Effects of parking management on worktrip mode choice: case study Winnipeg

by

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A thesis
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in
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EFFECTS OF PARKING MANAGEMENT ON WORKTRIP MODE CHOICE:
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ABSTRACT

The parking problem is usually acute in the Central Business District (CBD), where the personal nature of commercial business creates the need for a high concentration of employees per acre. Parking factors (e.g. parking cost, proximity of parking, etc.) are some of the various transportation factors which affect the utility or disutility of intraurban auto-trips (e.g., worktrips, social trips, shopping trips, etc.).

Since effective parking management could improve the parking conditions of a downtown area, the present study examines how parking policies (e.g. parking cost) influence the egress segment of worktrips, i.e., the segment related to leaving the primary vehicle and arriving at the workplace, and induce or accelerate the shift of commuters from auto to common carrier modes. The Direct Utility Assessment (DUA) method was employed to analyze the perceptions of Winnipeg's commuters related to the egress segment of downtown worktrips.

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DEDICATION

To my parents

PREFACE

The interest of this thesis related to the parking behavior of commuters is in the fact that transportation researchers have apparently overlooked the significance of perceptions related to parking and walking factors in worktrips at the downtown area. In many cases, the worktrip modes have been divided into the access and line-haul segments, because these are perceived differently by commuters. Excluding a couple of researchers, no researcher seems to have considered a third dimension of the worktrip, namely, the egress segment or the segment related to leaving the primary vehicle and arriving at the workplace.

The present thesis examines exactly this complementary part of the main or line-haul trip. Parking and walking commodities are considered both complementary to auto trips and one of them, i.e., walking, is complementary to public transit trips. In other words, this study examines how different socioeconomic strata of commuters make up their existing trade-off, having to choose between parking close to workplace with high monetary cost and low walking time, and parking far from workplace at low cost but with a long walk.

CHAPTER 1

INTRODUCTION

1.1 The problem

Whenever the concentration of people is high, the problem of automobile parking is usually acute. In the Central Business District (CBD), the personal nature of commercial business creates the need for a high concentration of employees per acre, so that communication among people, businesses and agencies be accomplished quickly. A large number of employees, shoppers and businessmen wish to travel by automobile because they find comfort and convenience in having personal door-to-door transportation. This situation creates competition for a proper parking space in the CBD and many communities face the dilemma "to park or not to park", e.g., Manhattan (New York), Washington D.C., Toronto, etc.. Actually, the principal question is where to park, because parking will be transferred rather than eliminated. The parking of automobiles requires a great amount of space and is an intergral part of our life style. It affects a lot of people and a broad range of public and private interests.

After the Second World War, parking management strategies have traditionally been used as a means of accomodating automobile traffic demand. For instance, Rappoport A. (1977)

states that "in years past, efforts to manage parking were concentrated on providing an ample supply of spaces at a nominal rate so that retail business could flourish and commuters would find it convenient to drive to work". However the provision of better roads and sufficient parking (in the 50's and 60's) has had severe negative social consequences, i.e., air pollution, misallocation of transportation and land resources, concerns of energy and social impacts of equity. Because of these consequences, a recent interest has been spurred in the need to revitalize ridesharing services. Little or no regard has been given to the environmental and social implications of providing parking. Also the zoning regulations have contributed little guidance to parking development in CBD and they seem to be weak and nebulous. For example, most parking lots are privately owned and operated without any overall parking scheme until such time as they are converted to "higher and better use".

While the provision of parking has always been recognized as a major component of a transportation system in an urban area, the traditional independence of parking supply from public control (other than the constrains of zoning requirements) has resulted in very little consideration of the use of parking as an effective mechanism for controlling travel patterns. Furthermore, in most cites, a holistic point of view for parking management has been either non-existent or is a fairly recent development because public agencies associated with the provision, management and regulation of parking supply have been fragmented, in a functional and geographical sense. As a result, parking has not been viewed as a policy tool for achieving larger goals in the context of overall transportation objectives.

Private enterprise provides the majority of parking on a basis of rates and periods which yield the best economical return and without any consideration to the parking needs of the city. The abscence of any regulation of the pricing structure has resulted in favoring the work-trip (long-term) parkers at the expense of the short-term parkers. For example, Ellis R. (1977) sustains that work-trip parking has an average duration nearly four times that of shopping and personal business parking in nearly all city sizes. Existing commercial off-street parking rates encourage and attract automobile commuters. On the other hand, the limited number of publicly owned garages and the on-street metered parking does not have enough leverage to influence this rate structure on the basis of competition.

Thus, economic circumstances act as an incentive for motorist to commute to the central city, generating more traffic volume and cause an increase in congestion during peak periods. Because of this, mass transit service becomes less reliable and its patronage is reduced. This trend creates a vicious circle: reduced transit service causes reduced patronage which in turn causes a steadily declining demand for public transportation.

Congestion pricing policies and parking policies have been suggested as regulating means for the flow of traffic in the short run. Brown G. (1972) supports that "the major problem with congestion pricing is a lack of any effective technique to meter and administer the change for congestion... A more practical and easily administered system may be to control parking policies. Parking charges have been criticized as a mechanism for congestion pricing because it neglects through traffic. This criticism does not, however, apply to mode split adjustment since each trip has a common terminating point and adjustment is effected to the mode used not to whether or not the trip is made". Even though there is not a concensus among researchers on whether parking controls are effective or not in congestion relief (e.g., Kulash D. (1973) concluded that parking taxes are not an effective instrument for congestion relief, air pollution reduction and energy conservation given that traffic conditions are insensitive to parking taxes and the parking demand elasticity is low) parking seems to be an appropriate control mechanism which can be used for public intervention and adjustment of the balance among the various transportation modes.

The sensitive point of this public intervention is the need to establish transportation controls and policies which achieve some measure of equity in distributing limited parking resources in areas where demand greatly exceeds supply. The equity issue arises in the establishment of hierarchies of "preferred users", i.e., shoppers over commuters, or carpoolers over lone drivers. The question of "what is equitable" is exacerbated when we keep in mind that public, political and business establishments have generally opposed parking regulations.

Nevertheless, the only promising avenue for reducing parking problems in the CBD seems to lie in controlling employee parking. For example, the study "Parking feasibility study: Historic Winnipeg area" states that "the greatest potential for increasing the off-street parking supply economically would be by securing for public use a portion of the parking spaces presently reserved for employees... If even 10 percent of the employee parking within the historic area could be secured casual public parking availability during weekdays could increase by some 40 spaces". Among all CBD trip types, probably work trip is most conveniently served by an "appropriate" transit service. Therefore the transit alternative seems to be the more likely answer to the peak periods. On the other hand, predicting the impacts and effectiveness of radical changes in parking policies for trips which may not have a common carrier alternative is a highly speculative undertaking, due to a lack of empirical data substantiating such conditions. However, recent research indicates that groups of people choose their travelling mode in accordance to their socioeconomic status. It is obvious that some commuters will always favour those attributes which are only available with an automobile, i.e., privacy and prestige. But there is little doubt that certain socioeconomic groups would have a high propensity to opt for other modes if their needs were met by introduced incentives, for example forfeiture of parking charges for carpoolers or subsidized travelling cost for bus riders.

An efficient and rationalized parking system requires that parking spaces located closest to commercial and shopping facilities be reserved for those travelling for personal business and shopping reasons, because studies have indicated that the longer the distance shoppers have to walk, the less merchandise they buy. Also a maximum use of the limited number of those parking spaces should be obtained by a high turnover of automobiles parked. But the existing practice is the opposite: it is well known that work-trip parkers generally arrive earlier than shopping-trip or personal-business-trip parkers and they always obtain the most advantageous spaces unless some form of parking restriction favouring short-term parkers is in effect. As a consequence, short-term demand of parking is affected much more strongly when there is a localised parking "shortage".

1.2 Approach-methodology

This study examines the mode preferences of downtown workers and concentrates on the sensitivity of automobile commuters to walking time and cost aspects of the parking system. The purpose is to understand how commuters perceive the trip- end attributes of bus, carpool and auto modes and to investigate the nature of the controls which could effectuate a shift in commuting patterns from the automobile (long-term parkers) to a common carrier mode (carpool or bus transit). The question to be answered is whether or not municipal parking policies as planning and control mechanisms, can be effectively used to change commuters' modal choice. The method of investigation is to develop a statistical model consisting of instrumental variables which reflect different parking policies. Possible shifts from auto mode to common carrier modes can be studied by changing the instrumental variables of the model.

Commuters' mode decisions are based on their socioeconomic characteristics and the performance attributes of the transportation system according to which they select the preferred mode: auto, carpool or transit. The principal premise of this study is that different combinations of walking time at the destination, parking time and parking charge can decrease (or increase) the utility of auto work-trips, e.g., Segelhorst E. and L. Kirkus (1973) estimate that auto driving is reduced by 20 percent when solo drivers must pay parking. The various degrees of this utility can drive certain socioeconomic groups to other modes. Further, the size of the city, the age structure of driving populations, weather conditions and available space for parking are the main elements which affect travel behavior.

The research procedure is an empirical analysis of Winnipeg's CBD commuters. The analysis is based on a questionnaire drafted, tested, corrected and administered to a sample of CBD employees. It deals with four specific questions: (1) What is the correlation of the socioeconomic structure of commuters and the service attributes of the mode used (especially in relation to walking time and parking cost variables)? (2) How parking influences employee's mode decision in the case study and how these results compare with other findings? (3) Can work-trip parkers be classified into distinct groups based on parking attributes and what are the most representative variables of these attributes? (4) Can statistically developed disutility functions of statements about the parking system be used to predict auto commuters shifts to other modes, if incentives are provided, e.g., subsidized transit fares or low parking fees for carpoolers, and what is the influence of their socioeconomic status?

The analysis of data will be based on the direct utility assessment (DUA) technique, which is also known as conjoint analysis. The responses to a series of hypothetical situations are analysed with multiple linear regression and produced models are based on stated behaviour, not actual or observed behaviour.

At present time, no one agency in Winnipeg has the responsibility for considering the total parking problem within the context of comprehensive transportation planning. Because of this, the study touches upon parking policy as regards current institutional and adminstrative perspectives.

CHAPTER 2

WORK-TRIPS LITERATURE

2.1 Introduction

Despite the wealth of literature on work-trip mode, relatively little work has examined the behavior of commuters towards their work-trip end. Minimal amount of research has explored in a systematic way how the transportation conditions at the workplace affect commuters' modal choice. Most of the literature addresses specific aspects of the problem, e.g., walking distances, compares a limited number of modes, e.g., auto and carpool, and evaluates particular projects, e.g., individuals' behavior given that shortages of gas supplies exist.

This chapter mainly reviews previous work on identifying impacts of parking policies on modal choice. Nevertheless, much of the relevant previous findings exist in a broad framework, for example, work-trip or public transit studies touches upon the studied topic. Because of this, the present bibliographical research examines carpooling, public transit, work-trip, logit/DUA, and parking studies.

2.2 Carpooling studies

Daniels (1981) dealt with the variation of carpooling characteristics for worktrips throughout Great Britain. Analyzing statistically (e.g., chi square test) data related to the incidence and the attributes of carpooling in office establishments and collected in a survey undertaken in 1976, he concluded that no general carpooling patterns exist but rather factors favoring carpooling. For example, he states that distances above average length, office establishments with large numbers of employees and homogeneity in commuters' occupations contribute in the creation of car sharing schemes. Further, he identified that car ownership does not exert a consistent influence on vehicle sharing.

The study of three mode choices for work trips (Ganek & Saulino, 1976) evaluated the car-pool/public-transit program administered by the southwestern Pennsylvania regional planning commission and suggested how commuters could be attracted to shared ride modes. The data were collected form commuter surveys and were analysed with the multinomial logit form. The major conclusion was that commuters should be enticed to ride sharing modes not on the basis of travel costs but rather on the basis of travel times, preferential parking spots and provision of back-up service for carpoolers. Further, it is suggested that carpool encouragement effort should be addressed to commuters who have one of the following attributes: (1) regular commuting schedules, (2) moderate or low number of cars in the household, (3) annual income less than $15,000 and (4) drive alone to the CBD.

Based on open-ended discussions with commuters of the Washington D.C. area and analysing the quantified results of these discussions with discriminant and factor function procedures, the authors (Margolin, Mish & Stahr, 1978) assessed the effects of given psychological and socioeconomic factors on mode choice, explained the ways in which these factors do or do not favor carpooling, and developed carpool-promoting strategies addressing specific traveler needs and attitudes. The study concentrated on carpooling, time variables, carpool routes, parking management and convenience issues, and demographic characteristics of auto and carpool commuters. The study concluded that parking management and carpool routes are the strongest strategies to convert solo drivers to carpoolers.

The study of factors affecting work trip carpooling (Wood, 1982) reviewed accomplished carsharing schemes in British towns and developed a model to predict the effects of carsharing at a national level. Using data from one of the cases reviewed, the author calibrated a binary logit model, i.e., auto vs. carpooling, and estimated possible increases in the amount of carsharing resulted from increased petrol prices or provision of convenient parking spaces for car shares. The findings of this study were that 25% of increase in petrol prices should divert to carpooling only 1/2 percent of existing solo drivers and a 5 minute reduction of walking time at the end of the work journey has approximately the same effect as a 50 percent increase in "real" cost of petrol prices.

The validity of the multinomial logit model's forecasts (Ben Akiva & Atherton, 1977) was tested using "before and after" data from the implementation of car-pooling incentives and transit service improvements in Washington D.C., Los Angeles and Minneapolis. The data were collected from home interviews and represented a cross section of households. The results indicated that the model successfully predicts the changes on modal choice. The same logit model was used to analyze car pooling incentives, there is a significant increase of ride sharing in their travel patterns when parking-related policies combine disincentives for driving alone with incentives for carpooling (e.g., increase of walking distance and parking cost for driving alone and decrease of walking distance for carpooling members).

Levin and Gray (1979) analysed the role of interpersonal factors in carpooling in three phases at the University of Iowa. In the first two phases, laboratory simulation techniques and the evaluation of an existing carpooling program revealed attitudinal and behavioural findings, related to carpoolers and noncarpoolers. In the third phase, promising strategies, i.e., chaining of acquaintanceships among carpooling persons, personal meetings among carpoolers and identification of a contact person in each potential carpool grouping, were developed to promote carpooling. The major conclusions of the study were that acquaintanceship is a potent factor in carpooling and carpooler characteristics had effects comparable to those of cost and time factors in the formation and promotion of carpooling programs.

Further, two authors (Horowitz & Sheth, 1977) developed a mathematical model (i.e., factorial analysis) and examined the perceived advantages and disadvantages of ride sharing and their effect on behavioral predispositions toward ride sharing. The collected data were furnished with the help of the personnel departments of 43 firms in the Chicago area, were related to work trips and were based on a self-administered, mail-back questionnaire. The multivariate analysis of variance test (MANOVA) performed on the aforementioned data showed that demographic and travel characteristics are poor indicators and predictors of the choice between driving alone and ride sharing strategies (exception are individuals having a relatively high socioeconomic status), negative perceptions of drivers toward time, convenience and reliability of ride sharing characteristics mainly determine mode choice (while perceptions of economic advantages have a minor role), and finally, promotional campaigns of ride sharing are needed to change solo drivers' perceptions before their travel behavior would change.

A quasi-experimental study design (Brunsco & Hartgen, 1981), related to a carpool coordinator project, examined the effect of carpool coordinators on the formation and stability of carpooling at six state agencies of Albany, New York. Spliting the agencies in control and test agencies, before and after surveys were conducted and showed that, even if there is a high degree of carpooling at a work place, a trained carpool coordinator can increase existing carpooling significantly. An Automatic Interaction Detection (AID) analysis of the collected data concluded that demographic data are poor indicators of carpooling. Finally, the specific project had an overall B/C ratio, benefits resulted from fuel savings, of 3.9 which the authors characterized extremely cost effective.

The study of spatial relationships among carpoolers (Richardson & Young, 1981) examines factors that contribute in the generation of work-trip carpools in physical terms, e.g., the density of common trip ends, the deviation from a direct route, trip lengths, pick up and delivery radii. Based on a roadside questionnaire survey, data were collected for both morning and evening work trip carpools in Melbourne, Australia. Internal and external carpools of work trips (i.e., refering to the same household and different households carpool members, respectively) were analysed and revealed that, first, the mean distance for external carpools is significantly greater than the mean distance for internal carpools, second, the proportion of external carpools increases with increasing trip length, third, travelers tend to form work based carpools at work sites rather than within residential areas and, fourth, the average total deviation, including home-end and work-place deviations, for external carpools is 3.0 km.

Work-trip survey data from Baltimore region were used by Bailey (1982) to estimate cost-effective distances among vanpooling, carpooling and driving alone transport modes. Developed models, based on the relative distances, the perceived costs of operating automobile, and the perceived value of time, indicated that carpooling is cheaper than driving alone in every case and vanpooling is more cost effective than carpooling or driving alone for distances longer than 18 miles one way. Both ridesharing schemes become less costly than auto driving when either the perceived value of time and the perceived cost of operating automobile raise to more realistic levels, i.e., a commuter takes into account maintenance, tires, oil, insurance, or real commuting costs increase, e.g., fuel cost, parking cost.

The potential for organized carpooling in the Sheffield area, U.K., was examined by Tomlinson and Kellett (1978). Using manual matching techniques and data from home-work trips per residential area, the authors estimated that carpooling did not significantly increased the average car occupancy values and little reduced work purpose car trips, i.e., 8% and 14% reduction for 15 minutes and 30 minutes matching time respectively. Their results suggest that carpooling potential in U.K. is lower than in other countries, e.g., U.S.A., because there is lower dependence on the car in U.K. However, one should keep in mind that the study did not account for any carpooling incentives, but rather examined carpooling in time and physical terms.

Bonsall (1980 a,b & c) presented, in a series of reports, the methods and findings of the likely impacts of organized car-sharing schemes in West Yorkshire, Great Britain. He designed and administered three questionnaires in order to survey 10,000 households, developed a microsimulation model which consisted of three parts, i.e., the decision to join a car-sharing scheme, the matching of applicant and the acceptance of matches, and performed alternative tests of car sharing schemes, i.e., the provision of free reserved parking spaces, a doubling in the real cost of petrol etc. The first and second part of the microsimulation model are a derivation of logit and a doubly-constrained entropy-gravity model (i.e., utility maximization with a satisficing constraint), respectively. His major conclusion was that "voluntary car sharing schemes are unlikely to have more than a marginal effect on congestion, parking requirements or energy use, but they can confer considerable benefits on their participants". In relation to parking factors he states that free parking incentives increase the number of participants by 40% and the demand for parking spaces in the downtown area declines by 0.34% provided that an organized car-sharing scheme functions.

Finally, the study of car-sharing schemes in Yorkshire, U.K., (Bonsall, Spencer & Tang, 1981) tested the prediction of the sophisticated microsimulation model (i.e., logit) by establishing and monitoring a range of experimental car-sharing schemes, e.g., three employer-based schemes and a residential one. The results of these experiments agreed quite well with the model's predictions. Car sharing schemes attracted only limited interest from the population addressed, i.e., only 2 percent actually entered into or expanded arrangements. Because of this, there were a slight abstraction from public transport. An evaluation of the costs and benefits revealed that, while substantial benefits may accrue to participants, the net cost to the community depends upon whether the public transport impact is sufficiently localized to allow service rationalizations. Some further findings are that manual matching of applicants appears to be superior to computer methods, and applicants' journeys are generally longer than the average journey of the target population.

2.3 Public transit studies

The study of transit planning and automobile-use constraints (Hoey & Levinson, 1977) examined potential procedures to divert auto drivers of work-trips to public transit, in the greater New Haven area. In this case, a questionnaire was used to survey the employees of CBD and non-CBD and to address the characteristics of both the existing bus services and a future acceptable transit system. The findings established that a large portion of workers commutes with buses by choice and existing transit riders have much lower expectations about the bus level of service than automobile drivers. Further, it was concluded that the majority of auto drivers would not convert to bus riders even if acceptable transit system was available to them. In the authors' opinion, parking surcharges would have to be coupled with fuel taxes in order to be an effective automobile-use constraint and a successful measure in the diversion of auto trips.

The study of consumer attidudes toward public transit (Fielding, Blankenship & Tardiff, 1976) aimed in identifying means of improving the competitive position of public transit against the private automobile. Using both likert and semantic differential scaling, an attitudinal survey was conducted in the fixed and demand-responsive bus service of Orange county, California. The results of this survey were affected by the increasing scarcity of gasoline in the fall of 1972 and consumers overemphasized their willingness to use transit. However, a major finding was that use of transit is directly related to the closeness of the route to the patron's trip origin, e.g., if the bus ran was within one block, more than 50 percent of the respondents would use bus to some extent, and, if the bus ran was more than three blocks, the demand fell markedly. Also, 35 percent of the respondents who commute daily to work stated that they would use bus for their work trip. Finally, level of service factors, i.e., arrival on schedule, closeness to bus line, driver attitude and arrival frequency, ranked higher than attributes reflecting price, travel time and the inconvenience of transfers.

Gensch (1981) provided a practical segmentation methodology of identifying the groups of the population most likely to switch from their current mode of transportation. His method examines the differences in the deterministic utility components of logit model and predicts whether an individual is likely to switch based on the statistical significance of the preceived difference in utility values. He states that "individuals who do not perceive much difference in the satisfaction level of various modes are more likely to switch or be switchable than individuals who perceive significant differences in the satisfaction levels". Using data from the Santa Monica Freeway survey, Los Angeles, he concluded that empirical findings support his concept and the level of switchability between auto and bus is related to socioeconomic demographics, resulted from a discriminant analysis.

The study of convenience factors in modal choice for work trip (Algers, Hansen & Tegner, 1975) developed disaggregated behavioral choice models for work trips in the Stockholm metropolitan area and, especially, investigated the role of the assumed waiting behavior of commuters. Using logit analysis and survey data, from the greater Stockholm Labor Force survey, Algers et al (1975) concluded that the waiting time value becomes between 7 to 12 times the value of the in-vehicle travel time when the headway is over 5 min. and the actual waiting time is assumed to be lower than half the headway. Both value of time and transfer discomfort was affected by weather conditions and, in terms of travel time, a transfer is approximately equal to 24 min longer door-to-door travel time. Finally, they consider that their findings are transferable to another city if the transit system frequency characteristics are equal and the economic activity level is the same.

Kingham (1978) investigated the effect of competent transit service on household decision to have automobile(s) for serving home-based trips. The determination of possible causality was based on a comparison of similar areas which were or not served by transit. Also socioeconomic variables, like dwelling type (apartment, single-family home), income, life cycle (number of adults, existence of children), sex of traveler, were examined for possible causal effects on Automobiles available PER Worker (APERW) variable. The studied area was Laurel, Maryland, and 92 percent of its households were surveyed for their work trips to

Washington D.C. His findings suggest that the APERW variable is strongly related to mode choice and most significant of any other socioeconomic variable. An increasing APERW variable meant decreased percentages of carpooling or transit use. Also the results suggest that, in general, households must sold their second and/or third car when their members become regular bus riders.

Bly and Oldfield (1978) assessed the impact of increasing car ownership on bus travel in Great Britain, using regression analysis and data from national travel surveys, transport statistics, annual family expenditure surveys, and national censuses. During 1964 to 1976, increasing car ownership accounted for at least 40 percent of the overall decline in bus use. The analysis with respect to household size concluded that the loss in bus patronage attributed to the first car acquired by a household is approximately three to four times as great as that cause by second car ownership and the average bus use per head reduces about 20 percent with increasing household size, when that is car-owning household. Removing car ownership, three factors, i.e., fares, level of service and income, were examined as the most important causes of changes in bus patronage, since the secondary effects of increased car onwership are fares increases and service cuts to offset the initial loss of revenue. The statistical analysis disclosed that the relationship between fares and patronage is expressed by a strong correlation while no strong correlation existed between bus patronage and either bus-kilometers (an index for the level of service) or income, e.g., the effect of increasing average income on bus travel was very small, at least in non-car-owning households. It was estimated that the second round effects were almost as large as the direct effects. Finally, it was calculated that, from 1964 till 1969, the total effect of increased car ownership accounted for 78 percent of the decline in bus trips, provided that bus services did maintain break-even in Great Britain.

Goodwin (1983) evaluated the effects of low bus-fares policy in Yorkshire, England, and estimated the marketing potential of public transport. His conclusions were based on data from travel surveys, postal questionnaires, tape recorded interviews and the available travel patterns of national level. Calculating the relationship between changes in real fare level and other factors, such as unemployment, bus mileage (level of service indicator), negative trend in bus patronage (due to car ownership), he concluded that fares effect has better results in the long run than in the short run and a subsidized public transport had moderated their negative effects of unemployment, car ownership and similar factors. In his opinion, the long term fares effect is complicated and short term fare elasticities cannot be used to forecast long term patronage, because these elasticities oversimplify, and probably, underestimate, the complexity and scale of the longer term effects of low fares. On the other hand, bus use by car-owning households incresed more rapidly than for households without cars, the proportion of weekday bus trips that are work trips declined from 45 percent to 28 percent. However, the latter was explained by important structural changes, e.g., a shift of industrial employment away from inner city areas. Bus usage had increased consistently more for women than men and more for the young than the old. Finally, marketing potential existed especially among the young and a group of car users who were already fairly near the threshold of choosing bus instead of car, primarily for reasons of personal cost and convenience.

Also Goodwin (1973) examined the effects of free public transport on work-trip mode choice comparing the behavior of London Transport Executive (LTE) employees, who receive free public transport, and other central London workers, who pay the normal price. Analyzing cross-section and time-series data, he studied with two methods, i.e., logistic model and linear regression, the reaction of workers to varying commuting costs. He concluded that LTE employees did not face any constraints, e.g., parking supply or low car ownership, and used their cars for work-trips to a lesser extent than other downtown workers, i.e., 2.2% vs 6.6% of car usage respectively. Moreover, both methods indicated that the existing level of car usage for work journeys to central London would be reduced by two thirds if commuters were provided with free public transport.

The study of free public transport (Daly & Zachary, 1977) assessed the impacts of free public transport on work-trip mode choice among comparable groups of public transport employees, receiving free travel concessions, and other workers, e.g., clerical and manual, who paid their fares, in seven British cities. Employing linear logit models, the study estimated that provision of free public transport to the test groups will result in reducing by 22% the peak-hour auto commuters who do not need their car at work and in decreasing by a statistically non-significant 3% the car ownership of commuting households. In other words, the results suggested that the difficulty and cost of bus mode seemed to have an important effect on mode choice and car availability, but not on car ownership. A corollary of this study was that free travel to work can substantially convert auto drivers to bus riders, even if the recent thinking tends to stress the insensitivity of car users to the attributes of mass transit.

Finally, Beach (1979) examined the transit-free-prepayment program of Sacramento Regional Transit District (SRTD) and its success in obtaining employee and employer participation. The goal of the prepayment program was to increase transit ridership and to improve transit marketing through employer involvement. It was concluded that the program was extremely successful, given that 51 percent of the total of the SRTD monthly pass sales was achieved by the employer pass program, and pass sales indicated that the level of employers' involvement has a direct effect on the degree of employees participation.

2.4 Worktrip studies

Jovanis (1981) examined whether alternative work schedules are compatible with campaigns promoting carpools and encouraging transit use. He surveyed four San Francisco Bay Area firms, three of which were located in the CBD, and assessed the magnitude of workers' mode changes attributed to flexible work hours (i.e., flextime). His findings were that solo drivers were diverted to carpooling and bus use because flextime allowed them to form new carpool arrangements and to deal with unreliable transit service, respectively. Also carpoolers were enticed by the ability to escape peak-hours' congestion and bus riders avoided income constraints and increased gasoline prices. In other words, the flextime programs proved to be indeed in accordance with ridesharing and transit promotions.

Using multivariate and linear regression analysis, the authors (Ott, Slavin & Ward, 1980) examined the workers' activity changes and travel responses attributed to a system of flexible working hours, i.e., flextime. The flextime program was conducted at the U.S. Department of Transportation's Transportation Systems Center in Cambridge, Massachusets. The data were collected from surveys and arrival/departure time cards and their analysis suggested that workers enjoy significant benefits from varying work schedules and become more productive. Some of workers' benefits are savings on travel time and fuel consumption, resulted from travelling on non- or less-congested transport networks. Also the findings indicated small net changes in favor of ridesharing and public transit.

The study of staggered hours (Neveu & Koeppel, 1980) examined the impacts of a program of alternative work hours, implemented at the main office of the New York State Department of Transportation (NYSDOT), on employees' work schedules and their characteristics of work trips. The collected data were related to changes in work schedules, perceived impacts, characteristics of work trips and demographic information and were analysed with the Automatic Interaction Detector (AID) statistical tool. The simple random survey of NYSDOT employees revealed that more than half of the employees changed their work schedule, both switchers and non-switchers saved on travel times resulted from reduced highway congestion and, finally, ride sharing was increased because of the examined program and a number of other factors, i.e., the NYSDOT's Coordinator Demonstration project, gasoline shortfalls and rapid rise of energy prices.

Atherton, Scheuernstuhl and Hawkins (1982) examined the travel related impacts of the compressed workweek in federal agencies of Denver, Colorado. Using experimental and control groups of federal employees, surveys conducted before and after the implementation of changes in standard work schedules provided that the compressed work schedules resulted in a significant reduction of the average weekly household Vehicle Miles of Travel (VMT) and are compatible with other regional transportation policies such as ridesharing and transit. The results showed that the compressed workweek did not affect adversely the aggregate level of ridesharing and had little impact on transit ridership.

The effect of Flexible Work Hours (FWH) on mode choice and work trip times was examined by Daniels (1980). In this study, his specific example is the central and outer metropolitan area of London. Scanning data from surveys of decentralized offices throughout Britain, he concluded that, first, FWH and non-FWH workers have only marginal differences of trip times, second, in general FWH encourage the use of private cars and, third, FWH alleviate congestion during the peak hour.

Using logit analysis and an analytical procedure, which eliminates estimation problems related to heterogeneity of choice constraints and removes problems of multicolinearity in the independent variables of the choice models, Golob and Recker (1977) examined changes in the work- and shopping- trips served by bus or auto in the regional municipality of Ottawa-Carleton, Ontario. Regarding work trips, the study concluded that bus ridership could be increased by improving the transit frequency, minimizing bus transfers, and degrading the auto convenience attributes, i.e., weather protection and walking time, with the implementation of parking restrictions.

Using perceptual mapping techniques, the study of Neveu, Koppelman and Stopher (1979) examined the joint effect of comfort, convenience and reliability on the work trip mode choice. A self-adminstered survey collected data from auto and rail commuters in the Evanston and Wilmette suburbs of Chicago. Analysing the data related to access- and main-modes of travel with factorial statistical techniques and developing preference regression and first-preference logit models, the authors concluded that commuters do not perceive comfort, convenience and reliability, first, as independent attributes in their mode choice and, second, in the same manner for access- and main-modes of travel. Further, the preference regression and first-preference logit models revealed identical results but the logit model exibited more efficient estimation properties.

The study of multiattribute transportation decisions (Johnson, 1978) examined the relative importance of ten different travel attributes for the workers' choice among car, bus and BART (Bay Area Rapid Transit) in the San Francisco Bay area. Using matrices of Pearson correlation, factor and logit analysis, and the importance statistic, each attribute contributing to differences in utility of the examined modes was evaluated for its importance. Interviewing 258 workers of San Francisco, Oakland and Berkley by telephone, the authors collected and analysed data which showed that waiting time, dependability, total time and safety from crime were the most important attributes. Cost, seat availability and flexibility ranked next in importance and were followed by relaxation and safety from accidents. Finally, important attributes like seat availability, dependable arrival and safety from crime were suggested to be included in current quantitative planning procedures, e.g., travel demand forcasting.

Based on factor analysis (i.e., principal component factor analysis with a varimax rotation), clustering techniques (i.e., clustering algorithm of the Biomedical Computer Program P2M) and linear regression analysis, Dobson and Tischer (1977) examined the relation between perceived system attributes and modal choice, and compared the mentioned relation to the alternative relations between sociodemographic data and network data. Three transporting modes (i.e., bus, carpool and auto) were analyzed in the Los Angeles area for the CDB workers and the results revealed that perceived system attributes or beliefs about modes account for variance in modal choice above and beyond time and cost data, but the reverse is not true. Further, the relationship of modal choice and perceived system attributes is influenced to a small degree by sociodemographic data. Therefore, in planning studies, the author suggests the exploitation of beliefs that favor buses or carpools, since they can be easily realized into actual modal use patterns.

The study of occupational status for work trips (Cubukgil & Miller, 1982) examined the relationship between occupation and commuting behavior of workers in the Toronto metropolitan area using census data. Grouping workers in six homogeneous occupation classes with the help of chi square and Kolmogorov-Smirnov statistical tests and calibrating occupationally disaggregated work trip distribution models, the study concluded that income alone is inadequate to explain socioeconomic attributes of commuting propensities and residential location preferences. Further, the simple classification of white collar and the blue collar occupations does not reveal the existing extreme variation in each of those broad categories. For example, first, the travel time sensitivity attributed to an average income varies among groups with similar incomes but different occupational status and, second, housing preferences, excluding high income housing, appear to be primarily occupationally related.

Kitamura (1981) developed and applied a heuristic stratification procedure related to the variation of tastes in work-trip mode choice. Using a modified version of Automatic Interaction Detection (AID), a binary logit model and a d-statistic test, he generated subgroups of commuters whose structure sufficiently accounted for the existed variations in the mode preference of tripmakers. Analyzing data of a Pre-BART Travel Behavior Set related to bus and auto modes, he concluded that variation in commuter' tastes did exist and was expressed by a limited number of socioeconomic variables and that the conventional approach of adding linear terms of socioeconomic attribute variables in the utility function of logit model did not account appropriately for the existed variation in tastes. Also he determined that the most significant variable for all commuters' subgroups was the monetary cost of travel.

A validation of the equilibre multimodal-multimodal equilibrium (EMME) technique was performed (by Florian, Chapleau, Nguyen, Achim, James-Lefebvre, Galarneau, Lefebrve & Fisk, 1979) using data from the city of Winnipeg, Manitoba. The mentioned transportation planning technique is a combination of a zonal aggregate-demand model with both an equilibrium type road and transit assignment method, and a modal split, based on logit or dogit function. The study used aggregate data which were gathered from origin-destination surveys of work trips during the morning peak hour and the statistics Canada, 1976 census. The model successfully simulates changes in the modal shares or in route choices.

Utilising data from a home-interview travel survey and being one of the first attempts, the study (Ben Akiva & Richards, 1976) developed disaggregate modal-choice models to consider the full variety of travel modes (i.e., walking, bicycle, moped, car, bus and train) for work trips in medium- and small-sized Dutch communities. The multinomial logit model used in this study, confirmed that the estimation of disaggregate models requires fewer observations than does the calibration of aggregate models. Small marginal decreases existed in the standard errors of the coefficients for samples larger than 250 observations. According to the final findings, out-of-pocket travel costs had no significance on modal choice and the most satisfactory model was based on treating in-vehicle and out-of-vehicle travel time as generic and alternative specific variables, respectively.

Finally, Segal (1979) examined the choice among three modes, i.e., driving, bus and automobile passenger, applying discrete multivariate analysis which, in his opinion, has advantages over conditional logit analysis in the case of large data sets. Analyzing mode-choice behavior for work trips of Washington, D.C., in 1968, he concluded that the in-vehicle travel-time is non-linear explanatory variable, although it has been assumed, generally, that all the variables are linear in their impact on the mode choice logit.

2.5 Logit/DUA studies

The study of urban transportation demand (Aldana, Deneufville & Stafford, 1973) develops a microanalytic model for the Boston area and examines the advantages of microanalytic models over the macroanalytic models. The former models explain the underlying factors that determine the response of the population to transportation stimuli, while the latter models forecast travel-volumes. Microanalytic models of a system try to achieve a dynamic representation that simulates the adjustment, over time, of each household to different stimuli with the help of equilibrium-concept. The equilibrium-concept assumes that random observations of the system show it at, or very close to, the most stable or desirable position, given the set of stimuli upon it. The study stresses the need to stratify the population of households into groups having similar utility functions. This is required by the nature of microanalytic models and the procedure to assess the impacts of transportation policy changes on the different segments of society. A major conclusion is that indiscriminate improvements in transit service, i.e., changes not considering the existence of market segments, might lead to frustratingly small changes in transit use, because variations in the use of transit result from changes in the level of transit service and most importantly, dissimilar attributes and preferences of households located in different areas.

The study of short access trips (Inglis, 1973) was among the first to attempt the development of a multimodal, stochastic, disaggregate model of modal split for a short journey. Its data were collected from people using Chicago railroad suburban routes and were related to short access trips between home and the commuter station. Examining discriminant, probit and logit analysis, Inglis selected the logit analysis being most advantageous and validated his developed model. The involved modes were walk, drive and park, driven and bus and, among these four modes, walk mode, having no monetary cost associated with it, was used as the base mode of logit model. The results disclosed that time and cost are the significant explanatory variables, both of them attained the same level of significance and the value of time was derived to be $1.33/hr.

Talvitie (1972) evaluated the performance of logit, probit and discriminant analyses, by testing twelve models in each method. The formulation of the models in each menthod. The formulation of the models included various socioeconomic variables and alternative segmentations of the total travel time and total travel cost. The purpose of this was to investigate the need to differentiate among access, egress and line-haul times and costs, and the way that trip segmentation be done. His data consisted of 159 work trips made during the morning rush hour. By taking large enough samples of the original body of data, he performed statistical tests (t-tests) to examine any differences among the three methods or among the models, but no differences were detected this way, i.e., the hypothesis that the results were statistically equal could not be rejected.

Because of this, he did a ranking analysis of the estimation methods and the model specifications. His conclusions were that, even though logit analysis slightly edges both probit and discriminant analyses, all of them yielded comparable results and can be used with equal success. Further, he inferred that in-vehicle time and any economic study of a transportation improvement must consider the mentioned times seperately.

Curtis (1981) assessed the appropriateness of including perceptual variables in a work trip demand model of logit form. Collecting and analyzing data from a small municipality, Kingston township, Ontario, he concluded that combinations of perceptual and non-perceptual variables improve the predictive precision of logit model provided that they are measured with reasonable accuracy. Another finding was that travel cost and in-vehicle travel time are not critical attributes in mode choice decisions of small community workers, opposing normal travelling attributes of large urban centers.

Gensch (1980) assessed the predictive potential of logit model calibrated on current behavior rather than on stated intentions. Reconsidering data from the Santa Monica Diamond Lane project of Los Angeles, he concluded that logit predictions based on what people actually do, and not on what they say they will do, are highly accurate. For example, cost was the most significant variable in stated intentions and the least significant one in actual behavior provided that convenience ranked first in terms of actual behavior.

The study of Wisconsin work mode-choice (Kocur, Hyman & Aunet, 1982) evaluated by a combination of functional measurement, i.e., conjoint analysis, and disaggregate demand modeling, i.e., logit, the mode-choice policies of worktrips for urban areas of different character in the state of Wisconsin. The data were collected from mailout surveys to residents who renewed their driver's licences and the examined modes were walk, bicycle, ridesharing and drive alone. Two major conclusions were that ridesharing should be promoted in all urban areas while transit assistance should be provided to large urban areas where its effect is significant. Further, the study highlighted original key issues in intergrating function measurement and disaggregate modeling.

Four attitudinal measurement techniques, i.e., monotonic conjoint measurement, functional analysis, trade-off analysis and unidimensional scaling, were compared by Benjamin and Sen (1982) for their predictive ability. The authors tested the four techniques against the impact of transit service changes interviewing 300 individuals in Charlotte, North Carolina. The mentioned group was split in test and control groups which were interviewed and reinterviewed on a time difference of one year. The study concluded that functional analysis was the most cost effective overall and the results of attitudinal research are believable since observed behavior closely reflects stated preferences.

2.6 Parking studies

Gillen (1977a) developed a modal choice model that treats parking as a commodity that is complementary to automobile trips. He examined how to define and incorporate the parking variable into a model of modal choice, how parking costs affect the elasticity of modal choice and how changes in parking variable will affect the expected proportion of workers driving to CBD. Gathering data from the Toronto parking authority and the Metropolitan Toronto and Regional Transportation Study (MTARTS) and using binary logit analysis (bus vs auto), he concluded that parking taxes are a partially effective substitute for roadway pricing in relation to influencing traffic congestion and that a change in parking costs may result in a 10 to 15 percent increase of transit use, expressed as a percentage of current transit use.

Using logit analysis, Ergun (1971) examined the parking behavior of commuters and noncommuters in the CBD of Chicago and investigated the trade-offs related to parking price and walking time. Analyzing data of 226 automobile trips to downtown, he concluded, first, that commuters have a strong bias for parking in the first block from the workplace, second, that saving through walking was found to be $4.50/hr for commuters who did walk, third, that the proportion of walking commuters was higher where parking was expensive, and, fourth, that commuters' income was found to be an insignificant variable since the data where biased toward high-income groups.

Brown G. (1972) developed and tested a propensity model aiming to determine the propensity, or tendency, of auto drivers to switch to a new mode. He investigated the potential impact on mode choice of (a) a hypothetical park-and-ride system and (b) increases of parking costs in the CBD of Vancouver, Canada. The model developed was a utility (or disutility) model, essentially a version of logit model, which was validated with canonical correlation analysis, i.e., a correlation test of independence of preferences from existing service levels. The data were collected during the am-peak hours in one radial travel corridor of Vancouver with a "handout-mailback" questionnaire. His significant findings were that bus travel time and parking charges were dominant variables in affecting mode shift. More specifically, first, parking charges, by itself, needed an increase from an average of about $0.55 to about $1.00 per day in order to effect a 50 percent shift to bus transit and, second, a reduction in transit line-haul frequency from 17 min. to 4.5 min. was required by the average auto driver who was a potential transit patron.

The study of municipal parking-fee increases (Kunze, Heramb & Martin, 1980) assessed the effects of substantial increases in parking fees at Chicago's downtown city-owned parking facilities and determined that fee increases established, first, a drastic drop-off (72%) in the number of long-term day time parkers, second, most parkers were diverted to public transit instead of diverting to other parking facilities and, third, parking demand of commuters proved to be quite sensitive to parking price, i.e., elasticity approximately equal to -0.75. The parking patterns of Chicago's CBD were investigated by data related to semimonthly revenue summary sheets, daily revenue reports, time-stamped parking-receipt stubs and quarterly parking tax returns submitted to the City's Department of Revenue and Bureau of Parking.

Observing changes in the travel modes used by commuters who were deprived free parking and comparing differences in the travelling behavior among "identical" commuters who were eligible and noneligible for free parking, Pickrell and Shoup (1980) estimated the effect of employer subsidised parking on work trip mode choice. Although their findings were based on a diversity of case studies, e.g., in Ottawa, Washington D.C., Los Angeles, the conclusion was very consistent in all cases and suggested that free parking at work influences commuters in favor of auto drive and is a key variable in their mode choice decision. Approximately 20 percent of the auto drivers would form carpools or use public transit if they had to pay parking at their workplace.

The study of commuter parking prices (Miller & Everett, 1982) examined the effects of parking price increases on the modal split of federal employees' commuting trips in Washington D.C. The rates of government-controlled parking were increased by an amount to equal to one-half the commercial parking rate and the authors surveyed federal worksites located in downtown and suburban areas. Before-and-after surveys, using control and test groups, revealed that removing free parking and, in some cases, raising parking rates resulted in significant shifts to higher occupancy modes than single driver vehicles. In this case study, carpoolers were very sensitive to parking increases and were inclined to shift to transit service, especially in the worksites of the central area. The data were analysed with chi square statistical tests and various comparisons were performed between test and control groups.

Pearce and Jackson (1979) analysed the offstreet parking system of the London borough of Croydon, using multilinear regression analysis (SPSS program) and data acquired from a questionnaire survey. The analysis showed a strong correlation between the durations of stay in the car parks and parkers' trip purposes, revealing a 6.9 hours and 2.9 hours length of stay, on average, for work trips and shopping trips, respectively. The work-trip parkers represented the 44 percent of all parkers and occupied the 65 percent of the parking space. On the other hand, shoppers used only 28 percent of the parking space, even if they represented the 49 percent of the total parkers. The occupancy profiles of the individual car parks varied considerable and much depended on the car park location, e.g., car parks of main shopping area had a high level of short term use (operated near to capacity most of the year), car parks at main railway stations and business centers had a high of long term use. Considering three factors, i.e., prices of parking, petrol and public transport, in relation to varying pricing policies of short term nature, they concluded that the price of parking was by far most important for the car parking demand. Further, they examined the relationship between price of parking and either short term or long term parking. Short term demand showed no fixed relationship existed between price and long term parking. Assuming an inflation rate of 10 percent per annum and no parking price change, they forcasted an increase in long term use of 30 percent and the squeezing out of short term users.

Examining a number of elasticity studies related to car parking, Haworth and Hilton (1982) concluded that the potential of elasticities as an aid to rational policy formulation on parking is very promising. However, they highlighted that the parking system appears to be very complex, because there are conflicts in the parking provision and operation from other policies pursued by local government authorities, and too much ought not to be expected from parking elasticities. The major potential benefit of parking elasticities is to relate parking policy to other policy objectives, e.g., by indicating the extent to which it might be possible to induce parkers to redistribute their movement within periods of peak traffic congestion or by relating parking to public transport fare levels in a more satisfactory way. In the authors' opinion, there is a need for a number of demonstrations that elasticities were derived and used successfully in forecasting, before they are completely established in the area of parking policies.

The study of parking bias in transit choice (Segelhorst & Kirkus, 1973) examined how free or subsidised parking affects the modal choice of CBD employees, reviewing numerous previous related studies. Addressing the problem of traffic congestion and the inequity created by parking subsidies, the study developed economic linear equations to estimate the total benefits of workers in the CBD of Los Angeles provided that transit subsidies, equal in value to parking subsidies, were granted. The data were collected from numerous sources, e.g., U.S. Department of Transportation, Department of Commerce, Los Angeles Rapid Transit District, etc. The estimates concluded that the gain in net income per employee switched to transit was $1.36 per day or $345.00 pre year.

The study of Brown and Lambe (1972) explored the influence of three factors, i.e., supply, demand and walking distance, on parking price. Developing a linear programming model, the authors assessed the model's predictions based on data from the

CBD of Vancouver and utilised the developed model to predict the effects of the addition or deletion of facilities and to set parking meter rates.

The study of Chicago downtown trips (Winger, 1973) developed modal-choice models designed to be used as part of the urban transportation planning (UTP) package for the Chicago area and to combine both regional and behavioral aspects. The regional aspects include the zonal nature of data and the coverage of trip origins throughout the entire Chicago area. The data used were based on the CATS home interview study. Probit and logit analysis revealed almost identical binary choice models (i.e., car-rail, car-bus & car-other) for work and nonwork trips. Parking fee increases were estimated to have a significant effect on transit ridership and the marginal values of comfort and travel time were calculated. Finally, the study implied that existing conditions of the Chicago transportation structure favored the use of automobile in terms of time and comfort.

Olson & Miller (1980) scanned the impacts of residential parking regulations on the travel/parking patterns of commuters who used to park in areas adjacent to the CBD of Alexandria, Virginia. Conducting surveys, which were based on a postage-paid mail questionnaire and phone interviews, before and after the implementation of the parking-permit program, they concluded that only 12 percent of the commuters changed travel mode, i.e., switched to bus or carpools, and most of the commuters remained auto drivers and parked on either off-street spaces (frequently subsidized by their employer) or curbside spaces outside the restricted districts. Nevertheless, they suggest that the measures were popular among the residents and were successful in alleviating traffic and parking problems of the residential districts.

Using transition matrix analysis, Lueck and Beimborn (1979) investigated the relation between mode choice and parking restrictions. The case study was the campus of the University of Winsconsin-Milwaukee and the data were collected through a mail survey which covered 10 percent of the enrolled students. Considering behavioral changes in mode choice resulting from substantial changes in parking restrictions, transit service and transit fares, and evaluating respondent's reactions to possible future situations, the authors concluded that, first, increased parking restrictions made auto drivers and, especially, carpoolers into transit riders, second, cost reductions in transit fares appeared to increase bus ridership while cost increases did not affect drastically the bus ridership, and, third, automobile disincentives could cause shifts to other modes only to a limited extent because the tie to the automobile was strong for many.

The study of employers' encouragement programs for public transit (McClelland, Marks, Eidson & Cook, 1981) evaluated the success of large employers' programs in Denver metropolitan area to encourage their employees to use mass transit, carpooling and bicycling as work trip modes. Two surveys conducted one year apart examined the effects of two different programs on the mode choice of workers, i.e., the first addressed only financial incentives and publicity, while the second included convenience incentives and commitment levels of the participating agencies too. The study's major results pointed that the encouragement programs yielded a greater use of alternate transportation and the absence of free employee parking proved to be the strongest, most consistent measure in discouraging single occupant autos.

Kulash (1974) examined whether parking taxes can reduce problems of auto usage. Examining three types of experiences, namely, (a) before and after impacts of parking price changes, (b) Demographic cross-sectional differences related to parking price variations and (c) hypothetical responses of motorists to parking price changes, he concluded that parking elasticities suggest that the use of automobile is fairly intensive to parking price changes, because, first, a low percentage of automobiles uses paid parking and, second, parking patrons are not highly sensitive to the price of parking. However, he aknowledges that work trips are not as elastic as shopping trips and parking taxes do have to play a significant role in the transportation management system.

Finally, Gillen (1975) investigated the effects of alternative parking policies on modal choice. Using logit analysis, he examined parking location (or relocation) choice and/or switched modal choice as a function of (a) money cost, (b) time cost and (c) quality or comfort characteristics associated with a particular parking location. Data related to work trips were taken from the 1964 Metropolitan Toronto and Regional Transportation Study home interview survey. Based on the elasticity estimates for the mentioned instrumental variables, Gillen concluded that an increase of parking fee results in relocation of parking destinations, modal switching effect occurs in the portion of parkers who are dislocated the furthest out from their destination area, parking restrictions related to travel time are more effective than parking fee or time cost increases have to be applied over a wide area (e.g., entire urban area) in order to be successful. Some further examinations of this topic were done by the same author in the years 1977 and 1978.

2.7 Conclusions

The literature research revealed that there are no general rules which govern worktrip modal split. The findings of the above studies of examined studies often coincide but, at the same time, may contradict themselves as well. For example, there is no consensus among transportation researchers on whether mode choice is decided upon beliefs/perceptions or cost and time variables. Moreover, the transferability of these findings among cities is questionable because the various urban systems affect differently factors of the worktrip.

Nevertheless, there seems to exist a general agreement that three factors of worktrips, i.e., flexible work hours, parking fee increases and types of carpooling matches, favor common carrier modes. First, flexible work hours (or staggered hours or compressed work week) and parking fee increases result in greater carpooling and/or bus patronage. Second, intimate acquaintanceship among carpoolers is a potent factor in the formation of carpooling programs.

CHAPTER 3

PARKING AND WORKTRIPS OF WINNIPEG CBD

3.1 Introduction

In the present chapter, an analysis of the downtown parking supply aims to illuminate the framework in which commuters of Winnipeg have to make decisions related to parking locations. An examination of studies or data related to common carrier modes, i.e., public transit or carpooling, should determine the extent to which common carrier modes rather than auto can serve the metropolitan area of Winnipeg.

Finally, the elaboration of data collected with the help of a questionnaire provides additional information related to the existing modal split of Winnipeg's commuters and their socioeconomic characteristics. The procedure of contacting downtown employees and the survey's sampling design are examined as well.

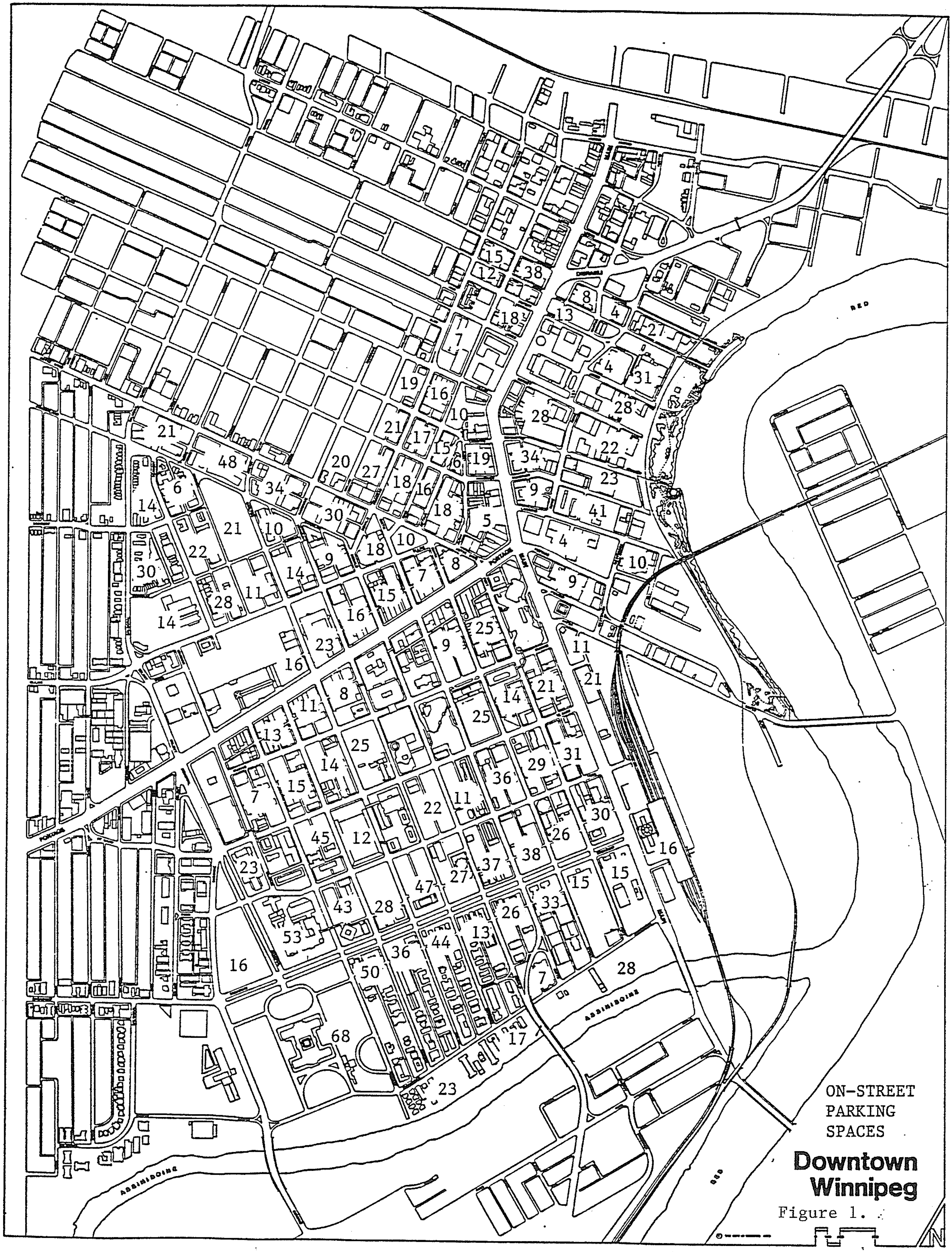
3.2 Existing parking conditions

The findings are the outcome of two extensive searches for available parking data. The first search took place in 1984, but it was unsuccessful because a parking inventory did not exist for the downtown area and other relevant information was collected in a piecemeal fashion, e.g., the "Parking feasibility study: historic Winnipeg area". Also the zoning by-laws of that time did not consider relationships among land uses and required parking spaces. In other words, parking policies and practices appeared nebulous and unclear at both City Planning, and Streets and Transportation Departments of the City of Winnipeg.

Because of the afore-mentioned reasons, a second search followed in the summer of 1987 and had some fruitful results. The City Planning Department proposed the first measures related to parking and loading areas which appear in the zoning by-laws of appendix B. On the other hand, the Civic Properties Department was undertaking the first extensive study of downtown parking. On its behalf, a consulting firm, Delcan, developed the Downtown Winnipeg Parking Study.

The Delcan study provided the number of parking spaces which are available for on-street and off-street parking in the CBD of Winnipeg, see figures 1 & 2. Nevertheless, there still was a disclosure problem and only a technical memoradum of parking usage characteristics was available.

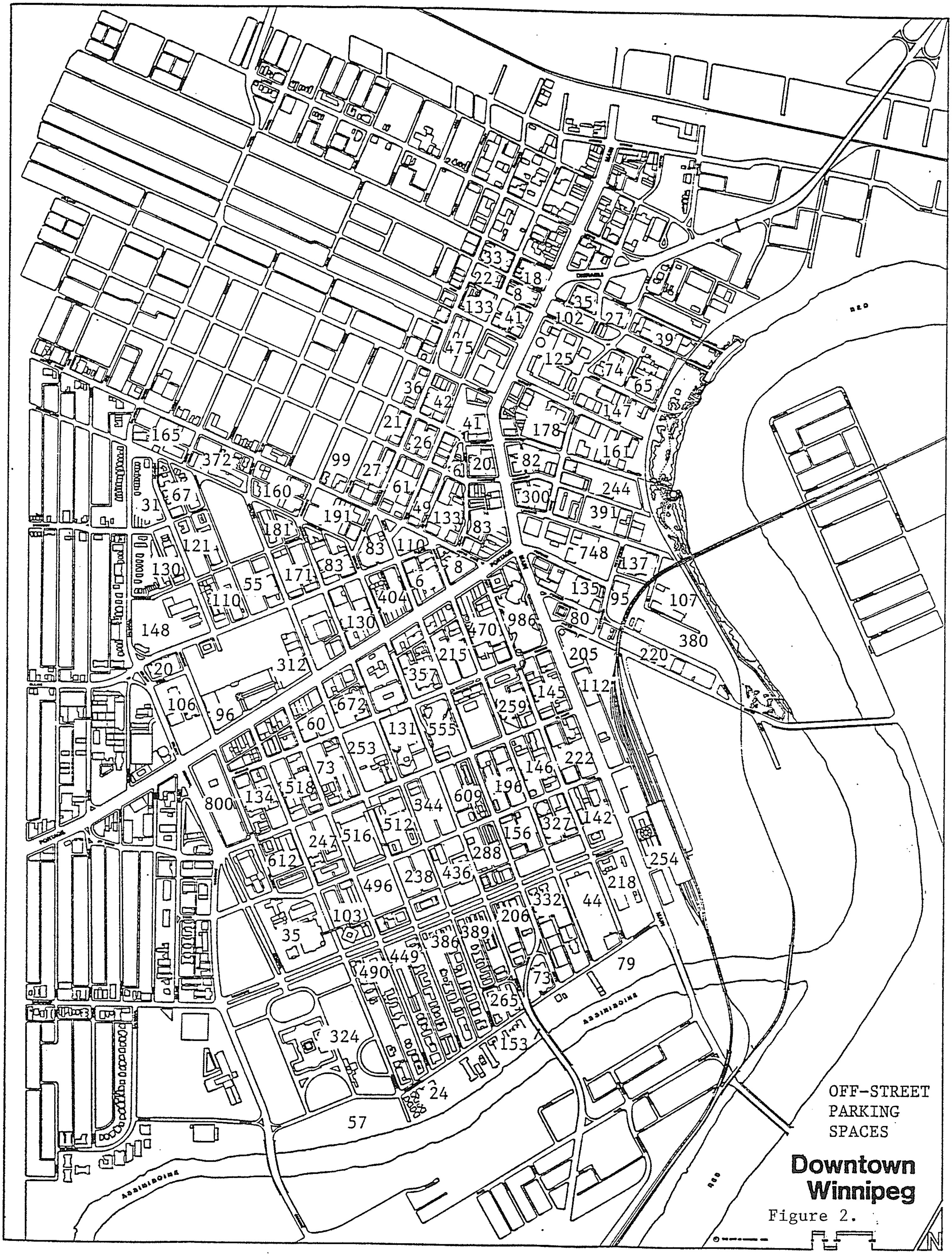
The technical memorandum (No. 2-10) examines the usage of parking by (a) traffic zones, (b) length of parkers' stay, (c) types of parking spaces, e.g., parking spaces publicly available or privately controlled, parking spaces used on a monthly or casual basis, etc., and (d) structual format of parking location, e.g., parking structures, surface parking lots, on-



ON-STREET
PARKING
SPACES

Downtown Winnipeg

Figure 1.



OFF-STREET
PARKING
SPACES

Downtown Winnipeg

Figure 2.

street parking, etc. However, parking spaces were not classified by types of users, e.g., workers, shoppers, visitors, etc. Because of this, someone reading the technical memorandum (No. 2-10) understands the structure of parking supply in the downtown area, but the document does not prioritize the parking needs and relates very little to the perspective of the subject study.

A parking space can be used by auto drivers for many purposes and should be assigned to those car users who yield the best economic benefits for the downtown area. For example, a shopper or short-term parker should have priority over a commuter or long-term parker, respectively (see I.D. Systems LTD., 1983). In Winnipeg, this seems not to be the case, because based on survey findings the Downtown Winnipeg Parking Study concluded that almost two-thirds of the parking spaces available to general public are leased on a monthly basis.

3.3 Public transit service and carpooling programs

In Winnipeg, the public transit service has not improved drastically the last decade in terms of travel time or frequency of service. For example, there has been a bus operation problem within the downtown area of Winnipeg for a long time, but the Winnipeg transit authority has recently studied the problem and developed appropriate bus priority measures with the help of

Dillon consulting firm.

In the study of bus priority measures, illegal parking is identified as one of the three factors, i.e., traffic congestion, turning vehicles, and illegal parking, which create significant delays to buses operating in the downtown area.

Apart from the mentioned study, no other study, to the knowledge of the author, had examined any characteristics of bus service. On the other hand, public carpooling programs have not existed in the recent years in the metropolitan area of Winnipeg.

3.4 Survey of Winnipeg commuters

Despite an extensive search for data related to parking behavior of commuters in Winnipeg CBD, the results were unfruitful. Because of this a systematic collection of behavioral data regarding parkers had to be pursued with the help of a questionnaire.

The objectives of the survey were to produce data useful for exploring the existing modal split of commuters and their socioeconomic characteristics, to assess existing patterns of parking demand among CBD workers and to aid in identifying means to increase bus ridership and create ridesharing patronage with the help of parking policies.

The survey approach involved self completion questionnaires distributed to employees of selected downtown agencies. The survey was administered over a three week period in August, 1984, and was entirely dependent on the internal circulation systems of the surveyed firms, i.e., to distribute and collect the questionnaires.

This method of contacting commuters through their personnel departments, used rarely in transportation research, has some advantages over other methods of data collections. According to Horwitz & Sheth (1977), the rate of return is significantly higher, approximately 50 percent, than rates of mail-out surveys and the final cost of these surveys is smaller than the cost of other approaches, e.g., home interviews or on-board transit surveys.

In some cases, the management was enthousiastic and helpful about the survey, e.g., Monarch Life Insurance Inc., but in others it was discouraging and uncooperative for a number of reasons, e.g., conflict of interests, perception on need for secrecy, etc.

3.4.1 Survey procedure and sampling design

Surveys of commuter attitudes toward parking, carpooling and mass transit were performed at six locations of the downtown area. The surveyed firms included a pronvincial governmental agency, two federal governmental agencies, a local municipal agency, a private enterprise and a crown corporation and were choosen so that they are dispersed all over the downtown area. A list of the contacted and surveyed firms is presented on table 1.

The purpose of the survey was to examine different types of organizations belonging in public and private economic sectors of the Winnipeg CBD. The sampling procedure may be biased towards high income workers because workers of shopping complexes were not surveyed, but this was done deliberately. The assumption is that high income commuters drive alone to work and this bias concurs with the target of this thesis, namely, the diversion of solo drivers to transit or carpooling.

The distributed questionnaire was designed so that it was largely self-coding, was easily understandable by the recipients and required the minimum possible time to be completed. The kind of information requested with this attitude survey appears on the appended questionnaires, see appendix C.

Initially, four formats of the questionnaire, i.e., one questionnaire addressing two alternative carpooling and mass transit DUA experimental designs, were reviewed by part of the personnel of City Planning Department, City of Winnipeg, and were pretested to clarify ambiguous questions and to assess their comprehension performance and completion time. The draft questionnaires were evaluated according to the results of this initial survey. The findings of the preliminary survey

Table 1 Surveyed Agencies

		CONTACTED	SURVEYED
1.	Department of Indian Affairs George Campbell, Regional Director 1100-275 Portage Avenue Winnipeg, MB, R3B 3A3	X	X
2.	Department of Parks Canada Doug Harper, Director #400-391 York Winnipeg, MB, R3C 4B7	X	X
3.	North American Life (Monarch Life) Paul Kelly, Vice President 333 Broadway Avenue Winnipeg, MB, R3C 059	X	X
4.	Canadian Wheat Board Jessie Bullock, General Director 423 Main Street, 8th Floor Winnipeg, MB	X	X
5.	Department of City Planning Len Vopnfjord Director Main Street, 8th Floor Winnipeg, MB	X	X
6.	Department of Municipal Affairs Irene Sutter #141 Legislative Building Winnipeg, MB R3C OV8	X	X
7.	Department of Public Works Tim Dupareu, District Manager #201-269 Main Street Winnipeg, MB, R3C 4B2	X	
8.	Great West Life Kathy Helbercht, Manager Staff 100 Osborne, 3rd Floor Winnipeg, MB, R3C 3A5	X	
9.	Royal Bank of Canada Art Mills, President & General Manager 224 Portage Avenue Winnipeg, MB, R3C 3A6	X	
10.	Canadian National Railroad D.L. Fletcher, Vice President #300-123 Main Street Winnipeg, MB, R3C 2P8	X	

indicated and determined that more thoughtful responses were elicited by the short DUA experimental designs. Because of this the final format of distributed questionnaire included a carpooling or mass transit DUA experiment of eight senarios.

The selected questionnaires, i.e., short carpooling and transit DUA experiments, were alternately piled up to form the required bunch of distributed questionnaires and were delivered to the personnel directors of the surveyed agencies. To avoid bias in the distribution of forms, each director was instructed to sample the whole of an agency-division and was given sufficient questionnaires for this purpose.

The self-administered questionnaire was mainly hand delivered to the employees, but it was impossible to keep an exact check on how they finally reached the hands of individual employees. Because the administrations, which distributed and collected them, used different approaches. For example, Parks Canada and Wheat Board agencies had each of them its own cover letter, see appendix C, which explained the purpose of the survey. While both personnel departments hand delivered the questionnaire, their collection procedure was different. The Parks Canada agency had a return-box for questionnaires in the lobby area and the Wheat Board agency had a hand collecting procedure, assigning a specific person for this purpose. The rest of the agencies did not have any of their own cover letters and probably had a hand-delivered and hand-collected procedure, but further specific details are unknown to the author. Of course, there must have been deficiencies in these procedures because an important number of questionnaires was mailed back from agencies, e.g., Department of Municipal Affairs (at Woodsworth Building), to City Planning Department of the University of Manitoba.

Nevertheless, the raw return rates were good and ranged from 41 to 76 percent and averaged 60.82 percent. More specifically, the personnel departments of each agency returned the questionnaires exibited on table 2. The collected questionnaires were exposed to a detailed validation before any further analysis of them was implemented.

In the validation procedure, the main problems were related to questionnaires which respondents failed to answer all the requested questions and had some confusion between an answer and more than one answer for the same situation of the DUA experiment. Therefore, extensive checks were accomplished to guarantee that all the fields were filled satisfactorily. Further, the objective of the carried validation was to ensure that all the answers fell within permitted ranges and that no illogicalities existed.

In general, the standard procedure of transportation analysis is to omit incomplete records. But this implies a loss of data which in the present study would be unacceptable. Individual records were excluded only in cases which contained

Table 2. Raw response rate of survey

	Distributed questionnaires	Collected questionnaires		Collected questionnaires with carpooling experiment		Collected questionnaires with mass transit experiment	
	#	#	%	#	%	#	%
Department of Parks Canada	100	71	71	37	74	34	68
Canadian Wheat Board	100	67	67	31	62	36	72
Monarch Life	100	63	63	33	66	30	60
Department of City Planning	226	106	47	50	44	56	49
Department of Municipal Affairs	200	82	41	39	39	43	43
Department of Indian Affairs	100	76	76	40	80	36	72
Total	826	465	56	230	55	235	56

unusual responses and, in my opinion, was felt that they were distorting the estimates. On the other hand, questionnaires lacking a significant number of responses were discarded as well, e.g., missing experimental responses or background individual data.

The results of the validation process yielded a usable response rate which is presented on table 3. Finally, the usable questionnaire dealing with experimental designs related to auto vs carpool and auto vs public transit are given by the table 4.

3.4.2 Behavioral profiles of parkers

The present analysis of downtown parking behavior investigates, in a broad conceptual context, what determines where commuters park. Based on the findings of conducted survey, existing modal split, socioeconomic characteristics and parking choices of CBD commuters are examined in order to explain the existing behavior of people in choosing, first, between auto mode and carpool or public transit mode, and, second, among parking locations.

The interest on the above analysis is in the fact that transportation researchers have apparently overlooked the significance of commuters' perceptions related to parking and walking factors in worktrips at the downtown area. In many

Table 3. Usable response rate of survey

	Total number of questionnaires	
	#	%
Department of Parks Canada	52	52
Canadian Wheat Board	59	59
Monarch Life	60	60
Department of City Planning	97	42
Department of Municipal Affairs	79	39
Department of Indian Affairs	67	67
Total	414	50

Table 4. Usable response rate of experimental plans

	Total number of questionnaires		Collected questionnaires with carpooling experiment		Collected questionnaires with mass transit experiment	
	#	%	#	%	#	%
Department of Parks Canada	12	12	7	14	5	10
Canadian Wheat Board	10	10	5	10	5	10
Monarch Life	16	16	9	18	7	14
Department of City Planning	52	22	21	18	31	27
Department of Municipal Affairs	44	22	21	21	23	23
Department of Indian Affairs	19	19	7	14	12	24

cases, the worktrip modes have been divided into the access and line-haul segments, because these are perceived differently by commuters, e.g., see Neveu A., F. Koppelman and P. Stopher (1979). Excluding Gillen D. (1977a) and Ergun G. (1971), no researcher seems to have considered a third dimension of the worktrip, namely, the egress segment or the segment related to leaving the primary vehicle and arriving at the workplace.

The present thesis examines exactly this complementary part of the main or line-haul trip. Parking and walking commodities are considered both complementary to auto trips and one of them, i.e., walking, is complementary to public transit trips. In other words, this study examines how different socioeconomic strata of commuters make up their existing trade-off, having to choose between parking close to workplace with high monetary cost and low walking time, and parking far from workplace at low cost but with a long walk.

The findings explaining the behavior of people travelling in downtown Winnipeg are examined according to the selected transport mode, below. Since explanatory variables related to system characteristics are perceived differently from tripmakers belonging to competing transport modes. For example, bus travel time is perceived more onerous by auto drivers than bus riders, see table 5.

1. Auto drivers. According to the survey results, all solo drivers have a driving licence and a car available on an every

day basis for the worktrip. Almost the majority of them parks free for more than seven hours on lots in the downtown area, see tables 6, 8, and 11. The 59 percent of CBD auto drivers walks less than a block from their parking lot to workplace. The usage of their car is very seldom during the work day and they avoid to ride a bus, actually 79 percent of them never uses bus for worktrip, see tables 7 and 9.

Professional and managerial males having income above $30,000 per year and age between 25 and 44 years dominate the socioeconomic characteristics of auto drivers. Further, the majority of auto drivers has at least two cars in their household and would consider switching to another transport mode or changing their parking location, if parking rates were imposed, regarding commuters who park free, or increased at a price range of $80.00 and over per month, see tables 13 and 12. Table 23 indicates that a minimal percentage of high income parkers pays a monthly fee of $70.00 to $80.00, and findings about the average walking distance of different income groups are inconclusive, assuming that the average block is 450 ft. in the downtown area.

Finally, a portion of auto drivers declared reluctance to switch to transit or carpooling. As regards carpooling an important reason given was that the respondent's car was "needed at work": while this might be a valid reason for being unable to receive lifts or to enter a carpool it is not itself a reason for being unable to give lifts. On the other hand, the statements of appendix C portray the unwillingness of auto drivers to shift to public transit.

2. Bus riders. A high percentage (67 percent) of bus riders has a car available for the worktrip and, at the same time, holds a driving license. Only 10 percent of them are captive to bus given that there is no available car in their household, see tables 19, 18 and 13.

Buses serving worktrips are mainly riden by secreterial and clerical females, young people (less than 25 years) and people with income between $10,000 and $24,999 per year, see tables 15 (or 22), 16 (or 21) and 17. Finally, bus riders have a more positive perspective for bus travel time than auto drivers and a small percentage of them compared to the respective percentage of auto drivers is unaware of travel time differences between auto and bus, see table 5.

3. Carpoolers. Carpooling is equally attractive to professional or managerial and secreterial or clerical people, see table 15 (or 22). It can be assumed that there is family carpooling because there are only two persons without a car in their household, see table 13. Carpoolers are dominated by females and people having annual income between $15,000 and $29,999, see tables 14 and 17. Finally, a significant percentage of carpoolers has a car available for worktrips and holds a driving license, see tables 19 and 18.

Table 5. Perceived difference of bus travel time and auto travel time

	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
BTTF 16 min. & over	0	0	2	2	0	0
BTTF 11 - 15 min.	1	1	1	1	2	1
BTTF 6 - 10 min.	0	0	1	1	3	2
BTTF 1 - 5 min.	0	0	0	0	0	0
BTT Same	5	3	0	0	16	9
BTTS 1 - 5 min.	2	1	3	3	9	5
BTTS 6 - 10 min.	12	8	14	16	36	20
BTTS 11 - 15 min.	40	25	27	31	50	28
BTTS 16 min. & over	49	31	27	31	44	25
Do not know	37	23	13	15	18	10
Not applicable	12	8				
Total	158	100	88	100	178	100

where BTTF = Bus Travel Time Faster
BTTS = Bus Travel Time Slower

Table 6. Parking cost (monthly and daily)

	Auto drivers	
	#	%
Free	71	45
$ 0 - 50	51	32
$ 50 - 60	23	15
$ 60 - 70	4	2
$ 70 - 80	0	0
$ 80 & over	0	0
$ 0.00 - 3.00	3	2
$ 3.01 - 3.50	0	0
$ 3.51 - 4.00	3	2
$ 4.01 - 4.50	3	2
$ 4.51 & over	0	0
Total	158	100

Table 7. Usage of car during work-day.

	Auto drivers	
	#	%
Never	50	32
Very seldom	42	26
Frequently	48	30
Always	17	11
Other	1	1
Total	158	100

Table 8. Commuters' parking duration in downtown area.

	Auto drivers	
	#	%
0-7 hrs.	66	42
7 hrs. & over	92	58
Total	158	100

Table 9. Usage of bus for worktrip

	Auto drivers	
	#	%
Never	125	79
Occasionally	25	16
Very often	7	4
Other	1	1
Total	158	100

Table 10. Walking distance

Blocks	Auto drivers	
	#	%
0.0 - 0.5	50	32
0.5 - 1.0	43	27
1.0 - 2.0	41	26
2.0 - 3.0	15	9
3.0 & over	9	6
Total	158	100

Table 11. Parking location

	Auto drivers	
	#	%
Structure	29	18
Lot	103	65
Parking meter	12	8
Restricted area	5	3
Street	9	6
Total	158	100

Table 12. Monthly parking rates at which commuters would switch mode

	Auto drivers	
	#	%
$ 0 - 64	58	37
$ 65 - 80	26	16
$ 81 - 95	14	9
$ 96 - 120	9	6
$ 121 - 135	1	1
$ 136 & over	8	5
Did not answer	24	15
Not applicable	18	11
Total	158	100

Table 13. Number of cars in household

	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
None	0	0	2	2	17	10
One	61	39	38	43	104	58
Two	78	49	35	40	44	25
Three & over	19	12	13	15	13	7
Total	158	100	88	100	178	100

Table 14. Sex of commuters

	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
Males	93	59	36	41	63	35
Females	65	41	52	59	115	65
Total	158	100	88	100	178	100

Table 15. Occupation of commuters

Occupation	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
Professional/managerial	108	68	46	52	72	40
Secreterial/clerical	50	32	42	48	106	60
Total	158	100	88	100	178	100

Table 16. Age of commuters

Years	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
0 - 19	2	1	1	1	1	1
20 - 24	10	6	14	16	36	20
25 - 29	25	16	15	17	27	15
30 - 34	22	14	12	14	28	16
35 - 39	24	15	10	12	24	14
40 - 44	29	19	9	10	12	7
45 - 49	14	9	9	10	15	8
50 - 54	10	6	9	10	16	9
55 - 59	12	8	2	2	11	6
60 & over	10	6	7	8	8	4
Total	158	100	88	100	178	100

Table 17. Income of commuters

	Auto drivers		Carpoolers		Bus riders	
	#	%	#	%	#	%
$ 0,000 - 4,999	1	1	1	1	0	0
$ 5,000 - 9,999	1	1	1	1	1	1
$ 10,000 - 14,999	9	5	13	15	27	15
$ 15,000 - 19,999	13	8	10	12	42	23
$ 20,000 - 24,999	25	16	22	25	35	20
$ 25,000 - 29,999	19	12	11	12	14	8
$ 30,000 - 34,999	38	24	11	12	21	12
$ 35,000 - 39,999	14	9	3	4	10	5
$ 40,000 & over	38	24	16	18	28	16
Total	158	100	88	100	178	100

Table 18. Commuters having driver's licence

	Carpoolers		Bus riders	
	#	%	#	%
Yes	84	95	157	88
No	4	5	21	12
Total	88	100	178	100

Table 19. Availability of car for worktrip

	Carpoolers		Bus riders	
	#	%	#	%
Yes	67	76	120	67
No	21	24	58	33
Total	88	100	178	100

Table 20. Sex and modal split

Sex	#	% of total sample	% of car users	% of bus users	% of carpool users
			(in each category)		
Male:	192	45	48	33	19
Female:	232	55	28	50	22
	424	100			

Table 21. Age and modal split

Age	#	% of car users	% of bus users	% of carpool users
		(in each category)		
<25	64	19	57	24
25-55<	310	40	39	21
>55	50	44	38	18
	424			

Table 22. Status and modal split

Status	#	% of car users	% of bus users	% of carpool users
			(in each category)	
Professional	226	48	32	20
Clerical	198	25	53	22
	424			

Table 23. Parking costs by income group for worktrips

Income Group

Parking Cost	$ 0 - 4,999		$5,000- 9,999		$10,000- 14,999		$15,000- 19,999		$20,000- 24,999		$25,000- 29,999		$30,000- 34,999		$35,000- 39,999		$40,000- & over		Number	Percent	Cumulative Percent
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%			
Free	1	100	1	100	3	33	7	54	11	44	9	48	21	55	4	29	14	37	71	45	45
$0-50					6	67	5	38	10	40	5	26	8	22	6	43	13	34	53	34	79
$50-60							1	8	3	12	5	26	7	18	2	14	8	21	26	16	95
$60-70									1	4			2	5	1	7	2	5	6	4	99
70-80															1	7	1	3	2	1	100
$80 & Over																					
Total	1	1	1	1	9	5	13	8	25	16	19	12	38	24	14	9	38	24	158	100	
Ave. Walking Distance	900		1350		234.16		722.69		813.54		742.10		567.55		645.00		444.86				

CHAPTER 4

DIRECT UTILITY ASSESSMENT OF PERCEPTIONS OF WINNIPEG'S COMMUTERS

4.1 Introduction

The aim of this chapter is to select the Direct Utility Assessment (DUA) experimental variables to be included in the carpooling and mass transit experiments and to define the form in which experimental and explanatory variables, i.e., socioeconomic variables, will be introduced into the models, see appendix D for a brief description of Direct Utility Assessement (DUA) method.

Combinations of experimental variables are included in DUA experimental designs. The process of developing these designs is explained and their final formulation is determined. The reasons contributed in the selection of specific levels for the explanatory variables are elucidated according to the transportation conditions of Winnipeg.

Binary DUA models are developed in theoretical terms and are applied to the survey responses of Winnipeg commuters in order to estimate the extent to which parking policies would effect a diversion of solo drivers to common carrier modes. A validation procedure established the robustness of these models comparing previous relative findings of Northamerican or British cities.

Finally, pivot point analysis is performed to reveal policy implications resulted from the manipulation of the selected causal DUA factors.

4.2 Selection of experimental and explanatory variables.

In this chapter, binary DUA models examine individual choice between the egress segments of either auto- and bus-trips or auto- and carpool-trips and treat parking as the basic commodity whose demand is derived from the choice of using automobile as the transit mode.

The selection of experimental variables was restricted by the lack of information gathered later on with the help of a questionnaire survey. For example, parking costs paid by CBD workers or walking distances from parking locations to workplace destinations were unknown.

In previous modal choice studies, parking costs are added to the automobile running costs. This assumption implies that modal choice is independent of parking conditions and parking-location decisions are unaffected by variations in parking costs. However, changes in parking costs can effect parking relocation or modal switching, see Gillen D. (1977a) and Ergun G. (1971). The latter effect is examined in the present thesis.

The variables which are considered for inclusion in the DUA models will be examined in three categories: (1) transport mode and trip characteristics, (2) characteristics of the trip-maker and (3) environmental characteristics.

1. Transport mode and trip characteristics. Parking conditions in the downtown area may affect the attractiveness of commuting by the car in several ways: (a) if parking space is in short supply or restricted for commuters, time will be spent looking for a parking spot. This implies increased total travel time. But time spent searching for parking has a higher disutility than in vehicle time. Consequently, the disutility of time spent commuting will increase more than proportionally to the increase of total travel time when searching time increases, (b) if no parking spot can be found close to workplace, walking time will increase as well. But walking time has a greater disutility than in-vehicle time and (c) if parking cost is not free or increased, the total commuting cost by automobile will be increased.

Walking time is linked largely to the choice of travel mode. Tripmakers object walking or waiting time when private versus public mode choice is considered, because walking or waiting time is 1.03 to 4.5 times more onerous than in-vehicle time, see Southworth F. (1981). Walking time or distance depends on the size of the city, available space for parking, weather conditions, walking habits of parkers, age structure of commuters and parking cost. In relation to public transit, walking time has a tolerance limit of approximately 6 min., i.e., 1,000 ft to 3,000 ft, and affects the population coverage of bus routes, see Hoey W. and F. Levinson (1977).

Carpooling factors affect two or more people regularly travelling to and from work by car. Carpooling is the combination of an economic phenomenon and a complex social/psychological phenomenon, perceived as an arrangement which does not have well established social customs.

Based on car-usage, carpoolers face the same parking and walking factors which solo drivers do. Carpooling is a competitive mode to both auto driving and bus riding. Commuters could shift among these three modes depending on their perceptions for each mode. Carpoolers are sensitive to parking cost and could switch to transit, if high parking fee is an incentive, see Miller G.and C. Everett (1982).

Carpooling programs are successful when one or more of the following factors exist: (a) areas with poor public transport, (b) great number of worktrips during peak periods, (c) workplaces distant from residential areas and (d) cooperation among employers and commuters about flexible work hours.

Finally, the level of mass transit service is apparently significant in terms of attracting and converting auto users to bus riders, because solo drivers have higher transit service expectations than transit users, see Hoey W. and F. Levinson (1977). Bus service having characteristics like low waiting time, calling without delay, shelter at pick up, low fares, trip without transfer, minimum total travel time etc., affects and increases the potential patronage.

Traditionally, transportation researchers have examined cost, time and frequency variables as the most significant ones depicting level of transit service. For example, free public transport would be expected to attract 21 percent of the existing auto users and short headways for bus service (i.e., 4.5 minutes) are required by the average driver who is a potential shift patron, see Daly A. & S. Zachary (1977) and Brown G. (1972), respectively. Nevertheless, some researchers claim that comfort and convenience factors are more important than the previously mentioned variables, e.g., see Algers S., S. Hansen and G. Tegner (1975).

2. Characteristics of the tripmaker. Income of auto drivers is selected as an explanatory variable because it may be correlated with modal choice for two main reasons: (a) The income level is probable to influence the perception of the cost difference between modes. Namely, the demand for the car-services is probably less elastic with respect to the trip-cost for higher income groups than lower income groups. The higher the commuter's income, the less a cost difference is likely to prevent him from using the favored mode, assuming other factors are identical. (b) There is intuitively a positive correlation between the level of income and the value attached to travel time savings. People maximize satisfactions under the

constraints of their income and time budget. For example, as income increases it is less desirable to spend time traveling.

Further, income influences and has complex cross-effects on many of the worktrip variables, e.g., auto ownership, occupation status, commuting time or cost etc. For instance, people with a higher income often have a higher level of education and more prestigious social occupation.

The gender of traveler (sex) affects modal choice for three reasons: (a) either sex may not have the same perception of some convenience or comfort characteristics of the studied modes, (b) there is a tendency among women to have a lower psychological preference for auto driving than men, and (c) in case of a working couple, the husband has a priority for using the car as head of household.

Age relates to modal choice for the following reasons: (a) perception of several comfort attributes of the competing modes may vary with age, e.g., older people incline not to be attracted by the automobile and (b) the subject variable may be collinear with other factors determining modal choice, e.g., usually there is a certain correlation between income and age or social status and age. The introduction of age in a modal choice model can be either as a continuous variable or as a dummy variable. The former is justifiable if only broad age brackets are relevant for explaining mode choice.

Social status or occupation status has rarely been used in the explanatory factors of a modal choice model. Nevertheless, it is a necessary explanatory variable for the creation of carpooling arrangements. A social status variable expressed in the form of a dummy variable can stand proxy for social norms which may be stronger in certain groups than in other, e.g., white collar employees vs blue collar workers. Of course, there is likely a certain correlation between social groups and incomes, e.g., high professions and high income brackets.

Finally, the level of auto ownership or the number of available cars in the household affects sensibly the decision to be or not to be an auto driver for any member of the household. Income is highly correlated with the subject variable.

3. Environmental characteristics. The perception of tripmakers, as regards the corresponding attributes of the competing modes, depends mainly on their socioeconomic characteristics, but it does depend on some physical characteristics of the environment as well. Weather conditons can increase or decrease the disutility of walking or travelling time and affect the psychological characteristics of tripmakers. For example, walking is more onerous during winter time than summer time, especially, wherever the mentioned seasons present severe climatological contrasts, i.e., snowy periods vs sunny periods of the year.

4.3 DUA experimental design

Aiming in a noncomplex understandable experimental design, the levels and number of variables included in the DUA experiment were selected so that the least possible senarios represent accurately the egress segment of a worktrip.

Based on the literature research and personal judgement, the maximum number of situations and variables investigated in the DUA experiments was decided to be sixteen and six, respectively. Only two binary models, i.e., automobile vs carpool and automobile vs bus, were pursued, because general carpooling programs did not exist in Winnipeg when the collection of data was taking place and, formally, there was no competition between public transit and carpooling.

For the auto mode, parking cost, walking time and season of the year, i.e., winter vs summer were the most obvious variables to investigate. In Winnipeg, weather conditions affect travelling behavior because of the severe snowy winters which force the individual to be exposed for the minimal possible time period in the natural environment.

In the carpooling experimental plan, the carpool variables are identical to the mentioned auto variables except that the type of carpooling matches variable, i.e., unkown or intimate carpooling parteners, substitutes the seasonal variable.

Further, the public transit DUA experiment examines the cost, travel time and frequency of bus in addition to the above auto variables.

Using a catalog of fractional factorial designs, see Kocur G., T. Adler, W. Hyman and B. Aunet (1982), several experimental plans were constructed so that a future selected plan could easily fit the requirements of the survey. The utilized catalog consisted of two parts, i.e., an index and a set of master plans. The index enumerates and describes the available experimental plans and the master plan designates the specific combination of variables so that it is possible the orthogonal estimation of the main effects and the denoted interactions among variables. The selection procedure for an experimental design requires decisions in relation to (a) the total number of variables (b) the number of their levels and (c) the existence or not of two-factor interactions. These decisions allow the identification of specific columns, which pertain to an appropriate master plan and are needed to create the desired experimental plan.

In the present case, there are six variables at two levels per experiment and their two factor interactions are presumed nonexistent in the analysis of certain main effects. These assumptions resulted in two experimental plans, see questionnaires of appendix C. One of the experimental plans considered sixteen situations and was rejected at the pretest stage of the survey, because it was too lengthy and complex. The other experimental plan was consisted of eight senarios and the levels of its factors are examined in detail below.

4.4 Levels of selected factors

Based on a statistical survey of parking costs in structures and lots of the downtown area of Winnipeg, the average and maximum parking cost was estimated $65 and $90 per month, respectively. Because of this, the base level of parking cost for automobiles was determined at the price of $65 per month. Also, the following reasons contributed in the selection of the alternative level for the parking cost variable, i.e. $110 per month. First, the DUA experimental design can predict the effect of each factor within the range of levels of selected variables and, second, Margolin J. et al (1976) estimated that 67 percent of solo drivers could switch from solo driving if parking costs increased by $20 per month. Attempting to capture the parking behavior of high income commuters the value of $20 per month was added to the maximum existed parking cost.

The average walking time of solo drivers ranges between 3 min. and 5 min., see Hoey W. and H. Levinson (1977) or Horowitz A. and J. Sheth (1977). However, the base level of this variable equates the value of 7 min. assessing that public transit could be competitive with auto mode at this level.

Further, the second level of walking time was deliberately set to the extreme value of 15 min. assuming that the equivalent walking distance could be a deterrent to auto mode and could convey solo drivers to ridesharing modes.

In contrast, the levels of carpool and bus factors intended to entice downtown commuters. The parking variable of carpooling deals with nominal costs, i.e., $20 per month or free, provided that the average parking cost was at least three times the highest selected value. Walking time of carpool mode was resolved to 5 min. and negligible corresponding to a base and incentive level, respectively. The latter value was based on the findings of Wood K. (1982) who estimated that a five minutes reduction at the end of the worktrip is equivalent to the 50 percent of the motoring "real" cost. Further, the carpool factors included two types of carpooling matches, namely general public and intimate acquaintances, e.g., coworker, neighbor, etc.

The base and incentive levels of bus factors depict the realistic and potentially improved conditions of public transit service in Winnipeg. Bus fare was $0.75 one way and was reduced to free, given that subsidized employer programs could exist. Assuming bus stops within 6 min. walk from both home and workplace, see experimental plan of bus factors in appenix B, the bus travel time is 27 min. and 17 min. slower than auto travel time. These assumptions approximate existing and future possible conditions of Winnipeg transit, respectively. Finally, the existing bus frequency for all routes is estimated to average 10 min. provided that this estimation accounts for residential service routes. The desirable level of frequency is 5 min. and represents the bus service of main routes during rush hours, e.g., Pembina Highway route.

4.5 Development of forecasting models

In this section, two binary models are developed to interpret the survey responses according to the experimental variables and the socioeconomic characteristics of the respondent. Using computer analysis, multiple linear regressions are performed on the data to capture the relationship between responses and the independent variables which influence the likelihood of carpooling or riding mass transit.

Based on the experimental plan, the general form of carpooling model is:

$$R = c + a1*PCA + a2*WDA + a3*SY + a4*PCC + a5*WDC + a6*T + a7*SEX + a8*AGE + a9*JS + a10*VN + a11*I$$

where: R = the response on "1"- "5" experimental scale

c = constant

a1,...a11 = coefficients

PCA = parking cost of auto driver

WDA = walking time of auto driver

SY = season of year (1 = summer, 0 = winter)

PCC = parking cost of carpooler

WDC = walking time of carpooler

T = type of carpooling matches

SEX = sex of respondent (0 = male, 1 = female)

AGE = age of respondent (continuous variable)

JS = job/occupation status (0 = professional or managerial, 1 = secreterial or clerical)

VN = number of vehicles in household (0 = one car, 1 = two or more cars)

I = annual income

Similarly, the general form of public transit model is:

R = c + b1*PC + b2*WD + b3*SY + b4*BC + b5*BT + b6*BF + b7*SEX + b8*AGE + b9*JS + b10*VN + b11*I

where: R = the response on "1"-"5" experimental scale

c = constant

b1,...b11 = coefficients

PC = parking cost of auto driver

WD = walking time of auto driver

BC = bus fare (one way)

BT = bus travel time

BF = bus frequency

other = identical to those defined in the carpool model.

The data from the DUA survey were manually coded and stored for data processing and computer-assisted analysis. The socioeconomic dummy variables were coded according to the values given in the carpool model. Using a mainframe IBM 4381-P13 computer, a SPSS statistical package (release 2.1 for IBM VM/CMS) estimated numerous regression equations which appear in the appendix E and result from various combinations of independent variables.

The calculated equations of appendix E represent utility equations of a binary choice and can be broken into two equations according to the variables of each mode. For example,

R1 = U(B1) - U(A1) or R2 = U(C2) - U(A2),

where:R1, R2 = utility equations,

U(A1), U(A2) = utility equations of auto mode,

U(B1) = utility equation of mass transit,

U(C2) = utility equation of carpools.

Variables of socioeconomic characteristics are assigned intuitively to the appropriate mode. For instance, the number of vehicles in the household are related to auto mode rather than mass transit mode. Of course, examining the case of auto vs carpool mode, this variable can be assigned to either mode.

The selected data were broken into carpooling and bus experimental data. Each of them was further divided into sets which included or not responses with no variation, i.e., respondent selects always the same mode with the same weight. Because of this, four groups of estimated equations are examined in the continuation of this study. The data sets examining responses with variations rendered regression equations with better statistical results than equations accounting for all kind of responses.

The experimental variables were combined with several socioeconomic variables in order to explain the influence of the latter factors on modal choice. Alternative combinations aimed to identify the dominant socioeconomic attribute or the percentage of significance of each variable and to determine a realistic interpretation for each of them.

The followed procedure in selecting the most representative equation(s) of mode choice was by rejecting estimated equations which had low statistical tests or contradicted expected assumptions. For example, several calculated equations account for the relationship of parking cost and income, namely the division of parking cost by the income PC/I or PCA/I which are expressed as PC1 or PCA1 in the respective models. Their results were rejected because their statistical goodness-of-fit, e.g., R-squared criterion, was lower than the counterpart of equations dealing with just the parking cost (other factors being the same) and the sign of their independent variables frequently perverted to contradict reasonable expectations.

On statistical grounds, someone could reject the groups of equations examining responses with no variation for both carpooling and bus experiments, but, in my opinion, all four sets of calculated equations give some insight in the behavior of commuters and the interpretation of all findings is worthwhile. Some representative equations of each category appear on tables 24, 25, 26 and 27 and the appendix E includes the total number of studied equations.

Starting the interpretation of findings with the carpool mode, someone notices that equations dealing with one socioeconomic variable at a time have reasonable and contradictory signs for the explanatory variables. The calibrated models indicate expected positive signs for parking cost and walking time of auto drivers, type of carpooling match, sex and occupation status, and unexpected ones for walking time of carpoolers and season of the year. The former variables having positive signs imply that, first, high parking cost or high walking time established for auto users switches solo drivers to carpooling, second, carpooling programs based on intimate acqaintanceships entice car users and, third, females and clerical or secreterial employees incline towards carpooling. In contrast, the latter variables signify that negligible walking time and summer periods turn away solo drivers from carpooling, which is unreasonable on a theoretical ground. However, these unexpected positive signs can be attributed to the orthogonality of the experimental plan.

On the other hand, variables having negative signs are: parking cost of carpoolers, age, number of vehicles in the

Table 24. Carpooling equations (database including responses with/without variation)

(.07 = R-squared)

$$R = \underset{(4.03)}{1.359} + \underset{(5.62)}{.016\text{PCA}} + \underset{(.48)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.19)}{.001\text{PCC}} + \underset{(.19)}{.005\text{WDC}} + \underset{(3.19)}{.409\text{T}}$$

(.15)

$$R = \underset{(3.08)}{1.007} + \underset{(5.87)}{.016\text{PCA}} + \underset{(.50)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(7.14\ =\ \text{t-statistic})}{.898\text{SEX}}$$

(.25)

$$R = \underset{(8.14)}{3.387} + \underset{(6.25)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(1.16)}{.169\text{SEX}} - \underset{(-8.48)}{.056\text{AGE}}$$

(.24)

$$R = \underset{(9.96)}{3.622} + \underset{(6.24)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} - \underset{(-11.32)}{.061\text{AGE}}$$

(.12)

$$R = \underset{(3.37)}{1.116} + \underset{(5.78)}{.016\text{PCA}} + \underset{(.49)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.28)}{.409\text{T}} + \underset{(5.70)}{.763\text{JS}}$$

(.22)

$$R = \underset{(6.64)}{2.951} + \underset{(6.15)}{.016\text{PCA}} + \underset{(.52)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.21)}{.001\text{PCC}} + \underset{(.21)}{.005\text{WDC}} + \underset{(3.49)}{.409\text{T}} + \underset{(.95)}{.763\text{JS}} - \underset{(-6.55)}{.820\text{VN}} - \underset{(-3.98)}{.0381}$$

(.16)

$$R = \underset{(5.98)}{1.979} + \underset{(5.91)}{.016\text{PCA}} + \underset{(.50)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.36)}{.409\text{T}} - \underset{(-7.67)}{.972\text{VN}}$$

(.16)

$$R = \underset{(7.79)}{2.932} + \underset{(5.93)}{.016\text{PCA}} + \underset{(.50)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.37)}{.409\text{T}} - \underset{(-7.67)}{.053\text{I}}$$

Table 25. Carpooling equations (database including only responses with variation)

$$\begin{array}{llllllll}
(.26 = \text{R-squared}) & & & & & & & \\
R = & .084 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} \\
 & (.22) & (8.90) & (.67) & (.13) & (-.22) & (.22) & (5.01)
\end{array}$$

$$\begin{array}{llllllll}
(.37) & & & & & & & \\
R = & -.450 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (-1.13) & (9.66) & (.73) & (.14) & (-.24) & (.24) & (5.44) \\
 & & + .980\mathrm{SEX} & & & & & \\
 & & (7.30 = \text{t-statistic}) & & & & &
\end{array}$$

$$\begin{array}{llllllll}
(.43) & & & & & & & \\
R = & 1.380 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (2.91) & (10.12) & (.77) & (.15) & (-.25) & (.25) & (5.70) \\
 & & + .980\mathrm{SEX} & - .041\mathrm{AGE} & & & & \\
 & & (2.47) & (-5.45) & & & &
\end{array}$$

$$\begin{array}{llllllll}
(.41) & & & & & & & \\
R = & 2.015 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (5.01) & (10.03) & (.76) & (.15) & (-.25) & (.25) & (5.65) \\
 & & & - .053\mathrm{AGE} & & & & \\
 & & & (-8.99) & & & &
\end{array}$$

$$\begin{array}{llllllll}
(.31) & & & & & & & \\
R = & -.182 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (-.48) & (9.22) & (.70) & (.14) & (-.23) & (.23) & (5.19) \\
 & & & & + .677\mathrm{JS} & & & \\
 & & & & (4.70) & & &
\end{array}$$

$$\begin{array}{llllllll}
(.37) & & & & & & & \\
R = & 1.914 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (3.51) & (9.64) & (.73) & (.14) & (-.24) & (.24) & (5.43) \\
 & & & & - .677\mathrm{JS} & - .245\mathrm{VN} & - .055\mathrm{I} & \\
 & & & & (-.94) & (-1.66) & (-4.53) &
\end{array}$$

$$\begin{array}{llllllll}
(.28) & & & & & & & \\
R = & .363 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (.92) & (9.01) & (.68) & (.13) & (-.22) & (.22) & (5.07) \\
 & & & & & - .424\mathrm{VN} & & \\
 & & & & & (-2.79) & &
\end{array}$$

$$\begin{array}{llllllll}
(.36) & & & & & & & \\
R = & 1.450 & + .028\mathrm{PCA} & + .012\mathrm{WDA} & + .019\mathrm{SY} & - .001\mathrm{PCC} & + .006\mathrm{WDC} & + .730\mathrm{T} + \\
 & (3.58) & (9.60) & (.73) & (.14) & (-.24) & (.24) & (5.41) \\
 & & & & & & - .048\mathrm{I} & \\
 & & & & & & (-7.00) &
\end{array}$$

Table 26. Mass transit equations (database including responses with/without variation)

```
(.04 = R-squared)
R =  1.782 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF
    (4.57)   (5.66)     (.14)      (-.19)   (-.44)    (-.09)    (-.29)

(.15)
R =  1.302 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (3.51)   (6.01)     (.15)      (-.20)   (-.47)    (-.10)    (-.31)
           + 1.08SEX
             (9.09 = t-statistic)

(.21)
R =  3.450 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (6.95)   (6.21)     (.16)      (-.21)   (-.48)    (-.10)    (-.32)
           + .453SEX  - .006AGE                      - .0521I
             (3.02)    (-1.11)                         (-6.01)

(.11)
R =  3.224 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (7.47)   (5.86)     (.15)      (-.20)   (-.45)    (-.10)    (-.30)
                      - .035AGE
                       (-6.85)

(.20)
R =  4.231 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (9.92)   (6.17)     (.16)      (-.21)   (-.48)    (-.10)    (-.32)
                      - .011AGE                      - .065I
                       (-2.00)                         (-8.42)

(.18)
R =  1.368 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (3.76)   (6.11)     (.16)      (-.21)   (-.47)    (-.10)    (-.31)
                                 +1.290JS
                                   (10.38)

(.04)
R =  1.752 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (4.39)   (5.66)     (.14)      (-.19)   (-.44)    (-.09)    (-.29)
                                           + .048VN
                                             (.37)

(.19)
R =  4.006 + .015PC   + .002WD   - .024SY  - .074BC  - .001BT  - .007BF +
    (9.71)   (6.16)     (.16)      (-.21)   (-.48)    (-.10)    (-.32)
                                                     - .072I
                                                       (-10.88)
```

Table 27. Mass transit equations (database including only responses with variation)

```
(.31 = R-squared)
R =   .455 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF
     (1.02) (11.19)    (.29)    (-.38)   (-.87)   (-.19)   (-.58)

(.35)
R =   .080 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
     (.18)  (11.59)    (.30)    (-.40)   (-.90)   (-.20)   (-.60)
           + .642SEX
             (4.60 = tstatistic)

(.42)
R =  2.037 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
    (3.72)  (12.23)    (.31)    (-.42)   (-.95)   (-.21)   (-.63)
           + .028SEX - .009AGE                    - .041I
             (.16)   (-1.55)                      (-4.81)

(.37)
R =  1.563 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
    (3.29)  (11.70)    (.30)    (-.40)   (-.91)   (-.20)   (-.61)
                     - .027AGE
                      (-5.22)

(.42)
R =  2.084 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
    (4.49)  (12.26)    (.32)    (-.42)   (-.96)   (-.21)   (-.64)
                     - .010AGE                    - .041I
                      (-1.73)                      (-5.29)

(.39)
R =   .109 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
     (.26)  (11.89)    (.31)    (-.41)   (-.93)   (-.20)   (-.62)
                               + .082JS
                                 (6.08)

(.33)
R =   .227 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
     (.51)  (11.36)    (.29)    (-.39)   (-.88)   (-.19)   (-.59)
                                        + .431VN
                                          (3.06)

(.42)
R =  1.881 + .035PC  + .005WD   - .055SY - .166BC - .002BT - .016BF +
    (4.18)  (12.21)    (.31)    (-.42)   (-.95)   (-.21)   (-.63)
                                                  - .049I
                                                   (-7.39)
```

household and income. Thus, free parking for carpoolers establishes carpooling more attractive than auto driving and the socioeconomic variables suggest that commuters in early stages of life tend to favor carpooling, high income people refuse ridesharing mode and the factor of only one vehicle in the household contributes in commuter's willingness to carpool.

In the review of bus factors, auto or socioeconomic variables having identical aforementined signs are not reexamined accepting bus mode as a substitute of carpooling mode in the above interpretations. Only the seasonal variable has different sign, i.e., negative sign, in the auto factors. The expected interpretation is that summer periods favor the public transit. The negative signs of all bus factors suggest that better public transit service can attract commuters. Free or subsidized fares, good total travel time and frequent service could switch auto drivers to mass transit. Further, the only socioeconomic variable exhibiting unexpected positive sign is the number of vehicles in the household. If the database accounts for responses with variation, the variable is insignificant because its t-test is low and the fit of the assumed model is poor, i.e., R-squared equals to 0.04. The developed model which fits the database of all responses, i.e., including responses with no variation, has the same variable with a positive sign and one could interpret this finding saying that people with two or more cars are switchable to bus riders!

Of course, an unexpected sign can be attributed to the orthogonality of the experimental plan, but a check of the data does not suggest this explanation.

Based on the indications of databases or criteria of reasonableness, the extent of multicollinearity or correlation among variables will be investigated and the model(s) exhibiting the best predicting ability will be picked up. Before pursuing the mentioned goal, a remark related to the sets of database are necessary. The sample of auto drivers answering the bus questionnaire was biased towards high income commuters. Probably, this is the reason that contributed to a high precentage (i.e., 56 percent) of responses with no variation.

Reviewing the equations of tables 24 and 25, someone notices a high correlation between income (I) and occupation status (JS) or the number of vehicles in the household (VN) variables for both carpooling databases, i.e., responses with variation and all possible responses. However, occupation status and number of vehicles variables do not present high correlation between themselves. In the case of responses with variation, income is the most representative of the three correlated variables exhibiting the best statistical standards and influencing the other two, e.g., see that equation with VN, JS & I as socioeconomic variables has best t-test for income(I).

Nevertheless, age and sex variables present even more robust statistical tests than the already examined variables.

Scanning the R-squared results of all models, one notices that these variables provide the best fitted model. The other variables improve minimally the goodness-of-fit for the developed model. Further, one should explain that males dominate the sample of all possible responses, i.e., database including responses with or without variation, and because of this, the sex variable has a low t-test when it is combined with the age variable.

With respect to carpooling experimental variables, the findings are consistent. Parking cost for auto drivers and type of matches for carpoolers are the statistically significant variables. In these variables, someone could add the walking time of auto drivers if a convention of literature for experimental variables is valid, namely, variables showing t-tests higher than 0.3 are assumed significant, see Kocur G., T. Adler, W. Hyman and B. Aunet (1982). However, these experimental plans are overwhelmed by the parking cost of auto drivers. Both carpooling and public transit results demand the existence of a more balanced experiment. Unfortunately, the high percentage of commuters parking free in the downtown area was not considered by the present DUA experiments because this information was unknown at the time DUA experiments were developed.

Regarding bus factors, one identifies income as the most significant variable among all socioeconomic variables because the forecasting model accounting for income provides an R-squared of 0.42 (or 0.19 for the database including all responses) which is closest to the best R-squared (0.46 or 0.22, respectively) of all possible models. For example, when all socioeconomic variables are introduced into the model. There is a high correlation between income and occupation status or number of vehicles in the household. Further, income influences the age and sex variables as well. The latter variables present high and low t-tests, if they are entered in a model by themselves and in combination with income, respectively.

Further, the occupation status is the second best socioeconomic variable rendering a model with good R-squared. The number of vehicles in the household ariable guarantees low forecasting ability because it is very questionable whether or not people owning two or more cars will be bus riders. Seeking an explanation for the emerged doubt, the sexual characteristics of auto drivers were investigated. In the gathered sample, there is a high percentage of females with high income and good occupational status. One should expect that females are switchable to bus riders, but a review of the particular databases suggests that this is not the case for Winnipeg commuters. Of course, the attitude of females varies between the databases of responses with variation and the database containing all responses. In the latter database, there is a higher number of females accepting to switch their worktrip mode.

The above discussion justifies the use of occupation status variable as a better predicting variable than the sex variable. Finally, the age variable is not a strong indicator of possible bus patronage because the age brackets of young (lower than 25 years old) and old people (over 50 years old) are underrepresented in the collected questionnaires. Finally, there is some correlation between age and income. Whenever age is regressed with the income variable, the age variable loses the strength of its t-test criterion.

Considering the experimental variables of DUA public transit, parking cost of auto drivers outstands as the dominant variable. Bus fare and frequency variables could be accepted as significant ones for models resulted from both databases. In addition, the seasonal variable is acceptable when the database of all responses is examined.

The above examination of socioeconomic variables revealed that carpooling and public transit forecasting models should include age and sex variables, and income variable, respectively.

4.6 Validation of developed models

The calibrated models, i.e., carpooling and public transit models, should be tested on different samples than the ones used to fit the models. This procedure evaluates the model's ability to predict behavior in varying situations.

In the present study, the full validation of developed models was impossible because the usable response rate did not provide a sufficiently large number of responses to create a validation database. Further, the usable response rate was poor when responses with no variation were excluded. On the other hand, actual carpooling data have not existed for the metropolitan area of Winnipeg and no previous study has examined the behavior of commuters with respect to public transit.

All the above reasons directed the validation procedure to be a comparison between calibrated models and previous models developed in Northamerican or British cities. The comparison of findings was done on a variable basis, below, because there is a lack of studies examining the egress segment of work-trips and no study has considered alike utility equations.

1. Parking cost. Parking cost has been a significant variable for both carpooling and mass transit DUA experiments. The finding of this study agrees well with the results of Margolin J. et al (1978) who determined that 70 percent of employees park free in employer lots and possible disincentives to guaranteed parking would divert solo drivers to carpooling. Miller G. et al (1982) showed that removing of free parking and raising parking rates (by $22 per month) effected some significant shifts among commuters to high-occupancy models.

Finally Brown G. (1972) claimed that a $0.45 increase of parking fee per day would trigger a 50 percent shift of auto drivers to bus riders. Although low parking cost for carpoolers did not emerge as a significant variable in the carpooling experiment, Bonsall P. (1980) concluded that the provision of free-reserved parking spaces yielded a 40 percent increase of carpoolers resulted from city-centre workers.

2. Walking time. Only the walking time variable of auto drivers indicated some statistical significance in the carpooling experiment. Apart from this, no other walking time variable significantly affects mode choice and someone could say that these results coincide with the opinion of Ganek J. et al (1976) that egress time is not significant for CBD workers because the egress time differences among different modes are too small to significantly influence mode choice decisions. Of course, Lambe T. (1969) opposes these results stating that "many drivers are willing to walk an extra 2,500 feet twice per day to lower their rental by $15.00 per month." Finally, Ergun G. (1971) concluded that there was no definitive relationship between walking time and income or age. He established that the maximum walking distance for commuter is six blocks and the individual's preference is to park within one block from his or her destination. The latter is observable in the behavior of Winnipeg's commuters as well.

3. Season of the year. This variable appeared not to

affect mode choice. However, Hoey W. et al (1977) found that the majority of auto drivers, i.e., over 50 percent, would consider bus service in bad weather only if a shelter was available. This finding may justify the existence of some statistical significance of the seasonal variable in the mass transit experiment.

4. Type of carpooling. Commuters of Winnipeg CBD revealed a strong preference for carpooling programs based on personal acquaintances, e.g., coworkers, neighbors, relatives, etc. The carpooling literature agrees and is consistent on this aspect. Bonsall P. et al (1981) determined that a major barrier to carsharing is the unfamiliarity among potential partners, see Bonsall P. (1979 & 1980) as well. Further, Margolin J. et al (1978) concluded that the personal/social aspects of carpooling programs were found to be the most important factor and, in contrast, the most common match-systems, i.e., locator lists and computerized match systems, had the least appeal for carpoolers.

5. Bus cost. Free public transport has not enticed the attention of commuters and bus cost variable has showed minimal significance in the DUA experiment. This finding concurs with the Northamerican attitude studied by Gensh D. (1980). He substantiated that "bus or carpool cost as a variable was the most significant of variables for stated intentions but in terms of current actual behavior it is least significant. In terms of actual current behavior convenience was by far the most

significant." Nevertheless, the British experience is very different. Goodwin P. (1973) claimed that free public transport was prefered by the London Transport Executive employees, who presented a low car use, even though free unlimited parking was available for them within five minutes walk. Further, Daly A. et al (1977) corroborated the previous result and estimated that the provision of free public transport would reduce by 22 percent the car use among commuters who do not need their car at work place and drive during the peak hour.

6. Bus travel time and frequency. The bus travel time variable had no effect on the choice between automobile and bus. Someone could infer that Winnipeg's auto drivers have high transit service expectations. The last remark concurs with the result of Hoey W. et al (1977) who calculated that only about 40 percent of the auto drivers would accept an extra ten minutes of travel time by public transit. On the other hand, bus frequency exhibiting low statistical significance appeared to have little influence on the modal split of commuters.

7. Sex. This socioeconomic variable dominated the choice of auto drivers in relation to carpooling. Women inclined towards carpooling and the conclusion is that, indeed, female office workers are more prone than men to share a vehicle for the work-trip, see Daniels P. (1981). Further, the present study identified that women predominated among transit commuters. Hoey W. et al (1977) estimated that women

approximate to the 75 percent of local transit riders in the United States and Goodwin P. (1983) corroborated that the British experience is similar.

8. Age. According to the literature, the carpooler may be somewhat latter in his or her life cycle than is the solo driver, e.g., see Horowitz A. et al (1977) and Margolin J. et al (1978). Nevertheless, the Winnipeg DUA experimental finding contradicts the above statement, i.e., it is young auto drivers who revealed carpooling preferences. In respect with public transit, Daly A. el at (1977) claimed that there was no evidence that age and sex affected the mode choice of travellers with a car available. Indeed, age and sex variables were weak socioeconomic variables in the studied public transit equations.

9. Occupation status and auto ownership (Number of vehicles in the household). In Winnipeg case study, both variables do not exert a consistent influence on mode choice, provided that other socioeconomic variables had stronger statistical criteria. Further, they correlated to a great extent with the income variable. However, regarding occupation status, both Daniel P. (1981) and Bonsall P. (1980) state that clerical/technical workers are more likely to engage in carpooling than managerial and professional office staff. Finally, there is no consensus among transportation researchers whether auto ownership has a positive or negative effect on public transit or carpooling programs. For example, Bly P. et

al (1978) and Kingham I. (1978) identified negative influences of automobile on ridesharing modes. but Goodwin P. (1983) and Daniel P. (1981) claimed that car-owning households increased their usage of common carriers.

10. Income. The utility equations resulted from the regression analysis indicated the income variable as a strong and weak factor for the public transit and carpooling experiment, respectively. The former result agrees with the studies of Miller G. et al (1982) and Fielding G. et al (1976) where transit shares were strongly related to low income households. On the other hand, Ganek J. et al (1976) stated that income did not influence mode choice among auto, carpool and bus work-trips. This finding coincides with the result of the carpooling experiment.

4.7 Pivot Point Analysis

Based on the developed DUA models, pivot point analysis, i.e., a method of quick policy analysis, can be performed to conclude policy issues related to the examined DUA factors, e.g., parking cost, type of carpooling matches, bus fare, etc.

The pivot point approach is derived from the incremental form of logit model. Given the existing mode shares and the changes of service levels resulted from political actions, the subject approach can predict the revised mode shares of driving along, carpooling and other modes.

The revised share (P_i') for mode i is determined as follows:

$$P_i' = \frac{P_i e^{\Delta U_i}}{\sum_j P_j e^{\Delta U_j}}$$

where P_i = base share of mode i (which changes due to a change in one or more variables)

P_j = the base share for mode j

ΔU_j = the change in the utility function for mode j.

e = base of natural logarithms

j = an alternative among the set of available modes.

Assuming base modal shares of Winnipeg's commuters to be represented by the results of the questionnaire survey, see table 5, the pivot point formula was used to evaluate changes in some of the experimental variables.

More specifically, parking cost increases of $10 and $20 per month (given the base level of $65 per month) would convert 7 and 12 percent of auto drivers to carpoolers, respectively. An extra five minute walk for auto drivers would affect only 2 percent of them to choose carpooling as worktrip mode. Public carpooling programs would deter a 15 percent of existing carpoolers to commute with their current travel mode if they have to join unfamiliar partners. Finally, free public transportation and parking cost disincentives of $10 and $20 per month for auto users would switch to bus 3, 9 and 18 percent of them, respectively.

CHAPTER 5

CONCLUSIONS

While the recent empirical evidence is piecemeal regarding the utility of transportation factors in the egress segment of worktrips, the present study examined in a systematic way how different factors of the journey to work, e.g., parking cost or walking time, affect the utility of the egress segment of worktrips and revealed to what extent transport policies, i.e., parking policies, may affect the mode choice of Winnipeg's CBD commuters.

More specifically, parking and walking commodities have rarely been considered complementary to auto trips. Based on the direct utility assessment (DUA) method, the study's goal was to investigate the role of these commodities, i.e., parking and walking, on the modal choice of auto drivers.

The subject study reinforced the notion that DUA method was a competent and efficient procedure in dealing with the utility or disutility of worktrip factors provided that there was a lack of related data. Further, the validation of developed models determined that the findings of this research agreed quite well with the results of other studies related to Northamerican cities which were examined with similar methods, i.e., logit analysis.

In Winnipeg, survey results indicated that the highest percentage, i.e., 45 percent, of auto drivers parks free for more than seven hours on lots in the downtown area. The 59 percent of them walks less than a block from their parking lot to workplace and the usage of their car is very seldom during the work day. Further, solo drivers avoid to ride a bus, actually 79 percent of them never uses bus for the worktrip, and their socioeconomic characteristics are dominated by professional/managerial males who have income above $30,000 per year and age between 25 and 44 years.

Analyzing the experimental plan of a conducted survey, i.e., the DUA experimental responses of Winnipeg's commuters, binary direct utility assessment models were developed between automobile and carpooling or public transit modes. Based on the developed models, pivot point analysis was performed on parking cost, walking time, bus fare and type of carpooling matches. Part of the result suggests that, first, a $20.00 raise of parking fees per month would switch 12 or 18 percent of auto drivers to carpooling or public transit, respectively, and, second, an extra five minute walk for auto drivers would yield a 2 percent increase of carpooling commuters.

Finally, areas of further research are: first, the relocation decisions of parkers within the downtown area, when parking cost increases realize or parking lots are converted to better use, second, the serviceability of the locations of parking structures assuming that parking lots are eliminated from the downtown market, and, third, the effect of parking capacity, i.e., restraining of parking spaces, on the behavior of commuters.

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APPENDIX A

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APPENDIX B

PROPOSED ZONING BY-LAWS OF LOADING AND PARKING AREAS

500 Parking and Loading

500(1) Every parcel of land used or occupied hereafter for a parking or loading facility shall be developed in compliance with the following regulations:

a) such facility shall be paved with asphalt or concrete;

b) such facility shall be provided with a system of drainage adequate to ensure that rainwater will not flow onto abutting lands or public sidewalks in a quantity or manner inconvenience to the users thereof;

c) such facility shall be screened from every adjacent public street or residential use by a lightproof fence 0.75 metres [2.5 feet] in height located at the interior limit of required or voluntary yards, provided that such fence shall not be installed within 1 metre [3 feet] of the intersection of any driveway or aisle within said facility with any public right-of-way.

500(2) In addition, every parcel of land, building or structure used or occupied hereafter for a parking or loading facility shall be developed in compliance with the following regulations:

a) every aisle within such facility shall be not less than 6 metres [20 feet] in width;

b) every driveway within such facility shall be not less than 3.6 metres [12 feet] in width;

c) every parking space shall be not less than 2.4 metres [8 feet] in width, not less than 6 metres [20 feet] in length, and not less than 2.13 metres [7 feet] in height;

d) every parking space shall be provided with either:

i) a wheel stop located 0.75 metres [2.5 feet] from the front limit of such space; or

ii) a bumper-guard fence at the front limit of each such space, which fence may be incorporated into the lightproof fence required under section 500(1)(c);

e) every service or courier loading space shall be not less than 2.4 metres [8 feet] in width, not less than 6 metres [20 feet] in length, and not less than 2.13 metres [7 feet] in height;

500(2) f) every delivery loading space shall be not less than 3.6 metres [12 feet] in width, not less than 6 metres [20 feet] in length, and not less than 4.26 metres [14 feet] in height;

g) every tractor-trailer loading space shall be not less than 3.6 metres [12 feet] in width, not less than 18 metres [59 feet] in length, and not less than 4.26 metres [14 feet] in height.

500(3) Where floor area must be calculated to determine the required number of parking or loading spaces, the calculation shall be based on the gross floor area of each building or structure but the calculation shall not include any area used for parking or loading spaces, aisles or driveways within a building or structure, and mechanical equipment or systems such as elevators, heating or cooling systems or similar facilities.

500(4) Where parking spaces are required for both residential uses and for offices on the same lot, and it is considered desirable to provide required accessory parking with a collective parking facility, such facility shall be established and maintained as follows:

a) the number of parking spaces provided in such collective facility shall be not less than the larger requirement for either residential uses or offices served by such facility;

b) no parking space within such collective facility shall be assigned to any individual person or use served by such facility except the residential component of such use.

510 "P/L 1" Parking/Loading Range One

510(1) In any district within which the "P/L 1" designation shall apply the following uses shall be provided with accessory parking as follows:

a) dwelling units:
not less than one space for each two units;

b) apartment hotels:
not less than one space for each two suites or other rental units;

c) boarding, rooming or lodging houses:
not less than one space for each two bedrooms;

d) neighbourhood care homes and neighbourhood rehabilitation homes:
not less than one space for each two bedrooms;

e) hotels:
not less than one space for each four guest rooms or suites;

f) offices, alone or in combination:
not less than one space for each 200 m^2 [2,150 ft^2] of floor area occupied by such uses.

510(2) In any district within which the "P/L 1" designation shall apply the following uses shall be provided with accessory loading as follows:

a) dwelling units:

not less than one service loading space for each 100 units or fraction thereof above 50 units;

not less than one delivery loading space for each 100 units or fraction thereof above 50 units;

b) apartment hotels:

not less than one service loading space for each 100 suites or other rental units or fraction thereof above 50 suites;

not less than one delivery loading space for each 100 suites or other rental units or fraction thereof above 50 suites;

c) hotels:

not less than one service loading space for each 100 guest rooms or suites or fraction thereof above 50 guest rooms;

not less than one delivery loading space for each 100 guest rooms or suites or fraction thereof above 50 guest rooms;

510(2) d) offices, alone or in combination:

not less than two courier loading spaces for each 4,00 m^2 [43,000 ft^2] or fraction thereof above 2,000 m^2 [21,500 ft^2] of floor area occupied by such uses;

not less than one delivery loading space for each 4,000 m^2 [43,000 ft^2] or fraction thereof above 2,000 m^2 [21,500 ft^2] of floor area occupied by such uses;

not less than one tractor-trailer loading space for each 8,000 m^2 [86,000 ft^2] of floor area occupied by such uses;

e) restaurants and cabarets:

not less than one service loading space for each 1,000 m^2 [10,750 ft^2] or fraction thereof above 500 m^2 [5,375 ft^2] of floor area occupied by such uses;

not less than one delivery loading space for each 1,000 m^2 [10,750 ft^2] or fraction thereof above 500 m^2 [5,375 ft^2] of floor area occupied by such uses;

f) retail businesses, alone or in combination:

not less than two service loading spaces for each 4,000 m^2 [43,000 ft^2] of floor area occupied by such uses;

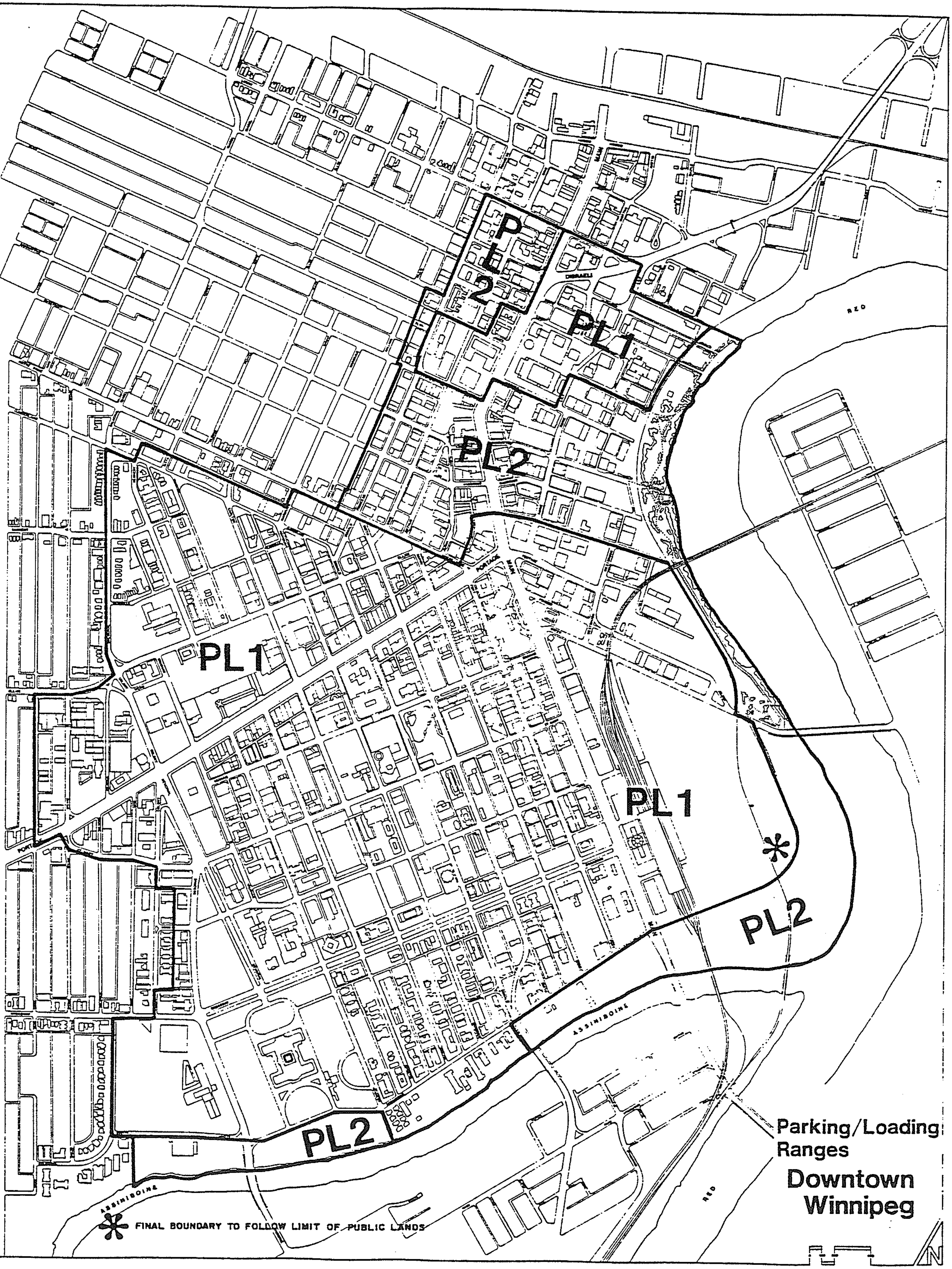
not less than one delivery loading space for each 1,000 m^2 [10,750 ft^2] of floor area occupied by such uses;

not less than one tractor-trailer loading space for each 4,000 m^2 [43,000 ft^2] of floor area occupied by such uses.

511 "P/L 2" Parking/Loading Range Two

511(1) No land, building or structure shall be provided with accessory parking in any district within which the "P/L 2" designation shall apply, except as approved as a conditional use.

511(2) No land, building or structure shall be provided with accessory loading in any district within which the "P/L 2" designation shall apply, except as approved as a conditional use.



✱ FINAL BOUNDARY TO FOLLOW LIMIT OF PUBLIC LANDS

Parking/Loading Ranges

Downtown Winnipeg

APPENDIX C

SURVEY QUESTIONNAIRES

THE UNIVERSITY OF MANITOBA Winnipeg, Manitoba, Canada R3T 2N2 FACULTY OF ARCHITECTURE
Department of City Planning
120 Bison Building
(204) 474-8761

July 24, 1984

Dear Commuter:

This short questionnaire is designed to test commuters' preference of the transportation mode they use to go to work, given a number of probable situations.

This research is being carried out under the auspices of the graduate programme in City Planning at the University of Manitoba.

Please answer the questions attached to this letter, take a few minutes and indicate how you would respond to the situations presented herein. Be assured that your responses will be kept completely confidential.

Thank you for your time and cooperation.

Sincerely

Basil M. Rotoff, P.Eng., MCIP
Associate Professor,

John Ziotas, Dip.Arch.
Research Assistant

BMR/ad
Enclosure

PLEASE ANSWER THE FOLLOWING QUESTIONS (please check only one square ☑ to each question unless otherwise requested):

1. Do you have a driver's license? ☐ Yes ☐ No.

2. Do you have a car available that you could take to downtown on a regular basis? ☐ Yes ☐ No.

3. How do you usually get to work?
   - ☐ Drive alone.
   - ☐ Bus.
   - ☐ Carpool (please specify number of people)_________.
   - ☐ Bicycle.
   - ☐ Motorcycle.
   - ☐ Walk.
   - ☐ Taxi.
   - ☐ Other (please specify)___________.

4. How does the door-to-door work-journey time by bus compare to that by car?

☐ Bus more than 15min. faster (specify)_______.	☐ Bus 1 - 5min. slower.
☐ Bus 11 - 15min. faster.	☐ Bus 6 - 10min. slower.
☐ Bus 6 - 10min. faster.	☐ Bus 11 - 15min. slower.
☐ Bus 1 - 5min. faster.	☐ Bus more than 15min. slower (specify)_________.
☐ Bus same.	☐ Do not know.

5. If you are driving a car to work please answer questions (5.a.) through (5.g.).

5.a. What do you now pay for parking? (check one only in the appropriate section).

Monthly	OR	Daily
☐ Free		☐ Free
☐ Less than $50.00		☐ Less than $3.00
☐ $50.01 - $60.00		☐ $3.00 - $3.50
☐ $60.01 - $70.00		☐ $3.51 - $4.00
☐ $70.01 - $80.00		☐ $4.01 - $4.50
☐ More than $80.00		☐ More than $4.50

5.b. How often was it absolutely necessary to use your car during the work-day last week? ☐ Never. ☐ Very seldom. ☐ Frequently. ☐ Other (specify)_____________.

5.c. Do you normally park your car for more than seven hours in downtown Winnipeg?
☐ Yes ☐ No.

5.d. Did you ever travel by bus instead of car last month?
☐ Never. ☐ Occasionally. ☐ Very often. ☐ Other (specify)____________.

5.e. How far is the parking place you use from where you work?
_________ Blocks OR _________ Feet.

5.f. Where do you usually park?
   - ☐ In a structure.
   - ☐ In a lot.
   - ☐ On street (parking meter).
   - ☐ On street (restricted areas, i.e. 2 hours).
   - ☐ On street all day unrestricted.

5.g. If parking rates in downtown Winnipeg increase substantially at what parking rate would you consider switching to transit?

☐ Less than $65.00 per month	☐ $ 96.00 - $120.00 per month
☐ $65.00 - $80.00 per month	☐ $121.00 - $135.00 per month
☐ $81.00 - $95.00 per month	☐ More than $135.00 per month

UNDER WHAT SITUATIONS WOULD YOU DRIVE ALONE OR SHARE A RIDE (CAR POOL) TO WORK?

- Consider that you are going to work and that driving alone or sharing a ride in a car pool are your only choices.
- Below are a number of factors describing eight different situations where you are faced with choosing whether to drive alone or share a ride to work.
- Look at each situation accross the entire line and please answer in the last column to the right how likely you are to drive alone or share a ride to work. (please circle only one number in each situation).

PLEASE ANSWER IN THIS COLUMN

	AUTO FACTORS			CARPOOL FACTORS			HOW LIKELY ARE YOU TO DRIVE ALONE OR SHARE A RIDE?				
	Parking Cost To Drive Alone	Walking Time From Car To Work	Season	Cost To Park Auto At Work	Walking Time	Carpool Matching (Type of Ride)	Always Drive Alone	Probably Drive Alone	In-different	Probably **Share** A Ride	Always Share A Ride
uation 1	$65.00/month	7min.	Winter	$20.00/month	Negligible	General Public	1	2	3	4	5
uation 2	$65.00/month	7min.	Winter	Free	5min.	Coworker&Neighbor	1	2	3	4	5
uation 3	$65.00/month	15min.	Summer	$20.00/month	Negligible	Coworker&Neighbor	1	2	3	4	5
uation 4	$65.00/month	15min.	Summer	Free	5min.	General Public	1	2	3	4	5
uation 5	$110.00/month	7min.	Summer	$20.00/month	5min.	Coworker&Neighbor	1	2	3	4	5
uation 6	$110.00/month	7min.	Summer	Free	Negligible	General Public	1	2	3	4	5
uation 7	$110.00/month	15min.	Winter	$20.00/month	5min.	General Public	1	2	3	4	5
uation 8	$110.00/month	15min.	Winter	Free	Negligible	Coworker&Neighbor	1	2	3	4	5

6. In order to correlate results, your filling in of the following personal data would be appreciated.

6.a. ☐ Male. ☐ Female.

6.b. Year of Birth 19________.

6.c. Occupation? ☐ Managerial Work. ☐ Clerical Work.
☐ Proffesional Work. ☐ Sales Work.
☐ Secretarial Work. ☐ Other Work (specify)______________.

6.d. How many cars in household? ☐ None ☐ One ☐ Two ☐ Three or more.

6.e. Do you have any children at school? ☐ Yes ☐ No.

6.f. Your annual income is:
☐ Less than $5,000
☐ $ 5,000 - $ 9,999
☐ $10,000 - $14,999
☐ $15,000 - $19,999
☐ $20,000 - $24,999
☐ $25,000 - $29,999
☐ $30,000 - $34,999
☐ $35,000 - $35,999
☐ More than $40,000

THANK YOU FOR YOUR COOPERATION

UNDER WHAT SITUATIONS WOULD YOU DRIVE ALONE OR TAKE THE BUS TO WORK?

- Consider that you are going to work and that driving alone or taking the bus are your only choices. Assume there is a bus stop within three blocks (6min. walk) of both your home and place of work.
- Below are a number of factors describing eight different situations where you are faced with choosing whether to drive alone or ride the bus to work.
- Look at each situation accross the entire line and please answer in the last column to the right how likely you are to drive alone or take the bus to work.(please circle only one number in each situation).

PLEASE ANSWER IN THIS COLUMN

	AUTO FACTORS			BUS FACTORS			HOW LIKELY ARE YOU TO DRIVE AN AUTOMOBILE OR TAKE THE BUS?				
	Parking Cost To Drive Alone	Walking Time From Car To Work	Season	Bus Fare*	Total Bus Travel Time (Home To Work)	How often Bus comes during Rush Hours	Always Auto	Probably Auto	In-different	Probably Bus	Always Bus
Situation 1	$65.00/month	7min.	Winter	$0.75	5min.(slower)	every 5min.	1	2	3	4	5
Situation 2	$65.00/month	7min.	Winter	Free	15min.(slower)	every 10min.	1	2	3	4	5
Situation 3	$65.00/month	15min.	Summer	$0.75	5min.(slower)	every 10min.	1	2	3	4	5
Situation 4	$65.00/month	15min.	Summer	Free	15min.(slower)	every 5min.	1	2	3	4	5
Situation 5	$110.00/month	7min.	Summer	$0.75	15min.(slower)	every 5min.	1	2	3	4	5
Situation 6	$110.00/month	7min.	Summer	Free	5min.(slower)	every 10min.	1	2	3	4	5
Situation 7	$110.00/month	15 min	Winter	$0.75	15min.(slower)	every 10min.	1	2	3	4	5
Situation 8	$110.00/month	15min.	Winter	Free	5min.(slower)	every 5min.	1	2	3	4	5

*Bus fare (One Way)

6. In order to correlate results, your filling in of the following personal data would be appreciated.

6.a. ☐ Male. ☐ Female.

6.b. Year of Birth 19________.

6.c. Occupation?
☐ Managerial Work.
☐ Proffesional Work.
☐ Secretarial Work.
☐ Clerical Work.
☐ Sales Work.
☐ Other Work (specify)________________.

6.d. How many cars in household? ☐ None ☐ One ☐ Two ☐ Three or more.

6.e. Do you have any children at school? ☐ Yes ☐ No.

6.f. Your annual income is:
☐ Less than $5,000
☐ $ 5,000 - $ 9,999
☐ $10,000 - $14,999
☐ $15,000 - $19,999
☐ $20,000 - $24,999
☐ $25,000 - $29,999
☐ $30,000 - $34,999
☐ $35,000 - $35,999
☐ More than $40,000

THANK YOU FOR YOUR COOPERATION

UNDER WHAT SITUATIONS WOULD YOU DRIVE ALONE OR SHARE A RIDE (CAR POOL) TO WORK?

- Consider that you are going to work and that driving alone or sharing a ride in a car pool are your only choices.
- Below are a number of factors describing sixteen different situations where you are faced with choosing whether to drive alone or share a ride to work.
- Look at each situation accross the entire line and please answer in the last column to the right how likely you are to drive alone or share a ride to work. (please circle only one number in each situation).

PLEASE ANSWER IN THIS COLUMN

	AUTO FACTORS			CARPOOL FACTORS			HOW LIKELY ARE YOU TO DRIVE ALONE OR SHARE A RIDE?				
	Parking Cost To Drive Alone	Walking Time From Car To Work	Season	Cost To Park Auto At Work	Walking Time	Carpool Matching (Type of Ride)	Always Drive Alone	Probably Drive Alone	In-different	Probably Share A Ride	Always Share A Ride
tuation 1	$65.00/month	7min.	Summer	Free	Negligible	Coworker&Neighbor	1	2	3	4	5
ituation 2	$65.00/month	7min.	Summer	$20.00/month	5min.	General Public	1	2	3	4	5
ituation 3	$65.00/month	7min.	Winter	Free	5min.	General Public	1	2	3	4	5
tuation 4	$65.00/month	7min.	Winter	$20.00/month	Negligible	Coworker&Neighbor	1	2	3	4	5
ituation 5	$65.00/month	15min.	Summer	Free	Negligible	General Public	1	2	3	4	5
tuation 6	$65.00/month	15min.	Summer	$20.00/month	5min.	Coworker&Neighbor	1	2	3	4	5
ituation 7	$65.00/month	15min.	Winter	Free	5min.	Coworker&Neighbor	1	2	3	4	5
ituation 8	$65.00/month	15min.	Winter	$20.00/month	Negligible	General Public	1	2	3	4	5
ituation 9	$110.00/month	7min.	Summer	Free	5min.	Coworker&Neighbor	1	2	3	4	5
ituation 10	$110.00/month	7min.	Summer	$20.00/month	Negligible	General Public	1	2	3	4	5
ituation 11	$110.00/month	7min.	Winter	Free	Negligible	General Public	1	2	3	4	5
ituation 12	$110.00/month	7min.	Winter	$20.00/month	5min.	Coworker&Neighbor	1	2	3	4	5
ituation 13	$110.00/month	15min.	Summer	Free	5min.	General Public	1	2	3	4	5
ituation 14	$110.00/month	15min.	Summer	$20.00/month	Negligible	Coworker&Neighbor	1	2	3	4	5
ituation 15	$110.00/month	15min.	Winter	Free	Negligible	Coworker&Neighbor	1	2	3	4	5
ituation 16	$110.00/month	15min.	Winter	$20.00/month	5min.	General Public	1	2	3	4	5

6. In order to correlate results, your filling in of the following personal data would be appreciated.

6.a. ☐ Male. ☐ Female.

6.b. Year of Birth__________.

6.c. Occupation? ☐ Managerial Work. ☐ Clerical Work.
☐ Proffesional Work. ☐ Sales Work.
☐ Secretarial Work. ☐ Other Work (specify)______________.

6.d. How many cars in household? ☐ None ☐ One ☐ Two ☐ Three or more.

6.e. Do you have any children at school? ☐ Yes ☐ No.

6.f. Your annual income is:
☐ Less than $5,000
☐ $ 5,000 - $ 9,999
☐ $10,000 - $14,999
☐ $15,000 - $19,999
☐ $20,000 - $24,999
☐ $25,000 - $29,999
☐ $30,000 - $34,999
☐ $35,000 - $35,999
☐ More than $40,000

THANK YOU FOR YOUR COOPERATION

UNDER WHAT SITUATIONS WOULD YOU DRIVE ALONE OR TAKE THE BUS TO WORK?

- Consider that you are going to work and that driving alone or taking the bus are your only choices. Assume there is a bus stop within three blocks (6min. walk) of both your home and place of work.
- Below are a number of factors describing sixteen different situations where you are faced with choosing whether to drive alone or ride the bus to work.
- Look at each situation accross the entire line and please answer in the last column to the right how likely you are to drive alone or take the bus to work (please circle only one number in each situation).

PLEASE ANSWER IN THIS COLUMN

	AUTO FACTORS			BUS FACTORS			HOW LIKELY ARE YOU TO DRIVE AN AUTOMOBILE OR TAKE THE BUS?				
	Parking Cost To Drive Alone	Walking Time From Car To Work	Season	Bus Fare*	Total Bus Travel Time (Home to Work)	How often Bus comes during Rush Hours	Always Auto	Probably **Auto**	In-different	Probably Bus	Always Bus
Situation 1	$65.00/month	7min.	Summer	$0.75	15min.(slower)	every 10min.	1	2	3	4	5
Situation 2	$65.00/month	7min.	Summer	Free	5min.(slower)	every 5min.	1	2	3	4	5
Situation 3	$65.00/month	7min.	Winter	$0.75	5min.(slower)	every 5min.	1	2	3	4	5
Situation 4	$65.00/month	7min.	Winter	Free	15min.(slower)	every 10min.	1	2	3	4	5
Situation 5	$65.00/month	15min.	Summer	$0.75	15min.(slower)	every 5min.	1	2	3	4	5
Situation 6	$65.00/month	15min.	Summer	Free	5min.(slower)	every 10min.	1	2	3	4	5
Situation 7	$65.00/month	15min.	Winter	$0.75	5min.(slower)	every 10min.	1	2	3	4	5
Situation 8	$65.00/month	15min.	Winter	Free	15min.(slower)	every 5min.	1	2	3	4	5
Situation 9	$110.00/month	7min.	Summer	$0.75	5min.(slower)	every 10min.	1	2	3	4	5
Situation 10	$110.00/month	7min.	Summer	Free	15min.(slower)	every 5min.	1	2	3	4	5
Situation 11	$110.00/month	7min.	Winter	$0.75	15min.(slower)	every 5min.	1	2	3	4	5
Situation 12	$110.00/month	7min.	Winter	Free	5min.(slower)	every 10min.	1	2	3	4	5
Situation 13	$110.00/month	15min.	Summer	$0.75	5min.(slower)	every 5min.	1	2	3	4	5
Situation 14	$110.00/month	15min.	Summer	Free	15min.(slower)	every 10min.	1	2	3	4	5
Situation 15	$110.00/month	15min.	Winter	$0.75	15min.(slower)	every 10min.	1	2	3	4	5
Situation 16	$110.00/month	15min.	winter	Free	5min.(slower)	every 5min.	1	2	3	4	5

*Bus Fare (One Way)

6. In order to correlate results, your filling in of the following personal data would be appreciated.

6.a. ☐ Male. ☐ Female.

6.b. Year of Birth__________.

6.c. Occupation? ☐ Managerial Work. ☐ Clerical Work.
☐ Proffesional Work. ☐ Sales Work.
☐ Secretarial Work. ☐ Other Work (specify)_______________.

6.d. How many cars in household? ☐ None ☐ One ☐ Two ☐ Three or more.

6.e. Do you have any children at school? ☐ Yes ☐ No.

6.f. Your annual income is:
☐ Less than $5,000
☐ $ 5,000 - $ 9,999
☐ $10,000 - $14,999
☐ $15,000 - $19,999
☐ $20,000 - $24,999
☐ $25,000 - $29,999
☐ $30,000 - $34,999
☐ $35,000 - $35,999
☐ More than $40,000

THANK YOU FOR YOUR COOPERATION

INTER-OFFICE CORRESPONDENCE

August 10th, 1984

<u>Memorandum to Staff</u>

We have agreed to participate in a survey being conducted by the City Planning Department at the University of Manitoba. The purpose of the survey is to identify the preferences of people who work in the downtown area for various modes of transportation. The data will be used in developing proposals for addressing traffic and parking problems downtown.

We would appreciate if you would take a few minutes to fill out the attached questionnaire and return it to Diane Obirek in the Personnel Division no later than Thursday, August 16th.

Thank you for your participation.

JGB/at

(Mrs.) J. G. Bulloch
General Director, Personnel

Att.

Government of Canada
Gouvernement du Canada

MEMORANDUM **NOTE DE SERVICE**

PRO STAFF

ROM
DE

W. D. Harper
Director
Prairie Region

SECURITY - CLASSIFICATION - DE SÉCURITÉ

OUR FILE/NOTRE RÉFÉRENCE

YOUR FILE/VOTRE RÉFÉRENCE

DATE August 10, 1984

SUBJECT
OBJET TRANSPORTATION SURVEY

Attached you will find a short questionnaire prepared by the University of Manitoba designed to test commuters' preference for the transportation mode they use to go to work.

While under no obligation, would you take a few moments and support this research by completing the attached questionnaire? Completed forms can be dropped off either in the box provided by the 4th floor elevators or through Central Registry. Your attention by August 24, is appreciated.

Should you have any questions, do not hesitate to contact Roseline Ferre at 949-4684.

W. D. Harper

Attch.

STATEMENTS OF AUTO DRIVERS

o With present day care arrangements a car is essential.

o Since I attend classes at the University of Manitoba during the week (part time) I must have car to return to my office as soon as possible.

o Biggest determining factor at present is location of child care, not efficiently accessible to bus routes.

o Bus service is unsatisfactory in Charleswood.

o I have not taken a bus more than ten times in the last 16 years. Having had to "bus-in" through highschool and University, my recollection is that buses are dirty, noisy, overcrowded, late, when you are in a rush, and too fast when you have got time to kill. Bus drivers and passengers are generally sweaty and discourteous. Drunks and other "animals" make bus rides unpleasant. Driving alone is much more enjoyable. And besides that, bus drivers do not provide change anymore. I hope never have to take the bus on a regular basis.

- I would never switch to transit as being on a bus is as close to "hell on earth" during rush hours as you can get. Skip the "death penalty" issue and make the punishment for murder, riding a bus four times a day in Winnipeg in July and August. You are welcome ... just never ask me to ride on a _____ bus.

APPENDIX D

DIRECT UTILITY ASSESSMENT (DUA) METHOD

1 Introduction

In recent years, travel demand has been forcasted on the actual past behavior of people or the expressed intentions of the individuals, i.e., behavioural intentions. The former is the traditional approach and examines the observable behaviour under changing factors, e.g., income, auto ownership, travel time, travel cost etc.. The latter has been recently employed by transportation planners to explore how individuals would react under future circumstances, namely, "what would you do if..." type of questions.

In this appendix, a behaviour intention or non-commitment response approach is evaluated whether and for what purposes is effective. The Direct Utility Assessment (DUA) is examined as the chosen demand modeling technique which is applied to estimate the effects on modal choice behavior of different variables related to parking factors, e.g., walking time, parking cost, seasonal variations etc..

More specifically, the advantages and drawbacks of DUA are examined from practical and theoretical aspects. Further, some considered issues relate to the theoretical validity of DUA, DUA's link with logit formulation, the experimental designs of

DUA, i.e., available factorial plans, and the validation procedure of developed models.

2 Methodology

There is afluent bibliography related to Direct Utility Assessment (DUA) or functional measurement or conjoint analysis, but this brief presentation of conjoint analysis will elucidate the role of DUA models in forecasting and analyzing travel demand.

DUA is a technique for assessing consumer responses to a number of hypothetical situations which are developed using an experimental design. The intentional responses to the experiment are analyzed with multiple linear regression. The behavioral intentions data establish DUA method being different from other aggregate and disaggregate techniques because DUA models can include variables which are not measurable or varying in existing data sets, e.g., convenience or comfort factors, and examine future modes or other alternatives which will be introduced in a transportation system, e.g., creation of a carpooling program, and are difficult to be treated in traditional demand models.

Consumer preferences are obtained by surveying a representative group of people. Each survey respondent is asked what he or she would do under a series of situations, which are developed according to an experimental design. The experimental design is structured so that no correlation among the independent variables exists, i.e., every independent variable is orthogonal (completely uncorrelated) with the rest of the variables. Therefore, the seperate effects of causal variables influencing the respondent can always be determined and inferred from his or her responses to the situations.

The experimental designs of DUA include a response scale which is assumed to have a cardinal (metric) interpretation. For example, the difference in preference between "3" and "5" is twice the difference between "3" and "4". Based on the individual ranking for each DUA senario, a utility function is derived for the various attributes of examined variables.

The senario format used in DUA is very compact and allows independent analysis of several factors accomodated in a small amount of space. Also this format handles qualitative variables which are difficult to quantify and are very hard to interprate from numerical data, e.g., subjective aspect of safety.

Past experience has shown that DUA experimental surveys which examine a large number of factors are unsuccessful in achieving a high usable response rate, because the easiness of completing the survey declines with increasing number of senarios. Although the best maximum number of manageable senarios for a layman is not determined, it seems to range between 10 and 30.

Satisfactory DUA models are usually derived from sample sizes which include between 96 and 384 usable questionnaires. In general, a 50 percent "raw" response rate, which accounts for incomplete questionnaires, to a mailout survey is considered very good and usually well-designed surveys are expected to have at least 20 percent usable response rate, even if 46 percent usable response rates are frequently feasible.

An integral part of developing DUA models is to have a focus group which will critique the priliminary draft of DUA experiment and reveal the issues and factors that public thinks are important to influence travel behavior. This is nacessary because the developer of a forecasting model has personal biases relating to the most of significant variables and cannot take into account all variables that have a strong influence on people's choices.

The mentioned evaluation of focus group reduces the complicated problems related to biases, misunderstandings of imprecise wording and omissions of important factors. Further, the complexity of DUA models can be reduced by considering pairwise or binary choices, i.e., selecting a base choice and comparing this choice with other choices, and creating experimental plans which contain a moderate number of variables and situations.

The binary choice DUA models are extensively used (as opposed to multiple choice DUA models) because the experience suggests that individuals can evaluate a limited number of factors simultaneously and have a tendency to analyze pairwise combinations in a hierachical principle which starts with important factors and proceeds to factors of minimal importance. On the other hand, the experimental plan of DUA model is essentially a statistical factorial design and usually belongs to a family of fractional factorial designs. A fractioanl design can be either full or fractional. The former allows the examination of all possible interactions among the variables and requires an unreasonable large number of combinations when there is a moderate number of variables at different levels. The latter examines only a fraction of the combinations needed for the full factorial design and estimates or discards specific points which are considered to be important or negligible, respectively.

The selection of fractional factorial plans is a matter of professional judgement. However, it is common practice for DUA models to assume that three-way and higher interactions are negligible. The two-way interactions are included or not on a case-by-case basis, because depending on the number of included interactions, model precision improves but the complexity of the survey increases too.

Thus, the group of selected variables related to the experimental design are compacted according to the following points: (1) Factors affecting both compared choices are included in one of them and are expressed as a difference between choices, (2) Current values of examined variables must be able to be obtained from supplementary source so that the validation of the model is possible, (3) Causal variables which are amenable to policy decisions or changable by other forces should have priority and be included for future forecasting.

A forecasting model estimated from DUA experimental design can predict the effect of each factor within the range of values, or levels, of selected variables. Predictions outside the encompassed range are subject to higher levels of uncertainty. Because of this, the extreme values of the variables must accomodate all the possible changes expected in the examined variables. In the case of successful experiments, all factors must affect proportionately the people's choice, because the respondent must consider and trade-off all the examined factors. The levels of dominating factors have to be modified and balanced senarios must be issued.

The DUA model is built so that the variables of the experimental design explain the survey responses, is fitted with multiple linear regression and has a clearly defined error theory which allows statistical tests of model validity. The linear regression model derived from the stated behavior responses provides an approximation to the utility functions of a logit model which assesses actual behavior. A logit model accounts for market shares, determines the probability of choosing a particular alternative among different considered options and is expressed by the ratio of utilities, i.e., the ratio of the selected alternative utility to the sum of utilities of every alternative under consideration.

The utility function required for DUA models is determined by the basic functional form of the multiple linear regression and can be estimated with any statistical package of regression analyses. The constant of developed regression equations is usually interpreted as the utility of "bias", which people have in favor of one transportation mode, given that the values of compared attributes for two modes are equal and the examined variables are defined in both alternatives. Otherwise, the constant of DUA models has little interest.

Coefficients of DUA's utility function are calculated on the basis of the difference in the mean scores which a group of respondents attributes to two levels of a factor. For example, assuming only a variable accounts for the change in a utility function, the coefficient of this variable is determined as follows:

$$\text{Coefficient} = \Delta R \,/\, \Delta \text{Variable}.$$

where: ΔR is the difference in the response scores and ΔVariable is drawn from the levels of the variable in the experiment. DUA coefficients usually have reasonable signs and magnitudes but unexpected results cannot be improved because of the orthogonality of the experiment.

In DUA models, the addition or deletion of regression variables has minimal or no effect to the goodness-of-fit statistics of the remaining variables due to the statistical independence of variables in the experimental design. In some cases, the goodness-of-fit statistics, e.g., t-statistics, F-statistics and R-squared, are low because, first, the response scale has drawbacks which limit the goodness-of-fit, e.g., a response of "2.5" vs "2" or "3" is not possible, and, second, responses with no variation exist, i.e., respondent selects always the same mode with the same weight (e.g., "1").

The t-statistic resulted from the ratio of the coefficient to its standard error is affected the most by analyzing responses with no variation for the following reasons: (1) The existence of no variation lowers the regression coefficients provided that an identical response for all situations implies a coefficient of zero for all the variables and (2) extreme responses with no variation (e.g., "1"s or "5"s) increase the standard error of the coefficient. The combination of the mentioned reasons result in a double effect on t-statistic.

The goodness-of-fit statistics for DUA models improve significantly when responses with no variation are excluded from the sample. Based on these statistical criteria a model is selected that explains the responses of people as a function of the variables in the DUA experiment and their socioeconomic characteristics.

The selected model is validated by the portion of the surveyed data which account for actual behavior and existing travel conditions. In other words, the estimated DUA demand model is tested on a different sample of data, than the one used to calibrate the model in order to establish the model's ability to explain behavior under varying situations.

In the validation process, DUA analysis is combined with revealed preference modeling. It is assumed that the stated behavior (expressed with linear models) corresponds to the actual behavior of respondents (expressed with logit model) if the utility equations derived from linear regression function well in the logit model.

Validation of DUA models can be based on aggregate or disaggregate data. In the case of disaggregate data, the use of logit analysis allows binary or multinomial validation, examining choices among two or more alternatives, respectively.

On the other hand, DUA models are often tested with short-cut validation procedures, e.g., single-point or two-point checks, or with comparisons to previously developed models, e.g., comparison of DUA coefficients obtained from the experiment and corresponding coefficients determined in a previous logit analysis. Single-point or two-point checks examine whether one or two averages obtained from survey responses which are closest to existing conditions can match the current choice behavior, i.e., determining whether they fit on actual behavior curves obtained from logit analysis.

If a validation procedure concludes that a DUA linear curve does not align approximately a logit curve, e.g., figure D.1, then the linear model is adjusted by multiplying its slope with an appropriate factor.

However, validation of DUA models is not always performed because their purpose does not dictate or allow such an implementation. For example, the developed model may rank the effects of policy options and ignore accurate probability estimates. Also the examination of nonexisting alternatives or extreme levels of variables precludes the validation of models attributed to unappropriate current data. When validation is not possible, comparisons with previous models and reasonableness checks are the only tests for the model's validity.

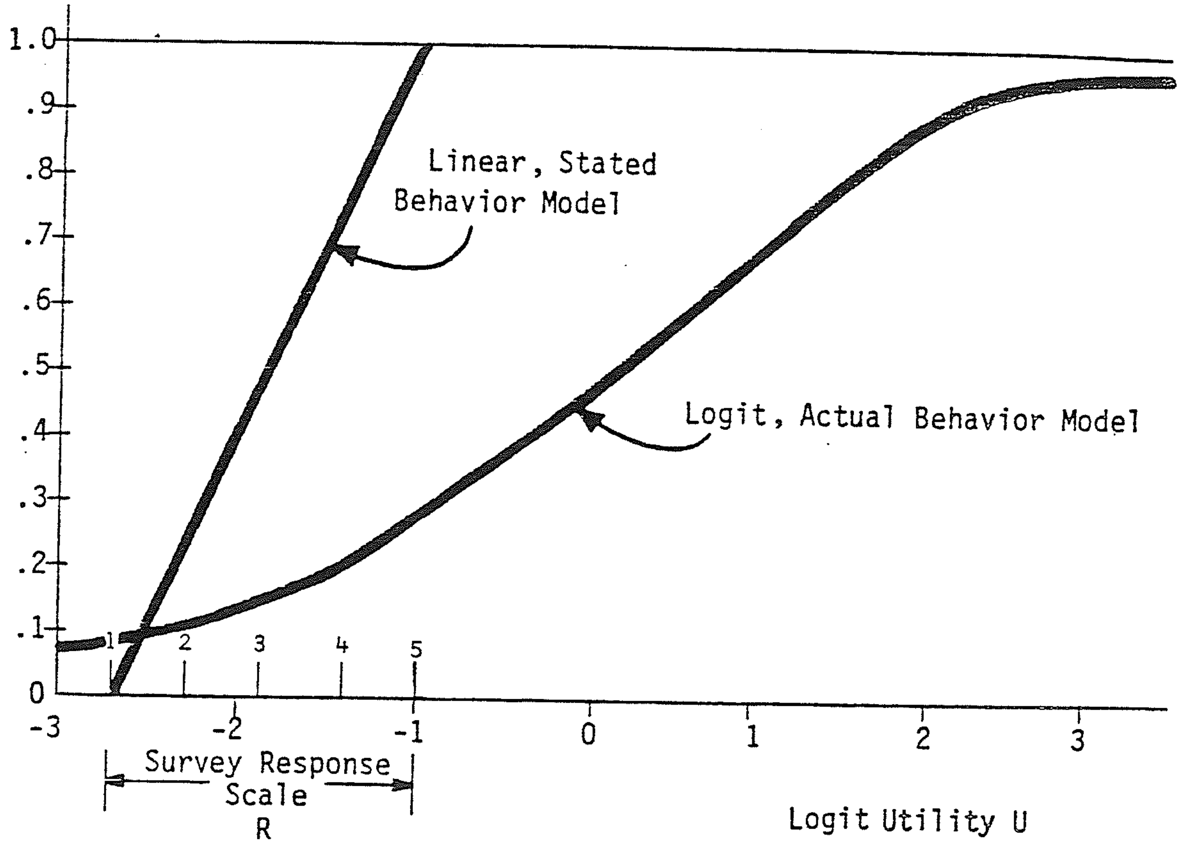
In general, absolute validation of models examining new situations or alternatives is not feasible and some level of uncertainty has to coexist in such models.

3 Comparison of DUA and revealed preference models

Whether or not "behavioral intentions" approaches are better than methods based on actual past behavior has been debated for a long period of time. But the important issue is that both approaches have their strenghts and limitations.

FIGURE D-1.

Comparison of Logit and Linear Model Forms
When Stated Preferences Do Not Correspond to Actual Behavior



Source: Kocur G., T. Adler, W. Hyman & B. Aunet (1982).

Either approach is advantageous in specific circumstances and by no means these approaches are mutually exclusive.

The selection of a demand modeling approach depends on many factors. Some of the most important factors to be considered are: first, the existence of data related to current or past behavior and future alternative conditions, second, time constraints and other resources needed to develop and apply a model of either approach, third, the ability to measure and quantify variations in the studied variables, and forth, the theoretical and practical validity of the final model. However, the most critical forecasting issue relates to the future alternative conditions, e.g., modeling the demand of a new mode service.

Assessing new alternative modes, revealed preference models are developed based on a similar existing alternative and predict the new alternative characteristics under some assumptions. On the other hand, DUA models are calibrated to demonstrate directly the choice among the new alternative and some existing choices.

The advantages of DUA models are attributed to the characteristics of simple, self-contained DUA surveys: (1) DUA models can examine various combinations of selected variables and address diversified alternative senarios based on their flexible experimental designs. (2) The possible high correlations among examined factors can be minimized with appropriate experimental senarios. (3) Factors contained in DUA models can be currently nonexisting or do not present any variability under existing conditions, e.g., weather conditons, convenience, reliability etc.. (4) DUA models can be developed faster than revealed preference models when the validation data set does not demand an extensive job and, at the same moment, the data set required for the revealed preference model is not readily available. (5) The procedure of developing DUA models is not costly and is rather a user friendly method.

Nevertheless, the DUA method has mainly three practical and theoretical drawbacks: (1) The experimental design of the DUA survey limits the potential to examine a large number of factors because its size must entice thoughtful and reasonable responses. (2) The stated responses of DUA experiments do not often imply actual future behavior. (3) In most cases, DUA validation results are poor for the same reason that DUA method is selected over revealed preference models, i.e., there is multicollinearity of variables, lack of variability in examined factors, nonexistence of variables at tested levels etc..

APPENDIX E

REGRESSION EQUATIONS

DATABASE INCLUDING RESPONSES WITH/WITHOUT VARIATION FOR CARPOOLING

(.07)

$$R = \underset{(4.03)}{1.359} + \underset{(5.62)}{.016\text{PCA}} + \underset{(.48)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.19)}{.001\text{PCC}} + \underset{(.19)}{.005\text{WDC}} + \underset{(3.19)}{.409\text{T}}$$

(.15)

$$R = \underset{(3.08)}{1.007} + \underset{(5.87)}{.016\text{PCA}} + \underset{(.50)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(7.14)}{.898\text{SEX}}$$

(.25)

$$R = \underset{(8.14)}{3.387} + \underset{(6.25)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(1.16)}{.169\text{SEX}} - \underset{(-8.48)}{.056\text{AGE}}$$

(.17)

$$R = \underset{(4.86)}{2.368} + \underset{(5.94)}{.016\text{PCA}} + \underset{(.50)}{.007\text{WDA}} + \underset{(.14)}{.018\text{SY}} - \underset{(-.20)}{.001\text{PCC}} + \underset{(.20)}{.005\text{WDC}} + \underset{(3.37)}{.409\text{T}} + \underset{(1.81)}{.349\text{SEX}} - \underset{(-3.73)}{.039\text{I}}$$

(.25)

$$R = \underset{(8.04)}{3.387} + \underset{(6.24)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(.984)}{.169\text{SEX}} - \underset{(-8.33)}{.056\text{AGE}} + \underset{(.003)}{.0005\text{JS}}$$

(.25)

$$R = \underset{(6.98)}{3.370} + \underset{(6.24)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.15)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.54)}{.409\text{T}} + \underset{(.961)}{.177\text{SEX}} - \underset{(-7.51)}{.056\text{AGE}} + \underset{(.06)}{.0007\text{I}}$$

(.30)

$$R = \underset{(8.04)}{3.671} + \underset{(6.46)}{.016\text{PCA}} + \underset{(.53)}{.007\text{WDA}} + \underset{(.16)}{.018\text{SY}} - \underset{(-.22)}{.001\text{PCC}} + \underset{(.22)}{.005\text{WDC}} + \underset{(3.67)}{.409\text{T}} + \underset{(.614)}{.102\text{SEX}} - \underset{(-7.73)}{.051\text{AGE}} + \underset{(.35)}{.058\text{JS}} - \underset{(-6.36)}{.751\text{VN}}$$

```
(.30)
R =  3.405 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (6.85)   (6.46)    (.52)     (.16)    (-.22)     (.22)     (3.67)
           + .177SEX - .054AGE + .128JS  - .766VN  + .011I
             (.96)    (-7.38)    (.72)    (-6.43)    (.94)

(.24)
R =  3.622 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (9.96)   (6.24)    (.53)     (.15)    (-.22)     (.22)     (3.54)
                     - .061AGE
                      (-11.32)

(.24)
R =  3.668 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (9.90)   (6.24)    (.53)     (.15)    (-.22)     (.22)     (3.54)
                     - .057AGE                     - .005I
                      (-7.69)                       (-.65)

(.30)
R =  3.755 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (9.75)   (6.47)    (.55)     (.16)    (-.22)     (.22)     (3.67)
                     - .052AGE + .110JS  - .756VN
                      (-8.64)    (.80)    (-6.41)

(.30)
R =  3.640 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (8.42)   (6.46)    (.55)     (.16)    (-.22)     (.22)     (3.67)
                     - .055AGE + .172JS  - .766VN  + .006I
                      (-7.57)    (.99)    (-6.43)    (.58)

(.12)
R =  1.116 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (3.37)   (5.78)    (.49)     (.14)    (-.20)     (.20)     (3.28)
                               + .763JS
                                 (5.70)

(.20)
R =  1.727 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (5.31)   (6.07)    (.51)     (.15)    (-.21)     (.21)     (3.44)
                               + .699JS  - .927VN
                                 (5.47)   (-7.49)

(.16)
R =  2.869 + .016PCA + .007WDA + .018SY  - .001PCC + .005WDC + .409T +
    (6.22)   (5.93)    (.50)     (.14)    (-.20)     (.20)     (3.36)
                               + .044JS            - .052I
                                 (.23)              (-5.32)
```

(.22)

$$R = \underset{(6.64)}{2.951} + \underset{(6.15)}{.016\mathrm{PCA}} + \underset{(.52)}{.007\mathrm{WDA}} + \underset{(.15)}{.018\mathrm{SY}} - \underset{(-.21)}{.001\mathrm{PCC}} + \underset{(.21)}{.005\mathrm{WDC}} + \underset{(3.49)}{.409\mathrm{T}} + \underset{(.95)}{.175\mathrm{JS}} - \underset{(-6.55)}{.820\mathrm{VN}} - \underset{(-3.98)}{.038\mathrm{I}}$$

(.16)

$$R = \underset{(5.98)}{1.979} + \underset{(5.91)}{.016\mathrm{PCA}} + \underset{(.50)}{.007\mathrm{WDA}} + \underset{(.14)}{.018\mathrm{SY}} - \underset{(-.20)}{.001\mathrm{PCC}} + \underset{(.20)}{.005\mathrm{WDC}} + \underset{(3.36)}{.409\mathrm{T}} - \underset{(-7.67)}{.972\mathrm{VN}}$$

(.22)

$$R = \underset{(8.75)}{3.196} + \underset{(6.15)}{.016\mathrm{PCA}} + \underset{(.52)}{.007\mathrm{WDA}} + \underset{(.15)}{.018\mathrm{SY}} - \underset{(-.21)}{.001\mathrm{PCC}} + \underset{(.21)}{.005\mathrm{WDC}} + \underset{(3.49)}{.409\mathrm{T}} - \underset{(-6.49)}{.806\mathrm{VN}} - \underset{(-6.76)}{.045\mathrm{I}}$$

(.16)

$$R = \underset{(7.79)}{2.932} + \underset{(5.93)}{.016\mathrm{PCA}} + \underset{(.50)}{.007\mathrm{WDA}} + \underset{(.14)}{.018\mathrm{SY}} - \underset{(-.20)}{.001\mathrm{PCC}} + \underset{(.20)}{.005\mathrm{WDC}} + \underset{(3.37)}{.409\mathrm{T}} - \underset{(-7.67)}{.053\mathrm{I}}$$

(.12)

$$R = \underset{(7.42)}{1.898} + \underset{(4.27)}{.195\mathrm{PCA1}} + \underset{(.49)}{.007\mathrm{WDA}} + \underset{(.14)}{.018\mathrm{SY}} - \underset{(-.20)}{.001\mathrm{PCC}} + \underset{(.20)}{.005\mathrm{WDC}} + \underset{(3.29)}{.409\mathrm{T}} + \underset{(3.18)}{.501\mathrm{SEX}}$$

(.20)

$$R = \underset{(10.70)}{4.281} + \underset{(2.90)}{.129\mathrm{PCA1}} + \underset{(.52)}{.007\mathrm{WDA}} + \underset{(.15)}{.018\mathrm{SY}} - \underset{(-.21)}{.001\mathrm{PCC}} + \underset{(.21)}{.005\mathrm{WDC}} + \underset{(3.45)}{.409\mathrm{T}} - \underset{(-.24)}{.040\mathrm{SEX}} - \underset{(-7.51)}{.052\mathrm{AGE}}$$

(.21)

$$R = \underset{(10.72)}{4.297} + \underset{(3.00)}{.138\mathrm{PCA1}} + \underset{(.52)}{.007\mathrm{WDA}} + \underset{(.15)}{.018\mathrm{SY}} - \underset{(-.21)}{.001\mathrm{PCC}} + \underset{(.21)}{.005\mathrm{WDC}} + \underset{(3.45)}{.409\mathrm{T}} + \underset{(.10)}{.019\mathrm{SEX}} - \underset{(-7.54)}{.053\mathrm{AGE}} - \underset{(-77)}{.137\mathrm{JS}}$$

(.26)

$$R = \underset{(11.67)}{4.533} + \underset{(3.37)}{.145\mathrm{PCA1}} + \underset{(.53)}{.007\mathrm{WDA}} + \underset{(.15)}{.018\mathrm{SY}} - \underset{(-.22)}{.001\mathrm{PCC}} + \underset{(.22)}{.005\mathrm{WDC}} + \underset{(3.57)}{.409\mathrm{T}} - \underset{(.64)}{.103\mathrm{SEX}} - \underset{(-6.87)}{.046\mathrm{AGE}} - \underset{(-6.37)}{.773\mathrm{VN}}$$

```
(.26)
R =   4.542 + .152PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (11.68)  (3.40)    (.53)     (.15)   (-.22)    (.22)     (3.57)
            - .063SEX - .047AGE - .091JS - .770VN
             (-.35)    (-6.87)   (-.53)   (-6.34)

(.20)
R =   4.255 + .124PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (11.08)  (3.11)    (.52)     (.15)   (-.21)    (.21)     (3.45)
                      - .051AGE
                       (-8.22)

(.26)
R =   4.509 + .147PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (11.94)  (3.43)    (.53)     (.15)   (-.22)    (.22)     (3.57)
                      - .046AGE - .117JS - .767VN
                       (-7.14)   (-.75)   (-6.34)

(.11)
R =   1.862 + .237PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (7.22)   (5.27)    (.49)     (.14)   (-.20)    (.20)     (3.27)
                                + .281JS
                                 (1.73)

(.19)
R =   2.483 + .231PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (9.53)   (5.37)    (.51)     (.15)   (-.21)    (.21)     (3.42)
                                + .232JS - .913VN
                                 (1.49)   (-7.32)

(.19)
R =   2.439 + .267PCA1+ .007WDA + .018SY - .001PCC + .005WDC + .409T +
    (9.41)   (7.49)    (.51)     (.15)   (-.21)    (.21)     (3.42)
                                         - .921VN
                                          (-7.39)
```

DATABASE INCLUDING ONLY RESPONSES WITH VARIATION FOR CARPOOLING

```
(.26)
R =    .084 + .028PCA + .012WDA + .019SY - .001PCC + .006WDC + .730T
      (.22)  (8.90)    (.67)     (.13)   (-.22)    (.22)    (5.01)

(.37)
R =   -.450 + .028PCA + .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (-1.13)   (9.66)    (.73)     (.14)    (-.24)    (.24)     (5.44)
            + .980SEX
             (7.30)
```

(.43)

$$\begin{aligned} R = {} & \underset{(2.91)}{1.380} + \underset{(10.12)}{.028\text{PCA}} + \underset{(.77)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.70)}{.730\text{T}} + \\ & + \underset{(2.47)}{.408\text{SEX}} - \underset{(-5.45)}{.041\text{AGE}} \end{aligned}$$

(.38)

$$\begin{aligned} R = {} & \underset{(.72)}{.403} + \underset{(9.70)}{.028\text{PCA}} + \underset{(.73)}{.012\text{WDA}} + \underset{(.14)}{.019\text{SY}} - \underset{(-.24)}{.001\text{PCC}} + \underset{(.24)}{.006\text{WDC}} + \underset{(5.46)}{.730\text{T}} + \\ & + \underset{(2.70)}{.623\text{SEX}} + \underset{(.36)}{.004\text{I}} \end{aligned}$$

(.43)

$$\begin{aligned} R = {} & \underset{(3.09)}{1.484} + \underset{(10.13)}{.028\text{PCA}} + \underset{(.77)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.71)}{.730\text{T}} + \\ & + \underset{(2.82)}{.554\text{SEX}} - \underset{(-5.62)}{.043\text{AGE}} - \underset{(-1.36)}{.255\text{JS}} \end{aligned}$$

(.43)

$$\begin{aligned} R = {} & \underset{(2.26)}{1.270} + \underset{(10.10)}{.028\text{PCA}} + \underset{(.76)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.69)}{.730\text{T}} + \\ & + \underset{(2.07)}{.464\text{SEX}} - \underset{(-5.09)}{.042\text{AGE}} + \underset{(.36)}{.004\text{I}} \end{aligned}$$

(.44)

$$\begin{aligned} R = {} & \underset{(3.45)}{1.689} + \underset{(10.18)}{.028\text{PCA}} + \underset{(.77)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.73)}{.730\text{T}} + \\ & + \underset{(2.30)}{.463\text{SEX}} - \underset{(-5.67)}{.043\text{AGE}} - \underset{(-.99)}{.188\text{JS}} - \underset{(-1.96)}{.271\text{VN}} \end{aligned}$$

(.44)

$$\begin{aligned} R = {} & \underset{(2.74)}{1.737} + \underset{(10.16)}{.028\text{PCA}} + \underset{(.77)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.72)}{.730\text{T}} + \\ & + \underset{(2.00)}{.451\text{SEX}} - \underset{(-5.15)}{.043\text{AGE}} - \underset{(-.87)}{.205\text{JS}} - \underset{(-1.89)}{.268\text{VN}} - \underset{(-.12)}{.001\text{I}} \end{aligned}$$

(.41)

$$\begin{aligned} R = {} & \underset{(5.01)}{2.015} + \underset{(10.03)}{.028\text{PCA}} + \underset{(.76)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.65)}{.730\text{T}} + \\ & - \underset{(-8.99)}{.053\text{AGE}} \end{aligned}$$

(.42)

$$\begin{aligned} R = {} & \underset{(5.15)}{2.083} + \underset{(10.04)}{.028\text{PCA}} + \underset{(.76)}{.012\text{WDA}} + \underset{(.15)}{.019\text{SY}} - \underset{(-.25)}{.001\text{PCC}} + \underset{(.25)}{.006\text{WDC}} + \underset{(5.66)}{.730\text{T}} + \\ & - \underset{(-5.40)}{.045\text{AGE}} - \underset{(-1.37)}{.012\text{I}} \end{aligned}$$

(.43)

$$\begin{aligned} R = {} & \underset{(4.72)}{2.133} + \underset{(10.11)}{.028\mathrm{PCA}} + \underset{(.77)}{.012\mathrm{WDA}} + \underset{(.15)}{.019\mathrm{SY}} - \underset{(-.25)}{.001\mathrm{PCC}} + \underset{(.25)}{.006\mathrm{WDC}} + \underset{(5.69)}{.730\mathrm{T}} + \\ & - \underset{(-7.18)}{.050\mathrm{AGE}} + \underset{(.35)}{.055\mathrm{JS}} - \underset{(-2.54)}{.345\mathrm{VN}} \end{aligned}$$

(.43)

$$\begin{aligned} R = {} & \underset{(4.62)}{2.444} + \underset{(10.11)}{.028\mathrm{PCA}} + \underset{(.77)}{.012\mathrm{WDA}} + \underset{(.15)}{.019\mathrm{SY}} - \underset{(-.25)}{.001\mathrm{PCC}} + \underset{(.25)}{.006\mathrm{WDC}} + \underset{(5.70)}{.730\mathrm{T}} + \\ & - \underset{(-5.51)}{.045\mathrm{AGE}} + \underset{(.59)}{.139\mathrm{JS}} - \underset{(-2.13)}{.300\mathrm{VN}} - \underset{(-1.13)}{.015\mathrm{I}} \end{aligned}$$

(.31)

$$\begin{aligned} R = {} & \underset{(-.48)}{-.182} + \underset{(9.22)}{.028\mathrm{PCA}} + \underset{(.70)}{.012\mathrm{WDA}} + \underset{(.14)}{.019\mathrm{SY}} - \underset{(-.23)}{.001\mathrm{PCC}} + \underset{(.23)}{.006\mathrm{WDC}} + \underset{(5.19)}{.730\mathrm{T}} + \\ & + \underset{(4.70)}{.677\mathrm{JS}} \end{aligned}$$

(.33)

$$\begin{aligned} R = {} & \underset{(.26)}{.100} + \underset{(9.34)}{.028\mathrm{PCA}} + \underset{(.71)}{.012\mathrm{WDA}} + \underset{(.14)}{.019\mathrm{SY}} - \underset{(-.23)}{.001\mathrm{PCC}} + \underset{(.23)}{.006\mathrm{WDC}} + \underset{(5.26)}{.730\mathrm{T}} + \\ & + \underset{(4.81)}{.683\mathrm{JS}} - \underset{(-2.97)}{.434\mathrm{VN}} \end{aligned}$$

(.37)

$$\begin{aligned} R = {} & \underset{(3.58)}{1.955} + \underset{(9.61)}{.028\mathrm{PCA}} + \underset{(.73)}{.012\mathrm{WDA}} + \underset{(.14)}{.019\mathrm{SY}} - \underset{(-.24)}{.001\mathrm{PCC}} + \underset{(.24)}{.006\mathrm{WDC}} + \underset{(5.41)}{.730\mathrm{T}} + \\ & - \underset{(-1.38)}{.327\mathrm{JS}} - \underset{(-5.19)}{.061\mathrm{I}} \end{aligned}$$

(.37)

$$\begin{aligned} R = {} & \underset{(3.51)}{1.914} + \underset{(9.64)}{.028\mathrm{PCA}} + \underset{(.73)}{.012\mathrm{WDA}} + \underset{(.14)}{.019\mathrm{SY}} - \underset{(-.24)}{.001\mathrm{PCC}} + \underset{(.24)}{.006\mathrm{WDC}} + \underset{(5.43)}{.730\mathrm{T}} + \\ & - \underset{(-.94)}{.229\mathrm{JS}} - \underset{(-1.66)}{.245\mathrm{VN}} - \underset{(-4.53)}{.055\mathrm{I}} \end{aligned}$$

(.28)

$$\begin{aligned} R = {} & \underset{(.92)}{.363} + \underset{(9.01)}{.028\mathrm{PCA}} + \underset{(.68)}{.012\mathrm{WDA}} + \underset{(.13)}{.019\mathrm{SY}} - \underset{(-.22)}{.001\mathrm{PCC}} + \underset{(.22)}{.006\mathrm{WDC}} + \underset{(5.07)}{.730\mathrm{T}} + \\ & - \underset{(-2.79)}{.424\mathrm{VN}} \end{aligned}$$

(.37)

$$\begin{aligned} R = {} & \underset{(3.85)}{1.575} + \underset{(9.64)}{.028\mathrm{PCA}} + \underset{(.73)}{.012\mathrm{WDA}} + \underset{(.14)}{.019\mathrm{SY}} - \underset{(-.24)}{.001\mathrm{PCC}} + \underset{(.24)}{.006\mathrm{WDC}} + \underset{(5.43)}{.730\mathrm{T}} + \\ & - \underset{(-1.94)}{.279\mathrm{VN}} - \underset{(-6.66)}{.046\mathrm{I}} \end{aligned}$$

```
(.36)
R =  1.450 + .028PCA + .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (3.58)   (9.60)    (.73)     (.14)   (-.24)     (.24)    (5.41)
                                                  - .048I
                                                   (-7.00)

(.23)
R =  1.543 + .233PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (5.16)   (4.73)    (.66)     (.13)   (-.22)     (.22)    (4.92)
           + .048SEX
             (2.35)

(.27)
R =  3.161 + .201PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (6.46)   (4.14)    (.68)     (.13)   (-.22)     (.22)    (5.05)
           + .020SEX - .035AGE
             (.09)    (-4.11)

(.30)
R =  3.208 + .269PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (6.66)   (5.14)    (.69)     (.13)   (-.23)     (.23)    (5.13)
           + .306SEX - .039AGE - .727JS
             (1.36)   (-4.60)   (-3.20)

(.28)
R =  3.427 + .210PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T -
    (6.86)   (4.33)    (.68)     (.13)   (-.22)     (.22)    (5.08)
           - .063SEX - .036AGE          - .347VN
            (-.302)   (-4.22)            (-2.25)

(.30)
R =  3.414 + .269PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (6.91)   (5.17)    (.69)     (.13)   (-.23)     (.23)    (5.15)
           + .213SEX - .039AGE - .660JS - .275VN
             (.930)   (-4.64)   (-2.87)  (-1.78)

(.27)
R =  3.179 + .203PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (7.00)   (4.69)    (.68)     (.13)   (-.22)     (.22)    (5.06)
                     - .036AGE
                      (-4.78)

(.30)
R =  3.579 + .279PCA1+ .012WDA + .019SY - .001PCC + .006WDC + .730T +
    (7.77)   (5.49)    (.69)     (.13)   (-.23)     (.23)    (5.15)
                     - .042AGE - .570JS - .307VN
                      (-5.49)   (-2.74)  (-2.04)
```

```
(.22)
R =  1.465 + .337PCA1+ .012WDA  + .019SY - .001PCC + .006WDC  + .730T +
    (4.82)   (6.39)    (.66)      (.13)    (-.22)     (.22)      (4.88)
                                - .195JS
                                 (-.95)

(.23)
R =  1.728 + .329PCA1+ .012WDA  + .019SY - .001PCC + .006WDC  + .730T +
    (5.38)   (6.28)    (.66)      (.13)    (-.22)     (.22)      (4.92)
                                - .169JS - .373VN
                                 (-.83)   (-2.38)

(.23)
R =  1.771 + .300PCA1+ .012WDA  + .019SY - .001PCC + .006WDC  + .730T +
    (5.58)   (7.69)    (.66)      (.13)    (-.22)     (.22)      (4.92)
                                         - .380VN
                                          (-2.43)
```

DATABASE INCLUDING RESPONSES WITH/WITHOUT VARIATION FOR MASS TRANSIT

```
(.04)
R =  1.782 + .015PC  + .002WD   - .024SY - .074BC - .001BT - .007BF
    (4.57)   (5.66)    (.14)     (-.19)   (-.44)   (-.09)   (-.29)

(.15)
R =  1.302 + .015PC  + .002WD   - .024SY - .074BC - .001BT - .007BF +
    (3.51)   (6.01)    (.15)     (-.20)   (-.47)   (-.10)   (-.31)
           + 1.08SEX
             (9.09)

(.16)
R =  2.082 + .015PC  + .002WD   - .024SY - .074BC - .001BT - .007BF +
    (4.59)   (6.05)    (.15)     (-.21)   (-.47)   (-.10)   (-.31)
           + .883SEX - .016AGE
             (6.51)   (-2.95)

(.15)
R =  1.205 + .015PC  + .002WD   - .024SY - .074BC - .001BT - .007BF +
    (3.17)   (6.01)    (.15)     (-.20)   (-.47)   (-.10)   (-.31)
           + 1.09SEX                     + .144VN
             (9.16)                       (1.17)

(.21)
R =  3.251 + .015PC  + .002WD   - .024SY - .074BC - .001BT - .007BF +
    (7.01)   (6.21)    (.16)     (-.21)   (-.48)   (-.10)   (-.32)
           + .499SEX                              - .055I
             (3.45)                                (-6.64)
```

```
(.21)
R =  1.896 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (4.28)   (6.20)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .396SEX - .014AGE + .905JS
             (2.53)   (-2.53)   (5.84)

(.17)
R =  2.002 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (4.41)   (6.05)    (.15)    (-.21)   (-.47)   (-.10)   (-.31)
           + .885SEX - .018AGE         + .196VN
            (6.53)   (-3.15)             (1.60)

(.21)
R =  3.450 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.95)   (6.21)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .453SEX - .006AGE                    - .052I
             (3.02)    (-1.11)                    (-6.01)

(.21)
R =  2.830 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (4.91)   (6.23)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .358SEX - .009AGE + .481JS             - .032I
             (2.29)    (-1.52)   (2.10)             (-2.52)

(.22)
R =  2.768 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (4.81)   (6.25)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .342SEX - .010AGE + .490JS + .196VN - .034I
            (2.19)   (-1.75)    (2.15)   (2.32)   (-2.65)

(.11)
R =  3.224 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (7.47)   (5.86)    (.15)    (-.20)   (-.45)   (-.10)   (-.30)
                     - .035AGE
                      (-6.85)

(.20)
R =  2.221 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.21)   (6.17)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
                     - .019AGE +1.115JS
                      (-3.72)   (8.47)

(.11)
R =  3.156 + .015PC  + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (7.28)   (5.86)    (.15)    (-.20)   (-.45)   (-.10)   (-.30)
                     - .036AGE          + .189VN
                      (-7.01)             (1.49)
```

(.20)

$$\begin{array}{lllllllll} R = & 4.231 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (9.92) & (6.17) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & - .011\mathrm{AGE} & & & - .065\mathrm{I} & & \\ & & & (-2.00) & & & (-8.42) & & \end{array}$$

(.18)

$$\begin{array}{lllllllll} R = & 1.368 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (3.76) & (6.11) & (.16) & (-.21) & (-.47) & (-.10) & (-.31) & \\ & & & & +1.290\mathrm{JS} & & & & \\ & & & & (10.38) & & & & \end{array}$$

(.18)

$$\begin{array}{lllllllll} R = & 1.224 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (3.29) & (6.12) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & & +1.319\mathrm{JS} & + .213\mathrm{VN} & & & \\ & & & & (10.54) & (1.76) & & & \end{array}$$

(.20)

$$\begin{array}{lllllllll} R = & 3.044 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (5.51) & (6.18) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & & + .568\mathrm{JS} & & - .047\mathrm{I} & & \\ & & & & (2.60) & & (-3.99) & & \end{array}$$

(.21)

$$\begin{array}{lllllllll} R = & 2.956 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (5.35) & (6.20) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & & + .566\mathrm{JS} & + .261\mathrm{VN} & - .049\mathrm{I} & & \\ & & & & (2.59) & (2.18) & (-4.19) & & \end{array}$$

(.04)

$$\begin{array}{lllllllll} R = & 1.752 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (4.39) & (5.66) & (.14) & (-.19) & (-.44) & (-.09) & (-.29) & \\ & & & & & + .048\mathrm{VN} & & & \\ & & & & & (.37) & & & \end{array}$$

(.20)

$$\begin{array}{lllllllll} R = & 3.913 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (9.46) & (6.17) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & & & + .263\mathrm{VN} & - .075\mathrm{I} & & \\ & & & & & (2.18) & (11.12) & & \end{array}$$

(.19)

$$\begin{array}{lllllllll} R = & 4.006 & + .015\mathrm{PC} & + .002\mathrm{WD} & - .024\mathrm{SY} & - .074\mathrm{BC} & - .001\mathrm{BT} & - .007\mathrm{BF} & + \\ & (9.71) & (6.16) & (.16) & (-.21) & (-.48) & (-.10) & (-.32) & \\ & & & & & & - .072\mathrm{I} & & \\ & & & & & & (-10.88) & & \end{array}$$

```
(.18)
R =  1.988 + .274PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.59)   (7.48)    (.15)    (-.21)   (-.47)   (-.10)   (-.31)
           + .637SEX
             (4.85)

(.18)
R =  2.320 + .263PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.50)   (6.96)    (.15)    (-.21)   (-.47)   (-.10)   (-.31)
           + .577SEX - .006AGE
             (4.08)   (-1.12)

(.19)
R =  2.091 + .220PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.92)   (5.37)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .435SEX           + .505JS
             (2.93)              (2.87)

(.18)
R =  1.768 + .287PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.60)   (7.77)    (.16)    (-.21)   (-.47)   (-.10)   (-.31)
           + .640SEX                    + .283VN
             (4.89)                       (2.32)

(.19)
R =  2.458 + .207PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.83)   (4.91)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .366SEX - .007AGE + .513JS
             (2.32)   (-1.24)    (2.92)

(.19)
R =  2.160 + .274PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.08)   (7.23)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .567SEX - .008AGE          - .300VN
             (4.08)   (-1.37)             (2.45)

(.20)
R =  2.295 + .217PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.40)   (5.14)    (.16)    (-.21)   (-.48)   (-.10)   (-.32)
           + .348SEX - .008AGE + .513JS + .314VN
             (2.21)   (-1.51)    (3.03)   (2.58)

(.16)
R =  2.787 + .311PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.78)   (8.55)    (.15)    (-.21)   (-.47)   (-.10)   (-.31)
                     - .015AGE
                      (-2.82)
```

```
(.18)
R =  2.742 + .211PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.77)   (4.99)    (.16)    (-.21)   (-.47)   (-.10)  (-.31)
                     - .016AGE + .700JS
                      (-2.18)    (4.46)

(.16)
R =  2.611 + .322PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.29)   (8.82)    (.15)    (-.21)   (-.47)   (-.10)  (-.31)
                     - .016AGE          + .314VN
                      (-3.07)             (2.54)

(.18)
R =  2.153 + .236PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (7.10)   (5.79)    (.15)    (-.21)   (-.47)   (-.10)  (-.31)
                               + .750JS
                                 (4.81)

(.18)
R =  1.923 + .248PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (6.08)   (6.05)    (.16)    (-.21)   (-.47)   (-.10)  (-.32)
                               + .763JS + .298VN
                                 (4.92)   (2.44)

(.15)
R =  1.795 + .367PC1 + .002WD  - .024SY - .074BC - .001BT - .007BF +
    (5.59)   (10.91)   (.15)    (-.20)   (-.47)   (-.10)  (-.31)
                                        + .276VN
                                          (2.23)
```

DATABASE INCLUDING ONLY RESPONSES WITH VARIATION FOR MASS TRANSIT

```
(.31)
R =   .455 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF
     (1.02) (11.19)    (.29)    (-.38)   (-.87)   (-.19)  (-.58)

(.35)
R =   .080 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
     (.18)  (11.59)    (.30)    (-.40)   (-.90)   (-.20)  (-.60)
           + .642SEX
             (4.60)

(.38)
R =  1.062 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (2.01)  (11.78)    (.30)    (-.41)   (-.92)   (-.20)  (-.61)
           + .348SEX - .019AGE
             (2.11)   (-3.20)
```

```
(.40)
R =   -.010 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (-.02)  (11.95)    (.31)     (-.41)   (-.93)   (-.20)   (-.62)
            + .314SEX             + .675JS
              (2.03)                (4.36)

(.37)
R =   -.043 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (-.10)  (11.66)    (.30)     (-.40)   (-.91)   (-.20)   (-.60)
            + .575SEX                      + .309VN
              (4.04)                         (2.20)

(.42)
R =   1.706 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (3.37)  (12.20)    (.31)     (-.42)   (-.95)   (-.21)   (-.63)
            + .123SEX                               - .045I
              (.76)                                  (-5.62)

(.41)
R =    .882 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (1.71)  (12.12)    (.31)     (-.42)   (-.94)   (-.21)   (-.63)
            + .065SEX  - .017AGE  + .641JS
              (.37)    (-2.96)    (4.18)

(.39)
R =   1.006 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (1.92)  (11.90)    (.31)     (-.41)   (-.93)   (-.20)   (-.62)
            + .081SEX  - .019AGE           + .363VN
              (1.43)    (-3.50)              (2.62)

(.42)
R =   2.037 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (3.72)  (12.23)    (.31)     (-.42)   (-.95)   (-.21)   (-.63)
            + .028SEX  - .009AGE                    - .041I
              (.16)     (-1.55)                      (-4.81)

(.43)
R =    .802 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (1.58)  (12.32)    (.32)     (-.42)   (-.96)   (-.21)   (-.64)
            - .081SEX  - .019AGE  + .691JS + .427VN
             (-.46)     (-3.33)    (4.56)   (3.17)

(.43)
R =   1.791 + .035PC   + .005WD    - .055SY - .166BC - .002BT - .016BF +
     (2.83)  (12.23)    (.31)     (-.42)   (-.95)   (-.21)   (-.63)
            + .216SEX  - .011AGE  + .187JS          - .033I
              (.053)    (-1.71)    (.77)             (-2.43)
```

```
(.46)
R =  2.143 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (3.45)  (12.58)    (.32)    (-.43)   (-.98)   (-.21)   (-.65)
           - .216SEX - .010AGE + .025JS + .572VN - .049I
            (-1.21)   (-1.64)    (.10)    (4.15)  (-3.60)

(.37)
R =  1.563 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (3.29)  (11.70)    (.30)    (-.40)   (-.91)   (-.20)   (-.61)
                     - .027AGE
                      (-5.22)

(.41)
R =   .956 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (2.01)  (12.14)    (.31)    (-.42)   (-.95)   (-.21)   (-.63)
                     - .018AGE + .063JS
                      (-3.59)    (4.70)

(.39)
R =  1.327 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (2.80)  (11.88)    (.31)    (-.41)   (-.93)   (-.20)   (-.62)
                     - .026AGE          + .411VN
                      (-5.21)             (3.05)

(.42)
R =  2.084 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (4.49)  (12.26)    (.32)    (-.42)   (-.96)   (-.21)   (-.64)
                     - .010AGE                   - .041I
                      (-1.73)                     (-5.29)

(.39)
R =   .109 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
     (.26)  (11.89)    (.31)    (-.41)   (-.93)   (-.20)   (-.62)
                               + .082JS
                                 (6.08)

(.41)
R =  -.112 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
     (-.26) (12.08)    (.31)    (-.42)   (-.94)   (-.21)   (-.63)
                               + .824JS + .424VN
                                 (6.15)   (3.20)

(.42)
R =  1.754 + .035PC  + .005WD  - .055SY - .166BC - .002BT - .016BF +
    (3.00)  (12.19)    (.31)    (-.42)   (-.95)   (-.21)   (-.63)
                               + .078JS          - .045I
                                 (.34)           (-3.95)
```

(.45)

$$R = \underset{(3.18)}{1.807} + \underset{(12.55)}{.035\mathrm{PC}} + \underset{(.32)}{.005\mathrm{WD}} - \underset{(-.43)}{.055\mathrm{SY}} - \underset{(-.98)}{.166\mathrm{BC}} - \underset{(-.21)}{.002\mathrm{BT}} - \underset{(-.65)}{.016\mathrm{BF}} +$$

$$- \underset{(.35)}{.081\mathrm{JS}} + \underset{(4.20)}{.546\mathrm{VN}} - \underset{(-4.81)}{.055\mathrm{I}}$$

(.33)

$$R = \underset{(.51)}{.227} + \underset{(11.36)}{.035\mathrm{PC}} + \underset{(.29)}{.005\mathrm{WD}} - \underset{(-.39)}{.055\mathrm{SY}} - \underset{(-.88)}{.166\mathrm{BC}} - \underset{(-.19)}{.002\mathrm{BT}} - \underset{(-.59)}{.016\mathrm{BF}} +$$

$$+ \underset{(3.06)}{.431\mathrm{VN}}$$

(.45)

$$R = \underset{(3.82)}{1.680} + \underset{(12.55)}{.035\mathrm{PC}} + \underset{(.32)}{.005\mathrm{WD}} - \underset{(-.43)}{.055\mathrm{SY}} - \underset{(-.98)}{.166\mathrm{BC}} - \underset{(-.21)}{.002\mathrm{BT}} - \underset{(-.65)}{.016\mathrm{BF}} +$$

$$+ \underset{(4.21)}{.538\mathrm{VN}} - \underset{(-8.00)}{.052\mathrm{I}}$$

(.42)

$$R = \underset{(4.18)}{1.881} + \underset{(12.21)}{.035\mathrm{PC}} + \underset{(.31)}{.005\mathrm{WD}} - \underset{(-.42)}{.055\mathrm{SY}} - \underset{(-.95)}{.166\mathrm{BC}} - \underset{(-.21)}{.002\mathrm{BT}} - \underset{(-.63)}{.016\mathrm{BF}} +$$

$$- \underset{(-7.39)}{.049\mathrm{I}}$$

(.21)

$$R = \underset{(6.26)}{2.462} + \underset{(7.59)}{.287\mathrm{PC1}} + \underset{(.27)}{.005\mathrm{WD}} - \underset{(-.36)}{.055\mathrm{SY}} - \underset{(-.81)}{.166\mathrm{BC}} - \underset{(-.18)}{.002\mathrm{BT}} - \underset{(-.54)}{.016\mathrm{BF}} +$$

$$+ \underset{(.63)}{.108\mathrm{SEX}}$$

(.21)

$$R = \underset{(4.69)}{2.626} + \underset{(7.04)}{.282\mathrm{PC1}} + \underset{(.27)}{.005\mathrm{WD}} - \underset{(-.36)}{.055\mathrm{SY}} - \underset{(-.81)}{.166\mathrm{BC}} - \underset{(-.18)}{.002\mathrm{BT}} - \underset{(-.54)}{.016\mathrm{BF}} +$$

$$+ \underset{(.38)}{.108\mathrm{SEX}} - \underset{(-.41)}{.003\mathrm{AGE}}$$

(.21)

$$R = \underset{(6.25)}{2.467} + \underset{(6.56)}{.284\mathrm{PC1}} + \underset{(.27)}{.005\mathrm{WD}} - \underset{(-.36)}{.055\mathrm{SY}} - \underset{(-.81)}{.166\mathrm{BC}} - \underset{(-.18)}{.002\mathrm{BT}} - \underset{(-.54)}{.016\mathrm{BF}} +$$

$$+ \underset{(.53)}{.097\mathrm{SEX}} + \underset{(.18)}{.036\mathrm{JS}}$$

(.26)

$$R = \underset{(5.30)}{2.075} + \underset{(8.72)}{.333\mathrm{PC1}} + \underset{(.28)}{.005\mathrm{WD}} - \underset{(-.37)}{.055\mathrm{SY}} - \underset{(-.84)}{.166\mathrm{BC}} - \underset{(-.18)}{.002\mathrm{BT}} - \underset{(-.56)}{.016\mathrm{BF}} +$$

$$- \underset{(-.72)}{.125\mathrm{SEX}} + \underset{(4.33)}{.684\mathrm{VN}}$$

(.21)

$$\begin{aligned} R = {} & \underset{(4.67)}{2.641} + \underset{(6.04)}{.277\text{PC1}} + \underset{(.27)}{.005\text{WD}} - \underset{(-.36)}{.055\text{SY}} - \underset{(-.81)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.54)}{.016\text{BF}} + \\ & + \underset{(.28)}{.057\text{SEX}} - \underset{(-.43)}{.003\text{AGE}} + \underset{(.22)}{.045\text{JS}} \end{aligned}$$

(.26)

$$\begin{aligned} R = {} & \underset{(4.15)}{2.281} + \underset{(8.12)}{.326\text{PC1}} + \underset{(.28)}{.005\text{WD}} - \underset{(-.37)}{.055\text{SY}} - \underset{(-.84)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.56)}{.016\text{BF}} + \\ & - \underset{(-.88)}{.171\text{SEX}} - \underset{(-.53)}{.003\text{AGE}} + \underset{(4.34)}{.686\text{VN}} \end{aligned}$$

(.26)

$$\begin{aligned} R = {} & \underset{(4.14)}{2.290} + \underset{(7.07)}{.323\text{PC1}} + \underset{(.01)}{.005\text{WD}} - \underset{(-.01)}{.055\text{SY}} - \underset{(-.04)}{.166\text{BC}} - \underset{(-.00)}{.002\text{BT}} - \underset{(-.02)}{.016\text{BF}} + \\ & - \underset{(-.88)}{.180\text{SEX}} - \underset{(-.54)}{.003\text{AGE}} + \underset{(.14)}{.027\text{JS}} + \underset{(4.33)}{.686\text{VN}} \end{aligned}$$

(.21)

$$\begin{aligned} R = {} & \underset{(5.25)}{2.709} + \underset{(7.29)}{.285\text{PC1}} + \underset{(.27)}{.005\text{WD}} - \underset{(-.36)}{.055\text{SY}} - \underset{(-.81)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.54)}{.016\text{BF}} + \\ & - \underset{(-.65)}{.004\text{AGE}} \end{aligned}$$

(.21)

$$\begin{aligned} R = {} & \underset{(5.23)}{2.705} + \underset{(6.05)}{.277\text{PC1}} + \underset{(.27)}{.005\text{WD}} - \underset{(-.36)}{.055\text{SY}} - \underset{(-.81)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.54)}{.016\text{BF}} + \\ & - \underset{(-.62)}{.004\text{AGE}} + \underset{(.339)}{.064\text{JS}} \end{aligned}$$

(.26)

$$\begin{aligned} R = {} & \underset{(4.09)}{2.123} + \underset{(8.18)}{.317\text{PC1}} + \underset{(.28)}{.005\text{WD}} - \underset{(-.37)}{.055\text{SY}} - \underset{(-.84)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.56)}{.016\text{BF}} + \\ & - \underset{(-.16)}{.001\text{AGE}} + \underset{(4.27)}{.646\text{VN}} \end{aligned}$$

(.21)

$$\begin{aligned} R = {} & \underset{(6.37)}{2.493} + \underset{(6.78)}{.288\text{PC1}} + \underset{(.27)}{.005\text{WD}} - \underset{(-.36)}{.055\text{SY}} - \underset{(-.81)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.54)}{.016\text{BF}} + \\ & + \underset{(.383)}{.072\text{JS}} \end{aligned}$$

(.26)

$$\begin{aligned} R = {} & \underset{(5.26)}{2.063} + \underset{(7.69)}{.323\text{PC1}} + \underset{(.28)}{.005\text{WD}} - \underset{(-.37)}{.055\text{SY}} - \underset{(-.84)}{.166\text{BC}} - \underset{(-.18)}{.002\text{BT}} - \underset{(-.56)}{.016\text{BF}} + \\ & - \underset{(-.13)}{.025\text{JS}} + \underset{(4.30)}{.651\text{VN}} \end{aligned}$$

$$(.26)$$

$$R = \underset{(5.28)}{2.066} + \underset{(9.47)}{.320PC1} + \underset{(.28)}{.005WD} - \underset{(-.37)}{.055SY} - \underset{(-.84)}{.166BC} - \underset{(-.18)}{.002BT} - \underset{(-.56)}{.016BF} + \underset{(4.33)}{.649VN}$$