Studies of Trends of Travel Between 1954 and 1964 in a Large Metropolitan Area

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•SINCE its inception in 1954 the Metropolitan Toronto Planning Board has pursued a progressive transportation planning and research program as one of its many statutory functions (1). Beginning with a worker origin-destination by mode survey in 1954, this was followed in 1956 by a conventional home interview survey (Fig. 1). Both surveys were used to derive travel characteristics of area residents as a first step in the development of a Traffic Prediction Model. The report "The Metropolitan Toronto Transportation Plan for the Year 1980" was published in 1964, and was based largely on the results of traffic prediction studies with the 1956 person travel relationships.

It is accepted practice to assume that the derived travel characteristics will not change so significantly as to invalidate the results of long-term transportation plan studies even where considerable changes are predicted in the social and economic structure of an area. Apart from the suspicions about the predictability of input data there is the question as to the long-term stability of travel characteristics which form the basis of the traffic prediction procedure. Largely because of this fundamental question, a second home interview survey was carried out in 1964 for the purpose of verifying the 1956 travel characteristics (2).

The purpose of this paper is to present some of the comparative results of these surveys to show to what extent the travel characteristics used in the traffic prediction model, which was calibrated to 1956 travel relationships, have changed. Work involved in the analysis of survey data and the development of the model has been undertaken almost exclusively by the Traffic Research Corporation under contract to the Metropolitan Toronto Planning Board.

Sufficient analysis was carried out to validate the travel characteristics incorporated in the traffic prediction model. In fact these analyses are only initial and do not represent, by any means, a comprehensive analysis of all survey data.

URBAN CHANGE 1956 TO 1964

A comparison of travel characteristics obtained from the 1956 and 1964 home interview surveys must, of course, be considered in relation to the socioeconomic changes in the area during this period. It is theorized that the more substantial such urban changes, the greater the likelihood of measurable changes to the 1956 travel characteristics.

Table 1 indicates the magnitude of urban change during the 8-yr period. The population of the study area increased by 33 percent and at an average rate of 56,000 persons a year. Dwelling units increased at a faster rate than population, by 40 percent, and increased the residential acreage by 52 percent. The total acreage of urban development increased from 135 to 170 square miles.

Automobile registrations increased to just over a half million, an increase of 140,000—roughly 38 percent and about equal to the increase in dwelling units, although there is probably no relationship between these two figures. Total vehicles increased by 45 percent.

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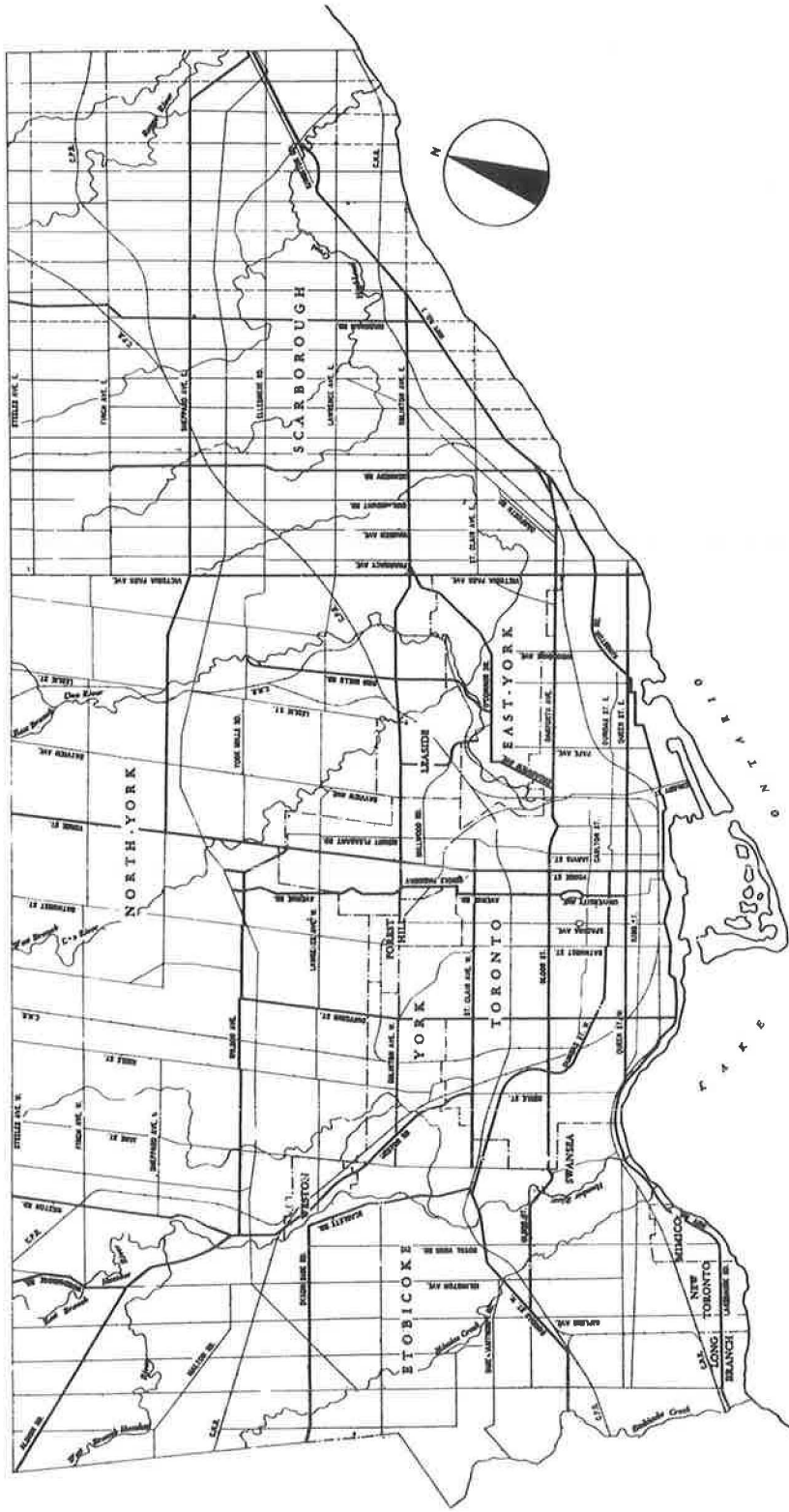


Figure 1. Metropolitan Toronto.

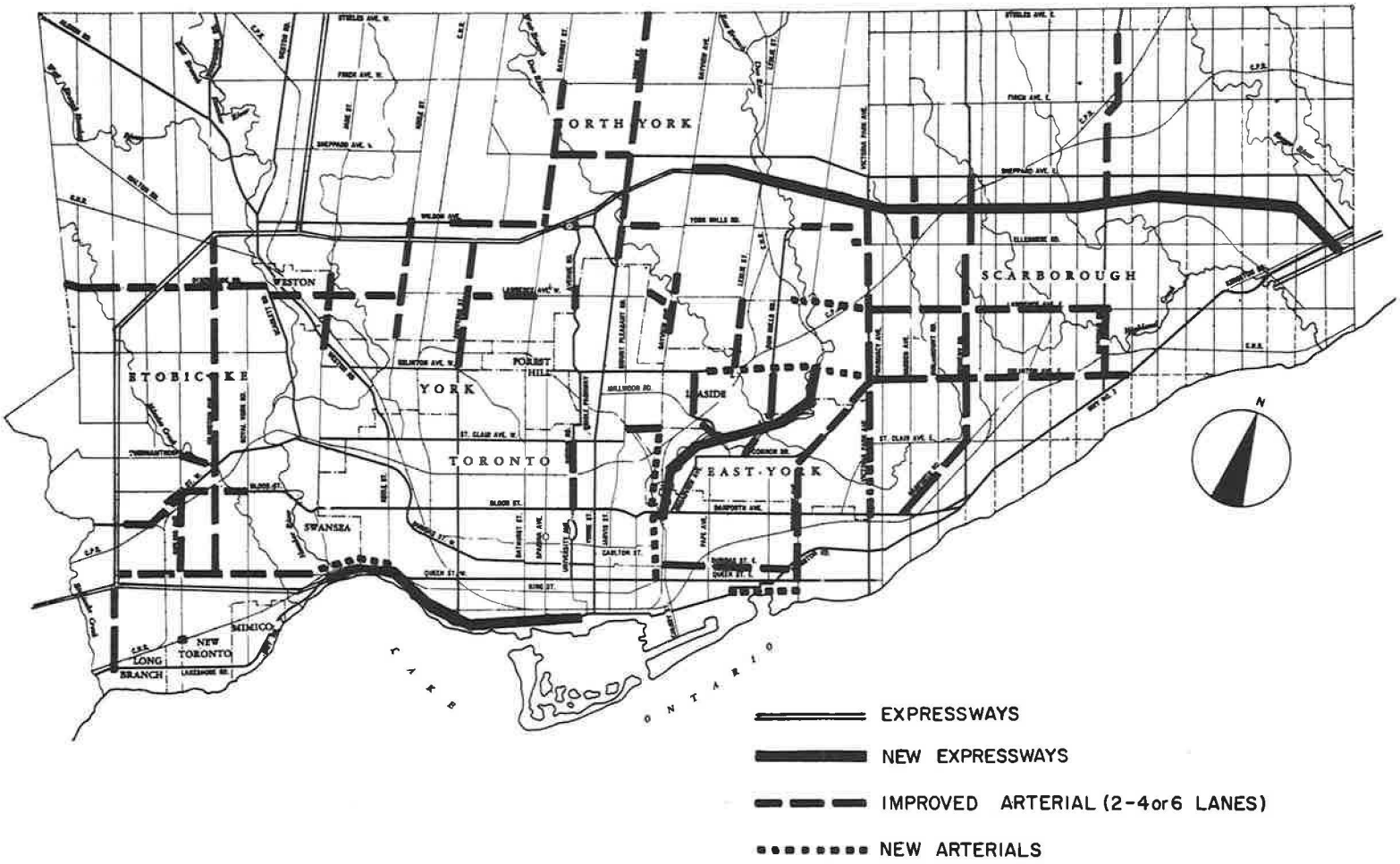


Figure 2. New and improved roads, 1956 to 1964.

TABLE 1

URBAN CHANGE, 1956 TO 1964

Item	1956	1964	± Diff.	Percent Change (rounded)
Population	1,358,000	1,813,000	455,000	+33
Dwellings	342,200	479,000	136,800	+40
Employment	630,200	711,700	81,500	+13
Developed urban area (sq mi)	135	170	35	+26
Auto registrations	363,900	503,600	139,700	+38
Total vehicle registrations	429,300	622,000	192,700	+45
Assessment (billions)	$3.2	$4.6	$1.8	+44
Metro budget (millions)	$82.2	$262.2	$180.0	+219
Expressway miles	26	54	28	+108
Transit annual revenue pass. (millions)	303.8	275.3	28.5	-10
Riding habit, rev. pass/pop	223	160	-63	-28
Transit route-miles	470	595	125	+27
Transit vehicle-miles (millions)	47.0	55.0	8.0	+17
Transit fares (Zone 1)	8 for $1.00 (12.5 cents)	6 for $1.00 (16.65 cents)		

TABLE 2

DISTRIBUTION OF POPULATION AND EMPLOYMENT, 1956-1964

Location	1956	1964	Change (1000)	1956-64 (%)	Percent of Metro 1956	Percent of Metro 1964
(a) Population						
City of Toronto	667.6	670.0	+2.4	+0.4	49.0	37.0
Six inner suburbs	241.4	274.0	+32.6	+13.5	18.0	15.0
Six outer suburbs	449.0	869.0	+420.0	+93.0	33.0	48.0
Total	1358.0	1813.0	+455.0	+33.5		
(b) Employment						
City of Toronto	460.2	432.3	-27.9	-6.0	73.0	61.0
Six inner suburbs	68.7	60.7	-8.0	-11.7	11.0	8.0
Six outer suburbs	101.3	218.7	+117.4	+116.0	16.0	31.0
Total	630.2	711.7	+81.5	+13.0		

It has been estimated that during the 8-yr period about $5 billion has been invested in all forms of construction. In 1956 the total budget of the Metropolitan Corporation was $82 million which, by 1964, had increased to $262 million. These figures include $6 million, respectively, for Metropolitan road works. Figure 2 shows new and improved roads, 1956-1964.

The trends in public transit usage have a significant effect on any transportation system. From 1956 to 1964, notwithstanding an addition of 125 route-miles to the system and a 17 percent increase in transit vehicle-miles, the number of revenue passengers decreased by almost 10 percent from roughly 304 to 275 million. Thus, the number of transit trips per head of population decreased from 223 to 160.

Suburban growth has produced significant changes in the areal distribution of population and employment (Fig. 3).

Within the city and inner suburban area there has been only a slight increase in population compared to the 93 percent increase in the outer suburbs (Table 2). The change in central sector employment is even more startling since it shows a substantial decrease of almost 10 percent and an increase of 116 percent in the outer suburban area. This is equivalent to the total increase in employment within the 8-yr period.

These shifts in employment, together with the shifts in residential population, have a pronounced effect on the travel pattern. Preliminary studies indicate that, while trends to the city center have decreased and those to the inner belt have remained stable, the share of the outer area has almost tripled and now practically equals that of the city center. Trips into Metro from outside, while still only accounting for one out

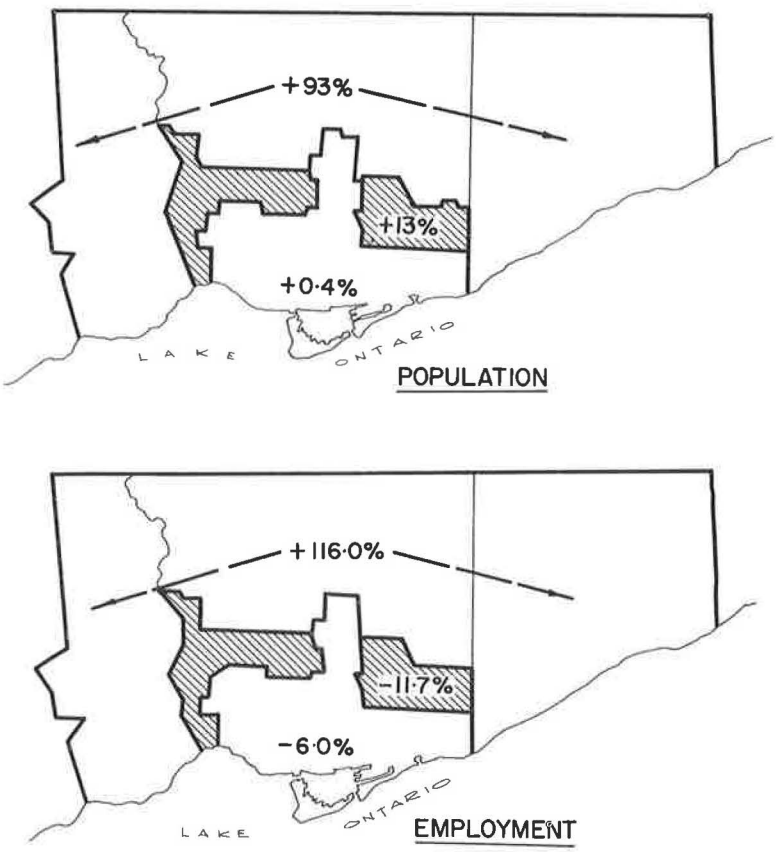


Figure 3. Change in distribution from 1956 to 1964.

of sixteen trips, have almost doubled. Particularly important is the fact that more than one-fifth (21% against 6% in 1954) now move entirely within the outer area.

As a result of these fundamental changes, the old notion that all trips during the morning rush hours are directed from the periphery toward the center has lost its validity. Of all trips, those inbound accounted in 1964 for little more than two out of five trips compared to two out of four trips in 1956.

These figures demonstrate the considerable changes in Metropolitan Toronto which, it is contended, have been substantial enough to influence changes in the 1956 travel characteristics.

TRAVEL CHARACTERISTICS

A research program was initiated to find the relationships between people's motivations to travel and the total production of trips according to the purpose, time of day, duration, method and route of travel. It was recognized that four primary travel decisions were common to the great majority of trips made in the metropolitan area, as follows: (a) Why travel? (b) When to travel? (c) Duration of travel? (d) Method of travel (inclusive of choice of route)?

These travel decisions were highly interrelated (Fig. 4). The purpose for traveling was readily identified with the trip origin and destination and the time of day. Such decisions were also shown to dictate the duration of trip and the method of travel used.

The decisions of why and when people travel appeared to establish the production of total travel during a particular time period of the day. The actual production of trips was highly dependent on the number and characteristics of persons living in each part of the metropolitan area, the number of work places and the number of opportunities for shopping, recreation, etc. Next, the decisions about duration of travel established the distribution of trips between any two particular population and employment centers. Research has shown that the distribution of trips between two centers was directly proportional to the opportunities at each center and inversely proportional to the travel impedances separating the centers. Lastly, the decision about method of travel and the route to follow determined the division of the total traffic between the different transportation modes and routes, such as automobiles, subways, streetcars, buses, or

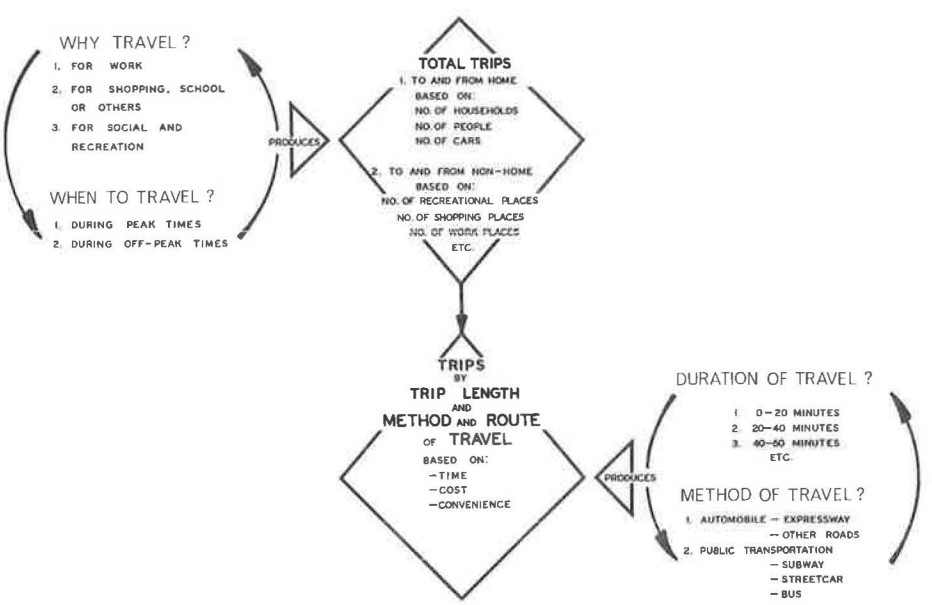


Figure 4. Travel behavior produces person trips.

combinations thereof. Systematic observations have shown that the choice of mode depends on such factors as travel time, travel cost and travel convenience in accordance with the purpose of travel and the socioeconomic status of the traveler.

WHY AND WHEN PEOPLE TRAVEL

The 1964 home interview survey showed that on an average weekday, about 2.5 million trips were made by 1.8 million residents of Metropolitan Toronto. This was 800,000 trips more than reported by the 1956 survey or an increase of 48 percent as compared to the population increase of 33 percent. On a per capita basis this indicates an increase in trip generation per person of 0.1: from 1.3 in 1956 to 1.4 in 1964. This increase does not appear to represent a significant change and would not be considered as indicative of a trend.

Why Travel

The dominant purpose of travel was between home (to and from) and work, as approximately 49 percent of all person trips were made for this reason. Trips between home and shopping, school, personal business or others comprised the next largest purpose for travel. In total, 89 percent of all person trips were home based with at least one end of the trip anchored at home.

The distribution of travel by major travel purpose is based on the data of the 1956 and 1964 surveys (Table 3). The shift between work travel and travel for other purposes during 1956 to 1964 was not significant. The slight shift from non-home based travel to home-based travel was explained by the special refinement of linking serve passenger and change of mode trips to the primary home-based leg of the trip. For example, if two trips are reported, such as one trip from home to serve passenger (school child driven to school) and a second trip from serve passenger to work, these would be combined or linked to form a single trip from home to work, etc. While this procedure was applied with the 1964 survey, it was not adopted in the 1956 survey summaries. Serve passenger and change of mode trips accounted for more than 10 percent of total trips of which approximately two-thirds would ordinarily be classified as non-home based trips, and therefore, should be linked. The removal of the non-home based serve passenger or change of mode trips from the file by linking with the home-based leg of the trip did account for the otherwise apparent shift to home-based travel.

During an average 24-hr period, the number of trips destined for any given area equaled the number of trips leaving that area. There was a distinct directional symmetry of travel associated with the home (Table 4). Of all person trips, 45 percent originated at home and 44 percent were destined to home in the metropolitan area. It was recognized that slightly more travel was destined to work than came home directly from work, while more trips returned from social and recreation to home than went there from home. It was noteworthy that this symmetry of travel appeared to have been maintained during the past 8 years.

TABLE 3

DISTRIBUTION OF TRAVEL BY PURPOSE OF TRAVEL
(Daily Travel by all Modes)

Purpose of Travel	1964 (%)	1956 (%)
Between home and work	49	50
Between home and shopping, school, personal business	27	25
Between home and social and recreational	13	12
Total home based	89	87
Non-home based[a]	11	13
Total	100	100

[a]No end at home.

When to Travel

A great variation in travel occurred throughout the day (Fig. 5). The average 24-hour weekday was based on a regular cycle of travel. The peaking of travel in the average morning rush hour was 2.5 times the average hourly travel. In the average evening rush hour, it was 2.7 times the average hourly travel.

TABLE 4

PERCENT DISTRIBUTION OF 1964 TRIPS BY EACH PURPOSE OF TRAVEL[a]

Purpose at Trip Origin	Purpose at Trip Destination (%)			
	Home	Work	Shopping, School, etc.	Social Recreation
Home	—	25 (26)	14 (13)	6 (6)
Work	24 (24)	3 (3)	1 (1)	1 (0)
Shopping, school, personal business, others	13 (12)	1 (3)	3 (3)	1 (1)
Social and recreational	7 (6)	—	1 (1)	1 (1)

[a]1956 purpose distribution is shown in parentheses.

This cycle had remained approximately stable throughout the decade. There was some evidence, however, that the PM peak period had been extended over a longer time interval. Further, the introduction of evening shopping had resulted in moderate increases in traffic after 7:00 PM.

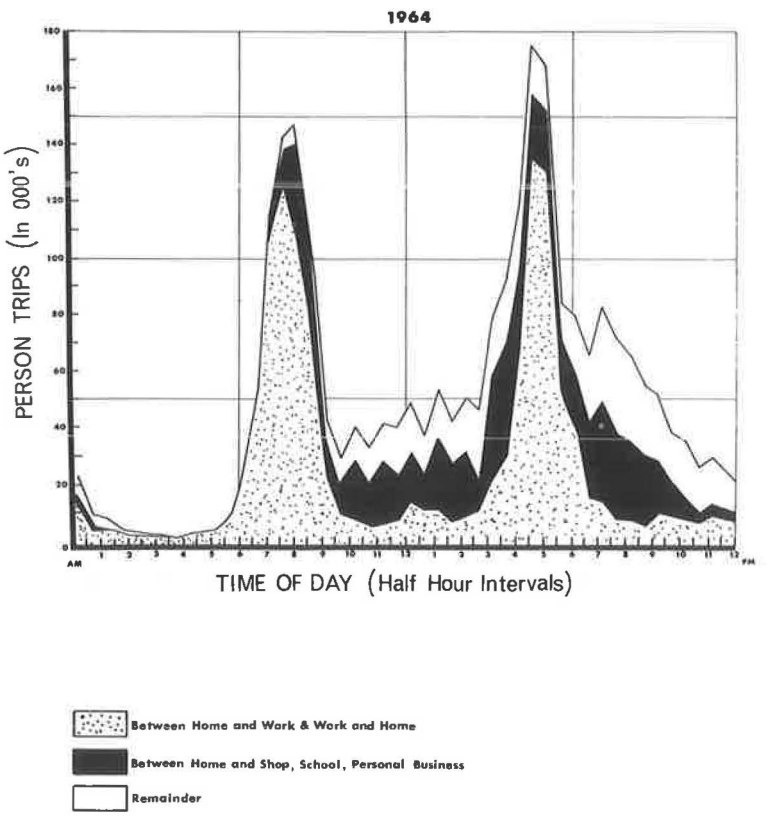


Figure 5. Peaking of travel within the average weekday in Metropolitan Toronto.

Trip Production as Related to Why and When People Travel

The 1964 home interview survey provided recent data on the frequency of travel. A summary of this information permitted the establishment of trip production rates for Metropolitan Toronto. The amount of travel generated by each small geographical area (census tract) was related to the number of people, the number of households occupied, and the number of cars owned by the resident population surveyed. By the statistical method of regression analysis, these relationships were reduced to mathematical equations.

Equation 1

Total Trips Generated at Home on Average Weekday in 1964 to All Purposes = 0.318 × population 5 yrs and older + 0.458 × number of households + 0.890 × number of cars owned (1)

Equation 2

Total Trips Generated at Home During 7-9:00 AM on Average Weekday in 1964 to All Purposes = 0.142 × population 5 yrs and older + 0.352 × number of households + 0.250 × number of cars owned (2)

Both equations showed a high degree of relationship between trips generated at home and the characteristics of the resident population. The correlation coefficient, a statistical reliability measure, substantiated this relationship and showed it to be highly significant. For Eq. 1, the correlation coefficient was 0.98; for Eq. 2, 0.96.

The percent variability associated with each of these equations was generally low (i.e., one root mean square errors as percent of average zonal trip generation) for Eq. 1, percent variability was 13 percent; for Eq. 2, 17 percent.

The coefficients derived for each equation were tested for levels of statistical significance and were found to be significantly greater than zero (i.e., t^2 of coefficients were significant on basis of 95% confidence test).

Applying these equations to a summary (Table 5) of the population characteristics of residents of Metropolitan Toronto, estimates can be made of total traffic produced from home during an average weekday and during the 7:00-9:00 AM period. Typical travel estimates are shown in Figure 6. Close agreement was observed between estimated traffic from Eqs. 1 and 2 and traffic reported by the 1964 home interview

TABLE 5

SUMMARY OF POPULATION CHARACTERISTICS OF RESIDENTS OF METROPOLITAN TORONTO, 1964

Characteristic	Number
Population	1,813,000
Population 5 years and older	1,602,000
Households	479,000
Cars owned	456,000

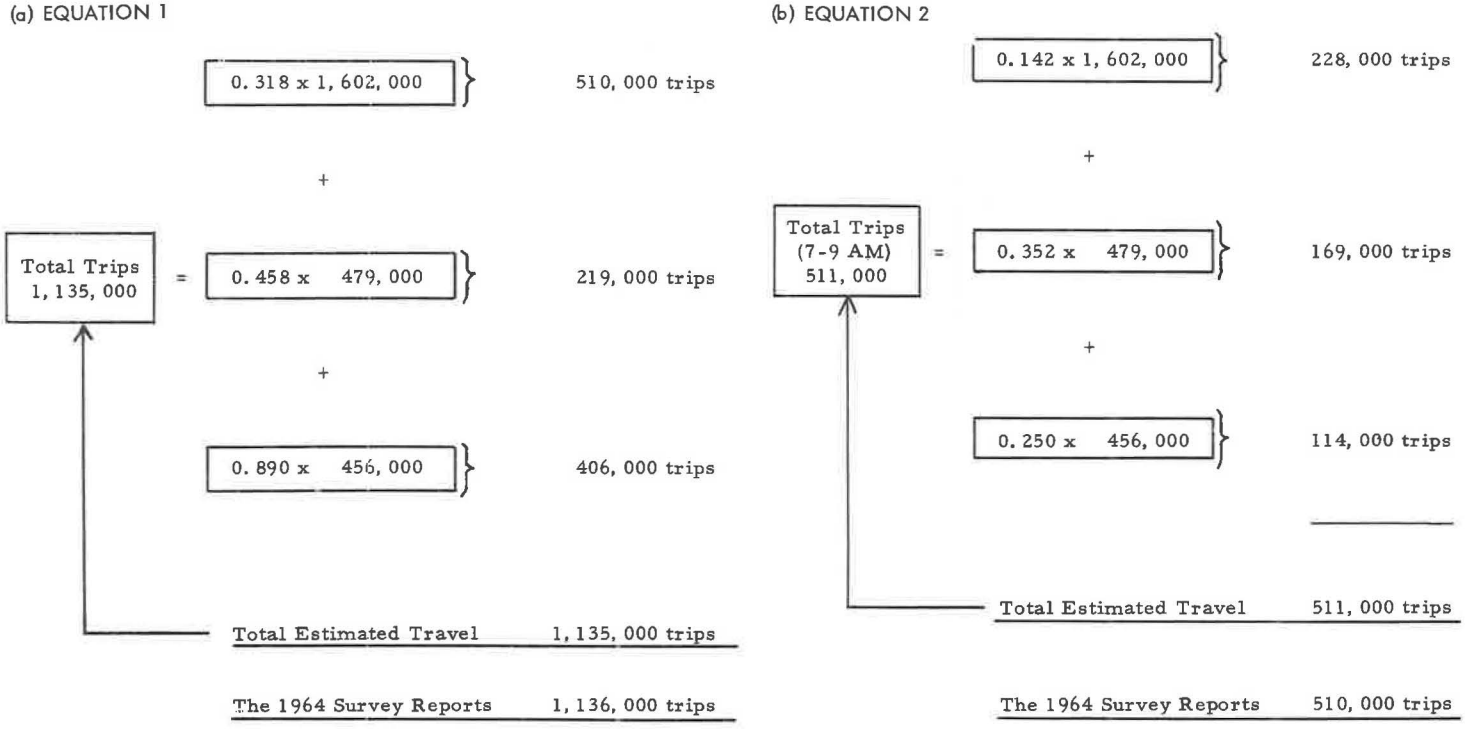


Figure 6. (a) Trips generated at home on average weekday in 1964 destined to all purposes; and (b) trips generated at home during 7:00-9:00 AM on average weekday in 1964 destined to all purposes.

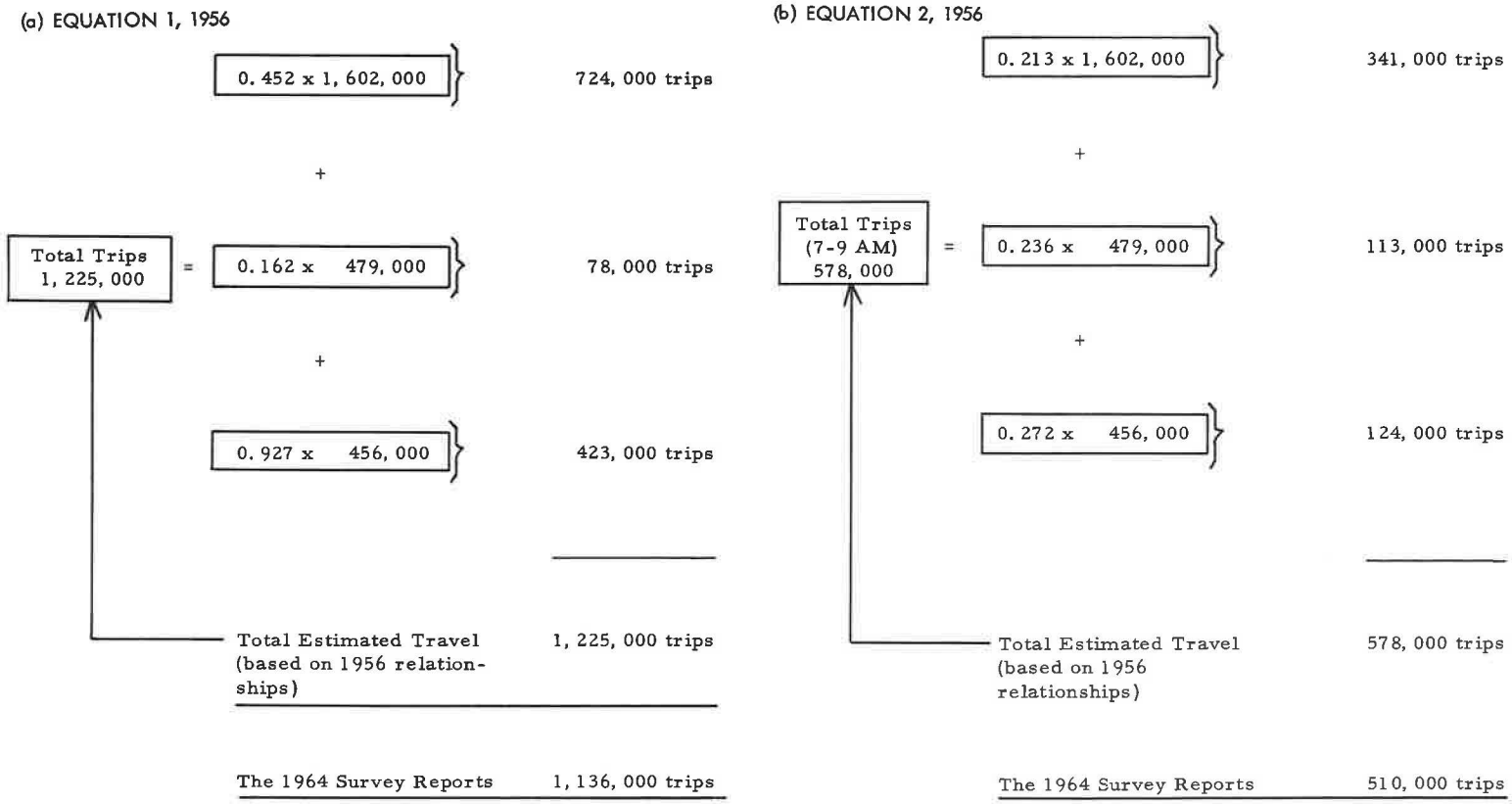


Figure 7. (a) Trips generated at home on average weekday in 1964 destined to all purposes; and (b) trips generated at home during 7:00-9:00 AM on average weekday in 1964 destined to all purposes.

survey. Although not demonstrated here, similar agreement occurred between estimated traffic and survey counts for each of the major trip purposes.

Using the known 1964 population characteristics, travel estimates were obtained from the relationships derived from the 1956 survey (Fig. 7).

A comparison of the 1964 and 1956 equations reveals a change in the coefficients associated with the different household characteristics. The stability of the coefficients associated with cars owned contrasts with the apparent instability of the coefficients associated with population and households. Due to the high degree of correlation between population and households, regression analysis techniques are likely to assign widely varying coefficients, based on different samples of data. This instability of the coefficients is not considered critical, providing it occurs between highly correlated variables. The stability of the coefficient associated with car ownership is deemed important however, and it appears to exist between 1956 and 1964. The slight decrease in this coefficient is not considered significant. A comparison of Figures 6 and 7 indicates that the 1956 relationships overestimate the actual 1964 traffic by 90,000 and 68,000 trips for the all day travel and AM peak period travel, respectively; i.e., by approximately 8 percent for all day travel, and approximately 13 percent for the 7:00-9:00 AM period. The reason for this overestimate is in the 1956 estimating equation for home-based trips destined for shopping, school, personal business and others during the

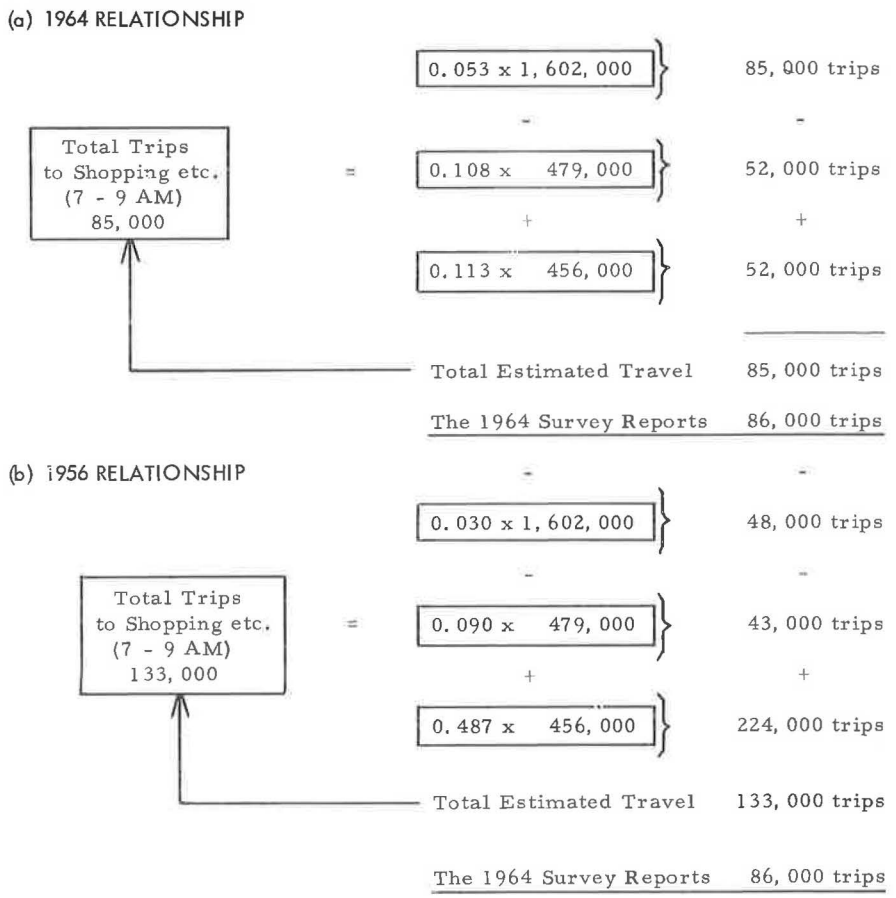


Figure 8. Comparison between 1964 and 1956 relationships to estimate home-based trips to school, shopping and personal business from 7:00-9:00 AM on an average weekday in 1964.

7:00-9:00 AM period. A comparison is made in Figure 8 between the 1964 and 1956 relationships used to estimate home-based travel to shopping, school, personal business and others during 7:00-9:00 AM, based on the 1964 population characteristics.

An overestimate of close to 47,000 home based person trips to shopping, school, personal business and others during 7:00-9:00 AM was disclosed by using the 1956 estimating relationship. This accounted for the majority of the overestimated trip production and it appeared due to a failure to link serve passenger or change of mode trips to the initial home based leg of the trip in the derivation of the 1956 relationships. Over 50,000 person trips during 7:00-9:00 AM were reported in the 1964 survey to be home based and destined to serve passenger or change of mode purposes. By combining the majority of these with their non-home based work leg of the trip, a reduced count of trip generation for other purposes was developed from the 1964 survey. As this procedure was not followed in 1956, an excessive "others" trip estimate would be produced by the 1956 equation.

The production of AM peak work traffic from the 1956 and 1964 equations is similarly based on 1964 household characteristics. The understatement of work trips in 1956, due to the omission of the unlinked home to serve passenger to work trips from the work file, appeared compensated by the higher labor force to population ratio in 1956 than in 1964 (i.e., 0.46 in 1956 versus a ratio of 0.41 today). Accordingly, it is understandable that the 1956 equation reproduces the 1964 work traffic correctly.

Due to the symmetry of travel to and from home, identical equations described the traffic destined to home and its relationship with the household characteristics. Thus the findings applicable to travel originating at home may be assigned equally well to traffic destined to home.

The relationships between non-home based trip production and employment characteristics did not change significantly between 1956 and 1964. The number of trips generated or destined to work opportunities was directly related to the amount of the employment in each area. This relationship attributed 95 percent of the production of these trips to the total employment and the remaining 5 percent to the population in the area. All trips originating or destined to places of shopping, school and personal business were strongly related to population centers and centers of retail and service employment. Social and recreation trips appeared to originate and be destined to retail and service employment, and to residential centers with equal frequency.

DURATION AND METHOD OF TRAVEL

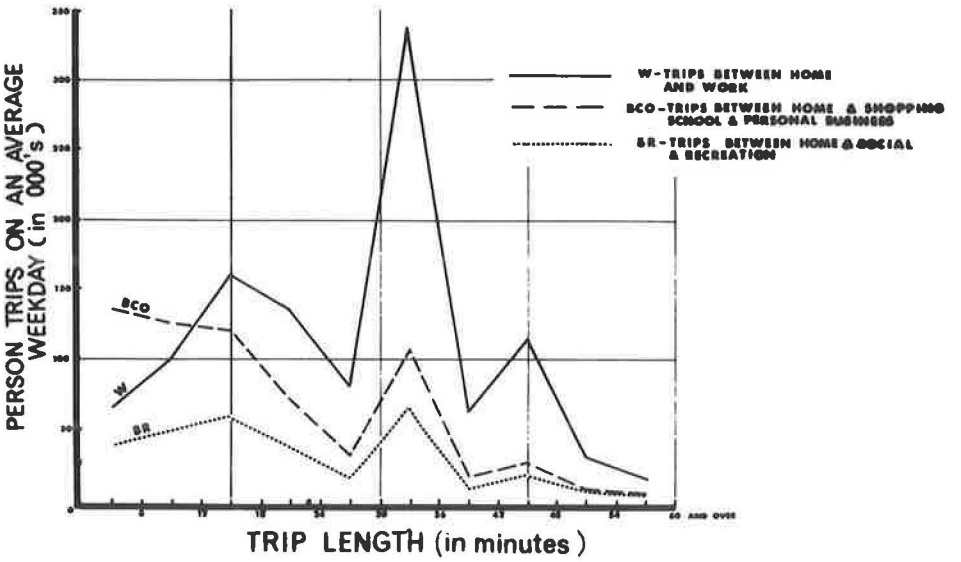
Average Trip Length

The frequency of travel on an average weekday varied with the trip time, and generally, trips of long duration were made infrequently (Fig. 9). Trip frequency generally appears to decline with increasing trip duration. The influence of trip purpose is clearly discerned. The necessity of travel to work was shown by the fact that longer trips were made more frequently, the average trip time being 30 minutes. Shopping, school and person business trips as well as social and recreational trips averaged approximately 15 minutes.

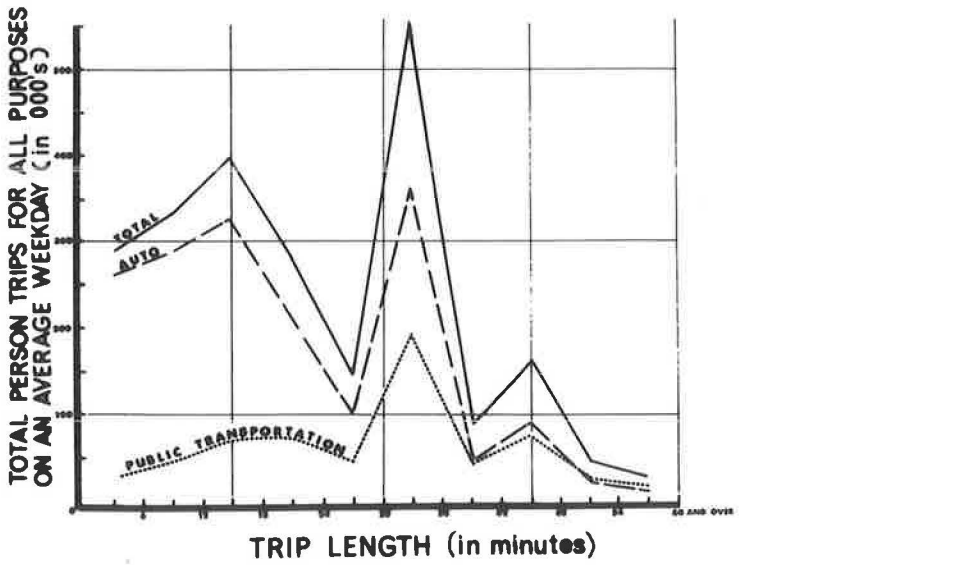
The method of travel was recognized as influencing the relationship between trip frequency and trip time (Fig. 9). While the average trip length was 20 minutes for motor vehicle trips, it was close to 30 minutes for transit trips.

Investigation of the relationships between frequency of travel and the trip length (Fig. 10) disclosed general agreement between the findings of the 1964 and 1956 surveys. People appeared to spend approximately the same time traveling in 1964 as they did in 1956. When the basic relationships were compared in relative manner, similar findings emerged. Table 6 gives the relationships between the accumulative trip frequency observed for each year and the trip length in minutes. The differences observed were small, and were generally considered insignificant.

The findings were particularly significant when one recognized the accelerated development of suburban areas in Metropolitan Toronto and the improvements in transportation made during 1956 and 1964. Time spent in traveling appeared to have remained stable, in spite of the increased numbers of people living in suburban areas



(a) ACCORDING TO PURPOSE OF TRAVEL



(b) FOR TRAVEL BY EACH MODE

Figure 9. Relationship between trip frequency and trip length.

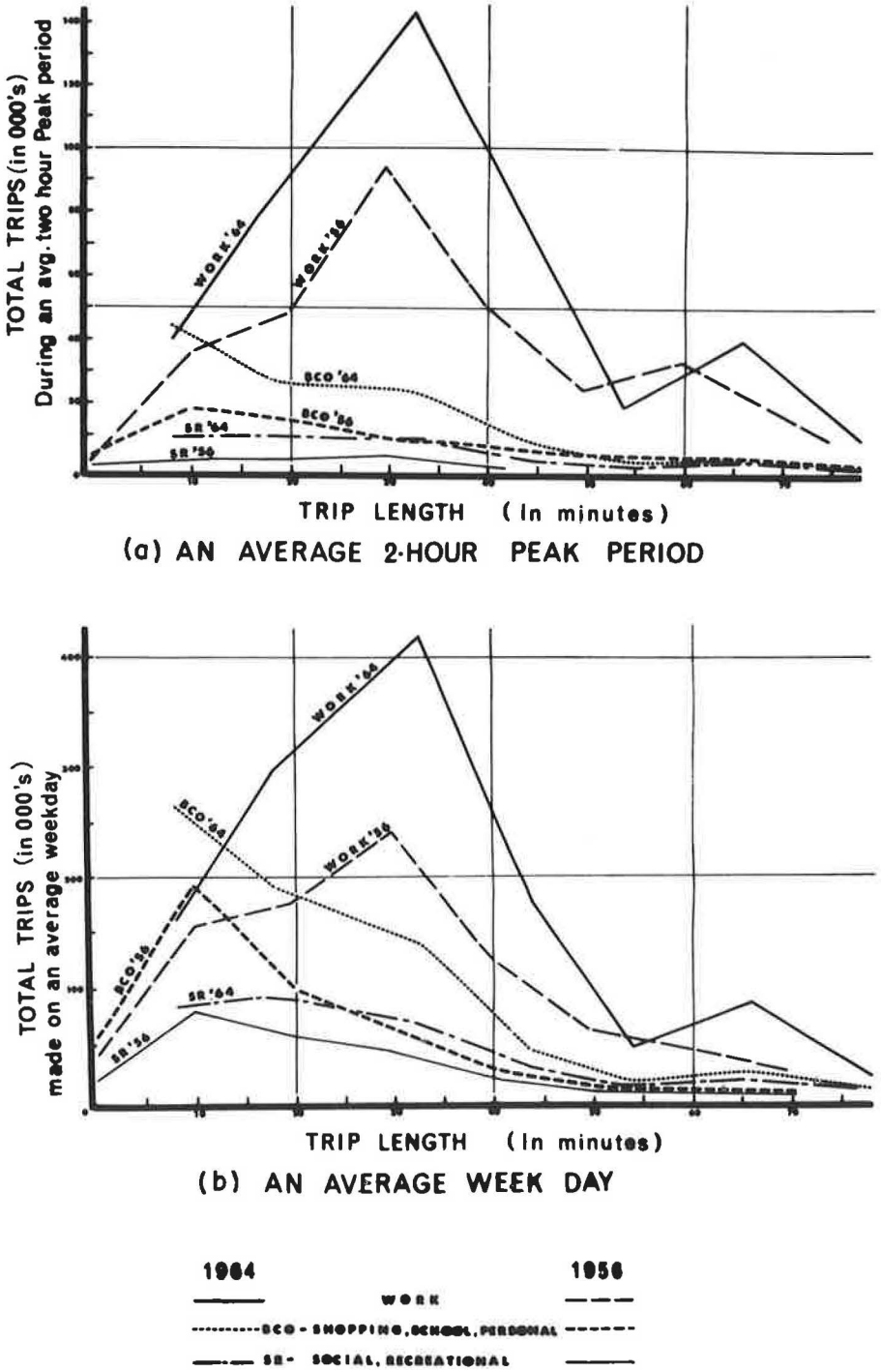


Figure 10. Comparison of the relationship between total trips and trip length.

TABLE 6

ACCUMULATIVE PERCENTAGE TRIP FREQUENCY VERSUS TRIP LENGTH

Trip Length (min)	Work (%)		B. C. O. (%)		S. R. (%)	
	1956	1964	1956	1964	1956	1964
	(a) Trips All Day					
10	15	15	40	35	30	25
20	20	20	25	25	25	25
30	25	25	15	20	20	20
40	15	20	5	5	10	10
50	10	10	5	5	5	10
60	10	5	5	5	5	5
Over 60	5	5	5	5	5	5
Acc. %	100	100	100	100	100	100
	(b) Trips in Peak Period					
10	10	10	30	30	20	20
20	15	20	20	20	20	20
30	30	30	15	20	20	20
40	20	20	15	15	20	20
50	10	10	15	10	10	20
60	10	10	5	5	5	—
Over 60	5	5	—	—	5	—
Acc. %	100	100	100	100	100	100

distant from the CBD area. It was expected that the transportation improvements had permitted higher speeds of travel over longer distances. Hence, it was perhaps not surprising that the average trip lengths had remained relatively constant.

Distribution of Trips as Related to Trip Length

The number of trips between any two zones for a particular trip purpose was considered to be dependent on the total number of trips generated for distribution at the trip origin (G_i), the total number of trips attracted to the destination (A_j), and the travel friction or impedence between the origin and destination as measured by the time factor (TF_{ij}).

The following formula was applied to describe this relationship, and hence to determine the trips distributed between each origin and destination zone:

$$J_{ij} = KG_i A_j TF_{ij} \qquad i, j = 1, \ldots, N \text{ zones} \qquad (3)$$

where

J_{ij} = number of trips leaving origin i for destination j for the purpose in question;

G_i = total trips generated at origin i for this purpose;

A_j = total trips attracted to destination j for this purpose;

TF_{ij} = time factor for trips made between origin i and destination j for this purpose, that is $e^{-BT_{ij}}$; where B = parameter to be determined, e = 2.718, and T_{ij} = travel time between i and j.

TABLE 7

PERCENT MOTOR VEHICLE RIDERSHIP BY TRIP PURPOSE

Major Trip Purpose	Motor Vehicle Ridership (%)	
	1964	1956
Between home and work	63	54
Between home and shopping, school and personal business	74	71
Between home and social and recreation	84	74
Total purposes	72	60

The constant K in Eq. 3 is an adjustment factor so that the following equalities are satisfied:

(a) Total trips leaving origin i equals total trips generated there; i. e.,

$$\sum_{j}^{N} J_{ij} = G_i$$

(b) Total trips arriving at destination j equals total trips attracted there, i. e.,

$$\sum_{i=1}^{N} J_{ij} = A_j$$

Eq. 3 is well known as "gravity formula," so called because of its similarity to the formula derived by Newton to describe gravitational attraction between two masses (3). All necessary parameters associated with Eq. 3 were first derived from the 1956 home interview survey in Metropolitan Toronto. During December 1964, the basic gravity formula was reestablished with the 1964 home interview survey data, for the AM travel period.

This basic formula (Eq. 3) was reestablished for each of the major trip purposes, i. e., (a) trips between home and work; (b) trips between home and shopping, school or personal business; and (c) trips between home and social recreation. The gravity formula was premised on the relationship between the frequency of travel and the length of travel (in minutes). It was this relationship which described the influence of travel friction on trip distribution and hence established the value of the parameter B of the gravity formula (Figs. 9 and 10).

An analysis of the gravity model formulation resulted in the following findings:

1. The time factor associated with travel to work would be based on B parameter value as established from the travel in 1956; and
2. Time factor associated with travel to other purposes would be based on B parameter value from the 1956 survey.

Choice of Method of Travel

Table 7 shows a significant trend in the use of the motor vehicle as opposed to public transportation. Although little change had occurred in the travel pattern established for shopping and personal business, the increased use of the motor vehicle for work and recreational travel had resulted in an overall increase in motor vehicle usage of 12 percent since 1956. This increase was probably attributable to the rapid rise in the socioeconomic conditions and shifts of the population to suburban and low-density centers.

Approximately 70 percent of all person trips made by private motor vehicles were made as drivers. Thus the average number of persons per car was approximately 1. 4, which agreed with the average car occupancy of 1. 4 observed in 1956.

Travel Mode Split—Relationships

People are influenced by many factors in their choice of travel mode. These factors will be characteristic of the relative travel time, travel cost, regularity and convenience of service, the socioeconomic status of the population, and trip purpose. Using graphical analysis methods, the influence of each of the factors was investigated separately and trends in transit usage were established.

The comparative advantages and disadvantages of each of the two major types of travel mode (public transportation and the private automobile) were measured by the

time, cost and convenience criteria. Other criteria, such as economic status and the trip purpose were considered to affect user reaction to the first three criteria. On the assumption that there were two primary travel modes, it was the intention to distinguish between that freedom of choice of routes and schedules offered by the automobile as opposed to the fixed routes and schedules imposed by all forms of public transportation. Accordingly, railway, subway, bus, and streetcar were all considered facilities of the public transportation mode.

The travel modal split relationships were derived in the form of diversion curves (4). The diversion curves demonstrated in quantitative form how the propensity to travel by public transit as opposed to travel by private automobile was related to five basic determinant factors:

1. The ratio of door-to-door travel time via public transit to the door-to-door travel time via private automobile;
2. The ratio of out-of-pocket cost via public transit to out-of-pocket cost via private automobile;
3. The ratio of excess travel time via public transit to excess travel time via private automobile (this ratio is a measure of the relative level of travel service and convenience);
4. Economic status of trip maker; and
5. Trip purpose.

These factors are described as follows.

$$\text{Travel time ratio} = \frac{TQ + WKQO + WKQD + WQ + TR}{TV + WKVO + WKVD + WVO + WVD} \tag{4}$$

where

TQ = time en route in transit vehicle;

WKQO = time spent walking from trip origin to transit vehicle (D refers to destination);

WQ = time spent waiting for transit vehicle;

TR = time spent transferring between transit vehicles;

TV = time en route in private automobile;

WKVO = time spent walking between trip origin and parking space;

WKVD = time spent walking between parking space and trip destination;

WVO = parking delay time at trip origin; and

WVD = parking delay time at trip destination.

$$\text{Cost ratio} = \frac{FR}{[CF + CO + (PKO + PKD)/2]/NPPV} \tag{5}$$

where

FR = transit fare;

CF = gasoline cost (gallons/mile × distance × cost/gallon);

CO = oil change and lubrication cost (cost of oil change/mi × distance);

PKO = parking cost at origin of trip;

PKD = parking cost at destination of trip; and

NPPV = number of passengers per vehicle.

$$\text{Service ratio} = \frac{WKQO + WKQD + WQ + TR}{WKVO + WKVD + WVO + WVD} \quad (6)$$

Economic status is expressed in median income per worker, and trip purpose is described individually or in combination. Different sets of diversion curves were used for each trip purpose.

There were 80 diversion curves for each trip purpose. The diversion curves demonstrated the relationships between transit use and the travel time ratios for each of 4 levels of cost ratio, for each of 4 levels of service ratio and for each of 5 levels of economic status ($4 \times 4 \times 5 = 80$).

Basic modal split relationships for travel to work were established from the 1954 worker survey and the 1964 home interview survey. These relationships described the correlation between transit use (as opposed to automobile use) and the travel time ratio for each of 5 levels of socio-economic status, 4 levels of cost ratio and 4 levels of service ratio.

The 1954 and 1964 relationships were compared for similarities in ridership habits of the public. Direct comparison of the relationships for 1954 and for 1964 was possible on account of identical procedures of derivation. Also, both sets of relationships were derived for worker income ranges expressed in terms of the 1961 cost of living index (income ranges expressed in 1961 constant dollars). The similarities and dissimilarities between the relationships are shown in Figures 11 and 12.

Based on this evidence, it was concluded that the basic relationships developed from the 1954 survey data were still applicable in the planning process but for the following exceptions:

> Middle income workers appeared to demonstrate a declining preference to ride transit over 10 years, as it became less convenient in comparison with motor vehicular travel. This decline in preference for transit occurred when the transit excess travel times exceed auto excess times by at least one and one-half times. The decline seemed to occur both for cheap and expensive travel by transit.

Provided the transit service was convenient, i.e., when the walks, waits and transfer times on transit were not more than one and one-half the walks and parking delays in motor vehicular travel, people in 1954 and again in 1964 appeared to demonstrate similar preference for transit ridership. Differences for 1954 and 1964 did not exceed 5 percent and hence were generally insignificant. The difference in ridership on less convenient transit between 1954 and 1964 was as high as 30 percent ridership and therefore appeared significant.

The design of the 1964 survey permitted an analysis of the captive ridership on both public transportation and the private automobile. Approximately 56 percent of transit riders who traveled to work could be classed as captive, in that they did not have a driver's licence or no car was owned by the members of the rider's family. In comparison, close to 40 percent of the automobile drivers going to work could be rated as captive, since they indicated their automobiles were necessary in the conduct of their work. Due to the similarity of these captive rates, and the expected close correlation with worker's incomes, the continued use of composite deversion curves (for captive and non-captive riders) seemed justified.

Choice of Travel Route

Route assignment is a term applied to the method of calculating the number of vehicles or persons that would use a given transportation facility under certain given travel conditions.

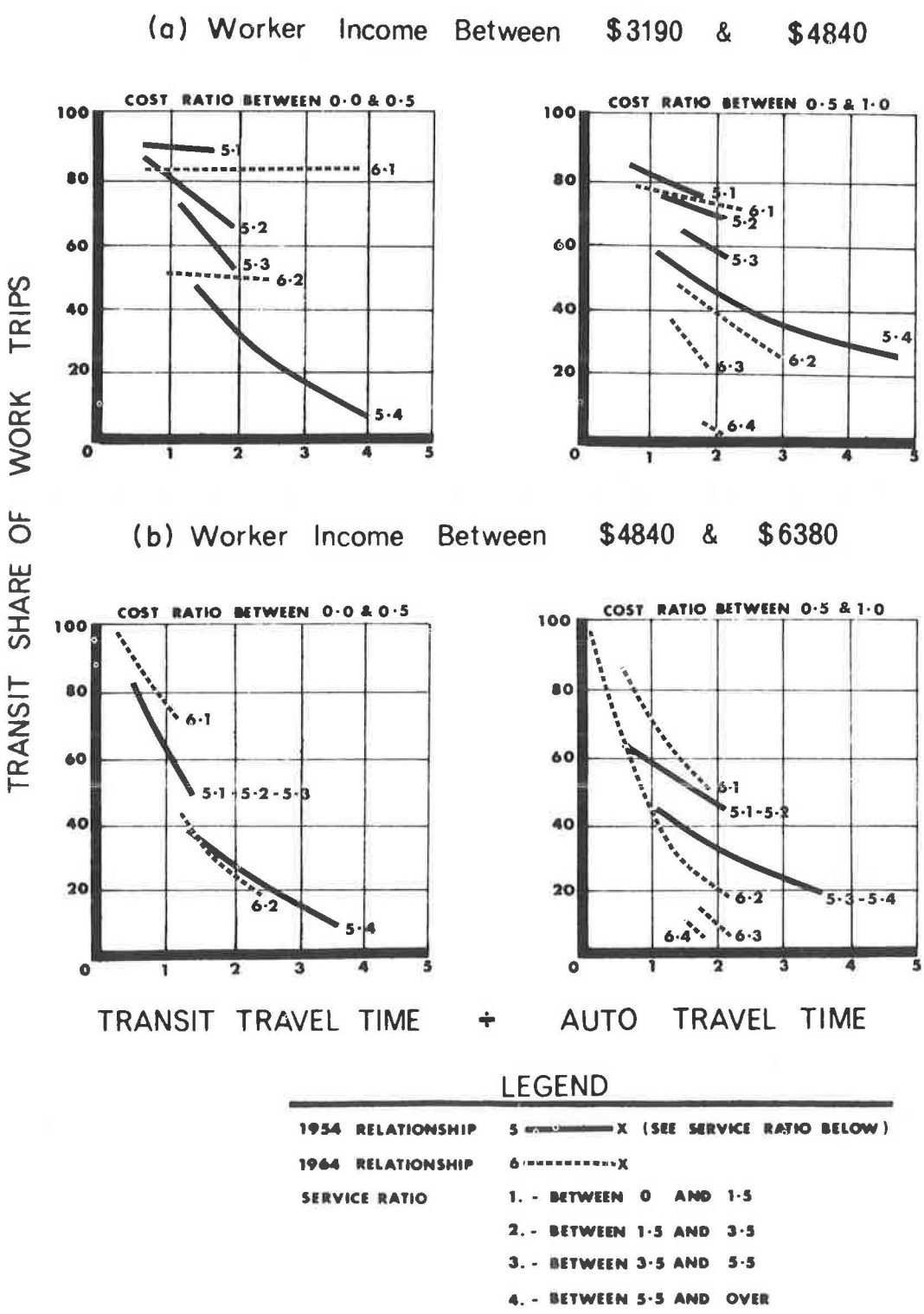


Figure 11. Comparison between 1954 and 1964 modal split relationships for work travel in Metropolitan Toronto.

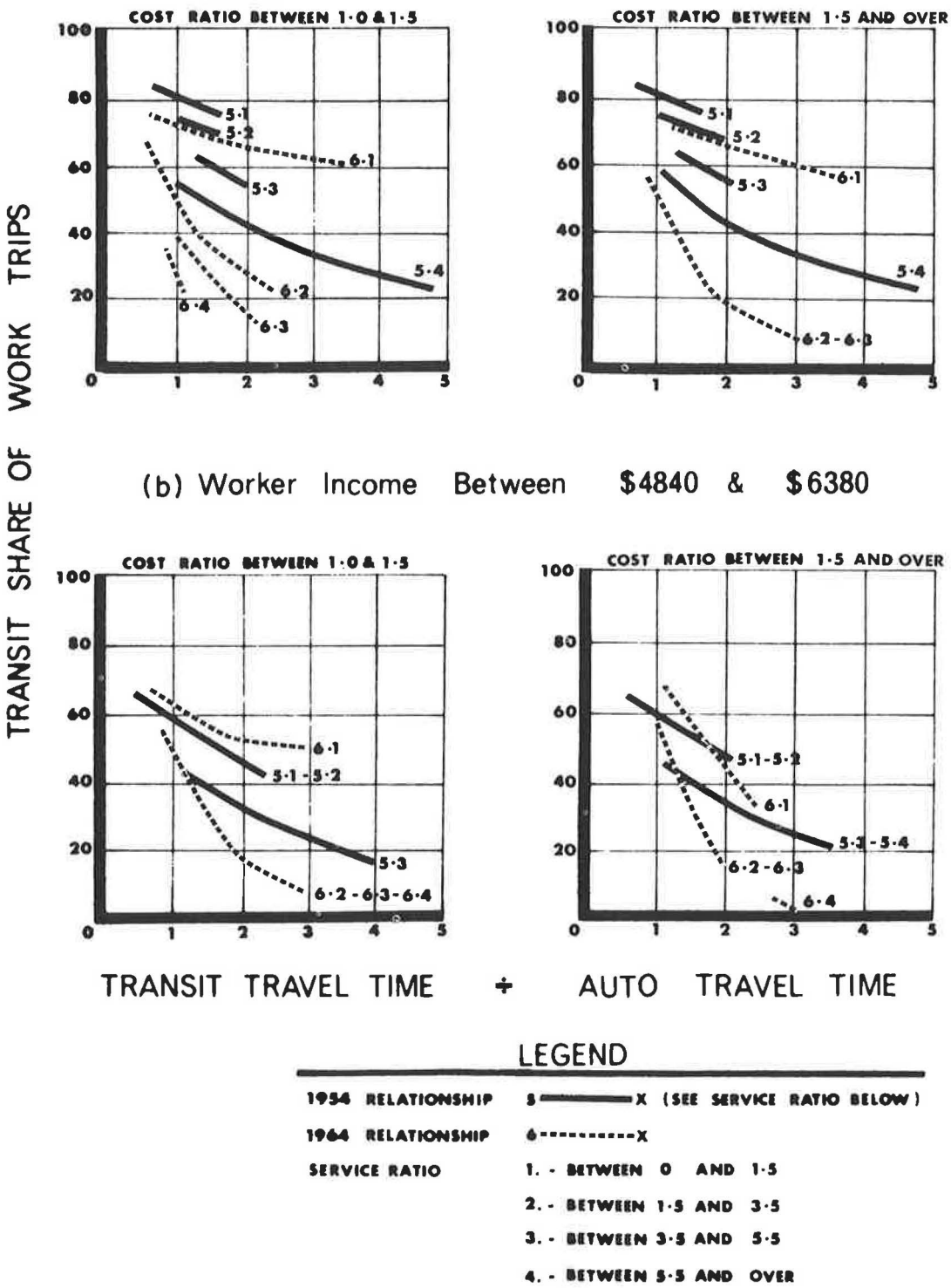


Figure 12. Comparison between 1954 and 1964 modal split relationships for work travel in Metropolitan Toronto.

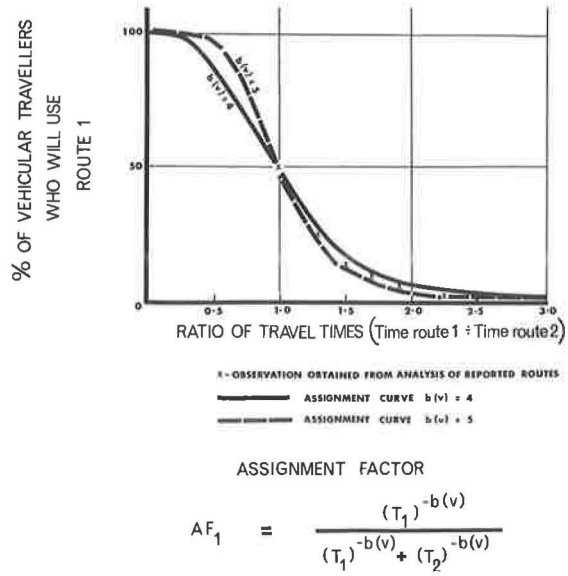


Figure 13. Traffic assignment curve showing percent of vehicular travelers who use route 1 when choice is between 1 and 2.

The task of assignment consists of determining the number of vehicles or persons using each of two or more routes for the same travel mode, given the origin-destination interchange movement. The assignment factors are calculated using the route travel times for each O-D pair, by means of the following (5):

$$AF_i = \frac{(T_1)^{-b(V)}}{(T_1)^{-b(V)} + (T_2)^{-b(V)} + \ldots + (T_n)^{-b(V)}} \qquad (7)$$

where

AF_1 = route assignment factor for route 1 (specifying what percentage of private vehicle travelers are using the first vehicle route for the O-D in question);

T_i = travel time via the ith route from the O to the D [i - 1, . . ., n (there is a total of n routes for the O-D pair in question)]; and

b(V) = assignment factor exponent for vehicles which is empirically determined by analysis.

Note:

$$AF_1 + AF_2 + \ldots + AF_n = 1.00$$

For determining assignment factors within a transit mode, b(Q) would replace b(V) in Eq. 7.

As part of the 1964 transportation survey, approximately 6000 Metropolitan Toronto residents were asked to trace their route to work and to give their reasons for their choice. These were used to derive empirically the assignment factor exponent b(V) of Eq. 7.

The alternatives of route choice were established for the main corridors of movement. The following information was assimilated from the survey for each major origin and destination interchange (on a study zone basis): (a) number of alternative routes chosen and their classification according to mix of facilities; (b) frequency of use

of each route; and (c) travel time for each major route choice. The analytical study of the basic assignment factor formula (Eq. 7) was carried out by graphical analysis (Fig. 13). It appeared that a b(V) exponent of 4 in Eq. 7 demonstrated the best explanation of route choice. No comparative facts were available from the 1954 or 1956 surveys for this study.

SUMMARY OF FINDINGS

Home interview surveys revealed the movement of people associated with the many different population and employment centers in the metropolitan area. As might be expected, an analysis of the results showed that travel was orderly and regular.

The comparative analysis of survey data collected during two different years approximately 10 years apart demonstrated an overall stability between person trips and the reasons motivating this travel. In particular, the following findings were disclosed:

1. Average production of person trips appeared to have remained unchanged between 1956 and 1964.
2. Average trip length did not seem to have significantly changed between 1956 and 1964. In spite of significant development of suburban areas and many improvements in the transportation system, the time expended while travelling had not changed.
3. Provided transit service was convenient to use, people demonstrated similar preferences to ride public transportation in 1964 as was their habit in 1954.

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The authors wish to point out that the conclusions presented in this paper do not necessarily represent the opinions of their agencies.

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