AN ANALYSIS OF TRANSPORTATION DEMAND IN THE TORONTO CENTRAL AREA

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ABSTRACT

In spite of the 1976 Central Area Plan, the Toronto Central Area still maintained its role as a major employment centre, and is likely to stay as the hub of increasing work trips generated throughout the Toronto region in the future.

The principal task of this study is to analyze and measure the effects and impacts of population and housing intensification in the Toronto Central Area on travel demand during the morning peak period associated with the Toronto Central Area for the period 1975-90. The findings could prove to be a very valuable tool in managing growth and development in the Central Area.

Detailed time series analysis from 1975 to 1989 is performed using the Metro Cordon Count data. A cross-sectional analysis for 1987 was also conducted using the 1987 Travel Diary Survey data. A simple travel demand model for the Central Area is developed to evaluate Cordon Count data.

RÉSUMÉ

Malgré la mise en place en 1976 du "Central Area Plan", la région centrale de Toronto maintient son rôle de centre majeur d'emploi. Tout semble indiquer d'ailleurs que rien ne changera et que cette région sera le noyau générateur de création d'emplois dans l'avenir.

Le but principal de cette étude était d'analyser, et de mesurer les effects et les impacts, de l'augmentation de la population dans la région centrale de Toronto durant l'heure de pointe matinale pour la période de 1975 à 1990. Les résultats peuvent être un outil très utile pour gérer la croissance et le développement de cette région centrale.

Ces analyses effectuées de 1975 à 1989 furent réalisées avec le système "Metro Cordon Count data". Une étude de déplacement modèle fût aussi développée pour évaluer le "Cordon Count data".

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1.0 INTRODUCTION

Over the past couple of decades there have been very significant changes in urban activity patterns which have taken place in North America. These patterns of change signifies that the "many to one" commuting pattern is gradually being replaced by the "many to many" travel patterns. These changes reflect that there is a continual process of decentralisation of jobs, as well as the continuing dispersion of the resident labour force.

A recent research (Bourne, 1989, p.325) attempted to put these changes into perspective and to verify them in his study using empirical data collected in the Canadian Census for 27 Canadian cities. It was found that "*overall commuting flows still tend to be dominated by the widespread dispersal of employment throughout the suburbs and by the continued attraction of the central core in terms of long distance commuting*". In spite of the policy of the 1976 Central Area Plan for the City of Toronto which encouraged decentralisation, a recent analysis (Hutchinson and Kumar, 1990) established that the Toronto Central Area still maintains its dominance as an employment centre. The following descriptions strongly support that the Toronto Central Area has maintained its dominance:

- In the Central Area, land value has gone up more than 300% in the past 15 years.
- Total office employment has grown over 30% in the same period.
- The Central Area population has increased nearly 17% in the period 1975-88.
- The number of dwelling units has grown by more than 40% the same time span.
- Both inbound person and vehicle trips have grown significantly over the years.
- The congestion during rush hour across the Central Area has spread beyond the traditional two hour period to three hours.

When addressing the 1989 Forum on the future of the City of Toronto, Soberman (1989, p.202) concluded that "*there is a common perception that congestion within the downtown has reached unacceptable levels from the standpoint of users, businesses, negative community impacts, and air quality. ...for many years to come, the Central Area of Toronto is likely to remain the focus of increasing work trips generated throughout the entire Greater Toronto Area* ".

Transportation "solutions" which involve the construction of new infrastructure faces considerable political and community opposition. Thus, in dealing with the congestion problems

of the City of Toronto, Soberman presented three inter-related approaches:

i) Reducing the number of vehicles entering the City by providing incentives for higher auto-occupancy, by encouraging the development of regional sub-centres to ease the travel demand to the City, and through the increase in the usage of transit for long distance trips.

ii) Achieve a better balance between housing and employment within the City itself.

iii) Use existing roads and streets more efficiently by various means of traffic system management.

It is the second approach which this study aims to examine closely. Nowlan and Stewart (1990, p.28) proposed a hypothesis which argued that "*urban land use policy, in the form of housing and population intensification, can be used as a tool to shape transportation developments in downtown Toronto*". This hypothesis is the result of a study of the present imbalance which exists in the development of the Toronto Central Area between available transportation facilities and the rapid growth in employment particularly in the office sector. The Nowlan-Stewart study derived two relationships between in-bound person trips, mid-year occupied office space, Central Area population and dwelling units, and is expressed as the two basic regression equation below

$$TRIPS = 179{,}000 + 0.04*SPACE - 0.7*POPULATION$$

and,

$$TRIPS = 165{,}000 + 0.04*SPACE - 1.2*DWELLINGS$$

where,

TRIPS = Three hour (7:00 a.m. - 10:00 a.m.) in-bound person trips crossing the Central Area Cordon

SPACE = Mid-year occupied office space in the Toronto Central Area Cordon in square metres

DWELLINGS = Number of dwelling units in the Central Area Cordon

POPULATION = Number of residents in the Central Area Cordon

When simply stated, the annual change in in-bound person trips crossing the Central Area cordon can be explained by three independent variables, namely, mid-year occupied office floor space and Central Area population or Central Area dwelling units. The two equations basically explained that, as Nowlan and Stewart (1990, p.24) concluded, "past changes in population and housing have had on in-bound trips: 70 fewer trips for each 100 increase in population in the Central Area, or 120 fewer trips for each addition of 100 dwelling units".

However, a recent study which analyzed the Nowlan-Stewart hypothesis (Sarsan, 1991, p.15) concluded that "the Nowlan-Stewart formula would, most likely, overestimate the effect of Central Area population growth on reducing the inbound commuting trips". This could be very important as there has to be a "match" between the skill levels of the Central Area residents and the type of jobs being offered in the Central Area. Otherwise it would undermine the belief that the Central Area residents will work in the Central Area. It is in this context that this study intends to clarify, revise, and refine both the Nowlan-Stewart and the Sarsan interpretations. It could prove to be a very valuable tool in managing growth and development and could possibly provide answers to the following questions (Kosny, 1990, p.5 and p.7):

- *What kinds of growth scenarios are appropriate for Toronto's Central Area?*
- *What measures should be pursued to relieve traffic congestion, to encourage more office workers to use public transit and to improve the environment for pedestrians?*

1.1 STUDY OBJECTIVES

The principal purpose of this study is to analyze and measure the effects and impacts of population and housing intensification in the Toronto Central Area on travel demand to the Toronto Central Area for the period 1975-89. As such, the objectives of this study are to:

i) review and verify the Nowlan-Stewart hypothesis which attempted to relate travel demand, housing and employment in the Central Area of Toronto through the use of available data,

ii) verify and further develop the Sarsan model which attempted to "fine-tune" the Nowlan-Stewart regression model,

iii) perform a more in-depth cross-sectional analysis using the 1987 Travel Diary Survey data as well as the Cordon Count data, and

iv) evaluate the Cordon Count data using the result of the cross-sectional analysis and the modified Sarsan model.

1.2 SCOPE OF THE STUDY

The geographical and temporal scope of the study is outlined. The source of the empirical data used is also described in the following section.

Geographical Context

The geographical context of this study is the Toronto Central Area (C.A.). When dealing with Cordon Count data the Central Area Cordon was used. The screenlines which define the C.A. Cordon are Bathurst Street to the west, the C.P.R. North rail line to the north, the Don Valley to the east and the waterfront to the south as shown in Map 1. In the analysis concerning census linkages and origin-destination 24 hour work trips the Greater Toronto Area (G.T.A) and Metropolitan Toronto were also reviewed. In this case the Greater Toronto Area, which includes Metropolitan Toronto, was condensed into seven zones using the 1979 T.A.R.M.S. zonal system as follows (Map 2):

Zone 1.	Toronto Central Area
Zone 2.	East Metro
Zone 3.	North Metro
Zone 4.	West Metro
Zone 5.	Durham Region
Zone 6.	York Region
Zone 7.	Peel Region/Oakville

Time Period of 1975 - 1989

A 14-year time period between 1975 and 1989 has been chosen for the study. It was 1976 when the Central Area plan went into effect in Toronto affecting housing, employment and transportation. A period of fourteen years was thought to be reasonable to reflect any significant structural changes in the time series analysis.

1.3 METHODOLOGY

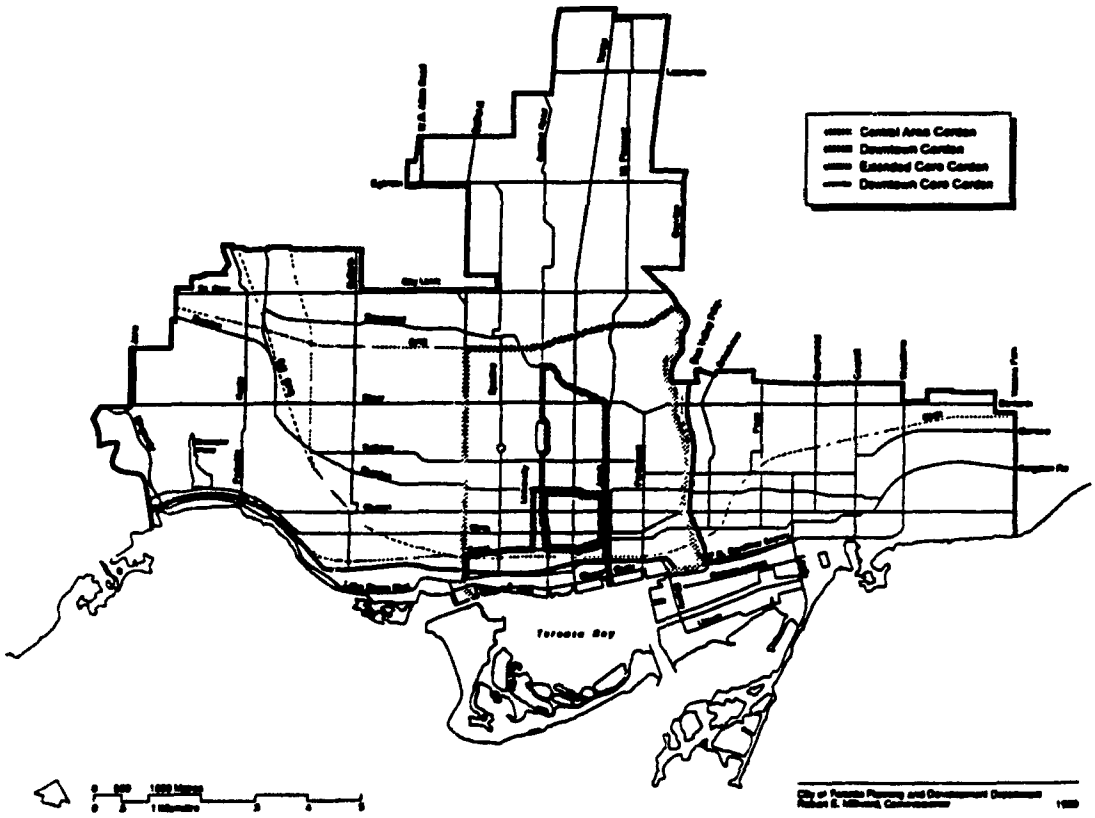
The approach used in this study has four components in order to evaluate the travel demand in the Toronto Central Area and is outlined as follow:

i) Review of existing literature and recent research.

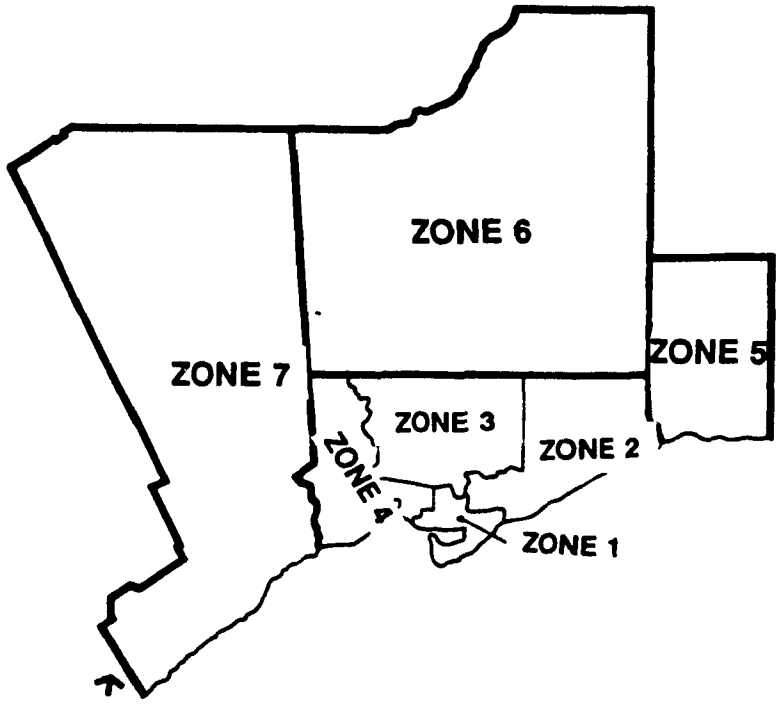
ii) Perform time series analysis of various Central Area trends and develop a travel demand model for the Central Area.

iii) Interpret the travel demand model using 1987 transportation trends associated with the Central Area.

iv) Evaluate model on its applicability for future transportation planning for the Central Area.



Map 1: Metro Cordon Count Boundaries



Map 2: Zonal System for the Greater Toronto Area

2.0 REVIEW OF CENTRAL AREA TRENDS

In many aspects, the 1976 Central Area Plan indicated the beginning of many structural changes in the Toronto Central Area. It has started a development process which has very significant impacts in economic, social and physical terms. However, some of the changes might not have been intended changes by the Plan. Whether these changes were anticipated or not, they deserve a very close examination in order to fully understand and evaluate the extent that these changes might have on the Toronto Central Area.

2.1 THE 1976 CENTRAL AREA PLAN OF TORONTO

In the early 1970's there was wide spread concern over the future development of the City of Toronto. After intensive and extensive studies it was concluded that Metropolitan Toronto was to be planned as a multi-centred urban form which formed the backbone of the Central Area Plan of 1976. Re-development constraints were introduced to protect valuable aspects of the City of Toronto. Mixed-use development in the Central Core of the City was encouraged such as downtown residential development and deconcentration of office employment growth. The objectives of the Plan were stated as follows (City of Toronto, 1986i, p.5-6):

"It is the policy of Council that the rate of growth in commercial offices and public institutions within the *Central Core* of the *Central Area* shall be such as to achieve the major objectives of this plan, including the deconcentration of office employment, the retention of low rise neighbourhoods within the *Central Area*, the expansion of the residential function of the *Central Area* emphasizing *housing suitable for families with children* in appropriate areas of the *Central Core* and the *Outer Central Area*, and housing for households without school age children in the form of mixed-use buildings in the *Central Core*, the preservation of buildings of historic or architectural value or interest, the avoidance of unacceptable levels of congestion on the transportation system, and a substantial increase in the availability of parks and recreation space for those who live and those who work in the *Central Core*."

Deconcentration was a major objective in the Central Area Plan which was designed to establish a balanced distribution of employment growth within the Central Core, the Central Area and the Toronto region. The policy was to promote a multi-centred urban pattern which in turn could promote a transit-oriented transportation network.

In order to achieve the deconcentration policy, the City of Toronto recognized the need to manipulate office growth and its spatial distribution, since the office sector comprised the largest and fastest growing employment sector in the Central Area. This sector also generated the highest peak-hour travel demand on the transportation system. Thus, in order to limit office space growth in the Central Area, the Plan called for no significant improvements on the transportation system that may improve the accessibility to the Central Area. Therefore, a principal task was to strike a balance between the capacity of the existing transportation infrastructures and a desirable office space growth rate. These factors combined with the allocation of office space prescribed a predominantly transit-oriented transportation system, and it was specifically stated in the Plan in section 7.2 (b) that "*it is the policy of Council to discourage further measures which would facilitate the use of automobiles for commuting into the Central Core*". However, the policies of discouraging the use of automobile commuting, along with the emphasis placed on encouraging the use of public transit were also treated as important goals, independent of accomplishing deconcentration.

The 1976 Central Area Plan reflected the times. It was a time when large capital projects such as the Spadina Expressway was abandoned due to heavy community and political pressures. It was topics such as heritage conservation and community planning that topped the priority list then. However, Toronto has faced considerable changes over the years since the 1976 Central Area Plan was originally implemented. A significant amount of office space has been built in the Central Area, the Central Area residentship has gone up, employment has became more office oriented, and travel demand into the Central Area has also grown. Table 1 summarizes the evaluation of the 1976 Central Area Plan as analyzed in the 1986 Quinquennial Review.

C.A. Plan Goals	Evaluation	
	Where Plan has been successful	Comments
Housing *Promote Mixed-Use and new housing in the Central Area and Central Core *Affordable Housing for all residents and target income groups	*Over 17,000 new units built *Further 11,000 approved *C.A. population is growing *Housing prices have soared	*Social housing production failed to meet target *Need to increase affordable housing production
Office Deconcentration *Control rate of growth in Core to permit transportation investment and growth in planned subcentres *Promote a deconcentrated Metro urban structure	*Rate of growth is within limits *From 1976-85 Core share of growth declines from 68% to 55% *Office space suburbanization	*Economic factors have affected the relationship between office and employment growth *Complete downtown employment studies *Establish relationship between employment and transportation *Monitoring
Transportation *Discourage private auto for commuting *In short term, no major transit improvements serving the Core *Balance transportation and development capacities	*Plan has been successful in postponing the need for transportation improvements for 10-15 years	*A long term imbalance between transportation and development capacities emerging *Identify roads and transit improvements *Incremental approach to transportation planning recommended

Table 1 : Goals and Evaluation of the 1976 Central Area Plan (Kosny, 1990)

Thus, it is essential to analyze closely how these transportation and land use factors have changed over the period 1975 - 1990. The following sections present a review of recent literature and research studies on various trends associated with the Central Area.

2.2 REVIEW OF POPULATION CHANGES AND TRENDS

In the 1970's, due to suburban sprawl, the City of Toronto experienced a drastic decline in its resident population. However, the population rebounded in the early 1980's and under the 1976 Central Area Plan's policy, it is likely that it will continue to grow.

The Census data revealed that, over the period of 1976-86, the Central Area population experienced a 17.2% increase. However, it was the Central Core which is smaller than the Central Area, which exhibited the largest increase of nearly 50% (City of Toronto, 1990). Between 1980 and 1988 the population has grown by 21,524 people (19.7%) as indicated by provincial assessment files (Nowlan and Stewart, 1991).

The major growth in the Toronto region, however, occurred in the fringe areas. Scarborough, Etobicoke and the four outer suburban region experienced dramatic increase. The trends reflected a continuation of the suburban sprawl ,which was part of the result of sky-rocketing cost of housing in the City. As a result, long distance commuting will intensify in the future.

Despite this growth, the older, more traditional neighbourhoods in the Outer City area experienced a decline of 8% in population, and the City of Toronto as a whole also experienced a decrease of about 4% (City of Toronto, 1990).

The number of dwelling units had also grown in the Central Area from 53,804 in 1980 to 66,961 in 1988, an increase of 24.4% over the 9 year period (Nowlan and Stewart, 1991). The average household size had also continued to decrease in the City of Toronto. The number of one person household increased more than 32% between 1976 and 1986. Two and three person households also showed growth of 10.6% and 7.1% respectively. However, household sizes of four persons or more showed considerable decline (City of Toronto, 1990). Table 2 summarizes the trends in population and dwelling units in the Central Area between 1980 and 1988.

YEAR	POPULATION	DWELLING UNITS
1980	109,405	53,804
1981	118,114	56,027
1982	121,093	57,714
1983	122,781	59,011
1984	123,874	60,141
1985	126,384	61,957
1986	127,493	63,395
1987	130,835	65,123
1988	130,929	66,961

Table 2 : C.A. Population and Dwelling Unit Trends, 1980-88 (City of Toronto, 1990)

2.3 REVIEW OF EMPLOYMENT AND LABOUR FORCE TRENDS

Two significant employment changes occurred in Toronto over the past two decades while the region was experiencing rapid growth. These changes were the increasing dominance of the office sector and an increasing proportion of part-time employment.

The total employment in the Toronto CMA has increased 61% in the period of 1971 to 1981. The financial, insurance and real estate sector registered the highest growth of nearly 80% whilst the community, business and personnel services sector came to a close second with over 77% growth. On the other hand, the manufacturing sector experienced the least growth of just more than 35% (Hutchinson and Kumar, 1990 and Miller et al, 1984). Table 3 summarizes the growth in employment by industry sector in the Toronto CMA between 1971 and 81.

INDUSTRY SECTOR	% GROWTH, 1971-81
Manufacturing	35 3
Construction	59 1
Transportation, Warehousing, Communications	68.4
Wholesale and Retail Trade	58.1
Finance,Insurance, Real Estate	79.7
Community,Business,Personal Services	77 4
Administration	49.8

Table 3: Growth in Employment for Toronto CMA, 1971-81 (Hutchinson and Kumar, 1990)

Between 1976 and 1988 the community, business and personal services sector had the largest growth at 60% or nearly 5% per annum on the average, and the finance, insurance and real estate sector also grew by 58% over the same period. The manufacturing sector as well as the administration sector experienced the least growth of under 15% in the Toronto CMA (City of Toronto, 1990).

Although all the industry sectors demonstrated respectable levels of growth between 1971 and 1988, it has also experienced significant changes in their relative importance. Over 50% of manufacturing and industrial jobs have diminished from 1970 to 1985 (Woodward, 1989). The labour force share of the manufacturing sector declined over 6% whilst the community, business and personal services sector increased its labour force share by nearly 7%. Table 4 summarizes the percent share of the labour force by industry sector in the Toronto CMA between 1971 and 1988.

INDUSTRY SECTOR	1971*	1976#	1981*	1988#
Community,Business,Personal Services	26.1	27.9	29.8	32.9
Manufacturing	27.4	25.6	24.0	21.4
Wholesale and Retail Trade	18.1	17.5	18.2	18.4
Finance,Insurance, Real Estate	7.3	7.9	8.5	9.3
Transportation, Warehousing, Communications	8.1	8.0	8.0	6.8
Construction	6.6	6.3	5.5	5.6
Administration	5.8	5.5	5.2	4.5

*Statistics Canada, Census
#Statistics Canada, Labour Force Survey

Table 4 : Percent Share of the Labour Force by Industry Sector, 1971-88

It was becoming more evident that Toronto was emerging as an administrative centre or an "executive city" with the middle and low level clerical works being shifted to the suburban centres. The clerical occupations in the Central Area were being replaced by managerial and professional occupations which in turn might have increased the absenteeism rate over the years (Woodward, 1989). From 1976 to 1988, managerial and clerical employees increased by more than 90% and nearly 25% respectively in the Toronto CMA. In the City of Toronto these trends were more exaggerated, as managers made up over 40% of the labour force (City of Toronto, 1990). These trends suggested that the City of Toronto was capturing more executives as their

place of work as well as their place of residence since the Labour Force Survey provided data by the place of residence.

Part-time work, defined as less than twenty hours of work per week, in the Toronto region has also increased substantially. The Labour Force Survey conducted by Statistics Canada showed that between 1976 and 1985 the share of part-time employment has grown nearly 80% in the City of Toronto as compared to a 7.5% growth in full-time employment. The ratio of part-time employment to total employment was also showing an increasing proportion of part-time workers working in the City of Toronto. In 1976 part-time work had a 7% share in total employment, and in 1985 its share has grown to 12% (City of Toronto, 1986b).

The Metropolitan Toronto Planning Department's Employment Survey results also supported this trend. It indicated an increase in part-time work from a share of 9% of total employment in 1983 to 14% in 1988 in the City of Toronto. Part-time work has grown almost 82% over this six year period, and out of the 84,144 jobs that was created after 1983, 32,247 (44%) were part-time in nature. In the Central Area, these trends were more exaggerated. Part-time work grew nearly 95% between 1983 and 1988, and in comparison full-time work grew by a relatively modest 11% at the same time. Table 5 summarizes the trends in Part-time, Full-time and Total employment in the City of Toronto and the Central Area for the period 1983-88.

YEAR	CITY OF TORONTO			CENTRAL AREA		
	Part-time	Full-time	Total	Part-time	Full-time	Total
1983	45,461	446,435	491,896	28,802	324,786	353,588
1984	51,542	458,507	510,049	33,370	332,716	366,286
1985	58,019	464,090	522,109	38,438	335,934	374,372
1986	72,059	473,193	545,252	48,634	344,502	393,136
1987	71,893	491,795	563,688	47,651	361,761	409,412
1988	82,708	493,332	576,040	56,012	361,446	417,458

Table 5 : Employment trends, 1983-88 (City of Toronto, 1990)

Another important change which is also emerging is the growing participation rate of the female labour force which partly accounted for the overall employment growth. The male labour force participation rates have remained at around 80 to 81% from 1976 to 1988 in the Toronto

CMA, whilst the female labour force participation rates have increased from 53.1% in 1976 to 62.9% in 1988 in the CMA. Metropolitan Toronto and the City of Toronto both reflected the same trends (City of Toronto, 1990).

The growth in part-time workers was partly responsible for the spreading of the peak hour and the increase in travel demand during the off-peak. The increase in female participation rates was also partially responsible for the growth in transit trips into the Toronto region. The popularity of the City as the place of residence of many executives could also contribute to an increase the "walk-to-work" trips into the Central Area. How these trends have actually affected travel patterns and demand into the Central Area will be discussed in later sections.

2.4 REVIEW OF OFFICE SPACE TRENDS

In 1988 the total number of office space amounted to over 10 million square metres in the Toronto region. The growth has been phenomenal as the total number of office space in 1966 was about 2 million square metres. This gave an average annual growth rate of about 370,000 square metres per year in the period between 1966 and 1988. However, between 1986 and 1988 the average annual growth rate was more than 600,000 square metres per year which coincided with the growth in employment in the office sector.

In the Central Area around 1.7 million square metres of office space was added between 1976 and 1985 (City of Toronto, 1986a). Between 1985 and 1989 over half a million square metres of office space was built which represented a 25.6% share of all office completions in the Toronto Region (City of Toronto, 1990).

The trend showing that the Central Area was losing its dominance as the office employment centre has emerged, although it was still the primary choice for new office locations and continued its strong demand for office space. In 1966 the Central Area held 76% of all office space in the Toronto region. However, its share of the market has been diminishing as its share dropped to 68% in 1976, 55% in 1985 (City of Toronto, 1986a) and 49% in 1989. Table 6 shows the spatial distribution of office space in the Toronto region in 1989.

	No. of Bldg.	Total Office Space, m^2	% Share	Vacant Office Space, m^2	% Share	Vacancy Rate, %
Central Area	345	5,224,979	49	279,041	35.2	5.3
Rest of Toronto Region	664	5,438,279	51	514,643	64.8	9.5
Total	1009	10,663,255	100	793,684	100.0	7.4

Table 6 : Office Space Distribution in the Toronto Region, 1989 (City of Toronto, 1990)

Although the Central Area was losing its share of new office development, its office absorption rate, which was measured through the yearly changes in the total amount of occupied office floor space, has remained quite stable between 1966 and 1985. Between 1986 and 1988 the Central Area experienced an explosion of growth in its office space absorption rate However, the absorption rate for office markets outside the Central Area grew at a relatively faster rate, thus gradually increasing its market share of office space. Table 7 summarizes the office space absorption rate in the Toronto region.

Period	Central Area, '000 m^2	Rest of Region, '000 m^2
1966-1970[1]	137	276
1971-1975[1]	170	381
1976-1980[1]	148	566
1981-1985[1]	123	556
1985-1988[2]	220	450

1. City of Toronto, 1986a.
2. City of Toronto, 1990.

Table 7 : Office Space Absorption Rate in the Toronto region, 1966-88

In the long run it seemed that office space demand in the Central Area should experience a slow down. The continuous decline of the Central Area's share of office space indicated the deconcentration of office space to suburban centres or office-parks. The cause of the suburbanization of office space could be attributed to the 1976 Central Area Plan, the sky-rocketing cost of rent in the Central Area ,the better access to the large pool of labour force in the suburban areas and the increased supply of office space in the suburban markets.

In order to relate office floor space and office employment, the Floor Space per Worker index (FSW) was used. The FSW indicates how intense the office buildings were used. It expressed the average amount of office floor space occupied by each office worker. The FSW ratio for the Central Core (see Map 1) ,where the majority of office buildings in the Central Area were located, has increased from 19.2 in 1960 to 22.9 in 1975, reaching a high of 26.0 in 1985, and has since fallen to a level of 25.2 square metres per worker in 1988 (City of Toronto, 1990. A number of factors could be attributed to the increase in the FSW index (City of Toronto, 1986e):

i) demand for office space exceeded employment growth,
ii) Central Area labour force becoming more "executive" in nature,
iii) office automation, and
iv) more affordable office space through tenant incentives and reduced rents.

Table 8 shows the trend in FSW ratio in the Central Core between 1960 and 1988.

YEAR	FSW, m^2 PER WORKER
1960	19.2
1970	21.5
1971/1972	21.4
1975	22.9
1980	25.0
1983	25.0
1984	26.2
1985	26.0
1986	25.5
1987	25.0
1988	25.2

Table 8 : Trends in Floor Space per Worker Index, 1960-88 (City of Toronto, 1990)

2.5 REVIEW OF WORK TRIP TRAVEL PATTERNS

This section of the study reviews the characteristics of the travel patterns which involved the trip to work to the Central Area for the period 1971 to 1988. Over this period of times several travel surveys, census, as well as an extensive cordon count program have been conducted Data such as worker place-of-residence and place-of-work linkages, 24-hour work trips and traffic volume counts were recorded. It will help to give a more thorough understanding of the commuting trip into the Central Area.

2.5.1 The 1971, 1981 and 1986 Census

The census data that is of interest is the place-of-residence to place-of-work (POR-POW) records. The survey essentially recorded where people live and work, and in this way it would give a general picture of "potential" work-trips. This generalised work-trip pattern was better described as home-to-work linkage since the census data did not give enough detailed information on the trip itself. The census data revealed that there was an increase of 84,714 more workers who travelled to workplace in the Central Area over the 10 year period (1971-81).

In a recent analysis, linkages were divided into 2 basic groups, namely of those which originated from the Metro Toronto area (Zones 2,3 and 4 as described in Chapter 1) and those from outside Metro Toronto and termed this area the "Fringe" area (Zones 5,6 and 7). It was found that there was a 32% increase in linkages to the Central Area. However, the Fringe area accounted for a much higher rate of growth than the Metro area, although Metro still accounted for 87% of the total linkages travelling into the Central Area in 1981 (City of Toronto, 1986g)

Intra-zonal linkages within the Central Area only increased by 6,000 or 20% over this 10 year period. In the Metro Toronto area, the East Metro Zone (Zone 2) accounted for the highest rate of growth of 28% or 20,000 linkages into the Central Area. The number of linkages to the Central Area have increased despite insignificant population changes in this area. In the Fringe area, the Peel Region (Zone 7) experienced the largest growth and also the highest growth rate The census data also showed a high population growth which led to a doubling of the percentage of POR-POW linkages to the Central Area from this area (from 7% to 14% of the total). Table 9 summarizes the findings of the 1971 and 1981 linkages to the Central Area from the 7 zones (City of Toronto, 1986g).

Origin Zone	1971 No.	%	1981 No.	%	1971-81 No.	% Change
Central Area, 1	29,985	11.2	35,965	10.2	5,980	19.9
East Metro, 2	68,865	25.7	88,440	25.1	19,575	28.4
North Metro, 3	96,420	36.0	114,540	32.5	18,120	18.8
West Metro, 4	54,000	20.2	65,260	18.5	11,260	20.9
Metro Sub-Total	**249,270**	**93.0**	**304,205**	**86.2**	**54,935**	**22.9**
Durham Region, 5	1,950	0.7	4,585	1.3	2,635	135.1
York Region, 6	4,785	1.8	12,070	3.4	7,285	152.2
Peel Region, 7	12,000	4.5	31,860	9.1	19,860	165.5
Fringe Sub-Total	**18,736**	**7.0**	**48,515**	**13.8**	**29,780**	**160.0**
Total	**268,005**	**100.0**	**352,720**	**100.0**	**84,714**	**31.6**

Source: Statistics Canada, Special Journey-to-Work Tabulation

Table 9 :POR-POW Linkages, 1971 and 1981

In a recent study (Transmode, 1991), it was shown that the annual growth rate of Central Area residents working in the Central Area has increased from 1.9% per annum between 1971 and 1981 to 2.67% per annum between 1981 and 1986. On the other hand, the growth rate of workers outside the Central Area commuting to the Central Area has declined from 2.87% between 1971 and 1981 to 1.33% between 1981 and 1986. Another significant change that occurred was the increasing amount of "reverse commuting". It was evident that the annual rate of growth of Central Area residents working outside has amounted to 7.5% between 1981 and 1986.

2.5.2 The 1981 and 1986 "Walk-To-Work" Surveys

These surveys were originally initiated by the City of Toronto's Planning and Development Department in 1981 to examine the travel characteristics of downtown residents with special emphasis being placed on the walk-to-work trip. The definition of "walk-to-work" was that the respondent walked to work more than 3 times a week.

The 1981 Survey found that 35.5% of summer work trips and 30.1% of winter work trips made by the Central Area residents were walk-to-work trips (City of Toronto, 1982). The 1986 results showed an increase in the percentage of residents who walked to work. 38% walked in the summer as compared to 32.4 % during the winter (Metropolitan Toronto, 1988).

However, both surveys had very low response, and the results could be biased. Thus, it could only be best served as an indicator of the general commuting trends that was happening in the Central Area. In general, there has been an increase in the walk mode for Central Area employees. In absolute terms it translated to roughly 20,000 work trips that used the walk mode, and it might partly explain the imbalance in the growth of inbound work trips into the Central Area.

2.5.3 The 1986 Transportation Tomorrow Survey (TTS)

The Transportation Tomorrow Survey was carried out to gather household-related, person-related, and trip-related data in the Greater Toronto Area (GTA). It was carried out from mid-September to mid-December 1986.

The Greater Toronto Area used in this study is larger than the study area mentioned in the census data analysis. Fifteen more municipalities were used which were outside the "Fringe" area in the census linkage analysis. Thus, the numbers found here are not be directly comparable to the linkage data.

The Survey analysis found that 20% of all work trips in the Greater Toronto Area were destined to the Toronto Central Area. The spatial distribution of the origin of commuters who arrive in the Central Area by mode is summarized in Table 10.

	Auto-Driver		Auto-Passenger		Transit	
	No.	%	No.	%	No.	%
5 Regional Municipalities	26,000	28	4,400	20	31,900	40
Metro Toronto	69,200	72	17,100	80	154,200	60
Total	**95,200**	**100**	**21,500**	**100**	**186,100**	**100**

Table 10 : Origins of Central Area Commuters, 1986 (Miller et al, 1990)

No trips were made from outside Metro Toronto to the Central Area by cycling or walking. The work trips made by these two modes accounted for less than 6% (18,300 trips) of all trips that are destined to the Central Area. Within the Central Area, 13,700 workers which represented approximately 40% of the workforce in the Central Area walked to work. This made walking the most dominant mode choice for the work trip for Central Area residents.

Metro Toronto accounted for 81% (258,800 trips) of the Central Area commuters since it housed nearly 52% of the Greater Toronto Area population. The City of Toronto residents accounts for 37% of the 81% of the Central Area commuters, and the five Regional Municipalities, namely Hamilton-Wentworth, Halton, Peel, York and Durham, represents the remaining 19% (62,300) of the work trip to the Central Area. Table 11 summarizes the travel pattern by mode.

MODE	G.T.A.[1] - C.A.		Metro[2] - C.A.		City[3] - C.A.		C.A. - C.A.	
	No.	%	No.	%	No.	%	No.	%
Auto-Driver	95,200	30	69,200	27	25,800	22	5,200	15
Auto-Passenger	21,500	7	17,100	7	7,800	7	1,800	5
Transit	186,100	58	154,200	60	66,800	57	13,200	38
Walk	15,800	5	15,800	6	15,600	13	13,700	39
Cycle	2,500	1	2,500	1	2,200	2	1,200	3
Total	321,100	100	258,800	100	118,200	100	35,100	100

1. excluding Metro Toronto
2. excluding City of Toronto
3. excluding Central Area

Table 11 : Spatial Distribution of Central Area Bound Work Trips, 1986 (Miller et al, 1990)

2.6 Review of The Metro Cordon Count for the Central Area Cordon

The Cordon Count program provides the number of person and vehicles by modes crossing various cordons in both directions during 15 minutes intervals from 6:30 a.m. to 11:30 p.m.. The Central Area Cordon was the primary focus of this review and its location is illustrated in Map 1.

Between 1975 and 1989, inbound person trips (all modes) during the morning peak period increased from 268,123 trips in 1975 to 323,706 trips in 1986 representing a 21% overall

growth, or an average annual growth rate of 1.4%. The number of people travelling by automobiles indicated a relatively modest increase of 4.7% and transit ridership (including GO-Rail) has gone up over 31%, or in absolute terms, 50,562 trips. Moreover, Go-Rail alone had a 226% increase in usage during the morning peak hours over this 14 year period. This explosion in Go-Rail usage could be attributed to the expansion of the rail network as well as service improvements. The increased usage of Go-Rail service also indicated an enlarging commuter shed in the Toronto Region and was growing at the expanse of the private automobile mode (Woodward, 1989).

It demonstrated that a gradual shift in the modal split was the result of increased percentage of transit users over the years. Between 1960 and 1965 the distribution of morning peak period between automobile and transit was nearly half and half. By the mid 1980's transit has taken about 2/3 of the total inbound person trips during the morning peak hours. A recent study (Woodward, 1989) also suggested that the transit services have nearly reached their capacities. With no additional highway infrastructure being built, the modal split ratio was unlikely to increase any further. Table 12 reveals the trends in inbound person trips entering the Central Area during the morning peak period from 1975 to 1989 .

YEAR	AUTO & TAXI		TRANSIT*		TOTAL PERSONS
	No.	%	No	%	No
1975	107,137	40.0	160,986 (10,082)	60.1 (3 8)	268,123
1977	110,425	39 6	168,523 (12,415)	60.5 (4 5)	278,948
1979	120,015	41.7	167,495 (16,119)	58 3 (5 6)	287,510
1981	110,052	35.7	198,319 (20,382)	64 3 (6.6)	308,371
1983	112,317	36.7	194,124 (20,758)	63 4 (6 8)	306,441
1985	113,573	37.8	186,969 (23,470)	62 2 (7.8)	300,542
1986	122,974	37.9	201,296 (23,526)	62 1 (7 3)	324,270
1987	116,726	36.3	204,358 (26,087)	63 7 (8 2)	321,084
1988	119,673	35.8	214,383 (28,021)	64.2 (8 4)	334,056
1989	112,157	34.6	211,549 (32,863)	65.4 (10 2)	323,706

* Figures in brackets are Go-Rail figures.

Table 12 : A.M. Peak Period Inbound Person Trips by Mode, 1975-89 (Metropolitan Toronto, 1990)

Between 1975 and 1989 the total number of inbound vehicles (those entering the Central Area Cordon) during the morning peak period (7:00-10:00 a.m.) increased by 17.2%. Automobile and Taxi vehicle inbound trips increased by 12.5% whereas transit vehicle trips grew by 8.8% (Metropolitan Toronto, 1990).

Automobile vehicle trips have increased by 12.5% whilst automobile person trips only increased by a comparatively small 4.7%. This trend implies that automobile occupancy rates must be declining. In fact, during this period it has dropped from 1.3 persons per vehicles in 1975 to 1.2 in 1988 (City of Toronto, 1990). Another significant change included the spreading or "flattening" of the peak hour period. The percentage of inbound automobile person trips occurring within the peak period have been found to be decreasing over time which indicated a shift of some inbound trips to the off-peak hours (Transmode, 1991).

2.7 SUMMARY

Population and Housing Trends

1) The Census data revealed that, over the period of 1976-86, the Central Area population increased by 17.2%.
2) The number of dwelling units had also increased by 24.4% between 1980 and 1988.
3) The average household size had continued to decrease in the City of Toronto.

Employment and Labour Force Trends

4) In employment, between 1971 and 81, the office sector experienced the highest growth. On the other hand, the manufacturing sector experienced the least growth.
5) The labour force share between 1971 and 1988 suggested that the City of Toronto was capturing more executives as their place of work.
6) In the Central Area part-time work grew nearly 95% between 1983 and 1988, and in comparison full-time work grew by a relatively modest 11% at the same time.

Office Development Trends

7) Around 2.2 million square metres of office space was added between 1976 and 1989 in the Central Area.
8) The Central Area's share of the office market has been diminishing as its share dropped to 68% in 1976, 55% in 1985 and 49% in 1989.
9) The FSW ratio for the Central Core has remained at a level of about 25 square metres per worker.

Travel Patterns

10) Metro Toronto accounted for 87% of the total linkages travelling into the Central Area in 1981.

11) The growth rate of external linkages to the Central Area has declined from 2.87% between 1971 and 1981 to 1.33% between 1981 and 1986.

12) The 1986 TTS showed that walking was the most dominant mode choice for the work trip for Central Area residents.

13) In 1986, Metro Toronto accounted for 81% (258,800 trips) of the Central Area commuters. The City of Toronto residents accounts for 37% of the 81% of the Central Area commuters.

14) Between 1975-89, inbound person trips (all modes) during the morning peak period (7-10 a.m.) increased from 268,123 trips in 1975 to 323,706 trips in 1986 representing a 21% overall growth.

15) As the result of increased percentage of transit users over the years, by the mid 1980's transit has taken about 2/3 of the total inbound person trips during the morning peak hours.

16) Automobile occupancy rates was declining from 1.3 persons per vehicles in 1975 to 1.2 in 1988.

17) The percentage of inbound automobile person trips occurring within the peak period have been found to be decreasing over time which indicated a shift of some inbound trips to the off-peak hours.

3.0 THE NOWLAN-STEWART HYPOTHESIS AND THE SARSAN MODEL

During the past two decades, the Central Area experienced tremendous growth in employment and office development. Although the size of the residential population of the Central Area has declined in the 1970's, for the past decade it has risen considerably. However, the morning peak period trips into the Central Area only experienced relatively modest growth (Woodward, 1989).

3.1 THE NOWLAN-STEWART HYPOTHESIS

The imbalance of growth between transportation demand and various land use variables was attributed to the increases in the Central Area housing stock and population. The Central Area residents could travel to work inside the Central Area, thus easing the demand on transportation into the Central Area.

The hypothesis which argued that the growing residential population in the Central Area has impeded the growth in inbound commuting trips into the Central Area was first put forward by Nowlan (1989), and finalised by Nowlan and Stewart (1990). Based upon the population and housing changes from 1975 to 1989, the analysis concluded that there will be "*70 fewer trips for each 100 increase in population in the Central Area, or 120 fewer trips for each addition of 100 dwelling units*" (Nowlanand Stewart, 1990, p.24).

The results implied that with further housing development and population intensification in the Central Area, further growth of downtown office space could be allowed without the provision of additional commuting infrastructure into the Central Area. If the implications were true, the benefits are twofold:

i) Housing policy would assume a much greater role in the future development of official plans. A desirable Central Area office development could be achieved by means of housing expansion in the Central Area without overloading the existing transportation system.

ii) The housing intensification process in the Central Area could impede the rate of residential sprawl which was becoming evident in the Greater Toronto Area.

The two basic equations derived in the Nowlan and Stewart study (1990) were:

TRIPS = 179,000 + 0.04*SPACE -0.7*POPULATION.....(1)

TRIPS = 165,000 + 0.04*SPACE - 1.2*DWELLINGS.....(2)

where,

TRIPS = The number of inbound person trips crossing the Central Area Cordon by all modes between 7:00 to 10:00 a.m.

SPACE = The amount of mid-year occupied office floor space within the Central Area Cordon in square metres.

POPULATION = The size of the residential population living within the Central Area Cordon.

DWELLINGS = The number of occupied dwelling units within the Central Area Cordon.

Table 13 illustrates the variation of these variables from 1975 to 1988.

YEAR	TRIPS	SPACE	POPULATION	DWELLINGS
1975	268,123	N A	112,991	46,621
1976	273,536	4,203,009	111,840	47,785
1977	278,948	4,393,591	111,374	49,117
1978	283,223	4,584,237	111,536	50,581
1979	287,510	4,745,510	112,270	52,138
1980	297,941	4,920,575	113,520	53,754
1981	308,371	5,047,522	115,230	55,390
1982	307,406	5,130,793	117,344	57,010
1983	306,441	5,210,051	119,806	58,577
1984	303,492	5,284,558	122,559	60,054
1985	300,542	5,392,955	125,548	61,404
1986	322,177	5,552,836	128,716	62,590
1987	317,487	5,825,906	132,090	64,296
1988	329,842	6,052,423	132,185	66,111
average annual growth rate	1.64%	3 38%	1.21%	2 99%

Table 13: Variation of Transportation and Land Use Variables in the Central Area, 1975-1988 (Nowlan and Stewart, 1990)

From equations 1 and 2, given the Central Area population or dwelling units and the mid-year occupied office space for any year in the study period, the number of morning peak hour inbound trips entering the Central Area can be estimated. For example:

in 1980,	POPULATION = 113,520
	DWELLINGS = 53,754
	SPACE = 4,920,575
therefore,	
from equation 1 :	TRIPS=296,359
from equation 2 :	TRIPS=297,318
observed:	TRIPS=297,941

The observed data fit quite well with these "best fit" equations proposed by Nowlan and Stewart. However, the use of dwelling units as a variable would complicate the analysis. The type of dwelling unit has to be considered, the average household size as well as the vacancy rate would have to be taken into account. Thus, for the purpose of this study only equation 1 of the Nowlan-Stewart hypothesis will be examined. Suppose in the year 2001, the mid-year occupied office space remained at the 1988 level of 6,052,423 square metres, with the Central Area population growing to 150,000, the inbound trip to the Central Area will be such that:

TRIPS = 179,000 + 0.04*(6,052,423) - 0.7*(150,000)
= 316,097 trips

i.e., a reduction of nearly 14,000 trips with an increase of 18,000 persons in the Central Area while the office space remained constant. Using the three variables in equation 1, a number or growth scenarios in the Central Area can be developed (Nowlan and Stewart, 1990).

From figures 1 and 2, it can be seen that if the amount of morning peak hour inbound trips were to remain at the 320,000 level, a number of combinations of Central Area population and occupied office floor space could be used. For example, if SPACE were to grow to 7.5 million square metres, the Central Area resident population would have to increase to 220,000 to accommodate the new jobs created without further growth in the morning inbound trips. Figures 1 and 2 illustrates a cross section of the plane surface as described by equation 1.

Figure 1: Cross Section of Equation 1

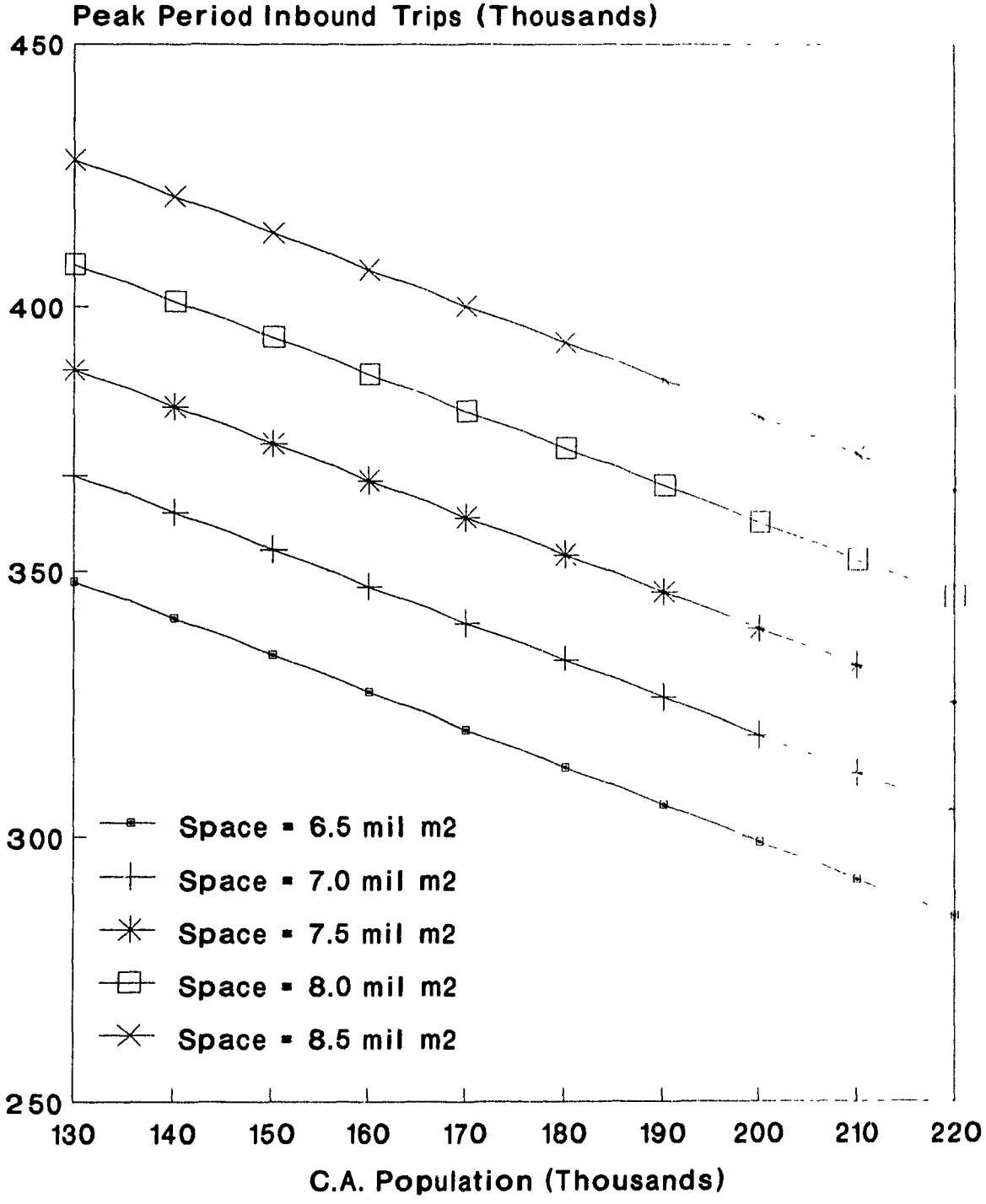
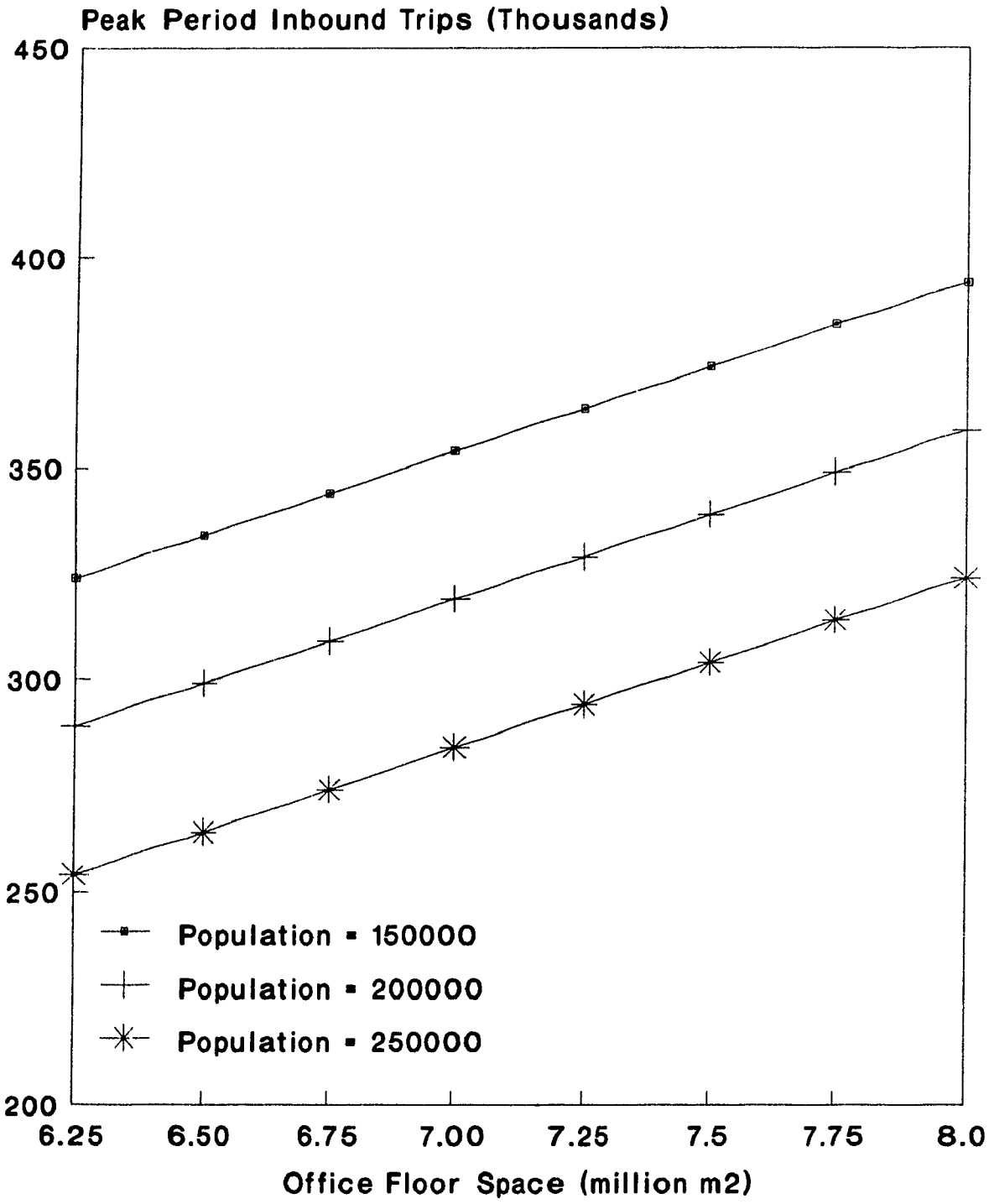


Figure 2: Cross Section of Equation 1



The Nowlan-Stewart hypothesis could prove to be very appealing to planners. By implementing a single policy, that is, increasing the number of Central Area residents, several benefits could be anticipated. These benefits include a more "livable, balanced" Central Area; the accommodation of Core office development without the provision of any new transportation facilities; and an increase in the amount of walk-to-work trips. Several assumptions were made in the Nowlan-Stewart hypothesis, as follows:

i) During the morning peak period, the amount of through trips, non-office trips as well as non-work trips entering the Central Area cordon had remained constant between 1976 and 1988.
ii) Part-time office work trips occurred in the off-peak hours.
iii) A Floor Space per Worker (FSW) ratio of 25 square metres per worker was used over the study period.
iv) No allowance was made for any absenteeism among the Central Area workers.

In the Nowlan-Stewart study a variable called ADJTRIPS (adjusted commuting) was calculated. It was the difference between the morning peak hour inbound trips (TRIPS) and the mid-year occupied office space (SPACE) divided by the FSW, i.e.,

ADJTRIPS = TRIPS - (SPACE)/25

It was shown that the variable ADJTRIPS had not stayed constant over the study period, but had in fact declined. The ADJTRIPS variable described the number of "background" trips entering the Central Area, thus contradicted assumption 1 that "background" trips had remained constant over the study period. In the Woodward study (1989), it was suggested that through travel into the Central Area might have declined over the years which further supports this view.

The second assumption stating that the majority of part-time office commuting trips occurred in the off-peak hours, deserves to be scrutinized more closely, as the economic recovery in the 1980's was partly caused by the creation of numerous part-time jobs. As discussed in the previous chapter, part-time employment had grown by 95% between 1983 and 1988 in the Central Area, and was partially responsible for the spreading of the peak-hour. Therefore, part-time travel demand into the Central Area will be examined in the subsequent chapters to explore its impact on the overall travel demand into the Central Area.

The impact of office automation in the work place, the increasing dominance of the office sector in the Central Area, as well as the continued structural change in employment in the Central Area as it became more executive in nature, has been well documented (City of Toronto, 1986e and 1986h, and Woodward, 1989). Although the FSW ratio has remained stable, the impact of the above mentioned factors will likely cause the FSW ratio to rise in the long term.

It was generally taken as a rule of thumb that an absenteeism rate of 10% for any given workday in the past was reasonable (City of Toronto, 1986h). It was also pointed that the absenteeism rate could indeed be on the rise. This is because of the large increase in part-time employment as well as the increased proportion of managerial and professional workers working in the Central Area. The increase in the absenteeism rate as well as a less well structured workday or workweek could have partially decreased the peak hour travel demand into the Central Area. This in turn might have caused an illusion that an imbalance existed between peak hour travel demand into the Central Area and the growth in office floor space. In effect an increasing absenteeism rate partly offset the increase in peak hour commuting trips which were related to employment and office space growth. The Nowlan and Stewart hypothesis did not address this potentially influential factor.

3.2 THE SARSAN MODEL

Some of the short-comings in the Nowlan-Stewart hypothesis were addressed by Sarsan (1991). The Sarsan analysis examined the applicability of the Nowlan-Stewart hypothesis for planning purposes. The Sarsan analysis concentrated on equation 1 of the Nowlan-Stewart hypothesis. The basic equation which Sarsan developed was of the form:

$$T = K + 0.9 * (0.04 * S - L * P) \quad \text{.....(3)}$$

where, T = Total inbound person trips entering the Central Area Cordon between 7:00 a.m. and 10:00 a.m.

S = Mid-year occupied office floor space in the Central Area in square metres

P = Central Area population

L = The percentage of Central Area population working in full-time office jobs in the Central Area

K = Background trips such as non-work trips, through trips, non-office work trips and part-time office work trips

A 10% absenteeism rate was included which was reflected by the 0.9 coefficient on the right hand side of equation 3. The FSW ratio was assumed to be constant at 25 square metres per worker over the study period.

In the Nowlan-Stewart hypothesis the K and L coefficients were assumed to be constant. K, the amount of background travel, was estimated to be 179,000, i.e., the constant term. L was calculated to be 70%, i.e., 70% of the Central Area population worked in full-time office jobs in the Central Area, without taking the absenteeism into account. However, the Sarsan study pointed out that there did not exist any time series data to analyze the variation of both the K and L coefficients between 1976 and 1988 to be able to derive a valid relationship.

As discussed before, the background travel into the Central Area might have been decreasing over time. Without knowing how it varied in the 1976-88 period, it was not feasible to project any future impact of the Central Area population had on reducing the morning peak hour inbound traffic. The K coefficient also proved to be very difficult to monitor as it required detailed origin-destination surveys to be conducted on a regular basis

The L coefficient calculated by the Nowlan-Stewart hypothesis appeared to be overestimated. The 1989 Central Area Residents' Survey (CARS) indicated that L could not have been anything higher than 35-40% (Sarsan, 1991). Thus, surveys similar to CARS should be conducted on a regular basis to monitor the structural changes in the Central Area in order to determine the L coefficient. This was a much less daunting task as compared to estimating the number of background trips using origin-destination surveys Given that the L coefficient was known over a reasonable length of time, it was then possible to derive meaningful relationship between travel demand and land use in the Central Area.

There are limitations to the use of the Nowlan-Stewart and the Sarsan models, when use to project future implications on the Central Area using housing, population, office development and transportation changes. Both models use past demographics as predictors of the future. The pitfall was implicit in these relationships, which assumed that all other factors and relationships affecting travel demand into the Central Area would remain unchanged over time. Therefore, using it as a planning tool to assess impacts of alternative strategies, as suggested by Nowlan and Stewart, could lead to erroneous evaluations. Also, the Nowlan-Stewart hypothesis appeared to be too simple to assess the impact of Central Area population growth on

morning peak hour inbound traffic entering the Central Area.

The estimated structural change in the Central Area population proved to be unrealistically high. This in turn overestimated its offset on the generation of additional inbound commuting trips into the Central Area during the morning rush hours. For the downtown population to have the desired effect of decreasing travel demand into the Central Area, the Central Area residents must be "self-contained". "Self-Containment" dictates that the jobs created in the Central Area must be filled by Central Area resident labour force. In the period between 1976 to 1989, the imbalance in growth between Central Area Travel demand and Core Area office floor space or employment was more likely to be caused by a number of factors including the growth of Central Area population as suggested in the Nowlan-Stewart hypothesis. These factors are summarized as follows (Transmode, 1991):

i) Additional housing was provided in the Central Area, accomodating part of the Central Area workers. In other wrods, the Central Area is becoming increasingly more "self-contained".

ii) The FSW ratio was in fact increasing over the study period. Little or no research was done in this area, although it was well documented that the recent trends of office automation, and the emerging executive nature of the Central Area workers would likely increase the FSW ratio (City of Toronto, 1986e, 1986h, 1990).

iii) An increase in a less structured workday or workweek for Central Area workers. As the Central Area was turning more executive in nature with higher proportions of managerial and professional workers, some of the commuting might have occurred outside the traditional morning peak hour.

iv) A decline in non-work trips and through trips entering the Central Area during the morning peak hours.

v) A decreasing proportion of office clerical workers making the commuting trip into the Central Area. Again, along with the increasing executive nature of the Central Area, a lot of "back office work" mainly done by clerical workers was moved outside the Central Area where rents were less expensive. These clerical workers tended to have a very rigid commuting schedule to travel inside the morning peak hours.

3.3 POLICY CONSIDERATIONS

The relationship between the location of activities and the transportation system has long been discussed and researched (Alonso, 1967). However, it has been treated as two independent entities in planning. In land use planning the transportation component was basically treated as an exogenous variable. On the other hand, transportation planners had tended to handle land use variables as an input to demand (De La Barra, 1989). A classic example is the urban transportation modelling system (UTMS). The demographic inputs were generated independently by a land use forecasting model, and usually the land use and the transportation models possessed implicit characteristics that were incompatible with each other. This could result in the development of UTMS models which had serious internal inconsistencies (Meyer and Miller, 1984).

At present, short-range and problem-oriented models dominate in the planning process This type of planning still requires considerable development as it finds the same old challenges as those faced by the long-range, comprehensive models. Therefore, the understanding of the urban activity system and its relationship with the transportation system was essential if one is to develop integrated land use-transportation models which would provide valuable and accurate results.

The Nowlan-Stewart hypothesis as well as the Sarsan model basically tried to link the relationship between transportation and land use in the Toronto Central Area through a simple, time series, linear format. Housing and employment were used as the two major inputs in the land use context. The development of Central Area Office Space would attract the location of businesses which in turn generated new employment. Some of these new workers would generate a demand for new housing in the Central Area. Those who worked and lived in the Central Area would only create travel demand that was internal to the Central Area during the peak period. Those who chose to live outside the Central Area would generate additional commuting trips to the Central Area, thus putting additional burden on the already heavy-loaded transportation system. The original Nowlan-Stewart hypothesis could provide a very simple framework for quick assessment of various policy options. Figure 3 illustrates the relationship between employment, housing and transportation as well as their policy measures. As development policy calls for further development in the Central Area, travel demand will be expected to grow as illustrated in figure 4.

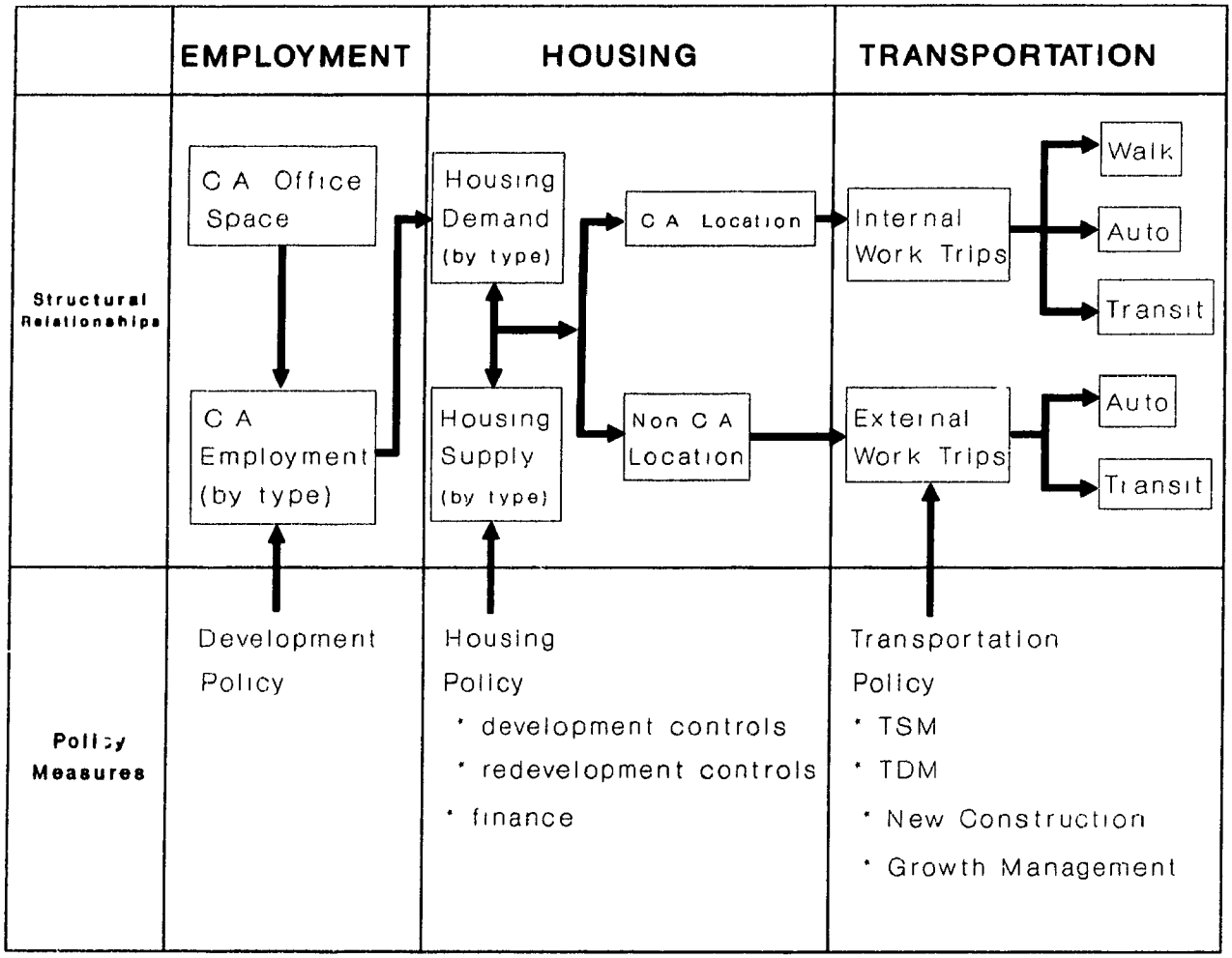


Figure 3:Policy Measures and Their Effects

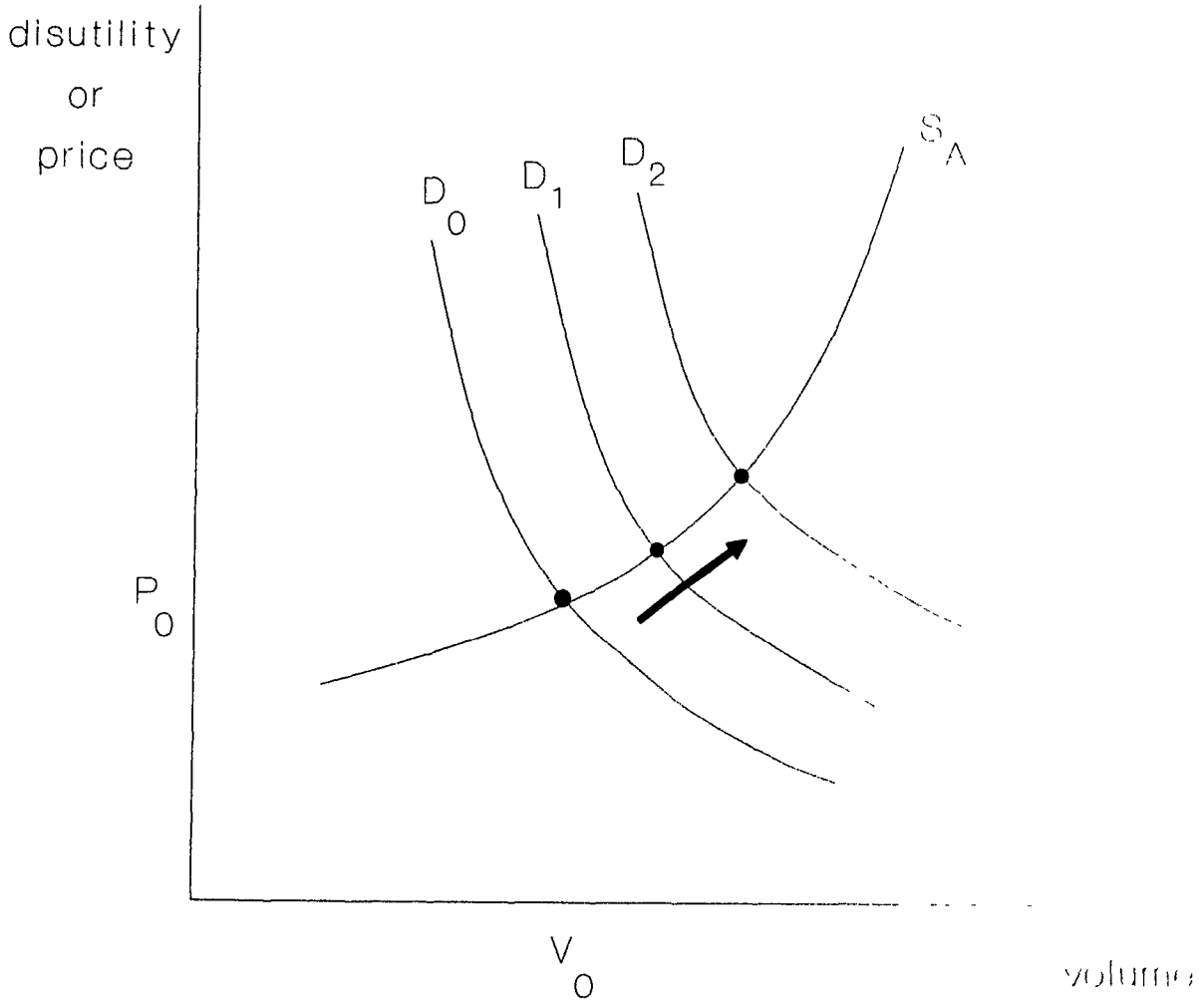


Figure 4: Increasing Demand and Congestion Over Time

In responding to this problem, a number of alternative strategies or policies are available to ease this problem (Rice, 1990). In the short term, the implementation of various transportation policies, such as Transportation Supply Management (TSM), Transportation Demand Management (TDM) and construction of new facilities to provide new capacities can be utilised to balance urban growth. The responses of these policies are illustrated in figure 5,6 and 7 respectively.

Transportation Supply Management (TSM) employs techniques which improve the management and operation of existing facilities. The supply curve would shift to the right from S_A to S_A', which in turn shifts the demand curve to the D_1 position (figure 5). Examples are traffic signal coordination, installation of HOV lanes, various traffic engineering measures and automatic control systems.

Transportation Demand Management (TDM) tends to be behaviour-oriented. It tries to change the commuter's travel behaviour such that the existing transportation system is used more fully, causing the supply curve to shift to the left from S_A to S_A'. The implementation of this policy would cause demand to slow its growth, shifting only to D_1' instead of D_1. However, the users will experience higher disutility (figure 6). Examples are ride sharing, park-and-ride programs, parking controls, road pricing and modified work schedules.

The provision of new transportation facilities give additional capacity to the existing system. The supply is greatly increased causing the supply curve to move from S_A to S_B. Demand will increase shifting to a new position at D_1 causing the disutility to decrease (figure 7).

These measures tend to be short term in nature and only treats the problem superficially. A longer term response which calls for urban growth management tends to treat the problem at the root level by redirecting urban growth patterns. It tries to strike a balance between development and transportation. For example, using the Nowlan-Stewart hypothesis, development in the Central Area is still feasible as long as housing is provided for those who live and work in the Central Area without the provision of new transportation facilities. However, the effect of Central Area population growth on travel demand was overestimated by the Nowlan-Stewart model. As long as urban growth is under control and well managed, the travel demand can be controlled to grow at a slower, more desirable rate as illustrated by figure 8.

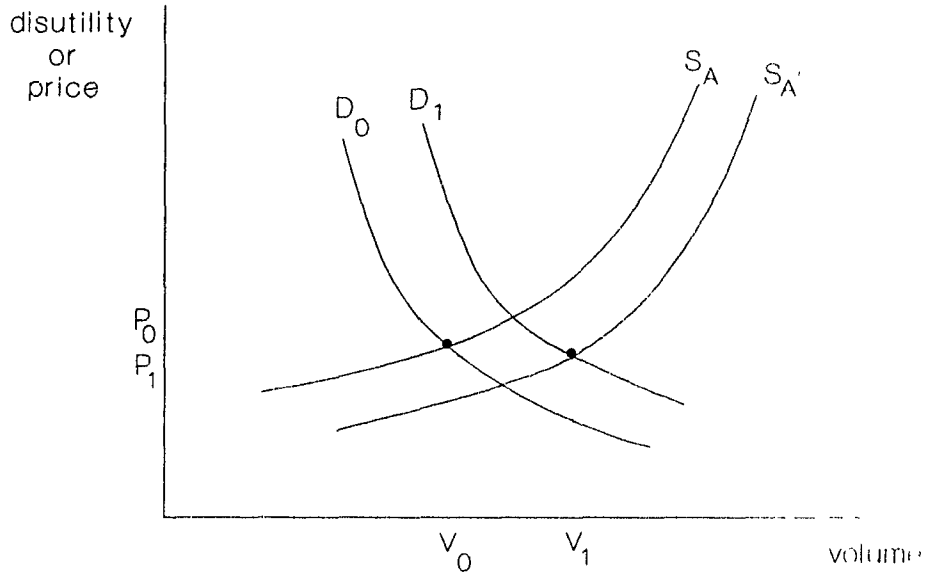


Figure 5: Transportation Supply Management (TSM)

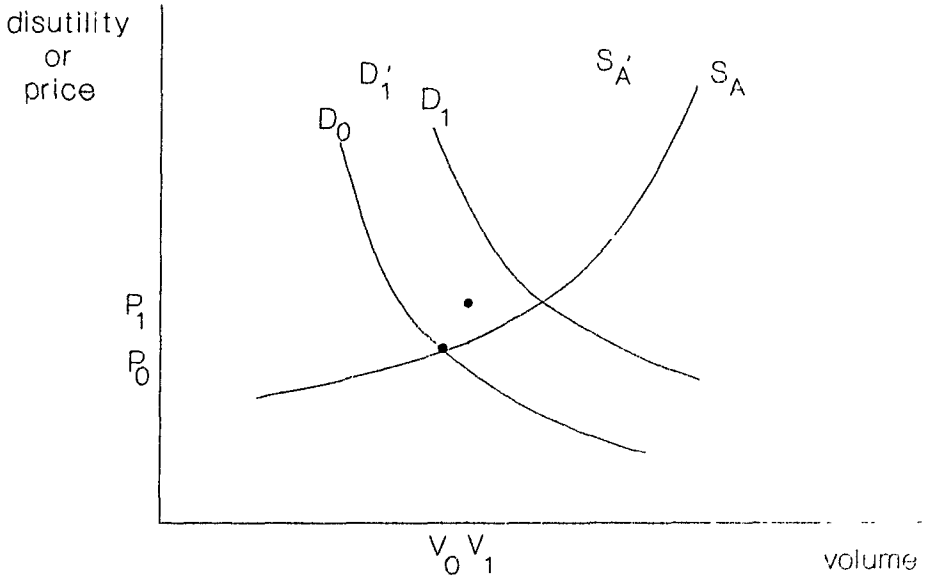


Figure 6: Transportation Demand Management (TDM) (travel behaviour)

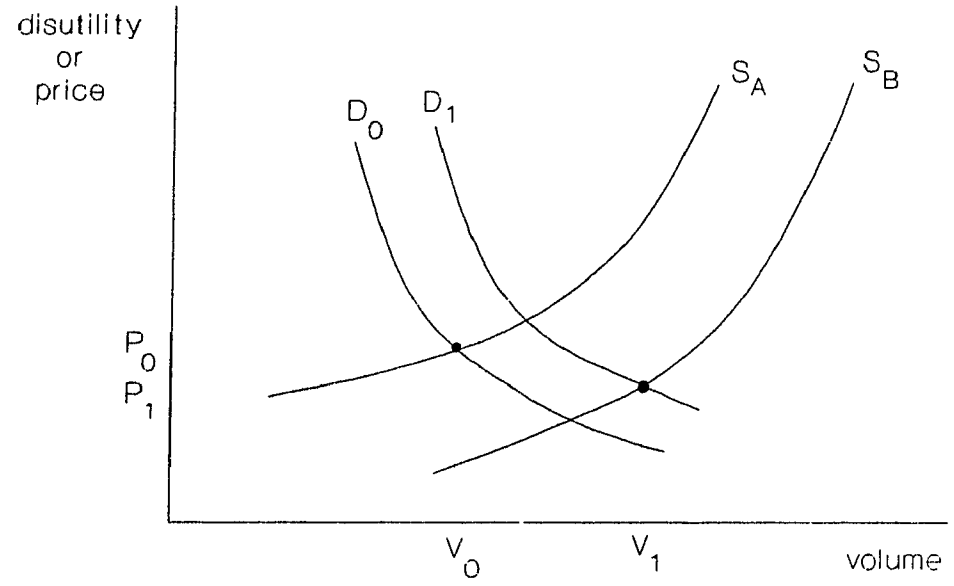


Figure 7 : Introduction of New Transportation Facilities

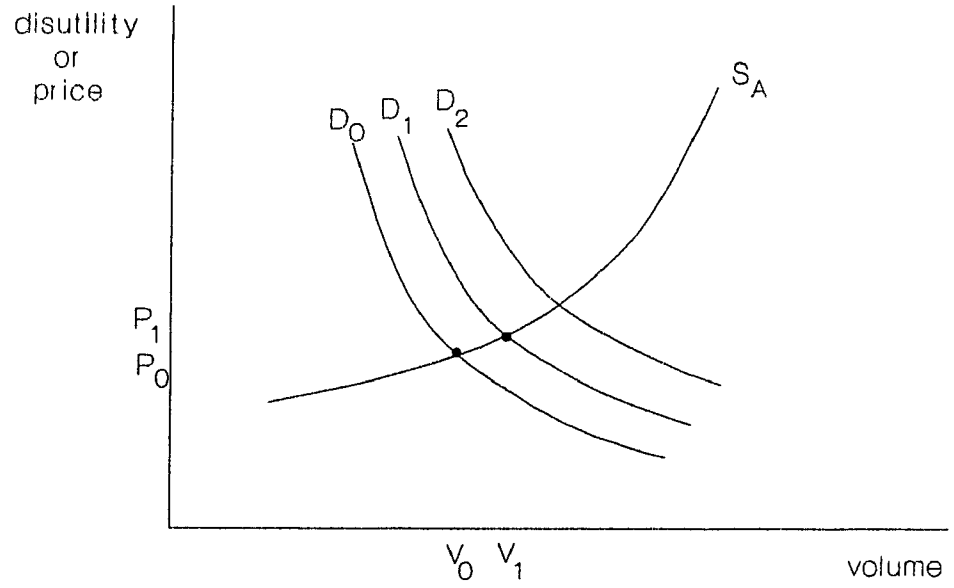


Figure 8 : Urban Growth Management

4.0 AN IN-DEPTH ANALYSIS OF TRAVEL PATTERNS IN THE CENTRAL AREA

The focus of this chapter is the assessment of travel patterns related to the central area. Detailed examination of factors such as Place-of-Residence and Place-of-Work (POR-POW)linkages, 24-hour work trips as well as mode choice were beyond the scope of the Nowlan-Stewart analysis. In this chapter the analysis utilizes data gathered in the past 14 years for a more detailed analysis, in order to understand the role of the Central Area as a trip attraction centre. The data used to support this analysis are as follows:

i) 1971,81 and 86 census POR-POW Linkages

ii) 1979 Metro Travel Survey (MTS) and 1986 Transportation Tomorrow Survey (TTS) 24 hours work trip tabulations.

iii) Time series Central Area Cordon Count data (1975-1989).

Although these data sets have been researched extensively and independently, it is worth examining them in the Nowlan-Stewart hypothesis context. The historical trends in the journey to work in terms of the spatial distribution of these trips, and the mode choice distribution would help to give a better understanding of commuting trips destined to as well as originating in the Central Area.

4.1 THE PLACE-OF-RESIDENCE TO PLACE-OF-WORK LINKAGES ANALYSIS

In order to get a general understanding of the travel patterns regarding the Central Area, the POR-POW linkages were used for this analysis. The analysis was divided into three stages.

First, the travel pattern was examined using a very simple two zone designation. The Central Area zone was designated as the internal zone, whereas the rest of the study area i.e., zones 2 to 7 were designated as the external zone. Three types of travel patterns were investigated, namely, internal to internal , external to internal and internal to external linkages. Table 14 summarizes these travel patterns from the three census sources.

YEAR	INT-INT	EXT-INT	INT-EXT
1971	32,760	241,980	14,175
1981	39,575	321,205	17,270
1986	45,147	343,097	24,789
% GROWTH,71-81*	20.8 (2.08)	32.7 (3.27)	21.8 (2.18)
% GROWTH,81-86*	14.1 (2.82)	6.8 (1.36)	43.5 (8.78)

* Number in brackets represent average annual growth rate.

Table 14: POR-POW Linkages by Zone

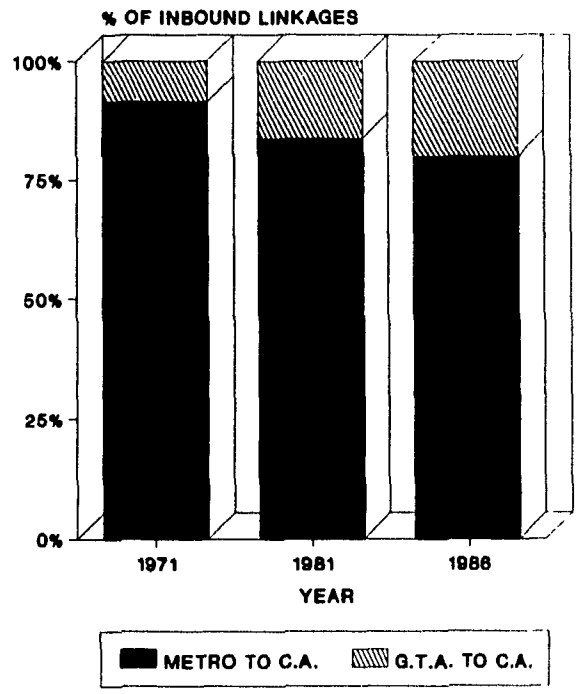
The volume of all three zonal pairs has grown over time at substantially different rates. Most significant was the growth rate of more than 40% shown by the internal to external linkages between 1981-86 The rate of growth of these internal to external linkages or "reverse commuting" have accelerated between 1981 and 1986 with an average annual growth rate of 8.8%. The internal to external linkages also experienced the highest growth of the origin-designation pairs between 1981 and 1986, and the most consistent growth at an average annual rate of around 2.5%.

The next stage of the analysis was to divide the trips from the external zones into those originating from or destined to the Metro Toronto Area (zones 2,3 and 4), and those originating from or destined to the rest of the Greater Toronto Area (zones 5,6 and 7). Table 15 and figure 9 summarizes the spatial distribution of these origin-designation pairs.

	INBOUND		OUTBOUND	
YEAR	METRO-C.A.	GTA-C.A.	C.A.-METRO	C.A.-GTA
1971	221,130	20,950	12,930	1,245
1981	268,405	52,800	14,755	2,515
1986	273,626	69,471	21,140	3,649
% GROWTH, 71-81*	21 4 (2.14)	153.2 (15.3)	14.1 (1.41)	102 (10.2)
% GROWTH, 81-86*	1.9 (0.39)	31.4 (6 31)	43.3 (8.65)	45.1 (9.0)

* Number in brackets represent average annual growth rate.

Table 15: Spatial Distribution of POR-POW Linkages, 1971-86



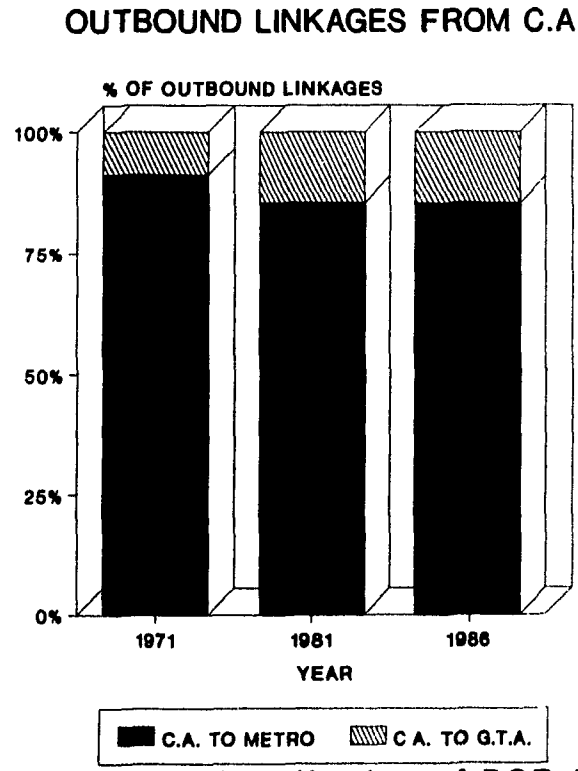


Figure 9: The Spatial Distribution of POR-POW Linkages

For inbound linkages i.e., those destined to the Central Area, Metropolitan Toronto linkages composed the majority, although its share was declining from 91.4% in 71 to 79.8% in 1986. Therefore, it illustrates that long distance commuting was increasing for those who worked in the Central Area, with nearly 1 in 5 linkages into the Central Area originated from outside Metropolitan Toronto. The reasoning can be seen by the growth in linkages into the Central Area from these 2 areas. The growth of Metro-Central Area linkages of 24% between 1971 and 1986 (1.6% annually) was small compared to the 233% (15.5% annually) growth experienced by the Greater Toronto Area-Central Area linkage. Again, the majority of growth occurred between 1971 and 1981. Between 1981 and 1986 the Metro-Central Area linkage exhibited near zero growth.

The outbound linkages demonstrated different trends. The majority of growth occurred between the 1981 and 1986 period. Both the Central Area-Metro and Central Area-Greater Toronto Area linkages grew by more than 40% during this period. However, the Central Area-Greater Toronto Area linkage also experienced tremendous growth between 1971 and 1981 of over 100%, but the absolute number was insignificant relative to other origin-designation linkages. The proportion of Metro bound linkages remained stable between 1981 and 1986. Seventeen out of twenty linkages originating in the Central Area were destined to the Metro Area.

Another disaggregate analysis was undertaken to examine these linkages by directional corridor. Table 16 and figure 10 summarizes the directional linkages by corridor The Eastern corridor was made up of zones 2 and 5; the Northern corridor was composed of zones 3 and 6, and the Western corridor consisted of zones 4 and 7.

	INBOUND			OUTBOUND		
YEAR	EAST	NORTH	WEST	EAST	NORTH	WEST
1971	67,050	89,520	85,410	2,505	6,195	5,475
1981	92,360	111,005	117,840	3,055	7,815	6,400
1986	95,145	118,508	129,444	5,420	10,208	9,161
% GROWTH, 71-81*	37.7 (3 77)	24.0 (2.40)	38.0 (3.80)	22.0 (2.20)	26.2 (2.62)	16.9 (1.69)
% GROWTH, 81-86*	3.0 (0.60)	6.8 (1.35)	9.8 (1.97)	77 4 (15.5)	30.6 (6.12)	43.1 (8 62)

* Number in brackets represent average annual growth rate.

Table 16: POR-POW Linkages by Directional Corridor

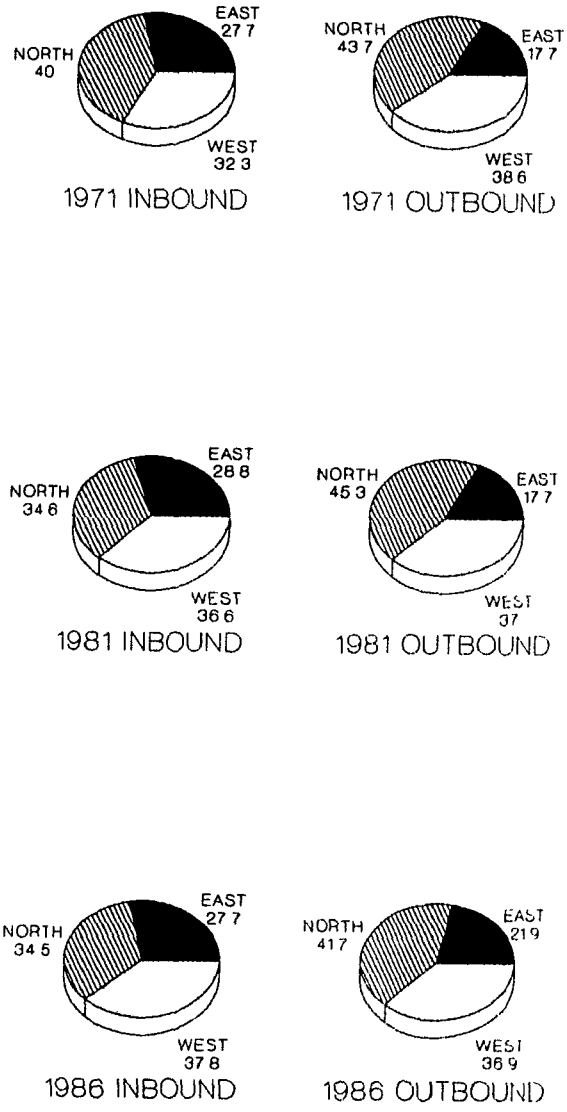


Figure 10: Spatial Distribution of Linkages by Directional Corridor

For inbound linkages, the western corridor has emerged as the major corridor for carrying commuters into the Central Area. The Northern corridor also shares similar but sightly less growth, whilst the Eastern corridor experienced little growth in the 1981 to 1986 period.

All three corridors for outbound linkages experienced significant growth. The most notable was the Eastern corridor growing 77.4% between 1981 and 1986. The Northern corridor carried the majority of linkages from the Central Area.

4.2 ASSESSMENT OF 24 HOUR WORK TRIPS

The POR-POW tabulations only record where people live and work. For a more detailed analysis investigating the mode choice used by these workers, the use of 24-hour work trip was required. The primary sources for this assessment came from the 1979 Metro Travel Survey (MTS) and the 1986 Transportation Tomorrow Survey (TTS). However, the 1979 MTS did not include data from areas outside Metro Toronto, therefore in order to make these survey results more compatible and consistent, the use of zones 5,6 and 7 was abandoned in the 1986 TTS. This limited the analysis to the examination of the spatial distribution of work trips by mode in the Metro Toronto region. Hence, the external zones only consist of zones 2, 3 and 4. Table 17 summarizes the findings between the internal and external zones.

	INT-INT		EXT-INT		INT-EXT	
MODE	79 MTS	86 TTS	79 MTS	86 TTS	79 MTS	86 TTS
AUTO*	26%	19%	35%	34%	51%	48%
TRANSIT#	37%	37%	64%	64%	47%	49%
WALK/OTHER	37%	44%	1%	2%	2%	3%

* Auto work trips include taxi
# Transit work trips include GO-Rail

Table 17: Spatial Distribution of Work Trip by Mode

The work trips that occur within the Central Area (internal-internal) show that the walk/other mode dominates and was consistent with other research (see Chapter 2). The walk/other mode actually increased its proportion from 37% to 44% between 1979 and 1986, and was apparently growing at the expense of auto trips.

The Metro to Central Area commuting was dominated by the transit mode, and shows little change over the period 1979 to 1986. This modal split of 1/3 auto trips and 2/3 transit trips has perhaps reached an equilibrium. It is unlikely to change unless new transport facilities were provided (Woodward, 1989).

For "reverse commuting" i.e., Central Area to Metro, the mode split appeared to be 50/50, because the transport facilities are relatively less congested in this direction, and it could become more transit oriented as congestion grows. It was also interesting to note that the same mode split of 50/50 was the case during the 1960's for inbound commuting trips (Woodward, 1989).

It is evident that the proportion of each mode used for commuting was strongly linked to trip orientation or commuting distance. Table 18 illustrates this trend using the 1986 TTS (including work trips to and from areas outside Metro).

MODE	GTA - C.A.	C.A. - GTA
AUTO*	47%	81%
TRANSIT#	52%	19%
WALK/OTHERS	1%	0%

* Auto work trips include taxi
# Transit work trips include GO-Rail

Table 18: Spatial Distribution of 1986 TTS 24 hour Work trips by Mode of Travel

4.3 METRO CORDON COUNT

The Metro Cordon Count program provides detailed person and vehicle counts, permitting a more detailed assessment of mode choice and the distribution of trips associated with the Central Area. The Central Area Cordon was used for the purpose of this analysis. Its boundaries were described in Chapter 1 (for more details see Metropolitan Toronto, 1990). The analysis period used was from 1975 to 1989. The peak period used in the analysis referred to 6:30 a.m. to 9:30 a.m. for all trip purposes and modes.

4.3.1 Passenger Trips

The overall inbound person trips during the morning peak period entering the Central Area has grown by 15.2% between 1975 and 1989. Approximately 340,000 passengers were entering the Central Area between 6:30 a.m. and 9:30 a.m. in 1989. The north cordon possesses the highest increase of 18%, whereas the east and west cordons have growth of 14.8% and 13.3% between 1975 and 1989 respectively. The west cordon has always contributed the most passengers entering the Central Area, while the north cordon has the least.

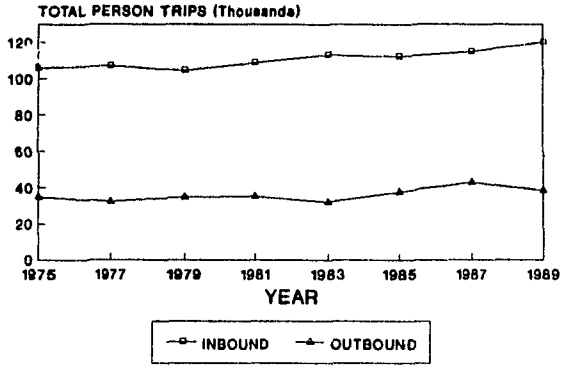
Table 19 summarizes the relative proportion of passenger flow for each cordon boundary. It is evident that these proportions have stayed stable during the study period. Figure 11 illustrates the number of total person trips (all modes) crossing the Central Area Cordon in both directions.

	INBOUND			OUTBOUND		
YEAR	EAST(%)	NORTH(%)	WEST(%)	EAST(%)	NORTH(%)	WEST(%)
1975	34.2	29.7	36.1	27.1	39.3	33.6
1977	31.8	32.5	35.7	27.2	39.8	33.0
1979	35.6	30.1	34.3	25.9	39.7	34.4
1981	34.9	31.6	33.5	24.9	42.7	32.4
1983	33.2	31.6	35.2	28.6	41.1	30.3
1985	32.5	32.0	35.5	28.1	39.3	32.6
1987	34.7	31.1	34.2	26.1	37.8	36.1
1989	34.1	30.4	35.5	27.2	39.5	33.3

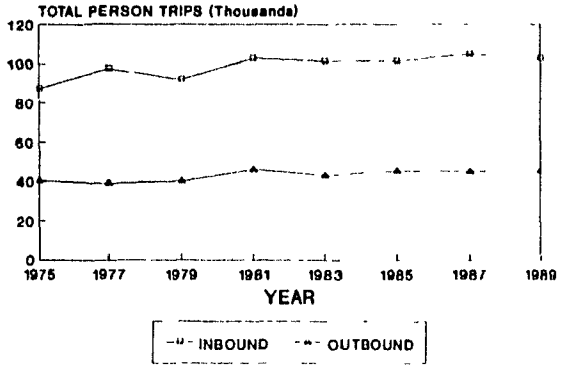
Table 19: Distribution of Total Passenger Trips by Cordons in Both Directions, 1975-89

Figure 12 displays the growth of passengers using automobile crossing the Central Area Cordon between 1975 and 1989. The Central Area Cordon inbound trips has seen little growth, and the net effect is a decline in auto-occupancy rate as discussed in the next section. Although the west cordon exhibits growth in auto person trips, the east and west cordons remained relatively constant over time. The west cordon's proportion also grew from 32.3% in 1975 to 35.5% in 1989 at the expense of the north cordon. The east cordon consists of nearly 40% of all passengers using automobile to enter the Central Area during this period (Table 20).

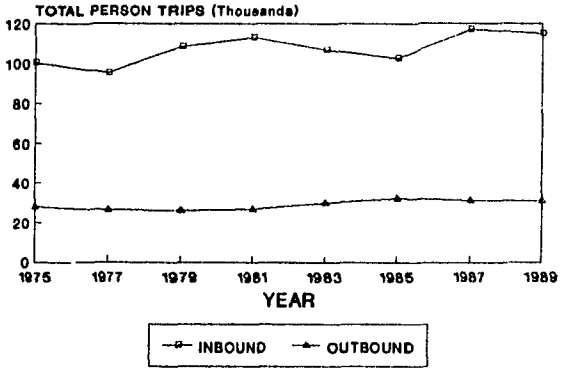
TOTAL PERSON TRIPS AM PEAK 06:30-09:30
BATHURST STREET (WEST)



TOTAL PERSON TRIPS AM PEAK 06:30-09:30
RAILWAY CORDON NORTH



TOTAL PERSON TRIPS AM PEAK 06:30-09:30
RAILWAY CORDON EAST



TOTAL PERSON TRIPS AM PEAK 06:30-09:30
CENTRAL AREA CORDON

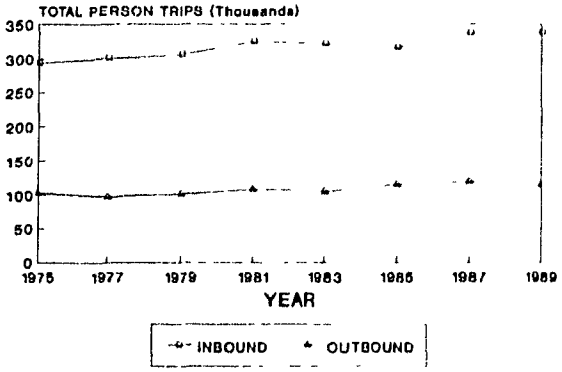
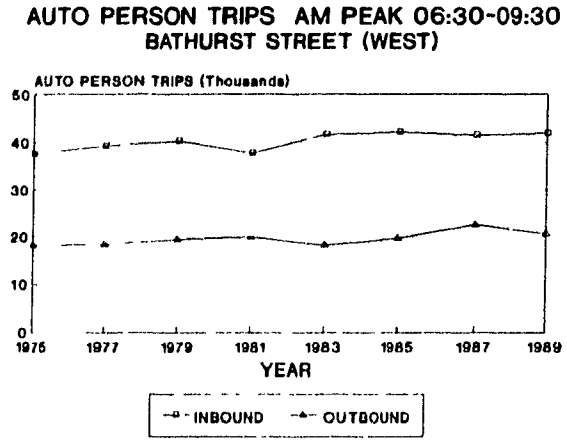
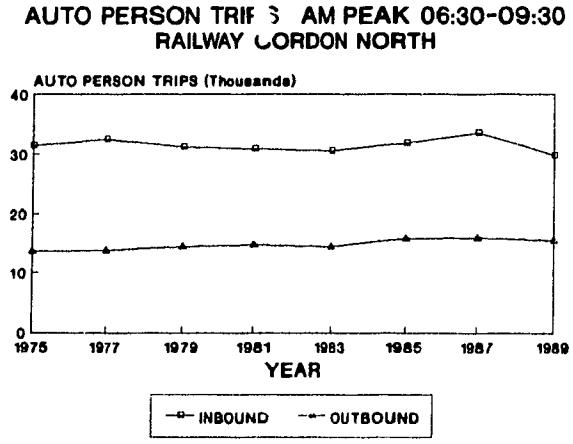
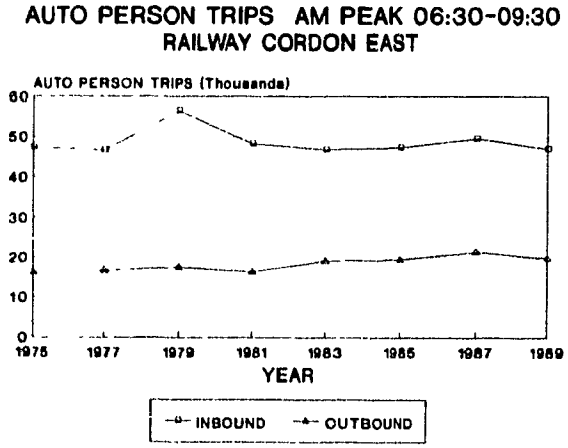


Figure 11: Total Person Trips 1975-89, All Mode







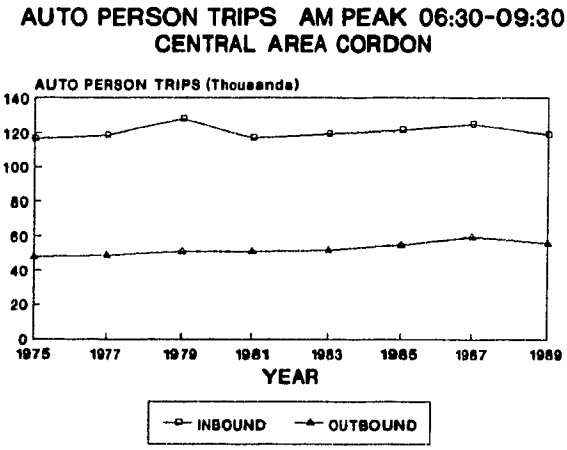


Figure 12: Auto Person Trips, 1975-89

The outbound trips showed some growth during this period, at a rate of 16.4%. However, the proportion of traffic leaving each cordon remains relatively stable with the west cordon accounting for the largest proportion (Table 20).

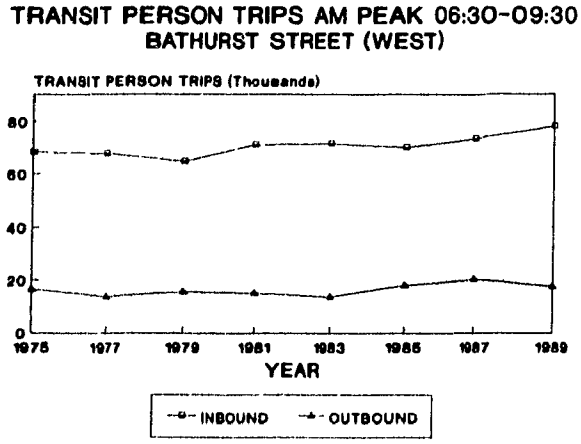
YEAR	INBOUND			OUTBOUND		
	EAST(%)	NORTH(%)	WEST(%)	EAST(%)	NORTH(%)	WEST(%)
1975	40.7	27.0	32.3	33 8	28.3	37 9
1977	39 5	27.5	33.0	34.0	28 2	37 8
1979	44.2	24.4	31 4	34.0	28.1	37 9
1981	41.4	26.4	32.2	32.0	28.8	39.2
1983	39.3	25.7	35.0	36 9	27 8	35 3
1985	39.1	26.2	34 7	35 4	28.7	35 9
1987	39.8	27.0	33.2	35 8	26.5	37.7
1989	39.6	25.1	35.3	35.3	27.7	37.0

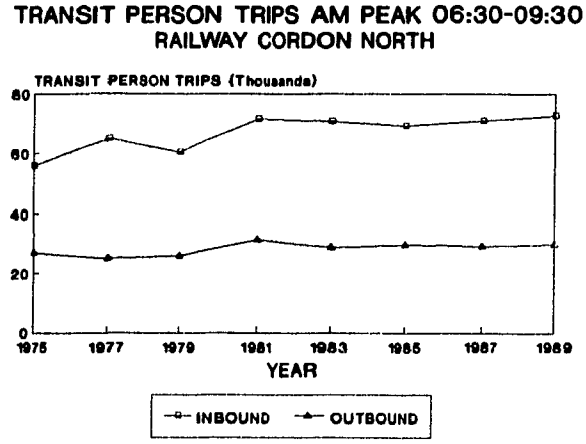
Table 20: Distribution of Auto Passenger Trips by Cordons in Both Directions, 1975-89

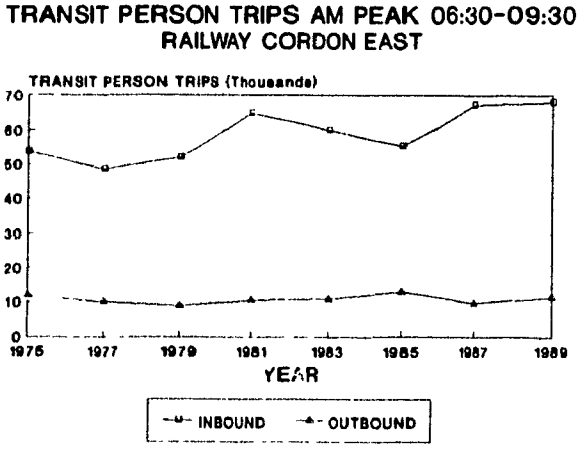
On the contrary, for passengers using transit to enter the Central Area, the historic trends showed significant growth during the study period. The north cordon experienced the highest growth of 31.1%, whereas the east and west cordons grew 28.5% and 14.4% respectively (Figure 13). Although the west cordon displayed the least growth, it accounted for the highest proportion of inbound transit person trips to the Central Area (Table 21). The overall result was that the number of Central Area bound transit passengers had increased from 177,700 trips in 1975 to 220,000 trips in 1989 as illustrated in figure 13.

YEAR	INBOUND			OUTBOUND		
	EAST(%)	NORTH(%)	WEST(%)	EAST(%)	NORTH(%)	WEST(%)
1975	30.2	31.3	38.5	21 4	48.7	29 9
1977	26.7	35.9	37.4	20 4	51.4	28 2
1979	29.4	34 2	36.4	17.7	51 6	30.7
1981	31.2	34.6	34.2	18.5	55.2	26 3
1983	29.6	35.8	35.4	20.5	54.1	25 4
1985	24.4	35.6	36.0	21.3	49 0	29 7
1987	31.8	33.6	34.6	16 2	49 2	34 6
1989	31.1	33.3	35.6	19 6	50 6	29 8

Table 21:Distribution of transit Passenger Trips by Cordons in Both Directions, 1975-89







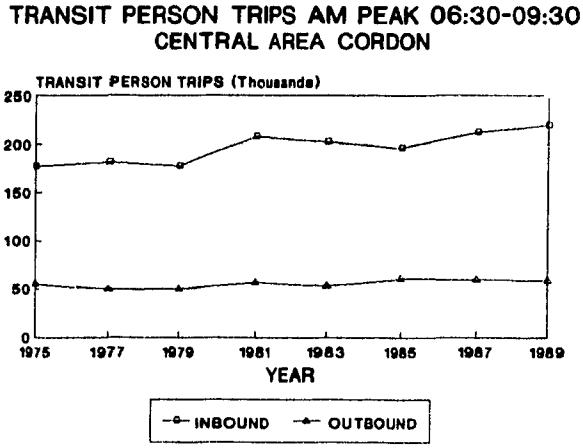


Figure 13: Transit Person Trips, 1975-89

The north cordon also showed an increase of nearly 10% in outbound transit passenger trips. However, the east and west cordon displayed little or no growth in terms of transit passenger trips leaving the Central Area (Figure 13).

4.3.2 Auto Vehicle Trips and Vehicle Occupancy Rate

Figure 14 illustrates the number of automobiles (including taxis) entering and leaving the Central Area between 1975 and 1989. Both inbound vehicle trips and outbound vehicle trips exhibited a steady increase. However, as illustrated in the previous section, auto person trips in both directions remained relatively stable over this period. The result is that the auto-occupancy rate must have fallen.

Figure 15 shows the auto-occupancy rate for inbound traffic between 1975 and 1989. The occupancy rate has decreased from 1.32 person per automobile to 1.23 person per automobile over 14 years. This averages to be nearly 0.5% annually in the decline, and is significant for this kind of factor. For outbound traffic, although the trends were much less clear for individual cordons, the general effect was that vehicles leaving the Central Area were carrying 1.19 persons per vehicle in 1975 as compared to 1.14 persons per vehicle in 1989 as illustrated in figure 16

4.3.3 The Peak Period Factor

Theoretically speaking, as the number of passenger trips entering the Central Area increases during the peak period, it causes the peak hour to spread. This phenomenon of peak period spreading is the result of "travel demand into the Central Area reaching or exceeding available capacity over a longer period" (Metropolitan Toronto, 1990, p.5). In order to explain the imbalance between travel demand growth into the Central Area and downtown development, it was important to examine if a greater number of commuting trips were being made outside the conventional three-hour morning peak period.

Figure 17 defines the peak period factor as the ratio of the number of person trips by mode during the morning peak period (6:30 a.m. - 9:30 a.m.) to the total number of person trips by mode between 6:30 a.m. to 11:30 p.m.

Figure 14: Auto Vehicle Trips
CENTRAL AREA CORDON, 6:30-9:30 A.M.

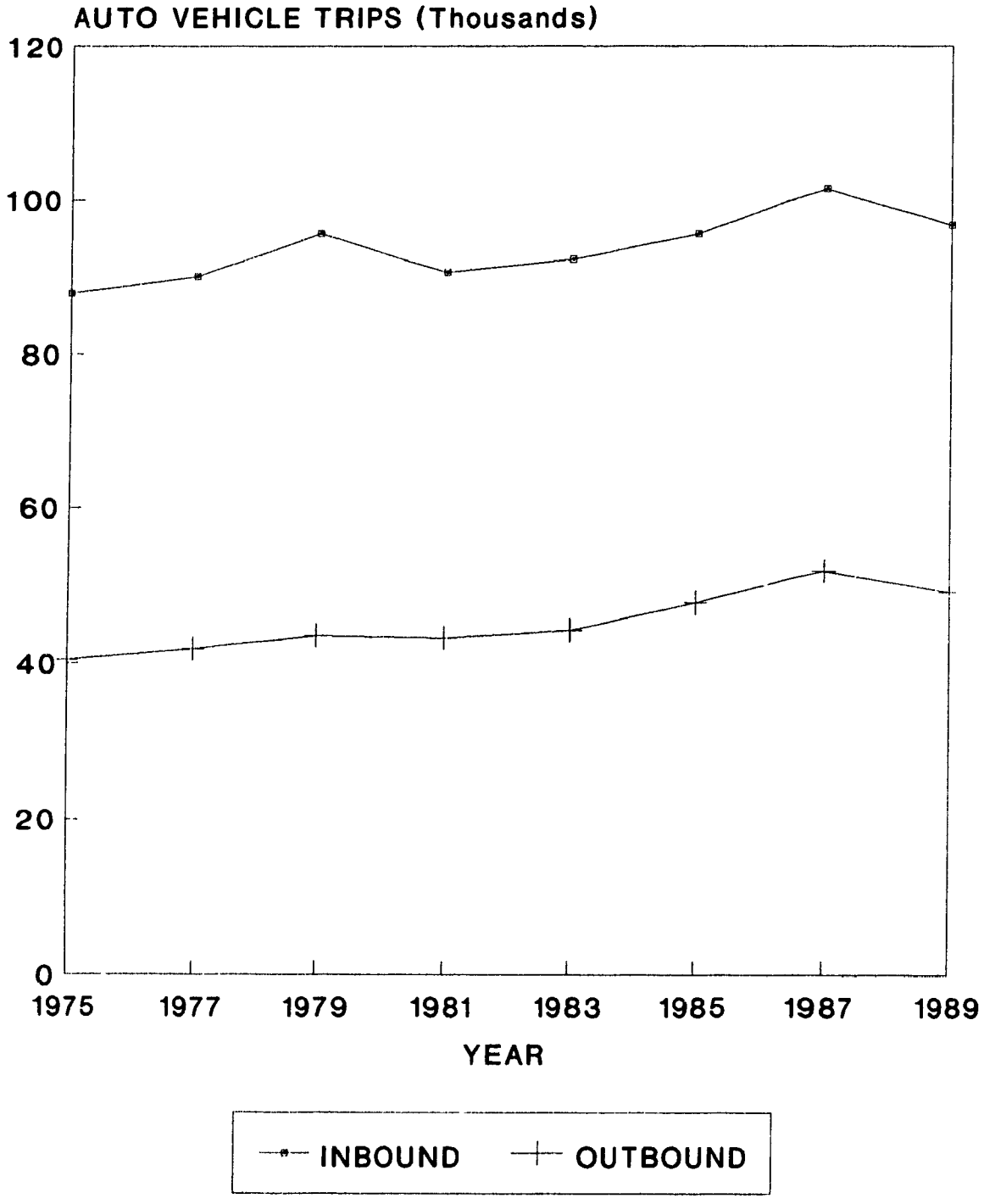
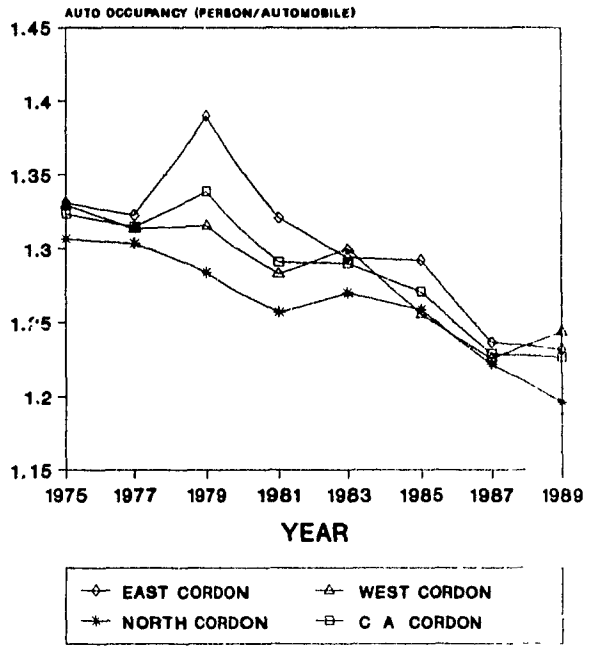
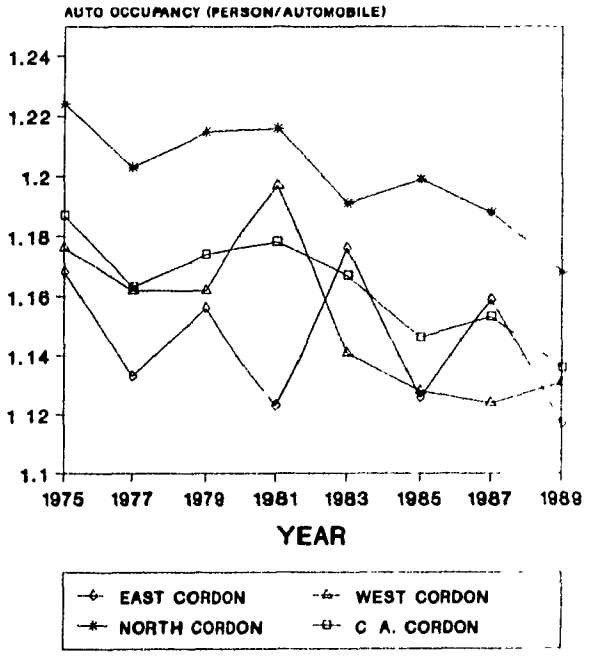


Figure 15: Auto Occupancy, 1975-89
Inbound Traffic

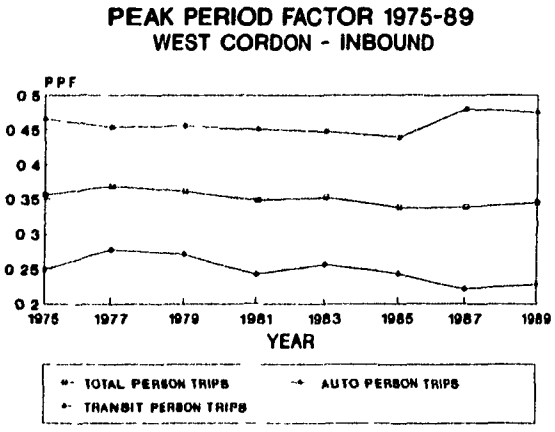


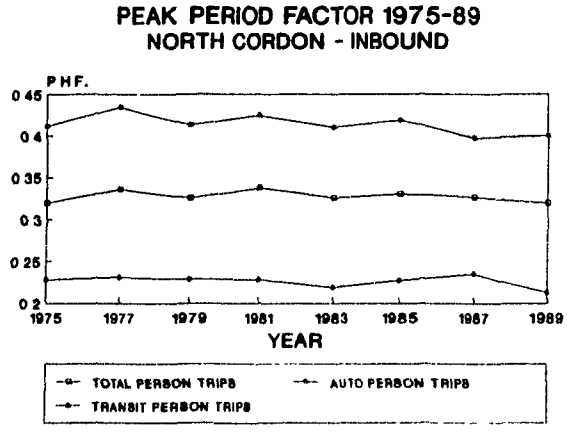
3 HOUR PERIOD, 6 30-9.30 A M

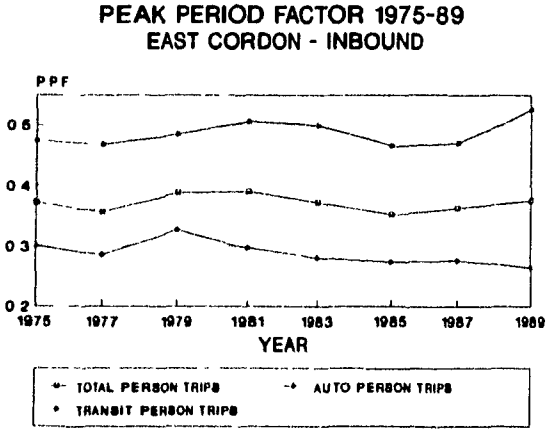
Figure 16: Auto Occupancy,1975-89
Outbound Traffic



3 HOUR PERIOD 6.30-9.30 A.M







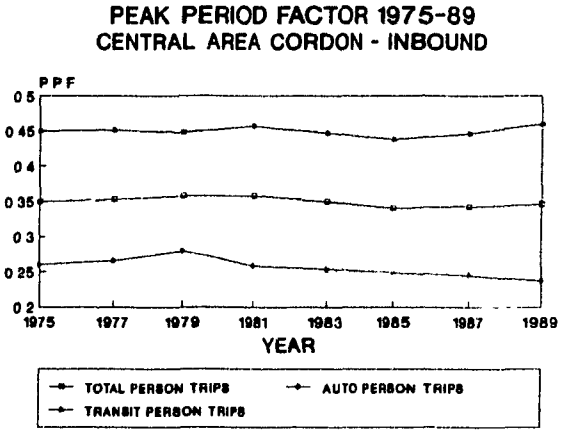


Figure 17: Variation of Peak Period Factor, 1975-89

For transit person trips, the peak period factor has remained quite stable at between 45-50% for both the west and east cordons. The north cordon exhibited a lower percentage of transit person trips than the rest, and was declining to a low of 40% in 1989. Overall, the transit person trips' peak period factor has remained constant at 45% over the years.

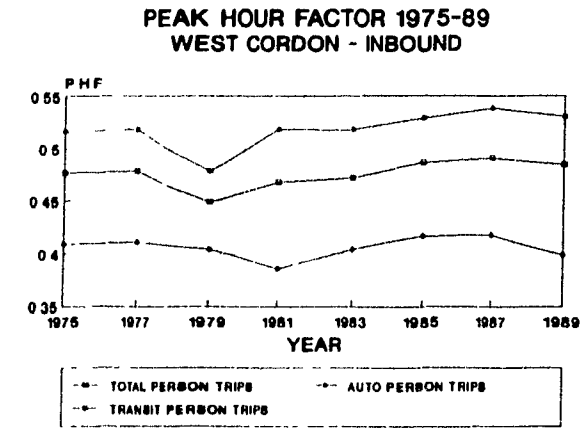
The peak period factor for automobile users behaves quite differently. All three cordons indicate that the peak period factor is declining. Thus, the net effect clearly shows that auto person trips are shifting away from the conventional morning peak period. Unfortunately, the proportion of auto person trips which involved the journey-to-work trip could not be estimated using these data alone.

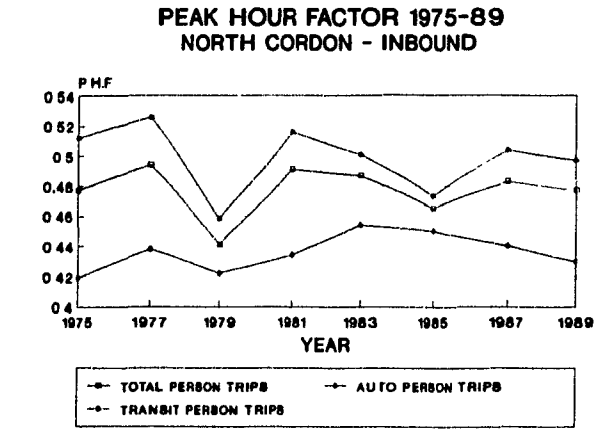
Further analysis was done to assess the "flattening" of the peak period. Figure 18 defines the peak hour factor as the ratio of the one-hour peak hour volume within the three-hour morning peak period. The peak hour factor for the Central Area indicated a continuous decline for inbound auto person trips from 1983 onwards. This fact demonstrated that the peak hour was in fact "flattening" and further supported the hypothesis that automobile trips were switching to travel in the off-peak hours. Figure 19 illustrates that for outbound trips, across the north and east cordons, the three-hour peak period factor for auto trips were in fact increasing, but the west cordon showed no definite trends. Transit person trips indicated that the peak period factor was on the decline. The result is that for total person trips, this ratio is decreasing. A review of the one hour peak hour factor further confirmed this result (figure 20).

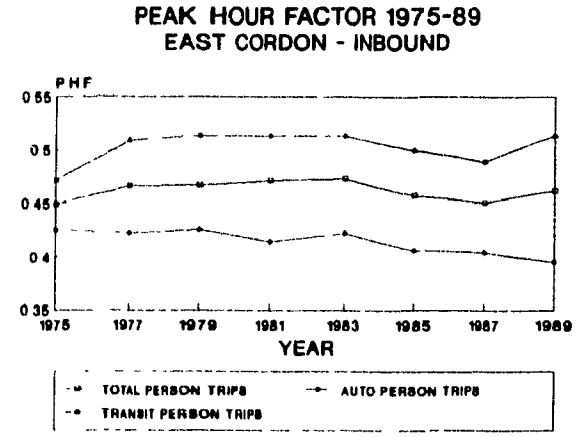
4.3.4 Modal Split

Given the detailed information from the Cordon Count data, the modal split issue was also analyzed. Figure 21 and 22 illustrates the historical trends in the percentage of transit and auto usage for the Central Area Cordon. In 1989, the automobile carried 35% of the inbound passengers into the Central Area, and this ratio correlated well with the travel survey results (see section 4.2). The north cordon accounted for the highest transit usage of about 70%, whereas the east cordon had the lowest percentage of transit users in 1989.

On the other hand, outbound traffic displayed considerably different trends. The east and west cordons shows a high auto usage of 63% and 54% respectively in 1989. The north cordon's outbound trips was made up of a ratio of one third auto and two thirds transit in 1989. However,







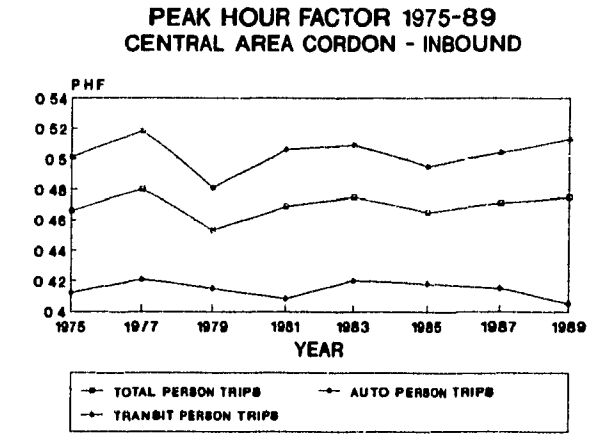
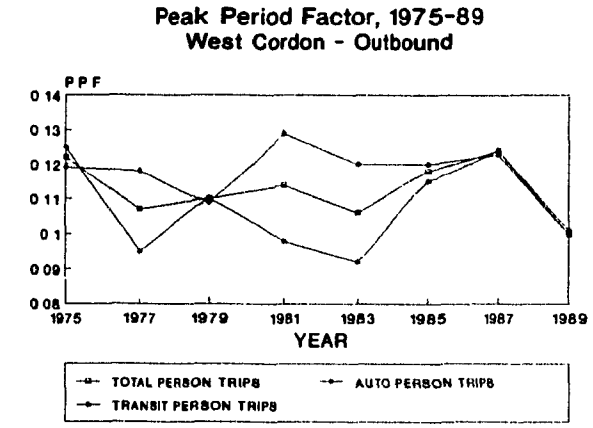
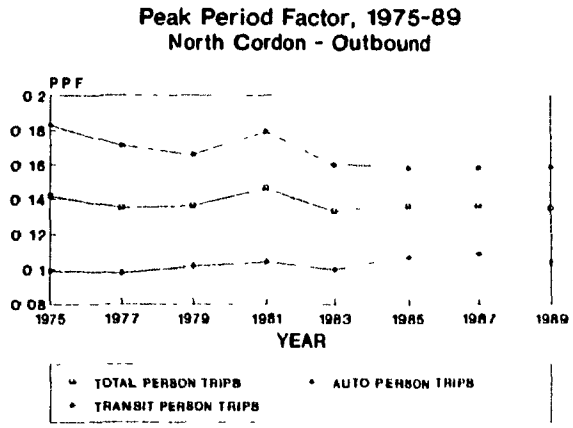
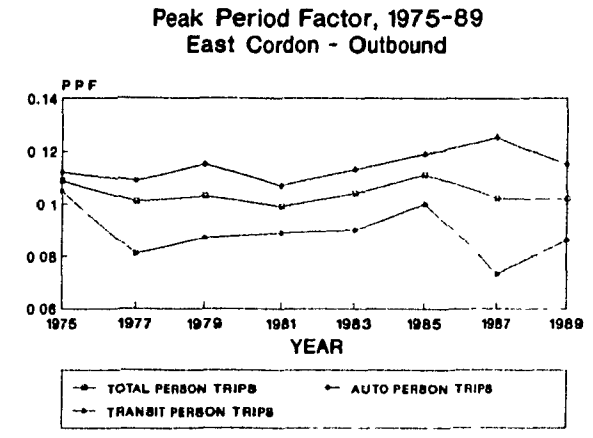


Figure 18: Variation of Peak Hour Factor, 1975-89







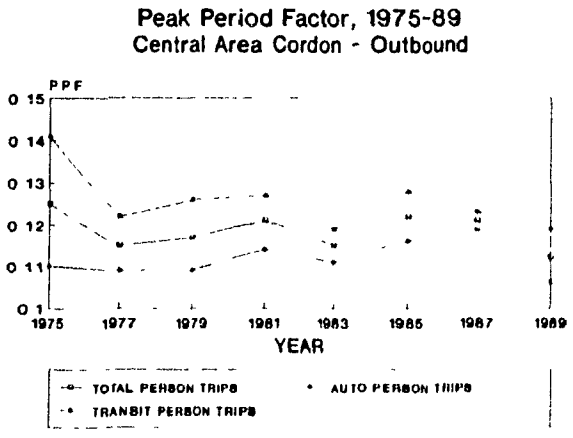
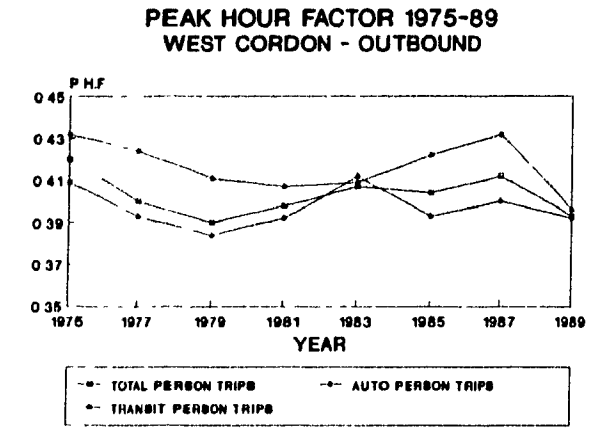
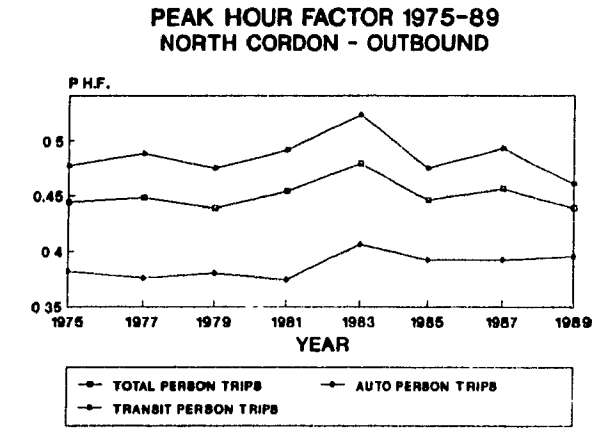
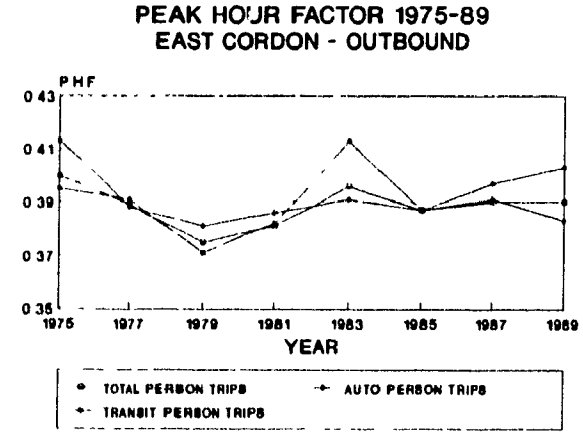


Figure 19: Variation of Peak Period Factor, 1975-89







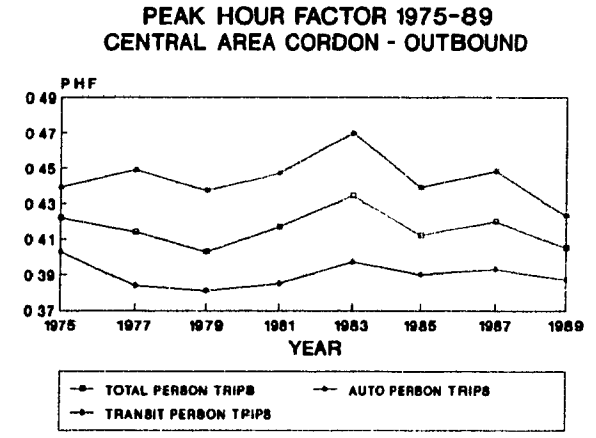


Figure 20: Variation of Peak Hour Factor, 1975-89

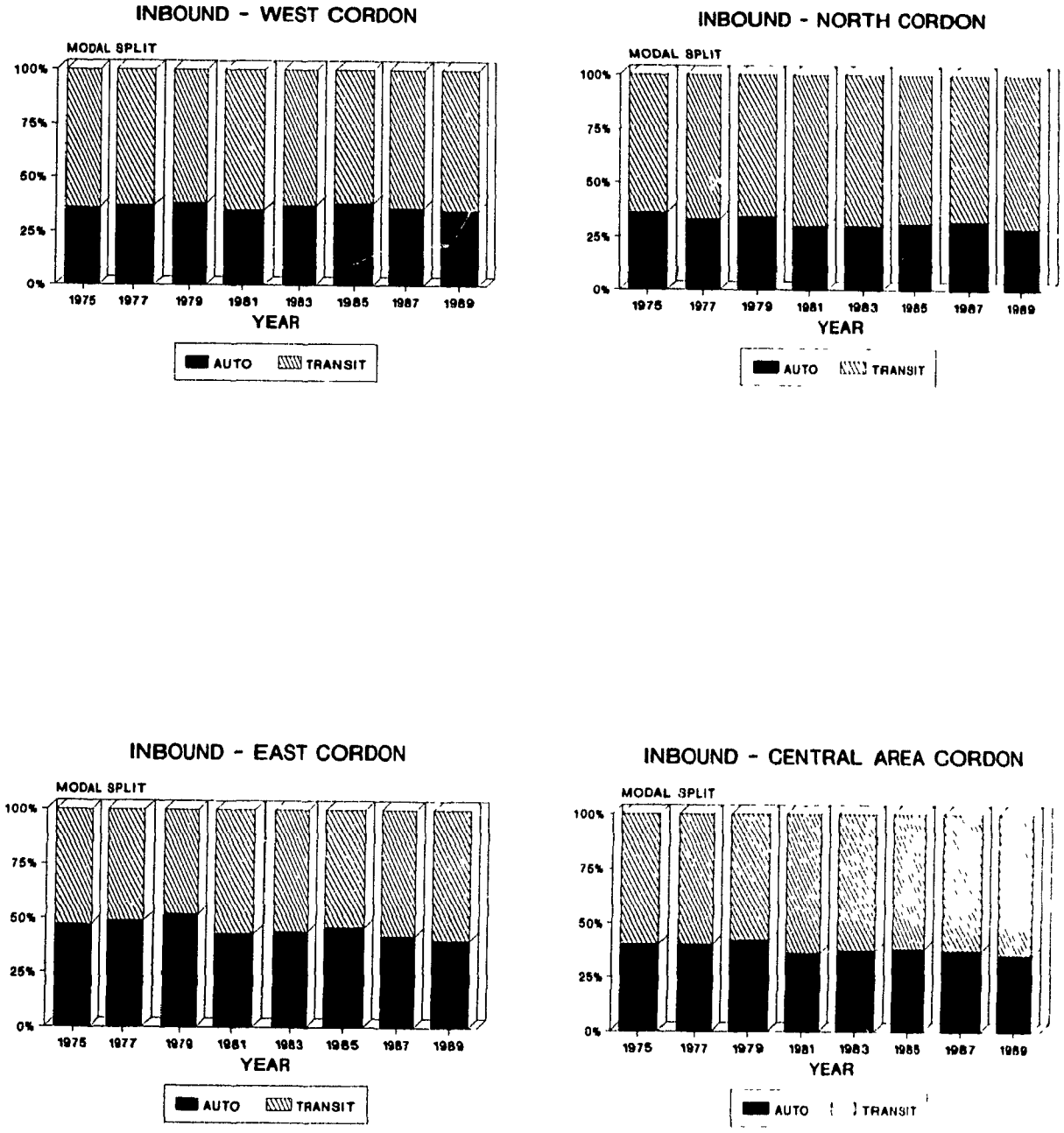


Figure 21: Modal Split - Inbound Trips, 1975-89

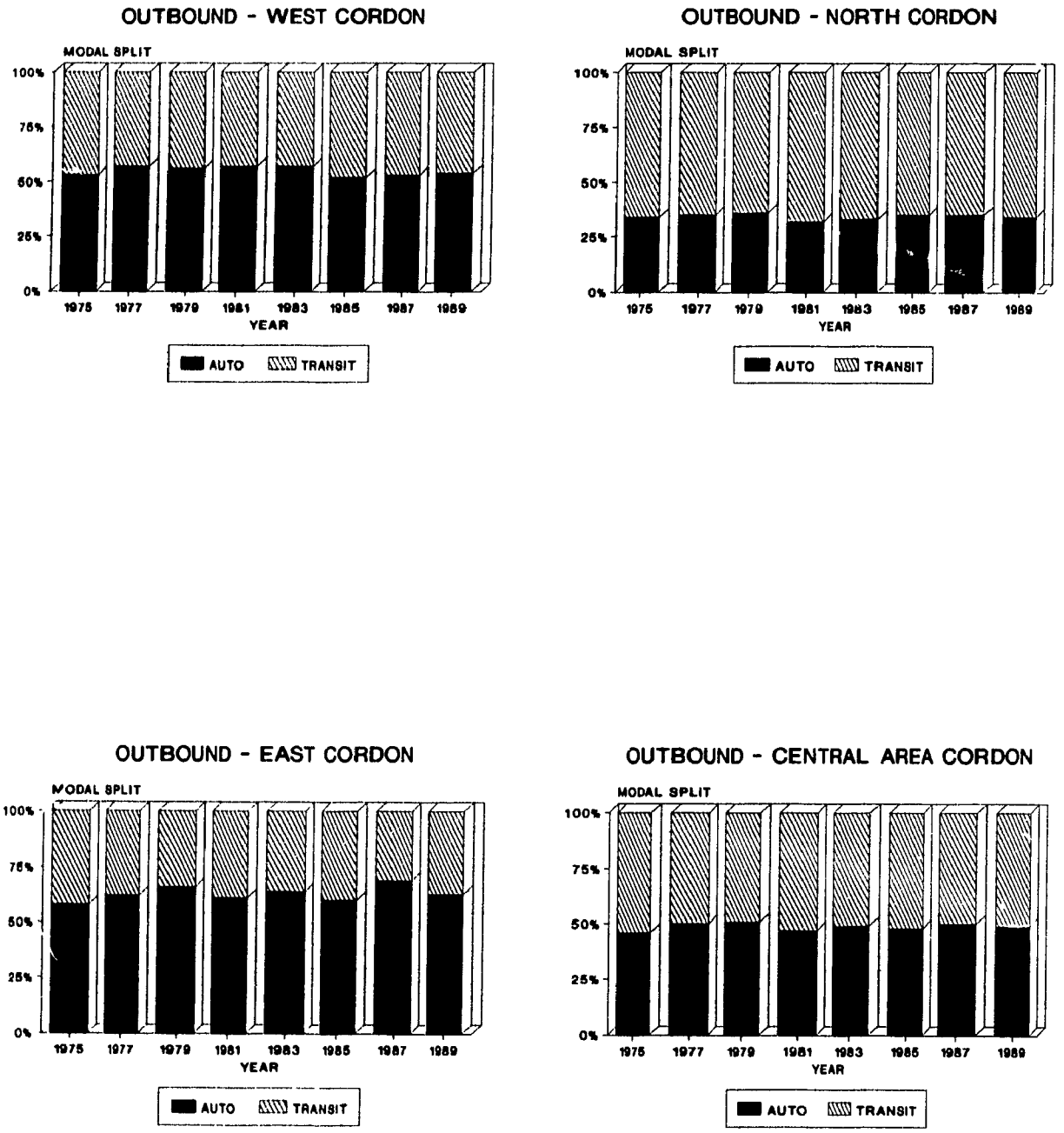


Figure 22: Modal Split - Outbound Trips, 1975-89

the general trend was that the mode choice for passengers leaving the Central Area was fifty-fifty, and such has been the case for the past 14 years.

4.4 SUMMARY

POR-POW LINKAGES

1) The most significant growth of more than 40% was shown by the internal to external linkages between 1981-86. The rate of growth of these internal to external linkages or "reverse commuting" have accelerated between 1981 and 1986 with an average annual growth rate of 8.7%.
2) For inbound linkages, Metropolitan Toronto originated linkages composed of the majority, although its share was declining from 91.4% in 71 to 79.8% in 1986.
3) Nearly 1 in 5 linkages into the Central Area originated from outside Metropolitan Toronto in 1986, this represented 233% (15.5% annually) growth experienced by the Greater Toronto Area-Central Area linkage between 1971 and 1986.
4) The western corridor had emerged as the major corridor for carrying commuters into the Central Area. The northern corridor also share similar but sightly less growth as the western corridor whilst the eastern corridor experienced little growth in the 1981 to 1986 period.
5) The majority of linkages from the Central Area commuted via the northern corridor.

24 HOUR WORK TRIPS

6) The work trips that occurred within the Central Area (internal-internal) showed the domination of the walk/other mode which increased its proportion from 37% to 44% between 79 and 86, and was apparently growing at the expense of auto trips.
7) The Metro to Central Area commuting was dominated by the transit mode between 1979 and 1986, which showed a modal split of 1/3 auto trips and 2/3 transit trips.
8) For "reverse commuting", the mode split was 50/50.

METRO CORDON COUNT

9) For total inbound person trips during the morning peak period, the north cordon possessed the highest increase of 18%, whereas the east and west cordons had growth of 14.8% and 13.3% between 1975 and 1989 respectively. The west cordon had always contributed the most passengers entering the Central Area and is consistent with the linkage analysis. The north cordon had the least. However, the proportions of each directional displayed some inconsistencies with the linkage analysis for both inbound and outbound traffic.

10) Although the west cordon exhibited growth in auto person trips, the east and west cordons remained relatively constant over time. The west cordon's proportion also grew from 32.3% in 1975 to 35.5% in 1989 at the expense of the north cordon. The east cordon consisted of nearly 40% of all passengers using automobile to enter the Central Area during this period. Auto person trips were shifting away from the conventional morning peak period

12) For passengers using transit to enter the Central Area, the north cordon experienced the highest growth of 31.1%, whereas the east and west cordons grew 28.5% and 14.4% respectively. Although the west cordon displayed the least growth, it accounted for the highest proportion of inbound transit person trips to the Central Area. Overall, the transit person trips' peak period factor had remained constant at 45% over the years.

13) The occupancy rate for inbound trips had decreased from 1.32 person per automobile to 1.23 person per automobile over 14 years. This result was consistent with other researches

14) At 1989, the automobile carried 35% of the inbound passengers into the Central Area, and this ratio correlated well with the travel survey results. The north cordon accounted for the highest transit usage of about 70%, whereas the east cordon had the lowest percentage of transit users in 1989.

5.0 TRAVEL DEMAND MODELLING

In order to explore the implications of the Nowlan-Stewart hypothesis for future transportation planning associated with the Central Area, some land use and demographic variables are analyzed next, in order to develop a simple travel demand model. The purpose of this model is to explain the Central Area's role as a work trip attraction centre, as well as the effect of Central Area population on the morning commuting trip. This part of the analysis explores the significance of a range of independent variables involving land use and demographics to provide an understanding of the Cordon Count data. This data base could be better used to serve as an indicator for future commuting patterns associated with the Central Area.

5.1 MODELLING APPROACH

The modelling approach is based on the Nowlan-Stewart hypothesis. It assumes that the amount of passenger flow into the Central Area during the morning peak period is associated with selected land use and demographic variables in the Central Area. The major focus in the approach is twofold, as follows:

i) The fine-tuning of the travel demand model as proposed by the Nowlan-Stewart hypothesis.

ii) The use of the 1987 Travel Diary Survey data base and the Sarsan model to gain a better understanding of the Cordon Count data.

The level of analysis is highly aggregated, and the whole Greater Toronto Area is considered as one "external" zone. Inevitably, because of this level of aggregation, some of the variation which exists in the independent variables would be masked. However, due to the nature of the Cordon Count data, there is little choice.

5.2 LINEAR REGRESSION MODELS

Most transportation demand models consists of a dependent variable, namely, travel demand, which is represented as a function of one or more independent variables. These independent variables are considered as the "predictor" variables which effectively explain the

impact of these variables on travel demand. Thus, it was logical to assume that the travel demand model took on the form of

$$Y = f(X)$$

where, Y represents travel demand and X represents the independent variables. The function and associated coefficients are estimated from a set of historical data. Linear regression analysis has been the traditional tool used for this process of estimation.

In Chapter 4 the peak period was defined to be 6:30 a.m. to 9:30 a.m.. When these figures were compared to the peak period defined in the Nowlan and Stewart study, the 6:30 a.m. to 9:30 a.m. period exhibited considerably higher volumes (Table 22).

YEAR	7:00-10:00 A.M. TRIPS	6:30-9:30 A.M. TRIPS
1975	268,123	293,445
1977	278,948	299,782
1979	287,510	305,306
1981	308,371	324,853
1983	306,441	321,623
1985	300,542	316,376
1987	317,487	336,706

Table 22: Comparison of Peak Period Volumes

It was felt that the 6:30 a.m. to 9:30 a.m. volumes better represented the peak period flow. It was decided that the 6:30 to 9:30 a.m. period should be used as the peak period for this analysis. The volume of inbound passenger trips during this period was defined to be the dependent variable TRIPS. AUTO and TRANSIT were defined as the amount of auto passenger trips and transit passenger trips crossing the Central Area Cordon during this peak period respectively. SPACE was defined as the mid-year occupied office floor space in square metres, and POPULATION was defined as the number of Central Area residents Both SPACE and POPULATION figures were extracted from Nowlan and Stewart (1990). These figures are shown in Table 23.

YEAR	TRIPS	AUTO	TRANSIT	SPACE	POPULATION
1976*	296614	117410	179204	4203009	111840
1977	299782	118449	181333	4393591	111374
1978*	302544	123218	179281	4584237	111536
1979	305306	127987	177229	4745510	112270
1980*	315080	122478	192557	4920575	113520
1981	324853	116969	207884	5047522	115230
1982*	323238	117999	205240	5130793	117344
1983	321623	119028	202595	5210051	119806
1984*	319000	120214	198786	5284558	122559
1985	316376	121400	194976	5392955	125548
1986*	326541	123057	203484	5552836	128716
1987	336706	124714	211992	5825906	132090
1988*	337361	121699	215663	6052423	132185

* These figures for TRIPS, AUTO, and TRANSIT were calculated as the averages of the preceding and following years

Table 23: Variation of Dependent and Predictor Variables

A linear regression model was developed to re-estimate the coefficients for SPACE and POPULATION as follows:

$$TRIPS = 232{,}640 + 0.0324*SPACE - 0.675*POPULATION \quad (4), \; R^2 = 0.9160$$

When a 10% absenteeism was included, equation 4 became:

$$TRIPS = 232{,}640 + 0.03*SPACE - 0.6*POPULATION \quad (5)$$

Equation 5 implies that the average amount of "background" travel between 1976 and 1988 was approximately 230,000. These background trips included home-based work trips for full-time non-office workers, home-based work trips for part-time workers, home- based school trips, home-based other trips such as shopping, non-home-based trips, and through trips. The coefficients imply that for each additional person living in the Central Area, there would be a decrease of 0.6 passenger trips entering the Central Area during the morning peak period.

By splitting the total passenger trips (TRIPS) into auto passenger trips (AUTO) and transit passenger trips (TRANSIT) as showed in Table 23, two more linear regression models were derived to investigate the effect of the two independent variables on mode choice. These regression models are as follows:

$$AUTO = 115{,}870 + 0.0022*SPACE - 0.050*POPULATION \quad \ldots\ldots(6),\ R^2 = 0.0670$$

$$TRANSIT = 116{,}425 + 0.0301*SPACE - 0.620*POPULATION \quad \ldots\ldots(7),\ R^2 = 0.7866$$

Equation 6 revealed that using AUTO as the dependent variable yielded an extremely low R^2 value. It demonstrates that the independent variables did not explain the variation of auto trips, thus equation 6 can be discarded. However, equation 7 demonstrated a relatively higher R^2 value and was considered quite reliable. This can be explained by the fact that the majority of trips into the Central Area consists of transit users as indicated in the mode split ratio of 2/3 transit and 1/3 auto. The regression equation reveals that SPACE and POPULATION has a more profound effect on transit trips. When a 10% absenteeism is factored into equation 7 it becomes:

$$TRANSIT = 116{,}425 + 0.0271*SPACE - 0.558*POPULATION \quad \ldots\ldots\ldots\ldots(8)$$

It is clear that the use of the SPACE and POPULATION variables could not explain the variations in auto passenger trips. Therefore, a further set of variables were used to estimate the auto trips as shown in Table 24. As a matter of further interest, these variables were also used to produce another set of results with respect to TRIPS and TRANSIT.

YEAR	FEOFF*	PTOFF*	CAFT*	CAPT*	FTNOFF#	PTNOFF#
1983	204,065	6,176	324,786	28,802	120,721	22,626
1984	213,549	7,031	322,716	33,570	109,167	26,539
1985	215,036	9,869	335,934	38,438	120,898	28,569
1986	221,124	13,157	344,502	48,634	123,378	35,477
1987	233,074	13,435	361,761	47,651	128,687	34,216
1988	238,367	16,593	361,446	56,012	123,079	39,419

* Source: City of Toronto, 1990
# These figures were calculated using figures from column 2 to 5

Table 24: Central Area Employment Figures

In Table 24, six new independent variables were defined as follows:

FEOFF = Full-Time Office Employment in Central Area

PTOFF = Part-Time Office Employment in Central Area

CAFT = Central Area Full-Time Employment

CAPT = Central Area Part-Time Employment

FTNOFF = Full-Time Non-Office Employment in Central Area

PTNOFF = Part-Time Non-Office Employment in Central Area

Using these new set of independent variables, four linear regression models were derived, and the results were described below:

AUTO = 103,860 + 0.074*FEOFF + 0.138*PTOFF .....(9), R^2 = 0.5419

AUTO = 81,724 + 0.119*CAFT -0.0217*CAPT.....(10), R^2 = 0.6488

AUTO = 59,609 + 0.0341*FEOFF + 0.445*FTNOFF.....(11), R^2 = 0.8146

AUTO = 116,113 + 0.185*PTOFF + 0.113*PTNOFF.....(12), R^2 = 0.520

Using the R^2 value as the criteria, equation 11 had the "best fit". Using full-time office employment and full-time non-office employment as the two explanatory variables yielded a least square value of more than 80%. By examining equation 11, the coefficients reveals that full-time non-office workers rely more heavily on the automobile as their choice of travel. When a 10% absenteeism rate was factored into equation 11, it became:

AUTO = 59,609 + 0.031*FEOFF + 0.40*FTNOFF.....(13)

Similar regression models were also developed using the variables from Table 24 for TRIPS and TRANSIT. The results are summarized below.

TRIPS = 183,933 + 0.65*FEOFF - 0.104*PTOFF.....(14), R^2 = 0.7814

TRIPS = 115,242 + 0.634*CAFT - 0.163*CAPT.....(15), R^2 = 0 8375

TRIPS = 112,432 + 0.449*FEOFF + 0 934*FTNOFF.....(16), R^2 = 0.8437

TRIPS = 321,409 + 3.474*PTOFF - 1.076*PTNOFF.....(17), R^2 = 0.6981

and,

TRANSIT = 80,070 + 0.576*FEOFF - 0.242*PTOFF.....(18), R^2 = 0.6808

TRANSIT = 33,518 + 0.515*CAFT - 0.142*CAPT.....(19), R^2 = 0.7065

TRANSIT = 52,827 + 0.415*FEOFF + 0.489*FTNOFF.....(20), R^2 = 0.7014

TRANSIT = 205,296 + 3.289*PTOFF - 1.189*PTNOFF.....(21), R^2 = 0.6044

Again, using the R^2 value as the criteria, equations 16 and 19 exhibits the "best fit". When comparing equation 7 and equation 19, equation 7, which had a R^2 value of 79%, demonstrates a better degree of "fit" than equation 19. Equation 20 also shows similar R-square value to those of equation 19, and the coefficient for full-time office employment resembles that of the Nowlan-Stewart hypothesis in equation 1.

Assuming these equations are statistically significant, some interesting trends emerge. Equations 14,15,18 and 19 all demonstrate that part-time employment had a "buffering" effect on peak period travel to the Central Area. This was indicated by the negative signs which appeared in front of the coefficient of the part-time variables. This could in turn imply that some part-time travel occurred outside the morning peak period. The coefficients for full-time office employment (FEOFF) also show an interesting trend. The coefficients ranged from 0.4 to 0.6 which meant that on the average, for every two new full-time office jobs created in the Central Area, there would only be one additional trip made during the morning peak period.

Although these equations show high R-square values which indicated a good "fit" between the variables, the results indicate that there exists considerable variations in the coefficients in these equations. Part of the variation could be explained by a high degree of correlation between these variables. Therefore, a correlation analysis was performed to investigate the degree of correlation between these variables. The results are summarized in Table 25.

	SPACE	POP	FEOFF	PTOFF	CAFT	CAPT	FTNOFF	PTNOFF
SPACE	1.000	0.942	0.983	0.955	0.970	0.940	0.680	0.926
POP		1.000	0.966	0.962	0.977	0.958	0.777	0.949
FEOFF			1.000	0.940	0.988	0.938	0.695	0.931
PTOFF				1.000	0.927	0.995	0.645	0.985
CAFT					1.000	0.918	0.799	0.907
CAPT						1.000	0.615	0.998
FTNOFF							1.000	0.592
PTNOFF								1.000

Table 25: Coefficient of Correlation between Independent Variables

As exhibited in Table 25, the independent variables show a high degree of correlation

between each other ranging from 0.592 to 0.998. The problem created by this high correlation between the explanatory variables is that the regression estimates became very sensitive when the independent variables are replaced. This is like saying that the impact of dependent variable Y on the independent variable X depended on whether independent variable Z was included in the regression equation or not. The regression coefficient essentially demonstrates the unique contribution of an independent variable to variation in a dependent variable. When there is only one variable in the equation, there was no complication. However, with the introduction of an extra, highly- correlated independent variable, then the unique contribution of the single independent variable on the dependent variable is changed. This results in misinterpretation of the impact of the independent variables, and led to spurious conclusions.

In this case, the choice of these independent variables was somehow restricted to the number of land use and demographic variables collected in the Central Area. The high degree of correlation of independent variables is inherent in this type of time series data base.

One way to overcome multicollinearity effects is to perform rigorous statistical procedures either by deletion of one of the predictor variable or by employing biased regression estimators to construct prediction equations. However, the use of statistical procedures in regression analysis did not always guarantee success. Part of the purpose of this analysis was to investigate the effect of Central Area Population had on inbound passenger flow, and this kind of cause-effect relationships among the independent and dependent variables could not be established solely on the basis of regression analysis. In order to be able to assert that POPULATION and SPACE actually determines the magnitude of TRIPS, there needs to be the condition that POPULATION and SPACE are not only able to predict TRIPS accurately, but they also control TRIPS. This implied that very stringent requirements had to be placed on the independent variables such that they were the only variables that affected the magnitude of TRIPS Hence, equation 4, which resembles the Sarsan model (equation 3), is felt to have demonstrated the most reliable representation of commuting trips into the Central Area. For further analysis in this study, equations in the form of equation 3 will be used.

Another way to examine the significance of the Nowlan-Stewart hypothesis was to perform a more in-depth analysis at a given point in time (cross-sectional analysis). By understanding the modal distribution and the purpose of peak period passenger trips associated with the Central Area could give a better understanding to how Central Area housing affected these inbound trips.

6.0 THE APPLICATION OF THE 1987 TRAVEL DIARY SURVEY (TDS)

The original purpose of the TDS was to provide additional socio-economic and travel characteristics information that was not covered in the 1986 Transportation Tomorrow Survey (TTS). The TTS was conducted between September and December of 1986, using telephone interviews to collect basic travel behaviour data for 61,000 Greater Toronto Area households. The TDS was conducted between February and March of 1987, using a mail-out mail-back, self-administered questionnaire. A diary format was used for the respondents to record their travel during the 24 hours period for a preselected weekday.

The additional data collected in the TDS that was of interest to this study included socio-economic characteristics (occupation and employment status), land use (place of residence and place of work), trip purpose and trip end times. In other words, the TDS data base contained disaggregated socio-economic and land use information which was not available from any other source. The data base was deemed to be accurate, despite some indication of bias and an underestimate of 24 hour trip volumes (Tranplan, 1990).

For the purpose of this analysis, the TDS data base was aggregated using the 1979 T.A.R.M.S. zones into the seven zonal system as described in Chapter 1 (see Map 2). The primary focus was the pattern of peak period, home-based work trips associated with the Central Area. Again, the morning peak period was defined to be between 6:30 and 9:30 a.m. Hence, the description of peak period work trips concentrated on workers that specified their trip end times to be between 6:30 and 9:30 a m.. For the purpose of this cross-sectional analysis, the following characteristics of peak period work trips are examined:

i) The volume of peak period work trips associated with the Central Area. A two-zone designation is employed. The Central Area is designated as the internal zone, whereas the rest of the study area i.e., zones 2 to 7, is designated as the external zone. Three origin/destination combinations were used: internal to internal, external to internal and internal to external.

ii) Work trip end times, divided into three periods: 6:31 a.m. to 7:30 a.m., 7:31 a.m. to 8:30 a.m. and 8:31 a.m. to 9:30 a.m.

iii) Land use for the work site, grouped into two categories: office buildings and non-

office buildings.

iv) The occupation of the workers making the home-based work trips, consolidated into three groups:

Occupation Group 1: Clerical/Sales/Service
Occupation Group 2: Professional/Managerial
Occupation Group 3: Others

v) The employment status of these workers, divided into two categories, full-time and part-time.

vi) The mode of travel chosen by the commuters, grouped into the following categories:

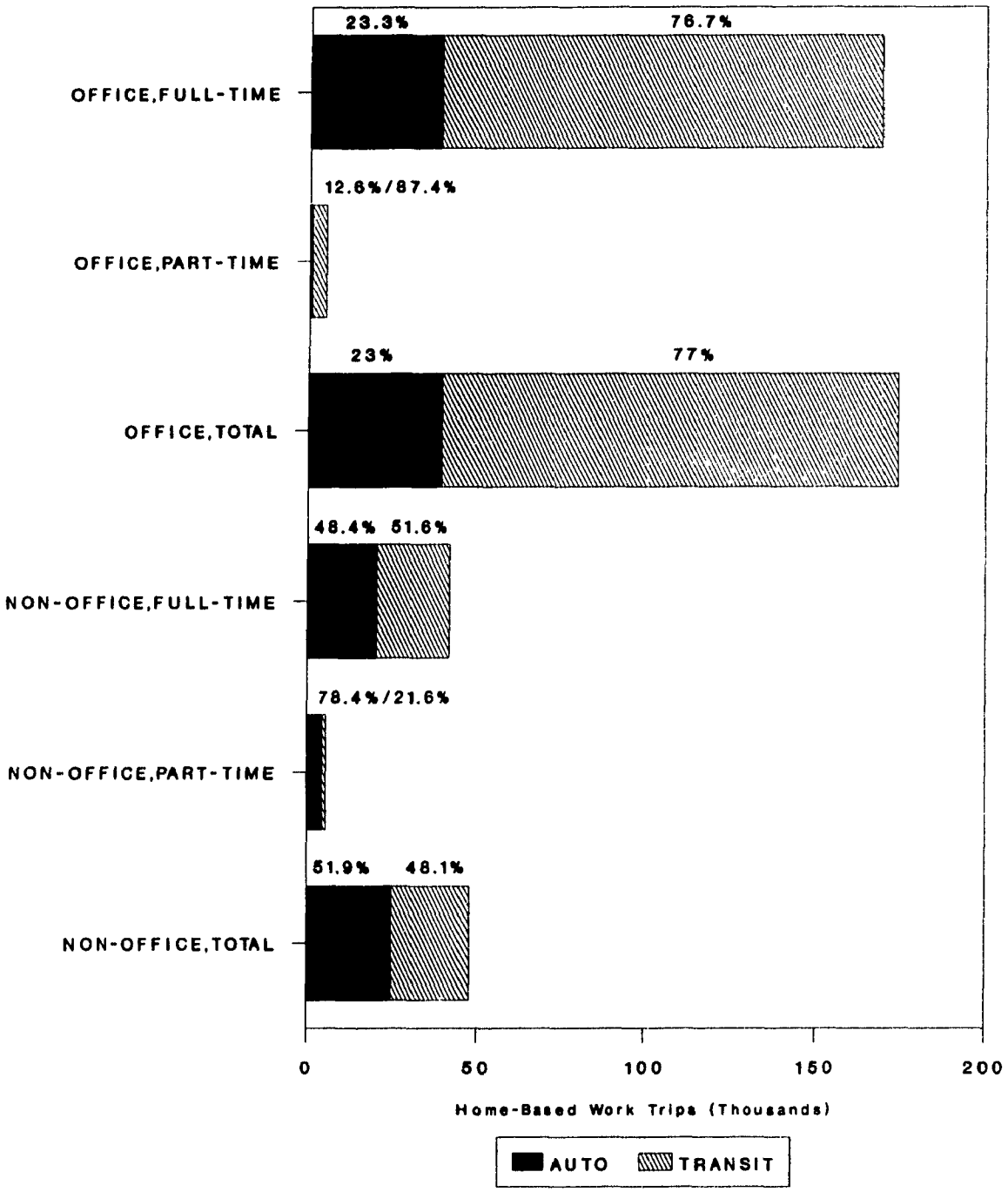
Auto - Auto-Driver
Auto-Passenger
Transit
Walk
Others

6.1 ANALYSIS OF WORK TRIPS BY LAND USE

The first part of the analysis is focused on the place of work for the peak period, home-based work trips. The TDS contains data where the worker's work site is described. In this analysis, the land use destination was divided into 2 groups: office building and non-office buildings. By examining the volume of work trips that arrived at various work site destinations, it provides a reasonable check on the Nowlan-Stewart hypothesis because one of the independent variables is occupied office floor space.

Figure 23 illustrates the modal variation by work site and employment status for external to internal trips. The full-time office-bound category clearly makes up the bulk of the volume of home-based work trips. It was found that of all the home-based work trips made by full-time employees that entered the Central Area during the morning peak period, nearly 80% were destined to office buildings. Home-based part-time work consisted of only 4.7% of all home-

Figure 23: Modal Variation by Land Use and Status, External-Internal



• Walk and Others modes were negligible

based work trips made to Central Area. The mode split for different land use categories exhibited quite different characteristics as summarized in Table 26.

	1987 C.A. CORDON COUNT	FULL-TIME, OFFICE BUILDING	FULL-TIME, NON-OFFICE BUILDING	FULL-TIME, TOTAL
% AUTO*	37% (1.23)	23.3% (1.48)	48.4% (1.26)	28.3% (1.40)
% TRANSIT	62%	76.7%	51.6%	71.7%

* Figure in brackets are auto-occupancy rates.

Table 26: Comparison of Modal Split

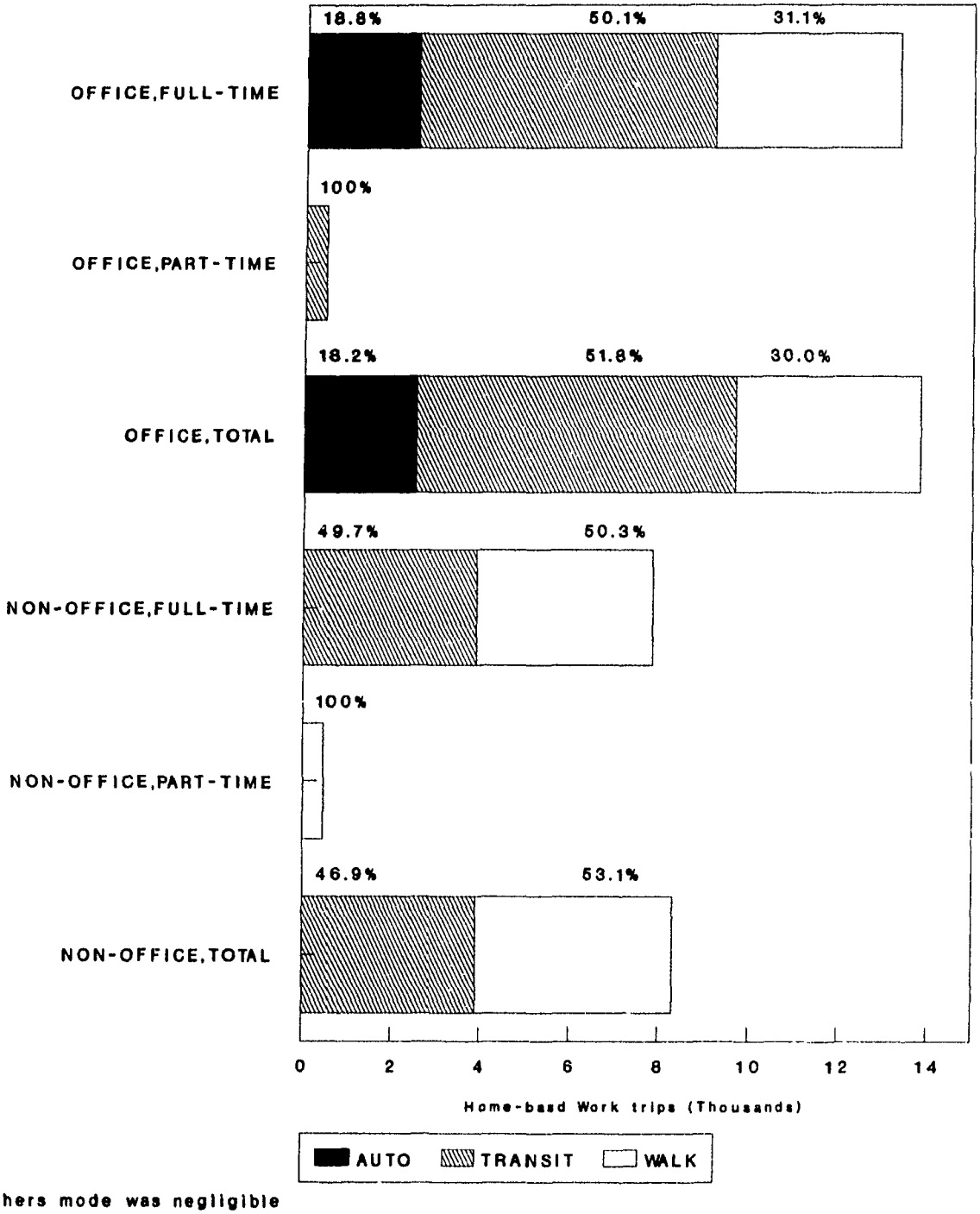
The non-office sector exhibits a near 50/50 mode split. However, the office sector showed a mode split of 23.3% auto and 76.7% transit, making the overall mode split to be near 30% to 70% for auto and transit users respectively. Part of the reason for the high percentage of overall transit usage when compared to the Cordon Count could be the fact that the "background" trips that entered the Central Area Cordon had a high percentage of auto users. The net result is the percentage of mode split as exhibited by the Central Area Cordon count. A discrepancy also appears in the auto occupancy rate (Table 26). The full-time office workers exhibited an occupancy rate of 1.48 as opposed to the rate of 1.23 presented in the Cordon Count data.

Figure 24 illustrates the modal variation by land use and employment status for internal to internal trips. The walk mode plays a major role for workers who live and work inside the Central Area. For full-time office bound workers, almost one-third walk to work. For non-office full-time workers, over half walk to work.

As expected, the number of office-bound full-time workers made up almost 65% of the internal full-time workers. Home-based part-time work trips made up about 4% of all internal home-based work trips during the peak period. It is worth mentioning that there was no auto usage for the non-office category. It was probably introduced by sampling error in the data base. However, it was reasonable to assume that the number of internal to internal auto trips was small compared to the modes of transit and walk.

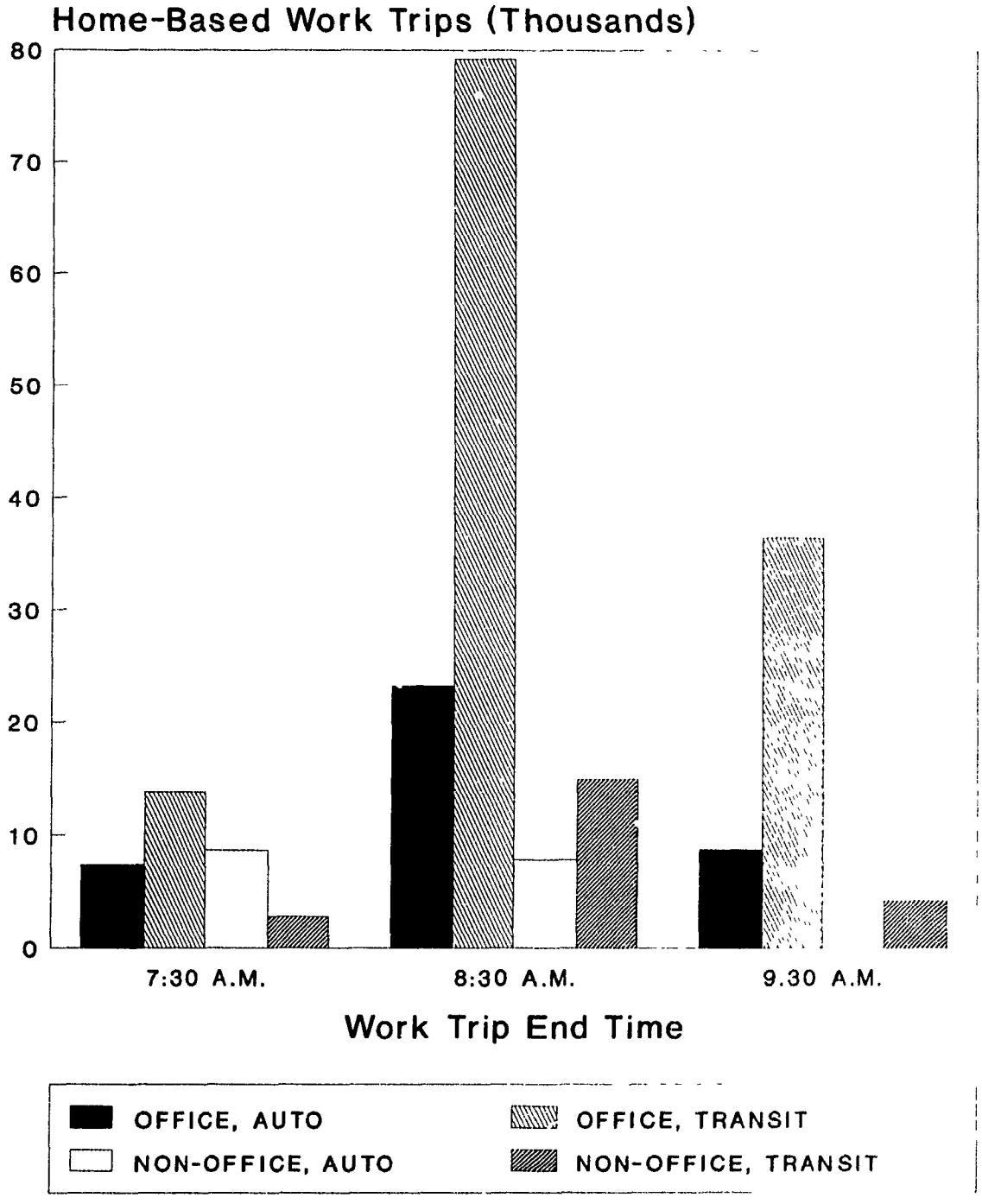
Figure 25 looks at the distribution of home-based work trips by trip end time for full-time workers entering the Central Area. The work trips peaked at 8:30 a.m. of which transit users

Figure 24: Modal Variation by Land Use and Status, Internal-Internal



• Others mode was negligible

Figure 25: Distribution of Work Trips by End Time, Full-Time Workers, Ext/Int



going to office buildings dominated (79,209 trips), and it consists of 37.7% of all trips arriving at the Central Area during the peak period. At the same time, auto trips destined to office building at 8:30 a.m. made up only 10.9% of all trips arriving at the Central Area. Another trend showed that auto trips destined to non-office work sites peaked at 7:30 a.m. and gradually declined.

Figure 26 summarizes the distribution of full-time and part-time workers at different work sites for external to internal and internal to internal work trips. Clearly, the majority of Central Area bound home-based work trips during the morning peak is composed of office-bound full-time workers. The percentage of part-time workers that went to work during this period is minimal compared to the full-time workers.

Another area for analysis is the internal to external trip patterns, indicating the number of workers living in the Central Area, but working outside the Central Area (Table 27). 18,400 home-based work trips were recorded during the peak period for "reverse commuting" Using the 1987 POPULATION figure of 132,090 (from Table 23), it consists of nearly 14% of the Central Area population.

MODE	FULL-TIME, TOTAL
AUTO	7,751 (42.1%)
TRANSIT	7,942 (43.2%)
WALK/OTHERS	2,709 (14.7%)
TOTAL	18,402 (100.0)

Table 27: The Distribution of Internal-External Home Based Work Trips

6.2 ANALYSIS OF WORK TRIPS BY OCCUPATION

As discussed in Chapter 3, one of the reasons for the imbalance between inbound trip growth and office development could be attributed to structural changes in employment in the Central Area. As the proportion of "executive" positions in the Central Area grew, there could be more work trips made outside the traditional peak period because of the nature of the work.

Figure 27 illustrates that the clerical/sales/service and professional/managerial group made up the majority (94%) of full-time work trips entering the Central Area. The professional/managerial group alone made up almost half of the full-time work trips.

Figure 26:Land Use Distribution of Full-Time and Part-Time Workers

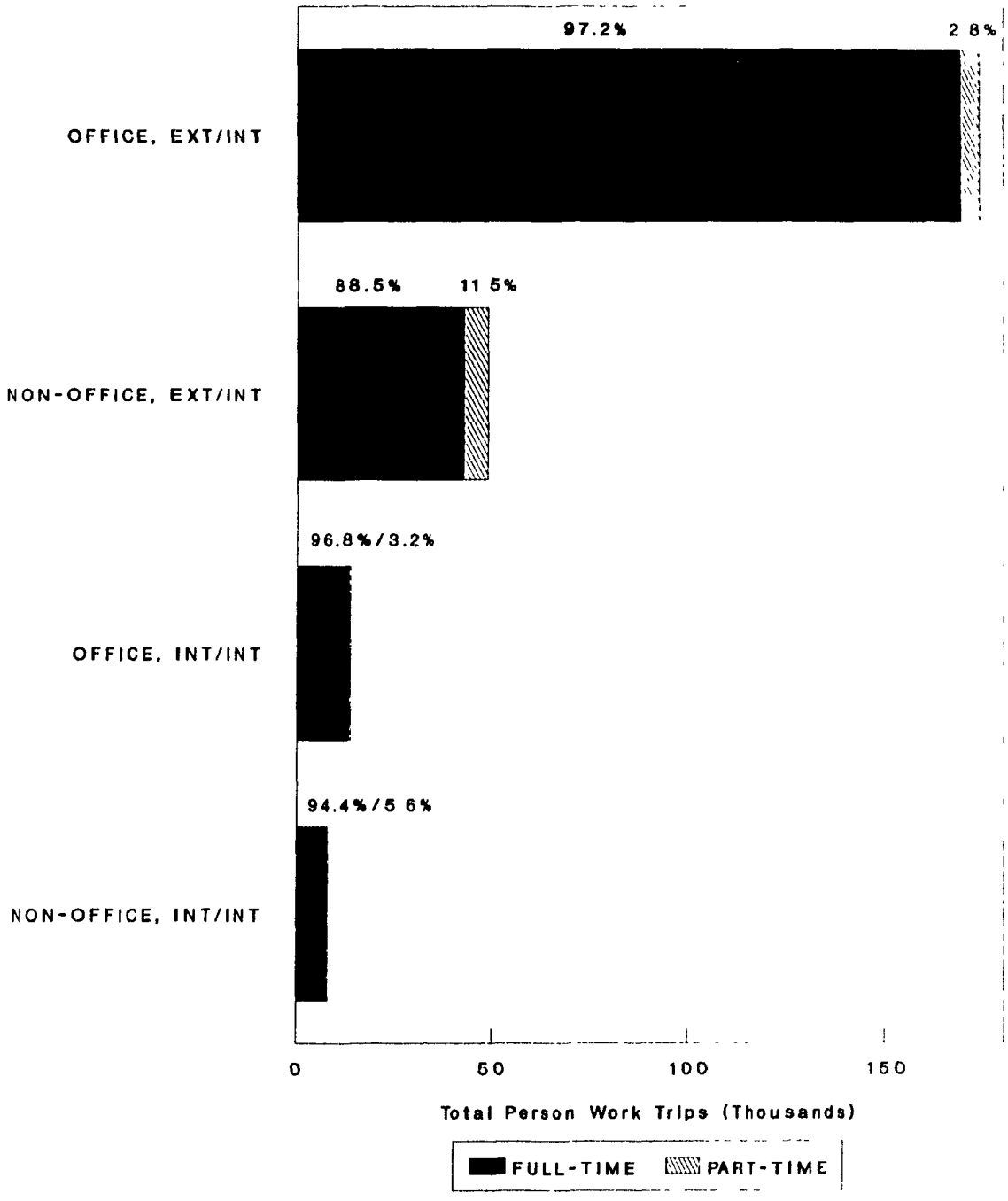
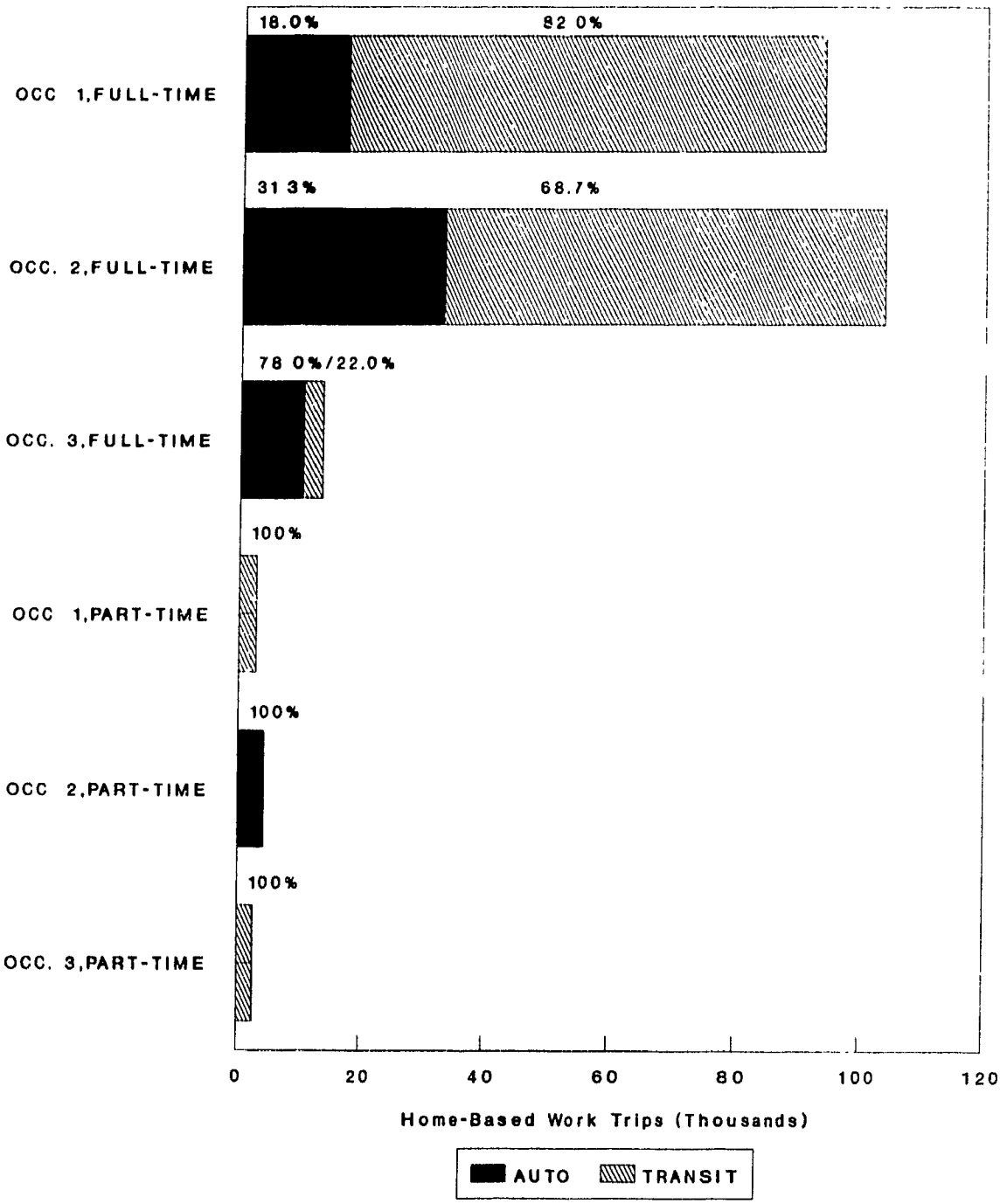


Figure 27: Modal Variation by Occupation and Status, External-Internal



•Walk and Others Modes were negligible

The three occupation groups also exhibit different modal distributions. The clerical/sales/service workers show strong preference to transit usage (82%), the professional/managerial employees demonstrated a modal distribution that is similar to the Cordon count data, and the rest of the workers (occupation group 3) clearly prefer to use the automobile for work.

The distribution of home-based work trips by trip end times for full-time workers entering the Central Area is displayed in figure 28. The clerical/sales/service transit users peaked early at 7:30 a.m., compared to the majority of this occupation group's auto users which peak at 8:30 a m

6.3 ANALYSIS OF EXTERNAL TO INTERNAL TRIPS BY TRIP PURPOSE

In order to understand the peak period inbound travel demand better, the overall volume of trips recorded during the morning peak period was examined by trip purpose Home-based full-time work trips overshadow the rest. It consists of 81.6% of all trips entering the Central Area during the peak by all modes. Trip purposes other than work only make up 14 4% of the trips that are made into the Central Area during the peak period. The period 7 31 to 8·30 a.m was clearly the peak: it consists of 56.9% of all trips made during the peak The results are summarized in Table 28. The following designations are used for trip purpose·

HBWFT - Home-Based Work, Full-Time

HBWPT - Home-Based Work, Part-Time

HBS - Home-Based School

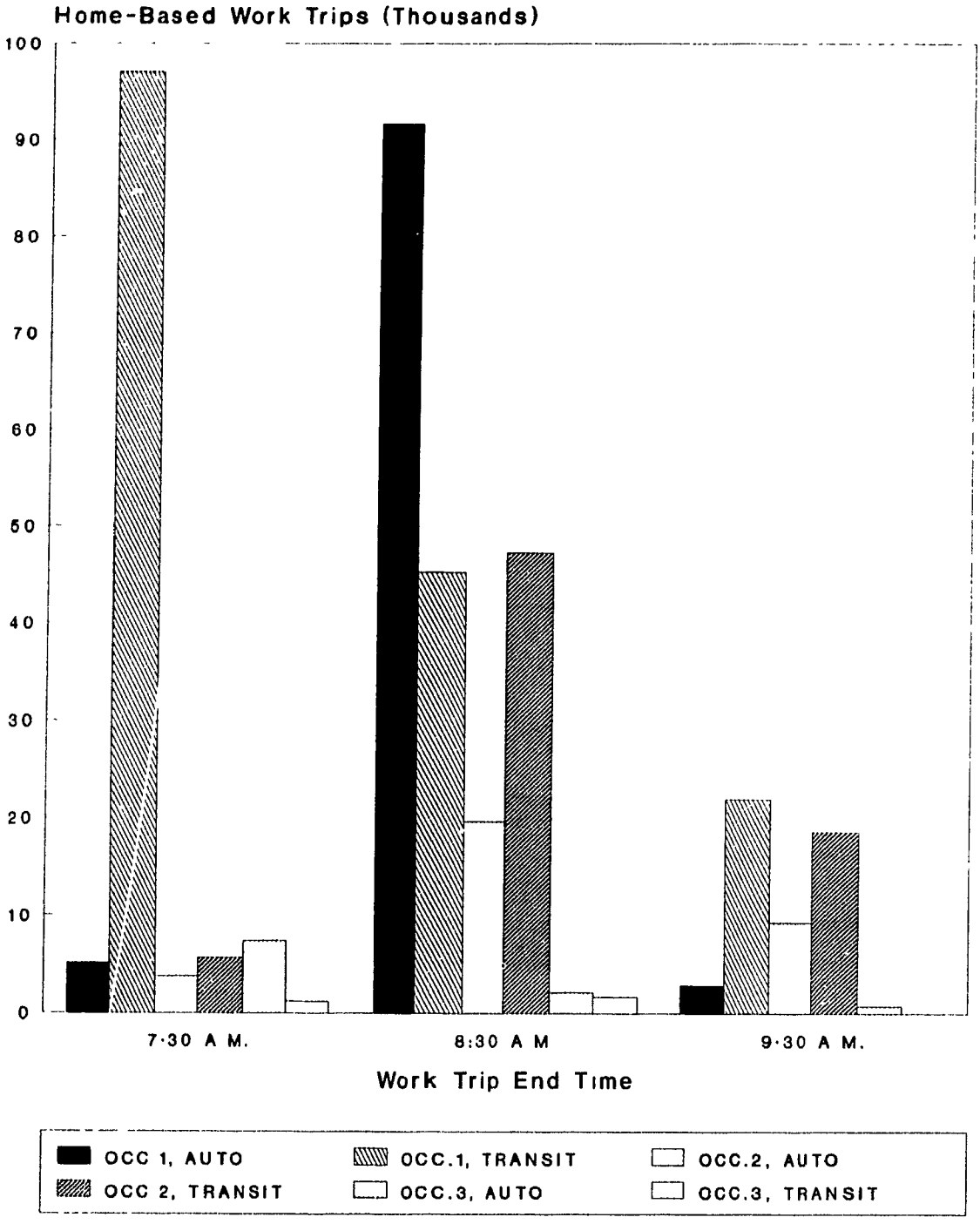
HBO - Home-Based Others

NHB - Non-Home-Based

PURPOSE	06:31-07:30	07:31-08:30	08:31-09:30	TOTAL
HBWFT	12.5%	48.3%	20.7%	81.6%
HBWPT	1.7%	0.9%	1.4%	4.0%
HBS	0.0%	1.8%	3.6%	5.5%
HBO	0.4%	3.7%	2.3%	6.4%
NHB	0.0%	2.2%	0.5%	2.5%
TOTAL	14.6%	56.9%	28.5%	100.0%

Table 28: Distribution of Trip End Time by Trip Purpose

Figure 28: Distribution of Work Trips by End Time, Full-Time Workers, Ext-Int



6.4 COMPARISON WITH 24 HOUR WORK TRIPS

In previous chapters, the possibility that some of the work trips were travelling in the off-peak hours was discussed. The TDS data base provides information for this kind of comparison

80% of the professional/clerical workers arrive at the Central Area during the peak period. 75% of the clerical/sales/service employees travel inside the 3-hour peak period compared to 72% of others workers. Overall, 77% of all workers arrived at the Central Area during this period

Most of the transit users arrived at work during the peak period, whereas the percentage of auto users that arrived at work during the peak period was comparatively lower this implies that some of the home-based work trips were actually occurring outside the traditional peak period for auto-users. The total number of home-based work trips (all modes) amounted to approximately 90,000 This further proves that the Nowlan-Stewart hypothesis overestimated the effect of Central Area population growth Table 28 summarized the findings

MODE	OCC. 1	OCC. 2	OCC. 3	ALL OCC.
AUTO	59.5%	72.9%	52.9%	71 0%
TRANSIT	79.5%	84.6%	91.3%	80 3%
ALL MODE	75.1%	80.2%	72.9%	77.3%

Table 29: Percentage of Work Trips that Arrive during Peak Period

6.5 INFERENCE

The main objective of the cross-sectional analysis is to achieve a better understanding of the socio-economic, land use and travel characteristics of trips associated with the Central Area.

The employed labour force in the Central Area was 85,198 (Nowlan-Stewart, 1990). The 1987 TDS indicated that during the peak period, 22,943 home-based work trips for internal to internal travel was recorded for full-time and part-time workers. However, the 1987 TDS also indicated there were 35,693 24 hour home-based work trips that occurred internally (Transmode, 1990). First, only 64% of the "internal" work trips occurred during the peak period. Second, if the

employed labour force and 24 hour work trips were compared directly, 42% of the Central Area employed labour force were also working in the Central Area. This compared favourably with the 1989 Central Area Residents' Survey (CARS) result of 35%-40% (Sarsan, 1991).

From the TDS result, it can be deduced that the number of peak period full-time office-building-bound work trips using either the auto or transit mode was 168,573 trips. For the purpose of this discussion, assume that this figure reflects the actual number of trips made in 1987. Recalling equation 3, the Sarsan model, the percentage of workers living and working in the Central Area (L coefficient) could be calculated. In this case:

T = 336,706 trips (1987 Cordon count data)
S = 5,825,906 trips (Nowlan-Stewart, 1990)
K = 336,706 - 168,573 = 168,133 background trips
P = 132,090 people (Nowlan-Stewart, 1990)

and, $T = K + 0.9*0.04*S - 0.9*L*P$ .....(3)

therefore, $L = 35\%$

However, as discussed in Chapter 3, a 10% absenteeism assumption could be conservative. Therefore, a range of absenteeism rate from 8%-14% is used to calculate the corresponding L coefficient. The results are summarized in Table 30.

Absenteeism Rate, %	L Coefficient, %
8	35
10	31
12	28
14	38

Table 30: Absenteeism Rate Vs. L Coefficient

It could be deduced that the L coefficient was quite sensitive to the absenteeism rate. Future monitoring of the absenteeism rate is required. All in all, the assumption of a 10% absenteeism rate would seem to be quite reasonable.

Another coefficient that was discussed in Chapter 3 was the FSW index of 25 m^2 per worker. This FSW index was used in equation 3, and appeared as the coefficient of 0.04. In this case, the absenteeism was assumed to be 10%, and a range of FSW ratios were used to estimate the corresponding L coefficient. It can be seen that the L coefficient is very sensitive to changes in the floor space per worker (FSW) index. However, the 1987 estimated FSW was indeed 25 0 m^2 per worker (City of Toronto, 1990), and it further supported the finding that the L coefficient was 35% in 1987. The results are summarized in Table 31.

FSW	Coefficient,(1/FSW)	L Coefficient, %
23	0.0435	50
24	0.0417	42
25	0.0400	35
26	0.0385	28
27	0.0370	21

Table 31: FSW Vs. L Coefficient

So far, the results indicates that the FSW index of 25 m^2 per worker and a L coefficient of 35% were reasonably accurate. However, it could be argued that the number of peak period work trips is understated because the 24 hour trip volumes in the TDS were understated Table 32 summarizes the result of using equation 3 to estimate the absenteeism rate if the number of work trips were indeed underestimated.

% Understated	No. of Work Trips	Absenteeism rate, %
0	168,573	10
1	170,276	8.8
2	172,013	8
3	173,787	7
4	177,597	5

Table 32: The Relationship between Absenteeism and Peak Period Work Trips

It can be seen that the change in the absenteeism rate was not very sensitive to changes in the number of work trips. For the absenteeism rate to change from 10.0% to 8% required approximately 3,400 trips.

From the above discussion, it can be deduced that if the Sarsan model held true, the following characteristics may be used for further analysis:

i) The TDS data base reflects a reasonably accurate 168,600 work trips crossing the Central Area Cordon during peak period.

ii) The number of background trip in 1987 was 168,000. This represented an approximate 50 to 50 split between work trips and background trips entering the Central Area.

iii) The FSW ratio of 25 m^2 per worker was accurately measured for 1987.

iv) An absenteeism rate of 10.0% is a reasonable estimate for home-based work-related travel.

v) The L coefficient of 35% estimated from the modified Sarsan model is reasonable (compared with the 1989 CARS figure of 35-40%).

vi) The final format of the Sarsan model is best described as:

T = 168,000 + 0.9*(0.04*S - 0.35*P).....(22)

This cross-sectional analysis provides an insight of the composition of traffic entering the Central Area Cordon during the peak period using equation 22. Half of the inbound trips entering the Central Area was home-based work trips. If this relationship holds true for the future, Cordon Count data could be used to a better extent. By applying equation 22, the number of inbound trips during the peak period can be determined for any given year given that the variables S and P are known. However, this relationship will change and regular surveys such as the TDS should be conducted to monitor any changes to the relationship described in equation 22.

7.0 FUTURE TRANSPORTATION PLANNING IMPLICATIONS

Based on the results of the previous chapter, it is possible now to look at a reasonable growth scenario for the Central Area.

Equation 22 implies that the impact of Central Area population on inbound trips is such that for each 100 increase in population in the Central Area there would be 32 fewer trips Therefore, if the number of inbound trips entering the Central Area must stay constant in the future, office development and Central Area housing must be planned hand in hand

The office space in the Central Area had an average annual growth rate of just 3% over the past 15 years. Assuming that this trend continues in the near future, then by 1993 the office space in the Toronto Central Area would have grown to 7 million m^2 by 1993. As illustrated in figure 29, for the amount of inbound trips to remain at the 340,000 level, the Central Area population had to be approximately a quarter of a million to accommodate the extra 1,000,000 m^2 office space. This means an additional 120,000 people living in the Central Area by 1993. Hence, in order for the Central Area to have healthy office development without any change in transportation policy, only by increasing the number of people living in the Central Area would not be feasible when the growth of the Central Area population have been approximately 2,000 people annually in the past decade (see Table 2).

The traditional way to accommodate increased travel demand is to construct new transportation facilities. However, in view of the present economic conditions, as well as the growing concern over the environment, this alternative does not appear to be attractive

Transportation demand management (TDM) appears to be an attractive alternative, to partially ease the burden on the existing transportation system associated with the Central Area. By developing and implementing TDM programs, it is possible to alleviate traffic congestion through improved management of person and vehicle trip demand, thus accommodating future commercial development in the Central Area.

As indicated in the 1987 cross-section analysis, only half of the number of inbound trips entering the Central Area Cordon is associated with full-time work travel. The rest of the inbound trips entering the Central Area possess different trip purposes. Figure 30 illustrates the composition of inbound trips entering the Central Area Cordon. Home-based part-time peak

Figure 29: Plot of SPACE Vs. POPULATION

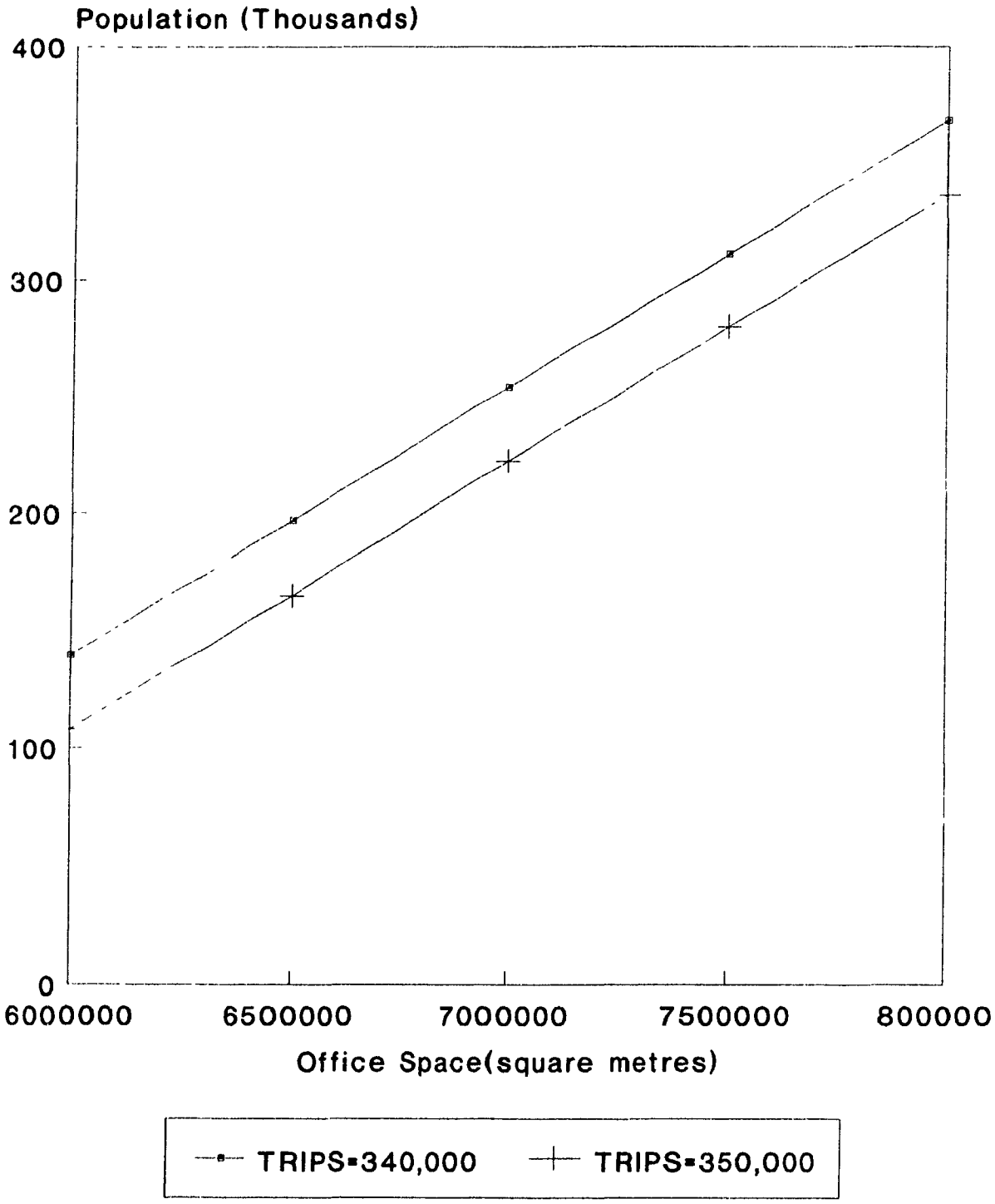
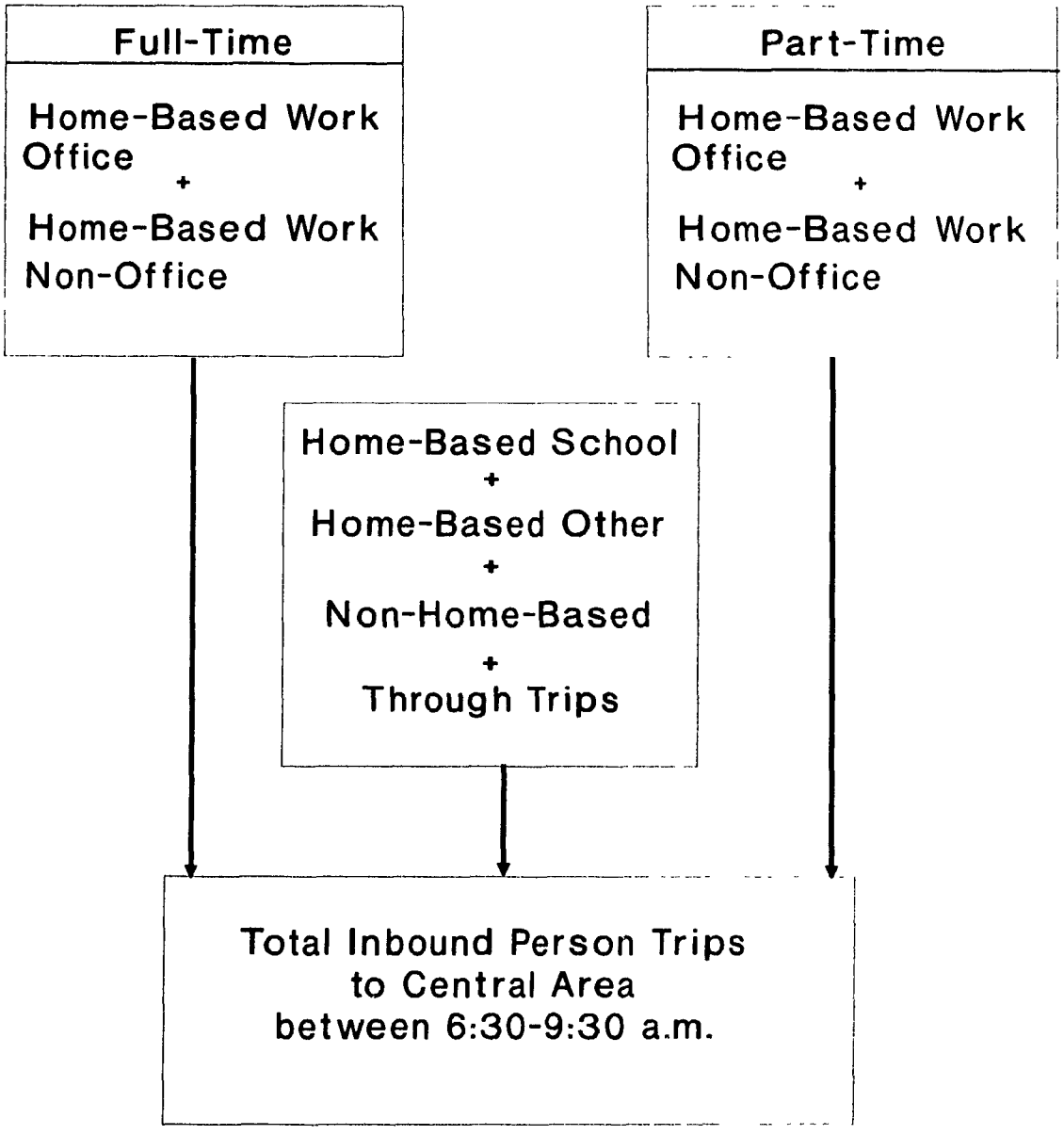


Figure 30: Distribution of Inbound Trips by Trip Purpose



period work trips only accounted for approximately 10,000 trips. Home-based school peak period trips, home-based other peak period trips and non-home based peak period trips were estimated in the 1987 TDS to be about 80,000. This suggested that the amount of trips going through the Central Area amounted to about 75,000 trips.

The discrepancy exhibited in the TDS auto occupancy rate and the Central Area Cordon Count data (see section 6.1) could be explained by the possibility that the background travellers preferred to drive alone or with very few passengers.

As indicated in the Cordon Count data, the number of inbound auto person trips was 124,714 in 1987, whereas the number of inbound transit trips was 211,992. If the number of auto and transit trips from the TDS full-time office work trips were subtracted from these figures, it gives a mode split of 51% auto and 49% transit for the "background" trips during the peak period. Hence, about 80,000 auto trips that entered the Central Area were not full-time office work trips

In view of the results, it points towards TDM as the ideal tool to ease travel demand entering the Central Area during the peak period. Programs such as road pricing or restriction of traffic entering the Central Area should be considered by the City of Toronto. By limiting the number of background trips entering the Central Area during the peak period, there would be room for office growth in the Central Area without the provision of new transportation facilities. TDM programs such as the Singapore Area License Scheme have proven to be very successful, as well as profitable, for reducing the number of automobiles entering the downtown area during the peak periods (World Bank, 1978).

By implementing TDM programs the background travel could be reduced, and using equations 23 to 25, the following scenarios might be possible using T=340,000 and P=130,000:

% reduction of K coefficient		Office Space (million m^2)
20%	T=134,400+0.036*S-0.315*P.....(23)	6.9
40%	T=100,800+0.036*S-0.315*P.....(24)	7.8
60%	T= 67,200+0.036*S-0.315*P.....(25)	8.7

As discussed before, the addition of Central Area population also helped to reduce the amount of inbound traffic going to the Central Area. However, this effect should be geared towards a more "self-contained" population in the Central Area. The L coefficient estimated for 1987 turned out to be 35%. If measures could be taken to increase the proportion of Central Area jobs filled by local residents, it would also serve to further reduce peak period inbound trips to the Central Area associated with full-time work travel.

By increasing the proportion of workers that worked and lived in the Central Area, and using equations 26 to 28 using T=340,000 and P=130,000, the following scenarios were examined:

L coefficient		Office Space (million m^2)
35%	T=168,000+0.036*S-0.315*P.....(26)	6.0
50%	T=168,000+0.036*S-0.450*P.....(27)	6.4
75%	T=168,000+0.036*S-0.675*P..... (28)	7.2

When TDM programs are considered along with the policy of increasing the "self-containment" of the Central Area residents, office growth in the Central Area can be further encouraged without the provision of new transportation facilities. The following scenarios were provided using a L coefficient of 55%, T=340,000 and P=130,000:

% reduction of K coefficient		Office Space (million m^2)
20%	T=134,400+0.036*S-0.5*P.....(29)	7.5
40%	T=100,800+0.036*S-0.5*P.....(30)	8.5
60%	T= 67,200+0.036*S-0.5*P.....(31)	9.4

Since the development of the Central Area of Toronto is important to economic growth in the Toronto region, it is recommended that TDM programs that limited the access of the Central Area to non-work related travel should be implemented. Policies that would increase the proportion of workers living and working in the Central Area should also be encouraged. Hence, affordable housing geared towards the average full-time office worker should be developed in the Central Area.

8.0 CONCLUSIONS

Nowlan and Stewart (1990, p.28) proposed a hypothesis which argued that "urban land use policy, in the form of housing and population intensification, can be used as a tool to shape transportation developments in downtown Toronto". A recent study which analyzed the Nowlan-Stewart hypothesis (Sarsan, 1991, p.15) concluded that "the Nowlan-Stewart formula would, most likely, overestimate the effect of Central Area population growth on reducing the inbound commuting trips".

This study was directed toward the clarification and refinement of both the Nowlan-Stewart and Sarsan interpretations. Time series analyses of various Central Area trends were performed A travel demand model was developed based on the Sarsan model and the 1987 trends associated with the Central Area. It can be used to evaluate the Cordon Count data. On the other hand it could be used to evaluate growth scenarios appropriate for Toronto's Central Area. Measures was developed to relieve traffic congestion associated with the Central Area during the peak period.

Some land use and demographic variables were analyzed in an attempt to develop a simple travel demand model. The purpose of this model was to try to explain the Central Area's role as a work trip attraction centre, as well as that the effect of Central Area population had on the morning commuting trip. However, the independent variables showed a high degree of collinearity. The problem created by this high correlation between the explanatory variables was that the regression estimates became very sensitive when the independent variables were changed.

Another way to examine the significance of the Nowlan-Stewart hypothesis is to perform a cross-sectional analysis. By understanding the modal distribution and the purpose of peak period passenger trips across the Central Area, it is possible to provide a better understanding to how Central Area housing affected these inbound trips. The 1987 TDS data base was chosen for this purpose.

It was found that the full-time office-bound category clearly made up the bulk of the volume of home-based work trips. Of all the home-based work trips made by full-time employees that entered the Central Area during the morning peak period, nearly 80% were destined to office

buildings. Home-based part-time work consisted of only 4.7% of all home-based work trips made to Central Area in the morning peak.

The walk mode played a major role for workers who lived and worked inside the Central Area. For full-time office bound workers, almost one-third walked to work. For non-office full-time workers, over half walked to work.

The work trips peaked at 8:30 a.m. and were dominated by transit users going to office buildings (79,209 trips). Transit trips made up 37.7% of all trips arriving at the Central Area during the peak period.

The clerical/sales/service and professional/managerial group made up the majority (94%) of full-time work trips entering the Central Area. The professional/managerial group alone made up almost half of the full-time work trips.

Home-based full-time work trips overshadowed the rest of the trip purposes. They made up 81.6% of all trips entering the Central Area during the peak by all modes. Trip purposes other than work only made up 14.4% of the trips that were made into the Central Area during the peak period.

80% of the professional/clerical workers arrived at the Central Area during the peak period. 75% of the clerical/sales/service employees travelled inside the 3 hour peak period compared to 72% of others workers. Overall, 77% of all workers arrived at the Central Area during this period. Hence, off-peak travel was quite significant. It further confirmed the fact that the Nowlan-Stewart hypothesis had indeed overestimated the effect of additional Central Area population.

Finally, using the Sarsan model, the following characteristics were considered:

i) In 1987 work trips crossing the Central Area Cordon during peak period was in the order of 165,000.

ii) The number of background trip in 1987 was in the order of 170,000. This represented a 50 to 50 split between work trips and background trips entering the Central Area.

iii) The FSW ratio of 25 m^2 per worker was accurately measured for 1987, although further monitoring is suggested.

iv) An absenteeism rate of 10.0% represents home-based work related travel. Additional monitoring of this variable is also required.

v) In 1987 an estimated 35% of Central Area residents were living and working locally (compared with the 1989 CARS figure of 35-40%).

vi) The final format and calibration of the modified Sarsan model is as follows:

T = 168,000 + 0.9*(0.04*S -0.35*P)

However, major limitations still apply to the use of the Nowlan-Stewart and the Sarsan models to project future implications. Both models use past demographics as predictors of the future. The pitfall is implicit in these relationships, which assumed that all other factors and relationships affecting travel demand into the Central Area would remain unchanged over time. This is highly unlikely, as some or all of the relationship between these variables would change over time.

If the relationship between these variables remain unchanged over time, TDM was viewed as the ideal tool to ease travel demand entering the Central Area during the peak period. How TDM programs might affect the rest of the transportation network should be reviewed However, this was beyond the scope of this study, and is recommended for future research.

The addition of Central Area population also helped to reduce the amount of inbound traffic going to the Central Area. However, this effect should be geared towards a more "self-contained" population in the Central Area. Policies that would increase the proportion of workers living and working in the Central Area should be encouraged. Hence, affordable housing geared towards the average full-time office worker should be developed in the Central Area.

APPENDIX A

CENTRAL AREA CORDON DATA

MORNING PEAK PERIOD: 6:30-9:30 A.M.

INBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	100394	47315	53079	47.12931	52.87069
1977	95217	46766	48451	49.11518	50.88482
1979	108623	56540	52083	52.05159	47.94841
1981	113279	48370	64909	42.69988	57.30012
1983	106898	46837	60061	43.81466	56.18534
1985	102873	47409	55464	46.08498	53.91502
1987	116991	49637	67354	42.42805	57.57195
1989	115246	47036	68210	40.81356	59.18644

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	87095	31433	55662	36.09048	63.90952
1977	97544	32516	65028	33.3347	66.6653
1979	91894	31223	60581	33.97719	65.92487
1981	102808	30913	71895	30.06867	69.93133
1983	101504	30578	70926	30.12492	69.87508
1985	101371	31865	69506	31.43404	68.56596
1987	104827	33633	71194	32.08429	67.91571
1989	102745	29780	72965	28.98438	71.01562

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	105956	37622	68334	35.50719	64.49281
1977	107021	39167	67854	36.59749	63.40251
1979	104789	40224	64565	38.38571	61.61429
1981	108766	37686	71080	34.6487	65.3513
1983	113221	41613	71608	36.75378	63.24622
1985	112132	42126	70006	37.56822	62.43178
1987	114888	41444	73444	36.07339	63.92661
1989	120025	41867	78158	34.8819	65.1181

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	293445	116370	177075	39.65649	60.34351
1977	299782	118449	181333	39.51171	60.48829
1979	305306	127987	177229	41.92089	58.04963
1981	324853	116969	207884	36.00675	63.99325
1983	321623	119028	202595	37.00855	62.99145
1985	316376	121400	194976	38.37206	61.62794
1987	336706	124714	211992	37.03943	62.96057
1989	338016	118683	219333	35.11165	64.88835

OUTBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	28018	16216	11802	57.87708	42.12292
1977	26531	16579	9952	62.48916	37.51084
1979	26257	17405	8852	66.28709	33.71291
1981	26845	16326	10519	60.81579	39.18421
1983	29913	19066	10847	63.73817	36.26183
1985	32268	19440	12828	60.24544	39.75456
1987	30999	21425	9574	69.11513	30.88487
1989	31165	19703	11462	63.22156	36.77844

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	40587	13597	26990	33.50087	66.49913
1977	38803	13746	25057	35.4251	64.5749
1979	40188	14345	25843	35.69473	64.30527
1981	45993	14663	31330	31.88094	68.11906
1983	43049	14342	28707	33.31552	66.68448
1985	45213	15739	29474	34.81078	65.18922
1987	44925	15894	29031	35.37896	64.62104
1989	45166	15478	29688	34.26914	65.73086

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	34621	18180	16441	52.51148	47.48852
1977	32114	18377	13737	57.22426	42.77574
1979	34755	19374	15381	55.7445	44.2555
1981	34867	19982	14885	57.3092	42.6908
1983	31733	18265	13468	57.55838	42.44162
1985	37486	19680	17806	52.4996	47.5004
1987	42940	22555	20385	52.52678	47.47322
1989	38129	20664	17465	54.19497	45.80503

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT	%AUTO	%TRANSIT
1975	103226	47993	55233	46.49313	53.50687
1977	97448	48702	48746	49.97742	50.02258
1979	101200	51124	50076	50.51779	49.48221
1981	107705	50971	56734	47.32464	52.67536
1983	104695	51673	53022	49.35575	50.64425
1985	114967	54859	60108	47.71717	52.28283
1987	118864	59874	58990	50.37185	49.62815
1989	114460	55845	58615	48.78997	51.21003

PEAK PERIOD FACTOR - 3 HOURS FROM 17 HOURS TOTAL

INBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.37	0.30	0.47
1977	0.36	0.29	0.47
1979	0.39	0.33	0.48
1981	0.39	0.30	0.50
1983	0.37	0.28	0.50
1985	0.35	0.27	0.46
1987	0.36	0.28	0.40
1989	0.37	0.26	0.53

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.32	0.23	0.41
1977	0.34	0.23	0.44
1979	0.32	0.23	0.41
1981	0.34	0.23	0.43
1983	0.33	0.22	0.41
1985	0.33	0.23	0.42
1987	0.33	0.23	0.40
1989	0.32	0.21	0.40

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.36	0.25	0.47
1977	0.37	0.28	0.45
1979	0.36	0.27	0.46
1981	0.35	0.24	0.45
1983	0.35	0.26	0.45
1985	0.34	0.24	0.44
1987	0.34	0.22	0.48
1989	0.34	0.23	0.47

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.35	0.26	0.45
1977	0.35	0.27	0.45
1979	0.36	0.28	0.45
1981	0.36	0.26	0.46
1983	0.35	0.25	0.45
1985	0.34	0.25	0.44
1987	0.34	0.24	0.45
1989	0.35	0.24	0.46

OUTBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.11	0.11	0.10
1977	0.10	0.11	0.09
1979	0.10	0.11	0.09
1981	0.10	0.11	0.09
1983	0.10	0.11	0.09
1985	0.11	0.12	0.10
1987	0.10	0.12	0.07
1989	0.10	0.11	0.09

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.14	0.10	0.18
1977	0.14	0.10	0.17
1979	0.14	0.10	0.17
1981	0.15	0.10	0.18
1983	0.13	0.10	0.16
1985	0.14	0.11	0.16
1987	0.14	0.11	0.16
1989	0.13	0.10	0.16

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.12	0.12	0.12
1977	0.11	0.12	0.10
1979	0.11	0.11	0.11
1981	0.11	0.13	0.10
1983	0.11	0.12	0.10
1985	0.12	0.12	0.12
1987	0.12	0.12	0.12
1989	0.10	0.10	0.10

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.12	0.11	0.14
1977	0.11	0.11	0.12
1979	0.12	0.11	0.13
1981	0.12	0.11	0.13
1983	0.11	0.11	0.12
1985	0.12	0.12	0.13
1987	0.12	0.12	0.12
1989	0.11	0.11	0.12

PEAK HOUR FACTOR - 1 HOUR TOTAL FROM 3 HOUR PEAK PERIOD

INBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.45	0.43	0.47
1977	0.47	0.42	0.51
1979	0.47	0.43	0.51
1981	0.47	0.41	0.51
1983	0.47	0.42	0.51
1985	0.46	0.41	0.50
1987	0.45	0.40	0.49
1989	0.46	0.39	0.51

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.48	0.42	0.51
1977	0.49	0.44	0.52
1979	0.44	0.42	0.46
1981	0.49	0.43	0.52
1983	0.49	0.45	0.50
1985	0.47	0.45	0.47
1987	0.48	0.44	0.50
1989	0.48	0.43	0.50

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.48	0.41	0.52
1977	0.48	0.41	0.52
1979	0.45	0.40	0.48
1981	0.47	0.39	0.52
1983	0.47	0.40	0.52
1985	0.49	0.42	0.53
1987	0.49	0.42	0.54
1989	0.48	0.40	0.53

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.47	0.41	0.50
1977	0.48	0.42	0.52
1979	0.45	0.42	0.48
1981	0.47	0.41	0.51
1983	0.48	0.42	0.51
1985	0.47	0.42	0.50
1987	0.47	0.41	0.50
1989	0.47	0.40	0.51

OUTBOUND PERSON TRIPS

EAST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.37	0.30	0.47
1977	0.36	0.29	0.47
1979	0.39	0.33	0.48
1981	0.39	0.30	0.50
1983	0.37	0.28	0.50
1985	0.35	0.27	0.46
1987	0.36	0.28	0.40
1989	0.37	0.26	0.53

NORTH CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.32	0.23	0.41
1977	0.34	0.23	0.44
1979	0.32	0.23	0.41
1981	0.34	0.23	0.43
1983	0.33	0.22	0.41
1985	0.33	0.23	0.42
1987	0.33	0.23	0.40
1989	0.32	0.21	0.40

WEST CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.36	0.25	0.47
1977	0.37	0.28	0.45
1979	0.36	0.27	0.46
1981	0.35	0.24	0.45
1983	0.35	0.26	0.45
1985	0.34	0.24	0.44
1987	0.34	0.22	0.48
1989	0.34	0.23	0.47

CENTRAL AREA CORDON

YEAR	TOTAL	AUTO	TRANSIT
1975	0.35	0.26	0.45
1977	0.35	0.27	0.45
1979	0.36	0.28	0.45
1981	0.36	0.26	0.46
1983	0.35	0.25	0.45
1985	0.34	0.25	0.44
1987	0.34	0.24	0.45
1989	0.35	0.24	0.46

AUTO OCCUPANCY RATE

INBOUND TRIPS

YEAR	EAST	NORTH	WEST	C.A.
1975	1.331	1.330	1.307	1.324
1977	1.323	1.314	1.304	1.315
1979	1.390	1.316	1.284	1.339
1981	1.321	1.283	1.257	1.291
1983	1.294	1.300	1.270	1.290
1985	1.292	1.256	1.259	1.271
1987	1.237	1.226	1.222	1.229
1989	1.232	1.244	1.196	1.227

OUTBOUND TRIPS

YEAR	EAST	NORTH	WEST	C.A.
1975	1.168	1.224	1.176	1.187
1977	1.133	1.203	1.162	1.163
1979	1.156	1.215	1.167	1.174
1981	1.123	1.216	1.197	1.178
1983	1.176	1.191	1.141	1.167
1985	1.126	1.199	1.128	1.146
1987	1.159	1.188	1.124	1.153
1989	1.117	1.168	1.131	1.136

AUTO VEHICLE TRIPS, 6:30 - 9:30 A.M. - CENTRAL AREA CORDON

YEAR	INBOUND	OUTBOUND
1975	87,874	40,447
1977	90,082	41,872
1979	95,562	43,537
1981	90,570	43,287
1983	92,283	44,264
1985	95,537	47,850
1987	101,463	51,938
1989	96,721	49,169

APPENDIX B

1979 MTS & 1986 TTS DATA

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1979 METRO TRAVEL SURVEY 24-HOUR WORK TRIPS BY MODE

Mode 1: Auto-Drive

	1	2	3	4	5	6	7	Total
1	6232	0	2290	3705	0	0	0	12227
2	16637	0	1646	637	0	0	0	18920
3	27490	0	907	246	0	0	0	28643
4	18506	0	0	1086	0	0	0	19592
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	68865	0	4843	5674	0	0	0	79382

Mode 2: Auto-Passenger (includes taxi)

	1	2	3	4	5	6	7	Total
1	2647	424	424	160	0	0	0	3655
2	5705	0	0	148	0	0	0	5853
3	5906	366	237	0	0	0	0	6509
4	4627	0	0	0	0	0	0	4627
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	18885	790	661	308	0	0	0	20644

Mode 3: Transit (includes regional bus)

	1	2	3	4	5	6	7	Total
1	12845	0	1182	5275	0	0	0	19302
2	38361	0	237	552	0	0	0	39150
3	51937	0	308	360	0	0	0	52605
4	50073	0	0	1054	0	0	0	51127
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	153216	0	1727	7241	0	0	0	162184

Mode 4: GO-Rail

	1	2	3	4	5	6	7	Total
1	0	0	0	0	0	0	0	0
2	1849	0	0	0	0	0	0	1849
3	738	0	0	0	0	0	0	738
4	1083	0	0	0	0	0	0	1083
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	3670	0	0	0	0	0	0	3670

Mode 5: Walk/Cycle/Other

	1	2	3	4	5	6	7	Total
1	13001	0	0	160	0	0	0	13161
2	1083	0	0	0	0	0	0	1083
3	450	0	0	160	0	0	0	610
4	1999	0	0	123	0	0	0	2122
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	16533	0	0	443	0	0	0	16976

Total, All Modes

	1	2	3	4	5	6	7	Total
1	34725	424	3896	9300	0	0	0	48345
2	63635	0	1883	1337	0	0	0	66855
3	86521	366	1452	766	0	0	0	89105
4	76288	0	0	2263	0	0	0	78551
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0
Total	261169	790	7231	13666	0	0	0	282856

****

1986 TTS 24-HOUR WORK TRIPS TO/FROM CENTRAL AREA BY MODE

Mode 1: Auto-Drive

	1	2	3	4	5	6	7	Total
1	4495	2168	2794	2343	158	1079	1567	14604
2	19241	0	0	0	0	0	0	19241
3	20941	0	0	0	0	0	0	20941
4	18631	0	0	0	0	0	0	18631
5	3216	0	0	0	0	0	0	3216
6	6329	0	0	0	0	0	0	6329
7	13743	0	0	0	0	0	0	13743
Total	86597	2168	2794	2343	158	1079	1567	96705

Mode 2: Auto-Passenger (includes taxi)

	1	2	3	4	5	6	7	Total
1	1700	210	445	321	0	125	161	2961
2	5482	0	0	0	0	0	0	5482
3	4337	0	0	0	0	0	0	4337
4	4878	0	0	0	0	0	0	4878
5	744	0	0	0	0	0	0	744
6	961	0	0	0	0	0	0	961
7	2611	0	0	0	0	0	0	2611
Total	20711	210	445	321	0	125	161	21973

Mode 3: Transit (includes regional bus)

	1	2	3	4	5	6	7	Total
1	12008	1760	4111	2419	22	331	309	20960
2	36752	0	0	0	0	0	0	36752
3	49633	0	0	25	0	0	0	49658
4	47317	0	0	0	0	0	0	47317
5	603	0	0	0	0	0	0	603
6	5876	0	0	0	0	0	0	5876
7	6142	0	0	0	0	0	0	6142
Total	158332	1760	4111	2444	22	331	309	167309

Mode 4: GO-Rail

	1	2	3	4	5	6	7	Total
1	0	0	30	0	25	22	0	77
2	3504	0	0	0	0	0	0	3504
3	486	0	0	0	0	0	0	486
4	866	0	0	0	0	0	0	866
5	3951	0	0	0	0	0	0	3951
6	1539	0	0	0	0	0	0	1539
7	12562	0	0	0	0	0	0	12562
Total	22907	0	30	0	25	22	0	22985

Mode 5: Walk/Cycle/Other

	1	2	3	4	5	6	7	Total
1	14528	228	134	157	0	0	0	15047
2	478	0	0	0	0	0	0	478
3	1123	0	0	0	0	0	0	1123
4	2309	0	0	0	0	0	0	2309
5	46	0	0	0	0	0	0	46
6	70	0	0	0	0	0	0	70
7	48	0	0	0	0	0	0	48
Total	18602	228	134	157	0	0	0	19120

Total, All Modes

	1	2	3	4	5	6	7	Total
1	32731	4366	7514	5240	204	1557	2037	53649
2	65457	0	0	0	0	0	0	65457
3	76520	0	0	25	0	0	0	76545
4	74002	0	0	0	0	0	0	74002
5	8560	0	0	0	0	0	0	8560
6	14775	0	0	0	0	0	0	14775
7	35105	0	0	0	0	0	0	35105
Total	307149	4366	7514	5265	204	1557	2037	328093

****

APPENDIX C

1971, 1981 AND 1986

CENSUS POR-POW LINKAGES DATA

****
1971 CENSUS POR-POW LINKAGES

	1	2	3	4	5	6	7	Total
1	32760	2445	5970	4515	60	225	960	46935
2	64260	83670	41475	13380	2430	2430	2460	210105
3	84510	20850	131280	35895	1020	5835	6975	286365
4	72360	8325	41205	130230	390	3255	17385	273150
5	2790	3285	2400	780	38355	315	165	48090
6	5010	12075	10650	3705	270	15645	1335	48690
7	13050	1740	7290	23175	135	825	67050	113265
Total	274740	132390	240270	211680	42660	28530	96330	1026600

****
1981 CENSUS POR-POW LINKAGES

	1	2	3	4	5	6	7	Total
1	39575	2835	7265	4655	220	550	1745	56845
2	84000	111275	64160	15905	3395	10630	7040	296405
3	98710	25485	160085	36340	1635	17075	13235	352565
4	85695	9570	49310	123855	745	6860	30225	306260
5	8360	11360	7740	1610	63550	1900	900	95420
6	12295	6895	26085	6415	575	51300	3870	107435
7	32145	4075	20540	47920	560	3715	146905	255860
Total	360780	171495	335185	236700	70680	92030	203920	1470790

****
1986 CENSUS POR-POW LINKAGES

	1	2	3	4	5	6	7	Total
1	45147	5164	9016	6960	256	1192	2201	69936
2	84348	144503	67175	19938	5118	19873	8579	349534
3	99701	41646	166835	42050	2018	26911	16207	395368
4	89577	15927	58557	152700	1095	13204	38783	369843
5	10797	18728	10185	2262	115024	5928	1507	164431
6	18807	16052	40056	12471	1846	87371	7564	184167
7	39867	6180	25450	67796	782	7958	307689	455722
Total	388244	248200	377274	304177	126139	162437	382530	1989001

APPENDIX D

1987 TDS DATA

1987 TDS
3-hour home-based work trips
Full-Time workers

Land Use: Office Building
External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	4229	15419	6805
AUTO-PASSENGER	3153	7758	1850
TRANSIT	13766	79209	36384
WALK	0	0	0
OTHERS	0	741	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	1576	941
AUTO-PASSENGER	0	0	0
TRANSIT	1329	1843	3525
WALK	0	3691	463
OTHERS	0	793	0

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	793	1918
AUTO-PASSENGER	0	0	0
TRANSIT	0	2428	3722
WALK	0	866	0
OTHERS	0	0	0

Land Use: Non-Office Building

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	6843	6127	3365
AUTO-PASSENGER	1836	1675	741
TRANSIT	2779	14910	4222
WALK	0	0	685
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	866	3036	0
WALK	0	2234	1720
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	2468	2572
AUTO-PASSENGER	0	0	0
TRANSIT	0	926	866
WALK	0	0	0
OTHERS	0	866	977

Part-Time Workers

Land Use: Office Building

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	610
TRANSIT	0	1668	2572
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	463	0
WALK	0	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Land Use: Non-Office Building

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	4379	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	741	463
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	463	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	708
AUTO-PASSENGER	0	0	0
TRANSIT	0	463	0
WALK	0	0	0
OTHERS	0	0	0

Full-Time Workers

Occupation Group 1

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	4408	4700	2745
AUTO-PASSENGER	610	4464	0
TRANSIT	9702	45218	21979
WALK	0	1904	0
OTHERS	0	741	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	1732	1843	2659
WALK	0	0	2184
OTHERS	0	793	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	977
AUTO-PASSENGER	0	0	0
TRANSIT	0	1171	0
WALK	0	866	0
OTHERS	0	866	0

Occupation Group 2

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	1168	14682	7424
AUTO-PASSENGER	2543	4968	1850
TRANSIT	5618	47244	18624
WALK	0	4021	685
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	1576	941
AUTO-PASSENGER	0	0	0
TRANSIT	463	3036	866
WALK	0	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	1586	3513
AUTO-PASSENGER	0	0	0
TRANSIT	0	2183	4588
WALK	0	0	0
OTHERS	0	0	977

Occupation Group 3

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	5496	2164	0
AUTO-PASSENGER	1836	0	741
TRANSIT	1225	1655	0
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	1675	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Part-Time Workers

Occupation Group 1

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	2409	463
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	463	0
WALK	0	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	708
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Occupation Group 2

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	4379	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	463	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	463	0
WALK	0	0	0
OTHERS	0	0	0

Occupation Group 3

External - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	2572
WALK	0	0	0
OTHERS	0	0	0

Internal - Internal

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

Internal - External

END-TIME	6:31-7:30	7:31-8:30	8:31-9:30
AUTO-DRIVER	0	0	0
AUTO-PASSENGER	0	0	0
TRANSIT	0	0	0
WALK	0	0	0
OTHERS	0	0	0

1987 TDS TRIPS TO/FROM C.A. BY TRIP PURPOSE AND END TIME

Home-based-School
End time 7:30 a.m.

	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	2258	0	0	0	0
5	0	0	0	0	383	0	0
6	0	0	0	556	0	0	0
7	0	0	388	0	0	0	0

Home-based-School
End time 8:30 a.m.

	1	2	3	4	5	6	7
1	1257	0	0	0	0	0	0
2	0	43175	773	0	0	0	0
3	743	0	16755	1609	0	0	0
4	2572	0	7659	19082	0	0	0
5	785	0	274	0	25993	0	0
6	0	1265	785	0	0	7635	0
7	695	0	0	360	0	0	25825

Home-based-School
End time 9:30 a m.

	1	2	3	4	5	6	7
1	12989	0	0	4977	0	0	0
2	0	44972	3287	649	0	1576	0
3	7089	430	44809	1685	0	0	0
4	743	1233	9681	31992	0	0	2572
5	0	785	0	0	32132	0	0
6	0	181	383	0	0	23442	0
7	1649	0	0	785	0	1850	67095

Home-based-Other
End time 7:30 a.m.

	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	11216	3153	0	0	0	0
3	0	463	12942	0	0	0	0
4	0	977	0	5523	0	0	1836
5	785	785	0	0	5812	0	0
6	0	0	610	0	0	3513	0
7	360	0	0	497	0	0	5673

Home-based-Other
End time 8:30 a.m.

	1	2	3	4	5	6	7
1	0	0	3002	0	0	0	0
2	2543	19696	6565	2572	610	1576	0
3	3311	0	22289	977	0	0	2913
4	3512	0	2543	10321	0	0	649
5	0	0	0	0	8478	0	0
6	233	326	2156	233	0	7315	0
7	0	0	497	1146	0	785	20791

Home-based-Other
End time 9:30 a.m.

	1	2	3	4	5	6	7
1	977	2543	2884	2572	0	0	0
2	2482	16228	1112	0	2572	6827	0
3	1586	2667	14730	0	0	0	0
4	1207	0	977	19912	941	0	2270
5	0	0	0	0	17734	383	0
6	0	360	2636	0	0	10675	0
7	610	0	0	0	0	0	21850

Non-Home-based
End time 7:30 a.m.

	1	2	3	4	5	6	7
1	785	0	0	0	0	0	0
2	0	3316	0	0	0	0	0
3	0	1576	0	2572	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	1173	0	0
6	0	0	0	0	0	0	0
7	0	0	0	210	0	0	5046

Non-Home-based
End time 8:30 a m.

	1	2	3	4	5	6	7
1	2797	0	1363	793	0	0	0
2	2258	3640	9198	0	0	773	0
3	695	0	6389	2572	0	3248	649
4	793	0	463	6900	0	0	0
5	497	1069	610	0	3034	0	308
6	675	1576	3033	0	0	1424	0
7	695	0	0	388	0	0	14215

Non-Home-based
End time 9:30 a.m.

	1	2	3	4	5	6	7
1	8036	0	0	0	0	0	941
2	866	6650	463	0	0	0	0
3	0	4343	7105	0	2258	3702	785
4	0	0	360	10499	0	0	793
5	0	0	0	0	7013	0	283
6	210	0	0	785	0	8833	0
7	0	0	1850	3044	0	0	20829

1987 TDS 24-HOUR WORK TRIPS GTA-WIDE BY OCC & MODE

Mode 1· Auto-Drive

Occupation Group 1: Clerical/Sales/Service

	1	2	3	4	5	6	7	Total
1	977	0	0	977	0	709	0	2663
2	3062	36786	16122	3732	942	6824	3483	70951
3	4583	11028	18414	4953	0	7577	5868	52423
4	9161	0	3842	15757	0	2630	4980	36370
5	0	4681	3806	1266	18060	1093	2084	30990
6	676	2526	12844	0	0	11882	1391	29318
7	3979	556	2385	12138	616	5481	70326	95481

Occupation Group 2: Professional/Managerial/Etc.

	1	2	3	4	5	6	7	Total
1	4355	0	793	1735	0	2573	0	9456
2	12022	27486	17227	5166	977	6330	2573	71780
3	7724	6703	33768	12707	2258	5716	7805	76681
4	8878	5474	12142	25562	942	3252	12216	68465
5	2641	11693	4393	0	19342	384	0	38453
6	1780	1611	18836	2714	1221	11110	2560	39833
7	5351	611	7001	13853	0	2546	67380	96741

Occupation Group 3: Other

	1	2	3	4	5	6	7	Total
1	0	0	0	0	0	0	1676	1676
2	2202	23690	7613	5093	1750	942	5961	47251
3	942	6928	20131	10040	2573	3811	2226	46650
4	1224	793	3907	16325	942	2544	5602	31336
5	0	4311	384	571	29850	1661	0	36776
6	1851	2104	3247	4582	0	6005	951	18739
7	2421	2867	3380	8863	283	2787	37636	58239

Mode 2. Auto-Passenger (includes taxi)

Occupation Group 1: Clerical/Sales/Service

	1	2	3	4	5	6	7	Total
1	430	0	0	866	0	0	0	1296
2	741	5067	0	0	0	0	0	5808
3	1689	2554	4672	0	942	0	0	9856
4	1676	0	1837	6865	0	0	0	10378
5	0	274	0	0	1296	0	0	1570
6	611	0	611	0	0	2097	0	3319
7	2283	0	1851	2546	0	1851	5879	14409

Occupation Group 2: Professional/Managerial/Etc.

	1	2	3	4	5	6	7	Total
1	866	464	0	464	0	0	0	1793
2	2167	2226	0	0	0	1676	0	6068

3	2319	0	2018	0	0	0	0	4337
4	2544	0	793	3439	0	0	1676	8451
5	1643	384	0	611	1022	0	0	3659
6	3701	326	1572	384	0	1561	0	7543
7	0	0	786	857	0	1397	2930	5970

Occupation Group 3: Other

	1	2	3	4	5	6	7	Total
1	0	0	0	0	0	0	0	0
2	2578	1225	0	0	0	686	0	4489
3	0	1225	4559	464	0	2258	1676	10181
4	0	1676	0	0	0	0	977	2653
5	0	1283	0	0	4034	755	0	6072
6	0	556	0	0	0	0	0	556
7	0	571	0	1851	0	0	6298	8719

Mode 3: Transit (includes regional bus)

Occupation Group 1. Clerical/Sales/Service

	1	2	3	4	5	6	7	Total
1	9172	464	0	0	0	709	0	10344
2	23711	11357	9209	0	0	0	0	44277
3	24188	1441	15660	3453	0	3036	0	47778
4	27167	1405	5294	8125	0	0	649	42640
5	611	0	497	0	571	0	0	1678
6	1894	676	845	0	0	1760	0	5174
7	9075	0	497	1084	0	0	3168	13825

Occupation Group 2: Professional/Managerial/Etc

	1	2	3	4	5	6	7	Total
1	6416	1330	6237	1330	0	0	0	15313
2	18790	2544	2482	0	0	0	0	23816
3	25879	464	4387	793	1159	1237	1639	35558
4	16466	0	1479	9155	0	0	0	27100
5	676	0	0	0	0	0	0	676
6	2552	0	652	0	0	0	0	3204
7	3973	0	1351	497	0	0	1266	7086

Occupation Group 3: Other

	1	2	3	4	5	6	7	Total
1	464	0	1257	0	0	0	0	1721
2	5139	8513	0	0	0	0	0	13651
3	0	686	9985	3334	744	2091	0	16839
4	3316	744	7519	7339	0	0	0	18919
5	0	274	0	0	676	0	0	950
6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	2586	2586

Mode 4: GO-Rail

Occupation Group 1: Clerical/Sales/Service

	1	2	3	4	5	6	7	Total
1	0	0	0	0	0	0	0	0
2	2835	0	0	1837	0	0	0	4672
3	0	0	0	0	0	0	0	0
4	1837	0	0	0	0	0	0	1837
5	5578	442	0	0	0	0	0	6020
6	210	0	0	0	0	403	0	613
7	3270	0	0	0	0	0	0	3270

Occupation Group 2: Professional/Managerial/Etc.

	1	2	3	4	5	6	7	Total
1	0	464	0	977	0	0	0	1441
2	2573	0	0	0	0	0	0	2573
3	0	0	0	0	0	0	0	0
4	464	0	0	0	0	0	0	464
5	1783	0	0	0	676	0	0	2458
6	2592	0	0	0	0	0	0	2592
7	8757	0	2001	0	0	0	0	10758

Occupation Group 3: Other

	1	2	3	4	5	6	7	Total
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	977	0	977
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	406	0	0	406
6	0	0	0	0	0	0	0	0
7	1851	0	0	0	0	0	0	1851

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