The Primary Destination Tour Approach to Travel Demand Modelling: An Empirical Analysis and Modelling Implications

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ABSTRACT

Recent research in the issues of trip chaining and travel time budgets have both highlighted the interrelationship between the trips made by an individual during a given day, and drawn attention to the shortcomings of travel demand models that assume independence among trips. An improved approach alternative strategy is to aggregate trips into round-trip tours, to which these same types of demand choice models can then be applied. Differences between this tour approach and the more common trip approach to travel demand modelling are examined here using empirical data from a recent travel survey in Holland. It is shown that tours can be modelled as easily and with greater accuracy than can trips. The tour approach has the constructive advantage of distinguishing primary destinations and purposes for travel from secondary or incidental ones. This approach is shown to have the effects of minimizing the destination modelling problem of non-home-based travel, reducing the travel generation problem of multiple daily occurrences of the same travel purpose by a single individual, and the time of day problem of interrelationships between the timing of trips.

1. Introduction and Motivation

The standard approach to modelling individual tripmaking, which estimates the characteristics of each trip independent of other trips, has been the object of increasing criticism. Recognition that the generation, mode choice, destination, and time of day of trips made by a given individual are interdependent can be traced back to a recognition that travel is itself a secondary aspect of the more fundamental set of population activity patterns. Underlying travel demand is the direct demand of individuals for the activities, goods and services that are obtained by visiting locations. The tripmaking decision process of an individual for a given activity involves selecting a travel mode and time of day jointly with a destination location and length of activity duration, all within the constraints of a time budget and a cost budget (Kutter, 1973; Jones, 1978; Ginn, 1969; Bain, 1976). This viewpoint has three important implications. First, it opens the possibility of developing a more systematic hierarchy of trip purposes. Travel surveys already stipulate that "incidental" stops on a journey (e.g. to buy fuel) should be omitted; the distinction between "incidental" and "important" steps is clearly arbitrary. Only by developing more realistic models of the way in which travellers schedule activities outside their homes can we begin to understand which such activities are truly important and which are incidental. Second, the possibility arises of the joint pursuit of more than one activity in a single journey. It has been estimated from a variety of travel

surveys in the U.S. and U.K. that one-quarter to one-third of all vehicular trips are part of such a multiple destination journey (Jones, 1975). Third, it introduces clearly the option of satisfying an activity need in the home. Travel is then the product of requiring to perform a certain activity AND of not being able to do so at home. This thought could prove the key to analysis of low-energy high technology developments based on telecommunications.

Demand models based on individual trip links involve a loss of information about the extent of chaining smaller trips into larger journeys, and the sequencing of multiple destinations. On the other hand, it is clear that trip chaining is a complex phenomenon to model, as it involves issues of scheduling convenience and cost in the evaluation of choice among a wide variety of possible activity pattern configurations (Adler and Ben-Akiva, 1977). The geographic pattern of such complex travel and relative time budgets for travel relative to activity time both depend directly on the extent to which activities are or can be clustered (Vidakovic, 1975). To date, analyses of multiple destination journeys have focused on the extent of such trip chaining behavior and the frequency of multiple destinations within round-trip home-based journeys, with some preliminary study of destination choice for non-work tours (Horowitz, 1978; Oster, 1977; Adler and Ben-Akiva, 1977).

The problem highlighted by the trip chaining issue is that activities, not trips, are the fundamental choice for decision-making. A full approach to the interdependence among activities

and trips requires the construction of a model of choice among all possible combinations of daily activities among those occurring at home, work and other locations. Research into activity duration and time allocation (Jones, 1978; Jacobson, 1979) and activity sequencing (Damm, 1979) have attempted to shed light on these issues. The importance of multiple destination journeys and the inadequacy of the standard approach to modelling frequency, destination, mode and time of day for individual trips indicates the importance of a more holistic approach in which the basic units for modelling are round-trip journeys, referred to as tours (Bentley, 1976).

The tour approach is potentially a powerful tool for explaining travel behavior, as a number of shorter trips may be better explained as links in one longer tour. The grouping of trips into tours is based on the fact that all travel can be viewed in terms of round-trip journeys based at the home. Each of these tours visits a number of stops as destinations. Within these destinations it is natural to assume some ranking of importance: perhaps we can view a subset of the destinations as motivating the tour, while others are visited by the traveller incidentally along the way. The first step in setting up such a ranking is to identify one of the destinations as the most important, the "primary" destination. From this point we can go on to investigate the extent to which other ("secondary," "tertiary," etc.) destinations are visited conditionally on the primary destination. This approach of

identifying a primary destination for every tour also incorporates satisfactorily in a general framework. In fact, the overwhelming majority of tours visit only one destination. The primary destination approach is thus a constructive approach for modelling complicated tours. It exploits the fact that multiple-stop journeys usually have a primary activity and destination that is the major motivation for the journey, and other secondary destinations that are of lesser importance as determinants of the frequency, mode, time of day, and even route of the journey.

It is shown in this paper that disaggregate choice models for frequency, destination, mode, and time of day can be applied to tours in much the same way as the modelling of simple trips. Thus without requiring extensive development of new techniques, we are able to achieve the greater understanding of traveller behaviors offered by the tour approach and, consequently, make more accurate predictions of future behavior. The remainder of this paper discusses issues in defining tours and discusses the applicability of the tours approach to travel demand modelling. The empirical analysis is based on data from a 1977 Zuidvleugel ("South Wing") area travel survey of Holland, an area including the Hague and Rotterdam. This data analysis is a preliminary phase in the ongoing development of a complete tour-based travel demand forecasting system being sponsored by the Netherlands Ministry of Transport and Public Works (see Daly, 1978; Weisbrod and Daly, 1979).

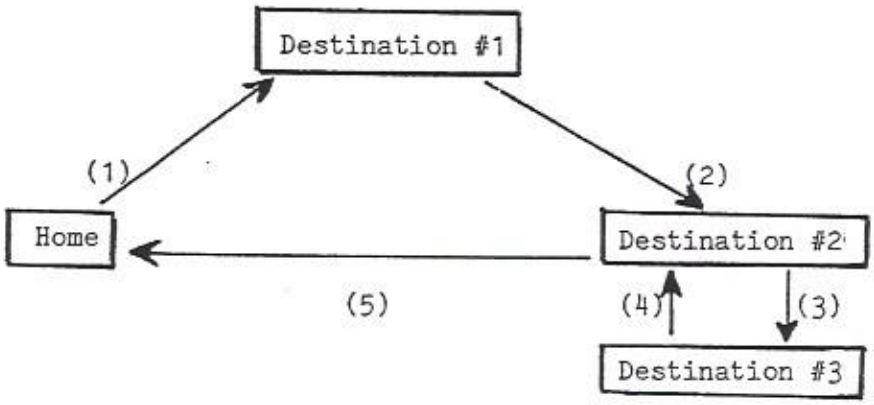
2. Construction of Tours

The concept of trip chaining is based on the fact that trips can be linked; i.e., the destination of any given trip will always be the origin for the next trip made by that individual. Viewed this way, it is possible to categorize all individual travel in terms of tours that ultimately start and end at home, regardless of the number of intermediate trips. In practice, we find that not all travel observed in the normal home interview survey is conveniently classified in this way. First, it is inevitable when a survey is conducted over a limited period that some tours should be in progress at either end of the period; we do not, therefore, collect complete information about these tours. Of course, the number of such tours may be minimized by selecting the time period carefully. Second, a number of tours visit no specific destination and, obviously, a primary destination cannot be defined. Such tours are generally very short, such as walks with a dog. In the Zuidvleugel study, from which the empirical evidence for this paper is drawn, travel in both these categories was excluded from analysis, thus discarding slightly over 1 percent of of the total trips observed.

While almost all travel can be defined in terms of home-based tours, it is also possible to identify non-home-based tours within the larger home-based tours. Figure 1, for example, can be interpreted in two different ways. First, it can be viewed as one home-based tour to destinations #1, #2, and #3. The same journey

FIGURE 1

Tour Formation



could alternatively be viewed as one home-based tour to destinations #1 and #2, within which there is a separate tour based at destination #2 to destination #3.

Such subtours can be modelled separately to the extent that they are based on locations which are reasonably fixed for the household or individual, and are regularly used as an origin for travel. This is necessary to assume confidence in the prediction of tour characteristics from such locations because, to be useful, such a model must assume the subtour to be contingent on the main tour. Home locations clearly meet those criteria, but workplace and education locations could also be included in this category. The group that clearly fails the criteria are shopping, social and recreation destinations, the locations of which are generally far less fixed and less constantly used.

For this study, 26,884 trips were organized into 11,470 home-based tours. Within these larger tours, there were 204 work-based tours. Only tours from the usual workplace to non-home destinations were separated and modelled separately from the larger home-based tours. Education locations were not used as a base for non-home-based subtours both because there was no data in the survey on fixed locations other than workplace, and because there would be even fewer education-based tours than work-based tours. It is notable that only 2 percent of the tours were not home based. By contrast, over 16 percent (4,365) of the 26,884 trips were not home based. This difference occurs because, in the process of tour formation, all trips that did not involve either the home or fixed workplace as origin or destination were linked to home-based or work-based tours. It is difficult to compare the proportion of non-home-based travel in the Zuidvleugel study with that in other travel surveys, because we found no strictly comparable information in other surveys. Among Dutch surveys, the proportion of trips that are not home-based has ranged from around 20 percent to 38 percent, while British surveys have found a proportion ranging from 12 percent to 28 percent of all trips (Heggie, 1976). These numbers, however, generally apply only to peak period vehicular trips within the study zone. It seems that the Zuidvleugel data is not inconsistent with the other survey information, but it is not possible to say whether the non-home-based proportion is high or low.

3. Defining Primary Destinations

A tour can be complex, involving several different destinations, activity purposes, modes of travel, and time constraints. The primary destination approach is based on the assumption that it is possible to identify one activity and destination that is the most important motivator for the tour generation and destination, and represents the principal constraint on the starting and ending times of the tour. For instance, it is generally recognized that the frequency, destination, and time of day for travel to work and school are far less flexible for most persons than are these characteristics for shopping travel.

As shown in Table 1, most tours (83 percent) involved a single destination. For that 17 percent of the tours for which there were multiple destinations, however, the primary destination approach requires that a primary destination be identified. Three alternative definitions of the primary distinction might readily be considered: (1) the destination that is the furthest from the (home or work) base, (2) the destination whose purpose is highest on a ranking list of importance, and (3) the destination at which the longest amount of time was spent. While the furthest destination will by itself always produce the best approximation to the total tour length (among approximations that ignore secondary destinations), is not necessarily a good predictor of the tour frequency, or even the mode or purpose of the tour. The importance list approach is rejected because it is arbitrary and there is little agreement on

Table 1

Types of tours

Tour type		Number of tours	% of total
Base	Destination(s)		
home	workplace only	1760	15.1
home	workplace and intermediate destination(s)	315	2.7
home	one non-work destination	7790	66.7
home	multiple non-work destinations	1605	13.7
work	one non-home destination	173	1.5
work	multiple non-home destinations	31	0.3
Total		11674	100.0%

this topic, other than that going to work and school are usually more important to travellers than other destinations visited along the way. A preferable approach for identifying the primary destination is to infer the relative importance of destinations from each individual's behavior. The use of time spent at an activity is one such measure of importance and the only convenient measure available in the Zuidvleugel data. The strategy adopted for this study was a modified activity time criterion in which work destinations take precedence over all others.

Recognizing a priori the dominance of working as an activity, and with our wish to model work-based tours, the primary destination was chosen as that destination highest on the following ranking:

(1) usual (fixed) workplace;

(2) other work-related destination;

(3) the non-work destination with the longest activity time.

Implications of the activity time criterion for ranking destinations is shown in Table 2, which presents the average activity time and distance from home for each type of primary destination chosen. The average activity time spent and the average distance from home was far higher at work-related destinations than at any other type of destination, suggesting that the chosen strategy of workplace precedence would seldom yield a different primary destination than that identified by either activity time or distance criteria. Shopping destinations, which had the shortest average activity time, also had the shortest average tour length. Education destinations, however,

Table 2

Mean Activity Time and Round-Trip Distance by Primary Destination Type (Home-Based Tours)

Primary Destination Type	Avg. Activity Time (hrs:min)	Avg. Round-Trip Distance (km)	% of Total Tours
Usual Workplace	6:32	12.9	18.1
Other Work Destination	4:23	35.8	3.1
Shopping	0:40	3.4	17.9
Education	3:34	3.9	24.4
Social Visiting	2:15	8.6	11.0
Recreation	1:26	4.7	9.3
Personal Business	0:50	5.7	3.3
Serve Passenger	0:16	3.5	4.7
Other	1:13	6.9	8.2
All Home-Based Tours	2:50	7.2	100.0

had one of the longest average activity times, but also one of the shortest average tour distances. On intuitive grounds, the activity time criterion appears to yield a ranking of destinations that is more reasonable than that of distance from the home.

4. Differences Between Primary and Secondary Destinations

Most tours have only a single destination. In addition, as in most travel surveys, the Zuidvleugel survey gave instructions to respondents to omit incidental stops for car refuelling, picking up a newspaper, etc. For the data used in this study, 83 percent of the home-based tours had one non-home destination, 9 percent had two destinations and 7 percent had three or more destinations. Since the primary destination approach to tour modelling focusses on the attributes of primary destinations in characterizing tours, it is important to understand the extent to which the specification and travel characteristics of primary destinations differs from those of secondary destinations. Tables 3 and 4 here compare the purpose and mode characteristics for the primary and secondary destinations of all multiple-destination (home-based) tours. Table 4 displays the mode used to the primary destination and to the secondary destination. In fact, very little mode switching was observed between outbound and return trips: more than 96 percent used the same mode both ways.

Table 3

Primary Destination Purpose by Secondary Destination Purpose

MULTIPLE-DESTINATION HOME-BASED TOURS

* * * * * * * * * * * * * * * * C R O S S T A B U L A T I O N O F * * * * * * * * * * * * * * *
SDPURPC PURPOSE AT SEC DEST BY PDPURPC PURPOSE AT PRIM DEST
* *

SDPURPC	PDPURPC: COUNT / COL PCT / TOT PCT	USUAL WORKPLAC 1.	OTHER WORKDEST 2.	SHOPPING 3.	EDUC 4.	SOCIAL VISITING 5.	RECREATION 6.	PERS BUSINESS 7.	SERVE PASS 8.	ROW TOTAL
2. OTHER WORKDEST	COUNT	103	102	0	0	0	0	0	0	205
	COL PCT	32.7	78.5	.0	.0	.0	.0	.0	.0	13.0
	TOT PCT	6.5	6.5	.0	.0	.0	.0	.0	.0	
3. SHOPPING	COUNT	56	10	192	33	141	23	22	11	488
	COL PCT	17.8	7.7	55.3	11.3	49.8	25.3	32.8	21.6	30.9
	TOT PCT	3.6	.6	12.2	2.1	8.9	1.5	1.4	.7	
4. EDUC	COUNT	9	1	7	141	5	5	1	0	169
	COL PCT	2.9	.8	2.0	48.1	1.8	5.5	1.5	.0	10.7
	TOT PCT	.6	.1	.4	8.9	.3	.3	.1	.0	
5. SOCIAL VISITING	COUNT	35	3	49	59	77	23	5	5	256
	COL PCT	11.1	2.3	14.1	20.1	27.2	25.3	7.5	9.8	16.2
	TOT PCT	2.2	.2	3.1	3.7	4.9	1.5	.3	.3	
6. RECREATION	COUNT	22	0	11	43	13	19	3	1	112
	COL PCT	7.0	.0	3.2	14.7	4.6	20.9	4.5	2.0	7.1
	TOT PCT	1.4	.0	.7	2.7	.8	1.2	.2	.1	
7. PERS BUSINESS	COUNT	35	4	33	4	24	10	26	2	138
	COL PCT	11.1	3.1	9.5	1.4	8.5	11.0	38.8	3.9	8.8
	TOT PCT	2.2	.3	2.1	.3	1.5	.6	1.6	.1	
8. SERVE PASS	COUNT	55	10	55	13	23	11	10	32	209
	COL PCT	17.5	7.7	15.9	4.4	8.1	12.1	14.9	62.7	13.3
	TOT PCT	3.5	.6	3.5	.8	1.5	.7	.6	2.0	
COLUMN TOTAL		315	130	347	293	283	91	67	51	1577
		20.0	8.2	22.0	18.6	17.9	5.8	4.2	3.2	100.0

Table 4

Primary Destination Mode by Secondary Destination Mode

CROSSTABULATION OF MODESDC MAIN MODE TO SEC DEST BY MODEPDC MAIN MODE TO PRIM DEST

MODESDC	MODEPDC	1. TRAIN & METRO	2. BUS-TRAM	3. CARDRIVE	4. CAR-PASS	5. BICYCLE	6. MOPED	7. WALK	8. OTHER	ROW TOTAL
1. TRAIN & METRO	COUNT	8	8	0	4	1	0	3	0	24
	COL PCT	17.8	11.0	.0	2.0	.2	.0	.7	.0	1.3
	TOT PCT	.4	.4	.0	.2	.1	.0	.2	.0	
2. BUS-TRAM	COUNT	8	26	0	2	2	0	25	2	65
	COL PCT	17.8	35.6	.0	1.0	.4	.0	6.0	4.4	3.4
	TOT PCT	.4	1.4	.0	.1	.1	.0	1.3	.1	
3. CARDRIVE	COUNT	0	1	596	7	2	0	17	3	626
	COL PCT	.0	1.4	94.9	3.5	.4	.0	4.1	6.7	32.6
	TOT PCT	.0	.1	31.0	.4	.1	.0	.9	.2	
4. CAR-PASS	COUNT	2	6	11	155	5	1	18	2	200
	COL PCT	4.4	8.2	1.8	77.5	1.1	1.9	4.3	4.4	10.4
	TOT PCT	.1	.3	.6	8.1	.3	.1	.9	.1	
5. BICYCLE	COUNT	7	0	2	4	410	1	30	4	458
	COL PCT	15.6	.0	.3	2.0	88.9	1.9	7.2	8.9	23.9
	TOT PCT	.4	.0	.1	.2	21.4	.1	1.6	.2	
6. MOPED	COUNT	0	0	0	0	1	48	4	0	53
	COL PCT	.0	.0	.0	.0	.2	88.9	1.0	.0	2.8
	TOT PCT	.0	.0	.0	.0	.1	2.5	.2	.0	
7. WALK	COUNT	19	32	18	28	38	4	308	3	450
	COL PCT	42.2	43.8	2.9	14.0	8.2	7.4	74.4	6.7	23.4
	TOT PCT	1.0	1.7	.9	1.5	2.0	.2	16.0	.2	
8. OTHER	COUNT	1	0	1	0	2	0	9	31	44
	COL PCT	2.2	.0	.2	.0	.4	.0	2.2	68.9	2.3
	TOT PCT	.1	.0	.1	.0	.1	.0	.5	1.6	
COLUMN TOTAL	COUNT	45	73	628	200	461	54	414	45	1920
	COL PCT	2.3	3.8	32.7	10.4	24.0	2.8	21.6	2.3	100.0

It is evident from Table 3 that the distribution of purposes for secondary destinations was very different from that for primary destinations, and that a majority of the multiple-destination tours involved different purposes for the two destinations. Much of this is a result of the rules for identifying primary destinations. By definition, a person can have only one "usual workplace," and that location will always be a primary destination. Education locations are overwhelmingly primary destinations. Shopping destinations, on the other hand, are more likely to be secondary destinations than primary ones. These differences between purposes at the primary and secondary destinations are consistent with the behavioral theory underlying the definition of the primary destination.

Unlike destination purpose, where differences between primary and secondary destinations are substantial, we see from Table 4 that there was relatively little difference in mode choice between primary and secondary destinations. Over 82 percent of the multiple-destination tours involved the same mode to both destinations. Three-quarters of the cases of mode switching were switches to or from the walk mode. The most frequent switch was between public transit and walk. Although differences were not large, public transit was more often used for the primary destination, while walk was more often used for the secondary destination. Since mode choice was not a direct factor in the identification of primary destinations, it is not surprising to see that a few tours involved walking to the "primary" destination and

automobile travel to the "secondary" destination. In general, however, mode choice to primary and secondary destinations was sufficiently stable that there is no appreciable bias from the use of primary destination mode as representative of overall mode choice for tours.

5. Alternative Representations of Tours

It is the basis of the primary destination tour approach that travel be modelled in terms of tours to a primary destination, but the option is left open of either ignoring some or all of the other destinations or modelling additional travel to them conditional on the primary destination. The exclusion of non-primary destinations has the advantage of eliminating stops that are incidental to the journey, but at the risk of also missing stops that represent significant influences on the journey. A possible measure of the importance of such stops is the relative contribution of the non-primary destinations to overall travel distances; this measure is obviously of particular importance in reflecting the forecasting accuracy of a model omitting secondary destinations.

The strategy of representing all travel in terms of simple tours to a primary destination, and ignoring all other tour destinations, is here referred to as the "single-destination representation." The alternative option of recognizing a primary and a secondary destination for each complex tour, but ignoring any tertiary destinations, is here referred to as the "two-destination representation" of tours. It

is natural to define the secondary destination, when more than two are visited, as the destination second highest in the ranking of Section 3.

The single-destination representation is an exact representation for all single destination tours, but only approximates travel for tours that involved multiple destinations. For those tours, it is an accurate approximation of the tour distance and route only if the non-primary destinations are all located along the direct path between the base and the primary destination. For tours where this condition is not met, the single-destination representation will underestimate the true length of travel.

Among home-based tours for which all the destination locations were known, the single-destination representation led to an estimate of the round-trip tour distance that was an average of 5.1 percent shorter than the true tour distance (assuming uniform circuity). While the magnitude of this "lost travel" may appear small, it was concentrated on a small number of tours. About 17 percent of the home-based tours involved multiple destinations, and the average length underestimation for those tours was 30 percent of the true tour length.

Multiple-destination tours are an important category of tours whose incidence is correlated with destination purposes, mode choices, and tour length. The average tour length difference between the single-destination representation and the true tour length for all home-based tours was positively related to the true length of the

tour, rising from under 5 percent for tours shorter than 4 km to over 13 percent for tours longer than 60 km. This relationship was, however, largely due to the fact that the proportion of tours involving multiple destinations (i.e., deviations from a simple round-trip journey) was also positively related to tour length. Among multiple-destination tours the tour length difference remained around the 30 percent range for all classes of tour length.

The length difference between the single-destination representation and the true tour length was also systematically related to mode, being greatest for auto/driver and auto/passenger tours (8 and 6 percent, respectively) and lowest for tours by train or public transit (2 and 3 percent, respectively). Additional stops and distance deviations are, of course, more easily accomplished by the automobile than by fixed-route public transportation. Of particular interest is that the proportional deviation from the direct, single-destination tour length was also significantly less for walk, bicycle and moped travel (3.9, 4.5, and 4.0 percent, respectively) than for auto travel.

Among categories of travel purpose, the most serious underestimation of tour length for the single-destination representation occurred for the small but important group of tours to non-fixed work destinations. Members of sales and service occupations may visit a number of destinations during a given day, none of which would be classified as the usual place of employment. The average length difference for such tours to non-fixed work destinations was over

12 percent, which contrasts sharply with the 3 to 7 percent length difference for all other tour purposes. Among the other groups, there was a smaller tour length differential for education and recreation tours than for others, largely because fewer of those tours involved multiple destinations.

The addition of information about secondary destinations can only improve the representation of tours. The essential questions are whether or not this improvement in the representation of travel is sufficiently great to justify the increased model complexity that it requires and whether the resulting representation of travel is sufficiently good to avoid the need for incorporating further (tertiary, etc.) destinations in the model. The two-destination representation is, of course, not relevant for the majority of tours that involved only one destination, and is a perfect description for the 9 percent of tours that involved exactly two destinations. It is an inexact description only for the 7 percent of tours that involved three or more destinations. For this last group, the two-destination representation yields a tour length averaging 21 percent shorter than the true tour length. That group accounts for a small proportion of all home-based tours, however, so the overall difference in tour length between the two-destination representation and the true tour length averages only 1.76 percent. This is a substantial improvement over the 5.05 percent average difference for the single-destination representation of tours.

Table 5 summarizes destination and distance differences for the single-destination and the two-destination representations of tours. In addition to this "lost distance" measure of the extent to which the one- or two-destination representations capture the essential features of travel, we need also to consider the extent to which the omission of destinations might detract from the value of the model. Both strategies for representing tours omit some travel destinations, but this is not necessarily a bad feature. The destinations omitted are those at which the least amount of time were spent, and should tend to be the least important for determining travel characteristics. In fact, the omission of "incidental" stops could significantly improve the explanatory power of travel models. In the very narrow sense that traditional analysis of travel surveys count each destination as a separate trip, it is also true that the omission of destinations implies a lower trip count. This again is of no concern, insofar as the tour approach connects multiple trips into single tours, and the omission of intermediate stops along a tour does not necessarily miss any of the travel route or distance. The important issue for the evaluation of these alternative strategies for viewing tours is the extent to which secondary and tertiary destinations do, in fact, represent significant influences on travel, which are lost by adoption of the single-destination or the two-destination representation of tours.

Table 5

Summary of the Single-Destination and Two-Destination Representation of Tours

	single-destination representation	two-destination representation
% of total destinations omitted	26%	13%
% of tours with some destinations omitted	17%	7%
mean % of tour length omitted		
- all tours	5%	2%
- automobile tours	7%	2%
% of total vehicle-kilometers lost		
- all tours	7%	1%
- automobile tours	10%	4%

6. Implications for Modelling

Thus far, we have defined an approach to the analysis of travellers' behavior that yields some interesting insights and, we have suggested, can be used to focus on the essential motivations of travel. We believe it is clear that this approach is more constructive and systematic than the traditional approaches for analysis of "home-based" and "non-home-based" trips. The question we now take up is the extent to which this approach can be made operational: this is discussed in the framework of disaggregate demand models, and in comparison to the more typical trip approach.

The Zuidvleugel study, from which the examples thus far have been taken, aims to set up an extensive system of demand models, applying disaggregate techniques to this end (Daly, 1978). This framework will incorporate models of frequency, time of day, destination, and mode choice. We consider the implications for each of these models in turn.

Frequency

At first sight, the modelling of tour frequency seems little different from that of trip frequency, and there is, in fact, no reason why the same procedures should not be applied. If we consider the issue more deeply, however, we can expect first that better results should be obtained with a primary destination tour approach, and second, that improved procedures are more easily applied.

We can expect better results from the tour approach because we expect the purpose of the tour to be more closely related to the traveller's true purpose than that of a trip. For example, in our tour-based model, journeys to work are always clearly identified, whereas a traveller making a detour to or from work will make fewer than two home-based work trips in the day, thus introducing unnecessary noise into the otherwise stable work trip frequency rate.

A further possibility, which relates mainly to work and school travel, is to improve the stability of tour rates by classifying lunchtime returns to home as work- or school-based tours. Most people in any case made no more than one work or school tour in the day (85 percent for work, 60 percent for school, of those making at least one tour). If lunchtime tours are removed, these figures become much higher (93 percent and 91 percent, respectively).

It is also reasonable to argue that the definition of primary destinations will increase the proportion of travel purposes whose frequency can be modelled more accurately (e.g., work) at the expense rate will, therefore, be more accurately represented than the overall of those that give more problems (e.g., shopping). The overall tour trip rate.

So far as modelling "non-home-based" travel is concerned, it is clear that modelling secondary destination frequency for a given purpose conditional on primary destination location and purpose is much more satisfactory than modelling non-home-based trips of un-

certain purpose (is it the origin or destination of the trip that defines its purpose?).

Finally, since each tour contains an average of two and one-third trips, the overall rates for tours are three-sevenths of those for trips. The whole issue of frequency, therefore, focusses strongly on the binary question of whether or not a tour was made, rather than whether 0, 1, 2, 3... trips were made. The possibility of a binary model opens more widely the prospect of escaping from the unsatisfactory continuous frequency models, which obviously do not represent properly the true decision process in the period surveyed. The extent to which this simplification is possible is shown in Table 6, which does, however, indicate a significant number of people making second tours for a particular purpose.

Time of Day

Time of day modelling with the tour approach offers a great advantage over the trip approach in that we can model simultaneously the trip from home and the return trip. This simultaneity is impossible to achieve in any conventional form of trip model. In a tour model it means that we can take advantage of our information about time spent at the destination; trivially, that it is non-negative, but more reasonably that the time is spent there is determined by the activity being undertaken. The magnitude of activity time at the primary destination (as shown in Table 1) determines the relationship between the times of day for travel to

Table 6

Extent of Multiple Tours of the Same Purpose Type

Tour Purpose (Primary Destination)	% of all persons making a tour of this type	Among persons making a tour, % making more than one tour	
		(unadjusted)	(adjusted)*
Usual Workplace	22%	15%	7%
Other Work Destination	22	15	15
Education	24	40	19
Social	14	10	10
Recreation	11	13	13
Personal Business	2	5	5

*Omitting multiple tours caused by lunch trips between work or school and home.

and from that destination, and usually the timing of the entire tour. Work hours, school hours, and store hours all constrain the timing of tours. Work and education tours, in particular, were strongly concentrated in their own peak travel periods, as shown in Table 7.

A further advantage of the tour approach is that it is possible to investigate the order in which primary and secondary destinations are visited. Ultimately, it may be possible to consider the total of activity time and travel time compared with some time budget as an influence on whether or not the traveller has time to visit the secondary destination.

Destination Choice

In principle, destination choice using a tour model should show a small but definite improvement over the use of a trip model, at least for primary tours. This is because a tour model is again able to consider both outward and return trips, therefore obtaining a better measure of separation. Otherwise, there is little difference in the mechanics.

In the case of secondary destinations, however, the tour approach offers a greatly improved basis for modelling. The choice of secondary destination can be modelled conditional on both primary destination and home, with the extent of detours taken as an input variable. As with the non-home-based trip approach, forecasting with such a model presents some problems, which can probably be overcome by the sampling of alternatives (McFadden, 1978) or by some restricting assumptions.

Table 7

Time of Day Distribution of Tours

Tour Purpose (Primary Destination)	% of Tours 1-6am	6-730am	730-9am	9-10am	10am-12N	12N-2pm	2-330pm	330-430pm	430-530pm	530-12M	Total
	(time leaving home)										
Usual Workplace	12	38	29	1	5	11	1	Ø	1	2	100%
Other Work Destination	18	18	32	3	5	15	1	2	1	5	100%
Shopping	Ø	Ø	16	18	18	24	9	8	5	2	100%
Education	Ø	11	55	1	5	24	Ø	Ø	Ø	3	100%
Social Visiting	Ø	1	16	13	7	20	6	6	5	27	100%
Recreation	Ø	2	9	3	5	16	8	11	7	37	100%
Personal Business	1	2	14	10	11	18	9	12	6	18	100%
Serve Passenger	1	2	27	2	20	15	13	4	4	14	100%
	(time leaving the primary destination)										
Usual Workplace	Ø	Ø	2	1	17	6	6	27	27	14	100%
Other Work Destinaition	1	1	4	5	17	13	7	29	13	12	100%
Shopping	0	Ø	7	13	26	17	14	12	9	4	100%
Education	0	0	1	1	43	11	20	9	2	4	100%
Social Visiting	0	0	1	2	18	8	10	12	12	38	100%
Recreation	Ø	1	4	1	7	7	7	13	15	45	100%
Personal Business	0	Ø	7	8	13	16	8	16	11	21	100%
Serve Passenger	Ø	1	25	1	20	15	14	3	5	16	100%

Ø denotes less than 1% but greater than zero

Mode Choice

For mode choice, some potential problems arise, in that tours using different modes to and from the primary destination are difficult to model. In fact, however, since 96.5 percent of the tours used the same mode in both directions, this problem is not severe. Further, because the tour model considers both outward and return trips together, we find again that the model is in principle working with better assumptions. Again, there is little difference in the mechanics of implementing a tour model compared with a trip model.

The modes used to secondary destinations are, as noted above, the same as those used to the primary destination in more than 82 percent of the cases. Naturally, for modes requiring a private vehicle (car driver, bicycle, moped), the rate is much higher at 92 percent, and two-thirds of the switches are to walking. Although there are some problems here, it seems that a fairly simple model will account for nearly all the variations.

7. Conclusions

The approach of classifying all travel into tours appears to be a natural step towards making trip-based travel demand models more realistic. Further, the specification of primary and secondary destinations seems the obvious first steps towards a systematics analysis of tours. We have shown that the results obtained from tabulations are intuitively plausible and of themselves give insignt

into travellers' behaviors. Moreover, we have also shown significant possibilities for simplifying and increasing the accuracy of modelling relative to trip-based approaches.

For forecasting, we suggested that omission of destinations subsequent to the primary or to the secondary might give adequate results. The "lost travel" consequent on these simplifications is quite small, and for many purposes can be ignored.

Considering the implications of a shift from trip to tour-based analysis for the development of models, we found that in nearly every case we could expect better results. Difficulties would arise in the models for secondary destination choice and the choice of modes to reach those destinations, but in each case these difficulties are real ones, concealed by trip modelling and brought to the surface by the tour approach.

We therefore conclude that the tour approach offers excellent prospects for improved modelling, and look forward to its successful exploitation in the continuing Zuidvleugel study.

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