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TRANSPORTATION DEMAND IN THE TORONTO CENTRAL AREA

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 signify that the traditional "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 decentralization of jobs, as well as the continuing dispersion of the resident labour force.

A recent research (1) based on Canadian census data found that "*overall commuting flows still tend to be dominated by the widespread dispersal of employment through 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 that encouraged decentralization, Soberman (9) concluded in the 1989 Forum on the future of the City of Toronto 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.*".

Nowlan and Stewart (7) 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 was 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. Based on one of the relationships derived Nowlan and Stewart (7) concluded, "*past changes in population and housing have had on inbound trips: 70 fewer trips for each 1000 increase in population in the Central Area, or 120 fewer trips for each addition of 100 dwelling units*". When simply stated, the annual change in inbound person trips crossing the Central Area cordon can be explained by three independent variables, namely, mid-year occupied office floor space, Central Area population and Central Area dwelling units.

However, a recent study by Sarsan (9) who analyzed the Nowlan-Stewart hypothesis 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.

STUDY OBJECTIVES

The principal purpose of this study is to analyze and to 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) perform time series analysis of travel demand trends associated with the Central Area,
ii) review and verify the Nowlan-Stewart hypothesis and the Saran analysis which attempted to relate travel demand, population and employment in the Central Area of Toronto through the use of available data,
iii) perform a cross-sectional analysis using the 1987 Travel Diary Survey data, and
iv) evaluate the Cordon Count data using the result of the cross-sectional analysis and a model derived from the Sarsan analysis.

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 screen lines 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. 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.

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 14 years was considered to be reasonable to reflect any significant structural changes in the time series analysis.

THE 1976 CENTRAL AREA PLAN OF TORONTO

Deconcentration was the 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. In order to achieve the deconcentration policy, the City of Toronto recognized that the largest and fastest growing employment sector was located in the Central Area which 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 might 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.

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 become more office oriented, and travel demand into the Central Area has also grown. 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 significant impacts on economic, social and physical terms. However, some of the changes might not have been intended changes by the Plan. TABLE 1 summarizes the evaluation of the 1976 Central Area Plan.

TABLE 1: GOALS AND EVALUATION OF THE 1976 C.A.PLAN (3)

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 resident and target income group	• Over 17,000 new units built • Further 11,000 approved • C.A. population is growing • Housing price have soared	• Social housing production failed to meet target • Need to increase affordable housing production
Office Deconcentration • Control rate 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 C.A. 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

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. The following section presents the findings of travel demand associated with the Central Area.

ANALYSIS OF TRAVEL PATTERNS IN THE CENTRAL AREA

The focus of this section is the assessment of travel patterns related to the central area. Detailed examination of travel demand 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 section the analysis utilized data gathered in the past 14 years for a more detailed analysis to understand the role of the Central Area as a trip attraction centre. The data used to support this analysis were 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)

THE POR TO POW 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. Travel pattern was examined using a very simple two zone designation. The Central Area zone was designated as the internal zone, whereas the G.T.A. was 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 2 summarized these travel patterns from the three census sources.

TABLE 2: POR-POW LINKAGES BY ZONE

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.

The volumes of the three zonal pairs have grown over time at substantially different rates. Most significant was the growth rate of more than 40 percent shown by the internal to external linkages between 1981 - 86. The rate of growth of these internal to external linkages or "reverse commuting" had accelerated between 1981 and 1986 with an average annual growth rate of 8.8 percent. The external to internal linkages experienced the lowest growth of the O-D pairs between 1981 and 1986, at an average annual rate of 1.4 percent.

ASSESSMENT OF 24 HOUR WORK TRIPS

The POR-POW tabulations only recorded where people lived and worked. 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 analysis was limited to the examination of the spatial distribution of work trips by mode in the Metro Toronto Region in the 1986 TTS. TABLE 3 summarized the finding between the internal and external zones.

TABLE 3: SPATIAL DISTRIBUTION OF WORK TRIP BY MODE

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

1 Auto work trips include taxi
2 Transit work trips include GO-Rail

The work trips that occur within the Central Area (internal-internal) showed that the walk/other mode dominated and was consistent with other research (4). The proportion of the walk/other mode had grown from 37 percent to 44 percent between 1979 and 1986, and was apparently growing at the expense of auto trips. The Metro to Central Area (external-internal) commuting was dominated by the transit mode, and showed little change over the period of 1979 to 1986. This model split of one-third auto trips and two-thirds transit trips had perhaps reached an equilibrium. It was unlikely to change unless new transport facilities were provided (11). The mode split was found to be fifty to fifty for the "reverse commuting" trips i.e., C.A. to Metro and this ratio was found to be similar to the mode split for inbound commuting trips during the 1960's (11).

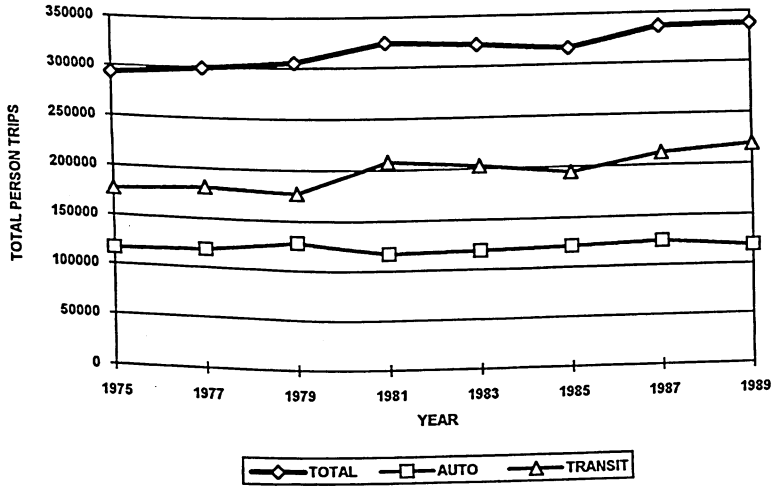
REVIEW OF THE METRO CORDON COUNT

The Metro Cordon Count program provided 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. The peak period used in the analysis referred to 6:30 a.m. to 9:30 a.m. for all trip purposes and modes.

Passenger Trips

The overall inbound person trips during the morning peak period entering the Central Area has grown by 15.2 percent 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 number of person arriving in automobile had seen little growth, and the net effect was the decline in auto-occupancy rate as discussed in the next section. On the contrary, for passengers using transit to enter the Central Area, the historic trends showed significant growth during the study period. FIGURE 1 illustrated the number of total person trips, auto person trips and transit person trips crossing the Central Area Cordon in both directions during the morning peak.

FIGURE 1: INBOUND PERSON TRIPS 1975 - 1989

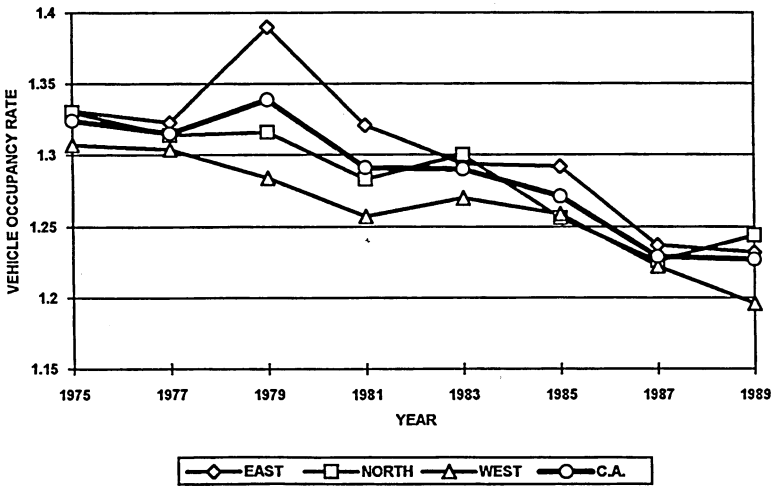


Auto Vehicle Trips and Vehicle Occupancy Rate

The number of automobiles (including taxis) entering and leaving the Central Area between 1975 and 1989 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 2 showed the auto-occupancy rate for inbound traffic between 1975 and 1989. The occupancy rate had decreased significantly from 1.32 person per automobile to 1.23 person per automobile over 14 years and averaged to be nearly 0.5 percent annually in the decline.

FIGURE 2: VARIATION OF VEHICLE OCCUPANCY, 1975 - 89
INBOUND TRAFFIC

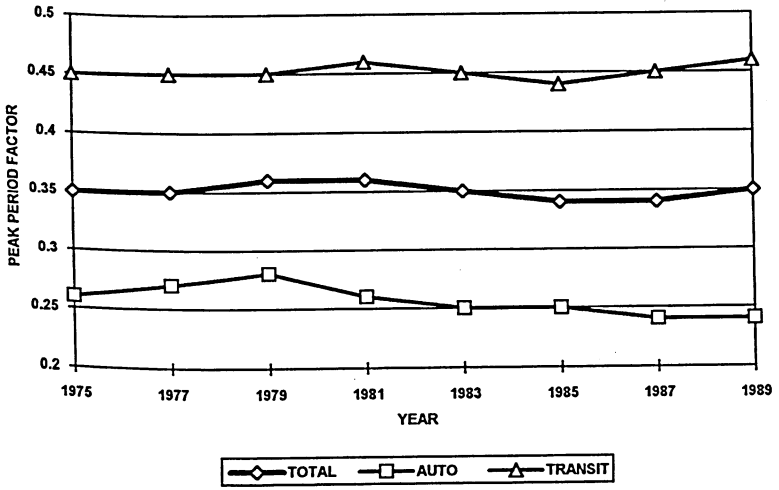


The Peak Period Factor

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*" (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.

The peak period factor is defined 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. For transit person trips, the peak period factor had remained quite stable at 45 percent over the years. The peak period factor for auto users behaved quite differently. The net effect clearly showed that auto person trips were shifting away from the conventional morning peak period, i.e., the peak period factor was declining. This indicated that the roadway capacity of major roadways into the C.A. has reached or exceeded their capacities. However, the overall result, by combining all modes, indicated that the peak period factor remains quite flat as illustrated in FIGURE 3.

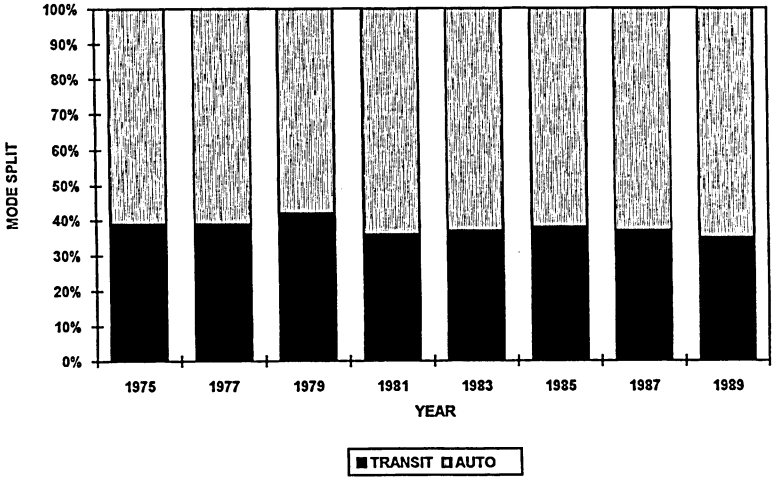
FIGURE 3: VARIATION OF PEAK PERIOD FACTOR, 1975 - 89
INBOUND PERSON TRIPS



MODAL SPLIT

Given the detailed information from the Cordon Count data, the mode split was also analyzed. FIGURE 4 illustrated the historical trends in the percentage of transit and auto usage for the Central Area Cordon. In 1989, the automobile carried 35 percent of the inbound passengers into the Central Area, and this ratio correlated well with the travel survey results. The ratio of automobile trips were declining, and have seemed to reached an equilibrium. However, any improvements on the road or transit systems would shift the equilibrium depending on the improvement policies implemented. For example, by building additional highway infrastructures, the share of automobile is expected to increase.

FIGURE 4: MODAL SPLIT OF INBOUND TRIPS, 1975 - 1989



THE NOWLAN-STEWART HYPOTHESIS

The hypothesis which argued that the growing residential population in the Central Area had impeded the growth in inbound commuting trips into the Central Area was first put forward by Nowlan (6), and finalized by Nowlan and Stewart (7). Based upon the population and housing changes from 1975 to 1989, the analysis concluded that there will be "*70 fewer trips for each 1000 increase in population in the Central Area, or 129 fewer trips for each addition of 100 dwelling units*" (7). The hypothesis 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.

One of the two basic equations derived in the Nowlan and Stewart study (7) was:

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

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 with the Central Area Cordon.

For the purpose of this study only equation 1 was examined. 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.

THE SARSAN MODEL

Some of the short-comings in the Nowlan-Stewart hypothesis were addressed by Sarsan (8). The Sarsan analysis concentrated on equation 1. The basic equation which Sarsan developed was of the form:

$$\text{TRIPS} = K + 0.9*(0.04*\text{SPACE} - L*\text{POPULATION}) \quad \text{.....eqn.2}$$

where,

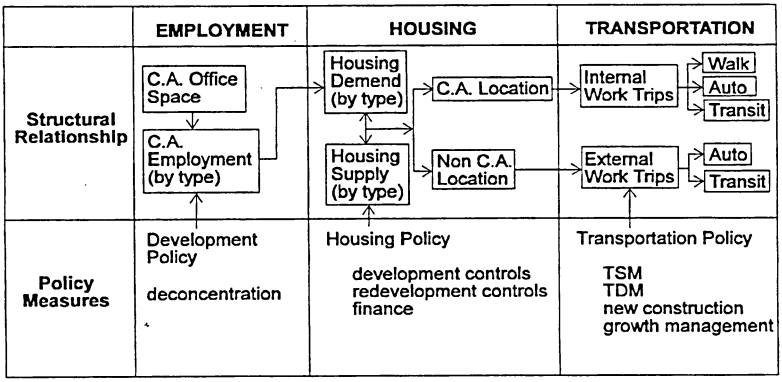
L = The percentage of Central Area population working full-time office job in the Central Area
K = Background trips such as non-work trips, through trips, non-office work trips and part-time office trips

A 10 percent absenteeism rate was included which was reflected by the 0.9 coefficient on the right hand side of equation 2. The floor space per worker 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 in equation 1. L was calculated to be 70 percent, i.e., 70 percent of the Central Area population worked in full-time office job in the Central Area, without taking 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. 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 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 percent (8). 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. 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.

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 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. FIGURE 5 illustrated the relationship between employment, housing and transportation as well as their policy measures.

FIGURE 5: POLICY MEASURES AND THEIR EFFECTS



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 used 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, it must be used cautiously as a planning tool to assess impacts of alternative strategies.

The Nowlan-Stewart hypothesis also appeared to be too simple to assess the impact of Central Area population growth on morning peak hour inbound traffic entering the Central Area because 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 (10):

i) Additional housing was provided in the Central Area, accommodating part of the Central Area workers. In other word , the Central Area is becoming increasingly more "self-contained".
ii) 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 hours.
iii) A decline in non-work trips and through trips entering the Central Area during the morning peak hours.
iv) 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 rigid commuting schedule to travel inside the morning peak hours.

TRAVEL DEMAND MODELLING

In order to explore the implications of the Nowlan-Stewart hypothesis for future transportation planning associated with the Central Area, a more in-depth analysis at a given point in time (cross-sectional analysis) was performed in order to develop a simple travel demand model. The purpose of this model was 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 attempted to establish the basic equation for use in the general assessment of various policy options in the future.

MODELLING APPROACH

The modelling approach was based on the Nowlan-Stewart hypothesis. It was assumed that the amount of passenger flow into the Central Area during the morning peak period was associated with selected land use and demographic variables in the Central Area. The level of analysis was highly aggregated, and the Greater Toronto Area was considered as one external zone. Inevitably, because of this level of aggregation, some of the variation which existed in the independent variables would be masked. However, due to the nature of the Cordon Count data, there was little choice. The 1987 Travel Diary Survey (TDS) data was used for the cross-sectional analysis in which the L coefficient could be estimated.

The volume of inbound passenger trips during this period was defined to be the dependent variable TRIPS. 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 (7). Based on equation 2, once the L coefficient is determined from the TDS analysis, the K coefficient can be determined by substituting the TRIPS, POPULATION, and SPACE values collected in 1987. Hence, the 1987 TDS data was analyzed in the following section to determine the travel demand pattern in 1987.

THE APPLICATION OF THE 1987 TRAVEL DIARY SURVEY (TDS)

The TDS provided socio-economic characteristics (occupation and employment status), land use (place of residence and place of work), trip purpose and trip end times information which was not available from any other source.

The primary focus of the analysis was the pattern of peak period, home-based work trips associated with the Central Area. The analysis of peak period work trips concentrated on workers who specified their trip end times during the morning peak period between 6:30 a.m. and 9:30 a.m.. The trip characteristics examined in this cross-sectional analysis were summarized in TABLE 4.

TABLE 4: SUMMARY OF TRIP CHARACTERISTICS

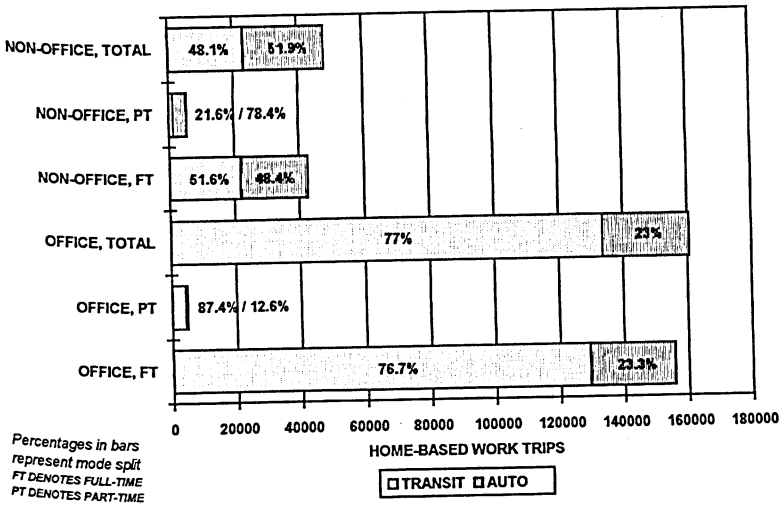
TRIP CHARACTERISTICS	CATEGORIES
Origin/Destination Pairs	External - Internal
Work Site and Use	Office Building Non-Office Building
Trip Purpose	Home-Based Work, Full-Time Home-Based Work, Part-Time Other
Employment Status	Full-Time Part-Time
Travel Mode	Auto Transit

ANALYSIS OF WORK TRIPS BY LAND USE

This part of the analysis was focused on the place of work for the peak period, home-based trips. By examining the volume of work trips that arrived at various work site destinations, it provided a reasonable check on the Nowlan-Stewart hypothesis because one of the independent variables was occupied office space (SPACE).

FIGURE 6 illustrated the modal variation by work site and employment status for external to internal trips. The full-time office-bound category clearly made up the bulk of the volume of home-based work trips made by full-time employees that entered the Central Area during the morning peak period, nearly 80 percent were destined to office buildings. Home-based part-time work consisted of only 4.7 percent of all home-based work trips made to the Central Area.

FIGURE 6: MODAL VARIATION BY WORK SITE LAND USE AND EMPLOYMENT STATUS



The non-office sector exhibited a near fifty to fifty mode split. However, the office sector showed a mode split of 23.3 percent auto and 76.7 percent transit, making the overall mode split to be near 30 percent to 70 percent 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 was the percentage of mode split as exhibited by the Central Area Cordon count.

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 overshadowed the rest. It consisted of 81.6 percent of all trips entering the Central Area during the peak by all modes. Trip purposes other than work only made up 14.4 percent of the trips that were made into the Central Area during the peak period.

COMPARISON WITH 24 HOUR WORK TRIPS

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

It was found that 77 percent of all workers arrived at the Central Area during the morning peak period. Most of the transit users (80.3 percent) arrived at work during the peak period, whereas the percentage of auto users (71 percent) that arrived at work during the peak period was comparatively lower. This implied 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 (all modes) amounted to approximately 90,000. This further indicated that the Nowlan-Stewart hypothesis overestimated the effect of Central Area population growth.

LINEAR REGRESSION MODEL

The employed labour force in the Central Area was 85,198 (7). 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 (10). First, only 64 percent 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 percent of the Central Area employed labour force were also working in the Central Area. This compared favourably with the 1989 CARS result of 35 percent to 40 percent (8).

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 2, 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 (7))
K = 336,706 - 168,573 = 168,133 background trips
P = 132,090 people (Nowlan-Stewart (7))

and,

TRIPS = K + 0.9*(0.04*SPACE - L*POPULATION).....eqn.2

therefore, **L** = 35 percent

Hence, 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 K coefficient of 35 percent estimated from the modified Sarsan model is reasonable (compared with 1989 CARS figure of 35-40 percent)
iv) The final format of the Sarsan model is best described as:

TRIPS = 168,000 + 0.9*(0.04*SPACE - 0.35*POPULATION).....eqn.3

This cross-sectional analysis provided an insight of the composition of traffic entering the Central Area Cordon during the peak period using equation 3. Half of the inbound trips entering the Central Area were 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 3, 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 3.

FUTURE TRANSPORTATION PLANNING IMPLICATIONS AND CONCLUSIONS

Based on the results of the previous findings, it is possible to look at a reasonable growth scenario for the Central Area. Equation 3 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 has an average annual rate of just 3 percent 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. For the amount of inbound trips to remain at the 340,000 level, the Central Area population has 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 a healthy growth of office development the Central Area 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 Are population have been approximately 2,000 people annually in the past decade (2).

The traditional way to accommodate increased travel 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 was associated with full-time work travel. The rest of the inbound trips entering the Central Area possessed different trip purposes. Home-based part-time peak 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 could be explained by the possibility that the background travelers 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 percent auto and 49 percent 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 pointed 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 automobile entering the downtown area during the peak periods (12).

By implementing TDM programs the background travel could be reduced, and using equation 4 to 6 , the following scenarios might be possible using TRIPS (T) = 340,000 and POPULATON (P) = 130,000:

% reduction of K coefficient		Office Space (million m^2)
20%	T = 134,000 + 0.036*S-0.315*P eqn.4	6.9
40%	T = 100,800 + 0.036*S-0.315*P.....eqn.5	7.8
60%	T = 67,200 + 0.036*S-0.315*P.....eqn.6	8.7

As discussed before, the addition of Central Area population also helped to reduce the amount of inbound traffic going 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 percent. 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 7 to 9 using TRIPS (T) = 340,000 and POPULATION (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.....eqn.7	6.0
50%	T = 168,000 + 0.036*S-0.450*P.....eqn.8	6.4
75%	T = 168,000 + 0.036*S-0.675*P.....eqn.9	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 percent TRIPS (T) = 340,000 and POPULATION (P) = 130,000:

% reduction of K coefficient		Office Space (million m^2)
20%	T = 134,000 + 0.036*S-0.5*P.....eqn.10	7.5
40%	T = 100,800 + 0.036*S-0.5*P.....eqn.11	8.5
60%	T = 67,200 + 0.036*S-0.5*P.....eqn.12	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. Polices 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.

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