# Characteristics of Multistop Multipurpose Travel: An Empirical Study of Trip Length

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ABSTRACT

An empirical study is presented of several issues associated with the trip lengths of multistop multipurpose nonwork travel; a 2-week travel diary survey of households in Hamilton, Ontario, is used. These issues include the relationship between average stop-to-stop (link) travel times and stop purpose and number, the extent to which multistop trips follow minimum paths, and the extent to which stop sequences are ordered by distance from home. The analysis indicates that significant differences exist in average link travel times among stop purposes but not among stop number. In general, multistop trips do not follow minimum time paths. It is also found that stops nearest the trip maker's home are most likely to be the first or the last stop on a trip. Finally, some implications of these results for future modeling efforts and empirical investigations are briefly discussed.

A set of empirical studies of selected characteristics of multistop multipurpose travel is presented. The importance of multipurpose travel as a form of spatial interaction has received widespread recognition. The work of Hanson (1,pp.81-100) attests to the variety of the research efforts in this field. Furthermore, some theoretical implications of complex behavior have been raised and given a mathematical formulation (2-5). The research reported here represents a second round of empirical study along the lines of the pioneering empirical and theoretical work of Hanson (1), Jones (6), and Hensher (7).

The major difficulty facing modelers of multistop multipurpose trip making is the great complexity and variety of behavior involved. Multistop multipurpose travel is highly discretionary and flexible in terms of the number and timing of trips made, the choice of destinations visited, and the combinations and sequencings of destinations or purposes within multistop tours. Complex but rarely observed temporal (or other) constraints can affect the timing of trips, the sequencing of stops within tours, and the set of feasible destinations available to a given traveler at a given time.

The range of research issues associated with representing this complex behavior is vast. One particularly challenging and fundamental issue concerns the structure of the process involved in choosing a specific multistop multipurpose tour. That is, given the decision to make a tour, how is the composition of this tour determined? Is a set of stops chosen before leaving home or is this set chosen sequentially on a stop-by-stop basis as the tour progresses? If the set of stops on the tour is chosen before leaving home, is the order in which these stops are visited determined in any systematic fashion (e.g., nearest stop next, minimum path sequence)? How does trip length interact with the number and type of stops within a tour? (Is one likely to travel further to visit the fifth stop on a tour or the first stop? Does the distance traveled vary with the purpose of the stop?)

Several investigations are presented that are designed to search for empirical regularities in multistop multipurpose travel relating to the questions raised in the previous paragraph as a first step toward the development of an improved understanding of nonwork travel behavior and ultimately an improved capability to model such behavior. These investigations are explicitly exploratory in nature, reflecting the basic assumption that in many ways so little is known about multistop multipurpose travel behavior that it is difficult at this stage to formulate specific, testable hypotheses and that a more open-ended investigation might prove to be a more fruitful preliminary approach.

The major linkage among these analyses is that they all involve the investigation of some aspect of trip length in multistop multipurpose travel (where in all cases the measure of trip length will be off-peak stop-to-stop automobile travel times). Specifically, these investigations can be grouped into two main topics: the analysis of the interaction between stop purposes and trip length and the analysis of stop sequence within multistop tours.

## INTERACTION BETWEEN STOP PURPOSES AND TRIP LENGTH

Studies of multistop multipurpose travel in terms of the types of activities that are linked together reveal several regularities (8-11). Furthermore, activity pattern analysis has now begun to model the entire time sequence of household travel (12). These studies do not explicitly emphasize the actual amounts of travel inherent in various travel patterns, although Damm (13) recognized that increased trip chaining might represent a rational response to higher fuel prices. Of particular interest in this study is the extent to which different types of activities are chained together on the same tour and the impact of various stop-purpose combinations on average travel times.

The motivation underlying this concern is threefold. First, the extent to which average travel time varies by stop-purpose combination may provide insights into the tour choice process. Second, many spatial interaction models require an estimate of average trip length as input data. It is common practice to estimate such an average trip length from survey information on single-stop home-based trips. Several studies indicate, however, that multistop multipurpose travel is common (2,7,14). Recognition of this leads to the need to reevaluate the concept of average trip length, possibly in terms of trip lengths measured over specific links of the trip chain, possibly given specific origin and destination purposes. Third, and perhaps of greatest practical importance, development of nonwork travel models is often motivated by a need to measure the impact of various transportation policies (e.g., energy prices) on total urban travel. If such models seriously mispredict average travel times (or distances), their usefulness in such policy analyses is seriously compromised.

## PATH CHOICE (SEQUENCE OF STOPS) IN MULTISTOP TOURS

In simple single-stop single-purpose trip analyses the problem of stop sequencing does not arise. When there are more than two stops on a tour, however, several paths exist to the desired destinations. How do trip makers organize these paths? Do they choose minimum time paths to their desired destinations? Do they visit the nearest (farthest) stop first (last)? Answers to these questions have implications for the conceptualization of travel. If it can be shown that tours invariably follow a minimum path, the models ought to encompass global optimization as an objective. If, on the other hand, tours do not usually follow a minimum path, a sequential approach to travel modeling may be appropriate.

The issue of ranking of stops by distance from home is also of importance because it further elucidates the problem of path choice. If all stops away from home are equally likely to be the first stop on a tour, trip making is very unstructured. If, on the other hand, most first stops on multistop tours are ranked nearest to home, trip making is likely to be structured; moreover, the activity that takes place first is less likely to be the major purpose of the tour. This last point is important; it reinforces the idea that tours may have some regularity in their ordering of stops spatially, but this does not help to discern the major purpose of a tour. Furthermore, given that it is difficult to uncover the motivation behind a tour simply by observing its progress, there are likely to be problems modeling the overall structure of the tour.

## BACKGROUND

The study area for this analysis is the regional municipality of Hamilton-Wentworth, Ontario. The residents of this region were surveyed by using an areally stratified sampling scheme. About 700 households kept a diary for 2 weeks. The respondents reported all trip-making activity by the adult members of the household together with information on household characteristics and children's activities.

For the purposes of this study the Hamilton-Wentworth region was divided into 181 neighborhoods. In the central region these neighborhoods correspond to census tracts in size, whereas in the suburbs the neighborhoods are generally only slightly larger and hence represent a significant disaggregation of census tracts. All information provided by the households was coded by using the neighborhood numbers; therefore a fine breakdown of activity at a spatial scale was possible. Off-peak neighborhood-to-neighborhood (including intraneighborhood) automobile travel times were collected for this zonal system during the survey period and represent an average of up to four timings over the actual road network.

Data on every trip (hereafter generally referred to as a tour if it involves more than one nonhome stop) made by the household during the 2-week survey period were collected, where a trip was defined as a journey in which any person 16 years or older and not in elementary or secondary school leaves the home, visits one or more places, and returns home. A stop on such a tour occurred each time someone stopped traveling in order to shop, work, engage in recreation, socialize, and so on. A change of mode (e.g., walk to bus stop, wait for bus) did not count as a stop. Trips of less than two blocks were not recorded as generating separate stops.

A total of 46 stop purposes (in addition to work) were used to characterize each stop on each tour made by the households during the 2-week survey period. In addition, multiple purposes could be recorded for any given stop on any tour. Thus, considerable detail concerning tour characteristics is available within the study data. For the purposes of this study, however, only one primary purpose was associated with each stop and the 46 nonwork purposes were aggregated into four categories: grocery shopping, nongrocery shopping, social-recreational-other (i.e., all other nonwork, nonshopping purposes, hereafter referred to as SRO), and return home. Further, the analysis dealt only with nonwork tours, that is, with tours that did not include a work stop.

Given these data, it is impossible to establish any direct evidence of travel strategy or travel routines. The diaries simply record actions and not the motivations and objectives surrounding these actions. Information on motivation should perhaps be collected in the future, but it will be difficult to extrapolate from the unique situation of every trip to a general model of travel behavior. To give just a simple example, suppose 90 percent of a given household's travel follows a regular routine. The other 10 percent occurs in response to particular household circumstances (e.g., the need to deliver someone to the airport). This unique trip might disturb an entire sequence of trips and, depending on the observation point, could be highly misleading about the bulk of the household's travel. The simplifying assumption to be made in what follows is that some inferences about the nature of urban travel can be drawn from simple average statistics computed from the diary responses.

In the next section the interplay between the purpose of a stop, the number of the stop within the tour, and the average travel times spent making various transitions will be examined. The path choice issues discussed earlier are dealt with next: the extent to which stop sequences correspond to minimum path tours and the extent to which stop sequences are ordered by distance from home. Finally, the major findings of the paper are summarized and their implications for future modeling efforts are discussed.

## TRAVEL TIME BY TRIP PURPOSE OR STOP COMBINATION

Table 1 shows the average one-way stop-to-stop (or link) travel time by stop number and purpose of the stop for all nonwork tours in the sample involving up to five stops. For example, 617 observations were made of nongrocery shopping on the third stop of tours and typically these involved 5.20 min of travel from the previous activity. Information concerning first stops is further broken down by whether the stop is the only nonhome stop on the trip or it is the first stop on a multiple-stop tour. Points to note from this table include the following:

1. Single-stop trips exhibit shorter average stop-to-stop travel lengths than do multistop tours, regardless of stop purpose. Single-stop grocery trips, however, exhibit by far the most dramatic tendency in this regard, with an average single-stop one-way link travel time 1.14 min less than the average first-stop link travel time for multistop grocery tours. This result implies that single-stop

**TABLE 1 Average One-Way Travel Time by Stop Number and Purpose**

| | Grocery Shopping | Non-Grocery Shopping | Social-Recreation-Other | Return Home | All Purposes |
|---|---|---|---|---|---|
| Stop No. 1 | | | | | |
| Single-stop | 3.10 (1386) | 4.94 (2016) | 5.90 (5292) | - | 5.23 (8694) |
| Multistop | 4.24 (495) | 5.68 (1536) | 6.45 (2363) | - | 5.94 (4394) |
| All trips | 3.40 (1881) | 5.26 (3552) | 6.07 (7655) | - | 5.47 (13088) |
| Stop No. 2 | 4.33 (865) | 4.99 (1668) | 5.93 (1861) | 5.23 (8694) | 5.24 (13088) |
| Stop No. 3 | 4.24 (314) | 5.20 (617) | 6.03 (889) | 5.41 (2565) | 5.42 (4385) |
| Stop No. 4 | 4.84 (135) | 5.66 (221) | 6.17 (343) | 5.62 (1117) | 5.67 (1816) |
| Stop No. 5 | 4.54 (31) | 5.45 (78) | 6.52 (130) | 5.71 (458) | 5.78 (697) |
| All Stops | | | | | |
| Multistop | 4.33 (1840) | 5.33 (4120) | 6.19 (5586) | 5.51 (4140) | 5.57 (15686) |
| All Trips | 3.80 (3226) | 5.20 (6136) | 6.05 (10878) | 5.32 (12834) | 5.39 (33074) |

Note: Travel time in minutes; sample size given in parentheses.

grocery destinations are more localized than are grocery stops that occur at the beginning of a multistop trip chain.

2. With the exception of the single-stop trips, no clear relationship emerges between average link travel time and stop number within any given purpose. Thus, it is not clear that stop number plays a significant role in determining trip lengths (or the spatial range of alternatives considered) for multistop tours.

3. A consistent pattern in average link travel times exists across purposes; grocery stops always incur the shortest travel time and SRO stops incur the longest. Averaging across all stops for multistop tours, this results in an average of 1.00 min (23 percent) longer for nongrocery stops than grocery stops and an average of 1.86 min (43 percent) longer for SRO stops than grocery stops.

In order to investigate the interaction between stop purpose and average trip length further, average link travel times were computed for each purpose-to-purpose transition (e.g., grocery shopping to nongrocery shopping) for each stop transition (from the first to the second stop, from the second to the third, etc.). As in Table 1, no discernible trends emerged with respect to stop number, so only the average link travel times for each purpose-to-purpose transition across all stops are presented here (see Table 2). The general trend of shorter grocery link times than nongrocery times, which in turn are less than SRO times, is reinforced in Table 2, from which the following observations may be made:

1. Regardless of the purpose of the destination stop, the link travel time is the least if the origin stop's purpose is grocery shopping and the greatest if the origin purpose is SRO;

2. With the exception of the grocery-to-nongrocery transition, the link travel time is the least if the destination stop's purpose is grocery shopping and the greatest if it is SRO, regardless of the purpose of the origin stop; and

3. Times along the main diagonal of Table 2 are monotonically increasing, whereas off-diagonal times are ordered so that a lower-triangle time is always greater than its upper-triangle counterpart (e.g., the average travel time for a nongrocery-to-grocery transition is greater than that for a grocery-to-nongrocery transition).

**TABLE 2 Average Travel Time on One-Way Links by Purpose Transition for All Stops**

| From \ To | Grocery Shopping | Non-Grocery Shopping | Social-Recreation-Other |
|---|---|---|---|
| Grocery Shopping | 4.13 (263) | 3.99 (358) | 4.12 (274) |
| Non-Grocery Shopping | 4.26 (605) | 4.84 (1228) | 5.81 (854) |
| Social-Recreation-Other | 4.71 (495) | 5.86 (1045) | 6.32 (2175) |

Note: Travel time in minutes; sample size given in parentheses.

The only anomaly that exists in Table 2 is the grocery-to-nongrocery transition, which possesses a smaller average travel time than the nongrocery-to-grocery transition. This transition, however, represents only 13.6 percent of all nongrocery stops in the sample. Thus, one can speculate that nongrocery stops will be linked to preceding grocery stops only infrequently, and then only if they can be chosen from a relatively localized (with respect to the grocery stop) set of destinations.

Tables 1 and 2 imply that link travel time impedance is highest for grocery stops and lowest for SRO stops or that only a relatively localized choice set of possible destinations is considered by grocery shoppers, whereas a considerably more dispersed set of destinations is involved in SRO trips (with, in either case, nongrocery occupying an intermediate position). This is not an unexpected result, but it does reinforce the need for explicitly considering trip purpose in nonwork travel demand modeling, because the trip distribution pattern (and associated average trip lengths) is likely to vary substantially depending on the purpose or purposes involved. Table 2 indicates that this result is accentuated when one controls for origin stop purpose, although it cannot be determined from this simple analysis whether this result is due to an actual interaction between stop purposes (i.e., a nongrocery-to-SRO transition is fundamentally different from an SRO-to-SRO transition) or whether it is simply due to variations in stop destination choice sets given previous stop choices (which in turn has implications for the stop choice process).

Table 3 shows the implications of these results

**TABLE 3 Travel Time on Selected Two-Stop Trips**

| Trip Pattern | Link Travel Time Home - Stop 1 | Stop 1 - Stop 2 | Stop 2 - Home | Total Travel Time |
|---|---|---|---|---|
| GGH | 4.24 | 4.16 | 3.63 | 12.03 |
| GNH | 4.24 | 3.72 | 5.01 | 12.97 |
| GOH | 4.24 | 4.15 | 6.82 | 15.21 |
| NGH | 5.68 | 4.22 | 3.63 | 13.53 |
| NNH | 5.68 | 4.67 | 5.01 | 15.36 |
| NOH | 5.68 | 5.57 | 6.82 | 18.07 |
| OGH | 6.45 | 4.52 | 3.63 | 14.60 |
| ONH | 6.45 | 5.71 | 5.01 | 17.17 |
| OOH | 6.45 | 6.23 | 6.82 | 19.50 |

Note: Travel time in minutes; G = grocery shopping stop; N = nongrocery shopping stop; O = social-recreation-other stop; H = return home.

by presenting representative average travel times for nine different two-stop multipurpose tours, constructed by adding together the appropriate stop-specific average transition times (i.e., these times are not taken from Table 2, which represents averages taken across all stops). As shown in Table 3, these trip times vary from 12.03 min for a grocery-grocery-home tour to 19.50 min for an SRO-SRO-home tour. This represents perhaps the most important implication of this section's analysis for nonwork trip modeling: there is no such thing as one average travel time for nonwork trips. Rather, this average varies with the number and the purposes of the stops involved, and hence models that ignore the multistop multipurpose nature of nonwork travel are unlikely to be able to replicate such travel adequately.

## STOP SEQUENCING IN MULTISTOP TRIPS

Given a symmetrical zone-to-zone travel time matrix whose entries all obey the triangle inequality (conditions that apply to the off-peak automobile travel time matrix used in this analysis), it can be shown that the number of distinct paths through n stops away from home is n!/2. For any tour consisting of a given set of stops, these n!/2 distinct paths can be enumerated in order to compute the minimum time path through the set of stops (denoted by a) and the maximum time path (denoted by c) and these quantities can then be compared with the travel time for the path actually chosen by the trip maker (denoted by b). Table 4 presents the results of such an analysis for all nonwork tours in the sample with five or fewer stops. The table shows the number of tours observed having n stops (n = 1, ..., 5), the number of distinct paths associated with an n-stop tour (n!/2), and the breakdown of observations into the following categories:

a = c: minimum and maximum time paths are equal, hence the chosen path must be a minimum;
a = b < c: a minimum time path is chosen;
a < b = c: a maximum time path is chosen; and
a < b < c: a time path between the minimum and maximum times is chosen.

**TABLE 4 Observations of Minimum Path Behavior**

| n | Paths | Observations | a = c | a=b<c | a<b=c | a<b<c |
|---|---|---|---|---|---|---|
| 1 | 1 | 8694 | 8694 | | | |
| 2 | 1 | 2566 | 2566 | | | |
| 3 | 3 | 1116 | 155 | 523 (54.4) | 328 (34.1) | 110 (11.4) |
| 4 | 12 | 458 | 20 | 175 (40.0) | 64 (14.6) | 199 (45.4) |
| 5 | 60 | 140 | 2 | 33 (23.9) | 8 (5.8) | 97 (70.3) |

Note: n = number of nonhome stops on the trip; a = minimum time path; b = path chosen by trip maker; c = maximum path. Numbers in parentheses express the percentage of observations less the a = c observations that fall into the given category for a given value of n. Thus, for example, 523/(1116 - 155) = 54.5 percent of the three nonhome stop tours for which a ≠ c fell into the a = b < c category.

As shown in Table 4, the percentage of tours that display distance minimization (excluding the a = c case) is 54.4, 40, and 23.9 percent for three-, four-, and five-stop tours, respectively. The decrease in minimization behavior as the number of stops increases reflects the difficulty facing trip makers in finding the minimum path on longer tours.

The percentage of tours that display distance maximization is 34.1, 14.6, and 5.8 percent for three-, four-, and five-stop tours, respectively. These percentages are lower than the corresponding values for distance minimization. Finally, the percentage of tours with intermediate behavior (a < b < c) is 11.4, 45.4, and 70.3 percent, respectively, for three, four, and five stops. Thus, as the number of stops on a tour increases, the probability of traveling on either a minimum or a maximum path decreases and the probability of using some intermediate travel path increases substantially.

Assuming that the relative attractiveness of locations for various purposes does not vary with the order in which they are visited and that temporal constraints do not exist that would force specific sequencing of stops on some tours, any utility-maximizing model of nonwork travel that assumes a simultaneous or joint choice process over the destinations and purposes associated with a given multistop multipurpose tour (with either a fixed or variable number of stops) implicitly assumes that a minimum path will be taken through the selected set of stops (because the utility associated with this set of stops can always be improved by moving from a non-minimum to a minimum path). Because 45.5, 60.1, and 76.1 percent of the three-, four-, and five-stop tours, respectively, in the sample did not choose a minimum path (i.e., they chose a maximum or intermediate path), there is some evidence either that tour chain decisions are made in some sequential stop-by-stop fashion (rather than simultaneously over all stops) or that the assumptions made earlier do not hold. This latter supposition, however, in turn argues for a more dynamic view of nonwork trip decision making, which, again, is probably most compatible with some form of sequential decision structure.

Table 5 presents the average minimum, maximum, and chosen tour times for three-, four-, and five-stop tours for each of the four cases presented in Table 4 (a = c, etc.). It can be seen from Table 5 that

1. The a = c case (all feasible paths have the same travel time) generally occurs for relatively short tours,
2. Travelers tend to choose minimum paths when large differences exist between the minimum and maximum path times and conversely maximum time paths tend to be chosen when the differences between the minimum and maximum path times are relatively small, and

**TABLE 5 Average Tour Times Versus Number of Stops and Type of Path**

| n | Type of Path | Chosen Path Case a = c | a=b<c | a<b=c | a<b<c |
|---|---|---|---|---|---|
| 3 | Minimum Time Path | 671 | 1331 | 1374 | 1504 |
| | Chosen Path | 671 | 1331 | 1599 | 1564 |
| | Maximum Time Path | 671 | 1709 | 1599 | 1866 |
| | | | (378) | (225) | (362) |
| 4 | Minimum Time Path | 788 | 1557 | 1480 | 1664 |
| | Chosen Path | 788 | 1557 | 1892 | 1866 |
| | Maximum Time Path | 788 | 2218 | 1892 | 2278 |
| | | | (661) | (412) | (614) |
| 5 | Minimum Time Path | 1849 | 1574 | 1933 | 1860 |
| | Chosen Path | 1849 | 1574 | 2420 | 2147 |
| | Maximum Time Path | 1849 | 2618 | 2420 | 2957 |
| | | | (1044) | (487) | (1097) |

Note: Travel time in seconds. The numbers in parentheses indicate the differences between the maximum and minimum path times for each case.

3. Intermediate time paths tend to be chosen when the differences between minimum and maximum time paths lie between the two cases described previously (although these differences and the chosen travel times tend to lie closer to the case of minimum path choice than that of the maximum path choice; i.e., people come closer to minimizing than maximizing).

These results imply that people are better able to choose between shorter and longer paths as the differences between these paths become more pronounced. This may simply be because the traveler does not possess (or is willing to gather) sufficiently accurate information to choose among alternative paths, except when it is obvious that major differences exist. It may also imply threshold effects, in which the traveler is relatively indifferent to variations in travel times, as long as they do not exceed certain threshold limits. Finally, the choice of intermediate paths that tend to fall closer to minimum time paths than maximum time paths and the choice of maximum time paths only when they exceed minimum feasible times by relatively small amounts tend to indicate that path choice, if not a global optimization process, is perhaps at least a relatively rational, structured one, in which good choices are probably made far more often than bad ones.

In order to further elucidate overall patterns in the stop sequencing of multistop tours, the spatial ordering of these stops can be investigated. That is, if a trip maker visits n locations away from home, these locations can be ranked in order of their proximity to home, with distance rank 1 being allocated to the location nearest home. If the temporal ordering of the activities on the tour is given by the stop number i = 1, ..., n, the spatial ordering is given by the distance rank of the location at stop i, that is, R(i). The question to be investigated is then whether consistent patterns exist with respect to R(i), i = 1, ..., n.

Table 6 summarizes the distributions of stop-sequence and distance-rank combinations for two-stop through five-stop nonwork tours, respectively.

**TABLE 6 Stop Ordering Versus Distance Ranking**

| | No. of Stops by Rank | | | | | |
|---|---|---|---|---|---|---|
| Stop No. | Rank 1 | Rank 2 | Tied for Rank 1 | Rank 3 | Rank 4 | Rank 5 |
| Two-Stop Trips | | | | | | |
| 1 | 917 | 1,203 | 446 | | | |
| 2 | 1,203 | 917 | 446 | | | |
| Three-Stop Trips[a] | | | | | | |
| 1 | 571 | 299 | | 246 | | |
| 2 | 361 | 322 | | 433 | | |
| 3 | 629 | 297 | | 190 | | |
| Four-Stop Trips[a] | | | | | | |
| 1 | 221 | 89 | | 82 | 66 | |
| 2 | 99 | 118 | | 107 | 134 | |
| 3 | 112 | 106 | | 126 | 114 | |
| 4 | 232 | 104 | | 68 | 54 | |
| Five-Stop Trips[a] | | | | | | |
| 1 | 71 | 30 | | 22 | 6 | 11 |
| 2 | 27 | 24 | | 27 | 27 | 35 |
| 3 | 26 | 31 | | 34 | 31 | 28 |
| 4 | 23 | 29 | | 34 | 29 | 25 |
| 5 | 55 | 42 | | 15 | 16 | 12 |

[a]Tieds ranks included.

Thus, for example, Table 6 indicates that for the two-stop tours in the sample, 917 had first stops that had distance rank 1 (i.e., were the closest to home of the stops visited on the tour), 1,203 had first stops that had distance rank 2 (i.e., were the second closest to home of the stops visited on the tour), and 446 had first stops that were tied for distance rank 1 (i.e., stops 1 and 2 were equidistant from home). Two major observations that emerge from consideration of this table are that the nearest stop is likely to be either the first or last stop on the tour and that increasingly distant stops are increasingly likely to be intermediate stops in the trip chain. This latter result is shown in Figure 1, in which it is seen that the percentage of intermediate stops increases both with distance rank (for a given number of stops) and with the number of stops (for a given distance rank).

These results are probably compatible with either a simultaneous or a sequential decision-making structure. They do, however, indicate that stop ordering tends to be at least partially a function of routing considerations (e.g., visit the nearest desired destination next) rather than an indication of activity priorities (e.g., visit the highest-priority destination next). This in turn implies that a priori categorization of tours according to their stop ordering (e.g., defining the tour purpose in terms of the purpose of the first stop) is probably not appropriate and probably does not represent a fruitful approach to conceptualizing multistop multipurpose tours.

## SUMMARY OF RESULTS AND IMPLICATIONS FOR FURTHER WORK

The major results that emerge from the analyses presented in the previous two sections include the following:

1. Grocery shopping trips have dramatically different average link travel times for single-stop and multistop trips; the latter are typically nearly 40 percent larger than the former (4.33 min versus 3.10 min). This implies a definite tendency for two modes of grocery shopping to exist: localized single-stop shopping and more dispersed multistop shopping. Although the single-stop link times for nongrocery and SRO trips are the lowest link times for each of these other purposes as well, they are only 7 and 5 percent lower than the average multistop link time for each purpose, respectively.

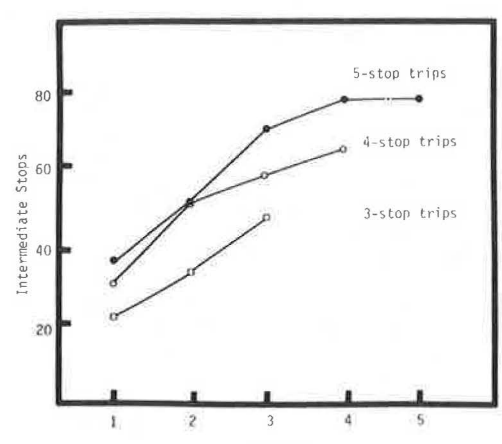


**FIGURE 1 Percentage of intermediate stops by distance rank.**

2. A consistent hierarchy exists in average link travel times with respect to purpose. Grocery stops consistently incur the shortest average link times, whereas SRO stops always incur the longest. This result holds regardless of whether one controls for the origin purpose of the link, the destination purpose, or both the origin and destination purposes.

3. No consistent pattern exists with respect to average link travel time and stop number. In particular, link travel times do not appear to grow either typically larger or smaller as the stop number increases.

4. A considerable number of multistop tours (between 46 and 76 percent, depending on the number of stops in the tour) do not exhibit minimum path stop sequences. This implies that temporal constraints exist that prevent the selection of minimum path routes, that within-tour dynamics exist that lead to the selection of nonminimum path routes, that information constraints typically exist that limit the traveler's ability to identify a minimum time path, or that tours are constructed through a sequential rather than simultaneous decision process.

5. Minimum time paths tend to be chosen when the differences between the minimum and maximum time paths are large, whereas maximum time paths tend to be chosen when this difference is small. This implies that people tend to make good path choices even if they are not ones that minimize travel time.

6. Stops ranked as being nearest to a trip maker's home tend to be either the first or last stop on multistop tours. If the locations visited on a tour are ranked according to distance, with the shortest distance ranked 1, places with high distance rank are unlikely to be either the first or the last stop on a trip. This result is consistent with the hypothesis that stop sequencing is at least partially determined by a path choice process (whether or not this process is a path-minimizing one), and it certainly implies that care should be taken in associating any priorities among a tour's purposes with the stop sequence.

Two major implications emerge from these results for the modeling of nonwork travel. First, it is clear that nonwork travel must be explicitly modeled as being multistop and multipurpose in nature. Ignoring multiple-stop tours will result in a serious underestimation of total travel as well as provide a poor conceptual starting point for behavioral modeling efforts. Significant variations in behavior exist among purposes (e.g., virtually a 100 percent difference in average link travel times between single-stop grocery links and multistop SRO links); thus it is unlikely that a sound behavioral model of nonwork travel that is capable of generating acceptable predictions can be constructed without its being explicitly multipurpose in nature.

Second, no strong evidence has been found to suggest that trip makers globally optimize their travel by means of a simultaneous choice process over all available destinations, purposes, and routes. Indeed, the results obtained are probably more consistent with a more sequential decision process. This is, on balance, a promising result for at least two reasons. First, sequential models provide a convenient mechanism for keeping the combinatorics or dimensionality of the choice process within practical limits (e.g., one might model two choices among n and m alternatives, respectively, rather than one choice among nm alternatives). Second, a more sequential decision process may well be more in keeping with actual human decision making than is a simultaneous or global-optimizing one.

To go beyond these preliminary speculations requires more work of both a theoretical and an empirical nature. With respect to the latter, logical extensions to the work presented here include the splitting of the analysis by mode of travel (a computerized transit network for the Hamilton-Wentworth region is currently under development that will enable this to be done), the analysis by means of computer-graphic displays of the shape of multistop travel patterns as well as the changes in the distribution of available alternatives for different purposes as the trip-maker moves from stop to stop, and the analysis of patterns in the generation of different tour purpose combinations (currently under way). In the longer run, the need exists to go beyond the revealed-preference travel diary data of the Hamilton-Wentworth survey and to question people directly concerning their choice process so as to achieve an improved understanding of this process.

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# Socioeconomic and Travel Forecasts for Alternatives Analysis in the Puget Sound Region

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ABSTRACT

The development and use of socioeconomic and travel forecasts for evaluation of major transit investments in the Puget Sound region of Washington State are described. Although procedures used to produce socioeconomic and travel forecasts may be considered standard relative to techniques used elsewhere, the analysis and interpretation of the results have had a substantial impact on the decisions of policy makers in the region. How the results are being used for decision making is the thrust of this paper. Highlighted is how forecasts have been used at each phase of the transportation planning process: for systems planning, for corridor analysis, and for project planning. First, forecasts played a key role in defining the nature of the future regional transportation system as contained in the Regional Transportation Plan. Predictions of levels of highway congestion and potential transit ridership were subsequently used to rank corridors as to priority for further analysis. In evaluating alternative transit projects within corridors, policy makers have given priority to those projected to generate additional transit patronage. Because billion-dollar decisions are being made today for tomorrow's transit capital and operating programs, the need for constant update of the regional data base and forecasting capabilities has been reinforced. Additional survey work and model refinements are planned to help ensure that adequate technical information is available as projects go into preliminary engineering.

In 1982 the Puget Sound Council of Governments (PSCOG) adopted a new Regional Transportation Plan (1). The plan constituted a major departure from earlier plans in that it contained an explicitly stated policy that there would be no new freeway corridors or major highway expansion in the region during the next 20 years. Yet the adopted population and employment forecasts used in preparing the plan implied that an almost 45 percent increase in daily person trips in the region would occur between 1980 and 2000. To help accommodate this growth in travel demand, the elected officials set as objectives of the plan to increase the market share of transit and of ridesharing over the next 20 years. These objectives were to be met through the development and implementation of aggressive transit and ridesharing programs.

Figure 1 shows the location of the Puget Sound region, which includes the cities of Everett, Seattle, and Tacoma. (The arrow indicates the corridor currently under study.) Population and transportation characteristics for the region are summarized in Table 1. As indicated in Table 1, use of transit for the work trip is forecast to increase from 9.6 percent to 11.7 percent during the 20-year period on a regional basis. Daily average vehicle occupancy is expected to increase from 1.38 in 1980 to 1.46 in 2000. Although this still is less than the average vehicle occupancy in 1960, a reversal of the downward trend that occurred between 1960 and 1980 is an objective of the plan. Figures 2 and 3 are graphs of transit use and average vehicle occupancy during the period 1960-2000.

Although a transit mode split for work trips of 11.7 percent in 2000 is forecast for the region as a whole, the proportion using transit for work trips destined for downtown Seattle is expected to increase from 40 percent in 1980 to 54 percent in 2000. In Table 2 downtown Seattle population, employment, and travel data are compared for 1980 and 2000. Given the large increases in employment projected for downtown Seattle and the high levels of transit use for trips to the central business district (CBD), the need for a higher-capacity transit system, such as light rail, seemed likely. PSCOG decided that the feasibility of a light rail transit