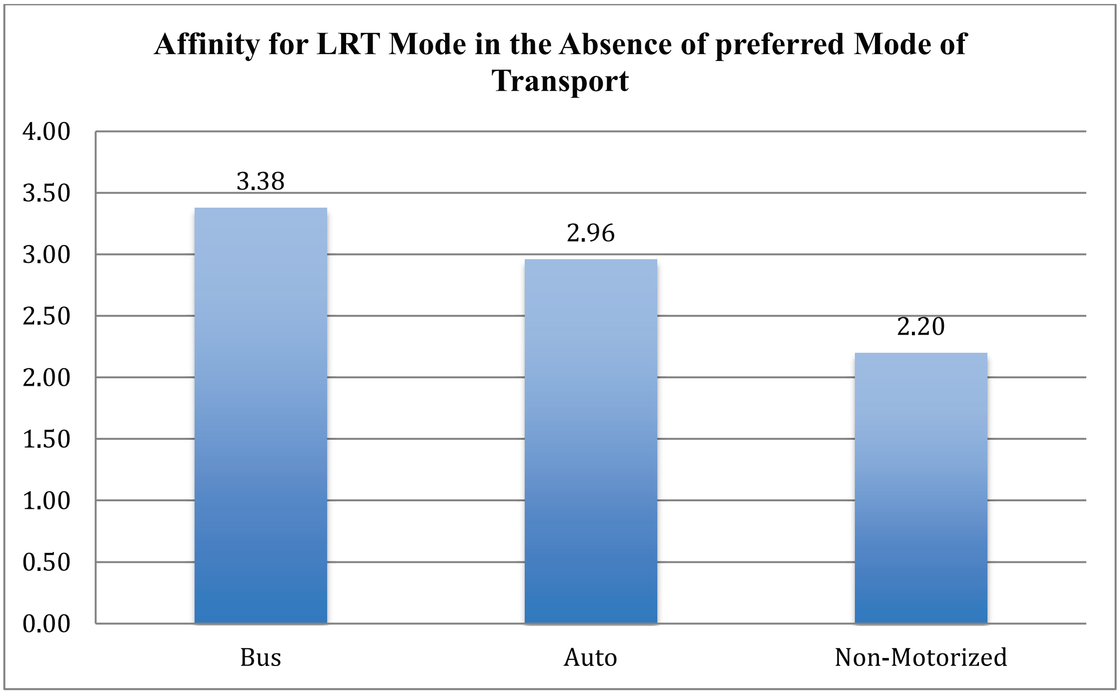


Figure 8.4: Affinity towards LRT mode of transport for respondents whose preferred mode of transport selected from the hypothetical SP choice sets was not the LRT Mode.

From the results shown in Figure 8.4 above, respondents who selected the bus as the preferred mode of transport for commuting have the highest affinity towards using the LRT should the bus become suddenly unavailable as a result of some unforeseen circumstance. Making reference to the same plot shown in Figure 8.4 above, respondents who selected non-motorized mode alternative as their preferred mode for commuting from each of the SP choice scenarios seem to have the least affinity for using the LRT mode of transport.

Although solid conclusions cannot be made from the above observations, the above findings at least provide an insight into what category of commuters would easily shift from using current existing modes of transport to using the LRT once it becomes operational. A discrete choice analysis based on the theory of utility maximization was implemented in order to predict with certainty what category of commuters are more likely to shift from using their current modes to using the LRT once it becomes operational. Binary choice logit models were developed and analyzed. The procedure is described in the following section.

8.3.1. Modal Shift Analysis from other modes to LRT

8.3.1.1. Introduction

As discussed above, improvements on one mode of transport could bring about redistribution in the percentage composition of each mode (modal split) and also a modal shift from one mode to another. The theory of utility maximization was used to analyze the potential modal shift. In the context of this research study, binary logit models between the LRT and the current modes used by commuters for commuting to the CBD were calibrated in order to assess the potential modal shift from the current modes to the newly proposed LRT. Figure 8.5 below outlines the steps involved in estimating what percentage of the population would probably shift from using their current modes to using the LRT for commuting.

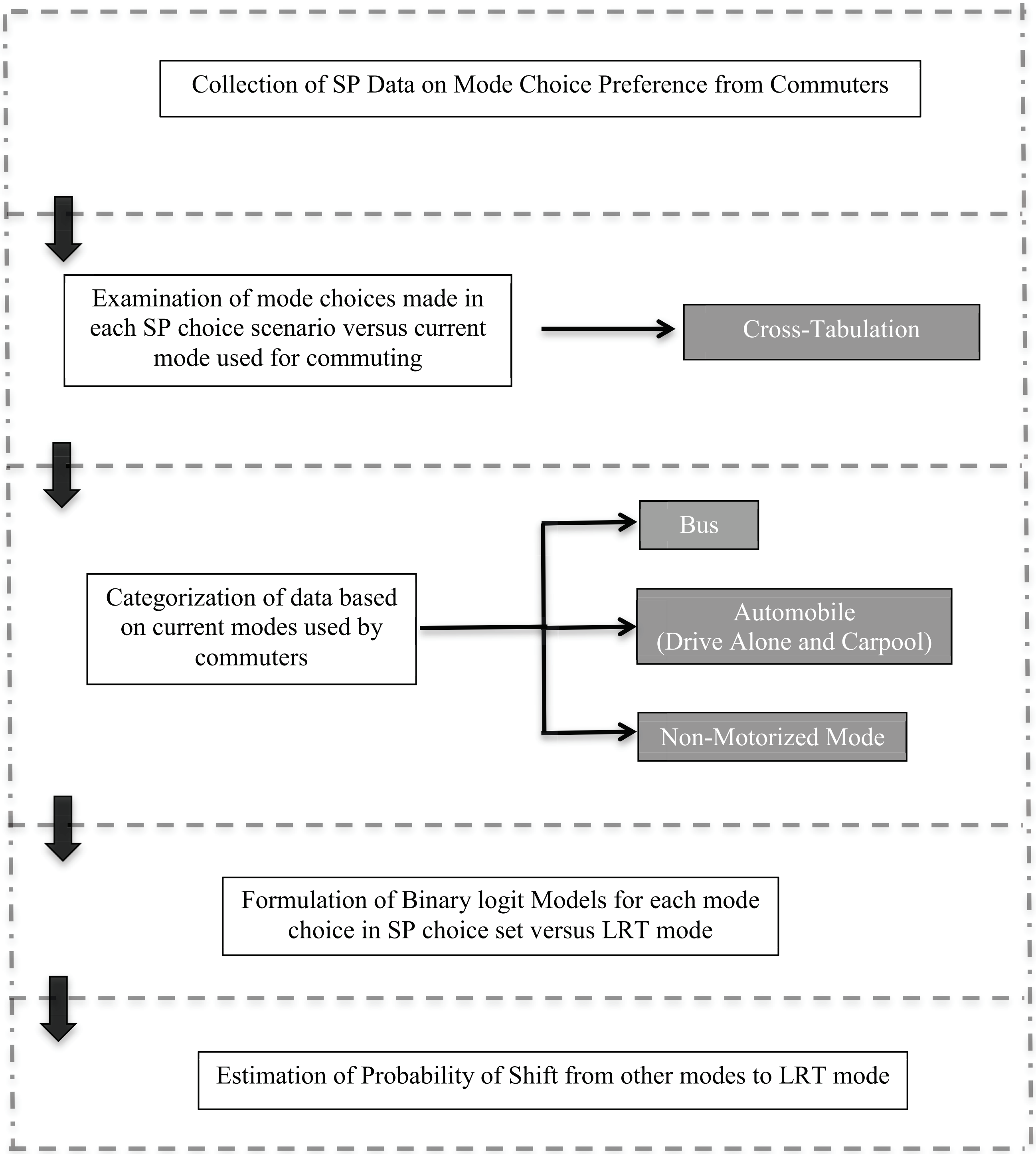


Figure 8.5: Modal Shift Estimation Process

8.3.1.2. Examination of preferred SP mode versus current model

Following the collection of SP data on mode choice preference for commuters, a cross-tabulation between respondents' preferred modes for commuting selected based on characteristics presented in each hypothetical SP mode choice scenario matrix versus the actual current modes used by the respondents was performed in order to cross-examine the manner in which respondents made their mode choice selection for commuting in each of the SP scenarios (see Table 8.8 below). From the Table, a total of 36.1 % of the respondents indicated that they would use the LRT as their preferred mode of transport. Amongst these respondents, 46.8% of them currently use the Bus; 34.4% currently commute by automobile (drive-alone/carpool); while only 11.1% currently commute by non-motorized modes. This compliments the observations made above that show that current bus commuters have the highest affinity for the commuting with the LRT system compared to commuters who currently commute by any other mode. However, likewise as above, the information contained in Table 8.8 cannot serve as the only base for making conclusions with respect to the modal shift.

Table 8.8: Cross-tabulation between Preferred Mode versus Current Mode

Preferred Mode based on SP Choice	Current Modes Used for Commuting			
	Automobile (Drive Alone/Carpool)	Bus	Non-Motorized	Total
LRT	34.4%	46.8%	11.1%	36.1%
Bus	10.1%	43.9%	7.2%	27.1%
Automobile	51.4%	1.5%	2.8%	15.6%
Non-Motorized	4.0%	7.8%	78.9%	21.1%
Total	100.0%	100.0%	100.0%	100.0%

8.3.1.3. Binary Logit Model Formulation and Estimation

Knowledge of the above distribution pattern between commuters of current modes of transport and their preference for LRT in each hypothetical SP choice scenario revealed an insight of the modal shift pattern. However, discrete choice analysis was implemented to examine: (1) what characteristics (variables) amongst those considered in each hypothetical SP choice scenario matrix have comparative advantage between each of the current modes of transport and the LRT; (2) to estimate the probability of commuters shifting from using their current transport modes to using the LRT taking into consideration certain important mode choice factors.

By controlling for the current mode of transport used by commuters, separate binary logit models were formulated between each mode of transport in the hypothetical SP choice sets and the LRT mode of transport i.e., each current mode of transport was independently compared to the LRT. A binary choice model suited the purpose for executing this modal shift analysis because models could only be calibrated between the LRT versus one other current mode of transport at any given time.

Three separate binary-mode choice models were calibrated to estimate the percentage of commuters who are likely to shift to the LRT from their current modes of transport. These included: (i) shift from Bus transit to LRT, (ii) shift from Automobile to LRT, and (iii) shift from Non-Motorized mode to LRT. Details in the development of these models are given in the following sections. As described in section 6.4.3, the general utility function for a discrete choice model can be written as:

$$U_{iq} = V_{iq} + \epsilon_{iq} \qquad [8.2.4]$$

The systematic element of the above equation can be more precisely described as a linear additive function of the attributes and their respective weightings as shown in below (Louviere *et al.* 2000):

$$V_{iq} = \sum_{k=1}^{k} \beta_{iq} X_{ikq} \qquad [8.2.5]$$

where:

U_{iq} = the utility of alternative *i* by individual *q*.

V_{iq}= systematic derived element of the i^{th} alternative for person *q*.

β_k = unknown alternative specific utility parameter

X_{ikq} = independent attribute

i = alternative

k = attribute associated with alternative *i.*

q = individual

With the assumption that the errors are independently and identically distributed and follow a Weibull distribution, and that there are a total of *K* attributes and *q* = 1, 2, 3,…, *n* individuals, the equation for the binary choice logit model can be expressed as (Louviere *et al.,* 2000):

$$\ln\left[\frac{P_i}{1-P_i}\right] = \alpha + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik} \qquad [8.2.6]$$

The left-hand side of equation [8.2.6] is known as the logit of the probability of choice, and it represents the logarithm of the odds that individual *q* will choose alternative *i.* With the logit model expressed in the form of a linear function, standard regression techniques can be used to formulate the model. For the purpose of this analysis, the binary logit function is represented in terms of ln[Odds]. However, it is more commonly expressed in terms of probabilities as shown in [8.2.7] below:

$$P_{iq} = \frac{e^{V_{iq}}}{1 + e^{V_{jq}}} \qquad [8.2.7]$$

The empirical structure of the utility function is critical to modeling individual choice, and represents the process by which alternative and individual specific attributes combine to influence choice probabilities, and in turn the predictive probability of the choice model (Louviere, Hensher and Swait, 2000). Throughout the remaining of this chapter, the unknown parameters α and β in equation [8.2.6] were estimated by the sequential Maximum Likelihood Estimation method using the data collected from the SP survey and the STATA 12.0 software.

Shift of Bus Transit Commuters to LRT

For this case, the dependent variable was defined as the willingness of the commuter to shift from using the Bus to using the LRT mode of transport while the independent variables considered included: In-vehicle travel time, travel cost, time to access mode, and mode frequency.

In the formulation of the model, a data set pertaining to some 80 respondents who currently commute by bus was considered. Amongst this category of respondents, their choices made between the LRT alternative and the Bus alternative in each hypothetical SP choice scenario matrix was examined and coded as a binary model as shown in Figure 8.6 below producing 838 valid data points. The binary model examined the characteristics considered by commuters in making their decision to shift from commuting by bus to commuting by LRT.

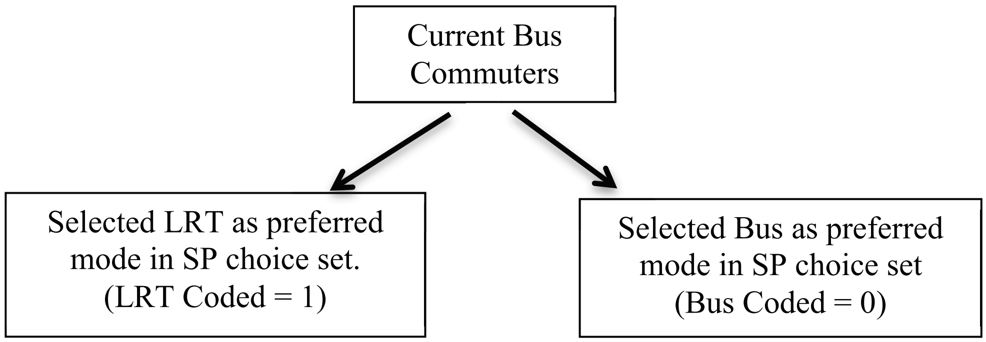


Figure 8.6: Binary Logit Model – Switch from Bus to LRT

Table 8.9 below shows the calibrated binary model representing factors that have an influence on commuters when deciding to shift from commuting by bus to LRT. It can be seen that the signs of the parameters considered to describe each of the characteristics of each mode in the SP choice set are logical and significant at $p = 0.00$.

Table 8.9: Modal Shift from Bus to LRT – Binary Model

Variable	Coefficient	S.E	p>|z|
Travel Time (minutes)	-0.15	0.02	0.00
Fare ($)	-0.33	0.13	0.01
Time to Access Mode (minutes)	-2.15	0.23	0.00
Mode Frequency (minutes)	-0.05	0.02	0.06
Constant	5.79	0.98	0.00
Goodness-of-Fit Test			
LL at Constant = -580.86		LL Ratio = 134.21	
LL at Convergence = -513.75		Number of observations = 838	
Hosmer & Lemeshow chi^2 = 4.25		Prob > chi^2 = 0.1193	
McFadden $\bar{\rho}^2$= 0.1155		ROC Area = 0.7272	

Important characteristics considered by commuters when deciding to shift from Bus use to LRT use include: in-vehicle travel time, cost, time to access mode and mode frequency. Overall, commuters would be less likely to switch from using the bus to using the LRT if they would experience an increase in travel time and cost with the LRT; if the LRT station is less accessible or operates less frequently. Socio-economic variables such as income, education level and ownership of vehicle turned out to be insignificant in the calibration of this model, hence they may not be considered by commuters as important factors when deciding to switch from using the bus to using the LRT. The model calibrated the observed data well with a McFadden ρ^2 value of 0.12 and it satisfied the Hosmer and Lemeshow tests.

<u>Shift of Automobile commuters to LRT</u>

In this context, automobile commuters included those who commute by car (drive-alone and carpool commuters). In the same manner as above, the dependent variable was also defined to measure the willingness of the commuter to shift from commuting by automobile to commuting by LRT.

In the formulation of the binary logit model, a data set pertaining to some 46 respondents who currently commute by automobile to the CBD of Ottawa was considered. Amongst this category of respondents, their choices made between the LRT alternative and the automobile alternative in each hypothetical SP choice scenario matrix was examined and coded as a binary model as shown in Figure 8.7 below producing 424 valid data points. The binary model examines the characteristics considered by commuters in the decision-making process to shift from commuting by automobile to commuting by LRT.

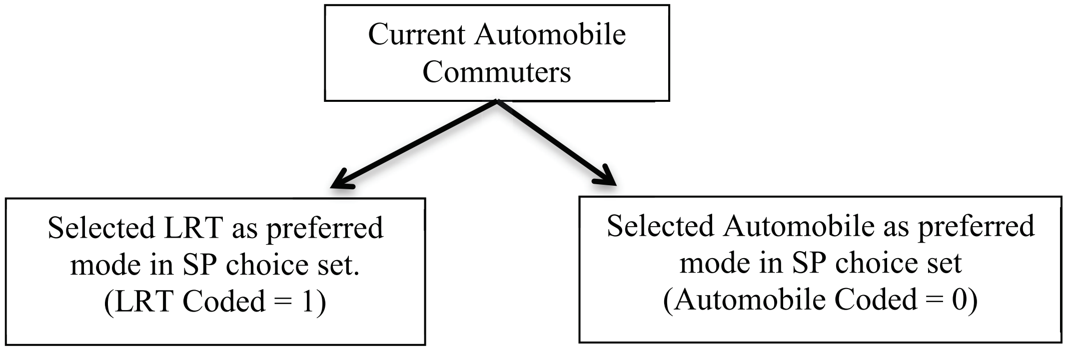


Figure 8.7: Binary Model Formulation – Switch from Automobile to LRT

Table 8.9.1 below shows a calibrated binary model representing factors that have an influence on commuters when deciding to shift from commuting by automobile to LRT. It can be seen that the signs of the variable parameters considered to describe the characteristics of each mode in the hypothetical SP choice set are logical and significant at p = 0.00.

Table 8.9.1: Modal Shift from Automobile to LRT – Binary Model

Variable	Coefficient	S.E	p>|z|
Travel Time (minutes)	-0.12	0.03	0.00
Fare ($)	0.09	0.03	0.00
Time to Access Mode (minutes)	-1.03	0.31	0.00
Constant	2.05	0.72	0.00
Goodness-of-Fit Test			
LL at Constant = -293.89		LL Ratio = 37.61	
LL at Convergence = -275.10		Number of observations = 424	
Hosmer & Lemeshow chi^2 = 3.16		Prob > chi^2 = 0.2061	
McFadden $\bar{\rho}^2$ = 0.1155		ROC Area = 0.6676	

Amongst the four attributes (travel time, cost, time to access mode and mode frequency) used to describe each mode of transport in each SP choice scenario matrix, three of them were considered important by current auto commuters when deciding to switch to commuting using the LRT. These include: in-vehicle travel time, travel cost and time to access mode. Overall, commuters would be less likely to switch from using automobile to using the LRT if they would experience an increase in travel time or if the LRT station becomes less accessible. However, in terms of cost, commuters who currently commute by car may be insensitive to increase in commuting fare for the LRT and may be better-off commuting with the LRT for every unit increase in fare/cost in comparison to commuting by automobile. Although this finding may somewhat be strange, it seems rational considering that the price for commuting by automobile would always surpass the absolute cost for commuting by LRT to/from the central business district of Ottawa. One travel characteristic variable not considered in the calibration of the above model is service frequency. It was left out of the model considering that it doesn't make sense to assign a service frequency to a mode of transport such as the automobile since it is readily available. Socio-economic variables such as income, education level and ownership of vehicle turned out to be insignificant in the calibration of this model, hence they may not be considered by commuters as important factors when deciding to switch from commuting by automobile to using the LRT. The model fitted the observed data well producing a McFadden ρ^2 of 0.12 and it satisfied the Hosmer and Lemeshow tests.

Shift of Non-motorized mode users to LRT

In this context, non-motorized users included those who commute by either of the following modes: walking/cycling/skating/rollerblading. In the same manner as above, the dependent variable was defined to measure the willingness of the commuter to shift from commuting by non-motorized modes to commuting by LRT.

In the formulation of the binary logit model, a data set pertaining to some 31 respondents who currently commute by non-motorized modes to the CBD of Ottawa was considered. Amongst this category of respondents, their choices made between the LRT alternative versus the non-motorized mode alternative in each hypothetical SP choice scenario matrix was examined and coded as a binary model as shown in Figure 8.8 below producing 324 valid data points.

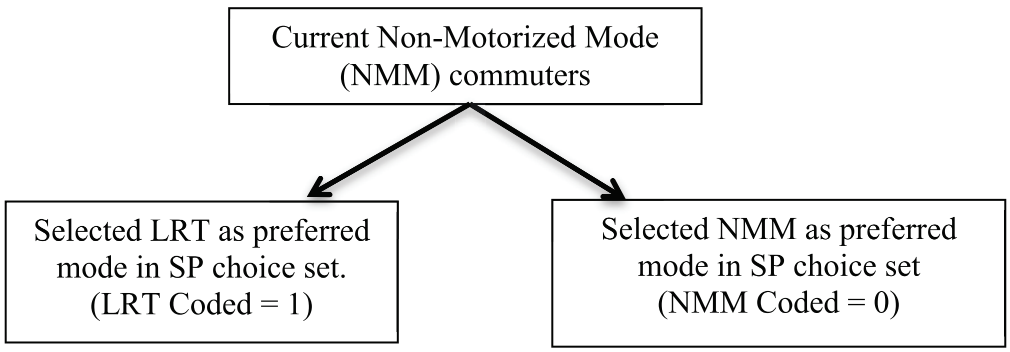


Figure 8.8: Binary Model Formulation – Switch from Non-Motorized mode to LRT

Table 8.9.2 below shows a calibrated binary model representing factors that have an influence on commuters when deciding to shift from commuting by non-motorized mode to commuting by LRT. It can be seen that the signs of the variable parameters are logical and significant at p = 0.10.

Table 8.9.2: Modal Shift from Non-Motorized mode to LRT – Binary Model

Variable	Coefficient	S.E	p>|z|
Travel Time (minutes)	0.15	0.05	0.00
Fare ($)	-0.43	0.21	0.04
Time to Access Mode (minutes)	0.89	0.53	0.09
Constant	-3.25	2.09	0.12
Goodness-of-Fit Test			
LL at Constant = -224.58		LL Ratio = 188.11	
LL at Convergence = -130.53		Number of obs = 324	
Hosmer & Lemeshow chi^2 = 19.78		Prob > chi^2 = 0.000	
McFadden $\bar{\rho}^2$ = 0.4188		ROC Area = 0.8799	

Amongst the four attributes (travel time, cost, time to access mode and mode frequency) used to describe each mode of transport in each SP choice scenario matrix, three of them were considered important by commuters of non-motorized modes when deciding to switch to commuting by LRT. These include: in-vehicle travel time, travel cost and time to access mode. Overall, commuters may be more likely to switch from using non-motorized modes to using the LRT as their travel time between their homes to the CBD increases. In terms of monetary cost, commuters who currently commute by non-motorized modes are less likely to switch to commuting with LRT in order to avoid paying for transit fares associated with the LRT mode. However, the more accessible the LRT stations become, the more likely are current non-motorized mode commuters going to switch from commuting using non-motorized modes to using the LRT. One travel characteristic variable not considered in the calibration of the above model is service frequency. It was left out of the model considering that it doesn't make sense to assign a service frequency to a mode of transport such as the non-motorized modes since they are always readily available. Socio-economic variables such as income, education level and ownership of vehicle turned out to be insignificant in the calibration of this model, suggesting that commuters may not consider these factors as important when deciding to switch from commuting by non-motorized modes to the LRT. This model fitted the observed data very well satisfying all goodness-of-fit tests and producing a McFadden ρ^2 value of 0.42. However, the researcher would like to draw the attention of the reader to the fact that this model did not pass the Hosmer and Lemeshow test. As discussed in section (6.5.2.4), researchers have found the Hosmer and Lemeshow test to have several limitations and question its integrity regarding its use as valid measure of goodness-of-fit for binary models (Allison, 2013). Possible reasons for the model failing the Hosmer and Lemeshow tests may have been due to a large sample size, absence of interaction effects between the variables or inadequate number of specified equal-sized groups required to partition the number of observations.

8.4. Summary

This chapter discussed the modal spilt and modal shift characteristics of commuters who commute to the central business district of Ottawa using discrete choice models. Findings showed that the introduction of the LRT would see an increase in public transit ridership within the CBD of Ottawa as well as a reduction in automobile ridership within this same area. Based on modal shift analysis carried out, majority of the riders of the future LRT system would come from commuters who currently commute by bus transit. In the following chapter, discrete choice models are used to model office location/relocation decisions within the City of Ottawa. There may be land use implications associated with results obtained from this model.

9. MODELING OFFICE LOCATION/RELOCATION DECISIONS

9.1. Introduction

This chapter discusses how the decision-making process of office managers regarding their office location/relocation preference was modeled using discrete choice analysis. Once more, the two location/relocation alternatives considered for this study were: (1) Central Ottawa versus (2) Satellite Communities. The approaches used in the formulation of the model, hypothesis and data preparation are presented, followed by the calibration of the logit model using data collected from the office location/relocation SP survey.

9.2. Model Formulation

9.2.1. Modeling Framework

Discrete choice analysis was used as the framework for modeling decisions throughout this office location/relocation study. Since the study investigated the decision-making process of office managers regarding their preferences for locating/relocating their offices between two possible location alternatives, the outcome of their decision is binary, given they only had two categories to choose from (central Ottawa versus Satellite community). Hence, amongst all other logistic regression models, the binary choice logit model suited the purpose for modeling the observed data collected from the office location/relocation survey. The binary logit model is described in section 8.3.1.3 using equations [8.2.4] to [8.2.7].

9.2.2. Model Formulation – Approach

The collected data from the office location/relocation SP survey were used to model the decision-making process of office managers regarding their preferences for locating/relocating their offices based on a set of attributes that described each location alternative. Binary choice logit models were developed to explain the relationships between each location alternative and its associated characteristics.

The formulation of the binary logit models was done following these two different approaches:

- **Approach I – Office Location**: based on the attributes that described each alternative location, this approach modeled the location preferences made by the office managers in a manner such that their business firms were assumed to be new incoming firms that decided to establish an office within the city of Ottawa.

- **Approach II – Office Relocation**: based on the attributes that described each alternative location, this approach modeled the location preferences made by office managers taking into consideration the current location of their offices within Ottawa and examining their preferences to relocate within either of the two location alternatives as influenced by attributes that defined each alternative.

9.2.3. Hypotheses

The following two hypotheses were investigated throughout this study.

H_1: The adoption of a telecommuting program within a company does not have an influence in the decision-making process regarding where a company chooses to locate/relocate its office with an urban area.

H_2: The adoption of a telecommuting within a company does not have a decentralization effect within an urban area.

9.3. Data Preparation

9.3.1. Coding of Dependent Variables

The dependent variable for this study was coded as a 0, 1 binary indicator following standard binary responses, where ‘0’ is usually associated with ‘failure’ outcomes and ‘1’ is often associated with ‘success’. In the context of this study, the dependent variable is the office location/relocation alternatives described by a combination of specific attributes in each hypothetical SP choice set.

During the data entry phase using MS Excel, the preferred office location/relocation alternative selected by each manager in each SP choice set was coded as ‘1’ and ‘0’ if no choice was made or if the ‘None’ alternative was selected. Upon completing the data entry, data needed for the calibration of the binary logit models as defined following approaches I and II above were categorized.

Figure 9.1 shows the binary choice structure for the formulation of the office location model following *Approach I*. Two office location models were formulated: (1) Central Ottawa and (2) Satellite Community. These models were based on the attributes that described each office location alternative as contained in the hypothetical SP choice sets. For example, considering the office location binary model for central Ottawa, managers who selected central Ottawa as their preferred office location alternative within each SP choice set were coded '1' and '0' otherwise. In the same vein, considering the office location binary model for the Satellite community, managers who selected the satellite community as their preferred office location alternative within each SP choice set were coded '1' and '0' otherwise. This binary model was structured in this manner to investigate what factors influence the siting of office space within a new environment with particular focus on the role of telecommuting.

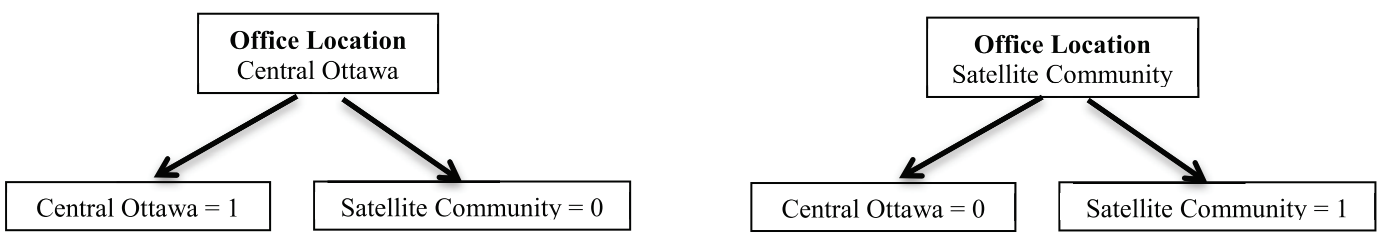


Figure 9.1: Approach I - Office Location

Figure 9.2 shows the binary choice structure for the formulation of the office relocation model following *Approach II*. Two office relocation models were formulated: (1) Relocate from Satellite Community to Central Ottawa and (2) Relocate from Central Ottawa to Satellite Community. These models were based on the attributes that described each office location alternative as contained in the SP choice sets. For example, considering the office relocation binary model from central Ottawa to the Satellite community, managers whose offices were currently located within central Ottawa but selected Satellite community as their preferred location alternative in each hypothetical SP choice set were coded '1' and '0' otherwise. In the same vein, considering the office relocation binary model from the Satellite community to central Ottawa, managers whose offices were currently located within the Satellite Community but selected Central Ottawa as their preferred location alternative in each SP choice set were coded '1' and '0' otherwise. The binary model was structured in this manner to investigate what factors influence pre-established companies to relocate their offices from one location to another within an urban area with a particular focus on the role of telecommuting.

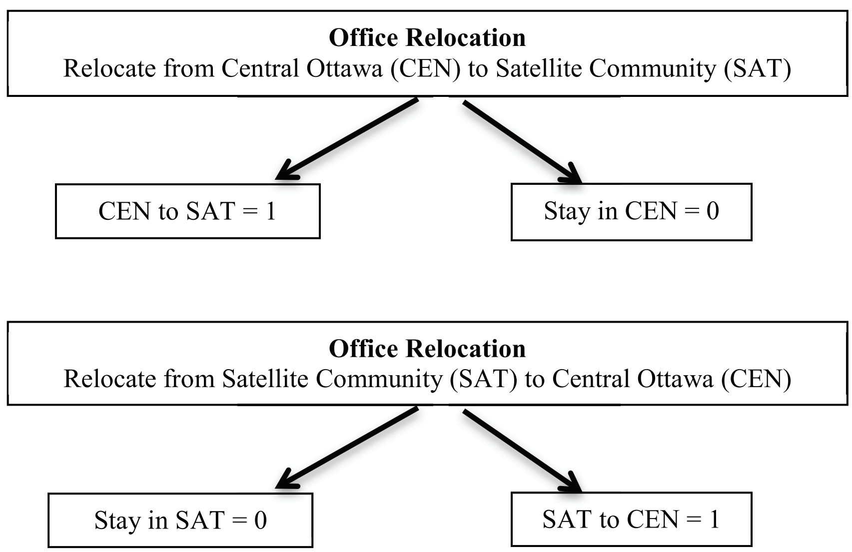


Figure 9.2: Approach II – Office Relocation

9.3.2. Coding of Independent Variables

The independent variables used for calibrating the office location/relocation models based on data collected from the SP survey were coded as follows (Table 9.1):

Table 9.1: Independent Variables – Office Location/Relocation

Explanatory variables	Level	Code
Employee Telecommuting Level **(ETL)**	0 Day/ week 1 – 3 days/week	0 1
Change in Overhead Cost **(OH COST)**	Decreases Increases	0 1
Office and Parking Space **(OPS)**	Reduces No Change Increases	0 1 2
Office Proximity to related businesses **(OFF PROX)**	Poor Excellent	0 1
Office Accessibility **(OFF ACES)**	Less than 5 minutes walk to major roads/transit hubs More than 5 minutes walk to major roads/transit hubs	1 0

Following the coding of the dependent and explanatory variables as explained above, the logit command in STATA 12.0 software was used to calibrate the binary models.

9.4. Model Calibration

In an attempt to understand what factors (attributes) influence the location/relocation of offices within the city of Ottawa municipal area, data collected from the hypothetical stated preference (SP) choice sets were used to estimate the unknown coefficients in the binary logit model contained in equation [8.2.6] above. Amongst all factors investigated, more focus was placed on the effects of telecommuting. The contribution of each attribute (variable) to the derived utility of a specific location/relocation alternative is indicated by the sign of the variable's coefficient. A positive sign indicates a positive impact on the utility and a negative sign indicates a negative impact. A level of significance was set at 10 % ($p \leq 0.1$) for this research study. Nonetheless, attributes with significance levels ($p > 0.10$) were also included in the model, considering that reasons for their insignificance might have been as a result of insufficient data points as opposed to their lack of importance. The main binary models calibrated following *Approach I* and *Approach II* made use of the entire data collected from the survey without controlling for any factor. However, given the insignificance associated with some variables, other binary models where calibrated while controlling for external factors such as company size and company sector following the same procedure (see Tables 9.4 – 9.6). The overall goal was to obtain the best possible explanation for each attribute. The following section discusses the findings and observations obtained from the calibrated office location/relocation models.

9.4.1. Office Location – Model Estimation with SP Data for the whole Sample

The calibration of this model was structured in a manner that the variables in the model were assumed to be the only factors that influence the decision-making process regarding the location of an office within a new area. The model structure is shown in Figure (9.1) above and the results are shown in Table 9.2 below.

Table 9.2: Base SP Office Location Model for the whole Sample

Variable	**CENTRAL OTTAWA**			**SATELLITE COMMUNITY**		
	Coefficient	S.E	p>|z|	Coefficient	S.E	p>|z|
ETL	1.00	0.62	0.10	-2.60	1.15	0.02
OH COST	-1.33	0.38	0.00	-3.29	0.65	0.00
OPS (1)	1.17	0.50	0.02	0.42	0.66	0.52
OPS (2)	0.56	0.77	0.47	0.26	0.92	0.77
OFF. PROX	2.33	0.61	0.00	0.60	0.79	0.45
OFF. ACES	-0.40	0.83	0.63	2.41	1.07	0.03
Constant	-1.79	0.88	0.04	3.64	1.34	0.01
Goodness of Fit Tests				Goodness of Fit Tests		
LL at constant = -167.73	LL Ratio = 82.64			LL at constant = -151.11	LL Ratio = 122.01	
LL at convergence = -126.41	# of obs = 242			LL convergence = -90.10	# of obs = 218	
H & L chi^2 = 22.42	Prob>chi^2 = 0.0000			H & L chi^2 = 10.99	Prob>chi^2 = 0.0041	
McFadden $\bar{\rho}^2$ = 0.2463	ROC Area = 0.847			McFadden $\bar{\rho}^2$ = 0.4037	ROC Area = 0.900	

(1) No Change; (2) Increase; H & L: Hosmer & Lemeshow

Description of derived utility obtained from locating an office within Central Ottawa versus Satellite Communities:

Table 9.1 represents the calibrated office location models for the two alternatives considered in this study. The constants in the model represent the effect of other important factors not considered in the model while the sign of the coefficients represent the contribution of each attribute (variable) towards the utility derived from locating within an alternative. Assuming that companies adopted a telecommuting program prior to locating their office within Ottawa, the models in Table 9.1 explain the utility derived by office managers from each location alternative and how each variable influences their office location decision-making process.

As the average number of employee telecommuting days increases, Table 9.1 shows that companies would tend to derive more utility from locating their offices within central Ottawa (*p-value =0.10*) as oppose to locating within the Satellite communities (*p-value = 0.02*). For every unit increase in overhead cost, companies are more likely to locate their offices within central Ottawa as oppose to locating within the satellite community (*p-value = 0.00*) i.e., upon adopting a telecommuting program, they would derive lesser utility from locating their offices within the satellite community compared to locating within central Ottawa for every unit increase in overhead cost.

With regards to their preference for office size, companies that choose to locate within central Ottawa are more likely to maintain their current office size as oppose to reducing it (*p-value = 0.02*). However, for companies that choose to locate within the Satellite community, no general conclusion can be made regarding their preference for office size given the coefficient in the model is insignificant. Nonetheless, while controlling for the sector to which the company belongs, Table 9.4

shows that non-high-tech[27] companies that choose to locate within the satellite community would prefer to maintain their current office size as oppose to reducing it (*p = 0.00*). However, while controlling for company size, Table 9.6 shows that mid-size companies (11 – 50 employees) that choose to locate within the satellite community upon adopting of a telecommuting program are more likely to reduce their office size relative to their current size (*p = 0.02*).

As the proximity to related businesses, clients, resources, personal and other amenities within central Ottawa becomes excellent, this tends to attract more companies to locate their offices within this area (*p-value = 0.00*). No general conclusion can be made at the moment regarding how office proximity could influence office location within the satellite community. However, results from Table 9.4 shows that while controlling for company sector, high-tech companies are likely to derive more utility from locating their office within the satellite communities so as to benefit from being in proximity to other businesses of similar type, resources, personnel, clients and other amenities (*p = 0.00*). Hence, proximity plays a very important role in the decision-making process regarding where companies choose to locate their office.

Lastly, with regards to the role of accessibility, companies are more likely to locate their offices within the satellite community provided their offices are made more accessible by means of provision of good public transportation services and good road networks (*p-value = 0.03*). No general conclusion can be made at the moment on the role played by accessibility in influencing the location of offices within central Ottawa.

[27] Non-high-tech companies were defined as those whose primary activities include provision of financial services, legal services, sales, marketing, etc.

In terms of testing how well the model fitted the observed data, the log likelihood ratio (LR Ratio) test turned out to be highly significant at rejecting the null hypothesis that all parameters are jointly zero and that all parameters except the intercept are jointly zero respectively. In addition, $\bar{\rho}^2$ values of 0.25 and 0.4 indicate that the models describe the data with some accuracy as oppose to low $\bar{\rho}^2$ values typically expected with SP models (Tayyaran, 2000). Nonetheless, the attention of the reader should be drawn to the fact that the model failed to pass the Hosmer and Lemeshow tests. As discussed in section (6.5.2.4), researchers have found the Hosmer and Lemeshow test to have several limitations and question its integrity regarding its use as valid measure of goodness-of-fit for binary models (Allison, 2013). Possible reasons for the model failing the Hosmer and Lemeshow tests may have been due to a large sample size, absence of interaction effects between the variables or inadequate number of specified equal-sized groups required to partition the number of observations.

9.4.2. Office Relocation – Model Estimation with SP Data for the whole Sample

The calibration of this model was also structured in a manner such that the variables in the model were assumed to be the only factors that influence the decision-making process regarding the relocation of an office from its current location to a new location. Model structure is shown in Figure (9.2) above and the calibrated model is shown in Table 9.3 below.

Table 9.3: Base SP Office Relocation Model for the whole sample

Variable	CENTRAL TO SATELLITE			SATELLITE TO CENTRAL		
	Coefficient	S.E	p>|z|	Coefficient	S.E	p>|z|
ETL	-4.59	1.59	0.00	-0.93	1.19	0.44
OH COST	-4.39	0.93	0.00	-3.87	1.21	0.00
OPS (1)	1.14	0.85	0.18	-1.48	1.02	0.15
OPS (2)	0.74	1.22	0.54	-1.21	1.60	0.45
OFF. PROX	-0.09	1.03	0.93	2.65	1.25	0.03
OFF. ACES	3.88	1.43	0.01	-3.72	1.94	0.06
Constant	5.91	1.86	0.00	-0.05	1.65	0.98
Goodness of Fit Tests				Goodness of Fit Tests		
LL at constant = -105.36		LL Ratio = 104.44		LL at constant = -38.78		LL Ratio = 25.50
LL at convergence = - 53.14		# of obs = 152		LL convergence = -26.03		# of obs = 56
H & L chi^2 = 5.9		Prob>chi^2 = 0.0523		H & L chi^2 = 1.94		Prob>chi^2 = 0.379
McFadden $\bar{\rho}^2$ = 0.4956		ROC Area = 0.947		McFadden $\bar{\rho}^2$ = 0.3288		ROC Area = 0.917

(1) No Change; (2) Increase; H & L – Hosmer & Lemeshow

Description of utility derived for relocating an office within Central Ottawa vs. Satellite Communities:

Table 9.3 represents two calibrated models for relocating an office within the two location alternatives considered in this study. Once more, the constants in the model represent the effect of other important factors not considered in the model while the sign of the coefficients represent the contribution of each attribute (variable) towards the utility derived from relocating from one alternative to another. Assuming companies adopted a telecommuting program, the models in Table 9.3 explain what factor influence managers of established companies to relocate their offices from its current location to a new location. In order words, while controlling for the current location of an office, this model sought to investigate what factors would influence managers' decisions with regards to relocating their office from its current location to a new location with the assumption that the company recently adopted a telecommuting program.

Taking a look at Table 9.3, companies whose offices are currently located within central Ottawa are less likely to relocate to the satellite community should their employees decide to telecommute within certain days of the week (*p-value = 0.00*). This concurs with findings made in the office location model above which shows that new incoming companies are more likely to locate within central Ottawa should their employees decide to telecommute. However, no significant conclusion can be made with regards to how the employee telecommuting level may influence the relocation decisions of companies currently located within the satellite communities.

In general, although there is a disutility associated with overhead cost and each office relocation alternative, companies whose offices are currently located within the satellite community are better-off relocating to central Ottawa for every unit increase in overhead cost incurred for running their offices within the satellite community assuming the adoption of a telecommuting program. However, companies whose office are currently located within central Ottawa, are worse-off relocating to the satellite community for every unit increase in overhead cost incurred for operating their office within central Ottawa assuming the adoption of a telecommuting program (*p-value* = *0.00*). Overall, the trend shows that companies are better-off relocating to central Ottawa for every unit increase in overhead cost assuming the adoption of a telecommuting program. This finding is also in line with that made from the office location model above which shows that new incoming offices would prefer to locate their offices within central Ottawa assuming the adoption of a telecommuting program.

Despite the results from Table 9.3 above reveal that no significant conclusions can be made about a company's preference for its office size should it decide to relocate from its current location. Notwithstanding, Table 9.5 shows that while controlling for company sector, high-tech companies are more likely to maintain their current office size as oppose to reducing it should they decide on relocating from central Ottawa to the Satellite community assuming the adoption of a telecommuting program ($p = 0.10$).

Taking office proximity into consideration, companies whose offices are currently located within the satellite community are more likely to relocate to central Ottawa assuming they adopt a telecommuting program and in order to benefit from being in proximity to other businesses of similar type, clients, personnel and other amenities ($p = 0.03$). No significant conclusions can be made on how office proximity would play a role in the relocation of offices from central Ottawa to the satellite community.

Lastly, with regards to the role played by accessibility, companies whose offices are currently located within central Ottawa are more likely to relocate their offices to the satellite communities provided their offices would be made more accessible through the provision of transportation improvement measures assuming the adoption of a telecommuting program (*p-value* = *0.01*). Notwithstanding, the accessibility provided by central Ottawa (in terms of its good transport network systems) may not likely cause offices currently located within the satellite communities to relocate to central Ottawa (*p-value* = *0.06*). This finding is also in line with that obtained from the above office location model. In general, assuming the adoption of a telecommuting program, it seems as though companies are more likely to locate/relocate their offices within the satellite community on the assumption that improvements are made to the transport network within these satellite communities.

This model fitted the observed data accurately. According to goodness-of-fit measures, the log likelihood ratios (LR Ratio) are both highly significant rejecting the null hypothesis that all parameters are jointly zero and also that all parameters except the intercept are jointly zero respectively. In addition, $\bar{\rho}^2$ values of 0.50 and 0.33 indicate that the models describe the data with some accuracy as oppose to low $\bar{\rho}^2$ values typically expected with SP models (Tayyaran, 2000). The model passed the Hosmer-Lemeshow test given that the p-value of the Hosmer & Lemeshow is greater than a set level of significance ($\alpha = 0.10$); hence, we fail to reject the null hypothesis.

Having calibrated the model and obtained relationships between how certain attributes influence the decisions of office managers regarding where they choose to locate/relocate their offices, the following section presents an interpretation and possible reasons surrounding the findings made so far.

Table 9.4: SP Model for Office Location controlling for Company Sector

Variable	High-Tech Companies: Central Ottawa Coef.	S.E	p>|z|	High-Tech: Satellite Community Coef.	S.E	p>|z|	Non-High-Tech Companies: Central Ottawa Coef.	S.E	p>|z|	Non-High-Tech: Satellite Community Coef.	S.E	p>|z|
ETL	1.16	0.87	0.18	0.82	1.26	0.51	0.34	0.91	0.71	**-8.13**	2.04	0
OH COST	-0.78	0.51	0.12	**-1.68**	0.65	0.01	-2.46	0.7	0	**-6.52**	1.33	0
OPS (1)	**1.51**	0.68	0.03	**-1.59**	0.91	0.08	0.22	0.79	0.78	**2.8**	0.95	0
OPS (2)	0.75	1.09	0.5	-0.95	1.33	0.48	-0.02	1.13	0.99	-1.6	1.22	0.19
OFF. PROX	**2.16**	0.87	0.01	**2.34**	1.11	0.04	**2.64**	0.85	0	-1.6	1.22	0.19
OFF. ACES	0.14	1.17	0.9	0.83	1.43	0.56	-1.69	1.29	0.19	**5.64**	1.82	0
Constant	-1.95	1.26	0.12	0.47	1.45	0.75	-1.21	1.24	0.33	**9.55**	2.51	0

GOODNESS of FIT STATISTICS

High-Tech: Central Ottawa	High-Tech: Satellite Community	Non-High-Tech: Central Ottawa	Non-High-Tech: Satellite Community
LL (C) = -79.02; LL Ratio = 32.0	LL (C) = -72.09; LL Ratio = 48.71	LL (C) = -88.71; LL Ratio = 57.45	LL (C) = -70.02; LL Ratio=93.09
LL (B) =- 63.02; # of obs = 114	LL (B) = -47.73; # of obs = 104	LL (B) = -59.98; # of obs = 128	LL (B) = - 32.48; #of obs = 114
McFadden $\bar{\rho}^2$ = 0.20	McFadden $\bar{\rho}^2$ = 0.34	McFadden $\bar{\rho}^2$= 0.32	McFadden $\bar{\rho}^2$ = 0.59
ROC Area = 0.855	ROC Area = 0.846	ROC Area = 0.814	ROC Area = 0.965
H & L chi^2 = 8.86; Prob>chi^2 = 0.01	H & L chi^2 = 14.06; Prob>chi^2 = 0.0	H & L chi^2 = 20.53; Prob>chi^2 = 0.00	H & L chi^2 = 12.99; Prob>chi^2 = 0.00

(1) No Change; (2) Increase; H & L: Hosmer & Lemeshow

Table 9.5: SP Model for Office Relocation from Central Ottawa to Satellite Community controlling for Company Sector

Variable	High Tech Companies: Coefficient	S.E	p>|z|	Other Companies: Coefficient	S.E	p>|z|
ETL	-5.40	2.09	0.01	-2.43	2.60	0.35
OH COST	-4.33	1.31	0.00	-3.97	1.29	0.00
OPS (1)	**1.70**	1.05	0.10	-0.29	1.60	0.86
OPS (2)	1.13	1.63	0.49	-0.19	1.99	0.93
OFF. PROX	-0.66	1.33	0.62	1.31	1.83	0.47
OFF. ACES	**4.37**	**1.92**	**0.02**	2.83	2.27	0.21
Constant	6.52	2.54	0.01	4.10	2.84	0.15

High Tech Companies: Goodness of Fit Tests		Other Companies: Goodness of Fit Tests	
LL constant = -48.520	LL Ratio = 43.05	LL constant = -56.838	LL Ratio = 63.81
LL convergence =- 26.10	# of obs = 70	LL convergence = -24.93	# of obs = 82
H & L chi^2 = 3.03	Prob>chi^2 = 0.2197	H & L chi^2 = 7.01	Prob>chi^2 = 0.03
McFadden $\bar{\rho}^2$ = 0.4436	ROC Area = 0.9404	McFadden $\bar{\rho}^2$ = 0.5613	ROC Area = 0.9048

(1) No Change; (2) Increase; H & L: Hosmer & Lemeshow

Table 9.6: SP Model for Office Location within Central Ottawa Controlling for Office Size

Variable	Small Companies			Mid-size Companies (11 – 50 Employees)		
	Coefficient	S.E	p>|z|	Coefficient	S.E	p>|z|
ETL	0.41	1.95	0.83	1.58	1.67	0.34
OH COST	-2.57	1.21	0.03	-2.16	0.79	0.01
OPS (1)	0.30	1.33	0.82	**-3.12**	1.32	0.02
OPS (2)	0.14	2.01	0.94	-2.01	1.88	0.28
OFF. PROX	0.60	1.62	0.71	3.89	1.56	0.01
OFF. ACES	-0.19	2.36	0.94	0.91	1.98	0.64
Constant	0.54	2.41	0.82	0.36	1.88	0.85
Goodness of Fit Tests				Goodness of Fit Tests		
LL constant = -22.181		LL Ratio = 13.94		LL constant = -69.32		LL Ratio = 69.49
LL convergence = -15.211		# of obs = 32		LL convergence =-34.57		# of obs = 100
H & L chi^2 = 1.11		Prob>chi^2 = 0.5745		H & L chi^2 = 10.79		Prob>chi2 = 0.01
McFadden $\bar{\rho}^2$ = 0.3142		ROC Area = 0.874		McFadden $\bar{\rho}^2$= 0.5012		ROC Area = 0.932

(1) No Change; (2) Increase; H & L: Hosmer & Lemeshow

9.5. Interpretation – Office Location/Relocation Models

This section summarizes the findings obtained from the above calibrated office location/relocation models and discusses possible reasons surrounding the trends observed for each attribute regarding their contribution to the utility derived from locating/relocating an office within each alternative following the adoption of a telecommuting program by a company. Once more, the City of Ottawa municipal area was used as the study area for this research study and the two office location/relocation alternatives included: (1) central Ottawa and (2) satellite communities.

In order to obtain a clear-cut understanding of how the adoption of telecommuting program may influence a company's decision with regards to locating/relocating its office within the City of Ottawa, binary models were calibrated for each office location/relocation alternative using data collected from the hypothetical SP survey. The binary models were formulated following two different approaches. Both approaches made use of the assumption that each company recently adopted a telecommuting program for its employees.

- In the first approach, binary models were calibrated to investigate how certain attributes influence corporate decisions regarding the location of their offices within the City of Ottawa amongst the two office location alternatives considered in the research study.
- In the second approach, binary models were calibrated to investigate how certain attributes influence corporate decisions regarding the relocation of their offices between

one office location alternatives to another office location alternative within the City of Ottawa.

From the binary models calibrated following the above two approaches, more emphasis was placed on the role of telecommuting in the office location/relocation decision-making process. Similar trends were also found between the attributes in each model with regards to their contribution to the utility (disutility) derived from locating/relocating an office within each alternative (despite the presence of some insignificant variables).

To begin, the adoption of a telecommuting program was found to have an influence on where business firms choose to locate their office. As more employees tend to telecommute within a company, it was found that managers of business firms are more likely to locate/relocate their offices within central Ottawa. We can therefore reject the null hypothesis (H_1), which states that the adoption of a telecommuting program within a company does not influence the decision-making process regarding where a company chooses to locate/relocate its office with an urban area.

Considering the benefits offered by being in proximity to other offices with similar business orientation, clients, personnel and other amenities, the general trend shows that companies are more likely to locate/relocate their offices in areas where they would benefit from the merits of this proximity. The calibrated office location/relocation models show that upon adopting a telecommuting program, both new incoming and pre-established companies within Ottawa are more likely to locate/relocate their offices within central Ottawa compared to locating/relocating to satellite community. At the moment, central Ottawa is currently concentrated with high employment growth and high level of activities. Given that face-to-face negotiations still play an important role in conducting business (see Tables 7.9.3 & 7.9.4, section 7.2.2), the high concentration of businesses within central Ottawa provides a medium to achieve business interactions over short times and distances. Hence, companies can merit from a reduction in time lost and cost savings that result from an overall shorter times and distances required to achieve business interactions between offices and their clients and/or other businesses. Being in proximity to these amenities is a possible reason why companies would prefer to locate/relocate their offices within central Ottawa assuming the adoption of a telecommuting program. Notwithstanding, while controlling for company sector, it was found that companies within the high-tech industry are likely to locate their offices within central Ottawa as much as they are likely to locate within the satellite communities. The result of this finding is not strange considering the satellite communities (especially Kanata) are the breeding ground for most high-tech companies. Hence, following the adoption of a telecommuting program, they would prefer to locate within the satellite communities to merit the benefits of being in proximity to other related high-tech companies. This therefore implies that an area with a high concentration of activities and which offers good proximity to businesses of related type serves as an attractive area where companies would seek to locate/relocate their offices.

Taking overhead cost into account, the overall trend shows that following the adoption of a telecommuting program, companies are better-off locating/relocating their offices within central Ottawa as oppose to locating/relocating within the satellite community for every unit increase in overhead cost incurred for operating their offices within either location alternatives. Considering that business activities in offices cover a wide range of fields, the merits and demerits obtained from an office location/relocation site can be analyzed from the viewpoint of the benefits and costs associated with locating/relocating within that specific site versus the benefits gained from that location. Considering some aspects of the costs (e.g. rental cost, utility cost, legal fees, etc.) associated with locating/relocating an office within central Ottawa versus those associated with locating/relocating within the satellite community alongside the benefits obtained from locating within either of these two alternatives, central Ottawa currently offers benefits such as good inter-office interaction between companies of similar types, better and more reliable transportation system, proximity to clients, and other amenities compared to the satellite community. Hence, despite that central Ottawa may be associated with an overall higher office rental costs compared to the satellite community, the net benefits obtain from locating within this area may substantially outweigh the demerits brought about by higher office rental costs when compared to the satellite community. It is therefore possible to perceive a pattern in which the merits of concentration within an area outweigh its associated cost. This would therefore encourage further concentration of offices spaces within such areas in order to obtain higher net benefit (benefits – cost). This reason may explain why business firms are likely to locate/relocate their offices within central Ottawa despite its high cost assuming the adoption of a telecommuting program.

At the moment, growth forecasts show that the satellite communities would experience an overall greater population growth compared to central Ottawa. The population growth within these communities would gradually change the pattern of the land-use. Changes in the land-use pattern would inevitably lead to changes in transportation needs. Although the relationship between land-use and transportation is already hard to make explicit (Priemus *et al.,* 2001), many transport-land use schemes focus on accessibility. These schemes follow a particular line of reasoning: since the accessibility of activities is important to the mobility of people, any improvement in accessibility will make certain regions, areas and locations more attractive for working, living, playing, etc. This relationship between accessibility and altered spatial choices is partially reflected by studies that indicate that accessibility plays an important role for companies (Louw, 1996) and people (Kim et al., 2005) when choosing locations. Improvements made to transportation infrastructure reduce congestion, travel time and travel distances between origins and destinations (Lakshmanan *et al.*, 2005). For example, Argiolu (2008) found in a research study that intelligent transportation systems (ITS) has an influence on the location preferences of offices within an urban area since they are successfully decrease travel time and cost and improve other factors like reliability and comfort. From a business perspective, the primary goal for siting an office within an area is to generate revenue for the company at minimal cost. One way companies seek to minimize cost is by optimizing their logistics to minimize the time lost while transporting resources[28] from one point to another, hence, the need for locating their offices in areas with good transportation network coverage. In a research carried out by Tayyaran *et al.* (2003) on the impacts of telecommuting and intelligent transportation systems on urban development patterns, results showed that telecommuting and ITS may have decentralization effects and reinforce the development of peripheral suburban centers. With the city of Ottawa currently promoting the adoption of telecommuting as a viable transportation demand measure (TMP, 2008), coupled with recent findings that shows that employees who telecommute prior to relocating their residences tend to relocate closer to their offices (Mokhtarian *et al.,* 2005), it is rational to see a reason why companies that adopt a

[28] Resources could be in the form of clients, employees or raw materials.

telecommuting program prior to locating/relocating within Ottawa would be more likely to locate/relocate their offices within the satellite communities. This would be so in order that they may benefit from future transportation improvements following changes in land-use within these communities as well as be in proximity to their employees. In this way, they could benefit from reduced travel times between their employees' residences and their office should cases of emergency arise where an employee would need to commute to the office. Hence, results from this finding show that the adoption of telecommuting by a company may have an effect on changes in land-use patterns. We can therefore reject the null hypothesis that the adoption of a telecommuting within a company does not have a decentralization effect within an urban area.

Lastly, the size of an office does not seem play a significant role in the office location/relocation decision-making process following the adoption of a telecommuting program. Part of the reason may have been due to the lack of sufficient data. Notwithstanding, controlling for certain factors such as company sector and company size revealed that companies are more likely to maintain their office size upon locating/relocating their offices within either alternatives following the adoption of a telecommuting program. However, upon locating within central Ottawa, new incoming mid-size companies are more likely to reduce their office size. No possible reason could be derived for this observation due to the mixed results obtained for this attribute.

Having completed modeling the mode choice preferences of commuters as well as the office location/relocation preferences of corporate managers, the next part of this report relates findings obtained from these studies to society.

PART IV: RESEARCH IMPLICATIONS, CONCLUSIONS & RECOMMENDATIONS

This part of the report presents overall findings made from the research and its contribution to society. It sheds light on some factors that may act as limitations to the findings made and also discusses possible areas for future research on this topic. Separate research implications, conclusions and recommendations are presented based on the two studies carried out on commuters' mode preference and office location/relocation preference.

10. RESEARCH IMPLICATIONS, CONCLUSIONS & RECOMMENDATIONS: STUDY ON COMMUTERS' MODE PREFERENCE

In this chapter, the implications and contributions of the research on commuters' mode preference are discussed. Limitations to the findings as well as other possible areas for future research on measures to consider for improving public transit usage within the City of Ottawa are also mentioned.

10.1. Modal Split – Application

Following the calibration of the above Nested logit model in section (8.2.3.3), the probability of a specific mode of transport being chosen by a commuter for commuting to the CBD of Ottawa was estimated using the STATA 12.0 software. The estimated probabilities were calculated based on equations [8.1.3] to [8.2.3]. The result is represented in the pie chart in Figure 10.1 below. This forecasted modal split shown in Figure 10.1 was assumed to be the estimated average modal split for both AM and PM peak periods. It was also assumed that commuters would use the same mode to commute during the AM peak as well as during the PM peak.

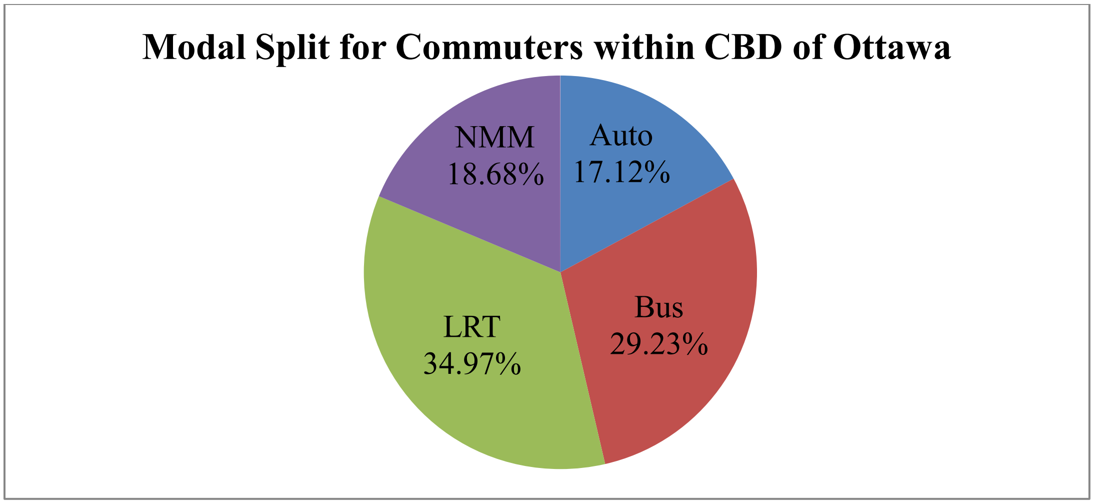


Figure 10.1: Modal Split for Commuters within CBD of Ottawa

Table 10.1 below shows the actual modal split for the CBD of Ottawa where this study was carried out extracted from the 2011 origin-destination survey conducted within the national capital region.

Table 10.1: Current Modal Split – CBD Ottawa

Mode	AM Peak		
	To District	From District	Within District
Auto Driver	29%	52%	12%
Auto Passenger	8%	5%	0%
Transit	51%	24%	11%
Bicycle	4%	1%	1%
Walk	7%	17%	74%
Other	1%	1%	2%
Total	100%	100%	100%

Mode	PM Peak		
	To District	From District	Within District
Auto Driver	37%	28%	12%
Auto Passenger	13%	8%	4%
Transit	31%	51%	14%
Bicycle	3%	4%	4%
Walk	15%	8%	64%
Other	1%	1%	2%
Total	100%	100%	100%

By collapsing some of the modes in Table 10.1 above into automobile, transit and non-motorized modes and considering only trips that are made to or from the CBD, the current modal split for both the AM and PM peak periods are shown in the pie charts below[29] (Figure 10.2 & 10.3).

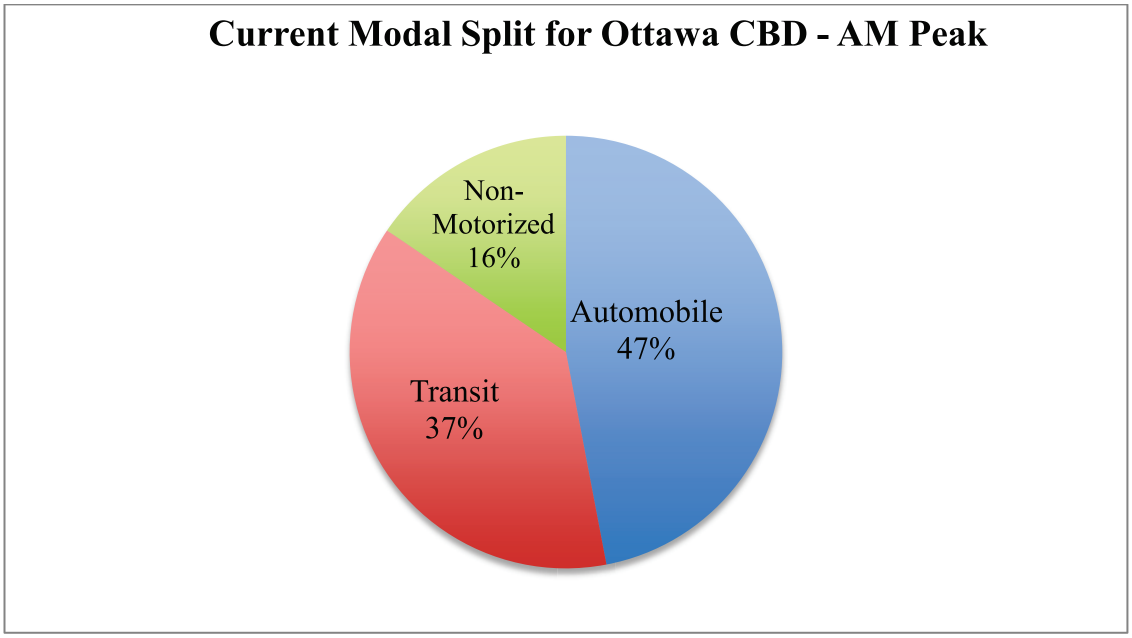


Figure 10.2: Current Modal Split for Ottawa CBD – AM Peak

[29] The reader's attention is drawn to the fact that the actual modal split may include modal split for several other activities (e.g., shopping, leisure, etc) other than commuting. However, the estimated modal split for this study was based on commuting. Hence, some discrepancies may be expected.

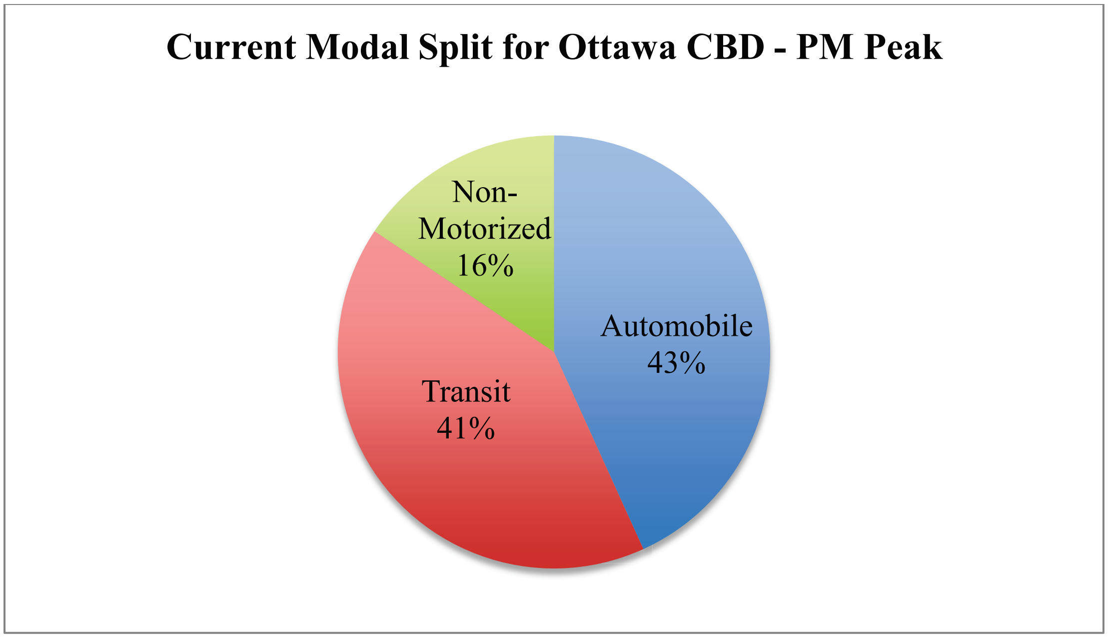


Figure 10.3: Current Modal Split for Ottawa CBD – PM Peak

Based on information revealed in both pie charts in Figures 10.2 & 10.3 above, about 45% of the current trips made during the AM and PM peak hours 'to and from' the CBD are done by automobile on average. This is closely followed by public transit that accounts for an average of 39% of the trips made during the AM and PM peak hours. Lastly, an approximate average of 16 % of all trips made during the AM and PM peak hours 'to and from' the CBD is done through non-motorized modes.

At the moment, public transit is composed of only a bus rapid transit that accounts for about 39% of the trips made to the CBD. Although the introduction of the LRT would see a reduction in the bus ridership level to 29.23% (approximately 10% reduction in current ridership level) based on observed data collected from the SP mode choice survey, there could be an overall increase in public transit ridership 'to and from' the CBD by as much as 64%, with 34.97% accounted for by the LRT (see Figure 10.1). This suggests that when the LRT mode becomes operational, public transit ridership 'to and from' the CBD could increase by as much as 25% from its current average level set at 39%. On the other hand, trips made by automobile to this area could reduce by as much as 27% (down to 17.12% on average compared to current average levels set at 45%). There wouldn't be a drastic change in the percentage composition of the trips made by commuters who commute 'to and from' the CBD by non-motorized modes although it may slightly increase by 2.88% from 16% to 18.88% when the LRT goes operational.

Comparing the modal split results obtained from the calibrated model to that obtained from the most recent origin-destination survey, probable reasons for no drastic changes in the modal split for non-motorized modes once the LRT becomes operational may be as follows:

- The non-motorized mode neither competes directly with the public transit mode nor does it compete with the automobile. Therefore, commuters who currently commute by this mode may not necessarily be affected by improvements made to either modes of transport, as oppose to public transit whose service is being improved through the provision of the LRT system.
- Secondly, 77% of the respondents who currently commute by non-motorized modes live within 5 km from the CBD while 9 % live within 6 to 10 km (see Table 10.2). Aultman-Hall (1996) found that an average cyclist rode 3.7 km on a one-way bicycle commute. Therefore, it can be deduced that majority of commuters who commute by non-motorized modes live within reasonable distances from the CBD of Ottawa that makes it convenient for them to commute by non-motorized modes.

Table 10.2: Current commuting modes as a function of one-way commute distance

Current Commuting Mode	Range of One-way Commute Distance					
	0 - 5 km	6 - 10 km	11 - 20 km	21 - 30 km	> 30 km	Total
Auto (Drive Alone)	7%	16%	19%	39%	75%	20%
Auto (Carpool)	3%	16%	7%	28%	25%	12%
Bus Transit	13%	59%	74%	33%	0%	50%
Non-Motorized Mode	77%	9%	0%	0%	0%	19%
Total	100%	100%	100%	100%	100%	100%

10.2. Modal Shift – Application

Having calibrated the binary models between each current mode of transport versus the LRT mode of transport (see section 8.3.1.3), the probability of respondents switching to the LRT or remaining with their current mode of transport was estimated using equation [8.2.7] above. The results are shown in Figure 10.4 below.

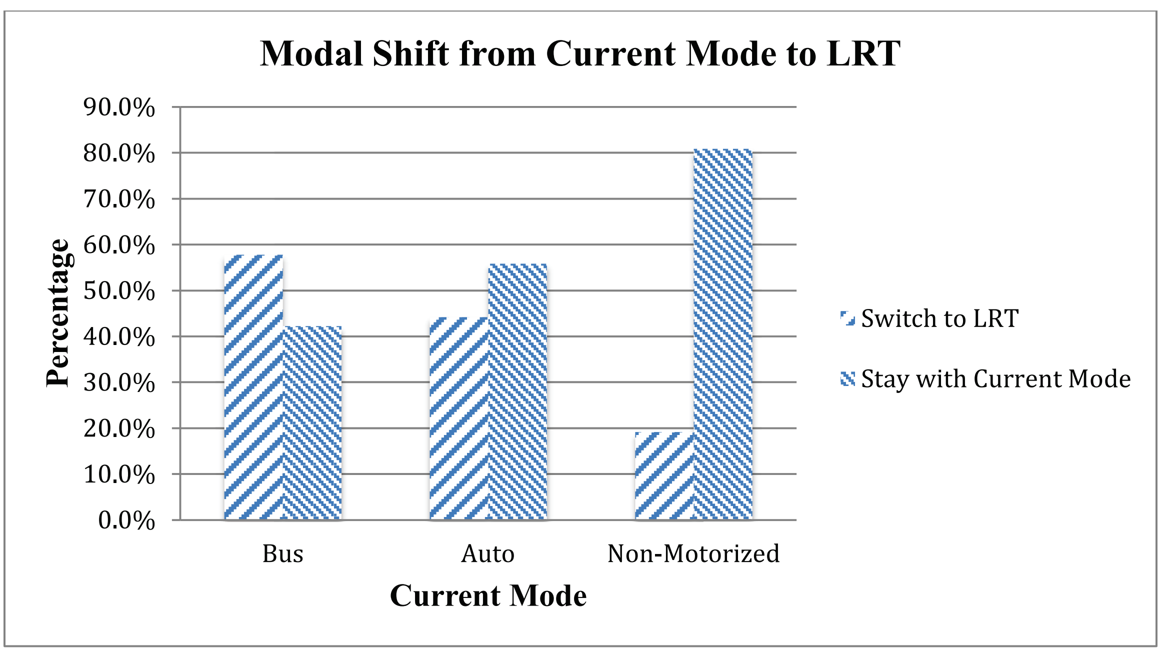


Figure 10.4: Estimated Modal Shift to LRT from other modes of transport

With reference to the results shown in Figure 10.4 above, approximately up to 57.8% of commuters who currently commute by bus are likely to switch to using the LRT. In the case of current auto users (both single occupant vehicle commuters and carpool commuters), approximately up to 44.2% of them are likely to switch to the LRT. Lastly, only approximately 19.2% of commuters who currently commute by non-motorized modes are likely to switch to the LRT for commuting once it becomes operational.

Once more, these findings are based on the attributes that describe each mode of transport presented in each hypothetical SP choice scenarios. The greatest percentage of commuters who are likely to use the LRT system once it becomes available would likely come from current commuters who currently commute by bus transit. Closely following this group are automobile users and then users of non-motorized modes.

As an observation, the reader may be curious to know why the automobile accounts for the greatest change in modal split amongst commuters who commute to the CBD of Ottawa following the introduction of the LRT. However, in the modal shift analysis, forecast shows that most of the LRT commuters will come from current bus transit users and not from current automobile users. Though it is rational to think that a reduction in automobile mode share would suggest its users would shift to start commuting by LRT, this however is not the case as investigated in this study for the following possible reasons:

- The LRT and Bus transit compete directly with each other as public transit modes. Hence, it is easier for current users of public transit to switch their mode choice following improvements made to one service;
- Following the introduction of the LRT, some current automobile users may decide to shift to other modes (e.g., bus transit, or non-motorized mode);
- The LRT may not have been the preferred choice for some current automobile commuters given that the planned route of the LRT is not readily accessible within most areas within the city;

A separate modal shift analysis would be required to accurately determine the modal shift pattern amongst all modes following the implementation of the LRT system. However, this was not carried out given that it is out of the scope of this research study.

10.3. Research Contributions

Throughout this research study, a stated preference methodology was used to design and collect data required to forecast the modal split for commuters who commute to the CBD of Ottawa once the LRT becomes operational. The methodology made use of hypothetical mode choice scenarios characterized by various attributes of ground modes of transport (including the forthcoming LRT mode) that would be available for use for commuting 'to and from' the CBD of Ottawa. In addition, a modal shift analysis was also carried out in order to estimate what percentage of commuters would likely shift from using their current modes for commuting to begin commuting using the forthcoming LRT mode. Models were calibrated using discrete choice analysis based on the theory of utility maximization.

With regards to the calibrated modal split model, results show that improvements made to the public transit system following the introduction of the LRT system would possibly attract commuters towards using more environmentally friendly modes such as public transit for commuting, increasing its mode share within the CBD of Ottawa by as much as 25%. At the same time, the presence of the LRT mode of transport could result in a reduction of automobile use within the CBD by as much as 27%. Some benefits that follow the reduction of automobile use include:

- A reduction of carbon dioxide and green house gas (GHG) emissions. So far, it is estimated that the introduction of the LRT could reduce approximately 94,000 tons of CO_2 gas emissions in total by the year 2031 (TMPIRS, 2008);
- A reduction in traffic congestion and improvement in travel efficiency in and out of the CBD of Ottawa. It is estimated that commuters who commute by LRT 'to and from' the CBD would experience large timesaving in the magnitude of approximately 10-15 minutes daily, creating a saving of about $1.5 billion by 2040 when converted in monetary terms (TMPIRS, 2008);
- Savings in vehicle-kilometer-traveled and accident avoidance savings given that there would be lesser vehicles on the road.

Aside from the above potential environmental contributions, findings made from this research study could be of assistance to transportation engineers and planners who carry out transportation forecasting especially at the mode choice phase given that the most recent 2011 origin-destination survey does not include the LRT mode as a viable mode of transport option (due to its absence at the moment).

10.4. Research Limitations

The results of this study were based on data collected using the stated preference methodology. SP surveys are based on hypothetical scenarios through which the preferences for new (non-existing) alternatives are elicited using specified choice sets. A significant disadvantage with this methodology is that people may not necessarily do what they say (Kroes *et al*, 1988). Given the scenarios are hypothetical, there is no way to determine the validity of the choices selected by the respondents versus the actual choices they would make in reality. Hence, there may be discrepancies between respondents' stated and actual choices. Notwithstanding, the SP methodology was the most appropriate methodology applicable for this type of quantitative study that involves modeling the mode choice preferences of commuters for informed decision making and planning. For future studies, a combination of revealed preference and stated preference methodology could be considered.

Secondly, the design of the SP choice scenarios was done in a manner such that respondents were required to assume that they had equal access to all four ground modes of transport alternatives considered in this research study. However, in reality, the forthcoming LRT system would have a very limited transportation network coverage and its planned route wouldn't be readily accessible by majority of the communities located in the South end of Ottawa as well as its far West end (Kanata) and far East end (Orleans). Hence, there might have been some bias in the selection of mode choice preference for commuting especially for respondents who live within areas currently not along the planned LRT route.

Despite the above limitations, the findings of this research study were reasonable and do reveal some information about commuters who commute ‘to and from’ the central business district of Ottawa as well as to the society at large.

10.5. Possible areas for future research

Aside from the contributions made by this research study to the society, there are other viable areas for future research to study and evaluate sustainable options for improving transit system usage within Ottawa. Some possible areas that future researchers could look into include:

- Investigating measures that could contribute towards attaining ‘chain mobility’ or ‘seamless multi-modal mobility’. This would involve studying how urban transportation systems could be designed in order to provide commuters/travelers with various connected modes of transport to ease their travel from their origin to their destination. For example, providing more park and ride facilities that could encourage commuters to use both private vehicles and public transit to complete one trip;
- Investigate the characteristics of trips such as their purpose, their commuting time/distance and the various mode choices available so as to derive the most efficient modes of transport applicable for each trip purpose. For example, there may be some trips that may be too long to commute by non-motorized modes, too expensive to commute by automobile due to restrictions and other factors and may not readily be accessible by public transit. For such trips, other viable alternatives could be investigates

in order to make transportation more sustainable (e.g. the use of personal rapid transit systems within highly dense urban areas).

- Investigate the impact of transit improvements combined with the implementation of travel demand management methods (e.g. congestion surcharge, parking restrictions, etc.) in alleviating traffic congestion.

11. RESEARCH IMPLICATIONS, CONCLUSIONS & RECOMMENDATIONS: STUDY ON OFFICE LOCATION/RELOCATION PREFERENCE

Findings made on the study of office location/relocation preferences may have some implications on the land-use development and transportation planning. A number of studies carried out on telecommuting and residential locations showed that the adoption of telecommuting might possibly lead to a decentralized pattern in urban development (Tayyaran & Khan, 2003; Muhammad *et al.* 2007). In the same vein, Tayyaran, Khan & Anderson (2003) hypothesized that the incorporation of information technology measures such as telecommuting and intelligent transportation systems could have an impact on the choice location of office space for business firms although no quantitative analysis was carried out to validate this. In a separate study, Argiolu *et al.* (2008) found that intelligent transportation systems (ITS) have an influence on the location preferences of offices within an urban area since ITS are successful in decreasing travel time and cost and improving accessibility. Hence, amid these findings, this quantitative research study made use of discrete choice models to investigate how the use of information technology measures (with particular focus on telecommuting) could influence the preference for office location/relocation. This chapter mentions the possible implications of the research findings to land use.

11.1. Research Implications and Considerations

11.1.1. Land Use Implications

The presence of advanced technology gives business firms the ability to have their employees telecommute and do work away from the conventional office environment thereby changing the overall purpose of an office (Sridhar *et al.* 2003). Notwithstanding, this study revealed that the adoption of a telecommuting program by business firms may have both decentralization and centralization effect on land-use patterns.

Telecommuting was found to have an influence on the office location/relocation decision-making process. The more employees telecommute within a business firm, the more likely they are to locate their office in an area with a high concentration of activities. In a separate study on the relationship between telecommuting, residential and job relocation, Mokhtarian *et al.* (2005) found that individuals who telecommute prior to moving their residential location tend to move closer to their offices. Based on the assumption of these two findings, the concept of telecommuting can be integrated alongside land-use and transportation plans within a city in order to foster high-density development areas. This could be realized given that the adoption of telecommuting could force companies to locate/relocate their offices within areas of high concentration of activities followed by telecommuting employees who may tend to relocate their residences closer to their offices. This sort of concept could lead to concentrated growth that would be beneficial in managing land-use and transportation demand.

On another note, accessibility was also found to be an important factor considered by business firms when deciding where to locate/relocate their offices following the adoption of a telecommuting program. Assuming the adoption of a telecommuting program, findings from this study showed that business firms are more likely to locate their offices within the satellite communities. Hence, in this context, the adoption of telecommuting has a decentralization effect on land-use pattern. In a study on office siting in Japan, Onishi (1994) recognized that modification of work patterns through the introduction of telecommuting was a contributing factor in the relocation of offices away from the congested central Tokyo.

With the above evidences that show that the adoption of telecommuting by companies could bring about a centralized as well as a decentralized land use pattern, blending the concept of telecommuting with land-use and urban transportation infrastructure planning could contribute towards attaining the development of a multinucleated urban structure. This form of urban development is characterized by a number of satellite cities that contain mixed business and residential land uses located outside a congested central urban area, along radial transportation corridors. If carefully planned, a multinucleated urban structure could be a sustainable form of development with transportation and environmental benefits (Tayyarran & Khan, 1996). They could help decongest central urban areas by directing concentrated growth towards a number of well-defined development nodes (satellite communities). This would offer the opportunity to some residents to live and work within the same community; reduce the number of trips generated and most of all, balance the inequalities that often exists within most cities as a result of employment, population and social differences. Hence, findings made from this study have implications on regional planners, transportation engineers and policy makers as they seek to control growth in a structured form in order to prevent urban sprawl and its adverse effects.

11.2. Research Limitations and Recommendations for future research

This research sought to investigate the influence of telecommuting on office location/relocation decisions. Due to the lack of powerful and useful theoretical and methodological perspectives on telecommuting and its influence on office location/relocation, the study used an exploratory modeling approach that involved the performance of empirical analysis in an attempt to fill-in (partially fill-in) the missing gap. However, various operational decisions in the explorative approach, such as the choice of the included attributes and the attribute levels or the number of choice sets presented to each respondent might be subject of debate. Hence, despite being some impacts on land use and urban development pattern associated with findings made from this study, some limitations and recommendations are discussed below.

As stated above, the results of this study were also based on data collected using the stated preference methodology. A significant disadvantage with this methodology is that people may not necessarily do what they say (Kroes *et al*, 1988). Given the scenarios are hypothetical, there is no way to determine the validity of the choices selected by the respondents versus the actual choices they would make in reality. Hence, there may be discrepancies between respondents' stated and actual choices. Notwithstanding, the SP methodology was the most appropriate methodology applicable for this type of quantitative study that involves modeling the office location/relocation preferences of managers for informed decision making and planning. For future studies, a combination of revealed preference and stated preference methodology could be implemented to evaluate the influence of telecommuting on office location.

Secondly, majority of the companies that responded to the survey were small to mid-size companies having less than 50 employees. Too much bureaucracy was required to solicit managers of big companies to take part in the survey. In most cases, majority of these managers were not directly reachable. Hence, business firms that participated in this study were not equally balanced or objectively represented leading to a selection bias associated with the collected data. Also, more offices were sampled from within central Ottawa compared to those sampled from within the satellite communities. This is because there are more offices currently located within central Ottawa compared to those located within the satellite communities. This therefore implies that from the general population, offices within the satellite communities were less likely to be sampled in the survey compared to those within central Ottawa leading to bias in the sampling process.

Insufficient time and resources allocated to this research study also served as a major limitation towards obtaining more data that would have made the findings more significant. In addition, given that there hasn't been any similar study carried out on the influence of telecommuting on office location/relocation, there was no set benchmark to compare the trends observed in this study.

In a much more broader scope, an examination of the impact of telecommuting (resulting from information technology) on land-use as well as commuting pattern would require the integration of a land-use and transportation models that would have the capability to take into account other certain factors not included in the discrete choice model used in this study.

To conclude, this research illustrated the calibration of a discrete choice office location/relocation model using stated preference (SP) data that was designed based on telecommuting as well as attributes that influence decisions regarding the location preferences of offices. In general, it is recommended that more research should be performed to further elaborate on the model and on testing its value for understanding the potential consequences of telecommuting on office location/relocation. Results from the study should be of interest to transportation engineers, planners, as well as policy makers and other researchers.

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APPENDIX A

Orthogonal Main Effect Design Codes for commuters' mode preferences – Pilot Survey

Table 1 – A: Orthogonal Main Effect Design Codes for commuters' mode preferences – Pilot Survey

Treatment combination	Attributes					
	Level of Convenience	**Accessibility (meters)**	**Service Frequency**	**Delay (minutes)**	**Cost/Fare ($)**	**Commute Time (mins)**
1	0	0	0	0	0	0
2	0	0	0	0	1	2
3	0	0	1	0	2	4
4	0	1	1	1	0	1
5	0	1	0	1	1	3
6	0	1	0	1	2	5
7	1	0	1	2	0	1
8	1	0	1	2	1	3
9	1	0	0	2	2	5
10	1	1	0	0	0	0
11	1	1	1	0	1	2
12	1	1	1	0	2	4
13	0	0	0	1	0	0
14	0	0	0	1	1	2
15	0	0	1	1	2	4
16	0	1	1	2	0	1
17	0	1	0	2	1	3
18	0	1	0	2	2	5
19	1	0	1	0	0	1
20	1	0	1	0	1	3
21	1	0	0	0	2	5
22	1	1	0	1	0	0
23	1	1	1	1	1	2
24	1	1	1	1	2	4
25	0	0	0	2	0	0
26	0	0	0	2	1	2
27	0	0	1	2	2	4
28	0	1	1	0	0	1
29	0	1	0	0	1	3
30	0	1	0	0	2	5
31	1	0	1	1	0	1
32	1	0	1	1	1	3
33	1	0	0	1	2	5
34	1	1	0	2	0	0
35	1	1	1	2	1	2
36	1	1	1	2	2	4
37	0	0	0	0	0	0
38	0	0	0	0	1	2
39	0	0	1	0	2	4
40	0	1	1	1	0	1
41	0	1	0	1	1	3
42	0	1	0	1	2	5
43	1	0	1	2	0	1
44	1	0	1	2	1	3
45	1	0	0	2	2	5
46	1	1	0	0	0	0
47	1	1	1	0	1	2
48	1	1	1	0	2	4
49	0	0	0	1	0	0
50	0	0	0	1	1	2

51	0	0	1	1	2	4
52	0	1	1	2	0	1
53	0	1	0	2	1	3
54	0	1	0	2	2	5
55	1	0	1	0	0	1
56	1	0	1	0	1	3
57	1	0	0	0	2	5
58	1	1	0	1	0	0
59	1	1	1	1	1	2
60	1	1	1	1	2	4
61	0	0	0	2	0	0
62	0	0	0	2	1	2
63	0	0	1	2	2	4
64	0	1	1	0	0	1
65	0	1	0	0	1	3
66	0	1	0	0	2	5
67	1	0	1	1	0	1
68	1	0	1	1	1	3
69	1	0	0	1	2	5
70	1	1	0	2	0	0
71	1	1	1	2	1	2
72	1	1	1	2	2	4
73	0	0	0	0	0	0
74	0	0	0	0	1	2
75	0	0	1	0	2	4
76	0	1	1	1	0	1
77	0	1	0	1	1	3
78	0	1	0	1	2	5
79	1	0	1	2	0	1
80	1	0	1	2	1	3
81	1	0	0	2	2	5
82	1	1	0	0	0	0
83	1	1	1	0	1	2
84	1	1	1	0	2	4
85	0	0	0	1	0	0
86	0	0	0	1	1	2
87	0	0	1	1	2	4
88	0	1	1	2	0	1
89	0	1	0	2	1	3
90	0	1	0	2	2	5
91	1	0	1	0	0	1
92	1	0	1	0	1	3
93	1	0	0	0	2	5
94	1	1	0	1	0	0
95	1	1	1	1	1	2
96	1	1	1	1	2	4
97	0	0	0	2	0	0
98	0	0	0	2	1	2
99	0	0	1	2	2	4
100	0	1	1	0	0	1
101	0	1	0	0	1	3
102	0	1	0	0	2	5
103	1	0	1	1	0	1
104	1	0	1	1	1	3
105	1	0	0	1	2	5
106	1	1	0	2	0	0

107	1	1	1	2	1	2
108	1	1	1	2	2	4
109	0	0	0	0	0	0
110	0	0	0	0	1	2
111	0	0	1	0	2	4
112	0	1	1	1	0	1
113	0	1	0	1	1	3
114	0	1	0	1	2	5
115	1	0	1	2	0	1
116	1	0	1	2	1	3
117	1	0	0	2	2	5
118	1	1	0	0	0	0
119	1	1	1	0	1	2
120	1	1	1	0	2	4
121	0	0	0	1	0	0
122	0	0	0	1	1	2
123	0	0	1	1	2	4
124	0	1	1	2	0	1
125	0	1	0	2	1	3
126	0	1	0	2	2	5
127	1	0	1	0	0	1
128	1	0	1	0	1	3
129	1	0	0	0	2	5
130	1	1	0	1	0	0
131	1	1	1	1	1	2
132	1	1	1	1	2	4
133	0	0	0	2	0	0
134	0	0	0	2	1	2
135	0	0	1	2	2	4
136	0	1	1	0	0	1
137	0	1	0	0	1	3
138	0	1	0	0	2	5
139	1	0	1	1	0	1
140	1	0	1	1	1	3
141	1	0	0	1	2	5
142	1	1	0	2	0	0
143	1	1	1	2	1	2
144	1	1	1	2	2	4
145	0	0	0	0	0	0
146	0	0	0	0	1	2
147	0	0	1	0	2	4
148	0	1	1	1	0	1
149	0	1	0	1	1	3
150	0	1	0	1	2	5
151	1	0	1	2	0	1
152	1	0	1	2	1	3
153	1	0	0	2	2	5
154	1	1	0	0	0	0
155	1	1	1	0	1	2
156	1	1	1	0	2	4
157	0	0	0	1	0	0
158	0	0	0	1	1	2
159	0	0	1	1	2	4
160	0	1	1	2	0	1
161	0	1	0	2	1	3
162	0	1	0	2	2	5

163	1	0	1	0	0	1
164	1	0	1	0	1	3
165	1	0	0	0	2	5
166	1	1	0	1	0	0
167	1	1	1	1	1	2
168	1	1	1	1	2	4
169	0	0	0	2	0	0
170	0	0	0	2	1	2
171	0	0	1	2	2	4
172	0	1	1	0	0	1
173	0	1	0	0	1	3
174	0	1	0	0	2	5
175	1	0	1	1	0	1
176	1	0	1	1	1	3
177	1	0	0	1	2	5
178	1	1	0	2	0	0
179	1	1	1	2	1	2
180	1	1	1	2	2	4
181	0	0	0	0	0	0
182	0	0	0	0	1	2
183	0	0	1	0	2	4
184	0	1	1	1	0	1
185	0	1	0	1	1	3
186	0	1	0	1	2	5
187	1	0	1	2	0	1
188	1	0	1	2	1	3
189	1	0	0	2	2	5
190	1	1	0	0	0	0
191	1	1	1	0	1	2
192	1	1	1	0	2	4
193	0	0	0	1	0	0
194	0	0	0	1	1	2
195	0	0	1	1	2	4
196	0	1	1	2	0	1
197	0	1	0	2	1	3
198	0	1	0	2	2	5
199	1	0	1	0	0	1
200	1	0	1	0	1	3
201	1	0	0	0	2	5
202	1	1	0	1	0	0
203	1	1	1	1	1	2
204	1	1	1	1	2	4
205	0	0	0	2	0	0
206	0	0	0	2	1	2
207	0	0	1	2	2	4
208	0	1	1	0	0	1
209	0	1	0	0	1	3
210	0	1	0	0	2	5
211	1	0	1	1	0	1
212	1	0	1	1	1	3
213	1	0	0	1	2	5
214	1	1	0	2	0	0
215	1	1	1	2	1	2
216	1	1	1	2	2	4

APPENDIX B: PILOT SURVEYS

Department of Civil & Environmental Engineering
3044 Minto Center
1125 Colonel By Drive, Ottawa, ON, K1S 5B6
Tel: 613 520 2600 ext. 5786
Mobile: (613) 853 4907
Email: teneme@connect.carleton.ca

October 11th, 2012

Dear Sir/Mme.,

Survey on Choice of Transport Mode for Commuting

You are hereby invited to participate in a survey focused on gathering information needed to forecast ridership levels for the newly proposed Light Rail Transit (LRT) network for the City of Ottawa.

Results from the 2005 Origin-Destination survey called for the need to develop a light rail technology to meet Ottawa's transportation needs considering future population and employment growth by the year 2031. Hence, as part of its 2008 transportation master plan set at attaining a 30% transit modal split by the year 2021, the City of Ottawa recently approved the construction of a Light Rail Transit (LRT) along its East-West corridor.

Benefits of LRT service in the downtown core are numerous. These include: improved efficiency in terms of travel time saving, increased capacity due to high train frequency, less congestion due to less number of buses and possibly less cars on the road, reduction in air pollution and greenhouse gas emissions, accident avoidance savings as a result of less use of personal vehicles, and lastly, creation of more jobs leading to an overall economic boost.

There are no risks in participating in this study. In addition, the responses you provide **will be kept confidential** and used only for aggregate statistical analyses. You may withdraw from this survey at anytime if you choose to. However, your contribution will help us to develop methods for forecasting ridership of this newly proposed LRT network, which will in turn help planners and decision makers to establish land use, transportation investment policies and measures that best meet your needs.

Upon reading this introductory message, we encourage you to take a few minutes to answer the questions that follow in sections 2, 3, 4 & 5. We would want to thank you for your time and effort set aside to participate in this survey.

You may contact me by email at teneme@connect.carleton.ca in order to inform me to stop by and collect your completed survey. For any questions or inquiries, please do not hesitate to contact me using the above address.

Sincerely,

Tabot Eneme

Project Manager

Multimodal Travel Demand and System Management: Modal Split Factors for Predicting Light Rail Transit (LRT) Ridership for the City of Ottawa Downtown Area

Carleton UNIVERSITY
Canada's Capital University

STATED PREFERENCE SURVEY

Consent Form

Date of ethics clearance: **11th October, 2012**
Ethics Clearance for the Collection of Data Expires: **31st May, 2013**

I, ________________________________ volunteer to participate in a **transport mode choice preference survey that include the following modes of transport usable for commuting to downtown Ottawa: light rail transit, bus rapid transit, automobile, and nonmotorized modes.**

I understand that my participation will contribute data on travel mode choice for the development of a new model with a capability to treat, in addition to the commonly used variables light rail transit, advanced bus transit, and traveller information (provided by a future advanced traveller information system).

My participation in this survey is limited to completing the hard copy of the questionnaire provided by the researcher. The instructions and descriptions of technical terms are clearly noted in the questionnaire document. I do not perceive any risk associated with the completion of the questionnaire and my voluntary participation is motivated by desire to contribute knowledge on traveller decision-making.

I understand that:

- I am voluntarily responding to a request to participate in this survey extended by Mr. Tabot Eneme (Research Assistant) and Professor A.M. Khan of Carleton University and that he can be contacted by email (ata_khan@carleton.ca) and by telephone (613 520 2600 ext. 5786).
- The project was reviewed and received ethics clearance from the Carleton University Research Ethics Board and that the Chair of the Research Ethics Board they can be reached by email (ethics@carleton.ca) and by telephone (613 520 2517).
- I will remain anonymous and my response will be used only for aggregate statistical analyses.
- My response will remain confidential and that the data obtained will be destroyed following the completion of the current study and extensions, if any.
- I may decline from answering any questions.
- The results of the research study will be published in scientific literature such as journals, books and conference proceedings. Also, results may be used in workshops and seminars for the purpose of advancing knowledge.

________________________________ ____________________
Signature of Participant Date

________________________________ ____________________
Signature of Researcher Date

SECTION 2: Information about Trips made to Ottawa's Central Business District (CBD)

In this section of the survey, we will like to know more about how you commute to the Central Business District (CBD) of Ottawa. *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

1. For each commute you make to your destination within the core central business district (CBD) of Ottawa, please select amongst the following the mode of transport you currently use most:

☐ Automobile
☐ Drive alone ☐ Carpool/Vanpool
☐ Public Transit
☐ Non motorized mode (Cycle/Skate/Rollerblade/Walk)
☐ Other_____________________________________

2. If the **automobile** is currently your most used mode of transport for commuting to the CBD of Ottawa, please provide answers to the following:
   a. For those who **drive alone – ONLY.**
      i. How much do you pay for parking (Estimate):
$_______/day **or** $_______/week **or** $_______/month
      ii. Approximately how much do you pay per week for gas for your ***one-way*** commute to downtown ***only***? $_______/week

   b. For those who **carpool/vanpool – ONLY.**
      i. How many persons do you carpool/vanpool with on average? _______Persons.
      ii. Approximately how much do you pay individually per week for carpooling? $______/week

   c. How much time do you spend inside the vehicle (driving alone or carpooling) while commuting from your home to downtown on a ***one-way trip*** (driving time/In vehicle time)?
________minutes or ______ hours

   d. What is the approximate ***one-way*** driving distance between your home and your downtown destination? ______Km.

   e. Do you have a monthly transit pass?
☐ Yes ☐ No

3. If **public transit** (includes users of Park & Ride facilities) is currently your most used mode of transport for commuting to the central business district (CBD) of Ottawa, please provide answers to the following:
   a. How long do you wait at the transit stop/station for your bus/train (wait time)?
Approximately ______minutes.

   b. Approximately how long does it take you to get to downtown Ottawa from the moment you board your public transit on a ***one-way trip*** (Riding time/ in-vehicle time)?
______minutes or _____hour(s)

   c. Do you make any transfer during your daily commute from your origin to your downtown destination on a ***one-way trip***?

☐ Yes. How many? _____Transfers. ☐ No

   d. Approximately how many minutes does it take you to walk to your final destination from the moment you get off your public transit (Egress time)? ______minutes

   e. How much do you pay for transit fare for each one-way trip to downtown
☐ $2.60 - $3.30 ☐ Own transit pass
☐ $3.90 - $4.65 ☐ Other _________

☐ $7.75 (day pass)

4. How many days a week do you commute to your downtown office in a typical week?

☐	5 days/week	☐	2 days/week
☐	4 days/week	☐	1 day/week
☐	3 days/week	☐	Other_______

SECTION 3: Stated Preference Survey – Modal Choice Game

This part of this survey contains attributes (features) that describe different possible hypothetical scenarios of different modes of transport available for use to commute to downtown Ottawa. As noted earlier, the overall goal of this survey is to evaluate the acceptability of the new Light Rail Transit (LRT) mode of travel by the respondents as oppose to other ground modes of transport (i.e., bus, car and non-motorized modes) within the downtown area.

Your responses to this part of the survey are equally very important because this will help ensure that the survey represents the views of all those who commute to downtown Ottawa.

Here's an overall idea of how this part of the survey works: given that the City of Ottawa plans to add the LRT mode of transport to currently existing modes (i.e., automobile, bus transit and/or non-motorized modes) that are available for use to access downtown Ottawa, you are hereby presented with specific features (attributes) pertaining to these four alternative modes of transport available for commuting (1) **LRT;** (2) **Bus transit;** (3) **Automobile;** and (3) **Non-Motorized Modes** (e.g. walk/cycle/skate/rollerblade)**.**

There are twelve scenarios presented, each containing different features associated with the four alternative modes of transport. Upon evaluating the features in all alternatives for each scenario, you are required to select your preferred mode of transport for commuting and then, kindly express your perception about the LRT mode of transport on a scale of **1** to **5** based on its features presented in each scenario. The aim is to determine the respondent's preferred mode of transport for commuting and to evaluate his/her acceptability of the LRT alternative for each given scenario.

In doing this survey, we are conscious of the fact that you may consider other very important factors such as privacy, the environment, and comfort level alongside many others in the process of making your choices. However, it is required for the respondent to assume that these additional factors are all relatively the same for all the scenarios under consideration. In addition, please do not forget to take into account your personal needs and objectives when making your choices.

<u>Example of Scenario</u>

Table 2 below represents an example scenario containing all four modes of transport. ***This example scenario is meant for the purpose of demonstrating how each scenario matrix works. You are not required to select any choices for this scenario at the moment.***

The definition of each attribute (feature) is as follows:

1. **<u>Commuting/Traveling time (minutes) (one-way):</u>** This is an estimate of the time spent while commuting starting from the moment you board your mode of transport to the moment when you get off upon arriving at your final destination including time spent while waiting for a transfer from one mode to another if need be.

2. **Cost/Fare ($):** This is how much it costs you in monetary terms for each one-way trip you make from your home to your destination downtown.

3. **Time variability (minutes) (affected by traveller information):** This is the level of delay that might occur due to accidents, road repairs, unexpected congestion, poor weather, etc. or variability in arrival/departure time of transit vehicles that can not be avoided or predicted. However, a traveller information system has the potential to reduce the extent of this time variability.

4. **Accessibility (meters):** This is the sum of the total relative walking distance to and from the transit station (*for public transit users*) or parking garage (*for automobile or non-motorized mode users*) away from the commuter's primary destination.

5. **Frequency of service (minutes):** This is defined as how often the service mode is provided/made available to users.

6. **Level of Convenience** This is the relative ease of using a particular mode of transport for commuting taking into consideration factors such as flexibility, reliability, ability to do work on board mode of transport, availability of traveller information systems, number of transfers made, comfort, etc. Table 1 below presents an overall idea of some attitudinal factors that contribute to the different qualitative levels of convenience of each mode of transport.

Table 1

Attitudinal Factors	Qualitative level of Convenience			
	Excellent	Very Good	Good	Poor
Reliability	✔	✔	✔	✖
Flexibility	✔	✖	✔	✔
Comfort	✔	✔	✔	✖
Availability of traveller information systems	✔	✔	✖	✖
Ability to do work while commuting	✔	✔	✖	✖
Transfer required	No	No	No	Yes

This implies a transport mode offering an **Excellent** level of convenience is reliable, flexible, comfortable, enables commuters to plan their trip using advanced traveller information systems, offers commuters the ability to do work on board while commuting, and lastly, offers a direct connection between the commuters origin and destination without need to transfer from one mode of transport to another while commuting. Meanwhile, a transport mode offering a **Poor** level of convenience is flexible yet unreliable, uncomfortable, lacks advanced traveller information systems to enable commuters plan their trip, does not offer commuters the ability to do work on board while commuting and lastly, it does not offer a direct connection between the commuters origin and destination with at least one transfer from one mode to another required while commuting from home to work.

Table 2: Example Scenario *(Please, see explanation below on how to interpret the information contained in the following table.)*

Example Scenario				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives.				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	12	18	14	30
Cost/Fare ($)	4.50	4.00	11.00	1.00
Delay / (Travel time variability) (minutes)	(+/- 1)	(+/- 10)	4	2
Accessibility (Walking distance to and from transit station or parking garage)	Lesser than 500 meters	Greater than 501 meters	Lesser than 500 meters	Greater than 501 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐LRT	☐Bus	☑ Automobile	☐Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT 1 ☐ May use LRT 2 ☑ Not Sure 3 ☐ May not use LRT 4 ☐ Will definitely not use LRT 5 ☐			

The way you may want to read the above example scenario in Table 2 will be as follows:

Given that I have to commute daily to work and assuming that my office is located within the downtown area of Ottawa, I have at my disposal, four alternative modes of transport each with peculiar features amongst which I need to choose my preferred mode of transport. The four alternative modes of transport include: (1) Light Rail Transit (LRT), (2) Bus Transit, (3) Automobile or (4) Non-motorized mode (cycle/skate/rollerblade/walk).

Note: According to the example scenario in Table 2 above, the Automobile has been selected as the preferred mode of transport. However, in the event where the Automobile is unavailable, the respondent stated that he/she may use the LRT as an alternative mode of transport.
The features contained in the above example scenario matrix can be read and interpreted as described below.
Considering that I choose the Automobile as my preferred mode of transport upon evaluating the features in all four alternative transport modes presented above (see Table 2), this implies I will spend a total travel time of 14 minutes driving my automobile counting from the moment I board to the time I get off excluding time spent walking to access my automobile in the parking lot; it will cost me a total of $11.00

to make a one-way trip (including cost for fuel and parking); due to unexpected traffic congestion and other factors, I may be delayed for up to 4 minutes during my commute; I will need to walk a cumulative distance of less than 500 meters away from my home and work place to access my automobile, and lastly, my automobile will offer me an overall good level of convenience.

However, in the event where my automobile becomes unavailable, I may choose to use the LRT mode of transport for commuting instead (see Table 2). Commuting with the LRT transport mode will imply I will spend a total travel time of 12 minutes on board the LRT counting from the moment I board to the time I get off excluding time spent walking to or from the LRT stop/station; I will pay a fare of $4.50 per trip (one way), based on unforeseen circumstances and changes in schedule, the LRT may arrive about 1 minute early at its stop/station or may be delayed for up to 1 minute; I will need to walk a cumulative distance of less than 500 meters away from my home and work place to access the LRT stop/station; the LRT is scheduled to arrive at every 3 minutes interval provided everything runs smoothly, and lastly, the LRT will offer an overall excellent level of convenience.

With a similar interpretation of each scenario as that contained in the above example scenario, please go ahead and select your preferred mode of transport for commuting in the following twelve scenarios. ***All scenarios represent one-way travel only.***

Please, endeavour to take into account your needs and priorities when doing your selection. Assume that all other important factors you may consider but not indicated here remain the same for each scenario and for all modes of transport. Repeat the same rating process for all scenarios for the following four alternative modes of transport considered.

Scenario #1				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	12	18	3	18
Cost/Fare ($)	5.50	2.00	12.00	2
Delay /(Travel time variability) (minutes)	0	(+/- 8)	9	0
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT May use LRT Not Sure May not use LRT Will definitely not use LRT	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐		

Scenario #2				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	15	4	4	23
Cost/Fare ($)	5.50	2.00	12.00	2.00
Delay/ (Travel time variability) (minutes)	(+/- 1)	(+/- 10)	4	1
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT May use LRT Not Sure May not use LRT Will definitely not use LRT	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐		

Scenario #3				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	7	16	12	30
Cost/Fare ($)	4.50	4.00	11.00	1.00
Delay/ (Travel time variability) (minutes)	0	(+/- 8)	9	0
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel	Will definitely Use LRT	1 ☐		

should your selected preferred mode of transport become unavailable (☐one only)	May use LRT	2 ☐
	Not Sure	3 ☐
	May not use LRT	4 ☐
	Will definitely not use LRT	5 ☐

Scenario #4				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	12	18	14	13
Cost/Fare ($)	4.50	4.00	11.00	1.00
Delay / (Travel time variability) (minutes)	(+/- 2)	(+/- 6)	6	2
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐LRT	☐Bus	☐Automobile	☐Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT 1 ☐ May use LRT 2 ☐ Not Sure 3 ☐ May not use LRT 4 ☐ Will definitely not use LRT 5 ☐			

Scenario #5				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	14	20	3	18
Cost/Fare ($)	5.50	2.00	12.00	2.00
Delay / (Travel time variability) (minutes)	(+/- 1)	(+/- 10)	4	1
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐LRT	☐Bus	☐Automobile	☐Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May not use LRT	4 ☐
	Will definitely not use LRT	5 ☐

Scenario #6

Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	3	6	6	25
Cost/Fare ($)	3.50	3.00	13.00	Free
Delay / (Travel time variability) (minutes)	0	(+/- 8)	9	0
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May not use LRT	4 ☐
	Will definitely not use LRT	5 ☐

Scenario #7

Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	7	16	12	30
Cost/Fare ($)	4.50	4.00	11.00	1.00
Delay / (Travel time variability) (minutes)	(+/- 2)	(+/- 6)	6	2
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the**	Will definitely Use LRT	1 ☐

LRT alternative, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	May use LRT Not Sure May not use LRT Will definitely not use LRT	2 ☐ 3 ☐ 4 ☐ 5 ☐

Scenario #8				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	4	8	11	26
Cost/Fare ($)	3.50	3.00	13.00	Free
Delay/ (Travel time variability) (minutes)	(+/- 2)	(+/- 6)	6	2
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐LRT	☐Bus	☐Automobile	☐Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT May use LRT Not Sure May not use LRT Will definitely not use LRT	1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐		

Scenario #9				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	15	4	4	23
Cost/Fare ($)	5.50	2.00	12.00	2.00
Delay/ (Travel time variability) (minutes)	(+/- 1)	(+/- 10)	4	1
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐LRT	☐Bus	☐Automobile	☐Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May not use LRT	4 ☐
	Will definitely not use LRT	5 ☐

Scenario #10

Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	12	18	14	13
Cost/Fare ($)	4.50	4.00	11.00	1.00
Delay / (Travel time variability) (minutes)	0	(+/- 8)	9	0
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Very Good	Very Good	Poor	Good
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May not use LRT	4 ☐
	Will definitely not use LRT	5 ☐

Scenario #11

Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	4	8	11	26
Cost/Fare ($)	3.50	3.00	13.00	Free
Delay / (Travel time variability) (minutes)	(+/- 2)	(+/- 6)	6	2
Accessibility (Walking distance to and from transit station or parking garage)	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters
Frequency of service (minutes)	8	7	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor

1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT 1 ☐ May use LRT 2 ☐ Not Sure 3 ☐ May not use LRT 4 ☐ Will definitely not use LRT 5 ☐			

Scenario #12				
Assume you work in the downtown area of Ottawa. Please, indicate which mode of transport you will prefer to use for commuting and your perception about the LRT mode of transport taking into account the following features alongside your personal needs and objectives				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
Commuting/Traveling time (minutes)	3	6	6	25
Cost/Fare ($)	3.50	3.00	13.00	Free
Delay / (Travel time variability) (minutes)	(+/- 1)	(+/- 10)	4	2
Accessibility (Walking distance to and from transit station or parking garage)	**Lesser** than 500 meters	**Greater** than 501 meters	**Lesser** than 500 meters	**Greater** than 501 meters
Frequency of service (minutes)	3	15	N/A	N/A
Level of convenience	Excellent	Poor	Good	Poor
1). Please, select your preferred mode of transport for commuting (☐only)	☐ LRT	☐ Bus	☐Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☐one only)	Will definitely Use LRT 1 ☐ May use LRT 2 ☐ Not Sure 3 ☐ May not use LRT 4 ☐ Will definitely not use LRT 5 ☐			

Section 4: General Attitudes and Perceptions

Assume the following factors to be the primary factors that affect the choice of your preferred mode of transport used for your daily commute to the downtown area. Please, indicate by ranking on a scale of **1 to 7** your overall notion about these factors. *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

1 = 'Strongly Disagree' **7 = 'Strongly Agree'**

Factor ***Rank***

1 2 3 4 5 6 7

a) I can ***rely*** on the car to get me to my destination on time ☐ ☐ ☐ ☐ ☐ ☐ ☐

b) The car offers me the ***flexibility*** I need for my schedule ☐ ☐ ☐ ☐ ☐ ☐ ☐

c) Using public transport is ***environmentally*** friendly ☐ ☐ ☐ ☐ ☐ ☐ ☐

d) Public transport is not ***secure*** ☐ ☐ ☐ ☐ ☐ ☐ ☐

e) Public transport is very ***uncomfortable*** ☐ ☐ ☐ ☐ ☐ ☐ ☐

f) Commuting by car is ***costly*** ☐ ☐ ☐ ☐ ☐ ☐ ☐

Section 5: Socioeconomic and Demographic Information

This section of the survey is concerned about finding out some basic socioeconomic and demographic information in relation to your daily lifestyle. **This information will only be used to classify your responses and will never be presented in an individually identifiable form.**

Household and Demographic Information

Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.

1. What year were you born? 19____
2. What sex/gender are you? ☐ Male ☐ Female
3. How many people live with you in the same house?

   Adults (16 and over including you) ________ children (under 16) ________

4. How many vehicles are owned/leased by occupants within your house? ______ Vehicles
5. How many licensed drivers live with you in your house? _______ driver(s)
6. What is your highest level of education attained?

☐ Did not complete High school ☐ Bachelor's Degree

☐ High School Completion ☐ Master's Degree

☐ College Diploma ☐ PhD or other Doctoral level degree

☐ Other___________________

7. What was your total yearly household income from all sources before taxes and deductions in 2011?

☐ Under $20,000 ☐ $75,001 - $100,000

☐ $20,001 - $35,000 ☐ $100,001 - $150,000

☐ $35,001 - $50,000 ☐ Over $150,000

☐ $50,001 - $75,000 ☐ Do not wish to disclose

8. Which amongst the following best describes your profession or job title?

☐	Engineering	☐	Clerical/Administrative
☐	Sales/Marketing	☐	Management/Executive
☐	Finance/Accounting	☐	Lawyer
☐	Other_________________		

9. What sector does your current employment belong to?

☐ Public (e.g., municipal, provincial or federal government) ☐ Private

☐ Other (e.g., non-profit organizations)

10. Approximately how many hours do you work per week at your downtown office location?

___________ hours/week

11. Do you have a spouse (or common-law partner) who works? ☐ Yes ☐ No

If yes, what region does he/she work?

☐ Central Business District of Ottawa (Downtown area)

☐ Other: Please specify________________

What is his/her approximate distance to work (one-way trip)? ________km.

==

<<END OF QUESTIONNAIRE>>

==

Please take a few moments to tell us what you think about this survey. Your comments and feedback are highly appreciated, as they will be used to enable us to further improve the quality of this survey:

1. Were the survey instructions clear?

____

____

____

2. Did you find the overall experiment too lengthy or too complicated? How so?

____

____

____

3. Were any of the questions ambiguous? If so, which ones?

____

____

____

4. Did the attributes (features/factors) pertaining to the transport mode alternatives for the various scenarios seem reasonable?

____

____

5. Are the any other attributes (features/factors) other than those mentioned here that you think are important in your decision to choose a specific mode of transport?

____
____
____

6. How long did it take you to complete this survey
☐ 15 minutes ☐ 20 minutes ☐ 25 minutes ☐ Other________

7. Other comments and suggestions?

____
____

<<THANK YOU FOR YOUR TIME AND EFFORT SET ASIDE FOR PARTICIPATING IN THIS SURVEY>>

Carleton UNIVERSITY
Canada's Capital University

Department of Civil & Environmental Engineering
3044 Minto Center
1125 Colonel By Drive, Ottawa, ON, K1S 5B6
Tel: 613 520 2600 ext. 5786
Mobile: (613) 853 4907
Email: teneme@connect.carleton.ca

October 11th, 2012

Dear Sir/Mme.,

Survey on the influence of Telecommuting on Office choice location/relocation

You are hereby invited to participate in a survey focused on gathering information to determine the influence of *telecommuting* on office location/relocation choice within the City of Ottawa's municipal boundaries.

Telecommuting may be perceived as the use of telecommunication technologies (such as internet, telephone, audio-visual facilities, teleconferencing technology, fax machine, etc.) for working at home (or at a telecommuting center close to home) a few days a week in substitution for commuting daily to work. It has the potential to reduce traffic congestion in urban areas. In addition, it has been viewed as a means to increase employee job satisfaction and productivity. For businesses, a major benefit will be a reduction in office overhead and management expenses amongst others.

Today, some managers interested in improving job satisfaction and productivity while reducing company expenses take advantage of telecommuting benefits and allow some employees telecommute during some days of the week. What is not known at present is the influence employee telecommuting has on the choice of where to locate/relocate an office. Some business organizations currently located in the satellite communities (i.e., Kanata, Orleans or Barrhaven) may decide to locate/relocate within central area Ottawa for reasons beneficial to the organization. Likewise, other business organizations currently located within central area Ottawa may choose to locate/relocate to either one of the less costly satellite communities and give telecommuting employees the opportunity to spend less on travel while commuting to offices located in a relatively congestion-free area.

There are no risks in participating in this study. You may withdraw from this survey at anytime if you choose to. On the other hand, your contribution will enable us gain an understanding of the relationship between choice of office location/relocation and telecommuting, which will subsequently help regional planners and decision makers to establish land use and transportation investment policies and measures that best meet your needs. The responses provided by you **will be kept confidential** and used only for aggregate statistical analyses.

Upon reading this introductory message, we encourage you to take a few minutes to answer the questions that follow in sections 2, 3 & 4. We thank you for your time and effort set aside to participate in this survey. For any further questions or inquiries, please do not hesitate to contact me using the above address.

Sincerely,

Tabot Eneme
Project Manager

Multimodal Travel Demand and System Management: Role of telecommuting in office location/relocation decisions.

Carleton UNIVERSITY
Canada's Capital University

STATED PREFERENCE SURVEY

Consent Form

Date of ethics clearance: **11th October, 2012**
Ethics Clearance for the Collection of Data Expires: **31st May, 2013**

I, ____________________________________ volunteer to participate in a survey on the **role of telecommuting in office location/relocation decisions.**

I understand that my participation will contribute data on factors that will be used for the development of an office location/relocation decision model.

My participation in this survey is limited to completing the hard copy of the questionnaire provided by the researcher. The instructions and descriptions of technical terms are clearly noted in the questionnaire document. I do not perceive any risk associated with the completion of the questionnaire and my voluntary participation is motivated by desire to contribute knowledge on traveller decision-making.

I understand that:

- I am voluntarily responding to a request to participate in this survey extended by Mr. Tabot Eneme (Research Assistant) and Professor A.M. Khan of Carleton University and that he can be contacted by email (ata_khan@carleton.ca) and by telephone (613 520 2600 ext. 5786).
- The project was reviewed and received ethics clearance from the Carleton University Research Ethics Board and that the Chair of the Research Ethics Board can be reached by email (ethics@carleton.ca) and by telephone (613 520 2517).

- I will remain anonymous and my response will be used only for aggregate statistical analyses.
- My response will remain confidential and that the data obtained will be destroyed following the completion of the current study and extensions, if any.
- I may decline from answering any questions.
- The results of the research study will be published in scientific literature such as journals, books and conference proceedings. Also, results may be used in workshops and seminars for the purpose of advancing knowledge.

____________________________________ ____________________

Signature of Participant Date

____________________________________ ____________________

Signature of Researcher Date

SECTION 2: Information regarding business orientation of organization

In this section, we would like to know more about how your business organization/company carries out its daily business activities alongside your knowledge/attitude about telecommuting. *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

1. Amongst all employees in your business organization/company, approximately what percentage of them are professionals (i.e., hold certified professional licenses in their field of practice)?

☐ Less than 20%
☐ 21 – 40 %
☐ 41 – 60 %
☐ Above 60 %

2. Approximately how often do your employees rely on the use of telecommunications and computer technology (e.g. email, fax, telephone, internet, broadband, etc.) to facilitate their work?

☐ Less than 20 % of the time
☐ 21 – 40 % of the time
☐ 41 – 60 % of the time
☐ Above 60 % of the time

3. What is the most frequently used medium of communication amongst your employees?

☐ Electronic mail ☐ Telephone
☐ Face-to-face contact ☐ Video conferencing
☐ Other_______________

4. In terms of doing business and based on your judgment, how important is it for your employees to have face-to-face interaction between your organization's clients and other colleagues on daily basis?

☐ Extremely important
☐ Very important
☐ Important

☐ Slightly important
☐ Not important at all

5. In terms of supervising your employees, which method of supervision do you use most amongst the following? (Check (✔) all that apply)

☐ Review meetings	☐ On-site supervision
☐ Written reports	☐ Activity logs
☐ Review completed task	☐ Time-sheets
☐ Other________________________	

6. Does your company have an exhaustive security policy (plan) regarding its employees accessing company information from any other location other than at the office?

☐ Yes ☐ No ☐ N/A

7. Does your company currently have a fully operational telecommuting program?

☐ Yes – If Yes,
   i. Approximately what percentage of your employees telecommute per week________%
   ii. What is the approximate number of days a typical telecommuter actually telecommutes in a typical week? _______ Days.

☐ No (Please proceed to question 8)

8. Have you ever thought of introducing a telecommuting program as an option for your employees?

☐ Currently have an existing telecommuting program
☐ Working towards developing one
☐ Definitely thought of it
☐ Sometimes thought of it
☐ Rarely thought of it
☐ Never thought of it
☐ It is impossible for my employees to telecommute

9. What position do you currently hold in your business organization/company?

☐ C.E.O/Manager/Partner
☐ Other________________
☐ N/A

10. As the current manager of your organization/company and on a scale of 1 to 7, how much influence do you have on the decision-making process regarding where to locate/relocate your office within the City of Ottawa? (✔☐Only)

1 = 'Least influence' *7 = 'most influence'*

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7

SECTION 3: Stated Preference survey – Office Relocation/Relocation Alternatives

This part of the survey contains attributes (features) that describe hypothetical scenarios of two possible alternative places for locating/relocating an office within the City of Ottawa. As noted, telecommuting is under consideration to be used as a tool by many cities as a means to reduce traffic congestion and delays during peak commute times. Also, telecommuting may also have effects on land use, an aspect that may be of research interest in this study.

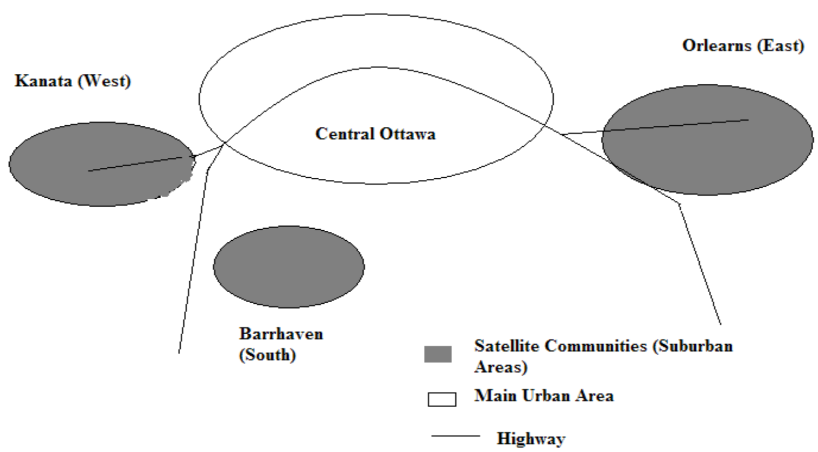
Your responses to this part of the survey are equally very important because this will help ensure that the survey represents the views of business organizations within the entire region.

Here is an overall idea of how this part of the survey works: suppose that your business organization/company recently adopted a telecommuting program for its employees and it chooses to locate/relocate to a new place within the Ottawa region. ***Assuming you are the Chief Executive***

Officer/Manager of your business organization/company with the final decision on where to best locate/relocate your office, you are required to please evaluate each of the following twelve scenarios and let us know your preference as to where you will like the office of your business organization/company to be located/relocated amongst these two alternatives:

1. **Central Ottawa** (inside the Green Belt), or
2. **First-tier Satellite Communities** (which include either Kanata (West), Orleans (East), or Barrhaven (South)).

In doing this survey, we are conscious of the fact that you may consider other very important factors such as privacy & security of company information, quality of communication amongst employees and their colleagues, attitudes of management towards employees (i.e., ability to maintain control over employees) amongst many other factors before choosing where to locate/relocate your office amongst the above two alternatives. However, it is required for you to please assume that such factors are identical for the two possible office location/relocation alternatives presented. In addition, please take into account your organization's/company's goals and objective when choosing your preferred alternative.
A schematic diagram of the office location alternatives within the city of Ottawa are shown below:



Example of Choice Scenario

Table 1 below outlines an example of the scenario matrix containing all the attributes (features) alongside, the attribute levels for the two possible office location/relocation alternatives within the Ottawa region. ***This example scenario is meant for the purpose of demonstrating how the scenario matrix works. You are not required to select any choices for this case at the moment.***

Below are definitions of the various attributes contained in Table 1:

1. **Employee telecommuting level per week:** This is the average number of days per week an employee chooses to telecommute assuming that the company adopts a telecommuting program.

2. **Monthly office rental cost:** This is the monthly cost paid out for renting your business organization's office location expressed in terms of relative change with respect to the current amount your organization currently pays per month for rent.

3. **Office and Parking Space:** This is the size of the office in terms of number of cubicles or desks and the number of parking spaces expressed as a change with respect to your current business organization's office size.

4. **<u>Proximity to related businesses:</u>** This is the relative importance of how the strategic location/relocation of your office would benefit your business organization in gaining customers through its office appearance, name branding and proximity to other businesses of similar type.

5. **<u>Office Accessibility:</u>** This is the ease of being able to access the office building.

6. **<u>Employee Productivity:</u>** This is a performance measure of both efficiency and effectiveness of the employees.

Table 1: Example Scenario *(Please, see explanation below on how to interpret the information contained in the following table.)*

Scenario 1			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	No Change	1% Decrease	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

The way you may want to read the above example scenario table will be as follows:

In all cases, you must assume that your business organization/company recently adopted a telecommuting program and your employees have the option to telecommute some days within the week or not. Then, if I choose to locate/relocate my office within:

1. **Central Ottawa (inside Greenbelt)**

This implies, for this scenario, my employees will choose not to telecommute during the week despite the existence of a telecommuting program, the monthly rental cost for renting my office space will remain the same, my office size and number of parking spaces available to me will reduce, the proximity of my office location to similar businesses of its kind will be excellent and this will be a beneficial technique for my company/organization to attract customers, my office will not be easily accessible since it will be located more than 500 meters away from major transit hubs/roads or streets, and lastly, the productivity of my employees will be increase.

2. **Satellite communities (i.e., Kanata (West), Orleans (East) or Barrhaven (South))**

This implies, for this scenario, my employees will take advantage of the telecommuting program and choose to telecommute on average between 1 - 3 days/week, the monthly rental cost for renting my office space will decrease by 1% each month relative to what I pay now, my office size and number of parking spaces available to me will remain the same relative to what I already have, the proximity of my office location to related businesses of its kind will be poor and this ***may not*** be a beneficial technique for my company/organization to attract customers, accessibility to my office will be excellent since it will be located within 500 meters of a major transit hub/road or street, and lastly, the productivity of my employees will remain the same.

3. **None**

This implies I do not find the attributes (features) in either of the two office location/relocation alternatives as persuasive as much to influence me to consider relocating my office.

Upon evaluating the two alternatives for office relocation based on the features presented for each scenario below, as well as taking into account the needs and objectives of your business organization, you should proceed and choose your most preferred office location/relocation area. Please endeavor to <u>CHECK ONE AND ONLY ONE BOX.</u> Repeat the same selection process for all 12 scenarios.

Scenario #1

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	Office Location Alternatives		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	1 % Increase	No Change	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #2

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	Office Location Alternatives		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	1 % Increase	No Change	
Office and Parking Space	No Change	Reduces	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	

Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #3

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	No Change	1 % Decrease	
Office and Parking Space	No Change	Reduces	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #4

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	2 % Increase	2 % Decrease	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #5

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	2 % Increase	2 % Decrease	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Poor	Excellent	

Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #6			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	No Change	1 % Decrease	
Office and Parking Space	No Change	Increases	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #7			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	No Change	1 % Decrease	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #8			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**

Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	No Change	1 % Decrease	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #9			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	1 % Increase	No Change	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #10			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Monthly Rental Cost ($)	1 % Increase	No Change	
Office and Parking Space	No Change	Increases	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located **more than** 500 meters away from major transit hubs/ streets or roads	Office located **less than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #11
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.

Features of Office Location/Relocation Area	Office Location Alternatives		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	2 % Increase	2 % Decrease	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Remains the same	Increases	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #12			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will choose to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	Between 1 - 3 days/week	0 days/week	
Monthly Rental Cost ($)	2 % Increase	2 % Decrease	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located **less than** 500 meters away from major transit hubs/ streets or roads	Office located **more than** 500 meters away from major transit hubs/ streets or roads	
Employee Productivity	Increases	Remains the same	
Please, select where you will choose to locate/relocate your office given the above conditions (✔only)	☐ Central Ottawa	☐ Satellite Communities	☐ None

SECTION 4: About the Company

In this section of this survey, we would like to know more about the company profile. **This information will only be used to classify your responses and will never be presented in an individually identifiable form.** *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

1. For how long has your company been in business within the Ottawa region?

☐ Under 10 years ☐ 31 – 40 years
☐ 11 – 20 years ☐ Over 41 years
☐ 21 – 30 years

2. In what part of the Ottawa region is your office currently located?

☐ Central Ottawa (Inside Green Belt and downtown area)
☐ Kanata
☐ Barrhaven/South Gloucester
☐ Orleans
☐ Other: Please, specify_________________

3. In terms of office space rental, how much does your business organization pay monthly for rent?

☐ 0 – 999 $ ☐ 5001 – 10000 $
☐ 1000 – 3000 $ ☐ Above 10,000 $
☐ 3001 – 5000 $ ☐ Owns office space/Does not pay rent

4. Ever since your company opened its doors to doing business within the Ottawa region, has there ever been a change in the building address of your office?

☐ Yes (if yes, please answer question 5)
☐ No (if No, please proceed to question 6)

5. For the past 10 years (or as far back as you can remember), please state the number of times that your office was relocated. Also, please state the primary reason why your office was relocated from its former address to its current address (e.g. reduced rental cost, strategic business reason, etc.).

____
____
____
____

6. Which of the following best describes the primary sector of your business organization/company?

☐ Accounting
☐ Financial Planning
☐ Engineering
☐ Computer programming
☐ Public relations
☐ Other: Please, specify_________________
☐ Database Administration
☐ Web design
☐ Transcription and Translation
☐ Customer support specialist
☐ Paralegal

7. What is the approximate size of your business organization in terms of the number of **full-time** employees employed at your current office location ***only***?

☐ Under 10 employees
☐ 11 – 30 employees
☐ 31 – 50 employees
☐ 51 – 100 employees
☐ Over 101 employees

8. Number of employees directly under your supervision?

☐ 0 – 5 employees
☐ >= 6 employees

===

<<END OF QUESTIONNAIRE>>

===

Please take a few moments to tell us what you think about this survey. Your comments and feedback are highly appreciated, as they will be used to enable us to further improve the quality of this survey:

8. Were the survey instructions clear?

____
____
____

9. Did you find the overall survey too lengthy or too complicated? How so?

____
____
____

10. Were any of the questions ambiguous? If so, which ones?

11. Did the attributes (features/factors) pertaining to office location sites for the various scenarios seem reasonable?

12. Are there any other attributes (features/factors) other than those mentioned here that you think are important in deciding where to locate/relocate your office?

13. Approximately how long did it take you to complete this survey?

☐ 15 minutes ☐ 20 minutes ☐ 25 minutes ☐ Other________

14. Other comments and suggestions?

<<THANK YOU FOR YOUR TIME AND EFFORT SET ASIDE FOR PARTICIPATING IN THIS SURVEY>>

APPENDIX C: FINAL SURVEY QUESTIONNAIRES

Carleton UNIVERSITY
Canada's Capital University

Department of Civil & Environmental Engineering
3044 Minto Center
1125 Colonel By Drive, Ottawa, ON, K1S 5B6
Tel: 613 520 2600 ext. 5786
Mobile: (613) 853 4907
Email: teneme@connect.carleton.ca

November 1st, 2012

Dear Sir/Mme.,

Survey on Choice of Transport Mode for Commuting

You are hereby invited to participate in a survey focused on gathering information needed to forecast ridership levels for the City of Ottawa's newly proposed Light Rail Transit (LRT) network.

Results from the 2005 Origin-Destination survey called for the need to develop a light rail transit to meet Ottawa's transportation needs considering its future population and employment growth by the year 2031. Hence, as part of its 2008 transportation master plan set at attaining a 30% transit modal split by the year 2031, the City of Ottawa recently approved the construction of a Light Rail Transit (LRT) network along its East-West corridor.

The benefits of a LRT service within the downtown core are numerous. These include: improved efficiency in terms of travel time saving, increased capacity due to high train frequency, less congestion due to less number of buses and possibly less cars on the road, reduction in air pollution and greenhouse gas emissions, accident avoidance savings resulting from less use of personal vehicles, and lastly, creation of more jobs leading to an overall economic boost.

There are no risks in participating in this study. In addition, the responses you provide **will be kept confidential** and used only for aggregate statistical analyses. You may withdraw from this survey at anytime if you choose to. However, your contribution will help us to develop methods for forecasting ridership levels of this newly proposed LRT network, which will in turn help planners and decision makers to establish land use, transportation investment policies and measures that best meet your needs.

Having read this letter, I encourage you to take a few minutes (approximately 10 – 15 minutes) to answer the questions presented in sections 1, 2, 3 & 4. Upon completion, I kindly ask that you please return your survey responses to your receptionist or the person who gave you this survey by **December 21st, 2012**.

I would want to thank you for your time and effort set aside to participate in this survey. Your responses will enable me to contribute towards advancing knowledge on developing solutions for solving transportation related issues. For any questions or inquiries, please do not hesitate to contact me using the above address.

Sincerely,

Tabot Eneme
Project Manager

Multimodal Travel Demand and System Management: Modal Split Factors for Predicting Light Rail Transit (LRT) Ridership for the City of Ottawa Downtown Area

Carleton UNIVERSITY
Canada's Capital University

STATED PREFERENCE SURVEY

Consent Form

Date of ethics clearance: **11th October, 2012**
Ethics Clearance for the Collection of Data Expires: **31st May, 2013**

I, _________________________________ volunteer to participate in a transport mode choice preference survey that include the following modes of transport usable for commuting to downtown Ottawa: **light rail transit, bus rapid transit, automobile, and nonmotorized modes.**

I understand that in addition to commonly used variables, my participation will contribute data towards the development of a new travel mode choice model with capabilities to treat light rail transit, advanced bus transit, and traveller information (facilitated by future advanced traveller information systems).

My participation in this survey is limited to completing this hardcopy of the questionnaire provided by the researcher. The instructions and descriptions of technical terms are clearly noted in the questionnaire document. I do not perceive any risk associated with the completion of the questionnaire and my voluntary participation is motivated by desire to contribute knowledge for research purposes.

I understand that:

- I am voluntarily responding to a request to participate in this survey extended by Mr. Tabot Eneme (Research Assistant) and Professor A.M. Khan of Carleton University and that he can be contacted by email (ata_khan@carleton.ca) and by telephone (613 520 2600 ext. 5786).
- The project was reviewed and received ethics clearance from the Carleton University Research Ethics Board and that the Chair of the Research Ethics Board can be reached by email at (ethics@carleton.ca) and by telephone at (613 520 2517).
- I will remain anonymous and my response will be used only for aggregate statistical analyses.
- My response will remain confidential and that the data obtained will be destroyed following the completion of the current study and extensions, if any.
- I may decline from answering any questions.
- The results of the research study will be published in scientific literature such as journals, books and conference proceedings. Also, results may be used in workshops and seminars for the purpose of advancing knowledge.

__________________________________ ____________________
Signature of Participant Date

November 1st, 2012
Signature of Researcher Date

SECTION 1: Information about Trips made to Ottawa's Central Business District (CBD)

In this section of the survey, we will like to know more about how you commute to the Central Business District (CBD) of Ottawa. *Please, select the applicable response by indicating with the (✔) symbol where appropriate.*

5. For each commute you make to your destination within the core central business district (CBD) of Ottawa, please select amongst the following the mode of transport you currently use most:

☐ Automobile
☐ Drive alone ☐ Carpool/Vanpool
☐ Public Transit
☐ Non motorized mode (Cycle/Skate/Rollerblade/Walk)
☐ Other____________________________________

6. If the **automobile** is currently your most used mode of transport for commuting to the CBD of Ottawa, please provide answers to the following:
   a. For those who **drive alone – ONLY.**
      i. How much do you pay for parking (Estimate):
$_______/day **or** $_______/week **or** $_______/month
      ii. Approximately how much do you pay per week for gas for your ***one-way*** commute to downtown ***only***? $_______/week

   b. For those who **carpool/vanpool – ONLY.**

i. How many persons do you carpool/vanpool with on average? _______Persons.
ii. Approximately how much do you pay individually per week for carpooling? $______/week

c. How much time do you spend inside the vehicle (driving alone or carpooling) while commuting from your home to downtown on a ***one-way trip*** (driving time/In-vehicle time)?
________ minute(s) or ______ hour(s)

d. What is the approximate ***one-way*** driving distance between your home and your downtown destination? ______Km.

e. Approximately how many minutes does it take you to walk to your final destination from the moment you get off your vehicle at the parking lot (Egress time)? ______minute(s)

f. Do you have a monthly public transit pass?
☐ Yes ☐ No

7. If **public transit** (includes users of Park & Ride facilities) is currently your most used mode of transport for commuting to the central business district (CBD) of Ottawa, please provide answers to the following:
a. How long do you wait at the transit stop/station for your bus/train (wait time)?
Approximately ______minute(s).

b. Approximately how long does it take you to get to downtown Ottawa from the moment you board your public transit on a ***one-way trip*** (Riding time/ in-vehicle time)?
______minute(s) or _____hour(s)

c. Do you make any transfer during your daily commute from your origin (home) to your downtown destination on a ***one-way trip***?

☐ Yes. How many? _____ Transfer(s). ☐ No

d. Approximately how many minutes does it take you to walk to your final destination from the moment you get off your public transit (Egress time)? ______minute(s)

e. How much do you pay for transit fare for each **one-way** trip to downtown
☐ $2.60 - $3.30 ☐ Own transit pass
☐ $3.90 - $4.65 ☐ Other _________
☐ $7.75 (day pass)

f. Do you currently own/lease a vehicle?
☐ Yes ☐ No

8. If a **non-motorized** mode (e.g. bicycle/walking/skating) is currently your most used mode of transport for commuting to the central business district (CBD) of Ottawa, approximately how long does it take you to commute from your home to work? ___________ minute(s) **or** _________ hour(s)

9. How many days a week do you commute to your downtown office in a typical week?
☐ 5 days/week ☐ 2 days/week
☐ 4 days/week ☐ 1 day/week
☐ 3 days/week ☐ Other_______

SECTION 2: Stated Preference Survey – Modal Choice Game

This section of this survey contains attributes (features) that describe ***hypothetical scenarios*** of different modes of transport available to use for commuting to downtown Ottawa. Your responses to this section of the survey are equally important to ensure that the survey represents the views of all those who commute to downtown Ottawa.

Here's an overall idea of how this section of the survey works: Given that the City of Ottawa plans to add the Light Rail Transit (LRT) mode of transport to currently existing modes used by commuters such as the automobile, bus transit and/or non-motorized modes, you are hereby presented with specific features pertaining to the following four alternative modes of transport available for commuting (1) **LRT;** (2) **Bus transit;** (3) **Automobile;** and (4) **Non-Motorized Modes** (e.g. walk/cycle/skate/rollerblade)**.**

There are six *hypothetical* scenarios presented, each containing different features associated with the four alternative modes of transport. Upon evaluating the features in all four alternatives in each scenario, you are required to select your most preferred mode of transport for commuting and then, express your perception about the LRT mode of transport on a scale of **1** to **5** based on its features presented in the scenario. The aim is to determine your preferred mode of transport for commuting under these conditions and to evaluate your perception of the LRT mode of transport.

In the process of selecting your most preferred mode of transport amongst the various choice scenarios, we are conscious of the fact that you may consider several other important factors such as your need for privacy, the environment, comfort level, convenience alongside many other factors. However, for the sake of making your choices in this section, it is required you assume that these additional factors are all relatively the same for all six scenarios under consideration. Lastly, although these scenarios may look similar, they are however statistically different from one another. Below is a sample scenario response meant to help you understand how to interpret the content in each scenario:

Sample Scenario Response

Table 1 below represents an example choice matrix of a scenario. ***This sample scenario is meant for the purpose of demonstrating how the choice matrix works. You are not required to select any choices in this matrix at the moment.***

The definition of each attribute is as follows:

1. **One-way commuting time (minutes):** This is an estimate of the time spent while commuting starting from the moment you board your mode of transport to the moment when you alight (get-off) upon arriving at your final transit stop or parking garage. It includes variations that may be experienced as a result of delay due to accidents, road repairs, unexpected congestion, poor weather, variability in arrival/departure times of transit vehicles and other aspects that cannot be predicted.

2. **Cost/Fare ($):** This is how much it cost you in monetary terms for each one-way trip you make from your home to your destination downtown.

3. **Access time (minutes):** This is the total cumulative time spent walking to the transit station (for transit users) or parking garage (for automobile/bicycle/skateboard users) in order to access your mode of transport and the time spent walking from the transit station or parking to your primary destination (home or office) having descended from your mode of transport.

4. **Frequency of service (minutes):** This is defined as how often the service mode is provided/made available to users.

Table 1: Sample Scenario *(Please, see explanation below on how to interpret the information contained in the following table.* ***You are not required to select any choices for this scenario at the moment****)*

Given that you work in the downtown area of Ottawa, please indicate which mode of transport you will prefer to use most for commuting and state your perception about the LRT mode of transport assuming the following attributes (features) to be the only factors that influence your choice of mode of transport.	
Attributes (Features)	**Modes of Transport**

	LRT	Bus transit	Automobile	Non-motorized mode
One-way commuting time (minutes) (*Includes delay and travel time variability*)	12 mins (±1 min)	18 mins (± 6 mins)	14 mins (± 5 mins)	30 mins (± 0 min)
Cost/Fare ($)	$4.50	$4.00	$11.00	$1.00
Access time (minutes) (*Cumulative time spent walking to and from transit station or parking garage*)	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins
Frequency of service (minutes)	3 mins	15 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☑ Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT May use LRT Not Sure May **not** use LRT Will definitely **not** use LRT	1 ☐ 2 ☑ 3 ☐ 4 ☐ 5 ☐		

The way you may want to read and interpret the above sample scenario in Table 2 will be as follows:

Given that I have to commute daily to my office located within the downtown area of Ottawa, I am presented with four alternative modes of transport each with peculiar features amongst which I have to choose my preferred mode of transport from amongst the following: (1) Light Rail Transit (LRT), (2) Bus Transit, (3) Automobile or (4) Non-motorized mode (cycle/skate/rollerblade/walk).

Note: According to the sample scenario in Table 1 above, the Automobile has been selected as the preferred mode of transport. However, in the event where the Automobile becomes unavailable, the respondent stated that he/she may use the LRT as an alternative mode of transport. *Assuming you to be in the place of the respondent, the above example scenario may be read and interpreted as follows:*

Considering that I choose the Automobile as my preferred mode of transport amongst all four modes of transport, this implies I will spend about 14 minutes driving my automobile counting from the moment I board to the time I get off and I may arrive at work 5 minutes ahead of time or be delayed for up to 5 minutes; it will cost me a total of $11.00 to make a one-way trip (including cost for fuel and parking) and lastly, my cumulative time spent walking away from my home to access my car and from the parking garage to my office will be less than or equal to 5 minutes.

However, in the event where my automobile becomes unavailable, I may choose to use the LRT mode of transport for commuting instead (see Table 1). Commuting with the LRT transport mode will imply that I will spend about 12 minutes on board the LRT counting from the moment I board to the time I get off and based on unforeseen circumstances such as changes in schedule, the LRT may arrive about 1 minute early at its stop/station or may be delayed for up to 1 minute; I will pay a fare of $4.50 per trip (one way); my cumulative time spent walking away from my home to access the LRT stop/station and from the LRT stop/station to my office will be less than or equal to 5 minutes; and lastly, the LRT will be scheduled to arrive at every 3 minutes interval provided everything runs smoothly.

With a similar interpretation of each scenario as the above sample scenario, **you may now proceed to select your most preferred mode of transport for commuting amongst all four alternative modes of transport presented in the following six scenarios starting with scenarios #1 and #2 below. Please endeavor to <u>check one and only one box where applicable.</u>**

Given that you work in the downtown area of Ottawa, please indicate which mode of transport you will prefer to use most for commuting and state your perception about the LRT mode of transport assuming the following attributes (features) presented in the following **scenarios** are the only factors that influence your choice of mode of transport.

Scenario #1

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (*Includes delay and travel time variability*)	15 mins (± 1 min)	8 mins (± 6 mins)	12 mins (± 5 mins)	30 mins (±1 min)
Cost/Fare ($)	$4.50	$4.00	$11.00	$1.00
Access time (minutes) (*Cumulative time spent walking to and from transit station or parking garage*)	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins
Frequency of service (minutes)	8 mins	7 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May **not** use LRT	4 ☐
	Will definitely **not** use LRT	5 ☐

Scenario #2

Attributes (Features)	Modes of Transport			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	13 mins (± 2 mins)	20 mins (± 5 mins)	6 mins (± 4 mins)	26 mins (± 0 min)
Cost/Fare ($)	$5.50	$2.00	$12.00	$2.00
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins
Frequency of service (minutes)	3 mins	15 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐

your selected preferred mode of transport become unavailable (☑ **one only**)	Not Sure	3 ☐
	May **not** use LRT	4 ☐
	Will definitely **not** use LRT	5 ☐

Scenario #3				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	7 mins (± 1 mins)	17 mins (± 8 mins)	14 mins (± 8 mins)	23 mins (± 0 min)
Cost/Fare ($)	$5.50	$2.00	$12.00	$2.00
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins
Frequency of service (minutes)	8 mins	7 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT	1 ☐		
	May use LRT	2 ☐		
	Not Sure	3 ☐		
	May **not** use LRT	4 ☐		
	Will definitely **not** use LRT	5 ☐		

Scenario #4				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	13 mins (± 2 mins)	20 mins (± 5 mins)	6 mins (± 4 mins)	26 mins (± 0 min)
Cost/Fare ($)	$3.50	$3.00	$13.00	Free
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins
Frequency of service (minutes)	8 mins	7 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May **not** use LRT	4 ☐
	Will definitely **not** use LRT	5 ☐

Scenario #5				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	7 mins (± 1 mins)	17 mins (± 8 mins)	14 mins (± 8 mins)	23 mins (± 0 min)
Cost/Fare ($)	$4.50	$4.00	$11.00	$1.00
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins
Frequency of service (minutes)	3 mins	15 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode
2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT 1 ☐ May use LRT 2 ☐ Not Sure 3 ☐ May **not** use LRT 4 ☐ Will definitely **not** use LRT 5 ☐			

Scenario #6				
Attributes (Features)	**Modes of Transport**			
	LRT	**Bus transit**	**Automobile**	**Non-motorized mode**
One-way commuting time (minutes) (Includes delay and travel time variability)	15 mins (± 1 mins)	8 mins (± 6 mins)	12 mins (± 5 mins)	30 mins (±1 mins)
Cost/Fare ($)	$3.50	$3.00	$13.00	Free
Access time (minutes) (Cumulative time spent walking to and from transit station or parking garage)	**Greater than** 5 mins	**Less than** or equal to 5 mins	**Greater than** 5 mins	**Less than** or equal to 5 mins
Frequency of service (minutes)	3 mins	15 mins	N/A	N/A
1). Please, select your preferred mode of transport for commuting (☑ **one only**)	☐ LRT	☐ Bus	☐ Automobile	☐ Non-motorized mode

2). **If your preferred mode of transport is not the LRT alternative**, please indicate on the scale of **1 to 5** your perception about the LRT mode of travel should your selected preferred mode of transport become unavailable (☑ **one only**)	Will definitely Use LRT	1 ☐
	May use LRT	2 ☐
	Not Sure	3 ☐
	May **not** use LRT	4 ☐
	Will definitely **not** use LRT	5 ☐

Section 3: General Attitudes and Perceptions

Assume the following factors to be the primary factors that affect the choice of your preferred mode of transport used for your daily commute to the downtown area. Please, indicate by ranking on a scale of **1 to 7** your overall notion about these factors. *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

1 = 'Strongly Disagree' **7 = 'Strongly Agree'**

Factor	***Rank*** 1	2	3	4	5	6	7
g) Public transit is ***reliable***	☐	☐	☐	☐	☐	☐	☐
h) Public transit offers me the ***flexibility*** I need for my schedule	☐	☐	☐	☐	☐	☐	☐
i) Using public transport is ***environmentally*** friendly	☐	☐	☐	☐	☐	☐	☐
j) Public transit is the ***most secure*** transport mode for commuting	☐	☐	☐	☐	☐	☐	☐
k) Public transport is very ***comfortable***	☐	☐	☐	☐	☐	☐	☐
l) Public transit is the ***cheapest*** mode of transport for commuting	☐	☐	☐	☐	☐	☐	☐
m) Commuting by non-motorized modes of transport (cycling/walking/skate) helps me to ***exercise***	☐	☐	☐	☐	☐	☐	☐

Section 4: Socioeconomic and Demographic Information

This section of the survey is concerned about finding out some basic socioeconomic and demographic information in relation to your daily lifestyle. **This information will only be used to classify your responses and will never be presented in an individually identifiable form.**

Household and Demographic Information

Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.

12. What year were you born? 19____

13. What sex/gender are you? ☐ Male ☐ Female

14. How many people live with you in the same house?

    Adults (16 and over including you) _______ children (under 16) _______

15. How many vehicles are owned/leased by occupants within your house? _____ Vehicles

16. How many licensed drivers live with you in your house? ______ driver(s)

17. What is your highest level of education attained?

☐ Did not complete High school
☐ High School Completion
☐ College Diploma
☐ Other__________________
☐ Bachelor's Degree
☐ Master's Degree
☐ PhD or other Doctoral level degree

18. What was your total yearly individual income from all sources before taxes and deductions in 2011?

☐ Under $20,000
☐ $20,001 - $35,000
☐ $35,001 - $50,000
☐ $50,001 - $75,000
☐ $75,001 - $100,000
☐ $100,001 - $150,000
☐ Over $150,000
☐ Do not wish to disclose

19. Which amongst the following best describes your profession or job title?

☐ Engineering/Science
☐ Sales/Marketing
☐ Finance/Accounting
☐ Other________________
☐ Clerical/Administrative
☐ Management/Executive
☐ Lawyer

20. What sector do you currently work for?

☐ Public (e.g., municipal, provincial or federal government)
☐ Private
☐ Other__________________

21. Approximately how many hours do you work per week at your downtown office location?

___________ hours/week

22. Do you have a spouse (or common-law partner) who works? ☐ Yes ☐ No

If yes, what region does he/she work?

☐ Central Business District of Ottawa (Downtown area)

☐ Other

What is his/her approximate distance to work (one-way trip)? ________km.

===

<<END OF QUESTIONNAIRE>>

===

Upon completion, please do not forget to kindly return your responses to the receptionist or to the person who gave you this survey for pick-up by **December 21st, 2012**

<<THANK YOU FOR YOUR TIME AND EFFORT SET ASIDE FOR PARTICIPATING IN THIS SURVEY>>

Carleton
UNIVERSITY
Canada's Capital University

Department of Civil & Environmental Engineering
3044 Minto Center
1125 Colonel By Drive, Ottawa, ON, K1S 5B6
Tel: 613 520 2600 ext. 5786
Mobile: (613) 853 4907
Email: teneme@connect.carleton.ca

November 1st, 2012

Dear Sir/Mme.,

Survey on the influence of Telecommuting on Office choice location/relocation

You are hereby invited to participate in a survey focused on gathering information to determine the influence of *telecommuting* on office location/relocation choice within the City of Ottawa's municipal boundaries.

Telecommuting may be perceived as the use of telecommunication technologies (such as internet, telephone, audio-visual facilities, teleconferencing technology, fax machine, etc.) to do work at home (or at a telecommuting center) for a few days a week in substitution for commuting daily to work. It has the potential to reduce traffic congestion in urban areas. In addition, it has been viewed as a means to increase employee job satisfaction and productivity. For businesses, a major benefit will be a reduction in office overhead and management expenses amongst others.

Today, some managers interested in improving job satisfaction and productivity while reducing company expenses offer the option of telecommuting to some of its employees. What is not known at present is the influence telecommuting may have on office location/relocation choices within a city. Some business organizations currently located in the satellite communities of Kanata, Orleans or Barrhaven may decide to locate/relocate within central Ottawa for reasons beneficial to the organization. Likewise, other business organizations currently located within central Ottawa may choose to locate/relocate to either one of these less costly satellite communities following benefits achieved from an effective telecommuting program.

There are no risks in participating in this study. You may withdraw from this survey at anytime if you choose to. On the other hand, your contribution will enable us gain an understanding if there is a relationship between choice of office location/relocation and telecommuting, which will subsequently help regional planners and decision makers to establish land use and transportation investment policies and measures that best meet your needs. The responses provided by you **will be kept confidential** and used only for aggregate statistical analyses.

Having read this letter, I encourage you to take a few minutes (approximately 10 – 15 minutes) to answer the questions presented in sections 1, 2 & 3. Upon completion, I kindly ask that you please return your survey responses to your receptionist by **December 21st, 2012**. I would like to thank you for your time and effort set aside to participate in this survey. Your responses will enable me to contribute towards advancing knowledge on developing solutions for solving transportation related issues. For any further questions or inquiries, please do not hesitate to contact me using the above address.

Sincerely,

Tabot Eneme
Project Manager

Multimodal Travel Demand and System Management: Role of telecommuting in office location/relocation decisions.

Carleton UNIVERSITY
Canada's Capital University

STATED PREFERENCE SURVEY

Consent Form

Date of ethics clearance: **11th October, 2012**
Ethics Clearance for the Collection of Data Expires: **31st May, 2013**

I, ____ volunteer to participate in a survey on the **role of telecommuting in office location/relocation decisions.**

I understand that my participation will contribute data on factors that will be used for the development of an office location/relocation decision model.

My participation in this survey is limited to completing the hard copy of the questionnaire provided by the researcher. The instructions and descriptions of technical terms are clearly noted in the questionnaire document. I do not perceive any risk associated with the completion of the questionnaire and my voluntary participation is motivated by desire to contribute knowledge for research purposes.

I understand that:

- I am voluntarily responding to a request to participate in this survey extended by Mr. Tabot Eneme (Research Assistant) and Professor A.M. Khan of Carleton University and that he can be contacted by email (ata_khan@carleton.ca) and by telephone (613 520 2600 ext. 5786).
- The project was reviewed and received ethics clearance from the Carleton University Research Ethics Board and that the Chair of the Research Ethics Board can be reached by email (ethics@carleton.ca) and by telephone (613 520 2517).
- I will remain anonymous and my response will be used only for aggregate statistical analyses.
- My response will remain confidential and that the data obtained will be destroyed following the completion of the current study and extensions, if any.
- I may decline from answering any questions.
- The results of the research study will be published in scientific literature such as journals, books and conference proceedings. Also, results may be used in workshops and seminars for the purpose of advancing knowledge.

____ ________________________
Signature of Participant Date

November 1st, 2012
Signature of Researcher Date

SECTION 1: Information regarding business orientation of organization

In this section, we would like to know more about how your business organization/company carries out its daily business activities alongside your knowledge/attitude about telecommuting. *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

11. Amongst all employees in your business organization/company, approximately what percentage of them are professionals (i.e., hold certified professional licenses in their field of practice)?

☐ Less than 20%
☐ 21 – 40 %
☐ 41 – 60 %
☐ Above 60 %

12. Approximately how often do your employees rely on the use of telecommunications and computer technology (e.g. email, fax, telephone, internet, broadband, etc.) to facilitate their work?

☐ Less than 20 % of the time
☐ 21 – 40 % of the time
☐ 41 – 60 % of the time
☐ Above 60 % of the time

13. What is the most frequently used medium of communication amongst your employees?

☐ Electronic mail ☐ Telephone
☐ Face-to-face contact ☐ Video conferencing
☐ Other_______________

14. In terms of doing business and based on your judgment, how important is it for your employees to have face-to-face interaction between your organization's clients and other colleagues on daily basis?

☐ Extremely important
☐ Very important
☐ Important
☐ Slightly important
☐ Not important at all

15. In terms of supervising your employees, which method of supervision do you use most amongst the following? (Check (✔) all that apply)

☐ Review meetings ☐ On-site supervision
☐ Written reports ☐ Activity logs
☐ Review completed task ☐ Time-sheets
☐ Other_________________________

16. Does your company have an exhaustive security policy (plan) regarding its employees accessing company information from any other location other than at the office?

☐ Yes ☐ No ☐ N/A

17. Does your company currently have a fully operational telecommuting program?

☐ Yes – If Yes,
   i. Approximately what percentage of your employees telecommute per week_________%
   ii. What is the approximate number of days a typical telecommuter actually telecommutes in a typical week? ________ Days.

☐ No (Please proceed to question 8)

18. Have you ever thought of introducing a telecommuting program as an option for your employees?

☐ Currently have an existing telecommuting program
☐ Working towards developing one
☐ Definitely thought of it
☐ Sometimes thought of it
☐ Rarely thought of it

☐ Never thought of it
☐ It is impossible for my employees to telecommute

19. What position do you currently hold in your business organization/company?
☐ C.E.O/Manager/Partner/President
☐ Other_______________
☐ N/A

20. As the current Manager/CEO/Partner/President of your organization/company and on a scale of 1 to 7, how much influence do you have on the decision-making process regarding where to locate/relocate your office within the City of Ottawa? (✔☐Only)

1 = 'Least influence' *7 = 'most influence'*

☐1 ☐2 ☐3 ☐4 ☐5 ☐6 ☐7

SECTION 2: Stated Preference survey – Office Relocation/Relocation Alternatives

This part of the survey contains attributes (features) that describe ***hypothetical scenarios*** of two possible alternative places for locating/relocating an office within the City of Ottawa. As noted, telecommuting is under consideration to be used as a tool by many cities as a means to reduce traffic congestion and delays during peak commute times. Also, telecommuting may also have effects on land use, an aspect that may be of research interest in this study.

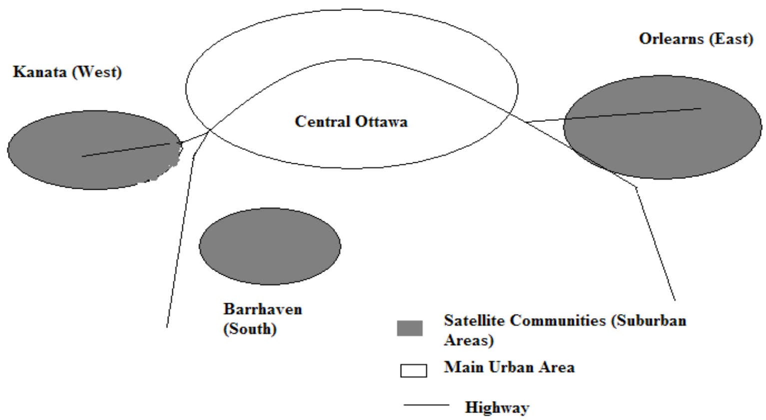
Your responses to this part of the survey are equally very important because this will help ensure that the survey represents the views of business organizations within the entire region.

Here is an overall idea of how this part of the survey works: suppose that your business organization/company recently adopted a telecommuting program for its employees and it chooses to locate/relocate to a new place within the Ottawa region. ***Assuming you are the Chief Executive Officer/Manager of your business organization/company*** with the final decision on where to best locate/relocate your office, you are required to please evaluate each of the following six scenarios and let us know your preference as to where you will like the office of your business organization/company to be located/relocated amongst these two alternatives:

3. **Central Ottawa** (inside the Green Belt and downtown), or
4. **Satellite Communities** (which include either Kanata (West), Orleans (East), or Barrhaven (South)).

In doing this survey, we are conscious of the fact that you may consider other very important factors such as privacy & security of company information, quality of communication amongst employees and their colleagues, attitudes of management towards employees (i.e., ability to maintain control over employees) amongst many other factors before choosing where to locate/relocate your office amongst the above two alternatives. However, it is required that you please assume such factors to be identical for the two possible office location/relocation alternatives presented. In addition, please take into account your organization's/company's goals and objective when choosing your preferred alternative.

A schematic diagram of the office location alternatives within the city of Ottawa are shown below:



Example of Choice Scenario

Table 1 below outlines an example of the scenario matrix containing all the attributes (features) alongside, the attribute levels for the two possible office location/relocation alternatives within the Ottawa region. ***This example scenario is meant for the purpose of demonstrating how the scenario matrix works. You are not required to select any choices for this case at the moment.***

Below are definitions of the various attributes contained in Table 1:

7. **Employee telecommuting level per week:** This is the average number of days per week an employee chooses to telecommute assuming that the company adopts a telecommuting program.

8. **Overhead Cost:** This refers to yearly the "operating expense" expressed as a percentage change to the current overhead cost incurred for operating a business. Overhead costs include accounting fees, advertising, depreciation, insurance, interest, legal fees, rent, repairs, supplies, taxes, telephone bills, travel expenditures, and utilities.

9. **Office and Parking Space:** This is the size of the office in terms of number of cubicles or desks and the number of parking spaces expressed as a change with respect to your current business organization's office size.

10. **Proximity to related businesses:** This is the relative importance of how the strategic location/relocation of your office would benefit your business organization in gaining customers through its office appearance, name branding and proximity to other businesses of similar type.

11. **Office Accessibility:** This is the ease of being able to access the office building.

Table 1: Example Scenario *(Please, see explanation below on how to interpret the information contained in the following table.* ***You are not required to select any choices for this scenario at the moment****)*

Example Scenario			
Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will prefer to locate/relocate your office.			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	Between 1 - 3 days/week	
Overhead Cost (%)	2 % ***reduction*** per year	5% ***increase*** per year	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located ***more than*** 500 meters away from major transit hubs/ streets or roads	Office located ***less than*** 500 meters away from major transit hubs/ streets or roads	
Please, select where you will choose to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

The way you may want to read the above example scenario table will be as follows:

In all cases, you must assume that your business organization/company recently adopted a telecommuting program and your employees have the option to telecommute some days within the week or not. Then, if I choose to locate/relocate my office within:

4. **Central Ottawa (inside Greenbelt)**

This implies, for this scenario, my employees will choose not to telecommute during the week despite the existence of a telecommuting program, my business organization/company will experience an annual reduction in overhead cost of approximately 2% compared to its current overhead cost, my office size and number of parking spaces available to me will reduce, the proximity of my office location to similar businesses of its kind will be excellent and this will be a beneficial technique for my company/organization to attract customers, and lastly, my office will not be easily accessible since it will be located more than 500 meters away from major transit hubs/roads or streets.

1. **Satellite communities (i.e., Kanata (West), Orleans (East) or Barrhaven (South))**

This implies, for this scenario, my employees will take advantage of the telecommuting program and choose to telecommute on average between 1 – 3 days/week, my business organization/company will incur and increase in overhead cost by 5% each year relative to what I incur now, my office size and number of parking spaces available to me will remain the same relative to what I already have, the proximity of my office location to related businesses of its kind will be poor and this ***may not*** be a beneficial technique for my company/organization to attract customers, and lastly, accessibility to my office will be excellent since it will be located within 500 meters of a major transit hub/road or street.

2. **None**

This implies I do not find the attributes (features) in either of the two office location/relocation alternatives as persuasive as much to influence me to consider relocating my office.

Upon evaluating the two alternatives for office relocation based on the features presented in each scenario below, as well as taking into account the needs and objectives of your business organization, you should proceed and choose your most preferred office location/relocation

area. Please endeavor to <u>CHECK ONE AND ONLY ONE BOX.</u> Repeat the same selection process for all 6 scenarios.

Assume you are in the midst of deciding where to locate/relocate the office of your business organization/company within the City of Ottawa municipality. Also assume that your company/business organization recently adopted a telecommuting program for its employees. Taking into account the following features, please select where you will prefer to locate/relocate your office in the following **scenarios**.

Scenario #1			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	1 – 3 days/week	0 days/week	
Overhead Cost (%)	2 % ***reduction*** per year	5 % ***increase*** per year	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐Central Ottawa	☐Satellite Communities	☐None

Scenario #2			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	1 – 3 days/week	
Overhead Cost (%)	10 % ***increase*** per year	7 % ***reduction*** per year	
Office and Parking Space	Reduces	No Change	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐Central Ottawa	☐Satellite Communities	☐None

Scenario #3			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	1 – 3 days/week	0 days/week	
Overhead Cost (%)	10 % ***increase*** per year	7 % ***reduction*** per year	
Office and Parking Space	No Change	Increases	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #4			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	1 – 3 days/week	
Overhead Cost (%)	2 % ***reduction*** per year	5 % ***increase*** per year	
Office and Parking Space	No Change	Increases	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #5			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	1 – 3 days/week	0 days/week	
Overhead Cost (%)	2 % ***reduction*** per year	5 % ***increase*** per year	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Poor	Excellent	
Office Accessibility	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

Scenario #6			
Features of Office Location/Relocation Area	**Office Location Alternatives**		
	Central Ottawa	**Satellite Communities**	**None**
Employee Telecommuting level	0 days/week	1 – 3 days/week	
Overhead Cost (%)	10 % ***increase*** per year	7 % ***reduction*** per year	
Office and Parking Space	Increases	Reduces	
Proximity to related businesses	Excellent	Poor	
Office Accessibility	Office located ***more than*** 500 meters from major transit hubs/ streets or roads	Office located ***less than*** 500 meters from major transit hubs/ streets or roads	
Please, select where you will prefer to locate/relocate your office given the above conditions (☑ **one only**)	☐ Central Ottawa	☐ Satellite Communities	☐ None

SECTION 3: About the Company

In this section of this survey, we would like to know more about the company profile. **This information will only be used to classify your responses and will never be presented in an individually identifiable form.** *Please, select the applicable response by indicating with the (✔) symbol in the appropriate box.*

9. For how long has your company been in business within the Ottawa region?

☐ Under 10 years
☐ 11 – 20 years
☐ 21 – 30 years
☐ 31 – 40 years
☐ Over 41 years

10. In what part of the Ottawa region is your office currently located?

☐ Central Ottawa (Inside Green Belt and downtown area)
☐ Kanata
☐ Barrhaven/Nepean
☐ Orleans
☐ Other: Please, specify _________________

11. In terms of office space rental, how much does your business organization pay monthly for rent?

☐ 0 – 999 $
☐ 1000 – 3000 $
☐ 3001 – 5000 $
☐ 5001 – 10000 $
☐ Above 10,000 $
☐ Owns office space/Does not pay rent

12. Ever since your company opened its doors to doing business within the Ottawa region, has there ever been a change in the building address of your office?

☐ Yes (if yes, please answer question 5)
☐ No (if No, please proceed to question 6)

13. For the past 10 years (or as far back as you can remember), please state the number of times that your office was relocated. Also, please state the primary reason why your office was relocated from its former address to its current address (e.g. reduced rental cost, strategic business reason, etc.).

____
____
____
____

14. Which of the following best describes the primary sector of your business organization/company?

☐ Accounting
☐ Financial Planning
☐ Engineering
☐ Computer programming
☐ Public relations
☐ Database Administration
☐ Web design
☐ Transcription and Translation
☐ Customer support specialist
☐ Law firm/Paralegal
☐ Other: Please, specify____________________

15. What is the approximate size of your business organization in terms of the number of **full-time** employees employed at your current office location ***only***?

☐ Under 10 employees
☐ 11 – 30 employees
☐ 31 – 50 employees
☐ 51 – 100 employees
☐ Over 101 employees

16. Number of employees directly under your supervision?

☐ 0 – 5 employees
☐ >= 6 employees

==

<<END OF QUESTIONNAIRE>>

==

Upon completion, please do not forget to kindly return your responses to your receptionist for pick-up by **November 30th, 2012**.

<<THANK YOU FOR YOUR TIME AND EFFORT SET ASIDE FOR PARTICIPATING IN THIS SURVEY>>

APPENDIX D: SURVEY DISTRIBUTION CONTACTS

Table 1-D: List of Office Contacted for the distribution of Commuters' Mode Preference Survey

Address	Office Name	Number of Questionnaire Distributed	Number of Questionnaires Returned/Picked Up
1300 - 360 Albert St, Ottawa	SAS Institute	20	6
1220 - 360 Albert St	HCM Works	5	3
1810 - 360 Albert St	Lavery Laws and Business	7	4
800 - 360 Albert St	Macquarie	9	5
701 - 360 Albert	Mercer	50	14
530 - 360 Albert	EADS	6	3
420 - 360 Albert	Canadian Chamber of Commerce	10	4
400 - 99 Bank St	Canadian Wood Council	40	17
110 O'Connor St	Certified Management Accountant	1	1
1150 - 220 Laurier Ave West	Construction Sector Council	5	0
1550 - 220 Luarier Ave West	Canadian Bureau for International Education	40	18
1202 - 99 Metcalfe St	Canadian Federation of Independent Business	5	1
315 - 50 O'Connor St	Bentall Kennedy	45	0
1850 - 45 O'Connor St	Sustainable Dev Technology Canada	40	15
750 - 45 O'Connor St	Raymond James	5	3
600 - 45 O'Connor St	Accenture	20	1
350 - 45 O'Connor	Telfer School of Business	10	0
200 - 171 Nepean St	Acart	20	15
110 Laurier Avenue	City of Ottawa	10	10
427 Gilmour St	Law Office	5	2

222 Laurier Ave	Government Building	25	11
150 Kent St	Place De Ville	50	15
300 Laurier Avenuue	Government Building	25	9

Table 2-D: List of Contacted Business Firms for Office Location/Relocation Survey Implementation

#	Company Name	Address	Survey Dropped off (Yes/No)	Survey Picked Up (Yes/No)
1	Metroland Media Group Inc	80 Colonnade Rd, Nepean, ON	Yes	No
2	Supreme Advocacy LLP	397 Gladstone Ave, Suite 100, Ottawa	No	No
3	The Ottawa Citizen	1101 Baxter Rd, Nepean, ON	No	No
4	Classique Translation Ltd	340 Albert St, Suite 1300, Ottawa	No	No
5	Stenotran Services Inc	2446 Bank St, Ottawa	No	No
6	Charles Ghadban Accounting	544 Bronson Ave, Ottawa	Yes	Yes
7	Leonard Tam CGA	275 Slater St, Ottawa	Yes	Yes
8	Bookkeeping Bureau	210-4275 Innes Rd, Orleans	No	No
9	Mackenzie & Associates	400 Island Park Dr, Ottawa,	No	No
10	Accvisors Bookkeeping Canada Ltd	544 Bronson Ave, Ottawa,	No	No
11	Johnson & Associates Accounting Services Inc.	343 O'Connor St, Ottawa,	No	No
12		300 March Road, Suite 503, Kanata	No	No
13		2451 St. Joseph Blvd, Suite 208, Ottawa	No	No
14	Saslove Stephen H Chartered Accountant	250-220 Laurier Ave W	Yes	No
15	Picco Accounting Ltd	1791A Kilborn Ave, Ottawa	No	No
16	Tahan Business Services	1673 Cyrville Rd, Gloucester,	No	No
17	Barbara's Bookkeeping Services	343 Parkin Cir, Gloucester,	No	No
18	Bouris, Wilson LLP	1701 Woodward Drive, 2nd Floor, Ottawa	Yes	No
19	DNTW Chartered Accountant	1700 Woodward Drive, Suite 101, Ottawa	Yes	No

20	McCORMICK RANKIN	1145 Huntclun Rd, Suite 300, Ottawa	Yes	Yes
21	AECOM	302 - 1150 Morrison Dr,Ottawa	Yes	No
22	CIMA Engineering	240 Catherine St, Ottawa	Yes	No
23	van Berkom Chartered Accountants	3-1493 Merivale Rd, Ottawa	Yes	No
24	Assante Wealth Management	301 Moodie Dr, Nepean	Yes	No
25	Assante Wealth Management	2725 Queensview Dr, Ottawa,	Yes	No
26	W H Scrivens Financial Services Ltd	270 MacLaren St, Ottawa	Yes	No
27	Craig & Taylor Associates	1525 Carling Avenue, Suite 504	Yes	Yes
28	Rick Sutherland Reg Financial Planner	1276 Wellington St W, Ottawa,	Yes	Yes
29	Rankin Rice Wealth Management	100-1600 Carling Ave, Ottawa	Yes	Yes
30	Professional Investments Inc	1493 Merivale Rd, Nepean	No	No
31	National Bank Financial	50 O'Connor St, Ottawa, ON	No	No
32	Alterna Savings	400 Albert St, Ottawa	No	No
33	SNIPPER financial planning	307-150 Isabella Street, Ottawa	Yes	No
34	Dundee Wealth & Capital Wealth	2301 Carling Ave, Ottawa,	No	No
35	McBane Patrick & Assoc Insurance Agencies Ltd	28 Deakin St, Nepean,	Yes	Yes
36	Cadence Design Systems (Canada) Ltd	1130 Morrison Drive, suite 240	Yes	No
37	Esri Canada Ltd	100-1600 Carling Ave, Ottawa,	Yes	No
38	CNW Group Inc	99 Bank St, Ottawa,	Yes	Yes
39	Alacris Inc	1600-100 Queen St, Ottawa,	No	No
40	Media X Systems Inc	1825 Woodward Dr, Ottawa	Yes	Yes
41	Novabrain Technologies Inc	515-1568 Merivale Rd	Yes	No
42	Gallium Visual Systems Inc	411 Legget Dr, Kanata	Yes	Yes
43	N-Able Technologies Inc	450 March Rd, Kanata	Yes	Yes

44	Data Kinetics Ltd	410 Laurier Ave W, Ottawa or 202-2460 Lancaster Road, Ottawa	Yes	No
45	Open Text Corporation	80 Aberdeen St, Ottawa	Yes	Yes
46	SAS Institute Canada Inc	360 Albert St, Ottawa, (Constitution Square)	Yes	No
47	Validian Corporation	30 Metcalfe St, Ottawa,	Yes	Yes
48	Kivuto Solutions Inc	987 Wellington St W, Ottawa,	No	No
49	Softchoice Corporation	541 Sussex Dr, Ottawa	No	No
50	Ascentify Learning Media Inc	44 By Ward Market Sq	No	No
51	DM Solutions Group	30 Rosemount Ave, Ottawa,	No	No
52	Frontex Reporting Systems Inc	1101 Prince of Wales Dr, Ottawa,	Yes	Yes
53	Financial Solutions	2134 St. Joseph Blvd, Orleans	Yes	Yes
54	Wealth Strategies	210 Blvd Centrum, Ottawa	Yes	Yes
55	Armstrong & Quaile Associates Inc	2451 St. Joseph Blvd, Orleans	Yes	Yes
56	Innovative Technology Inc	1420 Youville Dr, Ottawa,	No	No
57	Middleware Solutions Inc	344 River Ridge Cres, Orleans,	Yes	No
58	Conversart Consulting Ltd	1651 Autumn Ridge Dr, Orleans,	No	No
59	Dundee Wealth Management	6384 Fortune Dr, Orleans,	No	No
60	Attain Insight Solutions Inc	2-2026 Lanthier Dr, Ottawa,	Yes	Yes
61	Maranova Resources Corporation	202 Hoylake Cres, Orleans,	Yes	Yes
62	Grade A Student Inc	1701 Woodward Dr, Ottawa,	Yes	Yes
63	Zylog Systems (Ottawa) Ltd	1545 Carling Avenue, suite 600	Yes	Yes
64	Computer Onsite	1439 Woodroffe Ave, Nepean	No	No
65	Tech2Go	797 Somerset St W, Ottawa,	No	No

66	Nerd Machine	6335 Fortune Dr, Orleans,	No	No
67	GuruTech Corp	7 Millbrook Cres, Nepean,	No	No
68	Geek Onsite	510-1186 Meadowlands Dr E,	No	No
69	Devon Group Ltd	887 Richmond Rd, Ottawa	Yes	No
70	Coradix Technology Consulting Ltd	151 Slater St, Ottawa,	Yes	Yes
71	Computer King	1185 Shillington Ave, Ottawa	No	No
72	Amita Corporation	1420 Blair Pl, Gloucester,	Yes	Yes
73	Alcea Technologies Inc	2197 Riverside Dr, Ottawa	Yes	Yes
74	inRound Innovations	190 MacLaren St, Ottawa,	No	No
75	Wilcom Systems Ltd	887 Richmond Rd, Ottawa	Yes	No
76	MTS Allstream	45 O'Connor St, Ottawa,	No	No
77	Golden Ratio Tech Services	21 Glenmanor Dr, Nepean	No	No
78	BenBen Computer	620 Aberfoyle Cir, Kanata,	No	No
79	Chaumont Systems Development Inc	9-645 Belfast Rd, Ottawa,	No	No
80	PC Fixr	5450 Canotek Rd, Gloucester,	Yes	Yes
81	Global Public Affairs	901-50 O'Connor St, Ottawa	Yes	Yes
82	Oscapella and Associates	70 MacDonald St, Ottawa,	Yes	Yes
83	NATIONAL Public Relations Inc	130 Slater St, Ottawa	No	No
84	Gordon Group	334 Churchill Ave N	Yes	Yes
85	Rawson Group Initiatives Inc	222 Argyle Ave, Ottawa	No	No
86	Interchange Public Affairs	75 Rue Albert, Ottawa,	Yes	No
87	Bridges Consulting	28 State St, Ottawa,	Yes	No
88	Conference Interpreters	95 Main St, Ottawa,	Yes	Yes
89	Acart Communications Inc	600-171 Nepean St, Ottawa,	Yes	Yes
90	PACE Public Affairs & Community Enterprises	101-207 Bank St, Ottawa,	Yes	No
91	Public Sector Company Limited (PSC) The	200-440 Laurier Ave W, Ottawa,	No	No
92	Crestview Public Affairs Inc	85 Albert St, Ottawa,	Yes	No

93	Capital Hill Group	1540-45 O'Connor St, Ottawa,	Yes	Yes
94	West Hawk Associates	58 Fulton Ave, Ottawa,	Yes	No
95	Hillwatch Inc	334 MacLaren St, Ottawa	Yes	No
96	hmci hayter marketing communications inc	150 Queen Elizabeth Dr, Ottawa	Yes	No
97	Allium Consulting Group	76 Chamberlain Ave, Ottawa,	No	No
98	Tactix Government Relations & Public Affairs Inc	45 O'Connor St, Ottawa,	Yes	Yes
99	Bonsall Communications	32 Third Ave, Ottawa,	Yes	No
100	Blueprint Public Relations Inc	111 Sherwood Dr, Ottawa,	No	No
101	Y Media Creative Communications	1-425 Hamilton Ave S, Ottawa,	No	No
102	Brasseur & Associates Inc	1596 des Serins Lane, Orleans,	Yes	No
103	Burke Cader Media Strategies Inc	176 Gloucester St, Ottawa,	Yes	Yes
104	Drolet Daniel	176 Gloucester St, Ottawa,	Yes	Yes
105	MaxSys Staffing & Consulting	173 Dalhousie St, Ottawa	No	No
106	JSI Data Systems Limited	85 Auriga Dr,	No	No
107	Davis + Henderson	2405 Blvd St Laurent, Ottawa	No	No
108	Davis + Henderson	145 Robertson Rd, Nepean	Yes	Yes
109	Replinet	38 Auriga Dr, Ottawa,	Yes	No
110	Aubut & Nadeau Design Communications	16 Beechwood Av Studio 204,	Yes	No
111	Aditek Design Printing And Signs	24-2350 Stevenage Dr, Ottawa,	No	No
112	Le Studio Web Design	400 Oaklawn Cres, Orleans,	Yes	No
113	Print Three	220 Laurier Ave W, Ottawa,	No	No
114	Baytek Systems	1338 Wellington St W, Ottawa,	Yes	Yes
115	Innovacom Marketing & Communication	123 Beechwood Ave, Ottawa	Yes	No
116	MediaForce Website Services	1333 Michael St, Gloucester,	No	No

117	Bymedia Design Group	506 Kochar Dr, Ottawa,	Yes	No
118	Mcclintion Traffic Ticket Consultants	11 Naismith Cres, Kanata,	Yes	No
119	Read Paralegal Services	331 Cooper St, Ottawa	No	No
120	Daniel Pattullo Paralegal Services	33 Cordova St, Nepean	Yes	No
121	Cameron & Associates Ltd	294 Main St, Ottawa,	Yes	No
122	SanDouglas Health Care & Associates Inc	2387 Virginia Dr, Ottawa,	Yes	No
123	Sabina & Associates Paralegal Services	2115-2487 Kaladar Ave, Ottawa,	Yes	Yes
124	Services Tafat Inc	1150-45 O'Connor St, Ottawa,	Yes	No
125	CMN Compensation Consultants	427 Preston St, Ottawa	Yes	Yes
126	A Mathieu Bilingual Paralegal Services	111 Sparks St, Ottawa	Yes	Yes
127	Nelligan O'Brien Payne LLP	1500-50 O'Connor St, Ottawa	Yes	No
128	Valcom Consulting Group Inc	300-85 Albert St, Ottawa	No	No
129	Donna Cona Inc	106 Colonnade Rd, Nepean	Yes	Yes
130	Cistel Technology Inc	40-30 Concourse Gate, Nepean	No	No
131	Innovapost	365 March Rd, Kanata	Yes	Yes
132	RealiT Management Inc	150 Terence Matthews Cres, Kanata	No	No
133	Precision ERP	12 York St, Ottawa	No	No
134	Trillys Systems Inc	1645 Russell Rd, Ottawa,	No	No
135	MapleSoft Consulting Inc	408 Churchill Ave N, Ottawa,	Yes	Yes
136	RJR Innovations	1400 St. Laurent Blvd	Yes	No
137	Overlay TV	80 Aberdeen St, Ottawa,	No	No
138	Blackline Systems Corp	2794 Fenton Rd, Gloucester,	Yes	Yes
139	The Pythian Group	2934 Baseline Rd, Nepean,	Yes	No
140	Keys Direct	2580 Innes Road, Ottawa	No	No

141	On Call Centre	2405 Blvd St Laurent, Ottawa	Yes	No
142	Clientel Plus	570 Industrial Ave, Ottawa	Yes	No
143	Collins Barrow Brown Inc	400-301 Moodie Dr, Nepean	No	No
144	Minitel Communications Corporation	1775 Courtwood Cres, Ottawa,	Yes	No
145	Dare HR	275 Slater St, Ottawa,	No	No
146	P F Markham & Associates Inc	265 Carling Ave, Ottawa	Yes	No
147	Moss Melien & Associates	1725 St. Laurent Blvd, Ottawa,	Yes	No
148	Rainbow Translation Services Inc	1200-130 Albert St, Ottawa,	No	No
149	Dust Evans Grandmaitre	2589 St. Joseph Blvd,	No	No
150	Picard Law	33-5330 Canotek Rd, Gloucester	Yes	No
151	Castle-Trudel	403-331 Cooper St, Ottawa,	No	No
152	Low Murchison Radnoff LLP	4-1565 Carling Ave, Ottawa,	Yes	No
153	Tierney Stauffer LLP	510-1600 Carling Ave, Ottawa	No	No
154	Galarneau & Associates Associés	2831 St. Joseph Blvd, Orleans,	Yes	No
155	Carters Professional Corporation	70 Gloucester St, Ottawa,	No	No
156	Hollingsworth David	486 Gladstone Ave, Ottawa	Yes	Yes
157	Girones Lawyers	300-300 Terry Fox Dr, Kanata,	Yes	Yes
158	Segal D Larry Law Office	124 O'Connor St, Ottawa,	No	No
159	Ronald G Guertin	600-200 Elgin St, Ottawa,	No	No
160	Mann & Partners LLP	1600 Scott St, Ottawa,	Yes	Yes
161	Fitzgerald Family Law	180 Metcalfe St, Ottawa,	No	No
162	Williams McEnery	169 Gilmour St, Ottawa,	Yes	No
163	Carters Professional Corporation	124-117 Centrepointe Dr, Nepean,	No	No

164	McMechan Robert Professional Corporation	28 Glengarry Rd, Ottawa,	No	No
165	Brooker Thomas W	1400 Clyde Ave, Nepean,	No	No
166	Vary Professional Corp Lawyer Avocat	113 Pretoria Ave, Ottawa,	Yes	No
167	Macleod Nigel	202-900 Morrison Dr, Ottawa	No	No
168	Quinn Thiele Mineaut Grodzki LLP	310 O'Connor St, Ottawa,	Yes	No
169	P Barron Family Law	33-5330 Canotek Rd, Gloucester,	No	No
170	AGB Lawyers	1400 Clyde Ave, Nepean,	No	No
171	Engel Bruce & Associates	116 Lisgar St, Ottawa,	Yes	Yes
172	Immigration Law Office of Negar Achtari	427 Gilmour St, Ottawa,	No	No
173	Addelman Baum Gilbert LLP	800 - 85 Albert, Ottawa,	Yes	No
174	Soloway Wright	427 Laurier Ave W,	Yes	No
175	Merovitz Potechin	200 Catherine St, Ottawa,	Yes	Yes
176	Setzer Laura	24 Bayswater Ave, Ottawa	Yes	No
177	Rasmussen Starr Ruddy LLPBarristers & Solicitors	660-1600 Carling Ave, Ottawa,	Yes	No
178	Cooligan Ryan LLP	100-1600 Carling Ave, Ottawa,	Yes	No
179	Wyllie Spears Labour Lawyers LLP	55 Metcalfe St, Ottawa,	No	No
180	Colliers International	55 Metcalfe St, Ottawa,	Yes	Yes
181	Crystal Cry Barristers	310-309 Cooper St, Ottawa	No	No
182	Maxim Technology	275 Slater St, Ottawa,	No	No
183	Information Technology Assn Of Canada	1120 - 220 Laurier Ave W, Ottawa	No	No
184	AJJA Information Technology Consultants Inc	457 Catherine St, Ottawa	Yes	No
185	Information Technology Support Services	136-2446 Bank St, Ottawa,	Yes	No

186	Information And Communications Technology Council Of Canada	1169 Lisgar, OTTAWA,	No	No
187	Gibsons LLP	1520-360 Albert St, Ottawa,	Yes	No
188	Marks & Marks	201-190 Somerset St W,	Yes	No
189	Barnes Barristers	501-200 Elgin St, Ottawa,	No	No
190	MacKay Powell & Duvadie	201-1580 Merivale Rd, Nepean	Yes	No
191	Emond Harnden LLP	707 Bank St, Ottawa,	Yes	No
192	Brass Law Office	1002-200 Elgin St, Ottawa,	Yes	Yes
193	Borden Ladner Gervais LLP	100 Queen St, Ottawa,	Yes	Yes
194	Industrial Media Inc	200 Cooper St, Ottawa,	Yes	No
195	Tessier Translations Corp	222 Somerset St W, Ottawa	Yes	No
196	Veridox Canada Ltd	9-275 Slater St, Ottawa	Yes	No
197	CIC Cabinet d'interprètes de conférence	902-200 Elgin St, Ottawa	Yes	No
198	Conversa Language Services	154 MacLaren St, Ottawa,	No	No
199	Echo Translation	200-440 Laurier Ave W, Ottawa	No	No
200	IBI Group	400-333 Preston St, Ottawa	Yes	No

APPENDIX E: DISCRETE CHOICE ANALYSIS – PILOT SURVEYS

1. Commuters' Mode Preference: Pilot Survey Model Calibration

The pilot survey for this study was carried out throughout the month of October 2012. Fifteen pilot survey questionnaires were handed-out. The sample size for the pilot survey composed of friends and professors within Carleton University, alongside some former colleagues who work within the central business district of Ottawa. Out of the fifteen distributed surveys, eight completed and usable questionnaires were returned.

A conditional logit model was used to fit the collected data from the sampled respondents. Conditional logit models were developed by McFadden (1973) and have been widely used in transportation demand studies (see Ben-Akiva and Lerman, 1985). Although it does not stand out arguably as a preferable technique for calibrating models for which multinomial logit models is currently used, condition logit models are appropriate for a different class of models for which a choice amongst alternatives is treated as a function of the characteristics of the alternatives, rather than (or in addition to) the characteristics of the individual making the choice (Hoffman and Duncan, 1988). The conditional logit is a special case of the nested logit in which all the dissimilarity parameters are equal to one[30].

The calibrated conditional logit model for the pilot survey of this study made use of only the attributes considered in the stated preference hypothetical choice sets. The overall aim of the model was to obtain an idea of what variables were considered important by commuters during their selection of a mode of transport for commuting. The calibrated model is shown in Table 1 – E below:

[30] STATA Quick Reference and Index (Release 12). College Station, Texas. Stata Press. ISBN-13: 978-1-59718-086-6

Table 1 – E: Mode Choice Model – Pilot Survey

Alternative-specific conditional logit						Number of obs = 336
Case variable: Scenario ID						Number of cases = 84
Alternative variable: Mode					Alt per case:	min = 4
						avg = 4
						max = 4
						Wald chi 2(6) = 30.20
Log likelihood = -86.727						Prob> chi2 = 0.000
Choice	Coef.	Std. Err	z	p >|z|	[95% conf. Interval]	
Commute Time (mins)	-0.07	0.03	-2.92	0.00	-0.12	-0.02
Commute Cost ($)	-0.66	0.22	-2.98	0.00	-1.10	-0.23
Commute Delay (mins)	-0.20	0.10	-1.96	0.05	-0.40	0.00
Accessibility (meters)	0.09	0.26	0.34	0.73	-0.43	0.60
Service Frequency (mins)	0.01	0.06	0.12	0.90	-0.11	0.13
Level of Convenience	-0.01	0.21	-0.03	0.98	-0.42	0.41
Modes						
Automobile			(base alternative)			
Bus						
Constant	-8.05	2.47	-3.25	0.00	-12.90	-3.20
Light Rail Transit						
Constant	-5.15	1.75	-2.94	0.00	-8.58	-1.72
Non-Motorized Mode						
Constant	-7.01	2.44	-2.87	0.00	-11.79	-2.23

Based on results obtained from the above calibrated model, travel time, cost and delay/travel time variability tend to be important variables considered by commuters when choosing their mode of transport. Hence, these variables were considered in the design of the stated preference (SP) hypothetical choice sets in the final survey. Notwithstanding, despite the variable on accessibility (meters) and service frequency (time) turned out to be insignificant from the calibrated model using data collected from the pilot survey, these variables were still considered during the design of the SP choice sets in the final survey. In the design of the final survey, the unit for measurement of the variable on accessibility was changed from meters to minutes. The variable on level of convenience was omitted in the final survey design (see section 4.4.5).

2. Telecommuting and Office Location: Pilot Survey Implementation

The pilot survey for this study was carried out throughout the month of October 2012. Seven pilot survey questionnaires were handed-out to randomly selected managers of private business firms whose primary activity were within the sectors of information technology, legal services and engineering while one copy of the pilot survey questionnaire was handed to the chair of the department of civil and environmental engineering at Carleton University. Out of a total of eight questionnaires distributed, six responses were picked-up. Amongst the six picked-up pilot surveys, one of them was returned with no response provided in the stated preference section that contained the scenario choice sets. Hence, the number of usable pilot surveys for analysis was reduced to five (120 observations in total).

Table 2 - E: Binary Model – Pilot Survey

Variable	Coefficient	S.E	p>|z|
ETL	-0.21	0.77	0.78
RENTAL COST (1)	0.49	0.83	0.55
RENTAL COST (2)	1.52	0.69	0.03
OPS (1)	0.42	0.62	0.50
OPS (2)	1.02	1.04	0.32
OFF. PROX	5.30	1.08	0.00
OFF. ACES	2.34	0.79	0.00
EMP. PROD	-0.46	0.71	0.51
Constant	-3.55	1.06	0.00

Goodness-of-fit Tests	
LL at constant = -78.29	LL Ratio = 57.34
LL at convergence = - 49.62	Number of obs = 120
H & L chi 2 = 1.93	Prob>chi2 = 0.3814
McFadden $\bar{\rho}^2$ = 0.3662	Area of ROC Curve = 0.8790

(1) No Change; (2) Increase; H & L – Hosmer & Lemeshow

Table 2-E represents the calibrated binary model using data collected from the stated preference hypothetical choice sets of the pilot survey. The signs of the coefficient of each attribute relates to its importance in contributing in the decision-making process of locating/relocating an office following the adoption of a telecommuting program. The above result shows that proximity and are two important factors considered by business firms in their decision-making regarding where to locate/relocate their office following the adoption of a telecommuting program ($p = 0.00$). Firms would tend to locate/relocate their offices in areas where they will be in proximity to other offices, clients, resources and other amenities. They would also locate/relocate in areas with good accessibility. The result also shows that firms are more likely to locate/relocate their offices in an area where they would incur higher monthly rental cost compared to locating/relocating in an area that decreased by this same amount. Although this finding is statistically significant, it is somehow questionable given that the norm is to associate disutility with any alternative that would result to the subject incurring an increase in cost. The most probable reason for this finding may be because:

- The design of the attribute on office rental cost selected a narrow range of between +/-2% to represent the attribute-levels. Such a narrow range may not have been statistically preferable to cause a significant effect on in the selection of office location/relocation alternatives. Besides, with regards to the leasing of office space, most companies have long-term lease agreements.
- Office rental cost accounts is just a fraction of the other costs incurred by a company such as travel cost, wages, communication costs, utility costs, insurance etc. Hence, everything being equal, the slight increase only in office rental cost may not have had an impact on

business firms given that the attribute levels selected (+/-2%) are within the range of inflation.

The above model fitted the observed data collected from the pilot survey. The model has a McFadden $\bar{\rho}^2$ of 0.37, and it passes the Hosmer and Lemeshow goodness-of-fit test. In other to obtain more significant results, it was necessary to replace the office rental cost with an overhead costs. From Table 2.1 above, employee telecommuting level, office size and employee productivity do not seem to contribute significantly in the office location/relocation decision-making process. However, no conclusion can be made at this instant prior to analyzing SP data collected from the final survey.

APPENDIX F: TABLES on DESCRIPTIVE STATISTICS and MODELS

Table 1 – F: Comfort level of Public Transit by In-vehicle Commute time

Degree of Comfort of experienced by Respondent when using Public Transit for commuting * Commute Time Crosstabulation

			Commute Time			Total
			0 - 25 mins	26 - 50 mins	Above 51 mins	
Degree of Comfort of experienced by Respondent when using Public Transit for commuting	Very Uncomfortable	Count	288	264	24	576
		% within Commute Time	17.4%	14.7%	14.3%	15.9%
	Uncomfortable	Count	288	312	48	648
		% within Commute Time	17.4%	17.3%	28.6%	17.9%
	Uncomfortable Somewhat	Count	288	432	24	744
		% within Commute Time	17.4%	24.0%	14.3%	20.5%
	Not Sure	Count	336	456	24	816
		% within Commute Time	20.3%	25.3%	14.3%	22.5%
	Comfortable Somewhat	Count	336	240	24	600
		% within Commute Time	20.3%	13.3%	14.3%	16.6%
	Comfortable	Count	120	72	24	216
		% within Commute Time	7.2%	4.0%	14.3%	6.0%
	Very Comfortable	Count	0	24	0	24
		% within Commute Time	0.0%	1.3%	0.0%	0.7%
Total		Count	1656	1800	168	3624
		% within Commute Time	100.0%	100.0%	100.0%	100.0%

Table 1 – F (a)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	138.132[a]	12	.000
Likelihood Ratio	142.219	12	.000
Linear-by-Linear Association	1.385	1	.239
N of Valid Cases	3624		

a. 1 cells (4.8%) have expected count less than 5. The minimum expected count is 1.11.

Table 1-F(b)

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.195			.000
	Cramer's V	.138			.000
Ordinal by Ordinal	Gamma	-.037	.022	-1.661	.097
N of Valid Cases		3624			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 2 – F: Level of Reliability of Public Transit by Current Commute Mode

Degree of Reliability on Public Transit by Respondent for commuting * Current mode of transport for commuting Crosstabulation

			Current mode of transport for commuting				Total
			Auto (Drive alone)	Auto (carpool)	Bus	Non-motorized mode	
Degree of Reliability on Public Transit by Respondent for commuting	Very Unreliable	Count	24	24	72	0	120
		% within Current mode of transport for commuting	3.4%	5.9%	3.8%	0.0%	3.2%
	Unreliable	Count	48	24	24	0	96
		% within Current mode of transport for commuting	6.9%	5.9%	1.2%	0.0%	2.5%
	Unreliable Somewhat	Count	72	72	120	144	408
		% within Current mode of transport for commuting	10.3%	17.6%	6.2%	19.4%	10.8%
	Not Sure	Count	96	72	264	144	576
		% within Current mode of transport for commuting	13.8%	17.6%	13.8%	19.4%	15.3%
	Reliable Somewhat	Count	264	72	648	240	1224
		% within Current mode of transport for commuting	37.9%	17.6%	33.8%	32.3%	32.5%
	Reliable	Count	120	96	672	168	1056
		% within Current mode of transport for commuting	17.2%	23.5%	35.0%	22.6%	28.0%
	Very Reliable	Count	72	48	120	48	288
		% within Current mode of transport for commuting	10.3%	11.8%	6.2%	6.5%	7.6%
Total		Count	696	408	1920	744	3768

	% within Current mode of transport for commuting	100.0%	100.0%	100.0%	100.0%	100.0%

Table 2 – F (a)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	384.485[a]	18	.000
Likelihood Ratio	407.002	18	.000
Linear-by-Linear Association	13.779	1	.000
N of Valid Cases	3768		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 10.39.

Table 2 – F (b)

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.319			.000
	Cramer's V	.184			.000
Ordinal by Ordinal	Gamma	.027	.019	1.411	.158
N of Valid Cases		3768			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 3 – F: Calibrated Nested Logit Model (Nested Structure I)

STATA Commands

- nlogitgen type = Mode (Public: LRT | Bus, Private: Auto | NMM)
- nlogit Chosen Ttime SCost SAces_Time SFreq || type: DISTkm OWN_CAR_1 INCOME_2 EDUC_LEVEL_1, base(Private) || Mode:, case(Scenario_ID)

RUM-consistent nested logit regression	Number of obs = 2964
Case variable: Scenario_ID	Number of cases = 741
Alternative variable: Mode of transport	Alt per case: min = 4
	avg = 4
	max = 4
Summary Statistics	
Log likelihood at constant = -933.06186	Wald chi2 (8) = 27.10
Log likelihood at convergence = -904.65407	Prob > chi2 = 0.0007
LR Test = 2[LL(theta)C - LL(theta) = 56.82	Pseudo R2 bar = 0.0314
chi sq ((8-4)+1, 99.99%) = 15.086	Pseudo R2 min = 0.2862
LR Test > ch sq (5,95%) - Reject Ho	

	Chosen	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Mode							
	Ttime	-0.05171	0.021616	-2.39	0.017	-0.09408	-0.00935
	SCost	-0.1394	0.071724	-1.94	0.052	-0.27998	0.001176
	SAces_Time	0.051545	0.068976	0.75	0.455	-0.08365	0.186736
	SFreq	-0.01418	0.008955	-1.58	0.113	-0.03173	0.003376
type equations							
Public							
	DISTANCE	0.035353	0.010617	3.33	0.001	0.014543	0.056163
	OWN_CAR_1	0.027058	0.095513	0.28	0.777	-0.16015	0.214261
	INCOME_2	-0.38845	0.124865	-3.11	0.002	-0.63318	-0.14372
	EDUC_LEVEL_1	0.260388	0.112626	2.31	0.021	0.039645	0.481131

Private							
	DISTANCE	0 (base)					
	OWN_CAR_1	0 (base)					
	INCOME_2	0 (base)					
	EDUC_LEVEL_1	0 (base)					
Mode	equations						
Auto							
	_cons	0 (base)					
Bus							
	_cons	-0.39612	0.494908	-0.8	0.423	-1.36612	0.573885
LRT							
	_cons	-0.30306	0.459965	-0.66	0.51	-1.20457	0.598458
NMM							
	_cons	-0.56601	0.472683	-1.2	0.231	-1.49245	0.360431
dissimilarity	parameters						
type2							
/Public_tau		0.392233	0.17472			0.049788	0.734679
/Private_tau		0.889477	0.669146			-0.42203	2.20098
LR test for IIA (tau = 1):			chi2(2) = 8.43			Prob>chi2 = 0.0148	

Table 4 – F: Nested Logit Model (Nested Structure II)

STATA Commands

- nlogitgen type1 = Mode (Public: LRT | Bus, Car: Auto, Other: NMM)
- nlogit Choice Ttime SCost SAces_Time SFreq || type1: DISTkm OWN_CAR_1 INCOME_2 EDUC_LEVEL_1, base(Other) || Mode:, case(Scenario_ID)

RUM-consistent nested logit regression	Number of obs = 2964
Case variable: Scenario_ID	Number of cases = 741
Alternative variable: Mode of transport	Alt per case: min = 4
	avg = 4
	max = 4
Summary Statistics	
Log likelihood at zero = -948.10981	Wald chi2 (12) = 166.74
Log likelihood at constants= -882.68823	Prob > chi2 = 0.0000
Log likelihood at convergence = -778.80794	Pseudo R2 = 0.179
2[LL(theta)0 - LL(theta) = 338.60	Pseudo R2 bar = 0.07
2[LL(theta)C - LL(theta) = 207.76	Pseudo R2 bar adj = 0.056
chi sq ((12-4)+1,99.99%) = 21.666	
LR Test > ch sq (9, 99.99%) - Reject Ho	

	Chosen	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Mode							
	Ttime	-0.06138	0.019094	-3.21	0.001	-0.09881	-0.02396
	SCost	-0.16994	0.06021	-2.82	0.005	-0.28795	-0.05193
	SAces_Time	0.050837	0.078616	0.65	0.518	-0.10325	0.204921
	SFreq	-0.01722	0.009083	-1.9	0.058	-0.03502	0.000587
type2 equations							
Public							
	DISTANCE	0.277187	0.031603	8.77	0	0.215246	0.339128
	OWN_CAR_1	-0.20779	0.169774	-1.22	0.221	-0.54054	0.124957
	INCOME_2	-0.39096	0.171209	-2.28	0.022	-0.72652	-0.05539
	EDUC_LEVEL_1	-0.30568	0.16148	-1.89	0.058	-0.62217	0.010816
Car							
	DISTANCE	0.32149	0.033313	9.65	0	0.256197	0.386782

	OWN_CAR_1	0.132377	0.198181	0.67	0.504	-0.25605	0.520804
	INCOME_2	0.242882	0.227518	1.07	0.286	-0.20305	0.688809
	EDUC_LEVEL_1	-1.47856	0.23553	-6.28	0	-1.94019	-1.01693
NMM							
	DISTANCE		0 (base)				
	OWN_CAR_1		0 (base)				
	INCOME_2		0 (base)				
	EDUC_LEVEL_1		0 (base)				
Mode	equations						
Auto							
	_cons		0 (base)				
Bus							
	_cons	1.553075	0.599565	2.59	0.01	0.377949	2.728201
LRT							
	_cons	1.667674	0.54958	3.03	0.002	0.590516	2.744832
NMM							
	_cons	3.185673	0.595189	5.35	0	2.019125	4.352221
dissimilarity	parameters						
type2							
/Public_tau		0.459453	0.168998			0.128223	0.790683
/Car_tau		1	1079313			-2115413	2115415
/NMM_tau		1	185275.2			-363132	363133.8
LR test for IIA (tau = 1):			chi2(2) = 6.55			Prob>chi2 = 0.0878	

Table 5 – F: Nested Logit Model (Structure III)

STATA Command

- nlogitgen type = Mode(Public:LRT | Bus, Private: Auto, Other: NMM)
- nlogitgen choice = Mode (Enviro: LRT | Bus | NMM, NonEnviro: Auto)
- nlogittree Mode type choice, choice(Choice)
- nlogit Choice Ttime SCost Mode_Aces SFreq || choice: INCOME_2 OWN_CAR_1 EDUC_LEVEL_1, base (NonEnviro) || type: DISTkm, base(Private) || Mode:,

RUM-consistent nested logit regression	Number of obs = 2868
Case variable: Scenario_ID	Number of cases = 717
Alternative variable: Mode of transport	Alt per case: min = 4
	avg = 4
	max = 4

Summary Statistics	
Log likelihood at constants= -1068.2395	Wald chi2 (9) = 77.73
Log likelihood at convergence = -784.583	Prob > chi2 = 0.0000
2[LL(theta)C - LL(theta) = 567.313	Pseudo R2 min = 0.2863
chi sq ((9-4)+1, 99.99%) = 15.086	Pseudo R2 bar = 0.266
LR Test > chi sq (6,99.99%) - Reject Ho	

	Chosen	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Mode							
	Ttime	-0.05526	0.021201	-2.61	0.009	-0.09681	-0.01371
	SCost	-0.16555	0.064075	-2.58	0.01	-0.29114	-0.03997
	Mode Accessibility	-0.48337	0.215649	-2.24	0.025	-0.90603	-0.0607
	SFreq	-0.01728	0.009205	-1.88	0.06	-0.03532	0.00076
Choice Equations (Commute Style)							
Enviro Friendly Mode							
	Income	-0.57478	0.174565	-3.29	0.001	-0.91692	-0.23264
	Car Ownership	-0.33705	0.120327	-2.8	0.005	-0.57289	-0.10122

	EDUCATION LEVEL	1.197072	0.184889	6.47	0	0.834696	1.559448
NonEnviro Friendly Mode							
	Income			0 (base)			
	Car Ownership			0 (base)			
	EDUCATION LEVEL			0 (base)			
Type Equations							
Public							
	Distance	-0.0474	0.012921	-3.67	0	-0.07273	-0.02208
Private							
	Distance			0 (Base)			
NonMotorized							
	Distance	-0.24701	0.091146	-2.71	0.007	-0.42565	-0.06836
Commute Mode Equations							
Auto							
	_cons			0 (Base)			
Bus							
	_cons	1.689938	0.705449	2.4	0.017	0.307284	3.072593
LRT							
	_cons	1.793257	0.66293	2.71	0.007	0.493938	3.092576
NMM							
	_cons	3.030789	0.567271	5.34	0	1.918959	4.14262
dissimilarity	parameters						
Choice							
/Enviro_tau		0.807137	0.382766			0.05693	1.557344
/NonEnviro_tau		1	150833.6			-295628	295629.5
Type							
/Public_tau		0.415425	0.184187			0.054425	0.776424
/Private_tau		1	.		.	.	
/Other_tau		1	.		.	.	
LR test for IIA (tau = 1):			chi2(3) = 6.66			Prob>chi2 = 0.0834	

Table 6 – F: Preference for LRT Usage in the absence of Preferred Mode of Transport

Preference for LRT in the event of the absence of preferred mode of transport * Preferred mode of transport for commuting Crosstabulation

			Preferred mode of transport for commuting			Total
			Bus	Auto	Non-motorized mode	
Preference for LRT in the event of the absence of preferred mode of transport	Will definitely not use LRT	Count	22	27	37	86
		% within Preferred mode of transport for commuting	9.2%	20.0%	19.8%	15.4%
	May not use LRT	Count	23	2	16	41
		% within Preferred mode of transport for commuting	9.7%	1.5%	8.6%	7.3%
	Not Sure	Count	41	20	17	78
		% within Preferred mode of transport for commuting	17.2%	14.8%	9.1%	13.9%
	May use LRT	Count	110	57	94	261
		% within Preferred mode of transport for commuting	46.2%	42.2%	50.3%	46.6%
	Will definitely use LRT	Count	42	29	23	94
		% within Preferred mode of transport for commuting	17.6%	21.5%	12.3%	16.8%
Total		Count	238	135	187	560
		% within Preferred mode of transport for commuting	100.0%	100.0%	100.0%	100.0%

Table 6 – F (a)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28.837[a]	8	.000
Likelihood Ratio	32.745	8	.000
Linear-by-Linear Association	4.441	1	.035
N of Valid Cases	560		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.88.

Table 6 – F (b)

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.227			.000
	Cramer's V	.160			.000
Ordinal by Ordinal	Gamma	-.082	.052	-1.581	.114
N of Valid Cases		560			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 7 – F: Cross-tabulation between Preferred Mode versus Current Mode

Preferred mode of transport for commuting * Mode of Commuting Crosstabulation

			Mode of Commuting			Total
			1	3	4	
Preferred mode of transport for commuting	LRT	Count	85	216	20	321
		% within Mode of Commuting	34.4%	46.8%	11.1%	36.1%
	Bus	Count	25	203	13	241
		% within Mode of Commuting	10.1%	43.9%	7.2%	27.1%
	Auto	Count	127	7	5	139
		% within Mode of Commuting	51.4%	1.5%	2.8%	15.6%
	Non-motorized mode	Count	10	36	142	188
		% within Mode of Commuting	4.0%	7.8%	78.9%	21.1%
Total		Count	247	462	180	889
		% within Mode of Commuting	100.0%	100.0%	100.0%	100.0%

Table 7 – F (a)

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	783.775[a]	6	.000
Likelihood Ratio	690.080	6	.000
Linear-by-Linear Association	32.743	1	.000
N of Valid Cases	889		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 28.14.

Table 7 – F (b)

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	.939			.000
	Cramer's V	.664			.000
Ordinal by Ordinal	Gamma	.267	.044	5.898	.000
N of Valid Cases		889			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.