737

AN ANALYSIS OF CHANGES

IN

WORK TRIP TRAVEL BEHAVIOUR

AN ANALYSIS OF CHANGES IN WORK TRIP TRAVEL BEHAVIOUR

by

PUI-CHUN L. LO, B.A.

A Research Paper
Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree

Master of Arts

McMaster University
Hamilton, Ontario

December 1977

MASTER OF ARTS (1977)
(Geography)

McMaster University
Hamilton, Ontario

TITLE: An Analysis of Changes in Work Trip Travel Behaviour.

AUTHOR: Pui-Chun Lucia LO, B.A. (McMaster University)

SUPERVISOR: Dr. F.L. Hall

NUMBER OF PAGES: ix, 55

ABSTRACT

This work trip study is part of the studies on King Street closure. The objectives are to examine the effect of changed traffic conditions on change in travel behaviour, and to identify variables for choice modelling. Some behavioural changes are observed, but none is related to the increased road congestion. The household survey data shows that people did not perceive a difference in travel times before and during closure. Thus the reliability of reported times on modelling is suspected. However, modelling on time of day in a multinomial logit framework using measured travel data does not help to explain the behavioural changes with either travel time or a congestion factor. It is concluded that the changes observed in this study represent random occurrences and the change in congestion is too moderate to effect behavioural changes.

ACKNOWLEDGEMENTS

I would like to thank Dr. Fred Hall for supervising me in this research, for his guidance in improving the form and content of the report. I also want to thank Dr. Michael Webber for his comments. Thanks are extended to Desmond, Rafael and Rick for their help and discussions in different stages of the study. Finally, I am grateful to Josephine and Rosanna for typing this report within short notice.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

This research arose from some transportation planning decisions; it examines their impact on individual's travel behaviour and identifies variables for modelling changes in travel behaviour.

King Street (see Figure 1) is the most important westbound roadway in Hamilton, Ontario for both private cars and public transit. From late June to October, 1977, three out of four lanes of King Street were closed for construction work. During the construction period, bus routes were unaltered, but auto-users had to make detours.

The partial closure of King Street provided an ideal situation for testing a number of transportation-related hypotheses. It meant a major decrease in road capacity and under the assumption that the volume of traffic along the corridor remained unchanged, this would lead to an increase in driving time especially during the peak hours of traffic.

Many studies suggest that increased driving time should induce more transit use. It was therefore expected that some people would change to transit instead of driving their own car. On the other hand, since the blockage of King Street was only temporary, urban travellers could respond to the changed conditions by shifting routes or time of travel instead of changing mode.

The focus of this research was to enquire how people reacted to changed traffic conditions. There were two main objectives. The first was to examine the effect of increased congestion on individuals' travel behaviour, that is, relating change in mode, route or time of day to any change in travel time. The second objective was to model changes in travel behaviour which should help to identify variables related to these travel decisions. It was hoped that results from this study could serve planning and policy-making purposes in urban transportation.

This report consists of six chapters. Chapter 2 relates the development of the urban transportation planning process and points out the area that deserves attention. Chapter 3 outlines the data collection on which this report is based. Chapter 4 analyses the data with regard to work trips and attempts to identify variables for modelling changes in travel behaviour, and the final chapter concludes the report.

CHAPTER 2

URBAN TRANSPORTATION PLANNING

2.1 Introduction

A major concern in transportation planning is to make the transportation system efficient by minimizing the total costs of transportation. As Stopher and Meyburg (1975) have said, transportation is not a single isolated system by itself, but a subset of a much larger system. Urban life, urban economy, urban form and urban transportation are much interrelated. Urban transportation is responsible, at least, in part for many of the existing urban questions. For example, it has resulted in high costs in terms of ecological, urban space and energy conservation questions.

Both technically and financially, it is presently infeasible to cure directly the transportation - related urban ills. An improved transportation system is not a magic tool. However, an attempt to understand the phenomenon of transportation definitely provides a course of action. Through that understanding, transportation planners can devise new methods to tackle the problems and provide for total travel in the urban area. A more efficient transportation system may alleviate other urban- and transportation-related problems too.

This is where transportation planning has been moving, and the development of the urban transportation planning process is outlined in the next two sections.

2.2 The Conventional Aggregate Approach

The standard urban transportation planning process deals with a sequential set of travel demand models. These models make use of existing inventories of travel and of land use and predict future travel. They include landuse forecasts, trip generation, trip distribution, modal split and network assignment. Information is collected on a zonal rather than individual basis.

Though this conventional approach prevailed in the 1960's and early 1970's, it has recently been the focus of severe criticizms (Stopher and Meyburg 1975, Ch. 12), (Brand, 1972), (Ben-Akiva 1973). The strongest attacks are on the inflexibility and static nature of the approach: measurements are made and relationships estimated for a single point in time and it is assumed that those relationships and estimates will not change over time; it is unresponsive and insensitive to policies; and it is incapable of determining the effects on travel decisions of changes in travellers' circumstances. For good estimation, the conventional approach requires a lot of data too.

In an attempt to overcome some of the shortcomings of the conventional approach, there have been several directions of research. The first is centered on econometric models based on consumer behaviour theory (Quandt and Baumol 1966), (Quandt 1970). This approach attempts to combine the processes of trip generation, mode choice and trip distribution in one model.

The second approach attempts incremental improvements in the standard package by providing more reliable and more plausible models. Improvements are usually related to the techniques of modelling (Brown and Woehrle 1968).

The third approach is an attempt to restructure the models associated with the decision process. It results in a series of disaggregate, behavioural, probabilistic travel demand models. So far, this appears to be the most promising approach to be taken.

2.3 Disaggregate Approaches

The new approaches to transportation planning are termed disaggregate because they are based on individual observations, behavioural because they are based on causal relationships, and probabilistic because the models calculate the probability of a particular choice. These behavioural models are concerned with identification of decision variables in travel-choice situations and supposedly can explain changes in travel behaviour. They have clear advantages over the aggregate models (Reichman and Stopher 1971), (Watson and Westin 1975), (Liou et al. 1975).

Conventional demand models are not very useful in determining the number of potential users of the system and mode diversion in the system. Nor can they evaluate the effects of alternative technologies or of service improvements on transit ridership and automotive congestion (Domencich and McFadden 1975, p.1). For sound management and planning, we need models responsive to policy questions, models that contain variables that policy-makers are able to control. Disaggregate modelling contains both system variables and person-related attributes. The disaggregate approach is now becoming an accepted planning tool for it holds the greatest potential for the improvement of policy responsiveness and accuracy in the urban transporation-planning process.

The disaggregate approach first studied mode choice models because mode choice has been seen as one of the most policy-relevant steps in the travel-forecasting process. Since its initiation with Warner (1962), most of the disaggregate efforts have been expanded on the identification of variables (Stopher 1967), (De Donnea 1971), improvements in modelling techniques (Quarmby 1967), (Lisco 1967), (Lave 1969), (McGillivray 1970), (Domencich and McFadden 1975),the valuation of travel time (Hensher 1972), (Watson 1974),and quantification of non-physical variables (Stopher et al. 1974), (Nicolaidis 1975).

Most of these models are concerned with mode choice for work trips. But it is clear that many of the most significant impacts of transportation policy are on the overall pattern of travel rather than simply on modal shifts. Thus recently, extensions have been made to choices other than mode choice, such as route choice, time of day choice, and destination choice (Domencich and McFadden 1975, Charles River Associates 1972), trip purposes (Algers, Hansen and Tegner 1975) and the decision-making structures (Ben-Akiva 1974),(Ewing 1974).

The task of present research should aim at producing models that are sensitive to testing or defining transport-related policies (Stopher and Meyburg 1976), (Domencich and McFadden 1975). Efforts on disaggregate modelling so far have been helpful in our attempts to understand transportation phenomena. But still, most disaggregate travel-demand models are static, assuming people have static perceptions of their environment and perceive the same set of alternatives as available over time. In fact, urban residents are always engaged in a learning process. Thus there is a call for dynamic choice models (Lerman and Adler 1976). These would prove useful in situations where the short-run impacts of major transport facility changes are important. While it is quite unlikely for cities to conduct transportation studies on a continuing basis, before- and after-studies on changes in traffic services would prove particularly helpful in transportation planning. These studies enable the planners to have a clear understanding of the interrelationships among various components of the transporation system. For example, improved transit operations may lead to fewer vehicles on the road. Secondly, the studies assist policy-makers to realize the traffic impact of their decisions related to urban landuse and the urban transportation system. These studies can very well represent feedbacks to planning decisions. In general, before- and after-studies on changes in traffic services provide information about system operation, travel demand and response to public policy.

2.4 Summary

Conventional models have not been very useful in solving transportation problems because of their insensitivity to policy questions. Disaggregate behavioural models are much better in this respect. They are flexible and policy-oriented. Apparently, there has been an increasing number of applications of disaggregate models in both local and regional planning (Stopher and Meyburg, 1976, p.47). Thus it is worthwhile to conduct before- and after-studies on changes in traffic service in order to provide further understanding of the urban transportation phenomenon.

CHAPTER 3

DATA COLLECTION

3.1 Data Sources

This study arose from the closure of King Street. It examines the effect of this closure on travel behaviour in the hope of relating polciy decisions to transportation planning.

Data were collected in two different ways, (1) reported data through household interviews, (2) measured data through engineering efforts.

The entire project consisted of three phases of data collection. Phase 1 was carried out around June 20, 1977, shortly before King Street was closed. Phase 2 was conducted around August 8, allowing some time for the individuals to adapt to the changed traffic conditions. Phase 3 began in late September when students had returned to school and presumably less people were away for holidays. The three phases were meant to study changes under different intensities of congestion and at different lengths of time from the closure of King Street.

3.2 Household Surveys

Since King Street is only available for westbound traffic, the sample area for household surveys lay mainly to the west of Highway 403 which served as a screen line in subsequent analyses. There were eleven zones, all provided with transit services though the level of services varies considerably.

The total sample was of three types: randomly selected; auto drivers known to use the corridor, selected through a license plate survey; and from bus users. Information was collected in two ways, household interviews and postal surveys, with the former forming the majority.

The questionnaires asked about both work trips and shopping trips. (Copies of the questionnaires are in the Appendix). Information was collected on modal and personal characteristics, trip frequency, route selection, time of day of travel, and destination. Some of the work trip information was based on a work-home trip rather than a home-work-home trip as for the relevant sample, the home-work trip was not related to King Street.

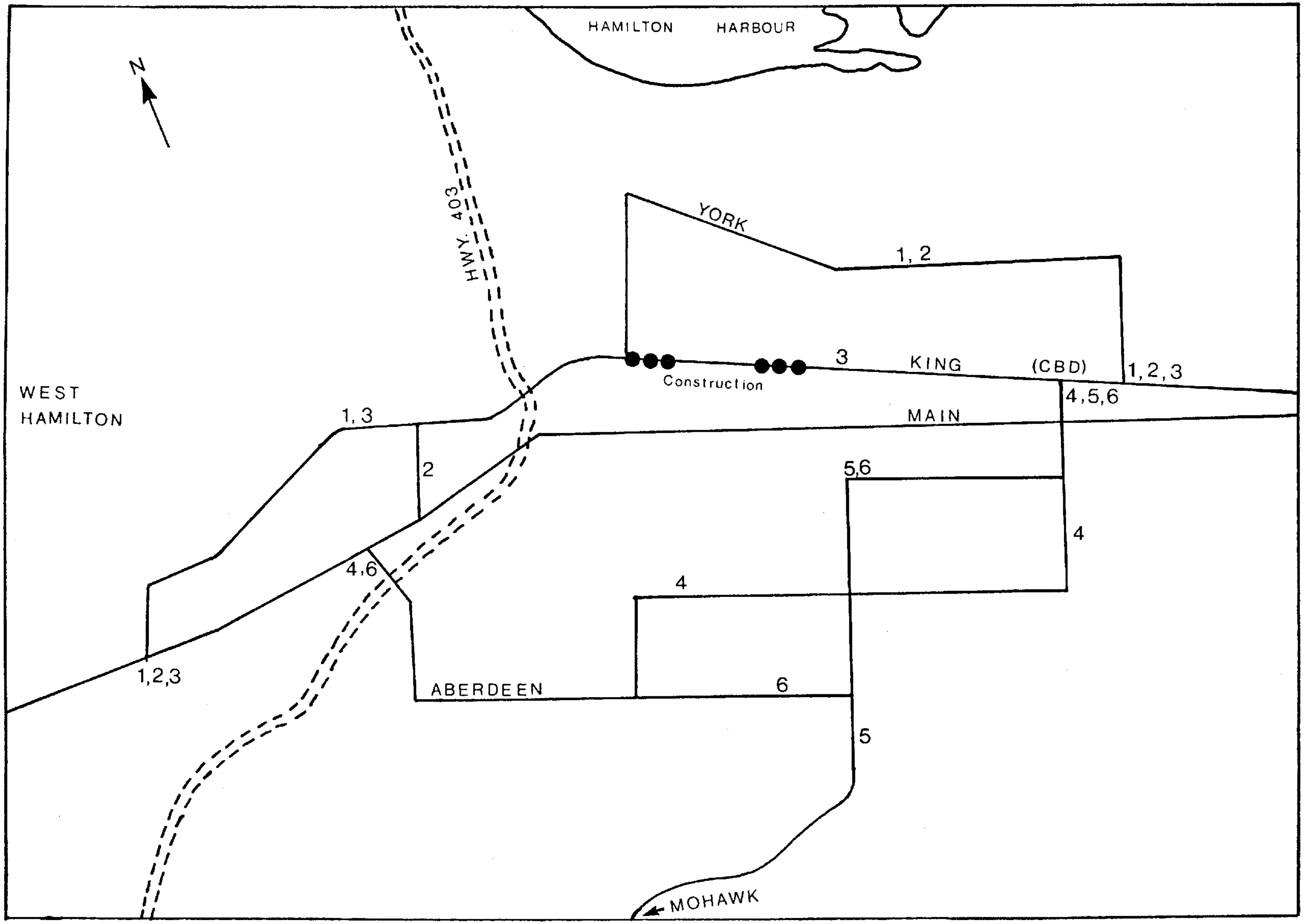
3.3 Engineering Surveys

Engineering surveys were conducted to measure travel times and volume of traffic along different corridors of westbound traffic. Both total and segmented travel times were obtained for routes originating in Downtown Hamilton and terminating in West Hamilton (see Figure 1). Meanwhile, at different sections of the chief westbound roads, traffic counts were taken during the afternoon peak hours.

3.4 Data Used in This Study

This research utilized the work trip information of Phases 1 and 2. For comparison purposes, only those workers appearing in both interviews were considered. This gave a total sample of 190. In a behavioural

Figure 1: Routes selected for travel time collection



framework as was employed by this research, individuals formed the basis of analysis. In the context of studying changes, observing the same group of individuals gives a better idea of how people respond to changed traffic conditions.

CHAPTER 4

DATA ANALYSIS

4.1 Introduction

The purpose of this chapter is to analyse the household data in an attempt to identify variables for modelling changes in travel behaviour. An attempt is also made to check if there is any congruence between reported and measured travel time data. Section 4.2 gives the results of the household data analyses. Section 4.3 compares the reported and measured values. Finally, Section 4.4 concludes on the travel behavioural changes observed from the household data.

4.2 Results from Household Data Analyses

This section reports the result of statistical analyses of the King Street data. Due to the presence of missing information and the need for control of other variables in certain situations, the subgroups chosen for analysis differed in many instances, and to avoid confusion and misunderstanding, the total number of cases in each analysis is denoted by (N = n) where n is the number of valid cases.

4.2.1 Changes in Travel Time (Table 1)

The change in reported travel time between the two periods - before and during closure - was very small, only .81 minute. This represents a 3 percent increase and can only be significant when the

Table 1: Significance of change in travel time: within groups and between groups (travel time in minutes)

Group	Sample Size	Time before (t_a)	Time during (t_b)	Within Group Change $t_b - t_a$	Within Group Change % change	T-value	Between Group Change	T-value
All	124	26.98	27.79	.81	3	1.30*		
Bus	10	39.00	42.80	3.80	10	1.18	3.26	.99
Auto	114	25.93	26.47	.54	2	.89		
Peak	39	29.77	32.03	2.26	8	1.96**	2.20	1.40*
Off-peak	48	26.54	26.60	.06	.2	.06		
Same route at peak	6	25.83	30.00	4.17	16	1.54*	2.80	.87
Different route at peak	19	25.21	26.58	1.37	5	.86		

* one tail significance of 10%

** one tail significance of 5%

10 percent level is accepted.

Generally, the increase was greater during the peak period of traffic (8% as against .2% at off-peak hours), for bus-riders (10% as against 2% for auto-users), and for people using the same routes (16% as against 5% for those using a different route). The magnitude of the change for peak travellers was significant at 5% and that for users of the same routes was significantly at 10% (Table 1, Column 6). The difference in the magnitude of average travel time changes between the groups in each pair was moderate (Table 1, Columns 5 and 7). Yet the differences in these average travel time changes were statistically insignificant (Table 1, Column 8).

4.2.2 Changes in Travel Behaviour

For the sample as a whole, the proportion changing mode was very small, less than 10%. However, the proportions changing route and time of day (here defined as hour of leaving work) were high, over 60% for both.

It should be noted that over 80% of the people favoured the car as a means of travelling to and from work. Between auto-users and bus-riders, the magnitudes of mode change were roughly equal, four from auto to bus and six from bus to auto.

As the main artery of the city, King Street, before closure, accommodated 70% of the westbound traffic. During the construction period, it suffered a large proportional drop. Diversion from King Street is of special interest to us (Table 2). Only 17.6% of the King Street users continued using King Street; the bulk of the rest used

Table 2: shift from King Street during the King Street closure (as percentage of original King Street users, N = 91)

	%
York-Dundurn	48.4
King	17.6
Aberdeen	18.7
Mohawk	3.3
Bus	5.5
Others*	6.6

*including trips no longer related to the screenline.

Figure 2: Frequency distributions in time of leaving work: before and during King Street closure

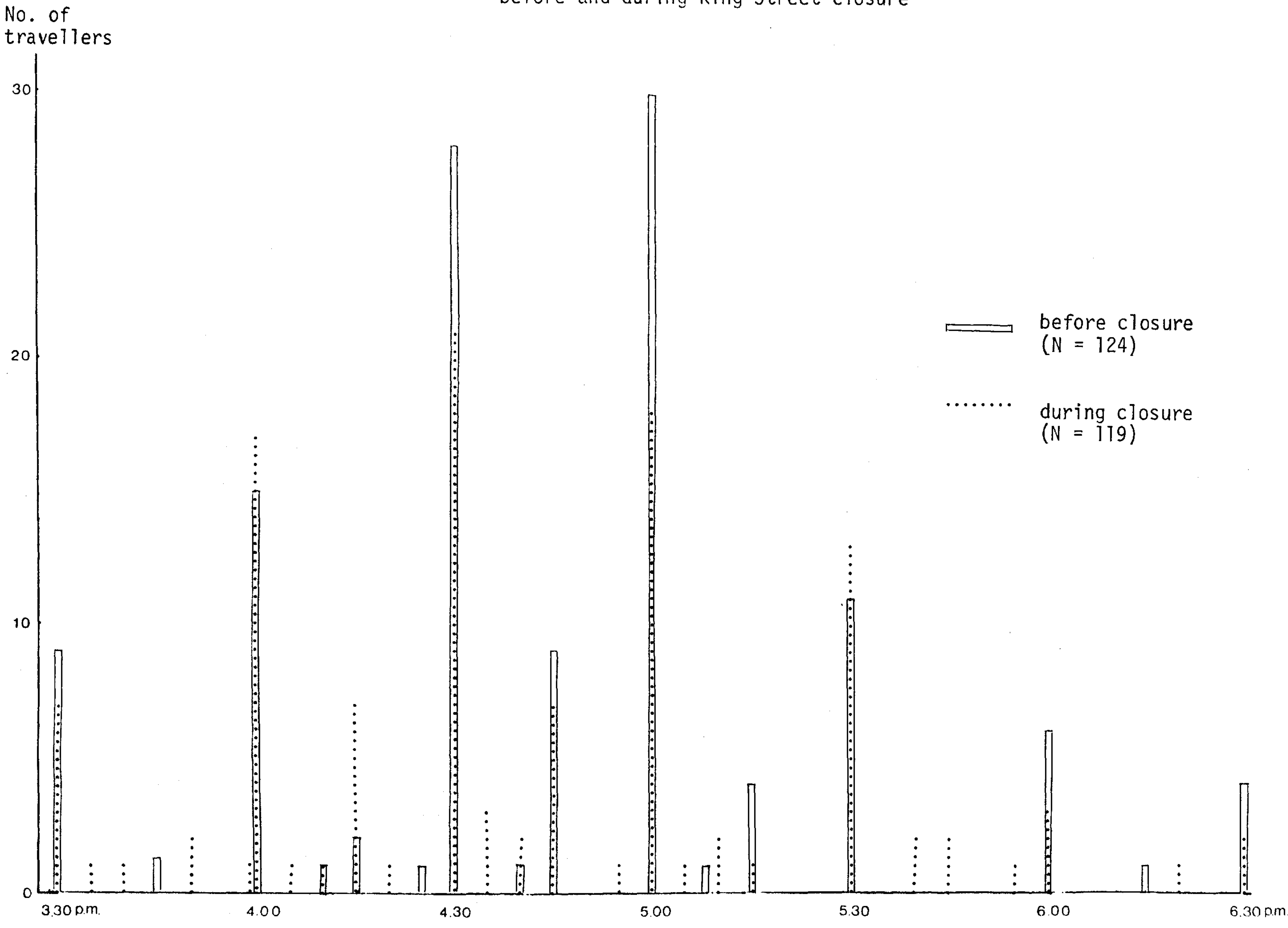


Table 3: change in time of leaving (in percentage)

	Between 3.30-6.30 p.m. (N = 95)	Between 4.30-5.30 p.m. (N = 52)
Leave earlier	29.5	17.3
No change	42.1	53.8
Leave later	28.4	28.8

Dundurn or Aberdeen, the two official detour routes.

As for time of day change, the frequency distributions of those who left work between 3:30 p.m. and 6:30 p.m. for both periods show that during the closure period, more people reported leaving their work places at times not by the 15-minutes intervals than before closure (Figure 2). This implies that people did make alterations in their hour of leaving. In fact, about 40% of the people kept their ususal time of leaving and there were roughly as many people who left earlier as those who left at a later hour (Table 3). During the peak-hour from 4:30 p.m. to 5:30 p.m., the proportion not making any changes was higher. This either reflects that less people leaving within this time had flexibility in choosing their hour of leaving or a fifteen-to-twenty minutes' difference did not get them home much faster.

4.2.3 Behavioural Changes in Relation to Travel Time Changes

Travel time increased more for non-changes of mode and route, and interestingly enough, for those who changed their time of leaving. Except for the time of day choice, marginal signficance existed in the difference between travel time changes for changers and non-changers (Table 4).

No significant relationship was found between change in travel time and change in travel pattern. For the 135 people who had not changed job locations, 11 people changed mode and reported an average travel time decrease of 11 minutes; for those who had not changed mode, the increase was .81 minutes. Their difference was significant only at the 9% level. For the same group, analysis of variance gave an F-value of .9

Table 4: change in travel time[1] with respect to change in mode, route or time of day.

	Same Choice	Different Choice	Between Group Difference	T-value
Mode	.81 (N = 124)	-11.00 (N = 11)	-11.81	-1.45*
Route	2.00 (N = 23)	-.31 (N = 59)	2.31	1.55*
Time of day[2] (1)	.60 (N = 33)	4.20 (N = 15)	-3.60	-1.70**
(2)	.60 (N = 33)	-.43 (N = 14)	1.03	.71

* one tail significance of 10%

** one tail significance of 5%

[1]A positive sign denotes increase and vice versa.

[2]Time of day

(1) The different choice is leaving earlier

(2) The different choice is leaving later

Table 5: change in travel time in relation to change in the time of leaving.

	Change in travel time[1] (in minutes)
Leaving earlier	4.20 (N = 15)
Leaving at same hour	.61 (N = 33)
Leaving later	-.43 (N = 14)

[1] A positive sign denotes an increase and vice versa.

(significance = .34), strongly indicating the lack of association between mode change and travel time change.

Again, analyses showed a lack of relationship between route change and travel time change. For a sample of 82, the observed Chi-square with two degrees of freedom was 3.81. It might be interesting to note that a high proportion of those who remained on the same route reported no change in travel time between the two periods - the proportion was 45.7% for the whole group, 54.2% for auto-users and 71.4% for auto-users travelling at peak hours. Moreover, of those taking a different route, only 40% reported a time increase and 36% of the peak-hour travellers reported that travel time actually decreased. This may explain the insiginficant relationship between route change and travel time change.

Changes in the time of leaving were found to be unrelated to change in travel time. Analysis of variance calculated an F-value of 2.39 which is significant at only the 10% level. The purpose of changing time of leaving is to avoid unfavourable increase in travel time. Average reported travel times were calculated for the group leaving between 3:30 p.m. and 6:30 p.m. both times (Table 5). Except for those who left early, there was hardly any change in travel time. It is understandable that those who left at the same hour as before and those who left later had chosen the best time to leave, but it is harder to understand why those leaving earlier suffered a travel time increase of 4 minutes.

4.2.4 Behavioural Changes in Relation to Hour of Leaving

No relationship existed between route change and the hour of leaving work. The proportion of peak-hour travellers who had changed routes was only slightly higher than that of non-peak travellers, 75.9% versus 71.4%.

However, change in the time of leaving was found highly related to individuals' time of leaving during the King Street closure period. A Pearson correlation test indicated that they were negatively related. For a sample of 83, the correlation coefficient was -.3523, significant at .001 level. It is plausible to assume that the preference of the chosen time of leaving truly reflected people's decision to change and their response to change.

4.3 Reported Versus Measured Values

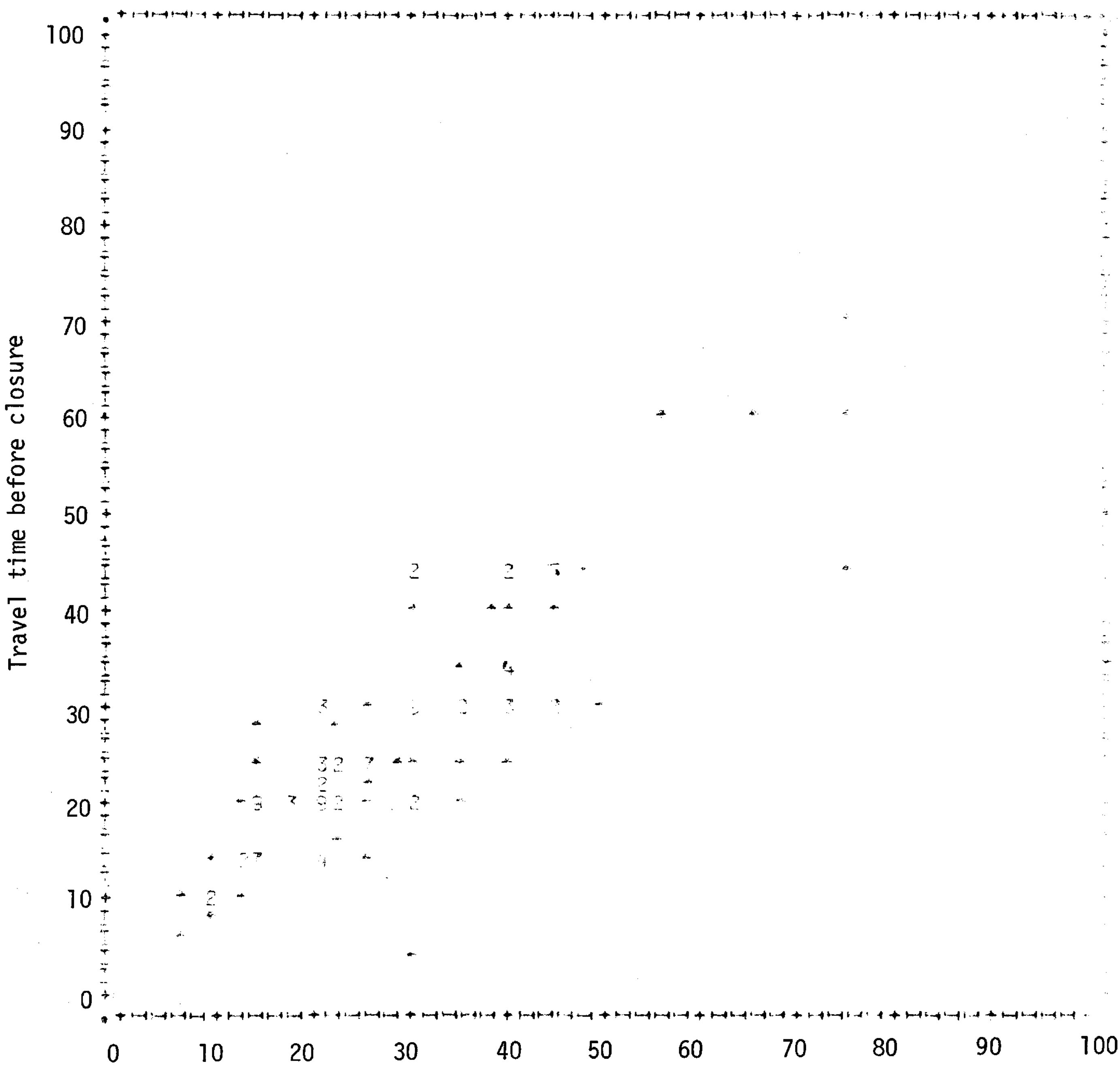
It was expected that change in travel time due to changed traffic conditions would play an important part in changes in travel behaviour. This hypothesis is not substantiated by analyses of the household survey data.

4.3.1 Comparison Between Reported and Measured Travel Times

It has been noted from Section 4.2 that the reported change in travel time was very small. The change does not correspond to the change observed from the measured data.

The scattergram in Figure 3 indicates that the travel times reported one time did not differ much from those reported in the other time. For those people not changing their routes home, their average

Figure 3: A comparison of reported travel times before and during closure



change in reported travel times are tabulated (Table 6). Due to the control of variables, changes in reported travel times were obtained only for King Street and Aberdeen Avenue. Even in peak hours, the change was not more than five minutes. For comparison purposes, these results can be compared to the measured changes in travel time.

Measured travel times for some routes specified in Figure 1 are reported (Figure 4). It indicates that travel time during the closure period inceased considerably for all routes. In fact, during the peak period, there were a nine minutes' increase for York-Dundurn users and a seven minutes' increase for King users. The measured travel time increase was smaller for those using Aberdeen Avenue and Mohawk Road. The engineering survey data also show that the change in travel times differed between peak and off-peak periods; the change was greater during the peak period.

So far, the discussion centers on auto-users only. As for bus riders, they reported an average travel time increase of about four minutes. Yet, the Hamilton Street Railway Company said that during the closure period, there were neither reports of bus schedule delays nor changes in bus schedules. This implies that the level of bus service remained the same.

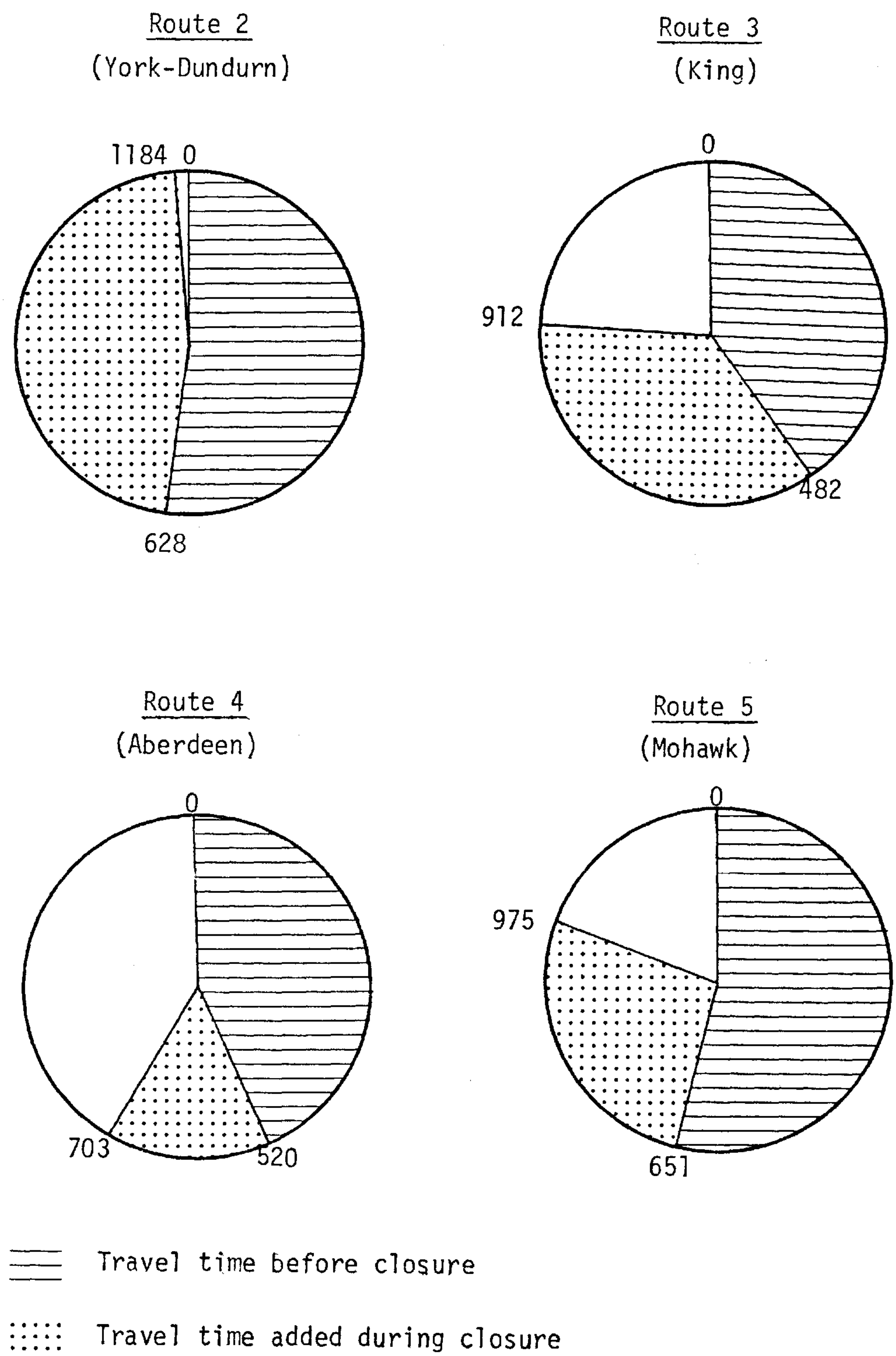
4.3.2 Reliability of reported travel times

The difference between reported and measured travel times raises the question of whether or not reported travel times are reliable enough to be used in travel choice modelling. This issue has been discussed

Table 6: average reported travel times for King Street and Aberdeen Avenue (in minutes)

	Peak		Off-peak	
	King	Aberdeen	King	Aberdeen
N	5	2	4	4
Travel time before closure (a)	28.30	17.50	27.50	14.75
Travel time during closure (b)	32.00	22.50	27.75	14.50
Change in travel time (b-a)	4.00	5.00	.25	-.25
T-value	1.37	1.00	.06	-.24

Figure 4: Measured peak travel times before and during closure (in seconds)



many times previously, and has not been fully settled: there are problems associated with each (Watson 1971). Stopher and Meyburg (1976) have suggested that a good explanatory model should be based upon reported values and prediction should use measured values (p. 37). However, in this case of changed traffic conditions, measured travel times would have superiority over the reported ones even in explanatory modelling. This is because the models are intended to explain changed behaviour and the reporting error is great. Comparing reported times with measured times calculated for the individuals shows a reporting error of five to fifteen minutes. This is likely due to the fact that people incline to report travel times in multiples of five minutes.

4.4 Conclusion

In this work trip study, we were particularly interested in changes in mode, route or time of day.

Many models of mode choice suggest that an increase in auto travel time should induce higher transit usage. However, such a change was not found in this study. The percentage of mode change was very small, about 10%. There are two possible explanations for this insignificant change. Perhaps, the travel time change was not enough to induce mode change. Or perhaps, this is related to the fact that during closure, buses remained running along King Street whereas auto-users had a choice in changing routes.

Route change was fairly significant but it was not related to either time of leaving work or reported travel time. This is largely because route change in this case was a forced behaviour. Most auto-users were forced off King Street, but the selection of an alternate route was free. Travel time is important in route selection (Wachs 1967, Thomas and Thompson 1971). However, the household data did not permit, on a statistical basis, exploration on why particular routes were chosen.

In the case of work trips, time of day is relatively fixed and the degree of flexibility for individual travellers is limited. Any changes in time of day will be important for people who want to avoid congested traffic and prevent any undue frustration. In this study, changes in time of day were observed. 60% of the travellers reported a change in time of day, but reported travel time did not account for their time of day choice unless the 10% significance level was accepted. The only highly statistically significant relationship observed in this study is the correlation between the amount of time shift and the selected time of leaving.

Two conclusions can be drawn from the data analysis. First, people did not perceive a travel time difference. Second, to model change in travel behaviour in the case of King Street closure, it is suggested that measured values of travel time are more reliable than reported values, and that the time of day choice represents a more reasonable decision to make than mode choice or route choice.

CHAPTER 5

THE TIME OF DAY LOGIT MODEL

5.1 Introduction

Most studies (for example, Charles River Associates 1976, Domencich and McFadden 1975) model time of day choices for shopping trips because the degree of flexibility in the choice of time is much greater for discretionary trips than for work trips. The relevant choice set usually consists of off-peak and mixed-peak travels. In the case of the King Street closure, changed traffic conditions accompanied by increased congestion led to an attempt to model time of day for work trips. The relevant alternatives are identified to be leaving at the same hour as before, leaving earlier or leaving later than usual.

This chapter describes the time of day multinomial logit choice model. A brief outline of the logit model and its estimation technique are presented.

5.2 The Logit Model

5.2.1 Reasons for selecting the logit model

The logit model has been selected for this research because of its proven value as a technique of disaggregate travel demand analysis. Previous research has indicated the workability and usefulness of logit models of individual choice (for example, Charles River Associates 1972, Domencich and McFadden 1975, Liou and Hartgen 1975). There are four modelling techniques - linear probability, discriminant, probit and logit - to choose from and the reasons for selecting the logit model are:

(1) Linear probability models do not restrict the dependent variables, which are interpreted as probabilities, to values between 0 and 1, even though a two pass least squares method can overcome the problem of heteroscedasticity in the error terms of linear regression analysis.

(2) Discriminant analysis operates on classification of groups rather than on a choice framework, and this is a conceptual difficulty in behavioural modelling (Watson 1974).

(3) Logit and probit models have similar predictive abilities: they calculate similar choice probabilities. Conceptually, the probit model is more satisfying as it requires less stringent assumptions about the distribution of error terms. However, computationally, the logit model is simpler, particularly in the multinomial case. This is the main reason why most studies utilize the logit model (de Donnea 1971).

5.2.2 The multinomial logit model

The theory and estimation of the logit model have received frequent attention in the literature (CRA 1972, McFadden 1974, Ben-Akiva 1973). Detailed derivation of the model has been discussed elsewhere (for example, Domencich and McFadden 1975). To specify more clearly the objectives of the modelling approach here, it is helpful to present a brief outline of the logit model.

The underlying assumption of the disaggregate choice model is that an individual maximizes his utility. His utility for an alternative is assumed to be a function of three components: observed attributes of an alternative, socioeconomic characteristics of the individual, and a random component due to omitted influences. That is,

$$U_{it} = V(X_{it}, S_t) + \varepsilon(X_{it}, S_t) \tag{1}$$

where: U_{it} is utility of alternative i for individual t,

X is a vector of observed attributes describing the alternative,

S is a vector of socioeconomic variables characterising the individual,

V is a function describing the observed component of utility,

and ε is a function describing the probabilistic component of utility.

The random component is assumed to have a distribution identical to the Weibull distribution. It can be interpreted as effects specific to a particular alternative. Then it can be shown that

$$P_{it} = \frac{\exp V_i}{\sum_{j=1}^{J} \exp V_j} \qquad (2)$$

where: P_{it} is the choice probability of individual t choosing alternative i,

J is the set of alternatives available to the individual,

and $V_i = V(X_{it}, S_t)$.

More usefully, if V is assumed to be linear in parameters, equation (2) can be written as

$$P_{it} = \frac{1}{1 + \sum_{\substack{j=1 \\ j \neq i}}^{J} \exp [(X_j - X_i)\ \theta + \sum_{k}^{K} f_{ij}\ s_k\ \theta_k]} \qquad (3)$$

where: θ is a vector of parameters of observed attributes,

K is a set of socioeconomic variables,

and $f_{ij} = 1$ if s_k is specific to alternative i

$f_{ij} = -1$ if s_k is specific to alternative j.

This result is derived from the random utility model, but it has the same form as that derived from the strict utility model (Domencich and McFadden 1975), (Smith 1977).

5.2.3 Assumptions

The underlying logic in the logit model is that there exists a set of discrete, identifiable alternatives among which an individual selects only one. There is also a set of attributes relating to each alternative and to the individual making the choice.

In the multinomial logit model, the key assumption is the independence of irrelevant alternatives (IIA). The choice model assumes that the ratio of probabilities of choosing two alternatives is invariant to the attributes or existence of a third alternative, i.e.

$$\frac{P_i}{P_j} = \frac{\exp\ U_i}{\exp\ U_j} \tag{4}$$

where P_i, P_j represent probabilities of choosing alternatives i and j, and U_i, U_j represent utilities obtained from the alternatives.

The IIA assumption has been a controversial issue especially in problems of forecasting demand for new modes. The IIA property states that if two modes are available and a new mode is introduced, the ratio of the probabilities of the two modes will be unchanged regardless of the choice probability for the new mode.

Analysis by Charles River Associates (1976) has indicated that the IIA property is not an inherent drawback of the multinomial logit model. Violation of the independence assumption can be tested and it only occurs when unobserved attributes have common values in two or more alternatives or unobserved attributes have a systematic relationship with observed attributes.

5.3 Estimation Techniques

Maximum likelihood methods are used to estimate the value of the parameters in the multinomial logit model. Domencich and McFadden (1975) have shown that the maximum likelihood estimators are the best in the context of travel choice modelling.

The maximum likelihood estimate of a parameter is that value of the parameter which maximizes the value of a particular function known as the likelihood. A likelihood function describes the probability of observing a given choice sample when the distribution of the underlying random component of utility is known. For logit model estimation the underlying distribution is assumed to be Weibull (or Gumbel) (CRA 1976, p. C-167) and the likelihood function is given by:

$$L(\theta) = \prod_{t=1}^{n} \prod_{j=1}^{J} P_{jt}^{\delta_{it}} \qquad (5)$$

where: n is the sample size,

J is the set of alternatives available to individual t,

P_{jt} is the probability that individual t chooses alternative j,

δ_{it} equals 1 if alternative i is actually chosen by individual t, and 0 otherwise and θ is a vector of model parameters.

We seek to find estimates of the parameters $\hat{\theta}$ which maximize the likelihood of observing the sample used in estimation. This leads to the specification of

$$\frac{\partial L(\theta)}{\partial \theta_k} = 0 \qquad (6)$$

and

$$\frac{\partial^2 L(\theta)}{\partial \theta_k \, \partial \theta_{k'}} < 0 \qquad \forall_k \qquad (7)$$

Normally, this maximization procedure is performed on a log transformation of the likelihood function to simplify the computation process. Thus

$$\ln L(\theta) = \sum_{t=1}^{n} \sum_{j=1}^{J} \delta_{it} \ln P_{jt} \qquad (8)$$

McFadden (1968) has shown that the $\hat{\theta}$ which maximize the likelihood are unique and possess optimal asymptotic properties provided that the explanatory variables are not multicollinear.

The optimum values of the parameters are found by using the Newton-Raphson search technique in an iterative procedure. Starting with an initial estimate of θ, the estimated value of θ is adjusted as follows:

$$\theta_{n+1} = \theta_n - \left(\frac{\partial L^*(\theta_n)}{\partial \theta_n}\right) \left(\frac{\partial^2 L^*(\theta_n)}{\partial \theta_n^2}\right)^{-1} \qquad (9)$$

where n is the number of iteration

and $L^*(\theta_n)$ is the logarithm of the likelihood function as a function of the parameter values θ_n.

5.4 Tests for Statistical Significance

Three statistics are used in this study. They are the t-statistic used to test if individual coefficients are significally different from zero, the X^2 statistic used to test that the entire vector of coefficient estimates is different from zero, and the ρ^2 statistic used to test the overall goodness of fit of the model (Smith 1977).

5.4.1 The t-statistic

Theil (1971, pp. 396-397) has shown that the negative of the inverse of the matrix of second derivatives of $L^*(\hat{\theta})$ - the maximum value of the log likelihood function - is the variance-covariance matrix of the coefficient estimates. Thus we may test the simple hypothesis that any given parameter differs from zero with a t-statistic defined as the ratio of the parameter estimate to its standard error:

$$t = \frac{\hat{\theta}}{\sqrt{\mathrm{Var}\ \hat{\theta}}} \qquad (10)$$

5.4.2 The X^2 statistic

The X^2 statistic is used to compare the strength of the estimated model to the null model which sets all linear coefficients equal to zero. This statistic is defined as

$$X^2 = -2\ [L^*(0) - L^*(\hat{\theta})] \qquad (11)$$

Thiel (1969) has shown that this statistic is asymptotically chi-square with degrees of freedom equal to the number of coefficients.

5.4.3 The rho-square statistic

This statistic, defined as

$$\rho^2 = 1 - \frac{L^*(\hat{\theta})}{L^*(0)} \qquad (12)$$

is analogous to the multiple correlation coefficient (R^2) in linear regression models. It represents the ratio of the explained log likelihood to the total log likelihood. It lies between 0 and 1 with higher values connoting improving goodness of fit and can be used to compare alternative models estimated on the same data set.

5.5 The Time of Day Logit Model

This choice model made use of information from both reported and measured data in the King Street study. The sample used in estimation consisted of 60 cases. They were restricted to those leaving their work between 3:30 p.m. and 6:30 p.m. both before and during King Street closure. This avoids including individuals working shifts. Further, the period specified should receive the greatest impact of changed traffic conditions.

5.5.1 The choice set

The model assumed that the individual traveller faced three alternatives with regard to the time of day choice. They are (1) leaving earlier than usual, (2) leaving at the same hour as before, and (3) leaving later than usual. The original hour of leaving (i.e. before closure) was taken to be the normal hour of leaving. The time of leaving during closure was the chosen alternative of the individual. For the alternatives "leaving earlier" and "leaving later", if they were not the chosen alternative, they were assumed to be fifteen minutes before or after the normal time of leaving. This is a plausible assumption supported by the data set. Analysis on the household data showed that for those making changes in the time of leaving, the average change was 17 minutes. This assumption helps to calculate travel times and congestion index for each alternative.

5.5.2 Definition of variables

Travel time and a congestion factor are the most relevant variables in this situation. They are represented as generic variables, i.e. varying over all alternatives.

Based on reported information on time of leaving and route selected, measured travel times from origin to destination were calculated for each individual in the sample. It is assumed that the changed traffic condition only affected that segment of the trip from downtown Hamilton to the Highway 403 screenline, i.e. as represented by the routes indicated in Figure 1. Both total and segmented travel times were available for the specified routes before and during closure. Then the other two legs of the trip, i.e. from work place to downtown if not working in downtown and from west of 403 to home, were calculated based on inter-zonal travel times obtained from a mini-path method.

Congestion is not readily measurable as a generic variable. The congestion index used in this model ranged between 0 and 1, with 0 indicating the individual travelling at the most congested time. Peak congestion for the various routes was identified from the traffic counts. The congestion index is defined as

$$CI = \frac{|\text{Peak} - \text{Time of leaving}|}{60}$$

Traffic counts showed that the volume of traffic stabilized at times an hour away from the most congested period of travel. So for people travelling an hour before or after the peak-time, their congestion index was 1. Otherwise, the scaling factor 60 was used to give a monotonic function to the congestion index.

5.5.3 The Results

Two models were calibrated. The first employed only generic variables specified in the previous section. The second model had the addition of a time specific constant. Alternative 2 - leaving at the same hour - was specified with the value of 1.

The maximum likelihood method estimated the following results:

For model 1,

$$\log \frac{P_i}{P_j}_{(j \neq i)} = \underset{(.256)}{.026}(TT_i - TT_j) + \underset{(.581)}{.498}(CI_i - CI_j)$$

For model 2

$$\log \frac{P_i}{P_j}_{(j \neq i)} = \underset{(2.48)*}{.656} + \underset{(.0004)}{.00004}(TT_i - TT_j) + \underset{(.758)}{.696}(CI_i - CI_j)$$

where: $\log \frac{P_i}{P_j}$ is the odds of choosing alternative i over alternative j,

TT is travel time for the individual,

and CI is the congestion factor associated with the individual's time of leaving.

In both models, travel time is very insignificant and is not even of the correct sign. The congestion variable has the expected sign but once again very insignificant. The only important term in the two equations is the constant term, significant at a 2½% level.

Chi-square statistics of .34 for Model 1 and 6.418 for Model 2 support the null hypothesis that the whole vectors of parameter estimates are equal to zero, although the second model is certainly an improvement over the first one.

The overall fit of the models is poor. The rho-square statistics are extremely small, .003 and .049 respectively for Models 1 and 2.

What the results indicate is the time of day decision in this situation of traffic condition changes is not affected by any time- or congestion- related variables. It is the random component that accounts for any shift occurrences.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Summary

This study of changes in travel behaviour finds no strong correspondence between behavioural changes and traffic condition changes. In the Phase 1 and Phase 2 studies of the King Street Closure Project, reported travel time changes were found to be small and insignificant. There were some significant changes in route and time of day. The former were largely forced changes. Time of day choices, however, were unrelated to both reported and measured travel times.

6.2 Conclusion

There are two possible explanations for the independence of behavioural changes and traffic condition changes in this study. First, although there is an increase in travel time, the change by itself is not great enough to induce behavioural changes. This, perhaps, is related to the fact that people realize that the change in traffic condition is only temporary. Observed behavioural changes are better interpreted as random occurrences. Second, Phase 2 surveys were conducted a month after partial closure of King Street; the adjustment period may not have been long enough for people to restructure their decision. Hopefully, Phase 3 of the Project can show some sort of relationship between change in behaviour and change in road congestion.

In the time of day multinomial logit model, the insignificance of travel time may be due to the lack of variation in travel times among the alternatives.

The prime objective of the study is to relate behavioural changes to traffic condition changes to serve some policy-making purposes. Though the results are not significant, the behavioural analysis can be useful. It has indicated that moderate changes in the travel environment are not likely to affect the decisions of most of the population.

Transportation Improvement Survey
McMaster University
Departments of Geography and of Civil Engineering
Transportation Research Group

Zone number ____________________
Address ____________________
Dwelling type ____________________

Interviewer ____________________
Date ____________________
Respondent ____________________

Hello, I am from McMaster University and I'm interviewing people as part of a study designed to improve transportation in this area. Could you spare me about 10-15 minutes of your time?

First, I would like to ask you some questions about the trips to work by members of your household.

1. Who in the household works outside the home? [*If more than one person is named, make sure each is identified unambiguously here. Ask the following questions for one person, then go through the list again for the second person, etc.*]			
2. By what means of transportation did you [*he/she*] get to work today?			
3. Approximately what time did you [*he/she*] start home from work today [*yesterday*]?			
4. a. Where do you [*does he/she*] work? b. [*If in Hamilton:*] Could you tell me the nearest street intersection? [*Or, accept the name of the firm and the street it is on.*]			
5. How many times a week do you [*does he/she*] travel to work?			

Now, I would like some information about your household's recent shopping trips.

1. Which member of this household made the last major grocery purchase? (i.e. greater than $10.00) ____________

2. What day was that trip? [*Interviewer put sufficient data to identify date*]. ____________

   Roughly what time did you [*he/she*] start that trip? [*Interviewer put hour*]. ____________

   Roughly what time did you [*he/she*] get home? ____________

3. What means of transportation did you [*he/she*] use for the trip? ____________

4. Where did you [*he/she*] shop? [*Nearby intersection or name of store and street*]. ____________

5. Did you [*he/she*] just go to the grocery store on that trip or did you [*he/she*] do other things such as stopping at the bank or hardware store or visiting friends? [*Interviewer indicate whether other stops were made and describe such stops*]. ____________

Now, I have some questions about the last two shopping trips by members of your household on which things other than groceries were bought. On the most recent trip of this kind ... [*Interviewer go through questions 1 through 6 for most recent trip; then repeat for the preceding trip*]. On the last trip before that one ...

	Trip 1 (most recent)	Trip 2 (least recent)
1. Which member of the household made the trip?		
2. What day was that trip made? [*Interviewer identify date*].		
3a. Roughly what time did you [*he/she*] start that trip?		
3b. Roughly what time did you [*he/she*] get home?		
3c. What means of transportation did you [*he/she*] use for the trip?		
4. Which of the following shopping areas were visited? [*Show printed card with list of areas. If an unlisted area was visited identify it and list it*]. 1st stop		
2nd stop		
3rd stop		

5. Now, I'd like to know what you [*he/she*] bought at each centre and any other kinds of errands which were run on that trip, such as taking children to school or visiting friends. [*Check categories volunteered by respondent, do* <u>not</u> *read list.*]

Centre	Trip 1 (most recent)			Trip 2 (least recent)		
	1	2	3	1	2	3
Goods						
groceries						
beer/liquor						
drugs/cosmetics/toiletries/sundries						
clothing/leather goods/bedding						
kitchenware/houseware/infants goods/small appliances						
hardware/sports, camping equipment/toys/games						
jewelry/watches						
records/books						
furniture						
major appliances						
other (specify)						
Services						
banking						
dry cleaning/laundry						
restaurants						
hair dresser/barber						
appliance repair						
doctor/dentist						
other (specify)						
Non-shopping (specify)						
6. Can you estimate how much you [*he/she*] spent at each centre?						

7. Could you estimate how long it takes to get to the following shopping areas by car and by bus? In each case I'd like the trip-time including parking or waiting for the bus - that is, the time from your door to the door of the first place you enter. I would also like the return-trip time by car.

Centre	Time to get there by car	Time to return by car	Time to get there by bus
Ancaster	________	________	________
Burlington	________	________	________
Dundas - downtown	________	________	________
- University Plaza	________	________	________
Hamilton - Westdale	________	________	________
- between Bay and Dundern	________	________	________
- Jackson Square and downtown	________	________	________
- east of Victoria	________	________	________
- Centre Mall	________	________	________
- Eastgate Mall	________	________	________
- Upper James	________	________	________

I would like to ask just a few additional general questions about your household.

1. How many people live here? ____________

2. How many of these are in each of the following age categories?

   5 or less ____________
   6 - 15 ____________
   16 - 25 ____________
   26 - 64 ____________
   65 + ____________

3. Which members of the household have a driver's licence? [*Use same identifiers as before*].
   ____
   ____
   ____
   ____

4. a. How long have you lived at this address? ____________

   b. [*If less than one year,*] Where didyou live before? ____________

5. a. How many cars are available to the household? [*Include light trucks or vans.*] ____________

   b. How many motorcycles? ____________

6. Can you indicate which of these categories [*hand card*] represents the combined annual income of all members of the household?

   Less than 10,000 ____________
   10,000 - 14,999 ____________
   15,000 - 19,999 ____________
   20,000 - 29,999 ____________
   30,000 + ____________

7. Do you own or rent this dwelling? ____________

Thank you for your assistance. I'd like to speak briefly with each person who made a work trip to obtain some more detailed information about their trip. [Or, if worker clearly not home: I'd like to leave a form to be filled out by each person who made a work trip, and a stamped envelope in which to mail it back to us. Fill in address, person, work place, and date, and hand form(s) to respondent.] This form can be easily filled out in less than five minutes. [*If respondent says she can answer those questions for others, let her; but if any hesitation occurs, offer once more to leave the form.*]

Transportation Improvement Survey
McMaster University
Departments of Geography and of Civil Engineering
Transportation Research Group

Work Trip Information

Person making trip ____________
Place of work ____________

Zone ____________
Address ____________

		AUTO DRIVER	AUTO PASSENGER	BUS	OTHER ( )
1.	For your trip to work on ________, what means of transportation did you use? [Please check the appropriate box]	☐	☐	☐	☐
2.	For that trip, what, if any, other means of transportation were available to you?	☐	☐	☐	☐
3.	What were the primary streets (such as Main Street) you used to travel from work to home? (Or, which bus route(s) did you use?)	____	____	____	____
4.	How many minutes did the trip to work take? How many minutes did the trip from work to home take?	____	____	____	____
5.	How many minutes would the trip take by the other available means of transportation? To work / From work	____	____	____	____
6.	Please identify the time each of the following segments takes or would take for the trip from work to home, for each available means of transportation: a) from the door at work to the bus/car; b) waiting time (for the bus, or to get out of a parking lot); c) time waiting on transfers; d) driving time or time on the bus; e) from the vehicle to the door at home.	____	____	____	____
7.	What is or would be the monetary cost to you of making the round trip by each available means of transportation?	____	____	____	____
8.	How many of your trips to work in the last two weeks have been made by each available means of transportation?	____	____	____	____

9. What time of day have you usually left work during the past week? ____________

10. Can you choose the time when you leave work? ____________

APPENDIX B (Survey 2)

Transportation Improvement Survey

McMaster University
Departments of Geography and of Civil Engineering
Transportation Research Group

one number ____________________ Address ________________

The questions on this page are about the trips to work by members of your household.

. How many members of your household usually work outside the home? [*If no one does, skip the rest of this page, and go to the next page of the questionnaire*]. ____________

	Worker 1	Worker 2	Worker 3
. In what city or municipality does each of these people work?			
[*Please answer the following questions for each person whose trip to or from work involved* <u>*crossing*</u> *highway 403.*]			
. What is the nearest major intersection to the place of work?			
. What means of transportation were used for the trip from work to home on Thursday August 4th [*If any individuals who normally travel to work did not do so on that day (because of vacation, illness, or whatever), please answer the questions for the last trips made.*]			
. Approximately what time did the worker <u>start home</u> from work on Thursday?			
. What were the primary streets used to get home from work on Thursday? (Or what bus route was used?)			
. How many minutes did the trip from work to home take on Thursday?			
. What was the monetary cost of the trips to and from work on Thursday?			
. What other means of transportation were available for that trip.			
. How many minutes would each of those means have taken for the trip home from work?			
What would have been the monetary cost of the trip to and from work by each of the other means?			
If the bus was either used or available for the trip home from work on Thursday, please estimate: a. the time from the door at work to the bus stop;			
b. the time waiting for the bus;			
c. travel time on the bus;			
d. time waiting during any transfers;			
e. the time from the bus stop to your door at home.			

The questions on this page are about grocery-shopping trips by members of your household. The questions refer to the last shopping-trip on which someone in your household spent at least $10.00 for groceries.

1. What day was the most recent major grocery-shopping trip (as a trip to the market) made? That is, on what day did someone in your household spend at least $10.00 for groceries? [date]

2. What time did the trip start? [hour of day]

3a. Which members of the household went on the trip? [e.g. father and son, daughter, mother and baby, wife]

3b. Were any children under age 12 taken on the trip?

4. When did they get home? [hour of day]

5. What means of transportation did they use?

6. Where did they buy groceries? [name of grocery store and nearby intersection]

7. Did they just go to the grocery store or market on that trip? ['Yes' if grocery store only; 'No' if other stops were made]

8. If other stops were made, describe them. [e.g., bought hardware or clothing, went to the bank]

This page concerns the last shopping trip made by any member of the household on which things other than groceries were bought. Please do not describe a trip which was made solely to buy groceries. But if you bought groceries and other things on your last shopping trip then describe that trip.

1. What day was the most recent shopping trip made (apart from trips made for groceries)? [date]

2. What time did the trip start? [hour of day]

3a. Which members of the household went on the trip? [e.g. father and son, daughter, mother and baby, wife]

3b. Were any children of under age 12 taken on the trip?

4. When did they get home? [hour of day]

5. What means of transportation did they use?

6. Which shopping centres did they visit? [check boxes]

	FIRST STOP	SECOND STOP	THIRD STOP
Ancaster			
Burlington			
Dundas - downtown			
- University Plaza			
- Pleasant Valley Plaza			
Hamilton - Westdale			
- between Bay & Dundurn			
- Jackson Square & downtown			
- east of Victoria			
- Centre Mall			
- Eastgate Mall			
- Mountain Upper Wentworth & East			
- Mountain West of Upper Wentworth (including Upper James)			
- Main Street west of Highway 403			
- Other [name]			
7. What kinds of goods were bought at each centre?			
8. Can you estimate how much money was spent at each centre?			
9. What else was done on this trip?			

This page concerns travel-times to various shopping areas. An identical question was asked in the first questionnaire. But we would like to know how travel times have changed since you were interviewed. Please re-estimate all travel times, whether you think they have changed or not. We realize that you may be uncertain about travel-times to some places and that some of the differences between your first answers and those you give now will reflect that uncertainty rather than any real changes. It is still useful to us, however, to have new estimates of all travel times. In all cases we would like total trip-time, including parking or waiting for the bus - that is, the time from your door to the door of the first place you enter. Estimate the trip-time for a day and hour at which you often shop. E.g. "Saturday at 11:00 a.m." or "Thursday at 3:00 p.m.".

Centre	Time to get there by car	Time to return by car	Time to get there by bus
Ancaster	________	________	________
Burlington	________	________	________
Dundas - downtown	________	________	________
- University Plaza	________	________	________
Hamilton - Westdale	________	________	________
- between Bay and Dundern	________	________	________
- Jackson Square and downtown	________	________	________
- east of Victoria	________	________	________
- Centre Mall	________	________	________
- Eastgate Mall	________	________	________
- Upper James	________	________	________

These estimates are for ________________ (day of week) at about ________________ (hour of day).

BIBLIOGRAPHY

Algers, S., S. Hansen & G. Tegner (1974) "On the Evaluation of Comfort and Convenience in Urban Transportation - A Choice Analytic Approach," *Transportation Research Forum*, Proceedings, 45, No. 1, pp. 470-481.

Ben-Akiva, M.E. (1973) *Structure of Passenger Travel Demand Models*, Ph.D. Dissertation, Department of Civil Engineering, MIT.

__________ (1974) "Structure of Passenger Travel Demand Models," *Transportation Research Record* 526, pp. 26-42.

Brown, G.J.H. & A.H. Woehrle (1968) "Program, Inputs and Calibration of the Direct Traffic Estimation Method," *Highway Research Record* 250, pp. 18-24.

Charles River Associates (1972) *A Disaggregated Behavioural Model of Urban Travel Demand*, Final Report to U.S. Federal Highway Administration, USDOT.

__________ (1976) *Disaggregate Travel Demand Models*, Phase 1 report to National Cooperative Highway Research Program, Transportation Research Board, National Research Council.

De Donnea, F.X. (1971) *The Determinants of Transport Mode Choice in Dutch Cities*, Rotterdam, Rotterdam University Press.

Domencich, T.A. & D. McFadden (1975) *Urban Travel Demand: A Behavioural Analysis*, North-Holland Publishing Co., Amsterdan.

Ewing, R.H. (1974) "The Nature of Travel Decision-Making," *Transportation Research Record* 526, pp. 66-72.

Hensher, D.A. (1972) *The Consumer's Choice Function: A Study of Traveller Behaviour and Values*, Ph.D. Dissertation, School of Economics, University of New South Wales, Australia.

Lave, C.A. (1969) "A Behavioural Approach to Modal Split Forecasting," *Transportation Research*, 3, No. 4, pp. 463-480.

Lerman, S. & T. Adler (1976) "Development of Disaggregate Trip Distribution Models," in P. Stopher and A. Meyburg (Eds.), *Behavioural Travel-Demand Models*, D.C. Heath, Lexington, Mass.

Liou, P.S. & D.T. Hartgen (1975) *Issues in the Inplementation of Disaggregate, Behavioural Travel Demand Forecasting Technique*. Second International Conference on Behavioural Travel Demand, Asheville, North Carolina, May 18-24, 1975.

Liou, P.S., G.S. Cohen & D.T. Hartgen (1975) "Application of Disaggregate Modal Choice Models to Travel Demand Forecasting for Urban Transit Systems", *Transportation Research Record,* 534, pp. 52-62.

Lisco, T.E. (1967) *The Value of Commuters' Travel Time: A Study in Urban Transportation,* Ph.D. dissertation, Dept. of Economics, University of Chicago.

McFadden, D. (1968) "The Revealed Preference of a Government Bureaucrary". Technical Report No. 17, Institute of International Studies, U.C. Berkeley.

__________ (1974) "The Measurement of Urban Travel Demand". *Journal of Public Economics,* pp. 303-328.

McGillivray, R.G. (1970) "Demand and Choice Models of Mode Split", *Journal of Transport Economics and Policy,* 4, No. 2, pp. 192-207.

Nicolaidis, G.C. (1975) "Quantification of the Comfort Variable", *Transportation Research,* 9, pp. 55-66.

Quandt, R. (1970) "Introduction to the Analysis of Travel Demand", in Quandt, R. (Ed.), *The Demand for Travel: Theory and Measurement,* D.C. Heath, Lexington, Mass.

Quandt, R. & W. Baumol (1966). "The Demand for Abstract Travel Modes: Theory and Measurement", *Journal of Regional Science,* 6:2, pp. 13-26.

Quarmby, D.A. (1967) "Choice of Travel Mode for the Journey to Work: Some Findings", *Journal of Transport Economics and Policy,* 1, No. 3, pp. 273-314.

Reichman, S. and P.R. Stopher (1971) "Disaggregate Stochastic Models of Travel-Mode Choice", *Highway Research Record*, 369, pp. 91-103.

Smith, D.P. (1977) *An Analysis of the Individual's Choice of Travel Mode.* Master Thesis, Department of Geography, McMaster University.

Stopher, P.R. (1967) *Factors Affecting Choice of Mode of Transport,* PH.D. dissertation, University of London.

Stopher, P.R., B.D. Spear & P.O. Sucher (1974) "Toward the Development of Measures of Convenience for Travel Modes", *Transportation Research Record,* 527, pp. 16-32.

Stoper, P. & A. Meyburg (1975) *Urban Transportation Modelling and Planning,* D.C. Heath, Lexington, Mass.

__________ (1976) *Behavioural Travel Demand Models,* Lexington, Massachusetts, D.C. Heath and Co.

Theil, H. (1969) "A Multinomial Extension of the Linear Logit Model", *International Economic Review,* No. 3, pp. 251-259.

__________ (1971) *Principles of Econometrics,* New York: John Wiley and Sons.

Thomas, T.C. & G.I. Thompson (1971) "Value of Time Saved by Trip Purpose", *Highway Research Record* 369, pp. 104-113.

Wachs, M. (1967) "Relationships between Drivers' Attitudes Toward Alternatve Routes and Driver and Route Characteristics" *Highway Research Record* 197, pp. 70-87.

Warner, S.L. (1962) *Stochastic Choice of Mode in Urban Travel: A Study in Binary Choice*, Evanston, Illinois, Northwestern University Press.

Watson, P.L. (1971) "Problems Associated with Time and Cost Data used in Travel Choice Modelling," *Highway Research Record* 369, pp. 148-158.

__________ (1974) *The Value of Time, Behavioural Models of Modal Choice*, Lexington, Massachusetts, D.C. Heath and Co.

Waston, P. & R. Westin (1975) "Transferability of Disaggregate Mode Choice Models", *Regional Science and Urban Economics*, pp. 227-249.