

ASSESSING THE POTENTIAL FOR ROAD AND PARKING CHARGES  
TO REDUCE DEMAND FOR  
SINGLE OCCUPANCY VEHICLE COMMUTING  
IN THE  
GREATER VANCOUVER REGION

by

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## **ABSTRACT**

Automobile use is an important contributor to serious environmental and livability problems on the local, regional and global scale. The external nature of many automobile use costs and the subsidization of this use by society lead to its under pricing and over consumption. There is a clear role for government intervention to correct this market failure and reduce demand for automobile use. This report describes a study that used stated preference research methods to test respondents' commuter mode choice behaviour in response to the application of road and parking charges to single occupant vehicles (SOV's) and the introduction of improved transit and carpool alternatives. A total of 650 Greater Vancouver Regional District commuters who presently drive alone to work were mailed an individually customized discrete choice experiment which asked them to choose between driving alone, carpooling or taking a hypothetical express bus service when those choices varied in terms of time and cost attributes. For the 548 commuters who responded, estimates of attribute importance made with a conditional logit model showed that road and parking charges had a significant influence on the odds of choosing to drive alone to work. Time spent picking up other carpoolers, time spent waiting for buses, and transfers between buses were significant influences on the odds of choosing to carpool or take transit. Model probability predictions showed that in suburban areas similar to those included in the study, emphasis should be placed on providing and improving carpooling infrastructure, ride matching services and support programs rather than on providing transit infrastructure and services, because carpooling is a more likely mode choice alternative to driving alone for the trip to work. Model results also showed that increases in drive alone costs will bring about greater reductions in demand for driving alone than improvements in the times and costs of alternatives above a base level of service. A \$5 return trip road charge was shown to reduce total commuter kilometres traveled (by SOV's and carpools) by 18 percent. Long term responses are predicted to be even greater, although there will be some rebound in demand as congestion decreases. Combining travel time improvements for alternatives with a \$2 road charge on SOV's resulted in the same reduction in total commuter vehicle kilometres traveled. Implementing road and parking charges for demand reduction will require the support of key stakeholder groups as well as a broad public dialogue about how to best address the subsidization and externality costs of automobile use. Previous research suggests that public support for such charges will be greatest if they are gradually introduced, if they are used to meet clear, broadly supported goals, and if the resulting revenue is applied in a transparent manner to the improvement of transportation alternatives. Pricing programs will be most successful if they are coordinated under one management authority and introduced in conjunction with appropriate parking supply and land use policies.

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## **1. Introduction**

### **Why the need for this research?**

Our dependence on the automobile for mobility and access and our embrace of it for freedom and independence have serious negative impacts on the environment and society, ranging from global climate change to decreased livability of neighbourhoods. The purpose of the study described in this report is to estimate the potential for two sets of policies – charging a price for single occupant vehicles to drive on the existing urban road system and park at work, and providing improvements to carpooling and transit services – to reduce demand for driving alone by shifting commuters from single occupant vehicles to carpooling and transit for their trip to work. The need for this study arises because there is a lack of information from the Lower Mainland of British Columbia about commuter responses to the use of financial disincentives such as road and parking charges to reduce demand for automobile use. In fact, there is a lack of such information across the country; the Transportation Table (1999) of the National Climate Change Process identified analysis of driver response to “promising” emission reduction measures such as road and parking pricing as a key information gap in the process of deciding on options to deal with greenhouse gas emissions. Collecting this information will enable governments to make informed decisions about the potential for such charges to bring about desired actions on the part of commuters.

Where road charges are used in North America today, their purpose is to earn a profit from private facilities, raise revenue to pay for new roads and their maintenance or to shift demand to different time periods in order to reduce congestion. This study looks at the application of road charges to existing roads in order to reduce demand for travel by single occupant vehicles. Similarly, this study examines the ability of commuter parking charges to reduce demand for driving alone, not to raise revenue. To date, the research that has taken place in the Lower Mainland on the use of these charges for demand reduction has focused on opinion polling of commuter attitudes towards new charges for vehicle use (see for example Viewpoints Research 1995); while documenting public concerns about proposed measures is essential if we are to successfully promote and implement road and parking charges, such research does not tell us how commuters will respond to those charges on the road.

The study described in this report aims to provide an initial estimate of the form that response would take in the urban areas of the Lower Mainland. It will provide an estimate of the percent change in both commuter demand for travel in single occupant vehicles and total commuter kilometres traveled in all private vehicles in response to the introduction of various levels of road and parking charges

and the introduction of improvements to carpool and transit alternatives. Detailed modeling of the effect of road and parking pricing on energy use or air quality is beyond the scope of this report. However, it is hoped that the results of this study will be of use to researchers who wish to model the potential for these pricing measures to reduce energy use and emissions.

### **Organization of report**

The remainder of Part 1 of the report will summarize the negative impacts of automobile use, build the argument that the costs of these impacts should be paid by auto users themselves, describe how road and parking pricing can be used to make this happen, summarize previous research on this topic, and briefly introduce the stated preference research methods used in this study to estimate the effects of road and pricing charges on commuter behaviour.

Part two, Survey Methodology, describes the sampling methods, the telephone presurvey, the design of the discrete choice experiment and mail out survey, conduct of the survey, its response rate, validation of the results against the regional population, and the methods used in analysis of the discrete choice experiment. Part three, Analysis, presents the study results, gives a comparison to results from other research and discusses areas of uncertainty in the results. Part four, Implementation, discusses briefly some of the major problems surrounding the introduction of demand reduction pricing, and outlines solutions that have been proposed to deal with them. Part five, Summary and Conclusions, summarizes the outcomes and implications of the research. The Appendices present the telephone interview script, covering and follow up appeals sent out to the survey respondents, a copy of the actual survey, and a descriptive summary of survey results.

### **The impacts of automobile use on society and the environment**

Automobile use is the largest source of greenhouse gas (GHG) emissions in the Lower Mainland of British Columbia; 29 percent of all GHG emissions here come from light duty vehicles (LDV's) including cars, minivans, pickup trucks, full size vans and sports utility vehicles (GVRD 2000).

The potential consequences of global climate change arising from increased anthropogenic GHG emissions are now well documented. The 2001 report of the Intergovernmental Panel on Climate Change (IPCC 2001) has catalogued a disturbing array of possible impacts on the environment and society. These include increased threats to human health through the spread of disease, increased risk of extreme weather events, reductions in crop yields, water shortages, ground water contamination

through salt water infiltration, rising sea levels, and the possibility of large scale, high impact, abrupt and irreversible changes to physical and biological systems. In British Columbia, possible specific impacts include more frequent drought and forest fire, increased pressure on freshwater resources, coastal flooding, erosion, damages to dikes and property, animal and plant species loss, loss of estuarine and other habitat, and damages to forests, fisheries, and agriculture MoELP (1995a).

Automobile use is also the single largest source of Lower Mainland emissions of nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOC's), the main precursors of ground level ozone (photochemical smog). In 1999 LDV's accounted for 35 percent of all anthropogenic VOC emissions and 36 percent of all NO<sub>x</sub> emissions in the Lower Mainland (GVRD 2000). Average ambient ground level ozone concentrations rose 13 percent in the Lower Mainland between 1987 and 1996, with most of that increase occurring in the period between 1993 and 1996 (GVRD 1998a)

The effects of exposure to ozone on human health are now understood to be quite serious. The World Health Organization has stated that there is no background ambient ozone level below which health effects cannot be detected. Whereas it was once thought that short term exposure to high ambient concentrations was the primary health concern associated with this pollutant, research now shows that long term exposure to relatively low concentrations of ozone are also damaging to health, especially among the elderly, individuals with underlying heart and lung illnesses, and children (WHO 2000). Epidemiological studies show that ambient ozone levels of 50 parts per billion increase hospitalization rates for respiratory illness by 4.5 percent, and premature death rates by 1.35 percent above average (Last et al 1998, also Raizenne et al 1998). At present, the Canadian National Ambient Air Quality Objectives state that health advisories are only indicated once ozone levels reach the "maximum acceptable" level of 82 parts per billion.

Health costs of declining urban air quality in the Lower Mainland are expected to be one and a half billion dollars per year by 2005 (MoELP 1995b), and a large portion of these costs will be associated with the health impacts of ground level ozone resulting from automobile emissions. Ozone exposure is also estimated to result in crop losses in the Lower Mainland worth over eight million dollars per year. Further losses occur to livestock, to forests, and to surfaces and materials (GVRD 1994a).

Long term trends in automobile related emissions are not encouraging. Despite signing the Kyoto protocol in 1997, which called for Canada to reduce its GHG emissions 6 percent below 1990 levels

by 2012,<sup>1</sup> GHG emissions in Canada in 1998 from all sectors (including transportation) were 13 percent higher than 1990 levels (Environment Canada 2000). Other sources put the increase even higher; the Suzuki Foundation (2001) claims that GHG emissions in Canada had increased approximately 20 percent above 1990 levels by 2000. The increase in transportation sector GHG emissions can be attributed both to the growing number of vehicles on the road and to the declining average fuel efficiency of those vehicles (Environment Canada 2000). Furthermore, researchers estimate that unless extensive measures are undertaken soon, GHG emissions in Canada will increase 36 to 44 percent above 1990 levels between 2010 and 2020 (Suzuki Foundation 2001, NRC 1997).

In the case of emissions of VOC's and NO<sub>x</sub> the situation seems, at first glance, more encouraging. Over the past 15 years programs at the regional and provincial level have led to a 50 percent reduction in VOC emissions and a 20 percent reduction in NO<sub>x</sub> emissions from transportation sources in the Lower Mainland.<sup>2</sup> These reductions are attributed largely to AirCare, a LDV emissions control inspection and maintenance program (GVRD 1998b). However, overall emissions from LDV's are expected to rise in the future, for the same reasons that explain projected growth in GHG emissions. Regional traffic volumes are expected to double between 1991 and 2021 and are currently increasing at twice the rate of population growth (MoELP 1995b, TransLink 2000a). In addition, in the period from 1985 to 1998 average trip lengths in the GVRD increased 16 percent -- indicating that land uses in the region are becoming more dispersed -- and average travel speeds decreased by 7 percent -- indicating that congestion is increasing on regional roads (GVRD 2001). Furthermore, overall LDV fuel efficiency declined by 13 percent between 1986 to 1997 as heavy, high performance vehicles went from one-quarter to one-half of the passenger vehicle market (Tollefson 2000, Statistics Canada data cited in Last et al 1998).

In summary, the regional trend in private vehicle use is for more vehicles burning more fuel while travelling longer distances at slower speeds, all of which will lead to a reversal of emissions reductions gained in the last 15 years. Given these trends, emissions of VOC's and NO<sub>x</sub> from LDV's in the Lower Mainland are expected to increase beyond 1985 levels by 2021 (MoELP 1995b). This in turn may lead to higher ambient concentrations of ground level ozone, and greater impacts to

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<sup>1</sup> British Columbia committed to meeting this same goal in its Greenhouse Gas Action Plan (MoELP 1995a). Note that the Intergovernmental Panel on Climate Change states that reductions of greenhouse gas emissions of 60 to 80% below 1990 levels will be required to stabilize global temperatures and minimize the impacts of climate change (WMO 1991). As of April 1 2002 Canada had not yet ratified the Kyoto Protocol.

<sup>2</sup> Note that even after these reductions, LDV's remain the single largest source of both VOC and NO<sub>x</sub> emissions in the Lower Mainland (GVRD 2000).

human health and the environment. Increases in ambient ozone levels may be further exacerbated by general warming trends brought about by global climate change. The predicted rise in emissions may be mitigated if ultra-low and zero emission vehicles are able to capture a substantial share of the automobile market, but this will depend upon those vehicles becoming more cost competitive.

However, even if automobiles in the future produce fewer emissions, their use still leads to other negative environmental and social impacts in addition to the air quality and health effects described above. Additional environmental impacts include habitat loss due to road building, increased rain water run off from paved surfaces, and contamination of ground and surface waters with oil, gasoline, and particulate. Additional social impacts include injury and loss of life due to traffic accidents, physical stress associated with exposure to traffic noise, the loss of shared community space, and the deterioration of social exchange networks based on face to face contact on the street (Engwicht 1999).

### **The under pricing and over consumption of automobile use**

Environmental and social impacts such as those described above come with costs, and when these costs are paid by society at large (through taxes, increased costs for goods, declines in health and quality of life, etc.) rather than by the automobile users who generate them they are referred to as external costs or externalities.

Litman (1998a) has identified a number of additional external costs generated by automobile use that are subsidized by society at large. These include:

- parking costs not borne by users (including construction, operation, maintenance, and land value);
- congestion delays vehicle use imposes on others (for example, on transit users, on society at large through delays to fire and ambulance services, or on consumers faced with increased costs of goods moved by roads);
- road construction and maintenance expenses not covered by user charges;
- roadway land value (opportunity cost of using lands for roads instead of other uses);
- municipal services (public services devoted to vehicle traffic);
- equity and option value (reduced travel choices, especially for disadvantaged people);
- resource consumption (external costs from consumption of petroleum and other resources);
- barrier effects (loss of access for pedestrians and cyclists);
- land-use impacts (economic, environmental and social costs resulting from sprawl); and
- waste disposal.

While it is often argued that automobile users pay these costs through taxes on fuel (see for instance Râtel 2000), there is ample evidence that this is not the case.<sup>3</sup> One study (KPMG et al 1993) estimated that 23 percent of the total cost of operating a motor vehicle in the Lower Mainland was subsidized by non-users.<sup>4</sup> Of this, 40 percent represented a financial subsidy – costs paid by taxpayers for road construction, maintenance, protection costs, and so on – and 60 percent represented an economic subsidy – externalities paid for by society at large through more expensive products (resulting from time delays in deliveries due to congestion, and subsidized parking costs), as well as through air pollution, noise, and uncompensated accident costs. The KPMG study argued that if fully internalized, the cost of the average 14 kilometre trip in the region would be increased by \$3.50 (2001 dollars). Other research puts the average subsidy (financial and economic) per car at \$2,600 per year (Tollefson 2000). To the extent that many of the costs of the environmental and social impacts described here are paid for by society at large and not by the automobile users who create them, they represent a market failure; automobile use is under priced, and so it is over consumed. Similarly, “businesses would willingly pay a price ... in order to avoid the externalized costs of too much traffic, but generally there is no way for them to do so. In that sense, the transportation market can truly be said to have failed” (Economist 1998).

### **Using TDM policies to correct market failure and meet air quality commitments**

There is a clear mandate for government intervention to correct the market failure resulting from the underpricing of automobile use; this intervention could be effectively undertaken through the application of transportation demand management (TDM) policies. TDM refers to policies that provide incentives or disincentives to influence the amount that people travel, the time they travel, the route they travel or the mode by which they travel. TDM policies can be implemented through regulation, application of economic instruments as financial incentives or disincentives, direct investment in infrastructure, and development of public education programs. The primary focus of the study described in this report is the potential for infrastructure investment and financial disincentives to influence commuter demand for travel by the SOV mode.

Infrastructure investment can be used to improve the availability and competitiveness of alternatives to the SOV. Examples of such investments include purchasing more buses to increase the frequency

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<sup>3</sup> It is fair to say, however, that the congestion costs that travelers incur directly by driving on crowded roads are fully internalized; they are “a price people pay for having a choice where to live and work” (Economist 1998).

<sup>4</sup> Litman (1998a) argues that 32 percent of private automobile operating costs are externalized.



of bus service and building high occupancy vehicle lanes. Investing in infrastructure to increase the time competitiveness of alternative travel modes provides an incentive to shift demand from SOV's to lower impact travel modes. This study focuses on investment in improved availability and reduced travel times for carpool and transit modes.

Financial disincentives could include annual vehicle levies or licensing fees, charges for road use, charges for parking, increased taxes for fuel, or distance-based insurance premiums. Introduction of any of these charges would help to bring the private costs of vehicle operation in line with the total costs which that operation imposes on society. However, pricing policies that increase the variable, per trip costs of vehicle operation are more effective at influencing consumer choice than policies which increase the fixed costs of vehicle operation. This is because the variable, per trip costs of driving are the ones most readily perceived by drivers, and the ones most likely to influence their travel decision making. Raising the per trip cost of vehicle operation would prompt some vehicle users to forego marginal trips or shift trips to less costly modes. This study focused on the potential of two such per trip pricing instruments, road and parking charges, to reduce use of single occupant vehicles for the trip to work.

In summary, the study described here estimates the potential for a TDM policy package represented by travel time improvements for transit and carpool alternatives and road and parking charges and travel time disimprovements for SOV's, to reduce commuter demand for travel by SOV.

### **Why road and parking pricing?**

Road and parking charges have consistently been identified as some of the most powerful transportation demand management levers available, and numerous provincial and regional transportation, land use, and air quality planning initiatives in the 1990's called for their introduction. These are summarized in the box on the following page.

**Government planning processes which have called for the introduction of road and parking pricing.<sup>5</sup>**

**TRANSPORT 2021 Long Range Transportation Plan for Greater Vancouver GVRD (1993a):**

“The Province should apply road pricing/tolls with the long-run purpose of shaping travel demand in addition to obtaining revenues. Governments should phase out subsidized parking for commuters...”

**British Columbia Greenhouse Gas Action Plan MoELP (1995a):**

“If the [provincial] transportation plan is to have a sizeable impact on emissions over the long term, the province must consider increased mass transit, bridge and highway tolls, and additional strong actions to cut vehicle use.”

**Transportation Plan City of Vancouver (1995):**

“The City will support ... the discouragement of car use by charging users a larger share of their costs through user fees such as bridge tolls, gas taxes, increased parking rates, or commuter levies.”

**Greater Vancouver Transportation Demand Management Project Final Report GVRD (1996):**

“Road pricing is probably the most powerful TDM support program that could be considered for the region.... Taken together, the effect of other TDM support programs recommended in this report ... would not be sufficient to achieve the target 10 percent reduction from “trend 2021” peak period demand levels if these elements are not also accompanied by the introduction of road or bridge tolls.”

**Strategic Transportation Plan: Discussion Paper TransLink (1999):**

“Without pricing of road use, transit expansion may be ineffective: A central assumption in the Livable Region Strategic Plan is that road use would be better priced with some form of tolling. Without this being in place, car drivers will not find transit attractive and, equally importantly, there will be less money for transit expansion.”

**Strategic Transportation Plan TransLink (2000b):**

“Action: Move toward road pricing, with tolls on new facilities to recover cost as permitted under the Greater Vancouver Transportation Authority Act, and a request to the Province for authority for system tolling to manage use.”

“Action: Implement a parking tax, established within an overall parking policy, as part of a transportation pricing program to limit the growth of single occupant vehicle travel and as part of the Financial Plan.”

Notably, the BC Greenhouse Gas Action Plan, the GVRD TDM Project Final Report, and the TransLink Strategic Plan Discussion Paper all conclude that without the introduction of road pricing,

<sup>5</sup> A panel convened by the Transportation Table of the National Climate Change Program also identified pricing mechanisms such as road and parking pricing as a first priority measure to reduce emissions in the region (Delcan et al 1999).

it is unlikely that the region will meet its long term emission reduction, SOV demand reduction, transportation revenue, or transit ridership goals. To date, however, no steps have been taken to introduce road pricing or expand the role of parking charges in the region, largely as a result of concern about public acceptance of such measures, but also because of the technical and administrative issues surrounding implementation of these charges. Implementation issues will be addressed further in Part four of the report.

The concept of charging for parking is straightforward and widely applied; however, charging for the use of roads has had more limited application and further discussion of the present study will benefit from a brief description of the concept here. Road use charges, or road tolls, are fees charged for the use of a road system. The concept was first proposed in 1920 by Arthur Pigou as a means of charging road users for their external congestion costs (Button et al 1998). Charging for road use is an appealing policy tool because it can be used to meet numerous goals, including shaping travel demand (i.e. shifting single occupant vehicle travel to carpools and transit, or shifting that demand from peak to off peak travel periods), reducing total travel demand, obtaining more efficient use of transportation infrastructure and reducing the need to build new road capacity, reducing congestion and increasing travel speeds, reducing air emissions (both through a reduction in total kilometres traveled, and through increased speed and efficiency of traffic flow as congestion decreases), generating revenue for transportation system improvements, and even encouraging demand for low or zero emission vehicles (if they are charged less or are allowed to use the system charge free). Road charges can be collected for use of individual facilities (bridges, tunnels, highways, or even lanes); for use of roads in delimited areas such as central business districts, through use of pricing cordons or toll rings; or, through the use of multiple cordons, for the use of roads throughout a metropolitan region.

This study focuses on the potential of all day, region wide pricing to reduce demand for SOV travel. Unlike peak-period pricing, which focuses solely on shifting demand out of peak travel periods in order to reduce congestion, all day pricing using multiple cordons can be used to achieve a wide range of policy goals, including demand, congestion and emissions reductions, and revenue generation for transportation system operation. Pricing cordons have been used in just a few centres to date, notably Trondheim and Oslo Norway, and Singapore (Economist 1998). London England

may adopt cordon pricing within the next few years.<sup>6</sup> Litman (2001) provides examples of road pricing for congestion reduction and revenue generation from throughout North America.

Whereas in the past road charges were collected at toll booths where cars were required to stop and deposit money, current technology allows charges to be collected as cars travel at highway speeds past overhead charging devices. Microwave communication between the overhead device and a windshield mounted transponder can be used to either deduct a charge directly from an onboard debit card, or else to identify the vehicle for billing to an account. Vehicles without transponders or without credit balances on their debit cards are recorded on video camera and billed at their licensed address. Such electronic systems are now used to charge for road use in 15 countries around the world, including Canada and the United States, although only a few cities such as Singapore use these charging systems as part of a demand reduction program (Economist 1997).

Using current technology, the amount of the charge levied on different vehicles could be varied according to the time of use, the type of facility, congestion levels, ambient air pollution levels, or vehicle emissions. However, whatever the basis for charging, drivers must be presented with pricing signals that are clear, consistent and predictable if charges are to be effective in meeting policy goals. Issues surrounding the implementation of road charges will be discussed further in Part four.

An additional benefit to the introduction of road pricing as a demand reduction tool is that it could be used to ensure a stable source of revenue for transportation system management, an issue of some urgency in the Lower Mainland of British Columbia. When the Greater Vancouver Transportation Authority (GVTA) was established in 1999 it proposed the introduction of an annual, weight-based vehicle levy in addition to transit fare increases to fund transportation system management. However, in the face of widespread opposition the provincial government of the day refused to assist with collection of the levy and that portion of the funding plan was dropped. Alternative sources of system

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<sup>6</sup> Peak period pricing – where road charges are set to a higher rate during peak periods when congestion regularly is greater – and dynamic congestion pricing – where prices vary in direct response to increases or decreases in congestion – have been adopted in several locations in the United States and Canada, most often on privately operated freeways such as Highway 407 in Toronto, I-15 in San Diego and SR-91 in Orange County (Economist 1998). In the case of peak period and congestion pricing, untolled alternative routes are usually provided nearby so that drivers can choose not to enter the tolled facility if prices rise beyond their preference level. Although congestion pricing may reduce demand, its primary goal is shaping demand and maintaining the free flow of traffic on high demand routes. However, much of the technology involved in collecting charges is directly applicable to the use of pricing cordons for demand reduction.

funding have since been obtained, but TransLink (as the authority is now called) has been forced to scale back its ambitious plans for improvement of alternatives to the private automobile.<sup>7</sup>

### **Outline of the stated preference study**

In this study, commuter responses to the introduction of road and parking charges and improved travel alternatives are measured using stated preference research methods. Unlike revealed preference research, which estimates preferences with direct observation of behaviour or through surveys which ask respondents to report on their behaviour, stated preference research presents respondents with hypothetical alternatives and measures their preferences through rating, ranking or choice making exercises. Stated preference methods are widely used in transportation and marketing research to measure consumer or commuter preferences for novel products or travel alternatives. The use of these methods to examine commuter responses to road and parking charges moves us from investigation of public opinion about these policies to the estimation of public response to them.

A stated preference exercise known as a discrete choice experiment was used to examine the mode choices of commuters when faced with road and parking charges for driving alone and improved travel times for alternative modes. This experiment was included in a travel behaviour and attitude survey which was mailed out to a sample of Lower Mainland residents who currently drive alone to work. The experiment asked respondents to choose between driving alone, carpooling, or using a hypothetical express bus service to travel to work in a series of questions which presented different levels of road and parking charges for driving alone and different travel times for all three choices. The questions assume that all day road pricing is introduced in the region and that all SOV commuters are charged for use of the road network. The questions also assume that these commuters are required to pay for parking at their workplace.

It is important to emphasize that the experiment did not examine how drivers would respond if road and parking charges were applied to SOV's with all else held equal, but how drivers would respond if those charges were applied and improved carpool and transit alternatives were made available. As such it does not measure the effect of the introduction of road and parking charges on the status quo,

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<sup>7</sup> The GVTA's enabling legislation allows the authority to introduce project cost recovery tolls but not general road charges. TransLink states that it is in discussion with the Province over revising the legislation to obtain the authority to introduce such charges. In addition, the legislation currently allows TransLink to introduce regional taxes on non-residential parking spaces, but there are numerous inter-governmental, legal and contractual obstacles to imposing such charges in an effective manner (Raad 2002). Nonetheless, TransLink's strategic plan proposes implementation of a tax on non-residential parking spaces by 2005 (TransLink 2000b).

but rather on a hypothetical situation where more competitive alternatives to driving alone are in place. The policy assumptions underlying this aspect of the research will be discussed in more detail in Part 2 below.

## **2. Survey Methodology**

### **Overview**

Data collection for the discrete choice experiment required a multi-stage survey process. First, a random sample of residential telephone listings was drawn for a Lower Mainland community. Next, 650 residents were selected through telephone interviews for participation in the study. Information collected from these telephone interviews was then used to create an individual version of the discrete choice experiment for each respondent that was customized to their particular commuting situation. These individual versions of the experiment were then bundled with a generic travel behaviour and attitude survey and mailed to respondents for completion and return. Follow up mailings were used to encourage respondents to complete and return their surveys.

### **Sampling criteria and sample selection**

The effort involved in customizing the experiment to reflect each respondent's commuting situation required that the respondents be selected from just one or two communities. The communities selected for sampling were chosen according to the following criteria:

- a large proportion of the commuting population should fit the travel patterns required for the study (driving alone to work at least three days per week for at least 20 minutes one way) in order to reduce the costs of respondent selection in the telephone presurvey;
- the major commuter routes out of the community should include "bottlenecks" where the application of road charges to capture the majority of travelers would be realistic; and
- the community chosen should not already offer express transit service, in order to avoid ambiguity over whether existing services were available to some survey respondents and not others.

Given these criteria, the South Delta communities of Ladner and Tsawwassen were obvious choices. Both have a relatively high proportion of commuters travelling by SOV (75 percent compared to the Greater Vancouver Regional District (GVRD) average of 62 percent – TransLink (2000c)), major employment centers (in Richmond, North Delta and beyond) are at least 20 minutes drive away, most long distance commuters travel by highway and over bridges or through tunnels, and existing transit

service includes limited express bus service only into downtown Vancouver. In addition, the population of these communities are almost 100 percent English speaking, eliminating the cost and complexity of survey translation.

A random sample of 12,000 residential telephone listings was drawn from the listed residential phone numbers in the Ladner and Tsawwassen area. Before sampling, postal codes were used to screen out rural listings in order to exclude a small number of rural residents who would not have easy access to the hypothetical express bus service described in the discrete choice experiment. Repeat listings for the same name and address and listings designated as children's or teenager's telephones were also removed from the list before sampling.

The sample universe did not contain unlisted telephone numbers. This introduced a potential bias into the sample, because not all households in Ladner and Tsawwassen had an equal chance of being included. The list service which provided the sample estimates that 9 percent of telephone numbers in the GVRD are unlisted. This study assumes that households with unlisted numbers do not differ significantly in travel characteristics and preferences from those with listed numbers.

### **Telephone presurvey**

In the period between April 9 and April 17, 2001 MarkTrend Research contacted households from the randomized list in order to select 600 respondents whose travel patterns qualified them for participation in the study. Participation required individuals to drive alone to work at least three times per week with a travel time of at least 20 minutes one way. On May 17, 2001 MarkTrend contacted additional households in those communities to select another 50 respondents who qualified for the survey. MarkTrend's incidence report for the telephone presurvey is described in Table 1 below.

**Table 1. Telephone presurvey incidence report.**

Total residential listings contacted	6404	
Invalid listings	-328	
Valid residential listings contacted	6076	100.0%
Completed interviews	650	10.7%
Busy/no answer	693	11.4%
Refused	1226	20.2%
Communication problem	111	1.8%
Did not meet study criteria	3235	53.2%
Requested callback	161	2.6%

The refusal rate of 20 percent is low for a "cold call" telephone survey. MarkTrend reports an average 30 percent refusal rate for telephone marketing surveys and an average 50 percent refusal rate for surveys such as this one where the respondent is asked to fill out a follow up mailed out survey. As a comparison with other telephone research surveys, the 1992 GVRD travel survey reported a 22 percent refusal rate (GVRD 1994b), and the 1997 BC Transit Usage and Attitude Survey (in the GVRD) reported a refusal rate of 30 percent (Campbell Goodnell Traynor 1997). The low refusal rate in the present survey indicates a high level of interest in the topic among area residents. This conclusion is reinforced by the large number of opinions and comments received from respondents in open ended opinion questions in the survey.

The telephone presurvey described the study, asked if residents were willing to participate in the research, confirmed that they met the study criteria, and collected additional information to be used in the customization of their discrete choice experiment. Information collected included home address, travel time between home and work, work destination, and parking costs at work. Potential respondents were informed that by completing and returning their survey within two weeks, they would be included in a draw for a \$100.00 gift certificate at a local restaurant. A copy of the telephone interview script is included in the appendices. Sampling methods were adapted from earlier travel studies conducted in the region (GVRD 1994b, 1995a; Campbell Goodnell Traynor 1997). All individuals who agreed to participate in the study were sent a survey containing a customized version of the discrete choice experiment within a week of the telephone contact.

### **Selecting a research instrument to measure choice making**

Generally speaking, most research into how people make choices starts with the assumption that individuals understand and evaluate their available choices by assessing the features, or attributes, of those choices (see Driver et al 1990 for an overview of the literature on this topic). For example, when choosing which car to purchase, shoppers may assess the cars available to them in terms of attributes such as cost, safety features, styling and power. Although separate attributes may contribute different weights to the evaluation of a choice (i.e., the presence or absence of side-impact bars may be less important than the availability of a four or six cylinder engine), it is also assumed that individuals generally add up the strengths and weaknesses represented by the attributes of a choice, and choose the option that provides them with the best overall value. The method used to analyze choices depends in part on whether researchers are studying revealed choice behaviour, or if they are asking respondents to state their preferences in response to hypothetical choices.



Revealed preference methods such as hedonic pricing and travel cost analysis attempt to predict choice preferences by studying observed choice behaviour and using regression analysis to estimate the influence of individual attributes on preferences. Revealed preference research has the advantage of measuring actual choice behavior; however, obtaining a sufficient number of high quality observations of choice behaviour for reliable analysis can be difficult. In addition, the actual effect of each attribute on choices can be hard to determine for a number of reasons: attributes of interest may not vary sufficiently over a sample to determine their effect on choice; attributes may vary together, making the effect of each difficult to determine; and other unmeasured factors may also influence choice behaviour and thus confound study results (Permain et al 1991). Furthermore, revealed methods cannot be used to measure preferences between choices which are not yet available, or between choices which are so new that reliable data is not available for preference estimation.

Stated preference methods, in contrast, use surveys and interviews which present respondents with hypothetical choices and ask them to state their preferences between these choices. Hypothetical choices constructed by researchers could mimic choices currently available to respondents in the real world, they could represent choices that are available but outside of the experience of respondents, they could represent as yet unavailable or undeveloped choices, or they could include some combination of all three. The choices are described in terms of attributes which the researcher knows or hypothesizes to be important to the choice process. The method used to estimate the importance of individual attributes to choice making depends on the design of the research instrument.

Stated preference methods allow researchers to overcome many of the problems associated with revealed preference methods. Researchers select choice attributes and determine their variation, which minimizes covariance and controls for the effect of outside variables. Respondents to stated preference surveys or interviews are presented with a number of choice scenarios with significantly different levels of choice attributes, which allows for a high quality set of observations to be collected from a relatively small sample of respondents. And of course, only stated preference methods can be used to estimate preferences for novel or untried choices. The disadvantage of stated preference methods is that statements of preference or intention do not always correspond to what individuals do in the real world. This problem can be minimized somewhat by ensuring choice scenarios are as realistic as possible for individual respondents, and by reducing incentive for biased choice behaviour in the survey setting (Permain et al 1991).

Stated preference methods include contingent valuation (which asks respondents their willingness to pay for changes in individual choice attributes), conjoint analysis (which asks respondents to rank two or more choices in order of preference), and discrete choice experiments (which ask respondents to choose between two or more choices). Both conjoint analysis and discrete choice experiments ask respondents to make trade offs between choice attributes. However, discrete choice experiments are widely thought to better reflect real world decision making, because individuals are more often forced to make choices than to rank their available choices. Discrete choice experiments are widely used in transportation research to measure traveler preferences for new or hypothetical travel alternatives.<sup>8</sup> In the case of the present study, a discrete choice experiment was used to measure respondent preferences among three travel modes (driving alone, carpooling and taking a hypothetical express bus service) when faced with increased costs for driving alone and when time attributes of all three mode choices were presented at levels above and below respondents' reported drive alone times.

### **Designing the discrete choice experiment**

Stated preference methods present respondents with sets of hypothetical choices described by attributes which are known (or hypothesized) to be important to the choice process. The values of the choice attributes are varied in each choice set according to a statistical design which ensures that each attribute varies independently of the others. For this study, consultation with a statistician led to the development of a design which allowed three attributes to be presented for each of the three mode choices in the experiment, with each attribute varying between four levels from question to question.<sup>9</sup> Respondents marked their choices on a mail back survey and the effects of changes in attribute levels on respondent choice preferences were analyzed using conditional logit regression.

In addition to travel time for the three mode choices and the drive alone road and parking charges, several other mode attributes were selected for inclusion in the discrete choice experiment. These are shown in Table 2 on the following page. While many attributes influence mode choice, only those

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<sup>8</sup> Examples include Hunt et al (1997) and Beaton et al (1992) on mode choice, Bunch et al (1993) and Ewing and Sarigollu (1998) on fuel choice, and Polak et al (1991) on responses to toll routes. Interactive and customized discrete choice models have been employed in numerous transportation studies (see for example Ewing and Sarigollu (1998), Ewing (1996) and Turrentine and Kurani (1998)).

<sup>9</sup> The design required 32 choice sets for estimation of all attribute main effects. To avoid respondent fatigue, each respondent was presented with only eight of the choice sets. Each block of eight choice sets had a balanced combination of attributes and levels. Measurement of the effect of attributes across the whole range of their values was calculated from the aggregated responses of individual respondents. Readable introductions to the design and estimation of discrete choice experiments can be found in Ewing (1996) and Permain et al (1991). A more detailed discussion of design is found in Louviere et al (2000).

that can be framed as numerical values or as discrete levels of qualitative attributes could be included in the design. The additional attributes included were consistently mentioned as key factors in mode choice decision making in the travel research literature (see Hunt et al 1997 for a good review). The levels chosen for each attribute are discussed in detail in the next section.

**Table 2. Discrete choice experiment mode choice attributes.**

Driving alone:	Carpooling:	Taking express bus:
1. In-vehicle travel time	1. In-vehicle travel time	1. In-express bus travel time
2. Road charge	2. Time spent picking up other carpoolers	2. Total time waiting for all buses
3. Parking cost	3. Parking cost	3. Travel time from express bus stop to work

Areas of the discrete choice experiment that were customized to respondents' individual commuting situations are listed below.

1. The in-vehicle travel time attributes for the three mode choices were presented as a percentage of respondents' reported in-vehicle time.
2. The "total time waiting for buses" attribute was set to a lower range if respondents were estimated to walk from home to the transit exchange, and to a higher range if they were estimated to take a local bus to the exchange.
3. Respondents' approximate travel time from home to the community transit exchange was included as a fixed value in the description of each express bus option, as they would have to reach this exchange to board an express bus. Depending on the distance, this travel time was presented as either a walk from home to the exchange or a walk from home to the nearest local bus route and then a local bus ride to the exchange. Estimates were calculated on an enlarged street map of the two communities using respondents' street addresses and the existing location of the Ladner and Tsawwassen transit exchanges, as well as route and schedule information for local bus services.
4. The bus fare between respondents' homes and work locations was also presented as a fixed value in each of the express bus choice descriptions. This was presented as a return trip fare based on the existing cost (in April, 2001) of a discounted monthly pass for the appropriate distance, divided by 21 working days per month.

### Selecting attribute levels

*In-vehicle travel time for the drive alone, carpool and express bus choices:*

The levels for this attribute were customized for each respondent based on the average drive alone travel time they reported on the telephone. Travel times for the three available modes were presented as a range around respondents' reported times, with the range for the HOV and express bus choices set slightly lower than the SOV choice. Selecting commuters for the study who had a minimum 20 minute travel time to work meant that a 15 percent increase or decrease away from their revealed time would still be a relatively significant change. The levels for this attribute were set as shown in Figure 1.

**Figure 1. Discrete choice experiment variation of in-vehicle travel times around respondents' reported drive alone travel times.**

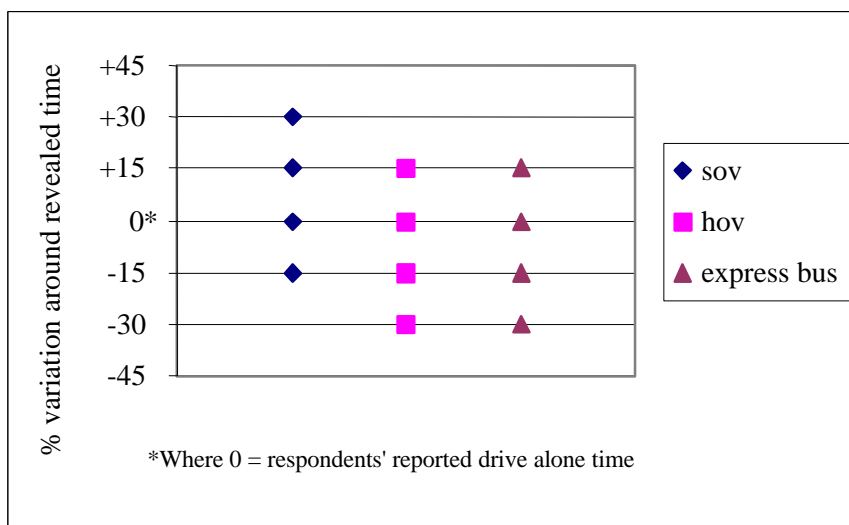


Table 3 below shows the actual time levels used, with rounding, for a respondent reporting a drive alone travel time of 35 minutes (the survey median value).

**Table 3. "In-vehicle time" attribute levels for a revealed time of 35 minutes.**

Attribute level	Driving alone:	Carpooling:	Taking express bus:
1	30 minutes	25 minutes	25 minutes
2	<b>35 minutes</b>	30 minutes	30 minutes
3	40 minutes	<b>35 minutes</b>	<b>35 minutes</b>
4	45 minutes	40 minutes	40 minutes

Note that while the overall variation in travel time is set to a lower range for both the carpool and express bus choices than for the drive alone choice, in any one question the drive alone in-vehicle time attribute may be set at a lower level than the other two – for example, as shown in Table 3

above, when drive alone time is set to level one (30 minutes) and carpool and express bus times are set to level four (40 minutes). In other words, the discrete choice experiment was able to measure respondents' choices when alternatives to driving alone were presented at both a competitive advantage and disadvantage.

**Policy assumption used in study:**

This study assumes that road and parking charges would not be introduced as transportation demand management policies without the corresponding introduction of improvements to alternative travel modes. One way this assumption is entered into the study is by presenting carpool and express bus in-vehicle travel time variations over a lower range than drive alone travel time variations as describe above. The carpool and express bus travel time improvements assumed in these lower ranges could be reflective of the introduction of bus or carpool only lanes, queue jumpers, or intersection priority measures for limited stop express buses. The increased travel time for driving alone could be reflective of increased congestion for that mode brought about by a reduction in system capacity as improvements are made for other modes, or by holding SOV capacity constant as traffic volumes increase. Other ways this policy assumption of improvements to alternative commuting modes enters the study are described below in the subsections entitled "Parking Charges" and "Presentation of the Choice Questions."

*Drive alone road charge:*

The levels for this attribute were initially set at inflation-adjusted values corresponding to charges used in research done with a traffic flow model by the GVRD (GVRD 1993b) which estimated the potential influence of bridge tolls on travel demand.<sup>10</sup> Pretesting these levels in the discrete choice experiment showed low levels of mode switching behaviour on the part of respondents, so the levels were revised up to daily round trip charges as shown in Table 4 below. The uneven spacing of the levels was selected on the advice of a TransLink researcher who suggested that the mode switching threshold for regional residents was likely to be at the low end of the \$0-\$9.00 pricing range.

**Table 4. Levels for the drive alone attribute "Road charge."**

Attribute level	
1	\$0
2	\$1
3	\$4
4	\$9

The instructions to the experiment stated that charges had to be paid in each direction, but in the choice questions the charges were presented as a total return trip cost in order to make them comparable with other costs presented in the experiment. Respondents were also told to assume that

<sup>10</sup> Bridge tolls in the 1993 study ranged from \$2.00 to \$4.00, charged one way in the a.m. rush hour only.

they would have to pay the charge and that there were no uncharged alternative routes available, implying a region wide, all-day road pricing strategy. The study assumes that a comprehensive strategy is in place for the implementation of such charges, and that all commuter traffic can be presented with charges. Issues surrounding implementation of such a strategy are discussed in more detail in Part four.

The instructions did not give a reason for the presentation of road charges in the experiment, or explain that the underlying focus of this study was on the use of road charges as a demand reduction and air quality management tool. This was intentional and aimed at reducing the potential for respondents to bias their answers in the experiment (for example, choosing carpooling or express bus because they perceive the study to be "anti-car," and they want to give the "right" answer, or vice versa).

*Parking charges for driving alone and carpooling:*

**Table 5. Levels for the drive alone and carpool attribute "Parking cost."**

Attribute level	Drive alone	Carpool
1	\$1	\$0
2	\$3	\$1
3	\$6	\$2
4	\$9	\$3

The drive alone parking charge range corresponds, at its highest level, to the daily portion of average monthly parking rates (in April 2001) set by a major parking corporation in the downtown core of Vancouver. The lower price range for carpool parking charges was selected in keeping with the policy assumption that there would be incentives for use of alternatives to the SOV if road charges were introduced on single occupant vehicles. In addition, in the study respondents were asked to assume that the parking charge presented for carpooling was shared among all carpool members. As with the road charge attribute, the study assumes that a comprehensive strategy is in place to ensure that all commuters are presented with parking charges. This is discussed further in Part four.

*Time spent picking up other carpool members at their homes:*

Respondents were asked to assume that they were picked up at their door and then spent some time traveling around to pick up other carpoolers before carrying on to work. The inclusion of door to door pick ups as a feature of the carpool option was based on the response of regional residents to

survey questions which asked them which carpooling features would most likely attract them to that mode (TransLink 2000c). Levels for this attribute are shown in Table 6 on the next page.

**Table 6. Levels for the carpool attribute "Time for pick ups."**

Attribute level	
1	3 minutes
2	6 minutes
3	9 minutes
4	12 minutes

*Time from an express bus stop to work:*

Since it is unlikely that all respondents would have express bus service available directly from their community transit exchange to their workplace, travel time between an express bus stop and work was included as a decision making attribute in the experiment. This attribute was arbitrarily defined at four discrete levels as shown in Table 7 below.

**Table 7. Levels for the express bus attribute "Time from express bus to work."**

Attribute level	
1	3 minute walk
2	6 minute walk
3	5 minute local bus ride and 3 minute walk
4	10 minute local bus ride and 3 minute walk

*Total time spent waiting for buses:*

In order to ensure that this attribute was realistic for respondents it was customized according to whether they live within ten minutes walking distance of their community transit exchange, or whether they are assumed to require a local bus trip to reach the exchange. Respondents who live within a ten minute walk of their exchange would have to wait for at most two buses in any given choice scenario (for example, a choice might include their fixed walk to the express bus, the express bus ride relatively near to their work, and then a local bus ride from the express bus stop to their work). However, respondents who live further than a ten minute walk to the exchange could be presented with three bus wait time periods in a scenario (associated with their fixed local bus ride to the exchange, the express bus trip near to work, and a local bus trip from an express stop to their workplace). Attribute levels for the "walk to exchange" and "walk and bus to exchange" respondents were set as shown in Table 8 on the next page.

**Table 8. Levels for the express bus attribute "Total time waiting for buses".**

Attribute level	"walk to exchange"	"walk and bus to exchange"
1	3 minutes	5 minutes
2	6 minutes	10 minutes
3	9 minutes	15 minutes
4	12 minutes	20 minutes

**Presentation of the questions in the discrete choice experiment**

A sum of the times presented for each of the three mode choices and a sum of the costs presented for the drive alone and carpool choices were included at the bottom of the mode choice descriptions in each of the questions. For the express bus choice, each respondent's fixed daily return fare cost was presented at the bottom of that mode choice description. A fixed estimate of each respondent's travel time from home to the express bus exchange was also included at the start of the express bus choice description in each question. As an example, one of the choice questions created for a respondent who reported a drive alone commute time of 30 minutes is shown in Figure 2 below. A full set of eight choice questions is included in the sample survey included in the appendices.

**Figure 2. A choice question from the discrete choice experiment.**

<b>CHOICE QUESTION 1</b>		
<p><b>Choice ①: DRIVE ALONE</b></p> <p><b>Travel time in vehicle:</b> 26 minutes</p> <p><b>Road charge:</b> \$1 return</p> <p><b>Parking cost:</b> \$3 day</p> <p><b>TOTAL TIME:</b> 26 minutes <b>COSTS:</b> \$4</p>	<p><b>Choice ②: CARPOOL</b></p> <p><b>Time for pick-ups:</b> 9 minutes</p> <p><b>Travel time to work:</b> 21 minutes</p> <p><b>Parking cost:</b> \$3 day shared by carpoolers</p> <p><b>TOTAL TIME:</b> 30 minutes <b>COSTS:</b> \$3 shared</p>	<p><b>Choice ③: EXPRESS BUS</b></p> <p><b>Time from home to exchange:</b> 1 min. walk + 4 min. local bus ride</p> <p><b>Travel time on express bus:</b> 34 minutes</p> <p><b>Time from express bus to work:</b> 6 minute walk</p> <p><b>Total time waiting for buses:</b> 15 minutes</p> <p><b>TOTAL TIME:</b> 60 minutes <b>COSTS:</b> \$4.00</p>
<p><b>If these were the only 3 commuting choices available to you, would you:</b></p> <p style="display: flex; justify-content: space-around;"> <span>DRIVE ALONE</span> <span>CARPOOL</span> <span>TAKE EXPRESS BUS</span> </p>		



Only those costs that were unique to the experiment were included in the choice questions. Some might argue that this biases the study against transit, because the questions do not explicitly acknowledge the other costs associated with owning and operating a private vehicle, such as fuel and insurance. However, as shown in Figure 3 below, the instructions asked respondents to keep in mind fuel costs for the drive alone and carpool choices, and since respondents may have chosen to take the bus but also to continue to own a vehicle, it was not appropriate to suggest that other ownership costs were not comparable between the choices (with the possible exception of insurance premiums for to-work travel). Furthermore, since different respondents consider different costs when choosing their commuting mode, inserting additional fixed or variable costs into the choice scenarios would have added complexity and bias to the choice process without adequate justification.

The choice questions in the discrete choice experiment were preceded by a description of the choices and a set of instructions, reproduced in Figure 3 on the following page. The descriptions explained the attributes presented for each alternative, the road pricing scenario, and improvements to carpooling and the hypothetical express bus service that respondents were to assume were in place.

**Figure 3. Mode choice descriptions from the discrete choice experiment.**

### **CHOICE ①: DRIVING ALONE**

*Some changes from your current situation that you should assume if you choose driving alone:*

- Your travel time may be higher or lower due to changes in congestion and available lanes;
- You may have to pay a road use charge ;
- You have to pay for parking;
- You pay your normal amount for fuel;
- Your time spent looking for parking and walking from parking to work remain the same.

**Some details about the road charge:** Assume the charge applies all day to all passenger vehicles driven alone in the Lower Mainland. You are charged both ways. The charge is deducted automatically from a card on your windshield as you drive by a scanner at normal speed. You can add money to your card at machines in places like corner stores and gas stations.

### **CHOICE ②: CARPOOLING WITH AT LEAST ONE OTHER PERSON**

*Some changes to travel times and costs you should assume if you choose carpooling:*

- You can use a network of HOV/bus lanes and bypass line ups at some on ramps to save time;
- You spend some additional time picking up and dropping off other carpool members;
- You may pay for parking, but you share that cost and fuel costs with the other carpoolers;
- Your time spent looking for parking and walking from parking to work remain the same.

*Some other features of carpooling you should be familiar with:*

- You may only have to drive your vehicle 1 or 2 days a week;
- On days you don't drive, you are picked up and dropped off door to door;
- You can call a service to help you set up a carpool or find one already running in your area.

### **CHOICE ③: USING EXPRESS BUS SERVICE**

*Some services and costs you should assume are available to you if you take the express bus:*

- Express buses use HOV/bus lanes, bypass on ramp line ups, make few stops, and extend green lights to save you time;
- You spend some additional time travelling from home to the Ladner express bus exchange, travelling from an express bus stop to work, and waiting for buses;
- You pay a return fare of \$4 between your home and work;
- Express buses run every 10 minutes from 6 a.m. to 7 p.m. and less often at other times;
- Local buses run every 15 minutes

Improvements to carpooling included priority lanes on major roads and bridge access ramps and a ride matching service. Improvements to bus service included priority lanes on major roads and on ramps and priority control of traffic signals at intersections. Improvements were limited to time and service changes that could be provided by government. In order to keep the carpooling choice comparable for all respondents, its description did not include any services which would have to be

provided by an individual employer, such as a guaranteed ride home program or reserved parking. The express bus service was based both on recently introduced "B-Line" express bus services in the GVRD, and on responses to survey questions asking commuters to rate transit service features on the likelihood that they would encourage them to switch modes (TransLink 2000c).

Finally, the instructions preceding the experiment asked respondents to keep their personal travel constraints in mind, to answer for the most flexible travel day in their regular schedule, and, if they worked shifts, to answer only for their daytime commute. The full instructions for the experiment are found in the introduction to Part three of the sample survey, which is included in the appendix.

### **Pretesting the discrete choice experiment**

The experiment was pretested on a non-random sample of 30 individuals for clarity, realism, completion time and mode switching in response to attribute levels. A late draft of the experiment was also reviewed with staff from TransLink, and two regional transportation advocacy groups (Better Environmentally Sound Transportation – BEST, and the Society Promoting Environmental Conservation – SPEC). In the actual study, the small number of returned surveys that had incomplete or incorrectly completed discrete choice experiments (15 out of 584) indicates that the experiment, though complex, was understandable.

### **Survey design, question selection and pretesting**

Questions were included in the survey for two reasons. The first was to collect information that would provide context for the choices made in the discrete choice experiment. A review of the travel research literature identified several topic areas important to this context, including respondent travel patterns; travel, household and work constraints; experience with carpooling and taking transit; attitudes towards carpooling and transit; general attitudes towards the environment; and respondent demographics. The second reason for including questions was to collect information that would enable validation of the survey sample against the community population from which the sample was drawn. Several simple questions from the 1996 Canada census were included in the survey to allow that validation. Many other potentially useful questions had to be discarded to keep the survey to a reasonable length so that respondents were not discouraged from its completion.

The survey was pretested on a non-random sample of 11 people of various socioeconomic, language and educational backgrounds. These pretests provided insights into the clarity of directions and

questions, gave a sense of the type of answers being given for each question, and identified any problems with coding the answers into a database. As with the discrete choice experiment, the survey was also reviewed with staff of TransLink, BEST and SPEC. The final version of the survey, including the discrete choice experiment, required approximately 30 minutes to complete. Survey question wording, order and directions, formatting, and mail out procedures followed *Mail and Internet Surveys: The Tailored Design Method* (Dilman 1999). A copy of the final version of the survey is included in the appendices.

### **Survey mail out procedures**

1. The initial mail out package included the survey and discrete choice experiment, a cover letter explaining the study in more detail, and a stamped, addressed return envelope. Both the letter and survey back cover noted a contact telephone number and email address where the researcher could be contacted with questions or concerns. A dollar coin was attached to the cover letter as a token of appreciation for each respondent's time and effort. A copy of the initial cover letter is included in the appendices.
2. One week after the survey was mailed out, a brightly colored follow up postcard was sent to all participants. This postcard thanked them for their participation if they had already returned the survey and asked them to complete and send in the survey if they had not, with a reminder that there was still a chance to be included in the draw for the restaurant gift certificate. A copy of the postcard text is included in the appendices.
3. Two weeks after the initial mail out, all participants who had not yet returned their survey were sent a second survey with a new cover letter by regular mail urging them to fill out and return the survey. A copy of this second cover letter is included in the appendices.
4. One month after the initial mail out, all participants who had not yet replied were sent a final copy of the survey and a new cover letter by express post. This final appeal explained that the study was drawing to a close, that most participants had responded, and that obtaining the opinions and advice of those who had not yet returned their surveys was important if the study was to produce representative results. A copy of this final letter is included in the appendices.

### **Mail survey response rate, sample error, bias and validity**

In total, 584 of the 650 surveys were returned for an overall response rate of 89 percent. The quality of these responses breaks down as shown in Table 9 on the next page.

**Table 9. Breakdown of mail survey return rate.**

Total surveys sent out	650	100%
Total returned surveys	584	89%
Blank surveys returned	5	
Problem with discrete choice experiment	15	
Respondent did not meet travel criteria	16	
Valid returned surveys	548	84%

After removing incomplete or incorrectly completed surveys, 548 valid returned surveys remained for a qualified response rate of 84 percent. Four percent of returned surveys were received after the second appeal was sent out and 4 percent more were received after the third and final appeal.

Assuming no bias in the sampling procedure, the final sample size of 548 indicates that proportions or means estimated from statistics collected through the survey are accurate to within 5 percent of study population values, with a 95 percent probability. Keep in mind that the study population is formed only of individuals who currently drive alone to work at least 20 minutes one way a minimum of three days per week, and is not equivalent to the general population of Ladner and Tsawwassen.

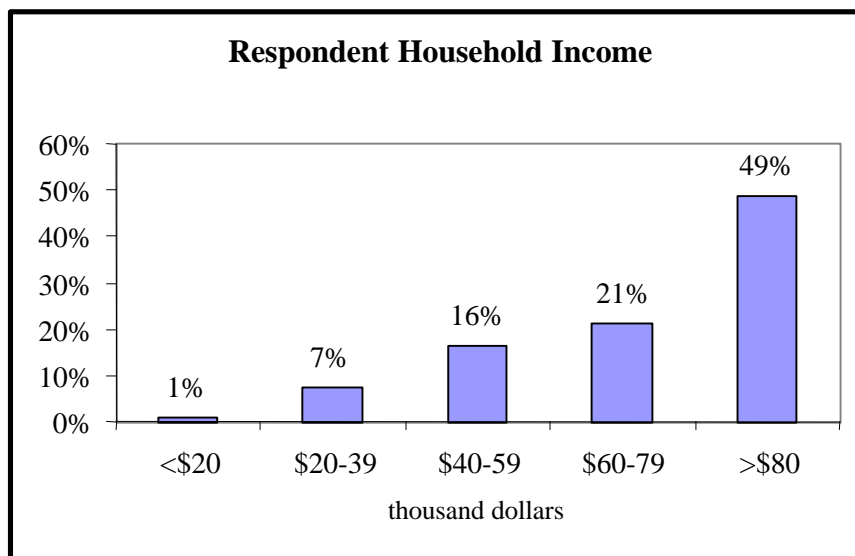
Several steps in the sampling procedure had the potential to introduce non-random bias into the sample. The list of residential telephone numbers from which the random sample was drawn for the telephone presurvey did not include unlisted numbers, nor numbers of households that had moved into the area within the previous 30 days. This study assumes that there is no relevant difference in commuter travel behaviour between residents with listed or unlisted numbers. New residents might be less familiar with transit services in their area, and also less able to find ride matches for carpooling. However, their familiarity would increase over time to match that of long term residents.

The survey company made its calls between 3:30 and 9:30 p.m., which had the potential to reduce the sample proportion of respondents who work shifts or evenings below the study population proportion. However, it still allowed the sample to include commuters travelling in both peak periods.

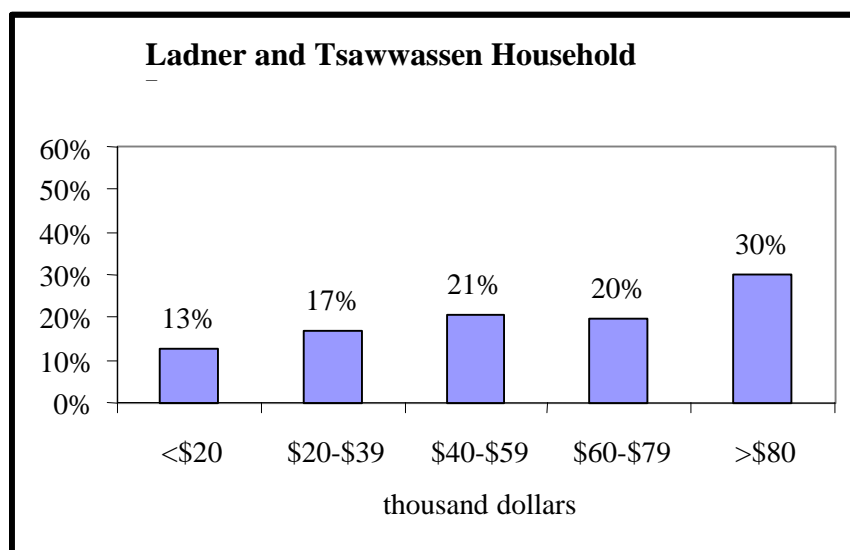
This study assumes that other possible sources of selection bias in the telephone presurvey (such as call screening or the absence from the sample of individuals who only have cell phones) would not result in the selection of respondents with travel behaviour that was significantly different from the

study population. A qualitative comparison of the sample with Census Canada data for the combined Ladner and Tsawwassen populations is discussed in Figures 4 – 6 and Tables 10 – 12 below.<sup>11</sup>

**Figure 4. Respondents' income against Ladner/Tsawwassen Income.**



No answer = 6%



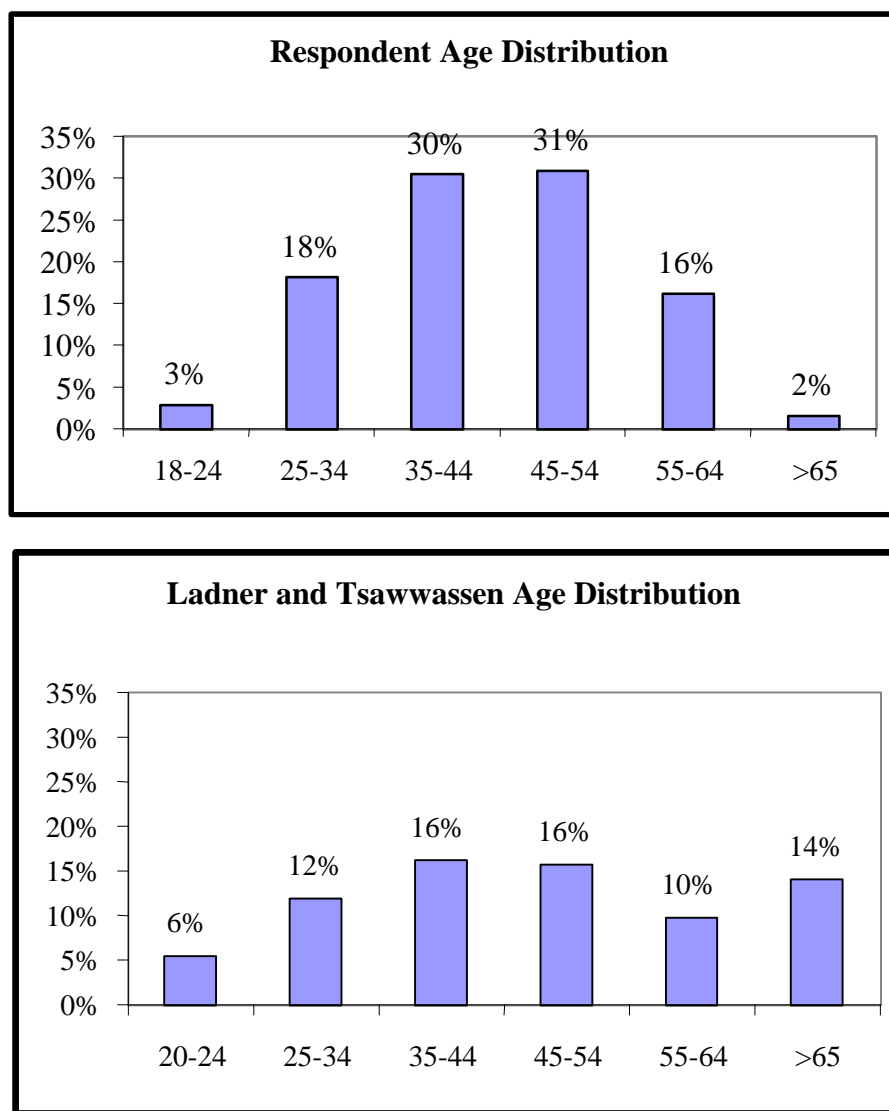
Census Canada data 1996

The study sample shows an income distribution skewed to higher incomes. This difference is likely due to the fact that the study selected for employed individuals travelling to work at least three days per week, which removed all unemployed and some part time employed residents from the sample.

<sup>11</sup> Tests of significance are not relevant for the comparisons of the sample to the Ladner and Tsawwassen populations as the study population of drive alone commuters differs from the general census population.

An additional part of the skew in distribution can be explained by income/education effects on survey response rates and biased self reporting. (Follow up appeals to respondents to complete and return their surveys generated the most increase in response in the \$20-39,000 and >\$80,000 categories.)

**Figure 5. Respondents' age distribution against Ladner/Tsawwassen age distribution.**



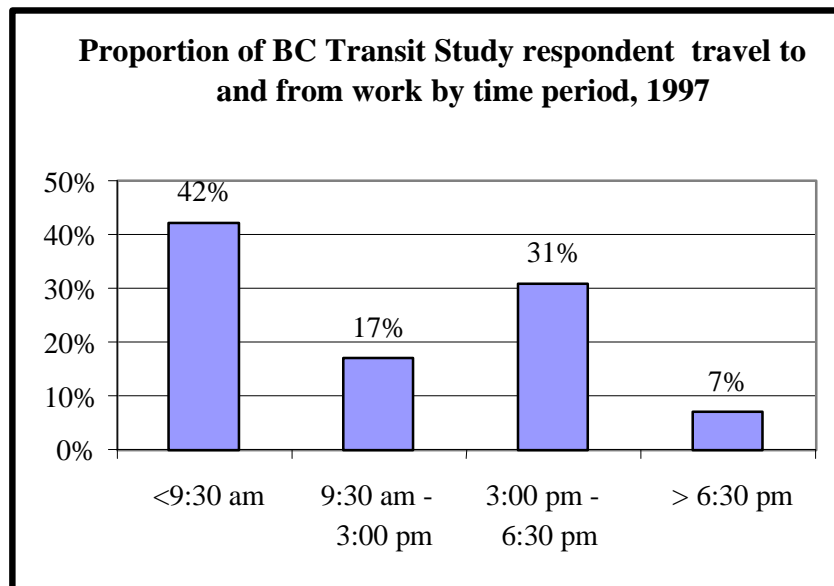
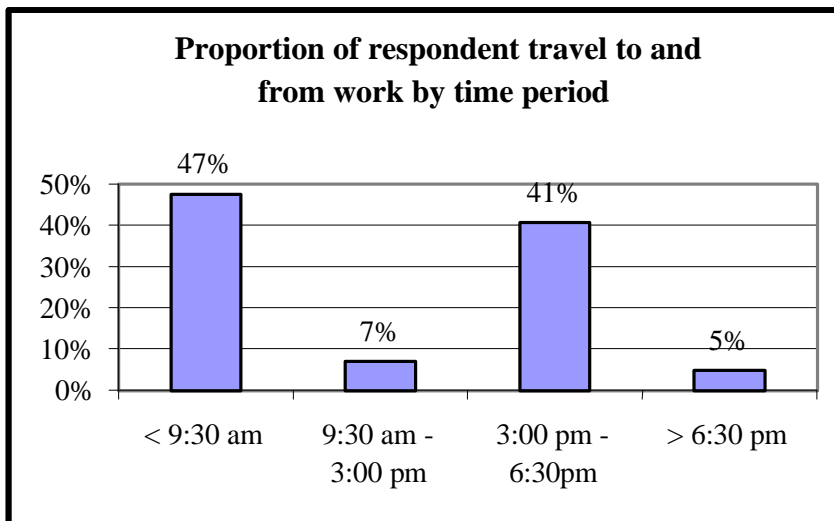
Census Canada data 1996

Note that the survey distribution adds up to 100 percent, whereas the Ladner/Tsawwassen distribution does not; in the latter case, individuals under 20 have been left off the chart. Note also that the first age category differs slightly between the study and the Ladner/Tsawwassen census data.<sup>12</sup>

<sup>12</sup> Census Canada data reports individuals between ages 15-19 as one group, whereas the present study only included individuals 18 and over, due to SFU research ethics requirements.

Nonetheless, there is clear under-representation in the first age category in the study sample as compared to the general Ladner and Tsawwassen populations. This probably reflects selection against these individuals due to lower labour force participation rates because of post secondary enrollment and higher unemployment rates for those in the labour force. Under-representation in the 65 plus age category reflects lower labour force participation rates due to retirement.

**Figure 6. Respondents' travel to and from work by time period (drive alone only), against BC Transit Study travel to and from work by time period (all modes).**





The BC Transit 1997 Usage and Attitude Study (Campbell Goodnell Traynor 1997) asked a random sample of GVRD residents about their work trip travel times using all modes, whereas the present study only asked about travel times by the drive alone mode. The B.C Transit study also distinguished weekend trips as a separate category (total response 3 percent), which the present study did not, so the figures are not entirely equivalent. Nonetheless, comparing the two figures reinforces the argument that the study sample is somewhat biased against evening and shift workers, in favour of workers who commute during the daily rush hour periods.

**Table 10. Respondent sex distribution against Ladner/Tsawwassen distribution.**

Study population:	Ladner/Tsawwassen population:
58% male	47% male
42% female	53% female
	(Census Canada data, 1996)

A number of factors may explain the difference between the study sample and Ladner/Tsawwassen population sex distributions. Females in the two communities display a lower labour force participation rate, a higher unemployment rate, a higher work at home rate, and a higher use of public transportation as their usual mode of commuting than males (Corporation of Delta 1999). All of these factors would lead to males being selected for the study more frequently than females. In addition, there may have been a greater tendency for male household members to answer the phone during the initial telephone contact, which would bias the study sample ratio of male to female commuters in comparison to the general population.

**Table 11. Respondent home ownership rates against Ladner/Tsawwassen rates.**

Study population:	Ladner/Tsawwassen population:
83% owned	78% owned
16% rented	22% rented
1% no answer	
	(Census Canada data, 1996)

The slight bias upward in the study sample on this statistic may be correlated with the skew in income distribution noted earlier for the sample.

**Table 12. Respondent type of workplace against Ladner/Tsawwassen type of workplace.**

Study population	Ladner/Tsawwassen population
85% one workplace	90% single workplace
14% multiple or no fixed workplace	10% multiple or no fixed workplace
1% no answer	
	(Census Canada data, 1996)

The difference between the study sample and Ladner and Tsawwassen population on this measure may be related to a different measurement definition of the workplace in Census Canada data.

In summary, along the compared characteristics, most major differences between the study population and the Ladner/Tsawwassen population appear to be the result of the study selection criteria. Possible effects on study results of sample biases relating to respondent incomes and work schedules will be discussed further in Part 3.

### **Methods used in analyzing the discrete choice experiment results**

Stated preference research methods rely on several assumptions about decision making and statistical inference. First, the method assumes that when making decisions individuals act to maximize their utility (or benefit), subject to their individual constraints. Second, the method assumes that decision making is compensatory – that respondents make tradeoffs between choices by essentially adding up the pros and cons associated with the attributes of each choice, and selecting the choice with the highest utility.<sup>13</sup> These assumptions can be described by the following equation:

$$U = a + \hat{a}_1 \text{ attribute}_1 + \hat{a}_2 \text{ attribute}_2 \dots \hat{a}_k \text{ attribute}_k \quad (1)$$

Where, in the case of the utility of mode choices, the attributes are features of the mode that are important in determining its utility (cost, travel time, and so on), the coefficients  $\hat{a}_1, \hat{a}_2 \dots \hat{a}_k$  describe the influence of the attributes on the decision maker's estimation of utility of each mode, and  $a$  is a mode specific constant which captures basic preference for the mode, or additional aspects of the utility of the mode not measured by the attributes.

Third, stated preference methods also assume that not all aspects of choice behaviour can be observed by the researcher, and that respondent biases and errors in decision making result in choice behaviour that is not strictly utility maximizing. As a result, what the researcher measures is actually "Random Utility," or the utility described in (1) above plus a random error term. This error term is assumed to

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<sup>13</sup> Decision making may no longer be compensatory if attributes of a choice reach extremely high or low values; therefore care should be taken in assuming the nature of choice responses outside of the range of attribute values tested, because assumptions about the form of the underlying utility function may no longer hold (Permain et al 1991).

be small relative to the non-random element of decision making, and to simplify analysis it is also assumed that this error is independently and identically distributed across all alternatives.<sup>14</sup>

The assumption that there is a random element in observed decision making implies that choice outcomes can only be represented as a probabilistic relationship. The choice utilities are transformed exponentially and their relationship to the probability of a choice outcome is described with a logistic function in order to constrain probability outcomes between 0 and 1. The statistical model used for analysis is the conditional logit,<sup>15</sup> which says that the probability that an individual  $i$  will choose mode  $j$  from a set of  $J$  alternatives is shown by (2) below.

$$P_{ij} = \frac{\exp(U_{ij})}{\sum_{k=1}^J \exp(U_{ik})} \quad (2)$$

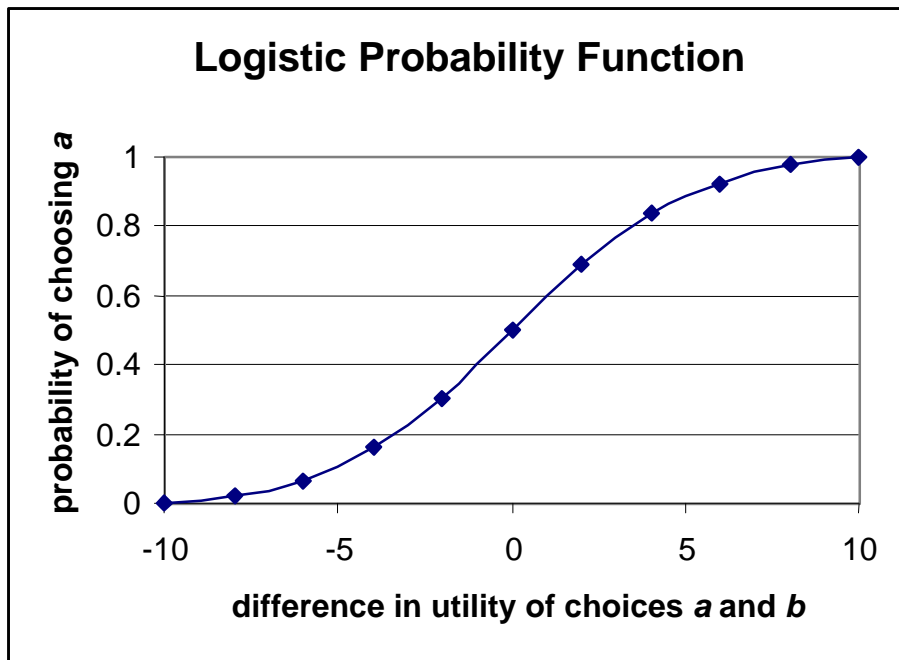
A simplified example of a logistic probability function for two choices is shown in Figure 7 on the next page.

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<sup>14</sup> The software employed in this analysis, LIMDEP, uses the Gumbel distribution to describe the error term. The assumption about the independence of the error term also leads to the independence of irrelevant alternatives property (IIA), which says that the ratio of the probability of any two choices in the model is independent of the presence or absence of other choices. The researcher must determine if this property holds in a particular choice scenario; if the choices are perceived by respondents to be close substitutes, then an alternative modeling method is required. In this study, the choices of driving alone, carpooling and taking transit are assumed to be sufficiently different that the property holds.

<sup>15</sup> The conditional logit was derived from random utility theory by McFadden (see McFadden 1974, Domencich and McFadden 1975). This model is often referred to as the discrete choice model and occasionally as the multinomial logit model. The latter term is more appropriately applied to models where choice probabilities are estimated in relation to characteristics of individuals such as age, income or sex, rather than the attributes of choices.

**Figure 7. Logistic probability function for two choices showing the probability of choosing option  $a$  given differences in the utility between options  $a$  and  $b$ .**



Adapted from Permain et al (1991)

Figure 7 shows that when the utility of choice  $a$  is much lower than that of choice  $b$  ( $U_a - U_b = -10$ ), the probability of choosing choice  $a$  is quite low. Where the utilities are equal ( $U_a - U_b = 0$ ), the probability of choice is 50 percent. Where the utility of  $a$  is higher than that of  $b$  ( $U_a - U_b = 10$ ), the probability of choosing  $a$  is quite high. The slope of the change in probability shows that slight changes in the utility of each option have the greatest effect on the probability of choice when the options are of similar utility, and less effect when the difference in utility is great.

Assuming in this simple example that the utility of each option is determined by a single attribute, the coefficient for that attribute controls the slope of the probability distribution curve. If a constant was present for either option, it would have the effect of shifting the curve to the right or left, implying a predisposition to that option independent of the effect of the attribute. In more complex cases where choices have multiple attributes, or there are more than two choices, the effect of a change in an attribute value on the utility of a choice (and hence its probability of being chosen) is identified by holding all other attribute values for all choices constant while varying the attribute of interest. Performing a logit transformation on (2) above gives us the linear additive model shown in equation

(3) below, for which the attribute coefficients are estimated using maximum likelihood methods.

$$\ln(P_j/1-P_j) = a + \hat{\alpha}_1 (\text{attribute}_1 - \text{attribute}_1') + \dots + \hat{\alpha}_k (\text{attribute}_k - \text{attribute}_k') \quad (3)$$

As shown by (3), the attribute coefficients indicate the change in the *log of the odds* of choosing an alternative given a unit change in the value of that attribute of the alternative. The mode specific constant indicates the effect of other unmeasured aspects of utility on the log of the odds. Essentially, deriving the logit equation described in (3) simplifies estimation of the non-linear, non-additive relationship between the attributes and the probability of mode choice by enabling the estimation of only one coefficient to describe the effect of each attribute on the likelihood of a mode choice outcome. Unfortunately, the resultant dependant variable, the log of the odds of mode choice, is not easily interpreted; however, two manipulations can be performed to make the results more easily understood. The first is to exponentiate the attribute coefficients to obtain their effect on the odds rather than the log of the odds of choice. The values obtained are referred to as odds ratios. The second manipulation is to insert attribute values for specific scenarios into equation (1) above, and, using the coefficients obtained in the model, calculate the predicted probability of choice for those scenarios using equation (2). Both approaches are utilized in the analysis in the next section.

An accessible introduction to stated preference research methods can be found in Permain et al (1991). Further details on the methods used here and their statistical background can be found in Ben Akiva and Lerman (1985), Louviere et al (2000) and Pampel (2000).

### 3. Analysis

#### Model estimation

Attribute coefficients were estimated first using categorical coding for all attributes at the four levels presented in the experiment, and then using continuous linear and quadratic coding for the numerical attributes and categorical coding only for the non-continuous attribute "time from express bus to work." Statistical comparison of the two coding methods showed that the model with continuous coefficient estimates provided a better overall prediction of the responses in the experiment; as a result, only the results for the continuous model are presented in Table 13 on the following page. All analysis was done using LIMDEP 7.0. Analysis was conducted only on the 529 surveys in which respondents completed all eight choice questions.

**Table 13. Coefficient and constant estimates for continuous attribute model of mode choice.**

Attribute/ constant	Initial model		Restricted model			
	coefficient	<i>t</i> -stat.*	coefficient	S.E.	<i>t</i> -stat.*	odds ratio
<i>Drive alone choice attributes:</i>						
In-vehicle time – linear effect	-0.037	-4.770	-0.028	0.008	-4.920	0.973
In-vehicle time – quadratic effect	0.001	1.769	-	-	-	-
Road charge – linear	-0.206	-15.176	-0.207	0.019	-15.217	0.813
Road charge – quadratic	0.016	3.731	0.016	0.006	3.840	1.016
Parking cost – linear	-0.182	-15.087	-0.179	0.016	-15.260	0.836
Parking cost – quadratic	0.003	0.666	-	-	-	-
<i>Carpool choice attributes:</i>						
Carpool in-vehicle time – linear	-0.052	-6.498	-0.055	0.012	-6.876	0.947
Carpool in-vehicle time – quad.	-0.003	-3.533	-0.003	0.001	-4.373	0.997
Pickup time – linear	-0.070	-4.595	-0.069	0.022	-4.575	0.933
Pickup time – quadratic	-0.067	-1.976	-0.067	0.048	-1.992	0.935
Carpool parking cost – linear	-0.052	-3.349	-0.051	0.022	-3.323	0.950
Carpool parking cost – quad.	-0.037	-1.093	-	-	-	-
<i>Express bus choice attributes:</i>						
In express bus time – linear	-0.037	-2.567	-0.055	0.016	-5.503	0.946
In express bus time – quadratic	0.002	1.707	-	-	-	-
Total wait time for buses – linear	-0.175	-3.026	-0.072	0.018	-5.972	0.930
Total wait time for buses – quad.	0.004	1.807	-	-	-	-
Time from express bus to work:						
3 minute walk	referent	-	referent	-	-	-
6 minute walk	-0.245	-1.446	-0.204	0.241	-1.214	0.815
5 min. local bus ride +3 min. walk	-0.315	-1.864	-0.295	0.277	-1.756	0.744
10 min. local bus ride +3 min. walk	-0.853	-4.488	-0.857	0.291	-4.510	0.424
Drive alone constant	0.496	1.633	0.966	0.262	5.667	2.628
Carpool constant	0.531	1.745	0.980	0.264	5.715	2.666
Express bus constant	referent	-	referent	-	-	-
$L(0)$	-4438.394		-4438.394			
$L(a)$	-3642.476		-3642.476			
$L(\hat{a})$	-3276.681		-3281.554			
Likelihood ratio index: $\tilde{n}^2$ (adjusted) = $1 - (L(\hat{a}) - k) / L(0)$	.258		.258			
Likelihood ratio test: $-2*(L(\hat{a})_{restricted} + L(\hat{a})_{initial})$	$\chi^2 = -9.746$ with 5 d.f.					
*a <i>t</i> -statistic of absolute value >1.96 = 95% confidence level; >1.64 = 90% confidence level						

As shown in Table 13 above, the initial model contained insignificant coefficients (at the 90 percent confidence level) for the quadratic estimations of both the drive alone and carpool parking cost attributes. In addition, the model contained three positive quadratic time coefficients significant only at the 90 percent confidence level. These quadratic coefficient values imply that there is a positive, non-linear response to travel time increases – that an increase in these times has less of an effect at higher times than at lower times. This result is counter intuitive, especially with regard to express bus in-vehicle and wait time, because respondents rated taking the bus poorly both in terms of comfort and making use of travel time.<sup>16</sup> Therefore a second model was estimated that restricted both insignificant coefficients and the three counter intuitive quadratic estimates to zero.<sup>17</sup> Results for this restricted model are shown in the third and fourth columns of Table 13.

The log-likelihood values for the models (designated  $L$  at the bottom of Table 13) provide an indication of how well each model approximates the data. Log-likelihood values approach zero where the model predicts a choice probability near one and the data indicates that that choice has actually been made. Log-likelihood values are shown for models where all constants and coefficients are zero ( $L(0)$ ), for models with constants only ( $L(a)$ ), and for models with the full set of coefficients ( $L(\hat{a})$ ). The likelihood ratio index values (also referred to as  $\tilde{r}^2$  (rho squared)) presented at the bottom of Table 13 for each model represent a transformation of the log-likelihood values to makes them analogous to  $R^2$  in linear regression. The values are adjusted for the number of degrees of freedom (equal to the number of coefficients, or  $k$ ) in each model, because increasing the number of coefficients inflates the  $\tilde{r}^2$  value. While there are no strict guidelines for the interpretation of  $\tilde{r}^2$  values, measures of 0.2 to 0.4 are considered equivalent to  $R^2$  values of 0.5 to 0.8 in linear regression and indicate a good fit of the model to the data (Domencich and McFadden 1975, see also Ben Akiva and Lerman 1985). The likelihood ratio index is generally accepted as the most theoretically sound measure of goodness of fit for probability models (Domencich and McFadden 1975). Both the initial and restricted model show the same good fit to the data.

The log-likelihood values can also be used to compare the restricted and unrestricted versions of the model to each other to determine if the coefficients which have been left out (restricted) have any effect on the fit of the model to the data. The likelihood ratio test of the initial and restricted models, shown in the second to bottom row of Table 13, tests the null hypothesis that the coefficients which

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<sup>16</sup> Responses to this set of ranking questions are described further in Figure 8 below.

<sup>17</sup> All coefficients with  $P$  values of greater than 90 percent also had  $\hat{a}$  values of less than 10 percent.

are left out of the restricted model are equal to zero. This test statistic is chi-squared ( $\chi^2$ ) distributed with degrees of freedom equal to the number of restricted coefficients (five in this case). The result of this test is less than the tabulated chi-squared value, indicating that we fail to reject the null hypothesis. In other words, the test shows that the coefficients left out of the restricted model are not significantly different from zero, and this model is an improved estimation of the effect of the attributes on mode choice compared to the initial model.

The column of the table titled S.E. presents the standard errors of the coefficients and constants for the restricted model. The standard error is a measure of the variability of the coefficient estimates and will be used later in the calculation of confidence intervals for elasticity estimates.

The final column of the table, titled odds ratio, displays the exponentiated form of the coefficients and constants of the restricted model. This is the first manipulation of the results described earlier. The odds ratio tells us the direct effect on the odds of a unit change in an attribute. Units are in minutes and dollars. As an example, the odds ratio for drive alone parking costs indicates that for every \$1.00 increase in parking cost, the odds of choosing to drive alone are multiplied by 0.836.<sup>18</sup> Attributes that decrease the odds of choice have an odds ratio between zero and one and a coefficient of less than zero. Attributes that increase the odds of choice have an odds ratio greater than one and a coefficient greater than zero.

### **Interpreting model results: coefficients, odds ratios and predicted probabilities**

In the restricted model all linear and quadratic continuous coefficients are significant at the 95 percent confidence level, as is the coefficient for one level of the categorical attribute "time from express bus to work." All linear and categorical coefficients also have the expected negative sign, indicating that an increase in time or cost leads to a decrease in the odds of choosing an alternative. The road charge attribute and two time attributes also show statistically significant quadratic effects, indicating that changes in these attributes have a non-linear effect on the odds of choice.

Looking first at the three cost attributes, coefficient estimates and odds ratios for the restricted model show that the road charge and drive alone parking charge have the greatest effect on mode choice of

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<sup>18</sup> This is called the odds ratio because it indicates the ratio of odds after to odds before the one unit change. Keep in mind that changes in the odds tell us nothing about the magnitude of the underlying probabilities themselves; 4 to 1 odds could represent a ratio of 40 to 10 percent probability, or a ratio of 8 to 2 percent probability.



the costs included in the experiment. Interestingly, the non-linear effect of the road charge, shown by the significant positive coefficient for the quadratic estimation of this attribute, indicates that at higher road charges the negative impact of an increase in cost is less than at lower charges. While this may initially appear counter intuitive, one possible explanation is that respondents associate higher road charges with less congested travel routes and are willing to pay a cost for the associated reduction in travel time.<sup>19</sup> A similar income effect in the response to road charges was noted in a stated preference study conducted prior to the implementation of the road pricing cordon in Trondheim, Norway (Polak et al 1991). The carpool parking cost attribute has an influence on the odds of choosing to carpool approximately one-third as great as the influence of drive alone parking cost on choosing to drive alone. This may indicate that respondents were relatively indifferent to increases in parking cost in the narrow price range presented in the carpool choice (from \$0 to \$3), especially if they assumed that they were sharing that cost with other individuals.

An examination of the time attributes shows that total wait time for buses has the single most significant influence of any time attribute on the odds of choice, followed closely by pick up time for carpooling. This indicates that time spent waiting for buses and picking up other carpoolers are perceived more negatively by respondents than travel time, possibly because they represent time costs over and above time spent travelling directly to work. One reviewer has suggested that coefficients obtained for wait and pick up times may reflect respondent perception of the risk of variability in these times, or, in other words, the reliability of transit and carpooling. Figure 8 below shows respondent ratings of the modes for reliability. Driving alone was rated the best and transit the worst along this dimension.

In terms of in-vehicle time, the coefficient value for the drive alone option is less than those for the express bus or carpool options, which are nearly identical. This indicates that respondents perceive time spent travelling while driving alone less negatively than time spent travelling while carpooling or taking express bus. This corresponds with responses received to a question in the survey which asked respondents to rate the three modes on a number of qualitative features, including comfort and

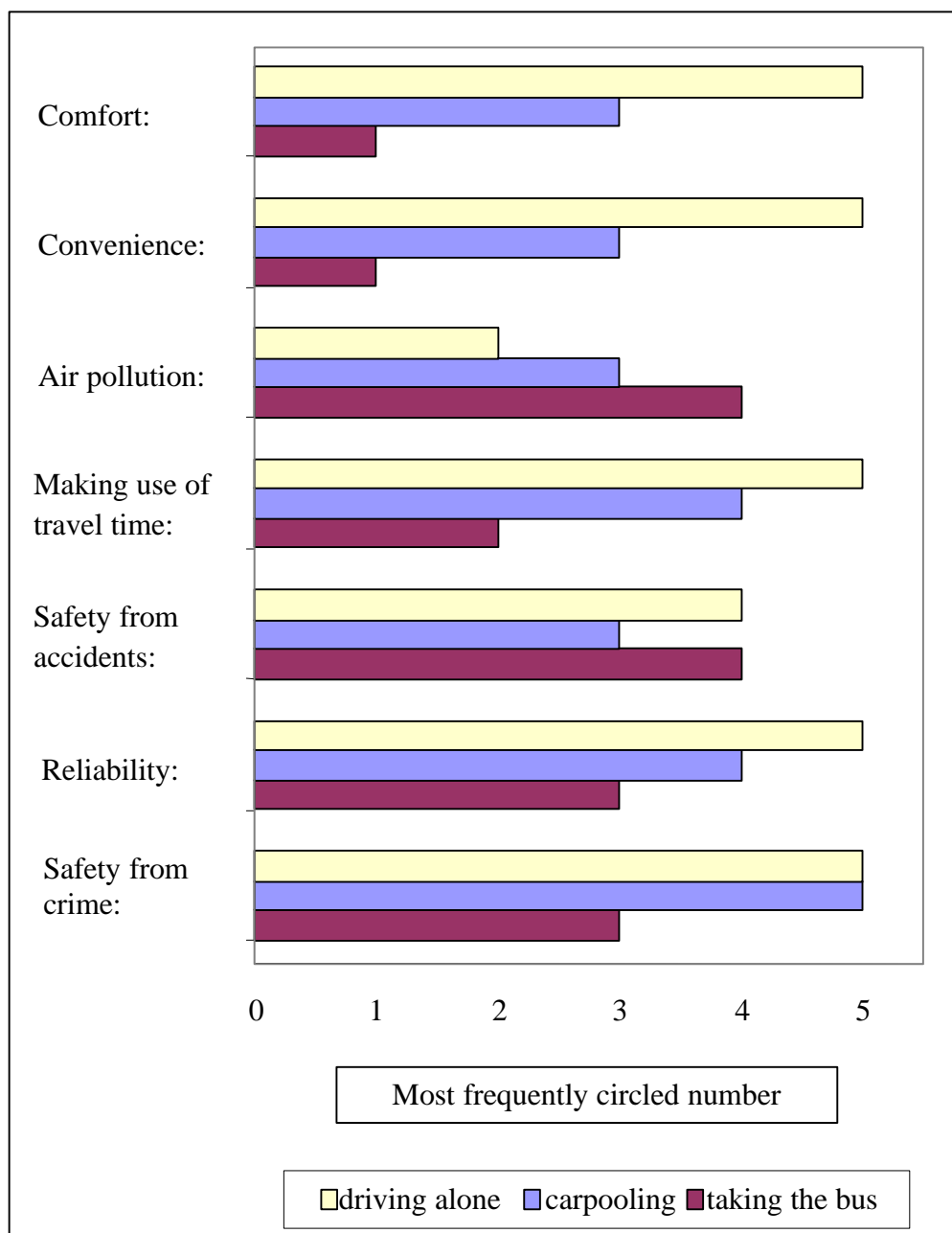
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<sup>19</sup> The non-linear effect of road charges on the odds of drive alone choice was significant only for respondents with incomes above \$40,000, strengthening the argument that this non-linearity represents an income effect. The income specific influence of the quadratic estimation of the road charge attribute was measured by re-estimating the model for sub samples based on income ranges. For incomes below \$40,000, the quadratic estimation was not significant at the 90 percent confidence level. The small number of respondents with incomes below \$40,000 indicates that this interpretation should be treated with caution.

making use of travel time, shown in Figure 8 on the following page. As the results in Figure 8 show, respondents rated driving alone most highly on both of these dimensions and transit lowest.

In addition, the carpool in-vehicle time attribute has a negative non-linear effect that is highly significant. This most likely indicates that respondents are less tolerant of traveling with others in a carpool as the time spent travelling together increases, and that they see little benefit in going to the effort of carpooling if it takes substantially longer than driving alone. The response to increases in carpool pickup time also has a significant negative non-linear component, and in this case it is quite large, indicating that while short pickup times are already an important reason not to choose carpooling to get to work, longer pickups become increasingly irritating to commuters. This may indicate a strong disinclination to wait for others and add time to the trip that does not contribute directly to getting to work.

**Figure 8. (Survey question 38): Listed below are some features of travelling to work. Please indicate how well you think driving alone, carpooling and taking the bus perform on each feature by circling the number next to each that best matches your opinion, where 1 is performs very poorly and 5 is performs very well.<sup>20</sup>**



The final express bus attribute shown in Table 13, "time from express bus to work," was estimated as a categorical attribute at four discrete levels rather than as a continuous attribute. Coding these

<sup>20</sup> Figure 8 shows only the most frequently picked rating for the features. The actual distribution of ratings for each feature can be found in Appendix C.

attribute levels for analysis requires that they be compared to a base or reference case. Selecting an attribute level as the reference or base level is arbitrary and has no influence on the values generated. The coefficients estimated for the three reported levels of this attribute indicate their effect on the odds in relation to the base level of a three minute walk. As the odds ratio column in the table shows, a five minute local bus ride and three minute walk from the express bus to work reduces the odds of taking the express bus by 25 percent compared to a three minute walk from the express bus to work (results significant only at the 90 percent confidence level). A ten minute local bus ride and three minute walk reduces the odds of taking the express bus by almost 60 percent (results significant at the 95 percent confidence level). Note that the six minute walk level of this attribute was not found to be significantly different from the three minute walk base level, suggesting that respondents did not perceive a substantial difference between the two walk only attribute values, but rather between walking and having to transfer to another bus to continue their trip.

The mode specific constants were also interpreted as categorical variables, with the express bus serving as the base case. These constants indicate the underlying attractiveness to respondents of the drive alone and carpool modes relative to the express bus mode, independent of the times and costs tested in the experiment. The interpretation of mode constants is described in the box below using a simplified example adapted from Ewing (1996).

Assume that there were just two travel modes available to respondents in a simplified choice question, and that these modes were identical in terms of cost and travel time and were otherwise unidentified. In this situation the probability of choice would be 0.5 each and the odds of choice for each would be one. If the two choices were then revealed to be express bus and driving alone, the odds of choice for driving alone would be multiplied by 2.6 (the odds ratio for the drive alone constant, in the final column of Table 13), and the underlying probabilities would shift to approximately 0.72 drive alone and 0.28 express bus. If the second choice instead was identified as carpooling, the odds of its choice would be multiplied by 2.7, and the underlying shift in probability would be much the same at 0.73 carpool and 0.27 express bus.

The positive mode constant values for driving alone and carpooling indicate that other, unmeasured attributes of these choices (such as convenience, flexibility, and comfort) make them relatively more attractive to respondents than taking transit. The actual constant values reported here are relevant only in the context of this study and the attributes presented. Some indication of this relative preference for driving alone and carpooling over taking transit is provided by the results in Figure 8. To summarize interpretation of the coefficients and odds ratios, an increase in any of the time and cost attributes associated with a travel mode reduced the odds of that mode being chosen for the

commute to work. Road and parking charges had the largest effect of the cost attributes on mode choice for the trip to work, with road charges showing an income effect at higher levels. In comparison, carpool parking charges had a small effect on the odds of carpool mode choice. In-vehicle time increases were perceived more negatively for both transit and carpooling than for driving alone. Increases in total transit wait time and carpool pick up time had an even larger effect on express bus and carpool mode choice than increases of in-vehicle time for those modes. In addition, the effect of further increases in carpool in-vehicle and pick up time on the odds of choosing that mode became more significant as those times grew larger. Response to the categorical attribute "time from express bus to work" showed that having to transfer to a local bus to continue on to work from the express bus decreased the odds that transit would be chosen for the trip to work. The constant values indicated an underlying preference for driving alone and carpooling over taking transit.

The coefficient values and odds ratios indicate how changes in individual attributes affect the odds of mode choice, but they do not reveal how those changes affect the predicted probability of choice. The probability of mode choice can only be predicted in relation to specific scenarios of travel time and cost. It will be useful to predict the probability of a base case in order to provide a point of comparison with probabilities predicted from policy oriented manipulations of the attributes. Ideally, a base case is equivalent to the status quo; in the case of the sample population for this study, the real world status quo is a drive alone market share of 100 percent and poor mode choice alternatives. However, the discrete choice experiment included improved hypothetical carpool and transit mode choices which must be taken into consideration in estimating a base case. In this situation, the closest we can come to mimicking the status quo is to set drive alone attributes at their revealed levels and carpool and transit attributes at less competitive levels as described in the box below.

Drive alone attributes:

- Set in-vehicle travel time at its revealed level, road charges at zero and parking charges at zero.

Carpooling attributes:

- Set in-vehicle travel time 15 percent above revealed level, parking charges at zero and pick up time at the experiment mean value of 7.5 minutes.

Transit attributes:

- Set in-vehicle time 15 percent above revealed level, wait time at the experiment mean value of ten minutes, and travel from the express bus stop to work at the base level of a three minute walk.

The differences in in-vehicle travel time shown above for the three choices reflect the time advantage that presently exists for driving alone for study respondents. Since the discrete choice experiment only tested express bus in-vehicle times up to 15 percent greater than drive alone in-vehicle times, the

model cannot predict probabilities for larger time differences between the two choices, even though for many respondents transit is undoubtedly more than 15 percent slower than driving alone. A revealed in-vehicle travel time of 35 minutes (the median work-to-home travel time for the study population) gives the attribute levels for the base case scenario probability prediction shown below in Table 14.

**Table 14. Probability Prediction Scenario 1: Attribute levels for base case settings.**

<b>Driving alone</b>	<b>Carpooling</b>	<b>Taking express bus</b>
35 minutes in vehicle	40 minutes in vehicle	40 minutes in vehicle
no road charge	7.5 minute pick up time	10 minute wait time
no parking charge	no parking charge	3 minute walk from express bus to work

Inserting the attribute values from Table 14 and the restricted model coefficients from Table 13 into equations (1) and (2) gives us a baseline mode choice probability prediction of 0.83 for driving alone, 0.15 for carpooling, and 0.02 for transit. These predicted probabilities can be interpreted more broadly as the predicted market shares for driving alone, carpooling, and taking transit in the sample population of commuters, if the hypothetical carpool and transit services were available at the attribute levels described above. (The terms "predicted probability of mode choice" and "predicted market share" will be used interchangeably below – keep in mind that the market in this study consists only of commuters who currently drive alone.) The 2 percent market share predicted for transit is expected given that this mode is not a competitive alternative to driving alone for respondents.<sup>21</sup> The predicted carpool market share of 15 percent, however, is greater than would be expected for the sample population given the base case attribute levels described above. This may indicate that there is a “latent” demand for carpooling among respondents that is presently not being filled, possibly because respondents cannot find other commuters with whom to form carpools (the predicted market share assumes that all commuters wanting to travel by carpool are matched together). Possible explanations for this outcome will be discussed in more detail shortly.

### **Using the model to predict the ability of improvements to transit and carpooling to encourage a shift away from the SOV**

The method of predicting probabilities described above can be used to estimate the effect of improvements in travel time and cost on the likelihood that respondents will choose alternatives to

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<sup>21</sup> The use of a probability function in logistic regression means that the model would still predict some market share for alternatives to driving alone even if the carpool and transit attributes could be set to much worse levels.

driving alone. Figure 9 on the following page shows how changes in bus or carpool travel times relative to the reported drive alone time affect the probability of choice (market share) for all three modes. Changes in transit versus drive alone mode choice probability are shown for two levels of bus wait time, and changes in carpool versus drive alone probability are shown for two levels of carpool passenger pick up time. Other details on the attribute levels used in these estimations of probability are shown in Tables 15 and 16 below. Table 15 differs from the base case described in Table 14 only in that the bus in-vehicle and wait times vary. Similarly, Table 16 differs from Table 14 only in that carpool in-vehicle and pick up times vary. Improvement in these attribute values could be obtained by introducing policies such as the following:

- improvements in transit and carpool travel times could be brought about by investing in road system infrastructure to favour those modes;
- improvements in bus wait time could result from increased frequency of service; and
- improvements in carpool pick up time (reducing the time it takes to collect all carpoolers from their homes) could result from investment in ride matching services, and introduction of incentives to encourage more people to carpool, in order to increase the number of potential carpoolers in the region.

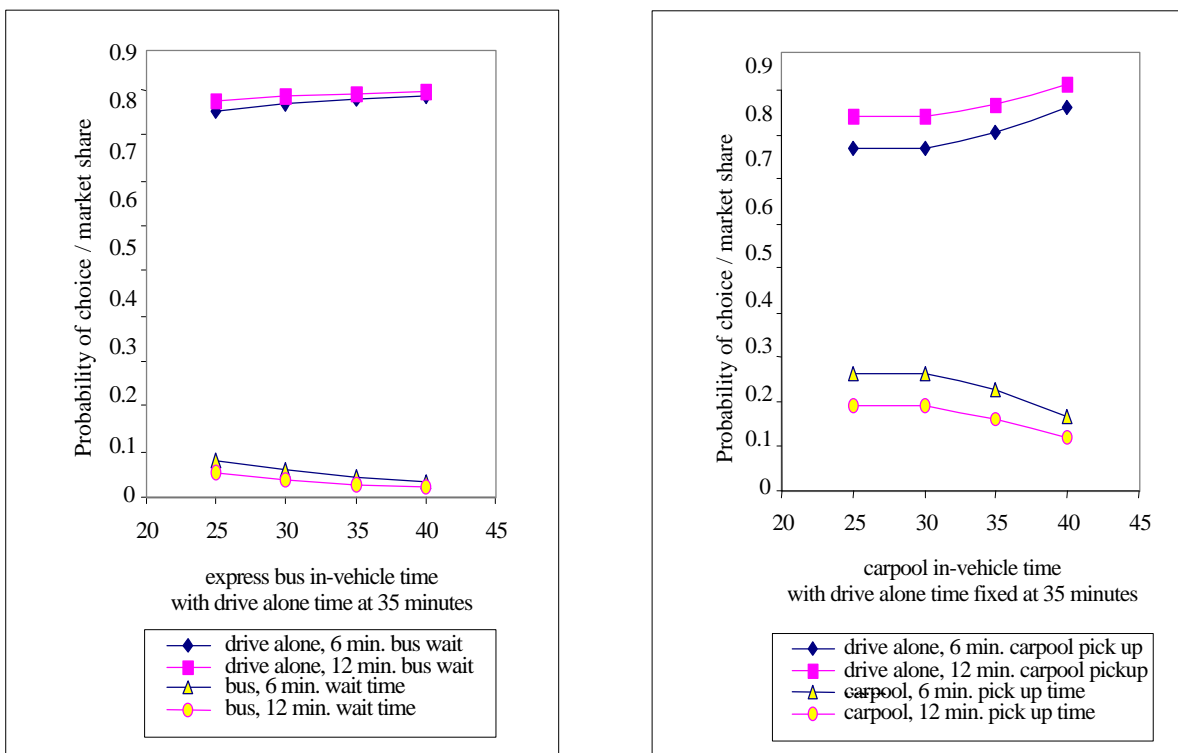
**Table 15. Probability prediction scenario 2: Attribute levels for driving alone versus taking express bus.**

<b>Driving alone</b>	<b>Carpooling</b>	<b>Taking express bus</b>
travel time fixed at 35 minutes	travel time fixed at 40 minutes	travel time varies from 25 to 40 minutes
no road charge	7.5 minute pick up time	6 or 12 minute wait time
no parking charge	no parking charge	3 minute walk from express bus to work

**Table 16. Probability prediction scenario 3: Attribute levels for driving alone versus carpooling.**

<b>Driving alone</b>	<b>Carpooling</b>	<b>Taking express bus</b>
fixed at 35 minutes	varies from 25 to 40 minutes	fixed at 40 minutes
no road charge	6 or 12 minute pick up time	10 minute wait time
no parking charge	no parking charge	3 minute walk from express bus to work

**Figure 9. Change in probability (market share) of driving alone versus taking transit and carpooling, given transit and carpool in-vehicle time improvements relative to respondents' reported drive alone time.**



#### a. Driving alone versus Taking Transit

#### b. Driving alone versus Carpooling

The comparison of driving alone versus taking transit in Figure 9a shows that given a six minute bus wait time and a drive alone in-vehicle time of 35 minutes, a decrease in express bus in-vehicle travel time from the base case level of 40 minutes to 25 minutes leads to a decrease in the drive alone market share from the base case value of 83 percent to 78 percent, and a corresponding increase in the express bus market share from 2 percent to 7 percent.<sup>22</sup> As with Taplin *et al* (1999), this study assumes that the number of commuting trips taken by respondents is more or less fixed in the short term, meaning that the commuting market size is constant. In this situation a decrease in market share is equivalent to a decrease in demand; the shift in market shares described above represents a 5 percent decrease in demand for driving alone and a 250 percent increase in demand for express bus travel for the commute to work.

<sup>22</sup> Note that the total travel time for the express bus choice in this scenario is 34 minutes, (25 minutes in bus, six waiting and three walking) which is equivalent to the total drive alone time. Respondents who chose express



Figure 9a also shows that a reduction of bus in-vehicle time to just 35 minutes (equal to drive alone in-vehicle time) shows a 1 percent shift of market share between the two modes. Doubling the transit wait time to 12 minutes reduces the shift in market share between the two modes by one-half. Note that all of these results assume that the commuter only has a three minute walk from the express bus to work. As will be shown below, a walk and a transfer would reduce the shift to transit given the same travel time improvements.

The comparison of driving alone versus carpooling in Figure 9b shows that, given six minutes spent picking up other carpoolers and a drive alone in-vehicle time of 35 minutes, a reduction in carpool in-vehicle time from 40 minutes to 25 minutes leads to a decrease in drive alone market share from the base case level of 83 percent to 73 percent (representing a drive alone demand reduction of 12 percent), and a corresponding increase in carpool market share from 15 to 25 percent (representing a demand increase of 67 percent).<sup>23</sup> A reduction of carpool in-vehicle time to just 35 minutes shows a shift in market share of 6 percent between the two modes. If the time spent picking up other carpoolers is doubled to 12 minutes, the shift in market share between the two modes is cut in half to 4 percent. Note that these results assume that carpool parking is free, and that all commuters who want to carpool are able to find ride matches. While these reductions in drive alone mode share are better than those shown for transit performance improvements, they are by no means dramatic, suggesting that improvements to carpooling performance alone will have only a moderate effect on drive alone mode share. Similar results have been found in other studies (see for instance Flannelly cited in Hunt et al 1997).

In Figure 9 only two attributes could be varied for the bus and carpool choices, because all other attributes had to be held equal in order to isolate the effect of each attribute on probability. Figure 10 on the following page shows the probability of choosing to take an express bus given different levels of the remaining attribute, "time from the express bus to work," over a range of different in-bus travel times. Bus wait time is held constant at six minutes. All other attribute levels are held to the levels shown in Table 15. As a policy measure, reduced travel time from express bus stops to workplaces could be brought about through expansion of the transit network and through land use zoning that directs the location of new employment to areas near existing transit routes.

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bus in this case must still travel from their home to the bus exchange, a time which varied from a short walk to a walk and a ten minute local bus trip, according to their home location.

<sup>23</sup> The total time for the carpool choice in this scenario is 31 minutes, (25 minutes in-vehicle, six picking up carpoolers) approximately five minutes less than the total drive alone time.

**Figure 10. Change in probability (market share) of transit given different travel requirements from an express bus stop to work.**

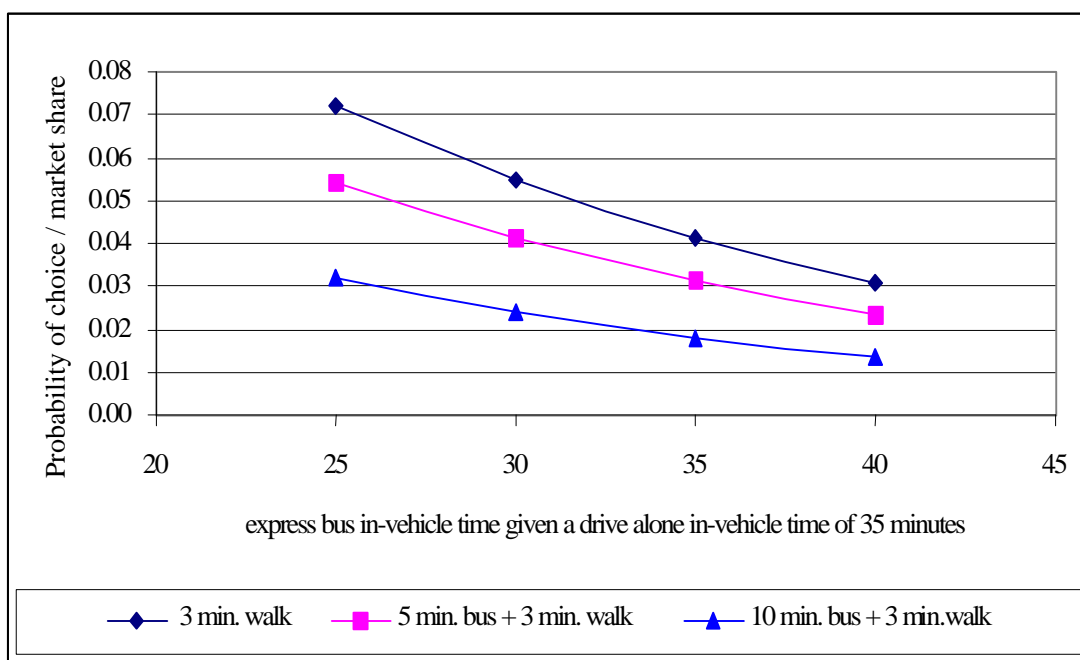


Figure 10 shows that a transfer to an additional bus from the express bus to continue to work had a fairly substantial impact on the probability of choosing transit. A five minute local bus ride and three minute walk reduced express bus market share by one-quarter compared to only a three minute walk, and a ten minute local bus ride and three minute walk reduced market share by one-half.<sup>24</sup>

Figure 11 on the following page shows the effect of three levels of carpool parking charges on carpool choice probability for the trip to work, with time spent picking up other carpools held steady at six minutes. All other attributes are held to the levels shown in Table 16 above. Although a situation where carpool parking charges increase while drive alone charges remain the same is unlikely, considering this case allows us to examine in isolation the effect of carpool parking cost increases on carpool mode choice. From a policy perspective, lower parking rates for carpooling than for driving alone could be brought about through regulation and taxation policies.

<sup>24</sup> It is also worth noting that while respondents showed a preference for walking over taking local buses and transferring between buses, their comments and research conducted elsewhere both indicate that they would prefer not to have to walk very far to access transit either (see for instance Ewing (1996) and TransLink (2000c)). Inclement weather and the need to carrying things to and from work were the two most common reasons provided by respondents for disliking the walk to the bus. More generally, the importance of transfers between buses as a disincentive to choosing transit reinforces the argument that, over the long term, changes to land use patterns (such increases in density and the mix of employment and housing) will be necessary if transit is to be a competitive alternative to driving alone.

**Figure 11. Change in probability (market share) of carpooling given different levels of carpool parking charges.**

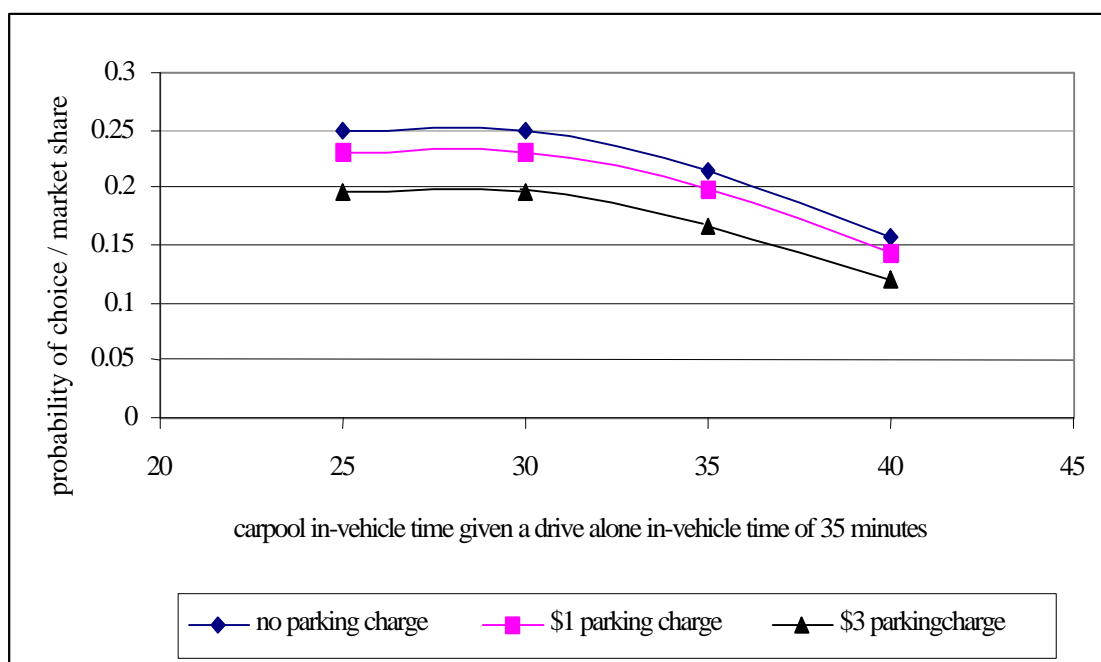


Figure 11 shows that carpool parking charges have a relatively small effect on the probability of choosing to carpool to work (note the different vertical scales between Figures 10 and 11). At an in-vehicle time of 35 minutes, a \$3.00 parking charge reduces carpool market share by one-quarter compared to no parking charge. Figure 11 also makes clear the negative, non-linear effect of increases in carpool in-vehicle travel time on the probability of choosing to carpool – the probability of carpooling begins to drop off rapidly as travel time increases above 30 minutes (which in this case represents 85 percent of drive alone in-vehicle time).

*Promoting transit as an alternative to driving alone: substantial constraints exist*

As shown in Figures 9 and 10, transit was an unattractive commuting option for most respondents, even given competitive in-vehicle travel times, no requirement to transfer from the express bus to continue on to work, and short wait times. In addition, many survey respondents commented that wait time and transfers between buses were key factors in deciding not to take transit to work. From a policy perspective, these results indicate that high frequency of service, efficient connections, and a minimum of transfers are just as important as competitive in-vehicle travel times if commuters are to consider transit a viable commuting option. These findings are generally supported by other survey research into the factors that influence transit use (see for instance Campbell Goodell Traynor 1997, TransLink 2000c). Ewing found similar results in a stated preference study of Montreal Commuters.

However, given the dispersed nature of employment in the GVRD, it is unlikely that it would ever be economical to provide all commuters with express bus service directly to their workplaces; for some transfer to a second local bus will always be necessary to reach their destinations.<sup>25</sup> Also, keep in mind that given the distance from their homes to their community's transit exchange, some respondent's transit choice scenarios always included a local bus trip to reach that exchange. Model analysis showed that having to take a local bus from home to the community transit exchange in order to board the express bus reduced the odds of choosing transit by 26 percent compared to only having to walk ten minutes or less from home to the exchange.<sup>26</sup> These transfer requirements before and after using express bus service mean that for many commuters transit will always be competing at a disadvantage to driving alone or carpooling.<sup>27</sup>

The competitive disadvantages of transit could be lessened somewhat if governments provided improvements to make use of express services as convenient as possible. These could include:

- equipping buses with GPS technology so that web-based transit schedules could show travelers the actual arrival time of the next bus to their nearest bus stop;
- locating transit exchanges as close to residential neighbourhoods as possible;
- developing well lit, direct pedestrian pathways and safe bike routes to exchanges;
- providing secure bike storage at exchanges and bike racks on buses;
- establishing dial-a-ride feeder bus services between low density residential neighbourhoods and community transit exchanges (Ewing 1996);
- allowing individuals to request stops closer to their homes than designated bus stops on neighbourhood transit routes; and
- incorporating convenient park and ride lots and drop off lanes at transit exchanges.<sup>28</sup>

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<sup>25</sup> More generally, the importance of transfers between buses as a disincentive to choosing transit reinforces the argument that, over the long term, changes to land use patterns (such increases in density and the mix of employment and housing) will be necessary if transit is to be a competitive alternative to driving alone.

<sup>26</sup> This estimate was obtained by including a dummy value for walking or taking a local bus to the transit exchange in the utility function for express bus.

<sup>27</sup> It is worth noting that these findings do not necessarily apply to non-commuting trips. Transit improvements may in fact lead to a large increase in market share for transit for other trip purposes. Delcan et al (1999) found that transit improvements such as rapid bus service lead to a 2.5 percent decrease in total VKT by private passenger vehicles for all trip purposes, an amount equal to the reduction in total VKT resulting from the introduction of a \$4 commuter parking surcharge.

<sup>28</sup> More information on these and other incentives to increase transit usage can be found in the Regional Travel Survey (TransLink 2000c), which asked Greater Vancouver residents to rate transit service improvements according to their likelihood of using transit more often if the improvements were made.

In addition, transit could be made somewhat more competitive with driving alone if employers could be encouraged to provide employees who take transit with guaranteed rides home by taxi if they are faced with an emergency, or stay late to work and miss their scheduled service.

In terms of costs, researchers (Hunt 1997, Merkle 1993, TransLink 2000c) have found that commuters generally do not perceive taking transit to be any less expensive than driving alone or carpooling. This perception is probably correct, as long as one only considers the marginal per trip vehicle operating costs commonly considered by commuters (fuel; possibly oil, tires and maintenance; and for some, parking) when comparing driving costs to transit fares. If one instead considers the total costs of vehicle ownership and operation when calculating per trip costs (by also including depreciation, financing, insurance, and so on) then taking transit is less expensive than driving alone (Merkle 1993). However, a comparison of total costs is only relevant if a commuter is willing to get rid of their car entirely when switching to transit. While most commuters who live in single car households would not forgo car ownership because of the benefits it provides for other purposes, some households with two or more cars may consider reducing car ownership and developing household ridesharing strategies for the commute to work. This suggests that a publicity campaign to educate commuters about the total costs of automobile ownership and use may help to shift some commuters out of their vehicles and into transit, especially since survey research shows that commuters are concerned about the high cost of driving (TransLink 2000c). Employers should also be encouraged to provide transit passes as an alternative to free or subsidized parking for employees.

In terms of use of travel time, Figure 8 suggested that drive alone respondents think that their travel time is better spent in their cars rather than on transit. There may be numerous reasons for this result: respondents may see time spent in their car as their only period in the day for relaxation away from others, they may assume that they will be forced to stand on transit and so will not be able to work or read (crowding is often identified by commuters as a draw back to taking transit (TransLink 2000c)), or they may be unable to work or read while travelling due to car sickness. It is also possible that some drive alone commuters have simply not considered the possibility of using their travel time on transit to work, read or relax. From a policy perspective, this suggests transit marketing campaigns should emphasize this potential use of “free” travel time on the bus, especially if long distance suburban express routes are able to guarantee commuters a seat for their trip. In addition, marketing campaigns that promote transit should point out that using transit saves time spent looking for and

walking from parking, which may help attract commuters without reserved or readily available parking at their workplaces.

Finally, figure 8 showed that the sample of drive alone commuters consulted in this study see transit's biggest advantage arising from its relatively small contribution to air quality problems. Although this alone is insufficient to get them out of their cars, it is a point worth reiterating in any marketing campaign used to promote transit.

*Promoting carpooling as an alternative to driving alone: the preferred suburban option?*

The results displayed in Figures 9 and 10 and the preceding discussion of transit's competitiveness indicate that it should be easier to encourage people to switch from driving alone to carpooling than to taking transit for short to moderate trip lengths, especially for those commute trips that start in residential suburbs and do not end in downtown cores easily served by transit.<sup>29</sup> Similar conclusions have been reached in other stated preference studies (see for instance Kuppam 1998 and Ewing 1996).

In fact, as was shown in the initial prediction of probabilities for the base case scenario, even when carpooling in-vehicle travel time was 15 percent slower than drive alone time and all else was held equal (refer to the attributes presented in Table 14), the model predicted market shares of 83 percent drive alone, 15 percent carpool and 2 percent transit. While it is likely that not every commuter predicted to carpool in this scenario would find a ride match, the base case results do suggest that there are a number of SOV commuters who are interested in carpooling right now. Considering that some incentives to promote carpooling are already in place, this begs the question: "Why are there not more respondents already carpooling?" An answer may be found in responses to some of the survey questions.<sup>30</sup>

First, a majority of survey respondents reported not being able to find someone to carpool with; this may be a result of both the dispersion of respondent employment locations and the relatively small populations of Ladner and Tsawwassen (which had approximately 23,000 people in the labour force

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<sup>29</sup> In Greater Vancouver, suburb to suburb trips for all purposes have been increasing, while trips between other origins and destinations have been declining (GVRD 1995c, TransLink 2001a).

<sup>30</sup> The preference of carpooling over transit as an alternative to driving alone is also supported by regional survey research which asked respondents what response they would take to the introduction of route-specific road tolls. Among a variety of other answers, 50 percent of respondents chose using public transit more often as a likely response, whereas 60 percent chose carpooling as a likely response (Viewpoints Research 1995).

according to the 1996 Canada Census). Other research has shown that commuters prefer to travel with household members rather than friends or coworkers (Hunt et al 1997, Ewing 1996), and with acquaintances rather than strangers (TransLink 2000c). These preferences would further reduce the number of commuters available to form carpools. The availability of carpool partners reported by respondents is shown below in Table 17.

**Table 17. (Survey question 26): Could you find one or more people to carpool to work with if you wanted to?**

yes	24.6%
no	61.4%
don't know	13.2%
no answer	0.8%
	100.0%

It is also possible that respondents only considered their ability to find a carpool ride match directly to their workplace when answering the question. There are probably numerous commuters in Ladner and Tsawwassen who travel to the same general location for work, and respondents may be unaware of existing ride matching services available in the Lower Mainland that help to link these commuters together.

Second, the majority of respondents do not have programs available at their work places to encourage car or vanpooling. Although the absence of an organized program would not prevent individuals from carpooling on their own, there would be fewer examples to follow and, depending on the services provided in such a program, less incentive to do so. Table 18 below shows responses to the survey question on this topic.

**Table 18. (Survey question 25): Is there an organized carpool service at your present workplace?**

yes	14.4%
no	77.7%
don't know	7.6%
no answer	0.4%
	100.0%

Third, numerous respondents provided comments that there are no HOV lanes available on their route to work, that three person occupancy requirements on existing HOV lanes in the local area are too high, and that these existing HOV lanes end abruptly on major highways, causing bottlenecks where

carpoolers are forced to merge with other traffic. All three constraints reduce the competitiveness of carpooling as an alternative to driving alone.

Fourth, a majority of respondents reported that they use their car to make regular stops on the way to or from work at least one day a week and that they go into work early or stay late at least three days per week. Responses to survey questions on these topics are shown below in Tables 19 and 20.

**Table 19. (Survey question 4): On average, how often do you make regular, routine stops or side trips on the way to work or home from work?**

every day	5.1%
3 – 4 days a week	14.6%
1 – 2 days a week	38.6%
1 – 4 days a month	36.5%
never	4.9%
no answer	0.4%
	100.0%

**Table 20. (Survey question 13 [modified]): On average, how often do you go in to work earlier or later than your usual time?**

every day	10.4%
3 – 4 days a week	43.5%
1 – 2 days a week	35.3%
1 – 4 days a month	9.3%
never	1.5%
	100.0%

Clearly, respondents value the high degree of flexibility and independence provided by driving alone, and consequently may see carpooling as a restriction on their freedom. This finding is supported by other research as well (TransLink 2000c, Dawson 1995, Ewing 1996). In addition, numerous respondents provided comments that they need their own car to carry tools, work boots, dirty clothes, and so on to and from work.

Fifth, respondents may simply have no experience with carpooling and may never have considered it outside of the context of this survey. Responses to a survey question on carpool experience are shown in Table 21 on the following page.



**Table 21. (Survey question 24): Have you ever carpooled to work at any job, including your present one?**

never	56.3%
sometimes	26.8%
regularly	16.4%
no answer	0.4%
	100.0%

Finally, as was the case with transit, research has shown that drive alone commuters generally do not perceive carpooling to be less expensive than driving alone (Hunt 1997, TransLink 2000c). In addition, as shown in Figure 8, survey respondents did not consider time spent carpooling to be better used than time spent driving alone. On the other hand, Figure 8 shows that respondents rated carpooling better than driving alone in terms of air pollution impacts.

These responses highlight several areas where supportive policies could be introduced to make carpooling more accessible to commuters and a more competitive alternative to driving alone, especially in suburban locations where express bus service may be difficult to provide. These could include:

- an expanded network of HOV lanes, bypasses at points of congestion such as tunnel and bridge on ramps, and a reduction of HOV lane occupancy requirements from three to two people;
- expansion and greater promotion of ride matching programs;
- a broad marketing campaign to make commuters aware of such benefits of carpooling as reduced costs, reduced air pollution, and the ability to read or relax en-route; and
- support for employer sponsored ride sharing programs with convenient and flexible features such as in-house ride matching, a guaranteed ride home service in case of emergencies, discount transit passes which allow commuters to take the bus if they miss their carpool, door to door pick up and drop off, and conveniently located, reduced cost parking reserved for carpoolers.<sup>31</sup>

It is worthwhile to note that in a survey question prior to the discrete choice experiment more respondents indicated that they are very or somewhat likely to take transit in the future (45 percent) than said that they were very or somewhat likely to carpool in the future (15 percent). However, in a follow up question to the experiment, these numbers were reversed: 40 percent of respondents stated that they would switch to carpool or vanpool if faced with a \$6 road charge, and 15 percent said that

<sup>31</sup> For more information on carpooling improvements which may attract commuters who presently drive alone, see Urban Systems (1995) and TransLink (2000c).

they would switch to the bus. Part of the explanation for the difference may be that respondents envisioned using rapid transit when they answered the first question about future transit use, whereas the second question referred directly to the express bus service described in the discrete choice experiment.

However, it is just as likely that when answering the first question, respondents had no clear idea of the implications of commuting by transit (over 50 percent reported never having commuted by transit to work in the past), whereas in the second question they took into consideration the issues of travel time from home to the transit exchange, wait time for busses, and travel time from the express bus stop to work that had been presented in the experiment. Carpooling was generally more competitive with driving alone than transit in the experiment because the only additional time cost was the time spent picking up other carpoolers, and the per trip costs were comparable to transit. In short, respondents were more willing to consider transit in the abstract in a survey question, but less willing to choose it once the walk and wait time costs were made explicit in the preference exercise. These results highlight the advantage of presenting realistic choice scenarios in stated preference research as a method for eliciting preferences rather than relying on the use of simpler survey questions.

On the other hand, while it was easy for respondents to choose carpooling in the experiment, it will not necessarily be easy for those respondents to carry through with their choice in the real world. Given that in many cases the arrangement of carpools is a private transaction between two or more commuters, it is difficult to evaluate the extent to which these commuters will be successfully matched up. Government's role is largely limited to establishing and promoting ride matching services to increase the number of available carpoolers, and encouraging private employers to provide similar services and incentives for their employees. Responses obtained in stated preference studies must be critically evaluated to determine how closely they reflect possible outcomes in the real world. In the case of carpooling, difficulty in finding ride matches means that real world market shares will be somewhat lower than those predicted by the model.

### **Using the model to predict the ability of economic instruments to reduce demand for driving alone**

The market share predictions for transit and carpool improvements discussed above show that, in addition to providing incentives for the use of alternatives, it will be necessary to apply disincentives to the use of SOV's if demand for driving alone is to be substantially reduced. Conceivably,

government could apply economic instruments such as road charges and commuter parking charges to increase the marginal per trip cost of SOV use and make alternative modes more competitive for the trip to work. It could also use travel time increases to make driving alone less attractive. Methods to increase travel times include allowing SOV traffic to grow at a faster rate than road system capacity, or diverting existing capacity away from single occupant vehicles to exclusive use by alternative modes such as high occupancy vehicles, transit and bicycles.

To best understand the potential effects of changes in these cost and time attributes on drive alone mode choice, it will be useful to compare the effect of a unit increase in each attribute on the base case predicted probabilities of 0.83 for driving alone, 0.15 for carpooling, and 0.02 for transit. The results presented in Tables 22 and 23 below are estimated with all attribute values held at the base case levels (shown in Table 14 earlier) unless indicated otherwise. Different results would be obtained with different starting attribute levels and their associated probabilities.

Table 22 below shows the separate effect of road charges and parking charges on drive alone choice probability when one or the other charge is held at zero, as well as the effect of a number of different settings for the two policy instruments applied together. Looking along the first row shows the effect of parking charges alone; looking down the first column shows the effect of road charges alone.

**Table 22. Effect of combined road and parking charges on the probability of choosing to drive alone to work.**

Road charge	Parking Charge				
	\$0	\$1	\$3	\$6	\$9
\$0	0.83	0.80	0.74	0.66	0.49
\$1	0.78	0.75	0.68	0.55	0.42
\$3	0.68	0.65	0.56	0.43	0.30
\$6	0.56	0.52	0.43	0.31	0.21
\$9	0.50	0.46	0.37	0.26	0.17

In terms of combined effects, the table shows that introduction of a \$1.00 parking charge and a \$1.00 road charge together reduce the probability that driving alone will be chosen from 0.83 to 0.75. At the other extreme, introduction of a \$9.00 road charge and a \$9.00 parking charge together reduce the probability of that choice to 0.17, which equals a total reduction in drive alone demand of 80 percent; most of the shift in demand goes to carpooling. New market shares (in the study market of commuters who currently drive alone) given this \$18.00 return trip cost are 17 percent drive alone, 74 percent carpool and 9 percent transit. This shift in mode shares would reduce the total private

vehicle kilometres traveled to work (for both SOV and HOV modes) by respondents by approximately 50 percent, assuming that average carpool occupancy was two and a half persons per vehicle<sup>32</sup>.

A 50 percent reduction in commuter kilometres traveled would represent a dramatic change in travel conditions on regional roads. This change would have its own effect on mode demand. As marginal SOV drivers switched commuting modes in response to increased per trip costs, traffic volumes would go down and travel speeds would increase; this in turn would attract other commuters (including some of those now travelling by carpool or transit) who valued the decrease in travel time more than the increase in travel cost back into their SOV's. This positive rebound in drive alone demand would mean that the final, equilibrium market share for the SOV mode would be somewhat less than reported here.<sup>33</sup>

The model predicts that a more modest \$5.00 return trip road charge introduced alone would reduce commuter demand for driving alone by 29 percent and total commuter private vehicle kilometres traveled by approximately 18 percent, using the assumption of carpool occupancy at two and a half persons per vehicle. A \$7.00 road charge – equivalent to the 1993 KPMG estimate of the total subsidy for the average 14 kilometer trip in the region in 2001 dollars – would reduce drive alone commuting demand by 36 percent and total commuter kilometers traveled by 24 percent. A \$5.00 commuter parking charge introduced alone would reduce commuter demand for driving alone by 20 percent and total commuter private vehicle kilometres traveled by 13 percent.

Keep in mind that these results assume that the alternatives are relatively competitive; as shown in Table 14, the express bus choice in this scenario involves a ten minute wait for all buses and a three minute walk from a bus stop to work and the carpool choice involves a seven and a half minute pickup time and free parking. Also, the results assume that all those who want to carpool are able to find rides. In addition, results for the road and parking charges assume that comprehensive strategies for their implementation have been put in place – in other words, that commuters are not able to travel an alternative untolled route or park in other locations for free. Finally, rebound elasticities resulting

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<sup>32</sup> This is an optimistic assumption of carpool occupancy that projects the effect of the introduction of carpooling incentives and drive alone disincentives. Using data from the 1996 GVRD screenline study (GVRD 1997), the author estimates that HOV occupancy at that time was 2.15 persons per vehicle.

<sup>33</sup> While the extent of the rebound would depend upon the extent of the initial reduction in demand, the Transportation Table for the National Climate Change Process estimates that rebounds in demand from reduced congestion may be as high as 20 percent (Hagler Bailly 1999b).

from reduced congestion would lessen somewhat the shift in demand away from the drive alone mode.

The model used in this study appears to produce similar results to a stated response study by Kuppam et al (1998). That study found that a \$5-\$6 US (\$8-\$9 CDN) parking tax reduced commuter drive alone demand by approximately 35 percent, whereas the model developed for the present study predicts that an \$8 CDN parking charge would reduce commuter drive alone demand by 36 percent. Also, Kuppam found that switching to carpooling in response to drive alone parking charges was highest among those with middle incomes, whereas switching to transit was highest among those with low incomes. The study described in this report found the same result – a \$5 parking charge led to a shift in carpool market share from the base case of 15 percent to 36 percent for middle income respondents (household incomes between \$60 and \$80,000 per year) but only 29 percent for lower income respondents (household income less than \$60,000 per year). Conversely, given the same increase in parking cost, the new transit market share was 4 percent (from the base case market share of 2 percent) for middle income respondents, and 11 percent for lower income respondents.

Estimating the effect of road charges on total vehicle kilometres traveled for all trip purposes requires assumptions about the percent of road traffic that can be presented with charges. A study completed for the National Climate Change Process (Delcan et al 1999) estimated a 3.3 percent reduction in total vehicle kilometres traveled (VKT) for all trip purposes by 2010, given pricing of \$0.10/km (equivalent to \$3.00 return for the average 14 kilometer trip in the region). These results assumed that only 20 percent of total traffic was tolled, and did not assume improvements to alternative travel modes. The same study estimated that an average commuter parking price increase (surcharge) of \$4.00 in the three largest Canadian metropolitan areas would reduce total VKT by 2.5 percent.

It is possible that government may want to introduce road or commuter parking charges in combination with measures undertaken to increase SOV travel time. Table 23 below shows the effect of a combination of travel time increases and road charges on the probability of choosing to drive alone. A comparison between travel time increases and parking costs is not shown because the overall effect is quite similar, with a maximum 1 percent difference when drive alone probabilities are at their lowest levels.

**Table 23. Effect of combined road charges and travel time increases on the probability of choosing to drive alone to work.**

Road Charge	Travel time increase (percent above present time)			
	present time	10%	20%	30%
\$0	0.83	0.81	0.80	0.79
\$1	0.78	0.77	0.75	0.73
\$3	0.68	0.66	0.64	0.62
\$6	0.56	0.54	0.52	0.49
\$9	0.50	0.48	0.46	0.43

Results in the first row of Table 23 show that, by themselves, the effect of travel time increases on drive alone choice probability are quite slight: a 30 percent increase in in-vehicle travel time reduces drive alone market share by just 4 percent (roughly equivalent to the introduction of a \$1.00 road charge). The table also shows that introduction of a \$1.00 road charge and a 10 percent increase in travel time would decrease the probability of choosing to drive alone from 0.83 to 0.77, which is slightly less than the combined effect of introducing a \$1.00 road charge and a \$1.00 parking charge shown in Table 22. Finally, the table shows that a 30 percent increase in travel time (from a revealed time of 35 minutes) combined with a \$9.00 road charge would reduce the probability of choosing to drive alone to 0.43. Market shares among those who currently drive alone for all three modes with this increase in drive alone time and cost are 43 percent drive alone, 51 percent carpool and 6 percent transit. This increase in one-way time and round trip cost for driving alone would reduce the total private vehicle kilometres traveled (SOV and HOV) to work by respondents by approximately 30 percent, assuming that average carpool occupancy was two and a half persons per vehicle. Keep in mind that these results make the same assumptions about the competitiveness of alternatives and the ability of carpoolers to find rides that were described earlier.

In order to further illustrate the effects described in Table 23, a graph of the effect of road charges on the probability of choosing to drive alone is provided in Figure 12 on the following page. Probability curves are shown for two drive alone in-vehicle travel times: revealed time and a 30 percent increase over revealed time. All other attributes are held to base case levels.

**Figure 12. Probability of choosing to drive alone given road charges, at two drive alone travel times.**

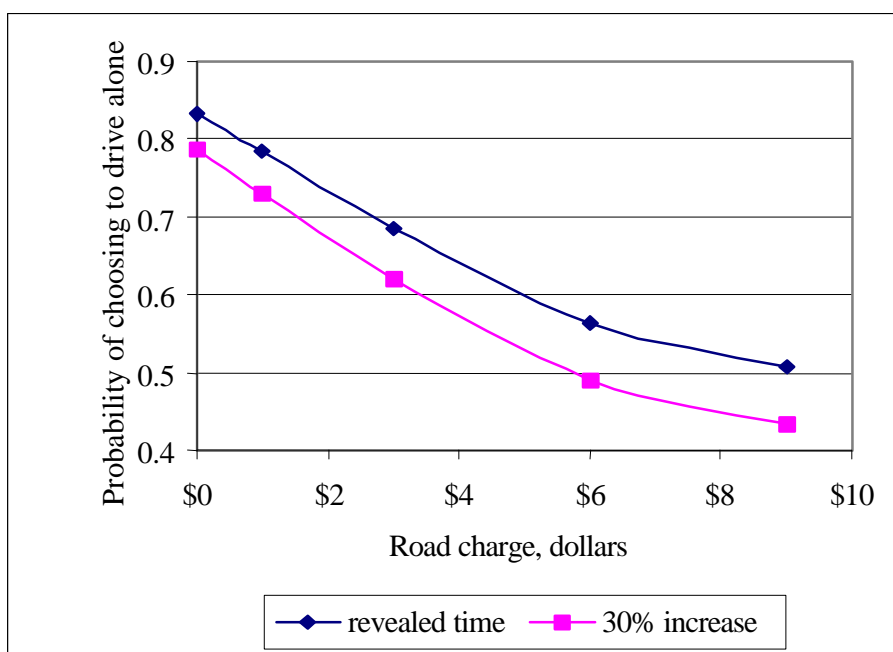


Figure 12 shows that a 30 percent increase in drive alone travel time leads to approximately a 5 percent decrease in drive alone choice probability over the range of road charges tested. The figure also shows how the non-linear influence of road charges on the probability of choosing to drive alone causes the probability to decline less quickly as road charges increase above \$6.00.

*Combining improvements to alternatives and disincentives for SOV use to reduce SOV demand*

It will be useful to briefly compare the effects that changes in drive alone attributes have on drive alone demand with the effect that changes in bus attributes were shown to have on drive alone demand. Figure 9 showed that a decrease in bus in-vehicle time from base case levels to 30 percent less than drive alone in-vehicle time reduced drive alone choice probability by only 3 percent. As shown in Table 23, this is equivalent to introducing a \$1.00 road charge on the drive alone choice while holding all other attributes steady. Clearly, relatively small increases in drive alone cost attributes will have a greater effect on drive alone market share than large decreases in express bus time attributes. A comparison between drive alone costs and carpool time improvements draws a similar conclusion, although the effects of changes in carpool attributes on drive alone demand are somewhat larger. Similar results were reported in a literature review by Apogee Research (cited in Litman 1999) which estimated that SOV demand could be reduced 5 percent with road pricing (at \$0.15 US per mile), 3 percent with parking pricing (no pricing level provided), 1.4 percent with HOV

lanes, and 1 percent with transit improvements. Used alone, drive alone pricing disincentives have a greater potential to reduce drive alone demand than transit or carpool use incentives.<sup>34</sup>

However, reductions in SOV demand can also be obtained at lower pricing levels if improvements are simultaneously made to carpool and transit alternatives. This approach would not introduce such high costs for commuters and would simultaneously provide them with alternative travel choices. Such a combination of policies will create less hardship for low income commuters while increasing mobility and access equity for all. Table 24 below shows the effect of various combinations of policy interventions on total (SOV and HOV) commuter vehicle kilometres traveled. All attributes not varied are set to the baseline levels described in Table 14.

**Table 24. The effect of the introduction of road and parking charges and travel time changes on total (SOV and HOV) commuter vehicle kilometres traveled.**

<b>Policy intervention</b>	<b>Effect on total (SOV and HOV combined) commuter VKT</b>
\$5 (return) SOV road charge	18 percent decrease
\$5 (daily) SOV park charge	13 percent decrease
increase SOV travel time 20% above baseline	3 percent decrease
decrease HOV travel time 20% below SOV baseline	6 percent decrease
decrease express bus travel time 20% below SOV baseline	2 percent decrease
\$5 (return) SOV road charge and 20% decrease in HOV and Express bus travel times below SOV baseline	29 percent decrease
\$5(daily) SOV park charge and 20% decrease in HOV and Express bus travel times below SOV baseline	24 percent decrease
\$2(return) SOV road charge, 10% increase in SOV travel time, 10% decrease in HOV and express bus travel times	18 percent decrease

The results in Table 24 are meant to provide a general comparison of the effects of different combinations of interventions, not a precise estimate of effects on VKT. This comparison assumes that improved alternatives are available, that all commuter SOV travel can be charged for road use and parking, that all carpoolers can find ride matches, and that average HOV occupancy is two and a

<sup>34</sup> These results may contradict results reported in earlier transit usage and attitude survey research, which asked respondents to rate the likelihood that changes to transit and travel factors would motivate them to switch from driving alone to taking transit. The survey reported that increased parking, gas or insurance costs were much less likely to increase transit usage than improvements to transit travel time or service frequency; unfortunately the summary presentation of these results does not indicate if the question referred to travel for all purposes or for commuting only (Angus Reid 1994 reported in Viewpoints Research 1995). These contradictory results highlight the difficulty in using opinion polls to estimate consumer responses to policy changes. The absence of realistic choices in survey questions makes it difficult to determine the possible behavioural responses to increased costs. The stated preference results described in this study indicate that



half persons per vehicle. The table shows that a \$5.00 road charge, when combined with travel time decreases of 20% for transit and carpooling, results in a reduction of total VKT that is 10 percentage points greater than that achieved by introducing the \$5.00 road charge alone. A \$2.00 road charge combined with 10 percent travel time reduction for carpooling and transit and a 10% travel time increase for driving alone reduces total VKT by the same amount as a \$5.00 SOV road charge alone.

*Elasticities of SOV demand and total vehicle kilometres traveled in response to charges*

Finally, it will be useful to standardize these estimates of the effects of road and parking charges on commuter demand for driving alone in order to make them comparable to estimates obtained elsewhere. This can be done by presenting them as elasticities, which in this study indicate the percent change in commuter drive alone choice probability given a percent change in road or parking charges. As described earlier, changes in drive alone choice probability are equivalent to changes in market share among respondents; assuming the commuting market size is constant, they are also equivalent to changes in drive alone demand.

Statistical software can calculate average elasticities for individual respondents and aggregate these for the sample. However, given the probability distributions assumed in logistic regression, average elasticities hide a great deal of variation in the marginal effect of changes in attributes. For this reason, the elasticities presented here were estimated by a different method. Using the base case attribute values described in Table 14, drive alone probabilities were estimated with the road charge attribute first set at \$5.00 and then 1 percent higher at \$5.05, with all other attributes held steady. The same procedure was followed to estimate the change in the probability of driving alone given an increase in parking cost from \$5.00 to \$5.05. The percent changes in drive alone probability resulting from these 1 percent increases in road and parking charges provide approximate point elasticities for the average commuter represented by the base case scenario.<sup>35</sup>

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increased costs are going to encourage some commuters to switch to the next best alternative, but that alternative will likely be carpooling and not transit.

<sup>35</sup> This is analogous to computing the "shrinkage" ratio of demand, a method used to estimate elasticities from historical data (see Hirschman et. al. 1995). In real world settings computing the shrinkage ratio can result in poor elasticity estimation because of overlooked explanatory variables; in the present study this is not an issue because of the controlled choice situation. Oum et al.(1992) compared a number of elasticity estimates from revealed preference discrete choice models using aggregate data and found that they are consistently somewhat *lower* than those estimated from direct demand models using aggregate data. Conversely, they found that elasticity estimates from discrete choice models using representative cases (as in this study) consistently estimate elasticities *higher* in absolute value than elasticities estimated with direct demand models. Dunne (1984) found that elasticities estimated using representative cases were in agreement with weighted aggregate

Elasticity estimates are shown below in Table 25 for the whole sample and for several segments of the sample population. Elasticity values for the 95 percent confidence interval are shown in parentheses.<sup>36</sup>

**Table 25. Elasticities of commuter drive alone probability for \$5 drive alone road and parking charges.**

	Road Charge Elasticity	Parking Charge Elasticity
Overall results for study	-0.32 (-0.41, -0.23)	-0.30 (-0.33, -0.28)
Household income: greater than \$80,000	-0.31 (-0.40, -0.17)	-0.23 (-0.27, -0.19)
Household income: \$60,000 to \$79,000*	-0.37 (-0.53, -0.13)	-0.46 (-0.51, -0.40)
Household income: less than \$60,000*	-0.41 (-0.56, -0.18)	-0.42 (-0.46, -0.36)
Need car at work 1 day <i>per week</i> or more*	-0.15 (-0.17, -0.12)	-0.11 (-0.13, -0.09)
Need car at work 4 days <i>per month</i> or less	-0.54 (-0.65, -0.44)	-0.51 (-0.57, -0.46)

\* small sample size for these subgroups indicates results should be interpreted with caution.

Overall results for the study show that elasticities of demand for driving alone to work are -0.32 for \$5.00 return road charges and -0.30 for \$5.00 daily drive alone parking charges. In other words, a 10 percent increase in road charges or parking charges from \$5.00 to \$5.50 would lead to a decrease of approximately 3 percent in the probability that the commuter represented by the base case scenario would choose to drive alone.

Elasticities have also been estimated for several segments of the sample to give an indication how different segments of the sample population respond to changes in road and parking charges. Results for income segments shown in Table 25 indicate that a 10 percent increase in road charge would lead to a 3.1 percent decrease in the probability of choosing to drive alone for those with household incomes above \$80,000, a 3.7 percent decrease in the probability of choosing to drive alone for those with household incomes between \$60 and \$80,000, and 4.1 percent for those with incomes below \$60,000. The table also indicates that a 10 percent increase in parking costs leads to a 2.3 percent decrease in the probability of driving alone for those with household incomes above \$80,000. The decrease for those with household incomes between \$80 and \$60,000 is 4.6 percent, and below \$60,000 it is 4.2 percent. While elasticity estimates for the segments with incomes between \$60 and

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elasticities when the sample was relatively homogenous – as is the case in the present study, which only includes travelers who currently drive alone.

<sup>36</sup> Since the individual estimates of the attribute coefficients are approximately normally distributed, the 95 percent confidence interval is calculated as the standard error multiplied by 1.96. The same approach was used to calculate the confidence intervals for the segments for income greater than \$80,000 (n=251) and needing a car at work 4 days per month or less (n=336). For the remaining three segments with sample sizes smaller than 200 the confidence intervals were calculated using Student's *t*-distribution following Cramer (1998).

\$80,000 and below \$60,000 are based on small numbers of respondents and should be treated with caution, the results indicate that elasticities are highest for respondents in the middle and lower income segments of the sample, and that they may in fact peak in the middle income segment and decline again with the lower income segment.

There is evidence in support of a middle income peak in elasticities of demand for car travel in response to cost. Research has shown lower elasticities of vehicle travel with respect to fuel price for households with one vehicle compared to households with two or more vehicles (Walls et al cited in Hagler Bailly 1999a). The explanation offered for this finding is that single vehicle households have no opportunity to park one vehicle and carpool together in another as a cost saving strategy in response to increased cost of vehicle operation. Assuming that lower income households tend to have fewer cars than middle and high income households, this suggests that those with lower incomes have fewer options in how to respond to travel price increases. This conclusion is reinforced by the finding, described earlier, that lower income respondents were more likely to switch to transit than to carpooling when faced with road and parking charges for driving alone. Where transit services are not available or commuters' constraints restrict their ability to take transit, the elasticity results indicate that these individuals will continue to drive alone. This result points to an important equity concern; not only can lower income drivers less afford to pay increased costs for travel, it is also likely that they have fewer opportunities to reduce those costs by ridesharing with other household members.

Finally, elasticities are also presented in Table 25 for individuals with different levels of constraint on their ability to switch from driving alone to other modes. Individuals who said they need their cars for work one day per week or more have elasticities three to five times lower than respondents who said they need their cars for work only four days per month or less. Put another way, the greater a respondent's flexibility in choosing how to travel to work, the greater the chance they will switch to another mode if faced with increased costs for driving alone. Note that elasticity estimates for the subgroup needing a car at work one day per week or more are based on a small sample size and should be treated with caution.<sup>37</sup>

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<sup>37</sup> Twenty percent of respondents reported household incomes between \$60 and \$80,000, and 24 percent reported incomes of less than \$60,000; 34 percent of respondents reported needing their car at work one day per week or more. Question wording and total distributions can be found in the descriptive summary of survey data included in the appendix.

For all sample segments except one, the 95 percent confidence interval for road pricing elasticities were substantially larger than for parking price elasticities. This suggests that variation in commuter response to parking pricing is smaller than the variation in response to road pricing, undoubtedly because regional commuters have more experience with parking pricing than with road pricing. The road pricing confidence interval for the >\$80,000 income segment showed substantial overlap with that of the full sample. The confidence intervals for road charge elasticities for the \$60 - \$80,000 and <\$60,000 income segments were quite large and overlapped substantially, reinforcing the conclusion that results drawn from these small samples should be treated with caution. In contrast, the confidence intervals for road and parking charge elasticities for those needing their cars at work versus those not needing their cars at work showed no overlap. In addition, the confidence intervals for those needing their cars at work were quite tight for both road and parking charge elasticities, indicating that there was a homogenous response to charges among this group.

The elasticities of SOV commuting demand reported above are directly equivalent to elasticities of SOV kilometres traveled when commuting. Elasticities of total commuting kilometres traveled by all private vehicles would depend on the shift in market share from driving alone to carpooling and on carpool occupancy. As an example, given the market share outcomes predicted by the model, introducing a \$5.00 drive alone road charge would result in an elasticity of total vehicle kilometres traveled of -0.17, assuming an average two and a half person occupancy in HOV's. In other words, a 10 percent increase in drive alone road charges from \$5.00 leads to a 1.7 percent decrease in total private passenger vehicle kilometers traveled to work by commuters who presently drive alone, given an average of two and a half commuters per carpool. Note that these results assume that improved transit and carpool alternatives are available, and that those who want to carpool can find a ride match.

#### *Long term responses to the introduction of road and parking charges*

Long term commuter drive alone demand elasticities in response to the introduction of road and parking charges may differ from short term elasticities. It is possible that over the long term (a year or more), commuters may make more radical changes to their travel behaviour than simply switching modes. A follow up question to the discrete choice experiment asked respondents to rate their likelihood of making long term changes to their commuting behavior that did not involve mode switching. Responses to this question are shown on the following page in Figure 13.

**Figure 13. (Survey question 32): Assume that a road use charge of \$6 return was introduced on all passenger vehicles driven alone in the Lower Mainland and applied all day. Over the long term (next year or later) how unlikely or likely are you to make any of the following changes to how you get to work?**

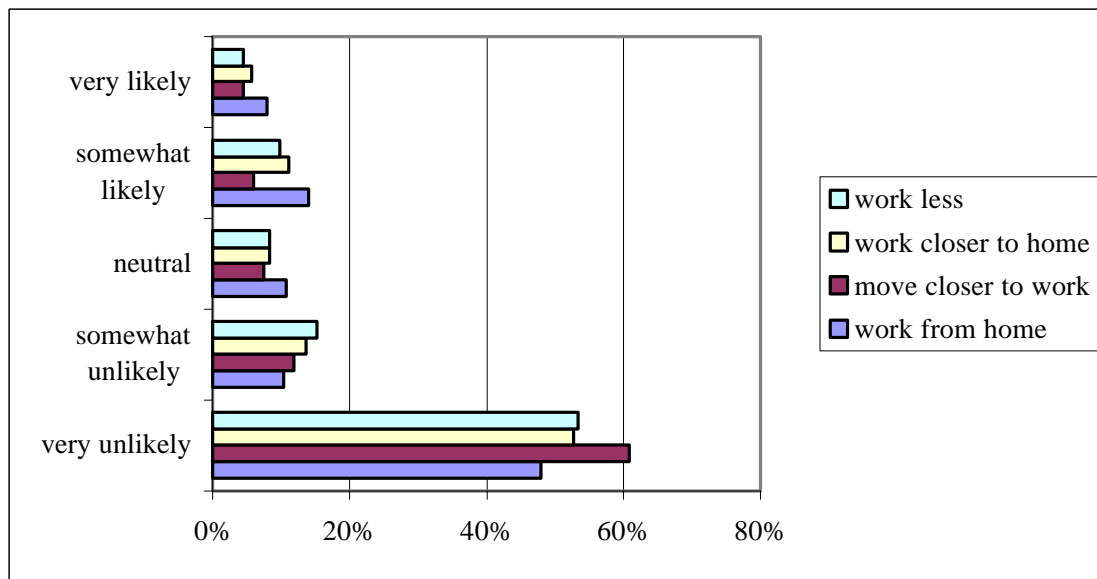


Figure 13 shows that more than 60 percent of respondents indicated that over the long term they were somewhat or very unlikely to work less, work closer to home, move closer to work, or work more from home if faced with \$6.00 return road charges. On the other hand, approximately 22 percent of respondents indicated that they would be somewhat or very likely to work from home if faced with a \$6.00 return road charge. While these preliminary results give us some indication that the majority of respondents are resistant to radical changes in their travel behaviour in response to the introduction of road charges, other individuals preparing to enter the employment and commuting markets may find the added expense of charges an inducement to make choices such as locating their home and work locations closer together, choosing a residence near a rapid transit route, or possibly avoiding the expense of a car purchase altogether. This would cause long term elasticities to be higher than those reported in the study. From a policy perspective, this suggests that a gradual introduction of charges with extensive prior marketing of coming changes will allow commuters to adapt their long term planning around their commuting mode choice and their residential and work locations with the least amount of disruption (Litman 1998a).

However, over the long term the reduced congestion resulting from marginal SOV drivers making choices such as working less or working more from home in response to the introduction of charges would undoubtedly lead to a positive rebound in demand for driving alone. This rebound could be

mitigated somewhat by gradually converting existing SOV road capacity to alternative modes (including commuter rail) as charges are introduced, so that overall SOV volume to capacity ratios are maintained. Clearly, long term responses to road charges would be complex, but it is reasonable to expect that over the long term elasticities of demand for the drive alone mode for the commute to work would be somewhat higher than those reported in this study.<sup>38</sup>

*Comparison of estimated elasticities to other research results*

Table 26 on the following page compares the elasticity results from the present study to estimates of elasticities for fuel costs, road charges and parking charges obtained in a variety of other studies. Note that the activity or demand for which elasticities are reported differs from study to study.

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<sup>38</sup> Since this study did not include commuters with travel times of less than 20 minutes, it did not present walk or bicycle choices in the discrete choice experiment. However, if road charges were applied throughout the region, it is likely that some commuters – especially those travelling shorter distances and not having to travel over major bridges or through tunnels – would switch to walking or biking. Encouraging adoption of these alternatives would also require investment in the appropriate infrastructure.

**Table 26. Comparison of study results to own-price elasticities reported in other research.**

Cost	Elasticity		Response variable for which elasticity is reported
	Short term	Long term	
<b>Present study</b>			
Road price	-.32 (-.41, -.23)		Drive alone commuting demand at \$5 road charge (return) with improved alternatives available
Parking price	-.30 (-.33, -.28)		Drive alone commuting demand at \$5 parking charge with improved alternatives available
<b>Other studies</b>			
Fuel price	-.23 to -.28		"Auto use" (empirical study) <sub>1</sub>
	-.16	-.33	"Traffic levels" (summary of studies) <sub>2</sub>
Parking price	-.16		Auto travel demand - downtown commute (empirical studies) <sub>3</sub>
	-.15		VKT in Canadian urban regions (assumption of NRTEE) <sub>4</sub>
	-1.0		VKT in Canadian downtown cores (assumption of NRTEE) <sub>4</sub>
	-.05 to -.30		Drive alone commuting demand (empirical studies) <sub>5</sub>
	-.20 to -.32		Drive alone commuting demand with respect to employer parking rate increases (empirical studies) <sub>4</sub>
Road price	-.2		VKT (assumption of NRTEE) <sub>4</sub>
	-.2 to -.33		VKT (based on review of economic literature and other studies) <sub>1</sub>
	-.1 to -.4		"Vehicle use" (summary of studies) <sub>6</sub>
	-.32 to -.36		Auto travel demand for downtown commute (modeling studies) <sub>3</sub>
	-.1		Auto travel demand (modeling study) <sub>7</sub>
		-.2 to -.9	"Auto use" (estimate) <sub>8</sub>

1. Hagler Bailly 1999b

2. Goodwin P.B. 1992

3. Decorla-Souza et al.

4. Delcan et al. 1999 (NRTEE refers to the National Roundtable on the Environment and the Economy)

5. Litman et al. 1998b

6. Litman 2001

7. Hirschman et al. 1995

8. Garling et al. 1998

To summarize Table 26, study estimates of elasticities of demand for driving alone to work in response to \$5.00 road charges (representing a \$2.50 charge each way) fall within the range of elasticities of demand for automobile commuting in response to similar charges reported in several other studies, with the confidence limits for the current study's elasticity estimates generally bounding the estimates of the other studies. The estimates of elasticities in response to \$5.00 daily parking charges correspond well with results from studies which specifically examined drive alone

commuting elasticities in response to parking charges. This indicates that the short term response of drive alone commuters in the Lower Mainland to road and parking charges appears to be in line with responses reported elsewhere.

### **Discussion of uncertainty in the model predictions**

The effect of uncertainty on model results will be discussed primarily in terms of its influence on estimated elasticities, although the following discussion is equally relevant to interpretation of model coefficients, odds ratios and predicted probabilities.

#### *Sample biases*

First, sample bias will influence estimated elasticities. As described in Figure 4, the sample income distribution is skewed towards higher incomes. As the results in Table 25 show, higher income segments of the sample display lower elasticities than middle and lower income segments. Since the sample is heavily represented by high income earners it is likely that average elasticities for road and parking charges are somewhat higher for the general commuter population than those estimated by this study.

Another bias in the sample may have had the opposite effect on the estimated elasticities. As described in Figure 6, the sample appears to be somewhat under represented in terms of individuals who work shifts. It might be expected that these individuals are more constrained in their choice of travel mode than the general sample population, because they would not have access to the hypothetical express bus service late at night (the discrete choice experiment described the service as running at high frequency from six a.m. to seven p.m.), or they may not have felt safe taking transit in the late evening or early morning. As discussed earlier, individuals with constraints on their choices have lower elasticities. Adjusting for this bias in the sample would probably result in slightly lower estimates of average elasticities.

#### *The influence of available alternatives*

Second, elasticities associated with the drive alone choice will also be influenced by the availability of alternative mode choices. Although respondents were asked to assume that the hypothetical carpool and express bus improvements described in the experiment were available to them, it is likely that their choices were also influenced by their awareness of existing transit services and carpool infrastructure in their area. As their comments in open ended opinion questions in the survey showed,



many respondents were highly dissatisfied with existing transit services and bottlenecks associated with carpool lanes. As a result, respondents may have been unwilling to accept the hypothetical alternatives as realistic (given the number of comments, this appears to have been more the case with the transit alternative than with carpooling). This suggests that if improved transit and carpooling services were in fact in place more mode switching would have occurred in the experiment and estimated drive alone road and parking charge elasticities would have been higher.<sup>39</sup>

The availability of carpooling infrastructure does not mean that all those who wish to carpool will be able to form carpools. While some respondents may not have chosen carpooling in the experiment under the assumption that they could not find people with whom to carpool, others may have chosen carpooling without any consideration of the difficulty involved in forming a carpool. Model predictions of the probability of mode choice give no indication of whether or not these choices are fulfilled. The uncertainty here is associated with how successful governments, employers, other organizations and individuals will be in matching potential carpools together, and how those commuters who are unable to join carpools will respond. Assuming that not everyone who wishes to carpool can be placed in one, and that of these people some may switch to transit, whereas others will choose to continue to drive alone, elasticities in the real world will be somewhat lower than those estimated by the model.

In addition, although the discrete choice experiment instructions asked them to assume that full transit service was available, the ongoing transit strike in the GVRD in 2001 – which started just before the survey was launched – may have biased respondents against considering transit a viable choice. Many respondents included unsolicited comments stating that, in light of the strike, they considered transit an unreliable alternative. It is likely that elasticities would again be somewhat higher than those estimated in this study if a transit strike had not occurred.

#### *Political context*

Third, the regional population is presently highly sensitive to increased charges for automobile use because of the failed attempt by the regional transportation authority to introduce a vehicle levy as a funding source for transportation system improvements. Numerous respondents provided unsolicited comments on their opposition to the levy (which was under consideration at the time of the survey)

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<sup>39</sup> In fact, numerous respondents noted that if rapid transit was available between home and work they would make use of it. However, it is unrealistic that rapid transit will run from suburb to suburb in the near future.

and indicated that they consider the road and parking charges introduced in the study as yet another "tax grab." This may have led to some strategic choice behavior – for example, choosing the drive alone option in all choices – as a form of protest against these charges. However, in the absence of explicit comments about their intentions, it is impossible to judge whether cases where respondents have chosen driving alone in all choice questions simply reflect preferences or are acts of protest. Assuming some strategic choice behaviour has influenced the study results, actual unbiased elasticities would be higher.

#### *Study method biases*

Finally, biases in the study methods could also have affected the elasticities. One reviewer pointed out that the experiment did not explicitly include the time that car drivers spend looking for parking and walking from parking to their workplace. While respondents were asked to keep this time in mind as they made their choices, its absence as an explicit attribute may have biased presentation of the alternatives in favour of both the drive alone and carpool choices over the express bus choice. However, as analysis of the attributes showed, time changes had a relatively small effect on the probability of mode choice. In addition, more than 75 percent of study respondents reported in a survey question that they spend no time looking for parking when they get to work. Removing this presentation bias from the study would at best result in only a minor increase in elasticities.

More generally, research comparing elasticities estimated with discrete choice experiments using the representative case method, as in this study, to elasticities estimated with direct demand studies has concluded that the discrete choice/representative case approach generally produces higher estimates than the direct demand approach. In the present study it is assumed that the relatively homogenous sample of drive alone commuters mitigates this effect somewhat, but use of the method may still have over estimated elasticities to some extent.

### Summary

Table 27 below summarizes this discussion of possible sources of elasticity biases in the study.

**Table 27. Summary of effects of bias on study elasticity estimates.**

Possible source of bias	Effect on elasticity if bias removed
sample biased to high income	elasticities increase +
sample biased against shift work	elasticities decrease -
existing alternative modes perform poorly	elasticities increase +
every commuter who chooses carpooling is assumed to find a ride	elasticities decrease -
transit strike	elasticities increase +
strategic anti-charge behaviour	elasticities increase +
drive alone parking time costs excluded	elasticities increase +
over estimation of elasticities by discrete choice experiments using representative cases	elasticities decrease -

While it is not possible to explicitly quantify the effects of these biases, Table 27 suggests that the overall effect on the study is to slightly underestimate elasticities of demand for driving alone to work in response to road and parking charges. In any case, as Table 26 showed, the elasticity estimates obtained in this study are quite comparable to those obtained elsewhere.

Generally speaking, the confidence intervals for parking charge elasticities were smaller than those for road charge elasticities, indicating that the point estimates of parking price elasticities are more certain than those for road pricing elasticities. The confidence intervals for road pricing elasticities were quite large for lower income segments, indicating that while income segmentation results in a shift in point estimates of elasticities, those estimates are somewhat less certain than estimates for the full sample. In contrast, the confidence intervals for both road and parking charge elasticities were quite tight for those needing their cars at work, indicating that there was a homogenous response to charges among this group and that its elasticity estimates are relatively certain.

Finally, estimates of the effect of road and parking charges on mode share and total VKT for all trip purposes contains an element of uncertainty associated with the nature and extent of the pricing network and the amount of drive alone traffic that can actually be presented with road and parking charges. For simplicity, this research has assumed that all commuter traffic with a travel time greater than 20 minutes could be charged for road use and parking. Other research in Canada has assumed that 20% of total traffic could be charged for road use and parking, either because this represents an estimate of the percent of regional travel on limited access highways (where road charges could be

most easily applied), or because it represents the commuter portion of total trips<sup>40</sup> (see Hagler Bailly 1999a, Delcan et al 1999). In Greater Vancouver, the network of limited access highways is relatively small, so estimating the percent of total traffic that can be presented with road charges will require a careful consideration of the siting of pricing cordons. Developing a commuter parking pricing strategy that ensures all commuters pay for parking at work would be somewhat more straightforward. Issues associated with effectively charging commuter traffic for road use and parking are discussed in more detail in the following section.

## 4. Implementation considerations

### **General issues around the implementation of road and parking pricing:**<sup>41</sup>

#### *The need to provide alternatives travel choices in advance*

Governments must provide high quality, flexible alternatives with high capacity (including walking and cycling as well as bus and carpool infrastructure) before they attempt to reduce demand for driving alone. If pricing were introduced, there would be immense public frustration if large numbers of travelers switched to transit only to find that overcrowded buses were passing them by, or if they joined carpools only to be stuck in congested traffic. As the study results showed, a small reduction in market share from driving alone can lead to a huge increase in demand for transit capacity. This points to the need for governments to invest heavily in alternative infrastructure, in advance of the introduction of pricing, if they are to provide travelers with high quality, alternative commuting modes. On the regional level, this will require that TransLink have sufficient annual revenue to support both its existing operating costs and the capital costs of improving carpooling and transit infrastructure. Governments can reduce their investment burden somewhat by encouraging voluntary actions by employers and employees such as the development of rideshare, trip reduction, telecommuting, and flextime programs (Litman 2001, Transportation Table 1999).

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<sup>40</sup> In Greater Vancouver, commuter and post secondary school trips together accounted for 35 percent of all trips in 1999 (TransLink 2001a).

<sup>41</sup> The Transportation Table reports of the National Climate Change Process (see Delcan et al 1999 and Hagler Bailly Ltd 1999a) and the reports of the Greater Vancouver Transportation Demand Management Project (GVRD 1996b, 1996c) provide additional discussion of issues surrounding the implementation of road and parking pricing. The Smart Growth Toolkit (Smart Growth BC 2001) provides examples of the land use policies necessary to compliment these transportation demand management measures described in this study.

*The need to coordinate policies under one management authority*

All policies that influence transportation demand – such as those addressing land use, the economy and taxation, and social marketing – need to be coordinated if this demand is to be effectively managed. Ideally, these responsibilities would be brought together under one managing authority at the regional level.

*Social and economic impacts of pricing*

By far the most widely held concern about road and parking pricing is its effect on user equity. Any situation where all users pay the same cost for necessities will be somewhat regressive, in that those with lower incomes will pay a greater share of their overall wealth for the same service. The appropriate response to this legitimate problem is to first get the prices right by removing subsidies and incorporating externalities into the costs charged for automobile use, and then to address resulting issues of regressiveness through some form of redistribution. Possible methods to increase user equity include providing income-based road and parking charge rebates or a commute trip tax credit similar to the GST rebate, or providing an income-based allotment of a base number of free trips to residents on an annual basis (Hagler Bailly 1999a, GVRD 1993c). Through careful management of revenues and costs, such programs could be funded through revenues generated by the introduction of charges. Other taxes (such as taxes on income) should not be reduced as a response to the introduction of road and parking pricing until it is clear that all the subsidies and externality costs of auto use are accounted for in the pricing levels.

It is also important to note that for society in general there is an increase in equity from introducing road and parking pricing to pay for the costs of automobile use, because only those who use the system are paying for it. Increasing the availability of transportation alternatives such as transit will also increase mobility equity for those without vehicles (GVRD 1996a, Litman 1998a).

Another concern about the introduction of road and parking pricing is that these costs will reduce the region's competitiveness with other areas. While it is possible that road pricing will increase the costs of goods as subsidies are removed and externalities are incorporated into the costs of goods movement, it is also likely that lower travel demand will result in reduced congestion and time savings for goods movement. This will increase the region's competitiveness as a gateway for the movement of goods (Hagler Bailly 1999a, GVRD 1996b).

More generally, the introduction of road and parking pricing will reduce the need for government to draw from general revenues to pay for transportation infrastructure. Road and parking pricing will involve relatively high administration, monitoring, enforcement, infrastructure, and public education costs; however, researchers have estimated that these costs range from 5 to 30 percent of revenue (see for instance Environment Canada 1995, GVRD 1996a, Hagler Bailly 1999a), indicating that pricing programs can operate with full cost recovery.<sup>42</sup>

### **Implementing employee parking pricing**

*The need for a comprehensive, region wide approach*<sup>43</sup>

Parking management needs to be uniformly applied across the region so that commuters are not able to simply switch to free parking when faced with a parking charge, and so that different areas of the region are not treated unfairly or attempt to obtain cost advantages to attract businesses and residents. To ensure this uniform management, there must be a comprehensive regional strategy for the pricing and supply of parking which coordinates actions by municipal and regional governments (Hagler Bailly 1999a). An important constraint to effectively managing parking pricing and supply is that employee parking is predominantly privately owned and operated. Appropriate regulatory and taxation mechanisms need to be put in place so that governments can effectively manage the price and supply of private employee parking (GVRD 1996b).

*Methods for managing parking supply*

Once pricing is introduced, effort needs to be taken to avoid spillover from employee parking into residential and retail parking. Such efforts should include:

- expanding metered parking on streets, setting relatively short time limits for this parking (i.e. two hours), and where necessary enforcing these limits 24 hours day;
- expanding and enforcing residential parking permit areas;
- reducing the development of temporary parking (presently 30 percent of downtown Vancouver's parking supply is located on temporarily vacant lots); and

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<sup>42</sup> Hagler Bailly (1999a) and Delcan et al (1999) provide further discussion of the costs and economic transfers associated with the introduction of road pricing policies.

<sup>43</sup> Note that the following section only discusses issues surrounding the implementation of demand management pricing for employee parking and long term (i.e. all day) parking at commercial lots, although the same considerations would generally apply for the introduction of pricing for demand management at post secondary institutions. Parking for other trip purposes, such as personal business or shopping, is generally shorter term and its management for demand reduction has additional implications for retail and commercial activities that are not addressed in this report.

- encouraging enforcement of existing time limits for retail parking at shopping malls (GVRD 1996a).

Additional measures can be undertaken to reduce the oversupply of parking throughout the region. These include:

- setting maximum, not minimum, parking requirements for new buildings and developments;
- removing municipal act regulations which require that money paid by developers in lieu of parking capacity in new buildings be used by municipalities for building parking off-site (Raad 2002); and
- further reducing parking requirements for new buildings and developments if they integrate TDM and trip reduction programs (such as the bulk purchase of bus passes for building tenants, or the establishment of guaranteed ride home programs for transit users and carpoolers) and remove parking incentives such as reserved stalls and long term payment options.

*Methods to increase parking pricing and send clear price signals to commuters*

Governments managing transportation need the authority to introduce taxes to ensure that employee parking is priced. TransLink has been provided with such authority in its enabling legislation, but there are obstacles to the introduction of a region wide tax on employee parking stalls. For instance, contracts between employers and employees may include provisions for free parking (Raad 2002). These issues need to be addressed before uniform, region-wide policies can be introduced.

Municipal public lots throughout the region should all charge consistent prices. Prices should be graduated in order to emphasize short term parking and reduce demand for long term commuter parking. In addition, governments should ensure that taxes paid by private commercial parking lots are also graduated to emphasize short term over all day parking (GVRD 1993c).

Finally, parking pricing should be administered in such a way that it sends a strong signal to commuters about the costs they are incurring. Simply requiring commuters to pay rather than park for free is first step. However, paying for parking on a monthly or yearly basis, while convenient, will not send a sufficient signal to most drivers to influence their behaviour. Also, once someone has paid a substantial amount of money into parking up front, there is a perverse incentive to drive more to maximize the benefit of that sunk cost. For these reasons, daily payment for parking will be most appropriate method for reducing demand. If possible, governments should regulate payment methods

to eliminate long term options. It might be appropriate to allow developers to reduce parking requirements in new buildings if they agree to only allow parking to be purchased on a daily basis. In addition, the federal government should ensure enforcement of existing tax laws which recognize free employee parking as a taxable benefit. This will help ensure that price signals are received directly by commuters when pricing is introduced.

### **Implementing region wide road pricing**

#### *Estimating the effect of pricing on SOV demand for all trip purposes*

Commuting to work is one of the most constrained travel activities; when estimating the full effect of road pricing on SOV travel demand for all trip purposes, additional travel choices will need to be considered. These choices include: the decision to travel or not travel at all, the time of travel, travel routes, and travel destinations. The effect of charges on demand for travel in general will be more complex than the effect on commuter demand and may also vary by market segment or specific user groups. All of these issues will need to be considered carefully when developing a charging program. As with commuter demand, there will be some take back or rebound congestion as system users adapt to reduced congestion resulting from the introduction of charges. Some researchers suggest this rebound in demand may be as high as 20 percent (Hagler Bailly 1999a).

#### *Sending drivers an appropriate pricing signal*

A key to using road pricing as a demand management tool is developing an effective method for charging drivers for road use; receiving a bill in the mail for the last month's driving will not provide travelers with a strong signal about those costs. The most effective method of pricing will be one where the driver is confronted immediately with the costs of driving. Such a signal can be sent using a system of debit cards and in-vehicle transponders which audibly signal that a charge has been deducted and provide visible read-outs of the cost as the vehicle passes a road system charging point. Debit cards would function in manner similar to photocopy or telephone cards; drivers could add value to their card or purchase new cards at locations such as gas stations or convenience stores, and the action of adding value to the card would also help to reinforce the cost of driving. Charging systems with these features are presently in use in numerous regions of the world.<sup>44</sup>

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<sup>44</sup> Vehicles without credit on their debit cards or without transponders could either have their licenses photographed for billing through the mail or could be directed to tolling booths for manual payment. Hagler Bailly (1999a) notes that it will be important to develop continental standards for transponder technology so that long haul carriers of goods can travel seamlessly between jurisdictions.



While charging for road use with debit cards and in-vehicle transponders can be done anonymously, incorporating the identification of individual vehicles into the charging system would allow the price charged to be more efficiently linked to the costs generated by individual vehicles, or the situation of individual vehicle drivers. Such identification is possible with existing technology and is currently used in systems where the vehicle is identified by the charging system and drivers are sent a monthly bill for road use. Incorporating the issuing and administration of vehicle transponders into existing procedures such as insurance renewal and emissions testing would allow vehicles and their owners to be identified as belonging to different charging rate groups and their transponders to be calibrated accordingly. This identification would enable the application of more sophisticated policies, such as:

- tailoring charges to vehicle emissions classes or emissions performance (cars polluting more could be charged more on a per kilometer or per trip basis);
- setting limits on the number of times per day that a vehicle could be charged;
- varying charges for commercial or private vehicles; and
- varying charges based on the vehicle owner's income level.

There are obvious administrative and privacy issues that would need to be sorted out in such a system, but the advantages of more precise charging for costs and the ability to vary charges by user class make it worthy of consideration.

It is also possible to create a pricing structure with rates that differ according to changes in external costs – for example, setting higher toll levels for peak travel periods when congestion is normally greatest, or setting higher toll levels for the summer months when ozone production is most likely (and when fair weather makes alternative travel modes more attractive). However, time of day or season of year changes to tolls must be clear and consistent and scheduled in advance. Given pricing policies outlined in this study – all day charges without untolled alternatives – it would be unfair to raise charges abruptly during the day in response to specific incidents of increased congestion or periods of ozone smog after the decision to travel and the choice of mode are already made.

Finally, the federal government should proactively revise tax legislation to recognize the reimbursement of road charges by employers as a taxable employee benefit, and it should subsequently enforce this change when road charges are introduced.

*Developing an appropriate charging network*

Effective use of road charges as a demand reduction tool requires that a large percentage of vehicle trips be presented with charges. In order to ensure fairness to all drivers and to avoid traffic distortions resulting from drivers travelling longer distances to avoid tolls, it is important that there be few untolled alternatives available. The two feasible systems available for charging for road use are facility pricing – where vehicles are charged for use of individual roads or sections of road – and cordon pricing – where vehicles are charged to cross a boundary, often in the form of a ring which completely surrounds an area.<sup>45</sup>

Cordons are the best choice for region wide demand reduction pricing because they can avoid some of the infrastructure and logistical problems associated with facility pricing. Facility pricing requires extensive investment in limiting access to existing arterial roads and establishing charging systems at each access point in order to prevent drivers from simply diverting onto uncharged roads. In addition to high implementation costs, there would be serious livability impacts associated with converting Greater Vancouver's existing road network into a system of de facto freeways.

The extensive system of water crossings in the Lower Mainland lend themselves to development of at least one cordon around the Burrard peninsula. Such a cordon would only need to develop infrastructure to limit access to the gridded street network along the eastern edge of the cordon where there are no water crossings. Of course, additional cordons inside and outside the Burrard peninsula would also be needed to ensure that a sizeable percentage of regional traffic was charged. The size and number of cordons will determine the number of trips inside each ring that do not pass a cordon and are uncharged. Careful analysis of the location and route of vehicle trips and trends in traffic patterns will need to be conducted with traffic flow and demographic models in order to ensure that cordons can be effective at presenting a majority of auto trips with a charge for road use. Livability issues associated with limiting access through the street network could be addressed in part through careful traffic calming of residential streets near the cordon.

*Social and economic impacts of road pricing*

Pricing cordons have several possible negative impacts. First, they have the potential to perversely

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<sup>45</sup> This discussion sets aside consideration of more complex pricing methods, such as continuous tracking of vehicle use with transponders and global positioning satellites, and those methods where the price signal is not delivered immediately, such as charging annually for road use based on yearly odometer readings.

effect land use patterns; it is unclear whether on balance cordons will reduce sprawl, by encouraging compact development inside the cordon as drivers and businesses seek to avoid tolls, or increase sprawl by encouraging the flight of jobs, housing, and auto-oriented “big box” retail outside the cordon (Hagler Bailly 1999a). This highlights the importance of managing and predicting land use in coordination with the management of transportation demand in order to avoid unexpected or counterproductive outcomes.

In addition, governments introducing pricing cordons – as with any pricing system – will have to address issues of user inequity arising from the location of the cordon (such as the inequity between drivers who live inside a cordon and never cross it but drive extensively, and drivers who live close to a cordon and cross it repeatedly but only travel short distances). It will also be important to monitor changes in traffic patterns resulting from the introduction of cordons in order to control the effects of traffic diversion and spillover on neighbourhoods.

More generally, although the use of electronic charging systems that identify vehicles provide important advantages for tailoring prices, they also create legitimate privacy concerns around the ability of governments to monitor vehicle movements. Introduction of such charging systems should be preceded by the enactment of legislated controls on use of vehicle identification data, including the length of time such data can be stored. Such legislation should include provisions for independent monitoring of the ongoing protection of privacy.

### **Issues to consider when introducing pricing policies to the public**

Clearly, public support must be established in advance of the introduction of such dramatic changes to how we pay for automobile use. Travelers need to be consulted about paying directly for something they now widely assume to get for free, and this should involve a broad public discussion about the externality costs to society and the environment of automobile use, and the extent of current subsidies for this use. Research has shown that the public is more likely to support the introduction of pricing policies if programs are simple, if they are introduced gradually, if they address clear and supportable goals (such as reducing the need to increase taxes, reducing congestion, or improving air quality and livability), and most importantly, if revenue goes to transportation system improvements – including providing improvements to alternatives (Hagler Bailly 1999a; Viewpoints 1996b, 1993b). In addition, key stakeholders such as the Port Authority, the Airport Authority, the Trucking

Association and the Chamber of Commerce need to be brought on side before introduction of these policies.

There are several important actions that government should not undertake if it is considering introducing road charges, because these actions will not help to prepare the public for full cost pricing for demand reduction. Governments should not introduce the concept of road pricing to the region through the development of High Occupancy Toll (HOT) lanes, where SOV drivers can pay a toll to use existing unused capacity in HOV lanes<sup>46</sup>. While HOT lanes might seem to be an intermediate step to full pricing, they do not address the issue of paying full costs for existing use, they appear to be regressive to those commuters who have already switched to carpooling or transit, and they will need to be reversed later when demand for alternative capacity increases. Likewise, governments should not introduce road pricing to the region through the high profile roll out of new road construction projects with tolls for cost recovery. While users should pay the costs of road construction, they should not receive the message that road tolls are associated only with new roads or increased capacity. At the very least, where tolls are used to pay for new road or bridge construction, there should be no promise that the tolls will be removed once the construction costs are fully paid. In addition, governments should not allow the construction of private toll roads or enter into public-private partnerships that provide private companies with a contractual right to collect tolls. Such roads will be managed for revenue generation, not demand reduction, and the region will lose an important policy lever for managing road traffic. Finally, government should not provide a free alternative to priced facilities. This is simply congestion pricing, and again sends out the signal that road tolls are paid to get something new (reduced congestion) rather than to pay for costs drivers are already incurring.

There is public support for strong action on Greater Vancouver's transportation problems. In numerous surveys residents consistently indicate that traffic congestion is the biggest problem in the region (Ipsos Reid 2002; TransLink 2001b; Viewpoints 1996a, 1993a). When asked forced-choice questions about how users should pay for transportation, regional residents consistently pick bridge or highway tolls as the first choice. (TransLink 2001b; TransLink 2000d; Viewpoints 1995, 1993a). Some opinion research into methods to pay for transportation system improvements has shown support for the concept of road tolls as high as 64 percent (Viewpoints 1995), and support for parking surcharges as high as 56 percent (Viewpoints 1995, Dawson 1995). More generally, survey research

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<sup>46</sup> Litman (2001) describes the use of HOT lanes on Interstate 15 in San Diego.

also shows a public willingness to pay a personal price to maintain a healthy environment. In the current study over 65 percent of respondents agreed with the statement “I’ll spend more to get ‘environmentally friendly’ products,” and less than 10 percent agreed with the statement “I’m not willing to go out of the way to change how I do things to help the environment.” Effective consultation with the public on their transportation concerns, open dialogue about the environmental costs of automobile use, and careful introduction of pricing policies with clear goals and transparent uses of revenue would go a long way towards ensuring that public support for action on transportation issues is maintained and strengthened.

## **5. Summary and conclusions**

### **The importance of time and cost attributes in commuter mode choice**

As one would expect, an increase in any of the mode time or cost attributes reduced the odds of that mode being chosen for the commute to work. Increases in drive alone road and parking charges had the largest effect on the odds of choosing to drive alone. Results suggest that some respondents with higher incomes were willing to pay high road charges to drive alone if it meant less traffic and shorter travel times.

Respondents perceived increases in drive alone in-vehicle time less negatively than increases in carpool or transit in-vehicle time. This is not surprising, given that all respondents currently drive alone, and that all rated driving alone higher in terms of comfort and making use of travel time. Increases in bus wait time and time spent picking up other carpoolers were perceived even more negatively than increases in in-vehicle time for those modes, probably because they represented an addition to travel time that did not contribute directly to getting to work. Perception of the two carpool time attributes worsened as those times increased, indicating that respondents were intolerant of spending long periods of time with others in a carpool. Generally speaking, these results suggest that at moderate travel times carpooling was seen as a more attractive alternative than transit to driving alone, but at longer trip lengths both choices were seen as poor alternatives to driving alone.

The response to the final bus attribute, "travel from express bus to work," showed that the odds of respondents choosing to take the express bus to work went down considerably if they had to transfer to a local bus to continue to work after traveling on the express service. The model showed a similar response to having to take a local bus from home to reach the transit exchange. However, these

results do not mean that respondents would enjoy walking to or from the express bus; their comments and the findings of other research suggest that they see it simply as the lesser of the two inconveniences.

The values obtained for the drive alone and carpool constants indicate that these two modes are generally preferred over transit for the commute to work. Respondent ratings of the three modes on a number of qualitative features reinforced this finding and generally supported the values obtained for the attribute coefficients. For instance, carpooling and driving alone both scored more highly than transit on safety from crime, on convenience, and on reliability.

### **The effect of available alternatives on demand for driving alone**

Market share predictions from the model showed that transit was an unattractive commuting option for most respondents: even an express bus travel time advantage of 30 percent over driving alone, minimal transfer requirements, and short wait times resulted in only a 4 percent shift in market share between the two modes. In addition, the results showed that high frequency of service (represented by short wait times for buses) and efficient connections (represented by short wait times and minimal transfers) were just as important as competitive in-vehicle travel times in predicting transit market share. However, even given highly efficient express bus services, commuters must still travel from home to the express bus exchange and from an express bus stop to work, which lessens the services competitiveness with driving alone.

The competitive disadvantages of transit could be lessened somewhat if governments provide services and facilities to make the use of an express bus as convenient as possible. For example, based on respondent comments and research done elsewhere, features that would improve access in the home community could include:

- providing accessible, real time information on the arrival of buses to your nearest bus stop;
- locating transit exchanges as close to residential neighbourhoods as possible;
- developing well lit, direct pedestrian pathways and safe bike routes to exchanges;
- providing secure bike storage at exchanges, and bike racks on buses;
- establishing dial-a-ride feeder bus services and the ability to request stops near your home; and
- incorporating convenient park and ride lots and drop off lanes at transit exchanges.

Model market share predictions showed that carpooling was somewhat more attractive to respondents than transit as an alternative to driving alone: a 30 percent in-vehicle travel time advantage for carpooling, short pick up times and free parking led to a 10 percent shift in market share from driving alone to carpooling. This finding suggests that, for suburban commuters especially, policies which aim to provide options to driving alone in order to encourage mode switching should emphasize carpooling over transit as an alternative to the SOV. Given that the regional trend in land use is for more dispersed suburban employment and that suburb to suburb trips have generally been increasing at a faster rate than suburb to core trips, the importance of carpooling as an competitive alternative to driving alone will only increase. Based on the comments of survey respondents and research conducted elsewhere, ways to improve carpooling competitiveness could include:

- expanding the network of HOV lanes in the region,
- expanded ride matching programs,
- reducing HOV occupancy requirements to two people, and
- supporting employer provided ridesharing services.

Perhaps most importantly, considerable effort should be put into expanding and promoting ride matching services in order to ensure that those individuals who choose to carpool are able to find others with whom to carpool. The results for the base case scenario suggest that there may be a number of commuters who presently travel alone who would carpool *right now*, without any further incentives or disincentives in place, if they could find others with whom to do so.

It is worth noting that some drive alone commuters traveling shorter distances may choose to switch to walking or riding a bicycle if road or parking charges were introduced. Encouraging switching to these alternatives would also require investment in appropriate infrastructure such as well lit sidewalks and dedicated bike lanes.

### **The effect of economic instruments on demand for driving alone**

Improvements to transit and carpooling alone will not have a significant effect on demand for travel by SOV. The market share predictions for transit and carpooling improvements shown above suggest that, in addition to providing competitive alternatives to driving alone, it will also be necessary for government to provide strong disincentives to the use of SOV's if demand for driving alone is to be reduced. Market share predictions for the effects of road and parking charges showed that a \$5.00 return trip road charge would reduce the drive alone commute to work market share among

respondents by approximately 25 percentage points and total (SOV and HOV) kilometres traveled to work by 18 percent, assuming an HOV occupancy of 2.5. A \$5.00 parking charge would reduce the drive alone market share by approximately 20 percentage points, and total vehicle kilometres traveled by 13 percent.

Both scenarios assume the presence of improved transit and carpooling alternatives, that all those who choose to carpool can find a ride match, and that all drive alone commuters can be presented with road and parking charges during their commute. The majority of the shift in market share in each case is to carpooling.

Increases in SOV in-vehicle travel time were shown to have a much smaller negative effect on the probability of choosing to drive alone than increases in drive alone costs. If used alone as a demand management tool, travel time increases would be much less effective at shifting demand from driving alone to alternative modes and would probably cause even greater frustration among commuters than the introduction of road charges. More generally, disimprovements in drive alone attributes were shown to have a greater effect on drive alone mode choice than improvements in the attributes of alternatives. These results indicate that if only a single policy is to be introduced, a greater reduction in SOV demand can be achieved by using financial disincentives to increase the cost of SOV travel than can be achieved by using travel time incentives to make alternatives more competitive beyond a base level.

On the other hand, if policies that reduce the travel time of carpooling and transit are combined with policies that increase the cost of SOV travel, similar reductions in SOV demand can be achieved at lower road and parking charge levels. Such a policy of providing improved alternatives along with moderate increases in cost for driving alone will also be more acceptable to the commuting public, and will therefore have a better chance of being implemented successfully. Revenue generated from introducing road and parking charges can be used to pay for improvements to alternatives. However, those alternatives will need to be put in place first, meaning that governments will be required to borrow money for transportation infrastructure investment. Revenue from road and parking charges can also be used to address equity issues arising from lower income commuters having to pay a larger share of income on transportation than higher income commuters.



Over the long term (one year or more), the introduction of road or commuter parking charges would have an even greater influence on mode choice and demand for travel to work by SOV's, as commuters worked more from home, worked less, and chose home and work locations that are closer together. Assuming the demand for travel to work is less elastic than the demand for travel for other purposes, the effect on overall travel demand if road charges were introduced would likely be higher. However, mode switching responses for other kinds of trips – serving passengers to grade school, personal business, shopping and so on – may be different than those reported here for the trip to work. For some of these other purposes, travelers may find continuing to drive alone, taking transit, or not travelling at all a better response to road charges than trying to find someone with whom to carpool. In addition, the nature of the road charging network would affect different non-work trips disproportionately. For instance, regional recreation trips and shopping trips to “big box” retailers on the urban periphery may be charged, whereas local shopping trips and trips serving passengers to school may escape being charged. Individuals travelling for all purposes with trips of 30 minutes or less may choose to walk or bicycle rather than take transit or carpool if faced with road charges. In short, the long term effects of the introduction of road charges on the demand for travel, time of travel and mode choice for all purposes will be more complex than the effects on the demand for SOV travel for commuting described in this study.

Survey respondents held strong opinions on the concept of road and parking charges. Recent experience with the failed attempt to introduce an annual vehicle levy in Greater Vancouver showed that the public will oppose new costs imposed on them without adequate consultation. However, previous opinion surveys have shown that the public is willing to accept charges for use of the transportation system if those charges are introduced gradually, if they are applied in support of clear, widely accepted goals, and if the revenue collected from these charges is reinvested in the transportation system. Successful introduction of such charges on SOV's would require a careful process of building public support through a discussion of the environmental and social benefits expected to result from the charges and the uses to be made of resulting revenues.

Introducing road and parking charges for demand reduction will require coordinated action by all levels of regional government, and the development of a comprehensive management strategy that is uniformly applied throughout the region. What ever the system developed, its primary goal must be to present drivers with a strong, clear signal of the costs they are incurring through driving alone.

In summary, the results of the study show that, if introduced with a program of public consultation and preceded by investment in improvements to carpool and transit alternatives, road and parking charges could be an effective way to reduce the negative social, economic and environmental impacts of single occupant vehicle use by commuters.

## Appendix A Telephone screening survey

1. Hello. I'm calling on behalf of researchers from Simon Fraser University who are conducting a study of the commuting preferences of people who drive to work alone in the Lower Mainland. We are not selling anything. May I speak to a resident of the house who is 18 years of age or older who drives alone to work, and who might be willing to help the researchers with this study?

**Continue with respondent** – GO TO QUESTION 2 AFTER BRACKETS

**Switch to new respondent** – GO TO QUESTION 2 IN BRACKETS ( )

**Refusal** – For our own records, do you want to give a reason for not participating in the study? RECORD, THEN THANK AND TERMINATE

**Call Back** – Your procedures here Lorraine.

2. (IF NEW RESPONDENT: I'm calling on behalf of researchers from Simon Fraser University who are conducting a study of the commuting preferences of people who drive to work alone in the Lower Mainland. We are not selling anything.) The purpose of this study is to get a better understanding of commuters' travel patterns and preferences in order to improve transportation planning. Our firm has been hired to select individuals who might be willing to help with this study, and your telephone number has been randomly selected as falling within the study area. This phone discussion will take only a few minutes and is meant to determine if you follow the travel patterns that are under study, and to ask for your help with a future mail survey. The information you share will be kept confidential. You can refuse to answer at any time. If you are eligible to participate in the study, and you complete and return your survey on time, your name will be entered in a draw for a gift certificate at a Delta restaurant. May I ask you some questions on this topic?

**Yes** – GO TO Q3

**No** – Is there anyone else who lives in your home who may be willing to answer some questions on this topic?

**Yes** – GO BACK TO Q2 ( ) WITH NEW RESPONDENT

**No** – For our own records, do you want to give a reason for not participating in the study? RECORD, THEN THANK AND TERMINATE.

**Call back**

3. Do you usually drive alone to work, at least 3 weekdays per week?

**Yes** – GO TO Q4

**No** – Is there someone else who lives in your home who does drive alone to work that I could talk to?

**Yes** – GO BACK TO Q2 ( ) WITH NEW RESPONDENT

**No** – THANK AND TERMINATE

**Call back**

4. Is your trip to work at least 20 minutes one way?

**Yes** – GO TO Q5

**No** – Is there someone else who lives in your home who does drive alone to work at least 20 minutes one way that I could talk to?

**Yes** – GO BACK TO Q2 ( ) WITH NEW RESPONDENT

**No** – THANK AND TERMINATE

**Call back**

5. Next we need to confirm that you live in the communities being surveyed. Do you live in Ladner or Tsawwassen?

**Yes – GO TO Q6**

**No (moved or rural location)/Refused – THANK AND TERMINATE**

6. According to your answers, your travel patterns match those of the people that are being asked to help with this survey. The survey involves mailing out a questionnaire for you to complete at home and return to the university in a postage paid envelope. The questionnaire asks about your travel patterns and commuting preferences, and how you would travel to work if faced with different services, travel times and costs. This survey will take you approximately 30 minutes to complete, and your responses will remain confidential. Your answers are important, because they will help give us a more complete picture of peoples' commuting preferences in the Lower Mainland. If you complete and return your survey within 2 weeks, you will be entered in a draw to win a \$100 gift certificate for La Belle Auberge Restaurant in Ladner

Are you willing to participate in this study and receive a questionnaire through the mail?

**Yes – GO TO Q7**

**No – Is there someone else who lives in your household who drives alone to work for at least 20 minutes each way who might be willing to fill out the questionnaire?**

**Yes – GO BACK TO Q2 WITH NEW RESPONDENT**

**No – For our own records, do you want to give a reason for not participating in the study? RECORD, THEN THANK AND TERMINATE**

**Call back**

7. In order to customize the questionnaire to your situation, I need to ask you a few more quick questions about your travel patterns. First, I need to get your full name and home mailing address to send you the survey.

First /Last Name \_\_\_\_\_

Unit # - \_\_\_\_\_

Street # Street Name: \_\_\_\_\_

City BC Postal Code: \_\_\_\_\_

**REPEAT NAME AND ADDRESS BACK**

**IF ADDRESS DOESN'T INCLUDE STREET NAME, ASK FOR STREET NAME**

**IF ADDRESS/STREET NAME REFUSED, EXPLAIN IT'S NECESSARY TO**

**CUSTOMIZE SURVEY TO RESPONDENT'S SITUATION**

**IF STILL REFUSED, THANK AND TERMINATE**

8. On an average day, how long does your trip from home to work take, door to door, one way? Please include any time you spend looking for parking once at work.

**RECORD TIME IN HOURS AND MINUTES**

**(IF RESPONDENT GIVES A RANGE RECORD AS SUCH i.e. 30—40 minutes)**

9. Do you pay for parking at work?

**Yes – Q10**

**No – Q11**

10. How much do you pay for this parking? Over what period?

RECORD AMOUNT IN DOLLARS AND CENTS,

AND RECORD PAYMENT PERIOD

Hour

Day

Week

Month

Other Specify\_\_\_\_\_

11. What community do you drive to work in?

CHECK OFF ONE FROM THE LIST BELOW:

Abbotsford  
 Anmore  
 Belcarra  
 Burnaby  
 Coquitlam (District Municipality)  
 Ladner  
 Langley (City and District)  
 Lions Bay  
 Maple Ridge  
 New Westminster  
 North Delta  
 North Vancouver (City and District)  
 Pitt Meadows  
 Port Coquitlam  
 Port Moody  
 Richmond  
 Surrey  
 Tsawwassen  
 Vancouver  
 West Vancouver  
 Whiterock  
 Other: \_\_\_\_\_

12. Those are all the questions we need to ask for now. You should receive your copy of the Lower Mainland Commuter Preference Survey in about a week. On behalf of the research team, we thank you for your participation in this important research and appreciate if you are able to promptly complete and return the survey to Simon Fraser University.

## Appendix B Cover Letters and Postcard

### B 1 Initial cover letter

SIMON FRASER UNIVERSITY

School of Resource and  
Environmental Management

Faculty of Applied Sciences



Burnaby, British Columbia  
Canada V5A 1S6  
Telephone: (604) 291-3074  
Fax: (604) 291-4968

Dear «FIRST\_LAST\_\_NAME»:

May 28, 2001

As a follow up to our recent telephone contact, please find enclosed your copy of the Lower Mainland Commuter Preference Survey. We appreciate your help and advice with this important research.

As you are probably aware, planning for the development and funding of road and transit services are important issues that affect all residents of the Lower Mainland of B.C. The purpose of this survey is to identify how commuters like yourself make choices between driving alone and alternative carpooling or transit services when faced with changing travel times and costs for use of the road system. Your answers to this survey are important because they will help to create a more complete picture of the travel patterns, preferences and opinions of all citizens in the region.

The results of this survey will be used in transportation planning by the province of British Columbia, as well as to enhance energy use models developed at Simon Fraser University. This research is supported by funding from the British Columbia Ministry of Environment, Land and Parks; the B.C. Ministry of Transportation and Highways; Environment Canada; and the Canadian Petroleum Producers' Institute.

It will greatly assist our research if you answer all the questions as completely and accurately as possible. Please take the opportunity to provide your input on these important issues by taking about 30 minutes to fill out the survey and return it to us in the enclosed postage paid envelope. We appreciate that this request for your limited time is probably inconvenient. Please accept the attached dollar as a small token of our appreciation for your participation in this research project.

Be assured that your answers will be held confidential. All information collected through this survey will be released only in summary, and no individual answers will be identified. Your participation in this survey is entirely voluntary, and we will assume that by completing and returning this survey you are indicating your consent to participate in this research. Please note that Simon Fraser University ethical regulations require you to be 18 or older to complete this survey. If you are not 18 or older, or if you decide for some reason not to complete the survey, please return it unanswered in the enclosed envelope.

If you have any questions or concerns about this research we would be glad to talk to you. If you have specific questions or concerns about the survey please leave a message for the primary researcher, Kevin Washbrook, on the survey information line at 732-4152 or via email at [kevin\\_washbrook@hotmail.com](mailto:kevin_washbrook@hotmail.com). All messages are returned the next day. More general concerns about the research can be directed to Peter Williams, Director of the School of Resource and Environmental Management at Simon Fraser University, at 291-3103.

Thank you very much for your time. Your help with this survey is greatly appreciated.

Sincerely,  
Kevin Washbrook  
Graduate Student Researcher  
School of Resource Environmental Management, Simon Fraser University

**p.s. Remember to complete and return the survey within 2 weeks to be included in the draw for one of 2 \$100 gift certificates at La Belle Auberge Restaurant in Ladner! The survey has been coded with your name in Part 3 so that you can be included in the draw.**

## B 2 Text of follow up postcard

Dear Delta Resident:

A week ago you were sent your copy of the Lower Mainland Commuter Preference Survey. If you have already completed and returned the survey, we want to express our appreciation for your help with this research project.

If you didn't receive your copy of the survey, or if you have misplaced it, please contact us and we will send you a replacement immediately. You can leave a message by telephone on the survey line at 732-4152, or by email at kevin\_washbrook@hotmail.com. Please provide your name and address in case your 1<sup>st</sup> copy was sent to a wrong address.

If you received your survey but haven't yet completed it, we encourage you to take about 30 minutes to fill it out and mail it to us at the address indicated on its back cover. Your input will help create a more complete picture of the opinions and preferences of commuters in the Lower Mainland. **Also, if you return your survey within the week you will be included in the draw for a \$100 gift certificate at La Belle Auberge Restaurant in Ladner.**

Thank you again for your participation in this project.

Kevin Washbrook, Graduate Student Researcher, Simon Fraser University.



### B 3 Letter accompanying second survey send out

#### SIMON FRASER UNIVERSITY

School of Resource and  
Environmental Management  
  
Faculty of Applied Sciences



Burnaby, British Columbia  
Canada V5A 1S6  
Telephone: (604) 291-3074  
Fax: (604) 291-4968

Dear «name»:

May 15, 2001

About four weeks ago I sent you your personalized copy of the Lower Mainland Commuter Preference Survey. To the best of my knowledge, it hasn't been returned as of May 18<sup>th</sup>.

Residents who have already returned their surveys have responded with strong opinions on the state of our road and transit systems and how best to pay for these services in the future. As well, they have provided a wealth of information on their commuting patterns and preferences. We think that the overall results of the survey will provide a clear picture of the opinions and preferences of Lower Mainland commuters, and will be very useful for both government transportation planning and energy use research at SFU.

However, in order for the results of the survey to be truly representative of the opinions and preferences of area residents, it is important that we hear back from as many people as possible. Your opinions are important, and we want to know what you think about the questions and choices presented in the survey. By returning your survey you will help make the results of the research more accurate.

If you have any questions about the survey or research please leave a message by phone on the survey contact line at 732-4156 or by email at kevin\_washbrook@hotmail.com. Both the voice mail and email are checked daily and any messages are returned the next day.

We hope you will fill out the enclosed survey and return it, but if for any reason you prefer not to complete it, please let us know by returning the blank survey or a brief note in the enclosed stamped envelope.

Thank you for your time and assistance.

Sincerely,

Kevin Washbrook  
Primary Researcher,  
Lower Mainland Commuter Preference Study

P.S. It is important that the person who was contacted by telephone complete the enclosed survey as it has been customized around their travel time and destination.

## B 4 Letter accompanying third and final survey send out

### SIMON FRASER UNIVERSITY

School of Resource and  
Environmental Management

Faculty of Applied Sciences



Burnaby, British Columbia  
Canada V5A 1S6  
Telephone: (604) 291-3074  
Fax: (604) 291-4968

«FIRST\_LAST\_\_NAME»  
«Unit\_»«STREET\_\_STREET\_NAME\_»  
«City\_BC\_Postal\_Code»

July 16, 2001

Over the past 2 months we have sent you 2 copies of a survey we are conducting for Simon Fraser University, the Province of British Columbia, Environment Canada and the Canadian Petroleum Producers' Institute.

The survey's purpose is to identify the value that individuals place on driving alone, carpooling or taking transit to get to work, and to collect opinions and advice on how Lower Mainland transportation services should be paid for.

The study is drawing to a close, and this is the last contact that will be made with the sample of residents who were contacted by phone late May.

We are sending this final contact by express post because of our concern that people who have not yet responded may have different commuting experiences and opinions from those who have. Hearing from everyone initially contacted for this survey helps ensure that the results of the survey are as accurate as possible and reflect the whole range of opinions found in the community.

If you feel you do not qualify for the survey, are opposed to the topic, or simply do not wish to participate, it would be extremely helpful if you could return the blank survey with a brief note on the inside cover in the enclosed stamped envelope.

We appreciate your willingness to consider this last request as we attempt to better understand transportation issues in the Lower Mainland. Thank you very much.

Sincerely,

Kevin Washbrook  
Primary Researcher,  
Lower Mainland Commuter Preference Study

## **Appendix C Descriptive statistics for responses to survey questions**

See the attached excel file titled "Appendix C."

## **Appendix D Sample Survey**

See the attached word file titled “Appendix D.”

## References

- Beaton, Patrick; Hamou Meghdir and Joseph Carragher 1992 "Assessing the Effectiveness of Transportation Control Measures: Use of Stated Preference Models to Project Mode Split for Work Trips." *Transportation Research Record* No. 1346.
- Ben-Akiva, Moshe and Steven Lerman 1985 *Discrete Choice Analysis. Theory and Application to Travel Demand..* Cambridge: MIT Press.
- Bunch, David; Mark Bradley; Thomas Golob; Ryuichi Kitamura and Gareth P Occhiuzzo 1993 "Demand for clean-fuel vehicles in California: A discrete-choice stated preference pilot project." *Transportation Research A* 27A(3):237-253.
- Button Kenneth and Erik Verhoef 1998 "Introduction." *Road pricing, traffic congestion and the environment.* Kenneth Button and Erik Verhoef editors. Northampton: Elgar.
- Campbell Goodnell Traynor 1997. *BC Transit Usage and Attitude Survey.*
- City of Vancouver 1997 *Transportation Plan.* As approved by Council May 1997.
- Corporation of Delta 1999 *Community Profiles: Labour Force, Working and Commuting.* Community Planning and Development Department.
- Cramer Duncan 1998 *Fundamental Statistics for Social Research. Step-by-step calculations and computer techniques using SPSS for Windows.* New York: Routledge.
- Dawson, Catherine 1995 *Go Green research review and analysis. Final Report.*
- Decorla-Souza et al. 1992 "Peak period tolls: precepts and prospects." *Transportation* 19:293-311.
- Delcan in association with KPMG and A.K. Socio-Technical Consultants 1999 *Strategies to Reduce Greenhouse Gas Emissions from Passenger Transportation in Three Large Urban Areas.* Transportation Table of the National Climate Change Process, Report 19, 18 June 1999.
- Dillman, Don 1999 *Mail and Internet Surveys: The Tailored Design Method.* New York: J Wiley. 2<sup>nd</sup> Edition.
- Domencich Thomas and Daniel McFadden 1975 *Urban Travel Demand. A behavioral analysis.* New York: Elsevier.
- Driver B.L., Krumpel Edwin and W. Paradise 1990 *An Evaluation of Models of Human Decision Making and Their Implications for Predicting Leisure Choice Behaviour.* Research Report 45, Hunter Valley Research Foundation.

- Dunne J.P. 1984 "Elasticity Measures and Disaggregate Choice Models." *Journal of Transport Economics and Policy* 18:189-197
- Economist 1998 "Survey on Commuting." Survey Insert, Sept 5<sup>th</sup> 1998.
- Economist 1997 "Jam today, road pricing tomorrow." and "Living with the car." Dec 6<sup>th</sup> 1997.
- Engwicht David 1999 *Street Reclaiming. Creating Livable Streets and Vibrant Communities.* Gabriola Island: New Society Publishers.
- Environment Canada 2000 *Canada's Greenhouse Gas Emissions 1990-1998.* National Inventory Data Report to United Nations as part of the Framework Convention on Climate Change. ([ec.gc.ca/press/000906\\_m\\_e.htm](http://ec.gc.ca/press/000906_m_e.htm)) September 6 2000 Press Release.
- Environment Canada 1995 *Potential Economic Instrument Approaches to Air Quality Management in the GVRD.* Report of the Fraser River Action Plan.
- Ewing, Gordon 1996 *The role of user charges in reducing automobile air pollution in Canada. Final Report.* Prepared for Environment Canada, Economic Instruments for Environmental Sustainability Program.
- Ewing, Gordon and Emine Sarigollu 1998 "Car fuel-type choice under travel demand management and economic incentives." *Transportation Research D* 3(6):429-444.
- Garling et al. 1998 *Theoretical Foundations of Travel Choice Modeling.* New York: Elsevier.
- Goodwin P.B. 1992 "A review of new demand elasticities with special reference to short and long run effects of price changes." *Journal of Transport Economics and Policy* 26(2): 155-169.
- GVRD 2001 Greater Vancouver Regional District. *Key Facts 2001*  
[gvr.bc.ca/services/air/pollution/pollution.htm#sources](http://gvr.bc.ca/services/air/pollution/pollution.htm#sources)
- GVRD 2000 Greater Vancouver Regional District. *1999 Emission Inventory Update for the Lower Fraser Valley Airshed.* August 2000.
- GVRD 1998a Greater Vancouver Regional District. *Trends in Ambient Air Quality in Greater Vancouver 1987-1996.* July 1998.
- GVRD 1998b Greater Vancouver Regional District. *Air Quality Management Plan 1997 Implementation Status Report.*
- GVRD 1997 Greater Vancouver Regional District. *Greater Vancouver Screenline Survey. 1996 Vehicle Volumes, Classifications and Occupancies.* October 1997.

- GVRD 1996a Greater Vancouver Regional District. *Greater Vancouver Regional Transportation Demand Management Project: Final Report*. September 1996.
- GVRD 1996b Greater Vancouver Regional District. *Greater Vancouver Regional Transportation Demand Management Project: Appendices*. September 1996.
- GVRD 1995a Greater Vancouver Regional District. *1994 Greater Vancouver Trip Diary Reports. Report 1. Design and Conduct of the Survey*.
- GVRD 1995c Greater Vancouver Regional District. *1994 Greater Vancouver Trip Diary Reports. Report 4. Analysis and Historical Comparison of Travel Characteristics*.
- GVRD 1994a Greater Vancouver Regional District. *Clean Air Benefits and Costs in the GVRD*. Prepared for the GVRD, BC Ministry of Environment Land and Parks, and Environment Canada by ARA Consulting Group and Bovar-Concord Environmental, November 1995.
- GVRD 1994b Greater Vancouver Regional District. *1992 Greater Vancouver Travel Survey. Report 1. Design and Conduct of the Survey*.
- GVRD 1993a Greater Vancouver Regional District. *A Long-Range Transportation Plan for Greater Vancouver*. Transport 2021 Report, September 1993.
- GVRD 1993b Greater Vancouver Regional District. *Transportation Demand Management: A Forecast Modelling Approach*. Transportation 2021 Technical Report No. 3.
- GVRD 1993c Greater Vancouver Regional District. *Transportation Demand Management Measures and Their Potential for Application in Greater Vancouver*. Transportation 2021 Technical Report No. 2.
- Hagler Bailly Ltd. 1999a *The Potential of Fuel Taxes to Reduce Greenhouse Gas Emissions in Transportation*. Transportation Table of the National Climate Change Process, Analytical Study No. 3.
- Hagler Bailly Ltd. 1999b *Strategies to Reduce GHG Emissions from Passenger Transportation in Urban Canada*. Transportation Table of the National Climate Change Process, Analytical Study No. 18.
- Hirschman, Ira; C. McKnight, J Pucher, R Paaswell and J Berechman 1995 "Bridge and tunnel toll elasticities in New York. Some recent evidence." *Transportation* 22: 97-113.
- Hunt J.D. and J.D.P. McMillan 1997 "Stated Preference Examination of Attitudes Toward Carpooling to Work in Calgary." *Transportation Research Record*. No. 1598.

IPCC 2001 Intergovernmental Panel on Climate Change. *Climate Change 2001 Synthesis Report*. (ipcc.cg/pub/tar/syn/index.htm).

Ipsos-Reid 2002 *Survey of GVRD Municipal Issues*. Survey conducted January 11 2002.

KPMG Peat Marwick Stevenson & Kellogg 1993 *The cost of transporting people in the British Columbia Lower Mainland*. Report prepared for Transport 2021.

Kuppam, Arun; Ram Pendyala and Mohan Gollakoti 1998 "Stated Response Analysis of the Effectiveness of Parking Pricing Strategies for Transportation Control." *Transportation Research Record* No. 1649.

Last, John; Konia Trouton and David Pengelly. 1998 *Taking our Breath Away. The health effects of air pollution and climate change*. David Suzuki Foundation. October 1998.

Litman, Todd 2001 *Online Transportation Demand Management Encyclopaedia*. Victoria Transportation Policy Institute. [www.vtpi.org/tdm](http://www.vtpi.org/tdm).

Litman, Todd 1999 *Guide to Calculating Transportation Demand Management Benefits*. Victoria Transportation Policy Institute. March 12 1999.

Litman, Todd 1998a "Driving Out Subsidies" *Alternatives* 24(1): 36-42.

Litman, Todd; Charles Komanoff, and Douglas Howell 1998b *Road Relief. Tax and Pricing Shifts for a Fairer, Cleaner and Less Congested Transportation System in Washington State*. Energy Outreach Centre.

Louviere, Jordan; David Hensher and Joffre Swait 2000 *Stated Choice Models: analysis and applications*. New York: Cambridge University Press.

McFadden, Daniel 1974 "Conditional logit analysis of qualitative choice behavior." *Frontiers in Econometrics*. Paul Zarembka editor. New York: Academic Press.

Merkle, Thomas 1993 *"Which route to take?": A strategic assessment of BC Transit*. Simon Fraser University Thesis. Faculty of Business Administration.

MoELP 1995a Ministry of Environment, Lands and Parks. *British Columbia Greenhouse Gas Action Plan*. November 1995.

MoELP 1995b Ministry of Environment, Lands and Parks. *Clean Vehicles and Fuels for British Columbia. A Discussion Paper*.



- Oum T.H., W.G. Waters II and Jong-Say Yong 1992 "Concepts of price elasticities of transport demand and recent empirical estimates." *Journal of transport economics and policy*. 26: 139-154.
- NRC 1997 Natural Resources Canada. *Canada's Energy Outlook, 1996-2020*.
- Pampel, Fred 2000 *Logistic Regression: a primer*. Thousand Oaks: Sage Publications.
- Permain, David, Eric Kroes, Mark Bradley and John Swanson 1991 *Stated preference techniques. A guide to practice*. Steer Davies Gleave (Richmond) and Hague Consulting Group (Den Haag).
- Polak, John; Peter Jones and Petras Vythoulkas 1991 *The Trondheim Toll Ring: Results of a Stated Preference Study of Travelers' Responses*. Deliverable 17, Transportation Studies Unit University of Oxford and Solveig Meland Terje Tretvik, Division of Transport Engineering, SINTEF, Trondheim Norway.
- Raad, Tamim 2002 "Creating Regional Parking Policies." Conference presentation at *Moving Beyond Planning: Implementing Transportation Solutions*. Organized by Better Environmentally Sound Transportation, March 6-8 2002.
- Raizzenne, Mark; R Dales and R Burnett 1998 "Air Pollution Exposures and Children's Health," *Canadian Journal of Public Health* Vol. 89 (supplement 1).
- Râtel, John 2000 "Transportation, but No More Taxation." *Westworld* (magazine of the British Columbia Automobile Association). Fall 2000.
- Smart Growth BC 2001 *The Smart Growth Toolkit*. Vancouver: Smart Growth BC.
- Suzuki Foundation 2001 *Fuelling the Climate Change Crisis. The Continental Energy Plan*.
- Taplin, John H.E., David Hensher and Brett Smith 1999 "Preserving the symmetry of estimated commuter travel elasticities." *Transportation Research Part B* 33: 203-214.
- Tollefson, Chris; Rhone, Chris and Chris Rolfe 2000 *Cleanair .ca. A citizens action guide*. Victoria: Environmental Law Centre, University of Victoria.
- TransLink 2001a *Recent Trends in Travel Behaviour: Analysis of the 1999 GVTA Trip Diary Survey*. Report to the GVRD Board September 24 2001.
- TransLink 2001b *TransLink Funding Options*. Results of a survey conducted for TransLink by Ipsos-Reid, November 2001.

TransLink 2000a *Regional Traffic Growth Trends, 1996-1999*. Sept 01 2000 Press Release.

TransLink 2000b *Strategic Transportation Plan*. April 2000.

TransLink 2000c *Regional Travel Survey. GVRD Results*. TransLink Marketing Department and Canadian Facts.

TransLink 2000d *Strategic Transportation Plan Resident Survey*. Results of a survey conducted for TransLink by Ipsos-Reid October 2000.

TransLink 1999 *Our future: Making the right moves*. Strategic Transportation Plan Discussion Paper, September 1999.

Transportation Table 1999 *Transportation and Climate Change: Options for Action*. The Options Paper of the Transportation Climate Change Table, National Climate Change Process, November 1999.

Turrentine, Thomas and Kenneth Kurani 1998 "Adapting interactive stated response techniques to a self-completion survey." *Transportation* 25: 207-222.

Urban Systems 1995 *Potential for Commuter Vanpool Services: Benefits and Costs*. Prepared for the Greater Vancouver Regional District.

Viewpoints Research. 1996a *Transportation Demand Management: Report on Quantitative Study*. Prepared for the BCTFA and the GVRD April 4 1996.

Viewpoints Research 1996b *Transportation Demand Management: A Qualitative Analysis of Public Views. Focus Group Results*. Prepared for the BCTFA and the GVRD March 28 1996.

Viewpoints Research 1995 *A comprehensive Overview of Transportation Demand Management Public Opinion Research*. Prepared for the GVRD November 8 1995.

Viewpoints Research 1993a *Public Opinion Surveys on Transportation Demand Management*. Transportation 2021 Report No. 5 July 1993.

Viewpoints Research. 1993b *A Qualitative Research Study on Transportation Demand Management Measures*. Transportation 2021 Report No. 4 March 1993.

WHO 2000 World Health Organization. *Guidelines for Air Quality*. Geneva.

WMO 1991 World Meteorological Organization. *Climate Change: The IPCC Response Strategies*. United Nations Environment Program.