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Implications of the Travel-Time Budget for Urban Transportation Modeling in Canada

A. CHUMAK AND J.P. BRAAKSMA

The travel-time-budget concept, which examines regularities in the allocation of travel time in urban areas, is investigated. Previous analysis of three U.S. cities suggests that the daily travel-time budget is approximately 1.1 h/traveler. The objective of this research is to (a) verify the theory in Canada and (b) determine the practical implications for transportation planning. Analysis of home interview surveys in Calgary, Toronto, and Montreal supports the conclusions previously developed in the United States. A detailed analysis of the Calgary data indicates that the travel-time budget is not affected by such factors as mode of travel, trip purpose, automobile ownership, or location of residence with respect to the central business district. Several practical applications of the concept are developed, including a procedure for conducting an independent validity check of conventional travel forecasts. This process is very simple to conduct and allows forecasts to be verified by using a different model. The travel-time budget is also a useful tool for developing equilibrium travel forecasts. Equilibrium models relate travel demand to available capacity and may reduce the demand for nonessential trips during peak periods. Further research is recommended on the application of the travel-time budget to other aspects of urban travel forecasting, including traffic assignment, modal split, and evaluation of personal mobility.

Since the early 1950s, several transportation planners and economists have suggested that individuals allocate a certain budget for the purchase of transportation goods and services. Tanner (1) produced the first empirical evidence to support the hypothesis that households allocate a fixed portion of their income for transportation.

Subsequently, Zahavi (2) and Goodwin (3) have extended this theory to the other resource that individuals must expend for transportation: time. Zahavi published the first empirical evidence to suggest that in urban centers the average daily travel per individual traveler is approximately 1 h (2). At present, this theory is supported by the travel data of three U.S. cities: Washington, D.C., Minneapolis, and St. Louis. This new concept is not yet completely accepted by transportation planning professionals and may even be considered with a certain amount of skepticism. The primary objective of this paper is to analyze Canadian data and investigate the validity of the travel-time-budget concept in Canada. This analysis may be considered an expansion of the work of Zahavi.

The secondary objective of this paper is to assess the practical implications of the travel-time-budget concept for conventional transportation planning. If proved valid, this concept may be very useful as a means of conducting an independent check of travel forecasts developed through the conventional models of trip generation, trip distribution, and modal split. A methodology is presented for developing equilibrium travel forecasts by using the travel-time budget. Equilibrium travel forecasts relate the travel demand projected by the conventional model to the availability of transportation facilities and congestion.

PREVIOUS RESEARCH

The travel-time budget describes an urban phenomenon in which the average travel time per trip maker appears to remain stable. The first empirical data in support of this concept were presented by Zahavi in the 1970s (2,4). The following table gives the results of Zahavi's analysis for Washington, D.C., and the Twin Cities of Minneapolis-St. Paul as well as data from the 1970 Nationwide Personal Transportation Survey, which provides data on average travel behavior in the urban centers of the United States. Similar data developed for St. Louis by Bochner and Stuart (5) are also presented:

City	Year	Avg Daily Travel Time per Trip Maker (h)
Washington	1955	1.09
	1968	1.11
Twin Cities	1958	1.14
	1970	1.13
St. Louis	1976	1.04
All United States	1970	1.06

In all cases, the average travel time per trip maker remains stable at approximately 1.1 h/trip maker. The most interesting result of the table is that not only has the travel-time budget remained stable over a 20-year period but the concept is also valid for all cities analyzed regardless of population size. This consistency is not characteristic of conventional transportation planning models of trip generation and trip distribution, which often have to be recalibrated for each city every 10 years. It is most difficult to apply these models interchangeably between cities without considerable calibration.

The results of the table above represent arithmetic averages that are obtained by dividing the total daily travel time in the city by the total number of trip makers. The results should therefore be treated strictly as an empirical observation, and no interpretation should be made as to whether individuals consciously or subconsciously allocate 1 h for travel. Zahavi obtained the estimates of the total daily travel time of trip makers through a special computer analysis of home interview surveys in each of the cities. The estimate of daily travel time, expressed as person hours of travel, includes travel by all modes and is obtained through a direct summation of all trip times reported by the survey respondents. It is important to note that this analysis is based on the travel times reported in the home interview surveys, which represent "door-to-door" travel times as perceived by the traveler. A trip maker is defined as an individual who makes at least one mechanized trip per day. Because an estimate of the number of trip makers is not readily available from the transportation data banks used in most cities, a separate computer analysis is required to estimate the number of people who report at least one mechanized trip. The ratio of trip makers to population varies considerably from city to city as a function of car ownership and household size. Accordingly, the estimate of travel time per capita may vary even though the travel time per trip maker remains stable. The need to conduct a separate computer analysis for each city accounts for the fact that more data are not currently available.

Recently, Zahavi (6,7) has published data for several cities outside of North America, such as Munich, Nuremberg, Bogota, and Singapore.

TRAVEL-TIME BUDGET AND CANADIAN CITIES

The principal results of the travel-time-budget analysis of Canadian cities are given below:

City	Year	Avg Daily Travel Time per Trip Maker (h)
Calgary	1971	1.11
Toronto	1964	1.09
Montreal	1971	1.18

The data indicate that travel patterns in Montreal, Calgary, and Toronto clearly confirm the previous research of Zahavi.

This paper analyzes the 1971 Calgary data in much greater detail in order to investigate the effect of such variables as mode, trip purpose, car ownership, and location of residence on the travel-time budget. It is anticipated that such an exercise will assist in understanding the basic underlying mechanisms of the travel-time-budget phenomenon. An attempt is also made to compare all observations and conclusions with the previous research of Zahavi.

Another objective of this detailed analysis of Calgary is to identify those socioeconomic conditions under which the travel-time budget is not valid. It is proposed that, if the theory is able to successfully withstand this rigorous testing, then the overall validity and acceptance of the theory will be considerably enhanced.

Mode of Travel

Table 1 (8) summarizes the analysis of the travel-time-budget concept for trip makers in Calgary who use a variety of transportation modes. The average travel time for all trip makers by all modes was 66 min, whereas those who traveled only by automobile or transit each had a budget of 61 min. As mentioned earlier, these figures represent perceived door-to-door travel time. All estimates are within the 95 percent confidence interval.

These data also reveal the interaction between trip rate and length that occurs along with the travel-time budget. There appears to be an inverse relation between trip time and trip rate. Trip

Table 1. Travel-time budget and mode of transportation (Calgary).

Mode	Trips per Trip Maker	Time per Trip (min)	Daily Travel Time per Trip Maker (min)	Ratio of Mean to Median
All mechanized	3.76	17.7	66.3	1.22
Car only	3.72	16.4	61.0	1.22
Transit only	2.09	29.0	60.6	1.02
Transit and car	3.92	21.3	83.5	1.18
Car driver	4.02	16.9	68.0	1.13

Figure 1. Distribution of daily travel time in Calgary for travelers by all mechanized modes.

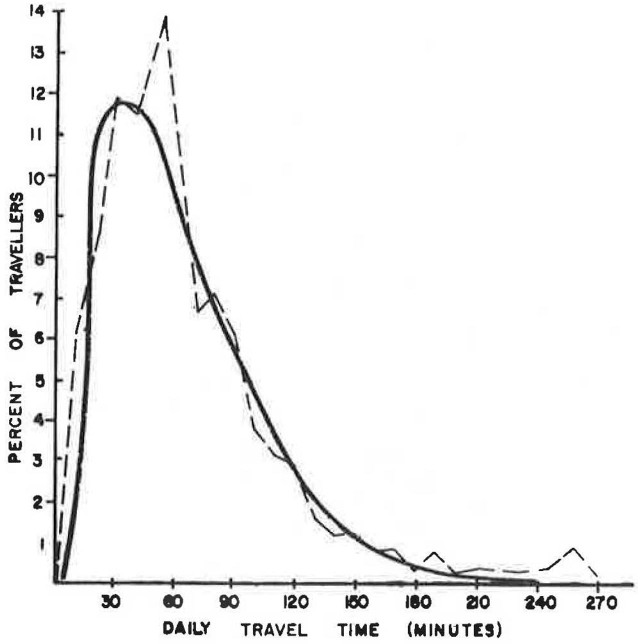
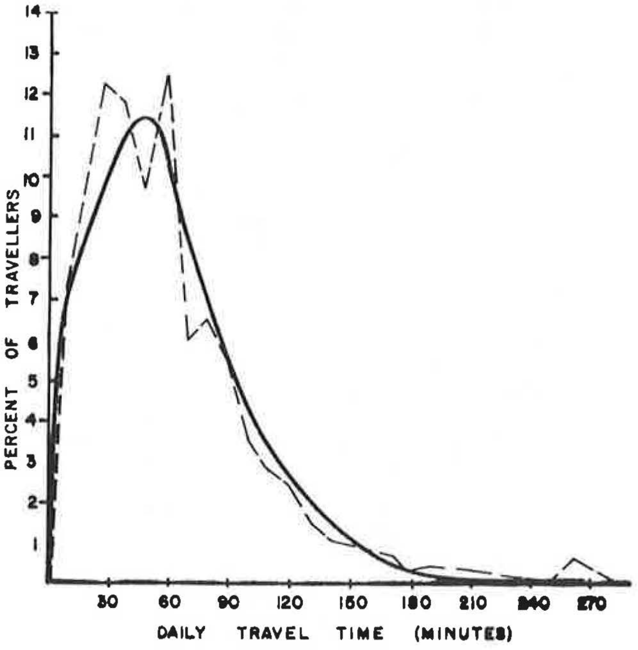


Figure 2. Distribution of daily travel time in Calgary for automobile-only travelers.



makers who use only transit have considerably longer trip times because of lower overall travel speeds, and these travelers can therefore accommodate only two trips within the daily travel-time budget. The overall mobility of these travelers, the ability to make mechanized trips, is therefore restricted to slightly more than the two trips usually required for work travel. Conversely, travelers whose only mode is the automobile have the shortest trip times and are quite willing to increase their trip generation rate to 4.0 trips/traveler in order to fully expend the travel-time budget. Although travelers who use the other modes have intermediate rates of trip generation and trip length, the basic inverse relation between the two variables continues to apply. Zahavi (4) identified a similar inverse relation in his analysis of Washington, D.C., and the Twin Cities.

It is also interesting to note that in Calgary as well as in the U.S. cities the group of travelers who consistently exceed the travel-time budget are those who use both transit and car. These travelers are partly restricted by low transit speeds. Their average trip time is 21.3 min compared with 16.4 min for automobile-only trip makers. This group, however, also has a very high trip generation rate, which may result from psychologically associating different modes with different purposes. After taking the two mandatory transit work trips, the individual still has a desire to make use of his or her car, which is available. As will be shown later, this is the only socioeconomic group identified in the analysis that exceeds the travel-time budget.

Figures 1 and 2 show the frequency distributions of daily travel time for trip makers by mode. These diagrams can be drawn by two methods. The travel times reported in the home interview surveys have many discontinuities, primarily because people tend to perceive their trip time to the nearest 10 min and therefore there is no smooth continuum for the data points on the time axis. It may be argued that the continuous curve interpolated between the data points is a more accurate representation of the actual travel-time distribution in a city. Both the "perceived" and "actual", or smoothed-out, travel-time distributions are shown in Figures 1 and 2.

The "actual" travel-time frequency distribution for automobile-only trip makers (Figure 2) shows a rather sharp peak at 50 min. The "perceived" plot indicates that this peak actually appears to consist of two peaks at 30 and 60 min. This 30-min peak was not expected, and the underlying reasons for it are investigated later in this paper. One hypothesis is that the 30-min peak is caused by trip makers who do not travel to work and that this second peak consists primarily of shopping and sociorecreation trips.

In the distribution of travel times for travelers by all modes (Figure 1), the perceived distribution has only one peak at 60 min, and the actual distribution peaks at 40 min. Similar distributions exist for travel by other modes, including automobile (drivers) and transit.

Trip Purpose

The objective of this analysis is to determine what effect trip purpose, particularly the need for the two daily work trips, has on the travel-time budget. Figures 3 and 4 and Table 2 (8) analyze travel time for workers and nonworkers, which can be directly compared with the daily travel time of the entire population presented in Table 1 and Figures 1 and 2. Those making nonwork trips have daily travel

Figure 3. Distribution of daily travel time in Calgary for nonwork travelers by all mechanized modes.

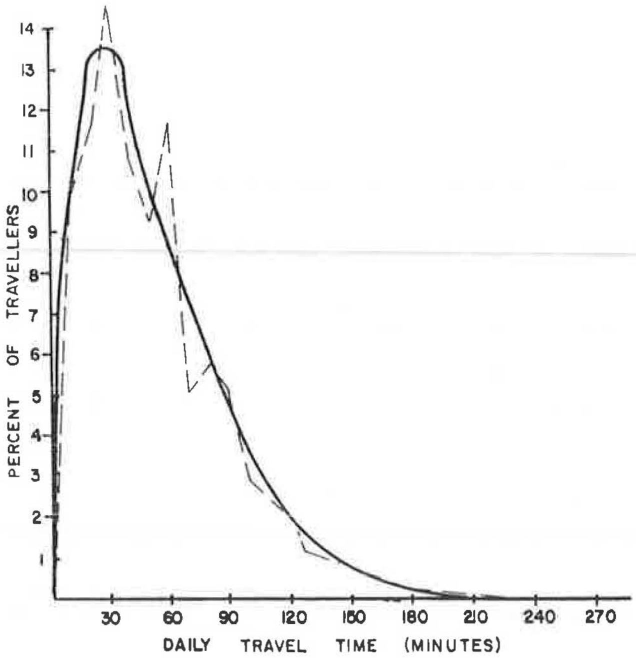


Figure 4. Distribution of daily travel time in Calgary for nonwork automobile-only travelers.

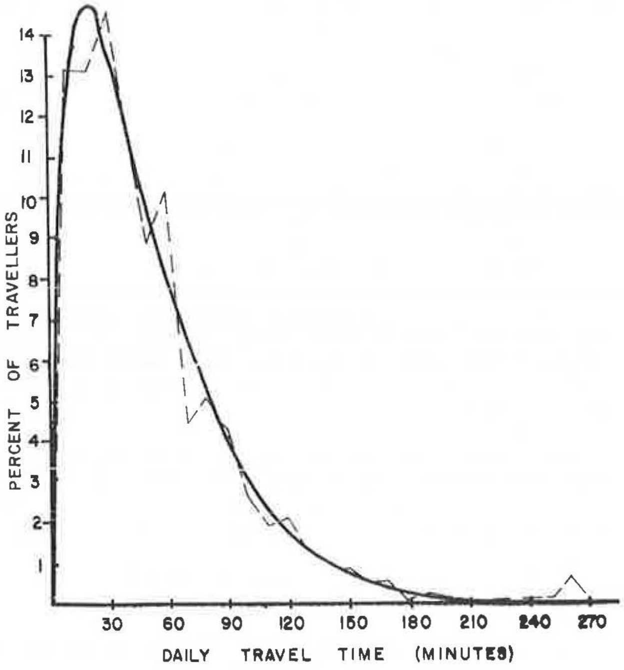


Table 2. Travel-time budget and trip purpose (Calgary).

Mode	Trip Purpose	Trips per Trip Maker	Time per Trip (min)	Daily Travel Time per Trip Maker (min)	Ratio of Mean to Median
All mechanized modes	Nonwork	3.23	17.1	55.2	1.22
	Work	3.76	17.65	66.3	1.22
Automobile	Nonwork	3.43	15.2	52.1	1.3

times of 55 min by all mechanized modes and 52 min by automobile only. The daily travel time of nonworkers is approximately 20 percent lower than that of the entire Calgary population or that of workers; both these populations have a daily travel time of 66 min. The major reason for this decrease is a reduction in the trip rate of nonworkers from 3.8 to 3.2 trips/trip maker. Trip times have remained similar.

The most interesting feature of Figure 3 is that the travel-time frequency distribution for nonwork travelers shows a pronounced peak at the 30-min mark. It may be reasonable to assume, therefore, that it is the nonwork travelers who are responsible for the secondary 30-min peaks in the travel-time frequency distribution of automobile-only trip makers shown in Figure 2.

Location of Residence

Now that the underlying mechanisms of the travel-time-budget concept are understood, it would be valuable to analyze separate groups of trip makers who have different socioeconomic characteristics. This analysis will determine whether the budget concept truly applies to the entire urban population or is valid only for certain identifiable socioeconomic groups.

Two factors that could have a strong influence on the travel-time budget are income and distance of residence from the central business district (CBD). The Calgary travel survey records include the traffic zone in which the residence is located. From a city traffic-zone map, it is possible to identify the zones that fall within a given radius from the downtown core. The appropriate zones are aggregated to calculate the daily travel time for trip makers who live 1.5, 1.5-3, 3-6, 6-9, and more than 9 km from the downtown core. The results are summarized in Table 3.

There appears to be very little variation in daily travel time between those trip makers who live in the downtown core through to those who live in the outskirts. Average trip rate and average trip time also appear to remain stable with increased distance from the CBD.

These results are again similar to those previously obtained by Zahavi (7), who analyzed two Washington, D.C., corridors to examine the relation between daily travel time and distance of residence from the CBD. In both corridors, the perceived daily travel time per trip maker remained constant at about 1.1 h as the distance between residence location and the CBD increased from 0 to 14 km.

Automobile Ownership

Other variables that may be expectd to strongly influence the daily travel-time budget are income and automobile ownership. Unfortunately, income data were not collected in the 1971 Calgary travel survey. It may be argued, however, that the number of cars owned per household is a surrogate measure of income for medium income ranges. Table 4 analyzes the effect of automobile ownership on the travel-time budget in Calgary (8). For comparison, travel-time-budget data for Washington, D.C. (4), are also included. It should be noted that the results of Table 4 refer to travel by automobile only.

The daily travel time of trip makers in non-car-owning households is 0.7 h and increases rather quickly to 1.06 h when a household acquires a car. This sudden increase in travel associated with the acquisition of a car is also exhibited in the data for Washington, D.C. The travel time among trip makers whose households own from one to three cars remains constant; the actual difference is less than 10 percent, in both Calgary and Washington, D.C.

Automobile Travel-Time Budget

The theory of the personal travel budget considers travel by all modes in the city. Zahavi (4) has developed an additional corollary that applies only to automobile travel. His analysis of 22 of the world's cities (see Table 5) reveals that automobiles are used for approximately 0.8 h (48 min) each day. The consistency of this relation is very strong, since the standard deviation is 0.08 or only 10 percent of the mean. A broad spectrum of urban areas was analyzed, including the Tri-State Region of New York.

This relation does not apply to cities in developing countries, which are defined as those where the rate of automobile ownership is less than 0.1 cars/person. In these cities, significantly higher daily automobile travel time is found. This increase may be partly explained by the lower speeds made necessary by a higher level of congestion. In these cities, the rate of car use is also considerably higher. Many different individuals may use the same car during the course of the day.

Table 3. Travel-time budget and location of residence (Calgary).

Distance of Residence from CBD (km)	Trips per Trip Maker	Time per Trip (min)	Daily Travel Time per Trip Maker (min)
0-1.5	3.73	18.0	67.0
1.5-3	3.46	18.0	62.6
3-6	3.79	17.6	66.8
6-9	3.86	17.2	66.5
>9	3.63	18.3	66.4

Table 4. Travel-time budget and automobile ownership (Calgary).

Automobiles per Household	Trips per Trip Maker	Time per Trip (min)	Daily Travel Time for Automobile Trip Makers (h)	
			Calgary	Washington, D.C.
0	2.62	16.0	0.70	0.9
1	3.87	16.5	1.07	1.12
2	4.26	15.9	1.13	1.12
⩾3	4.11	17.1	1.17	1.11

The automobile travel-time budget is calculated as the average of the daily interzonal vehicle hours of travel in the city divided by the number of personal vehicles. The estimate of vehicle hours of travel is directly available from the conventional traffic model assignment of traffic on the network and represents interzonal travel time with no access or egress time. This definition of travel time is considerably different from the perceived door-to-door travel time used to analyze the personal travel-time budget.

It is important to understand the underlying mechanisms that are responsible for the constancy of the travel-time budget. These mechanisms are best illustrated graphically in Figure 5 (4,8). It has been proved in several studies (4) that the average automobile trip distance is roughly proportional to the square root of the population, as indicated in Figure 5. The automobile trip rate, however, is inversely proportional to the average trip length, distance, or time. It is this complementary decrease in trip rate, as trip lengths increase, that is responsible for the constancy of the travel-time budget. If trip lengths become very long, as is the case in the New York Tri-State Region, the trip rate appears to decrease asymptotically to a basic 3 trips/car. (A similar inverse relation between trip rate and trip time was identified for the personal travel-time budget in the preceding discussion of travel mode.)

Table 6 (8) summarizes daily automobile travel times for the Canadian cities of Calgary, Toronto, and Montreal. Additional Canadian data are not available, since the other cities have not conducted 24-h travel surveys. The average daily travel time per car in these cities is 0.86 h, which is similar to the results of Zahavi's analysis. It is important to note, however, that the dispersion of the Canadian data is much greater. The automobile travel-time budget as identified by Zahavi clearly applied to Calgary both in 1964 and 1971 as well as to Montreal in 1971. The budget is slightly

Table 5. Analysis of vehicle travel-time budget for various world cities.

City	Year	Population	Cars per Capita	Daily Travel Time (h)	Trips per Day	Trip Time (min)	Speed (km/h)	Trip Distance (km)	Daily Travel Distance (km/car)
Athens	1962	1 900 000	0.0205	1.38	7.79	10.6			
Bogota	1969	2 339 560	0.0235	1.37	4.55	18.0	21.7	6.6	30.0
Singapore	1968	1 536 000	0.0485	1.10	5.03	12.7	31.7	6.7	33.7
Bangkok	1972	4 067 000	0.0430	1.27	3.50	22.8	18.4	7.0	24.5
San Jose	1973	656 670	0.0464	1.27	3.81	20.0			
Tel Aviv	1965	817 000	0.0485	1.10	7.28	9.1	25.1	3.8	27.7
Kuala Lumpur	1973	912 490	0.0717	1.40	6.78	12.4	24.7	5.1	34.6
Caracas	1966	1 719 030	0.0878	1.21	4.90	14.8			
Hull[a]	1967	344 890	0.125	0.72	6.25	6.9			
Belfast[a]	1966	504 520	0.128	0.81	5.63	8.6			
London[a]	1961	8 826 620	0.141	0.75	3.27	13.7			
West Midland[a]	1964	2 529 010	0.154	0.62	3.59	10.3			
Copenhagen[a]	1967	1 707 000	0.201	0.74	4.21	10.5			
Tri-State[a]	1964	16 303 000	0.257	0.97	2.89	20.1	47.1	15.8	45.7
Baltimore[a]	1962	1 607 980	0.272	0.67	3.26	12.3	45.4	9.3	30.3
Monroe[a]	1965	96 530	0.328	0.71	5.79	7.3	37.0	4.5	26.1
Cincinnati[a]	1965	1 391 870	0.348	0.83	3.63	13.7	38.5	8.8	31.9
Orlando[a]	1965	355 620	0.386	0.70	4.33	9.7	42.7	6.9	29.9
Washington[a]	1968	2 562 030	0.398	0.85	3.28	15.6	40.8	10.5	34.4
Los Angeles[a]	1960	7 595 830	0.411	0.80	3.66	13.1	60.0	13.1	48.0
Twin Cities[a]	1970	1 874 380		0.86	4.12	12.5	37.4	7.8	32.1
Philadelphia[a]	1968	2 558 100			3.96			7.5	29.7

[a] Average daily travel time = 0.86; standard deviation = 0.24.

Figure 5. Mechanisms of automobile travel-time budget for U.S. and Canadian cities.

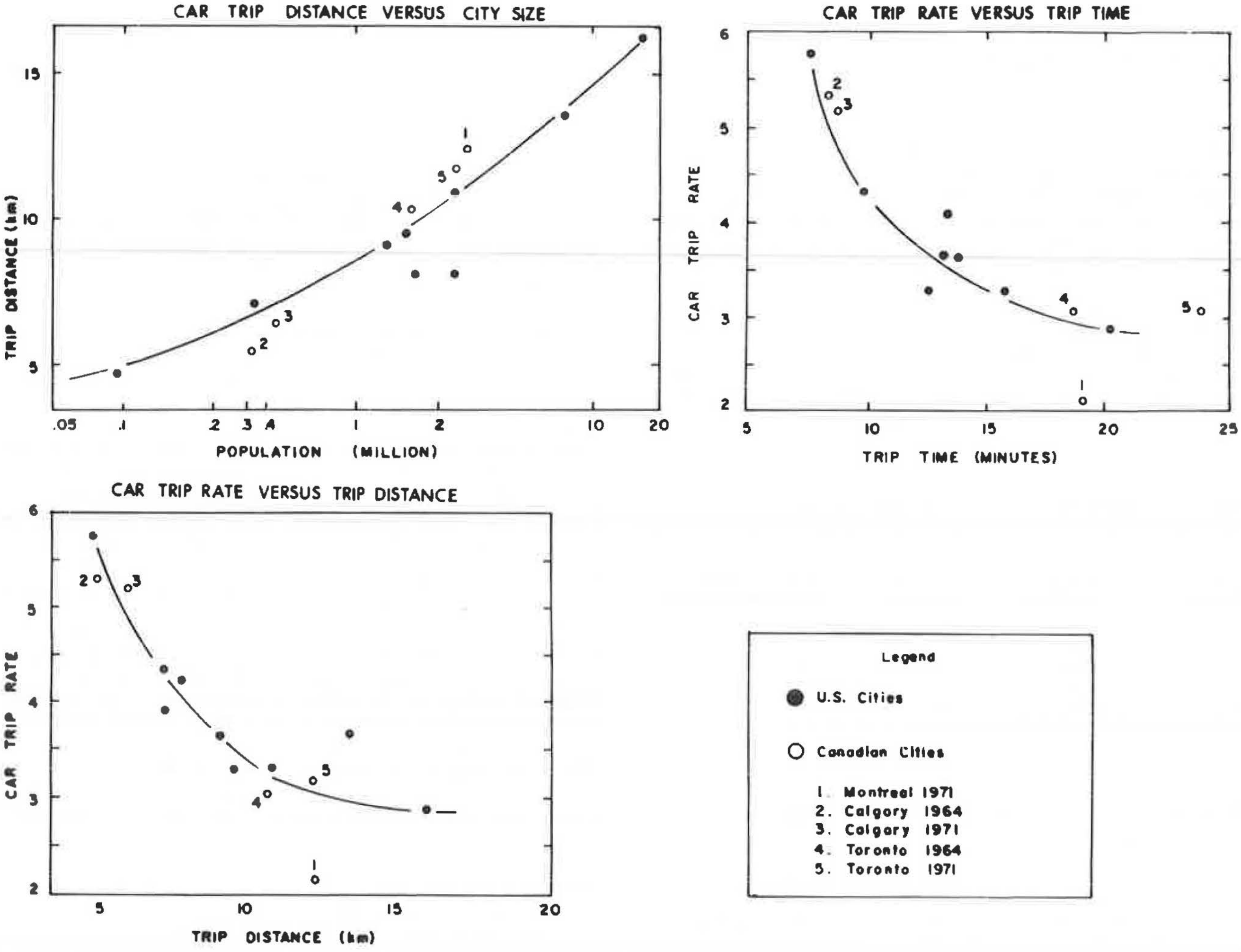


Table 6. Analysis of vehicle travel-time budget for Canadian cities.

City	Year	Population	Cars per Capita	Daily Travel Time (h)	Trips per Day	Trip Time (min)	Speed (km/h)	Trip Distance (km)	Daily Travel Distance (km/car)
Montreal	1971	2 484 462	0.25	0.62	2.03	18.4	41.4	12.7	25.8
Calgary	1964	304 065	0.34	0.75	4.5	9.1	33.6	5.1	27.3
	1971	408 000	0.37	0.76	4.6	9.4	38.2	6.0	31.5
Toronto	1964	1 774 570	0.26	0.93	3.02	18.5	33.4	10.3	31.1
	1971	2 096 920	0.33	1.25	3.17	23.6	30.8	12.1	38.4

Note: Average daily travel time = 0.86; standard deviation = 0.24.

exceeded in Toronto in 1964, but the discrepancy becomes much larger by 1971.

In the case of Toronto, the city grew quite rapidly from 1964 to 1971. Table 6 indicates that one of the main impacts of this rapid growth on transportation has been a deterioration in travel speeds, from 33 km/h in 1964 to 31 km/h in 1971. Throughout this period of rapid growth, travel behavior still adhered to the basic mechanisms of the automobile travel-time budget as indicated in Figure 5. Actually, Toronto is very similar to Washington, D.C. (Table 5), with respect to many travel characteristics such as population, trip rate, and trip length. The only major difference is that in 1971 Toronto travel speeds decreased to 31 km/h in comparison with speeds of 40 km/h in Washington, D.C. As a result, the average trip time in Toronto increased to 23.6 min versus 15.6 min in Washington, D.C., even though the average trip length in both cities is approximately 10-12 km. Since trip generation rates in both cities are rather similar, it appears that it is the deterioration in travel speeds that is responsible for the travel-time budget being exceeded in Toronto in 1971.

By 1971, the city of Calgary was also experiencing a growth rate similar to that of Toronto. In spite of this growth, however, Calgary has actually been able to improve travel speed through continuing expansion of the transportation system. As a result, the automobile travel-time budget has continued to apply in Calgary.

Montreal is a particularly interesting example because it is much less dependent on the automobile than any other Canadian city. The city's 24-h modal share for transit, approximately 30 percent, is one of the highest in North America. The automobile travel-time budget is also somewhat lower, primarily because of a low automobile trip rate of 2 trips/car. This low trip rate may be a result of people in Montreal relying much more heavily on transit for trip making. It is encouraging to note that when transit travel is included in the analysis, as it was in the personal travel-time budget, then the travel-time budget applies to Montreal.

The analysis suggests that the automobile travel-time budget exists in all of the Canadian cities analyzed except Toronto in 1971. Even in Toronto the trend exists, since it appears that the principal reason that the budget is exceeded is lower travel speed caused by an increase in congestion. This imbalance, however, may be of a temporary nature, and the travel-time budget may once again be adhered to in Toronto once travel speeds approach a more reasonable level of 35-40 km/h, as in Calgary and Washington, D.C.

Validity of Personal Travel-Time Budget in Canada

The personal travel-time budget is now supported by nine data points. It should also be noted that this analysis has included all the available data and that evidence to contradict the theory of the personal travel-time budget has yet to be established. The validity of the theory is further enhanced since it withstood a rigorous analysis that attempted to identify under which socioeconomic conditions the theory did not apply. In addition, it appears that there is an overall trend for an automobile travel-time budget in Canada, although the data are not as conclusive as those in support of the personal travel-time budget. It is suggested that the automobile travel-time budget be validated for each individual city before it is used for travel analysis.

The travel-time budget has some interesting and practical implications for the traditional transportation planning process. These implications are discussed in the following section and should be considered by the transportation planning profession in view of the above evidence in support of the theory.

IMPLICATIONS OF TRAVEL-TIME BUDGET FOR TRANSPORTATION PLANNING

The concept of the travel-time budget is not just an interesting phenomenon of urban travel behavior but also has some very practical applications for transportation planning. The two applications of the travel-time budget discussed in this section are (a) to perform an independent check on conventional travel forecasts and (b) to ensure that conventional traffic forecasts reflect an equilibrium between demand for travel and supply of transportation facilities. These applications of the budget concept can be used in direct conjunction with the transportation planning process and require a minimal amount of calculation.

Checking the Validity of Conventional Travel Forecasts

The basis of today's transportation planning process is a survey of individual households to measure such basic travel characteristics as trip generation. Traffic flows are then simulated by models such as the gravity model, which is calibrated to existing traffic counts.

Although these models are very effective at simulating existing travel patterns, forecasts of future travel should be considered very cautiously. Any forecast assumes a priori that present-day trip-making and trip distribution propensities, as measured in the surveys, will remain stable in the future. Trip-making characteristics may be forced to change because of changes in socioeconomic conditions. It is relatively easy to foresee socioeconomic changes such as reduced availability of gasoline, higher income levels, and increased leisure time. These factors could significantly affect trip-making characteristics.

In addition, travel forecasts developed today are unconstrained by the physical capacity of the transportation infrastructure. In many cities, there is now a policy to reduce roadway construction, especially facilities with limited access. If cities continue to grow and congestion is allowed to increase, residents may be forced to transfer nonessential trips to off-peak periods. The transportation planning process, as practiced today, does not recognize the effects of increased congestion and clearly overestimates travel under such circumstances.

The data currently available indicate that the travel-time budget is a much more stable indicator of urban travel behavior. The travel-time budget not only has remained consistent over a considerable period of time--more than 10 years in Washington, D.C., and the Twin Cities--but also is valid for a number of cities that have different population sizes and traffic problems. It would be very useful, therefore, to use the budget theory in order to perform an independent check of conventional travel forecasts, especially with changing socioeconomic conditions.

Conventional transportation planning models estimate not only traffic volumes on the various links of the urban network but also total vehicle and person hours of travel. It is very simple to use the travel-time-budget concept as a way of checking the validity of these forecasts of total vehicle and person hours.

Table 7 summarizes the travel forecasts developed for the city of Calgary for 1986 and 1996 along with forecasts developed through the budget concepts. As indicated in Table 6, the average interzonal travel time per personal vehicle in Calgary in 1971 may be estimated as 0.76 h. Given the population forecast, the number of vehicles can be calculated by assuming a saturation level of 0.5 personal vehicles per capita. If one combines these two variables, the daily vehicle travel time can be estimated as follows: For 1986, 0.76 (hours/vehicles) x 308 950

Table 7. Travel forecasts for Calgary.

	Conventional Forecast		Budget-Concept Forecast	
Item	1986	1996	1986	1996
Population	617 900	806 000	617 900	806 000
Number of cars[a]	308 950	403 000	308 950	403 000
Number of trip makers[b]	432 530	564 200	432 530	564 200
Vehicle hours of travel	259 518	338 100	234 800	306 300
Person hours of travel	NA	467 400	NA	507 780

[a] Assuming vehicle ownership will reach a saturation level of 0.5 personal vehicles per capita.

[b] Zahavi (4) has developed a regression equation to estimate the ratio of trip makers to population.

vehicles = 234 800 h; for 1996, 0.76 (hours/vehicles) x 403 000 vehicles = 306 300 h. The budget-based forecasts differ from the conventional ones by only 9 percent.

A similar verification can be conducted through the trip-maker travel-time budget. By 1996, the ratio of trip makers to population in Calgary is estimated at 0.7. The 1996 population will therefore generate 564 200 trip makers. A travel-time budget of 1.1 h cannot be directly applied, since this figure represents the door-to-door travel time perceived by the survey respondents. A detailed analysis of the Calgary data indicates that the actual interzonal travel time per trip maker based on network assignment is 0.9 h. This difference between actual and perceived travel time has yet to be thoroughly researched, and therefore each city must be analyzed on an individual basis.

The 1996 person hours of travel may therefore be calculated as follows: 564 200 trip makers x (0.9 h/trip maker) = 507 780 h. This figure can then be compared with the estimate of person hours of travel available from the traffic model. Once again, the difference between the conventional and budget-based forecasts is 8 percent.

This analysis considerably enhances the validity of the Calgary travel forecasts. The projections are now verified by another model that has a completely different theoretical base.

Equilibrium Travel Forecasts

The conventional transportation planning process assumes that trip generation rates will remain stable at existing levels regardless of increases in congestion. It appears reasonable to assume that if travel speeds deteriorate some trip makers would either transfer some trips to other, less congested periods of the day or possibly even forgo the trip.

There is an obvious need to relate trip generation to available travel speeds or other indicators of level of service. In other words, the demand for travel is expected to increase as speeds improve. Similarly, for a given transportation system, there is a physical limit to the volume of traffic that can be transported at a given speed. There must exist a state of equilibrium at which the volume of trips demanded equals the volume that can be accommodated by the facility. This equilibrium speed will also be the travel speed on that particular network. Of course, this concept is identical to the concept of price theory used in microeconomics, which states that at an equilibrium price the quantity of goods demanded equals the quantity that can be supplied.

The travel-time budget can be used to examine the relation between speed and travel demand. Through this procedure, it is possible to compare the speed associated with travel demand with the speed available through the transportation system and develop a truly equilibrium travel forecast. As an example, this procedure is now applied to the travel forecasts developed for the regional municipality of Ottawa-Carleton.

By the end of the century, the population of the Ottawa region is projected to grow from 620 000 to 1 400 000. The conventional traffic model forecasts 3 200 000 trips (10). According to the relation shown in Figure 3, the average trip length for a city of such size is 8.8 km. The number of vehicles is estimated to be 700 000, if we again assume a level of ownership of 0.5 vehicles/person. The vehicle travel-time budget may now be used to determine what speed of travel is actually implied by this travel demand forecast:

$$\text{Speed} = (3.2 \times 10^6 \text{ trips} \times 8.8 \text{ km/trip})/(0.7 \times 10^6 \text{ cars} \times 0.8 \text{ h/car}) = 50 \text{ km/h} \qquad (1)$$

Since existing travel speeds in Ottawa average only 32 km/h, this analysis implies that, if the forecast is to materialize, considerable road construction is necessary to increase travel speeds to 50 km/h. Such speeds are only achievable through an extensive freeway network such as that in Los Angeles. Even if the automobile travel-time budget does not apply and daily automobile travel times approach 1 h, as in Toronto in 1971, the speed implied in the travel forecast is still rather high: 40 km/h.

These results suggest that the Ottawa-Carleton forecasts were somewhat overoptimistic. The budget concept provides a mechanism for deflating these forecasts to reflect the physical capacity of the roadways. If it is assumed that travel speeds remain at 32 km/h, the actual demand or number of trips may be estimated as follows:

$$\text{Number of trips} = (0.7 \times 10^6 \text{ cars} \times 0.8 \text{ h/car} \times 32 \text{ km/h})/(8.8 \text{ km/trip}) = 2\ 040\ 000 \qquad (2)$$

The degree of overestimation in the Ottawa forecast can therefore be estimated as approximately 40 percent.

CONCLUSIONS AND RECOMMENDATIONS

This paper provides further evidence in support of Zahavi's theory of the travel-time budget. The data are based on the travel characteristics of the Canadian cities of Calgary, Toronto, and Montreal. As a result of this evidence, it is suggested that this new concept should be studied further. Two applications discussed in this paper are the use of the budget concept to verify conventional traffic forecasts and a method for developing equilibrium travel forecasts.

Much more research is required to truly establish the validity of the travel-time budget. If successful, the budget concept can be very useful in improving our understanding of travel behavior and consequently our ability to forecast it. Particularly useful applications of the budget concept, which should be investigated in further research, are identified below.

1. Traffic assignment--During periods of peak congestion, it is likely that some travelers will transfer nonessential trips to other periods of the day or simply forgo them. Conventional assignment techniques do not recognize this transfer, and trip generation rates are unaffected by congestion levels. The travel-time budget may provide a mechanism for deflating travel demand to equilibrium. Through further research, it may be possible to establish a criterion that states that, as long as the travel-time budget is being exceeded, the generation of some nonessential (nonwork) trips should either be transferred from the peak period to off-peak periods or, if necessary, completely suppressed. One very important research need is to examine whether the travel-time budget remains valid under increased congestion, when speeds drop below 30 km/h. All analysis to date has only considered cities where speeds are higher than 30 km/h.

2. Modal split--The personal travel-time budget reveals some interesting data about the behavior of transit and automobile trip makers. Preliminary data suggest that transit is acceptable for work trips only if the average travel time for the entire system is held to about 1 h. If this limit is

exceeded, a shift to automobile travel should be expected. Similarly, if transit speeds are improved through the development of better transit systems, and work travel could be accomplished in less than 1 h, then the travel-time-budget concept indicates that the use of the transit mode for additional nonwork trips may increase. This concept, if researched more thoroughly, could improve our understanding of the modal-split model.

3. Mobility--Whenever transportation plans are evaluated, a key concern is the impact on the mobility of residents, particularly those who do not own a car. It has always been very difficult to define what is an adequate level of mobility. The travel-time budget may provide the basis for a suitable mobility criterion. This preliminary research suggests that mobility may be defined as the ability to make more than the basic two work trips within the travel-time budget of 1 h. Further research of this concept is required.

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Analyzing Traveler Attitudes to Resolve Intended and Actual Use of a New Transit Service

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Traveler attitude data have been shown in the literature to be important in helping to predict the use of new transportation technologies or services. Reported prior intentions to use a new service often significantly overstate actual use once the service has been implemented. Differences obviously exist between the processes of intention formation and choice. An analysis is described that explores the differences between behavioral intentions and actual use of a new transit service by using extensive attitudinal data collected before and after implementation of a new transit system in Danville, Illinois. Several econometric models were developed, and the results are analyzed and compared. Choice constraints are treated explicitly in the analysis. Among the major findings are that level-of-service perceptions such as "convenience" and "enjoyment" and general feelings or biases regarding different transportation modes are important determinants in forming both intentions and choices. However, significant differences were found in terms of the relative importance of these attitudinal factors in the choice and intention processes, and these differences are highlighted.

During the past decade, a number of research efforts have been conducted on the use of attitudinal measures in travel demand models (1-4). Attitudinal measures that describe individuals' feelings, perceptions, and intentions with respect to the transportation system have been found to significantly improve the explanatory power of demand models, particularly disaggregate models of modal choice, because they take into account subjective or unobserved factors that are important in the travel decision process. Factors such as convenience, comfort, and safety have been shown in past research to be of considerable importance in modal-choice travel decisions (5,6) and should be included in choice models if possible.

In addition to these considerations, a major reason underlying the desire to use attitudinal information in the models, whether to supplement or replace the conventional use of observed information in the model specification, is to be able to better understand, and ultimately predict, the response to the introduction of new (i.e., untried) or greatly improved transportation services. It is felt that problems that involve demand for new modes or services are perhaps most amenable to solution through analysis of traveler attitudes rather than through extrapolation of observed measurements (1).

This study develops a set of behavioral models that incorporate attitudinal measures to aid in understanding the relation between the intended use of a new public transit system (reported prior to implementation) and actual use (reported after implementation). It is recognized in the literature