THE STRUCTURE OF SHOPPING TRAVEL

Some Developments of the Trip Generation Model

By R. W. Vickerman and T. A. Barmby*

The development of models in analysis of travel demand has tended to concentrate on decisions governing mode, destination and timing, and to neglect the element of choice in the generation of trips. In particular, the literature has concentrated on the area and transport determinants of trip frequency as part of the overall structure of travel choices (Richards and Ben Akiva, 1975; Domencich and McFadden, 1975). The research reported here was intended to investigate the more basic determinants of trip making by placing travel decisions within the context of decisions relating to the activity for which the travel is undertaken.

The underlying concern of this research is that traditional approaches to the trip generation model, whether by category analysis or by regression methods, have assumed a specific relationship between the main socio-economic determinants, such as income, occupation, age and sex, and trip making; this ignores the relationship between activity and trip generation. In an earlier paper (Robinson and Vickerman, 1976) an attempt was made in the context of shopping travel to demonstrate by use of regression methods the effects on trip generation of locational factors and the availability of transport. It was found possible to demonstrate the significance of such factors in determining variations in levels of trip making by households, but the models estimated demonstrated a weakness in identifying socio-economic determinants of variations. It is therefore necessary to go back to a more basic analysis of the underlying utility formulation of the implied decision model. This highlights the importance of considering variations in the level of activity, in this case shopping expenditure, as an additional dimension of the problem.

From this angle we have a joint decision between a continuous variable, expenditure, and a discrete variable, the number of trips necessary to undertake that

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expenditure. This is a problem with a much wider application than just travel demand models. It enables us also to consider variations in the efficiency of shoppers, which may have important distributional implications if low-income shoppers are making similar numbers of trips to high-income shoppers and thus spending more on the actual cost of acquiring goods.

In the next part of this paper we outline the theoretical considerations of the model. In the third part we discuss the data used, the nature of the implied relationships, and basic empirical approaches to estimation of the model. In the fourth part we consider possible further developments suggested by these results.

THE STRUCTURE OF HOUSEHOLD SHOPPING BEHAVIOUR

Shopping is only one of a set of spatially related decisions about location and travel taken by the household. The National Travel Surveys have shown us (Department of Transport, 1979) that shopping has increased somewhat in relative importance, from 12.7 per cent of all journeys in 1965 to 16.0 per cent in 1972/73 and 16.6 per cent in 1975/76. It is about as important as social purposes as a generator of travel, and only work journeys are more important (though increasingly less so, having fallen from 35.7 per cent in 1965 to 25.7 per cent by 1975/76). This evidence seriously underestimates the amount of shopping activity since it excludes walks of less than one mile, which would cover a high proportion of shopping (though not necessarily so when weighted by expenditure). Translated into average numbers of weekly trips per person, this means an increase from 1.47 in 1965 to 2.20 in 1975/76. If we add in trips made for personal business reasons (very closely related to shopping activity) the increase is from 2.32 to 3.45.

Our first assumption must therefore relate to the extent to which, first, residential location and, secondly, workplace and other activities are interrelated with decisions about shopping, and so whether or not these can be assumed to be given for a given household. Recent evidence from a study of household movement (Vickerman, 1984) suggests that even workplace is a relatively unimportant determinant of short-distance moves. General area amenities such as schools or shops may influence marginally a choice between two otherwise identical houses when a move is being undertaken, but housing is always the main consideration. It thus seems reasonable to assume that residential location is, for most households, independent of variations between households in shopping behaviour. There may be rather greater problems of inter-relationship between shopping patterns and other patterns of activity, as shopping can be the joint product of a range of other activities undertaken on a single trip. Evidence from survey material suggests that 25 per cent of a sample of people with jobs undertake some shopping in their lunch break, and many more do so on their way home from work (Vickerman, 1972). In the survey material used here some 40 per cent of all recorded trips included some other purpose, and of these 45 per cent included personal business, 17 per cent eating or drinking, and 14 per cent social activity.

This demonstrates that serious errors may arise from analysing shopping behaviour in isolation, but it would have been a complex task to incorporate
these additional dimensions at this stage of the analysis. Shopping trips are therefore defined as those on which some shopping was done, regardless of other activity. This is perhaps less serious for the purposes of this paper than it would be if we wished to model either total travel behaviour or the choice of destination.

Given these assumptions about the relationship of shopping to other spatial activity, we can identify three levels of choice relating to shopping. First, we have the determination of the level of expenditure on goods for which shopping is required; secondly, we need to consider the way in which that expenditure is divided into a number of separate trips, each of which has associated with it a cost which is itself determined by the third level of decisions relating to destination, mode of transport, etc. This paper concentrates on the first two of these choices.

A conventional utility-maximising approach to consumer behaviour is normally applied to justify a trip generation relationship of the form

$$T_h = f(p_{ih}, Y_h, s_{ih})$$

(1)

where $T_h$ is the number of trips made by individual $h$ in a given period, $p_{ih}$ is the set of prices of the goods to be bought, $s_{ih}$ is the set of shopping costs for those goods for that individual, and $Y_h$ is the individual’s income. Typically $p_{ih}$ is assumed constant over all individuals in a cross-sectional study. The shopping costs comprise both travel costs $t_{ih}$ and acquisition costs $a_{ih}$ (which cover individuals’ time spent in search and other incidental costs). Again a typical assumption is that $a_{ih}$ is constant, and so only the travel costs enter the decision.

A version of equation (1) was tested in some earlier work (Robinson and Vickerman, 1976). This suggested that variations in accessibility were important as a determinant of trip-making levels (using area approximations to the value of $t_{ih}$), but difficulty was experienced in obtaining significant results for the income variable, and indeed for a range of alternative specifications using socio-economic group variables. There are two possible directions in which it is felt the basic model may require development. First, there is the relationship between trip making and the purposes for which the trips are made — the shopping activity, which is the primary demand relationship emerging from the utility-maximising model and the derived demand for travel which equation (1) represents. Secondly, there is the problem that, though aggregate demand for shopping can be represented as an effectively continuous variable, the division of that total into separate shopping trips implies a transition from continuous to discrete which may blur some of the basic relationships. If we return to the basic formulation of an individual with a utility function over goods, he will face a shopping budget constraint (that is, the money available after meeting non-shopping expenses such as housing, fuel, etc., out of income) of the form

$$B_{hk} = \sum_{i=1}^{m} (p_{ih} + t_{ih} + a_{ih}) X_{ih}$$

(2)
where individual \( h \), living in location \( k \), buys quantity \( X_{ih} \) of good \( i \) at price \( p_{ih} \). He faces unit travel costs of \( t_{ihk} \) and acquisition costs of \( a_{ih} \). Using the dual relationship, we can derive an expenditure function on goods of the form

\[
E_h = \sum_{i=1}^{m} p_{ih} X_{ih} = f^{t}(B_{hk}, p_{1h}, \ldots, p_{mh}, t_{1hk}, \ldots, t_{mhk}, a_{1h}, \ldots, a_{mh})
\] (3)

Thus the flow of shopping expenditure created by an individual or household depends on the size of his budget, the range of prices faced, the travel costs incurred in buying the goods, and the acquisition costs. However, the individual can choose how to divide that total expenditure into shopping trips in any given period. We could then proceed to define the level of trip making as the result of a constrained planning process whereby the individual undertakes the minimum number of trips that will still enable him to achieve the desired level of expenditure and be consistent with the budget constraint. Thus we have a derived demand for trip making of the form

\[
T_{hk} = g(E_h, t_{1hk}, \ldots, t_{mhk}, c_h)
\] (4)

This formulation, however, does pose a number of problems.

First, we have assumed that we can relate an identifiable travel cost, \( t_{ihk} \), to the consumption of the \( i \)th good, \( X_{ih} \). This ignores the fact that most shopping activity aggregates expenditure so that the \( t_{ihk} \) are common costs to a wide range of goods. If we could assume that only goods of a similar type were purchased on any given trip, then it would be possible to group expenditures by using information on elasticities of substitution between goods. To some extent there is evidence that different groups of goods do come from different destinations. The survey used in this study showed that local shops were the destination of 55 per cent of trips for food purchases, but only of 16 per cent of trips for clothing and footwear and 10 per cent for furniture and fittings. This suggests considerable, but far from complete, aggregation of shopping expenditures into multi-good purchase trips. However, the survey also showed that, on average, only 5 per cent of all shopping trips from a given area were made to a destination outside a very limited range of the five nearest centres. This restriction on the usual destinations chosen implies that a fairly consistent estimate of shopping travel costs can be obtained from a fairly limited index of accessibility, without the need to try to identify precise travel costs associated with each good. Since the measures of accessibility can include a weighting for the attraction of each destination, they can also reflect ranges of choice available (see Vickerman, 1974, and Robinson and Vickerman, 1976, for further discussion).

Secondly, we need to consider the efficiency of decisions on shopping trips. There are various aspects to this. If we assume that individuals are making rational and efficient decisions about levels of expenditure in a given time period, it would be logical to assume initially that decisions about trips were also rational and efficient. Since shopping trips have a positive cost attached to them, this would suggest that an optimal strategy would be to minimise shopping trips. As Table 1 shows, except for the lowest income group, there is on average very little variation
in trip making levels between households with different incomes. There are much stronger variations across income groups in the average level of expenditure per trip, reflecting the rise in total expenditure. This would tend to confirm the view that trip levels have a small but significant positive relationship to expenditure. The additional expenditure necessary to generate a marginal trip is typically higher than the average total weekly expenditure, and seems to increase with the level of expenditure and income, suggesting that marginal trips are generally not undertaken lightly. Therefore there does appear to be a need to try to disentangle further the relationship between trips and expenditure. Formally there may be additional constraints on average expenditure per trip for certain people, occasioned both by financial (cash flow) problems and by physical problems: for instance, people may be unable to manage large quantities of goods because they are elderly or need to use public transport, or may be unable to store perishable goods for more than a few days because of the lack of refrigerators and freezers.

Thirdly, there is the question of arranging the sequence of trips and allocating specific expenditure to specific trips. Presumably, a basic assumption on the
rational efficient consumer is that when he decides upon the optimal level of expenditure he decides also the most efficient allocation of that total expenditure to specific trips for the period in question. But even the most rational and efficient consumer may suffer from uncertainty in realising his decisions. Failure to purchase a good at a particular shop at a particular time may mean that he must make an additional trip or revise a later planned trip to cover this unexpected break in his plans. For the less efficient shopper we face the problem that decisions about shopping trips are made on a more frequent basis than decisions about levels of expenditure, and that if more trips are made in a given period, for whatever reason, this leads to an increase in total expenditure because of unplanned purchasing on trips. It is also not clear that a temporal sequence is a true reflection of the order of importance of trips in any period. Many households may make regular, fixed, weekly main shopping trips on a particular day in order, for example, to ensure that a car is available. Subsidiary trips, even unplanned ones, may occur before or after that main planned trip — simply running out of butter on a Tuesday does not mean that a main shopping trip is brought forward from a Friday. This suggests that a better order of trips may be by incidence of expenditure. In our sample the most important trip in terms of expenditure accounted, on average, for over 90 per cent of total expenditure. However, there were clear differences between groups; for example, the proportion fell to about 60 per cent for non-car owners. This also suggests that many marginal trips are worth very little in terms of the expenditure on them, though they may, nevertheless, be essential.

These questions make very difficult the correct formulation of a trip generation model which can be related to the expenditure generation model implied by equation (3). It is possible to specify models which take account of both expenditure and discrete choice — for example, in the context of housing demands and choice of tenure (King, 1980) — but there are various dissimilarities between that case and this, in the number of alternatives and in the non-independence and strict sequence implied when the alternatives are numbers of trips rather than mutually exclusive ways of realising a given level of expenditure. Despite the consistency in average trip making across the sample, the variations in trip making which do occur appear to be an important reflection of a stochastic utility element in the utility function of the individual or household; it is therefore important to include trip making as an element in the utility function, and not just as a minimising constraint on behaviour. This suggests both that equations (3) and (4) should be regarded as determined simultaneously rather than sequentially, and that $T_{hk}$ would also appear as a determinant of $E_h$.

One further question which will affect any attempt to estimate equations (3) and (4) is how to handle the variations between individuals in the $p_{ih}$ and $a_{ih}$ without considerably more detail than we had available on actual prices and payment methods and on variations between goods in the $t_{ihk}$. We have already considered the variations between goods and suggested that some aggregation into general accessibility indices is acceptable. The variation in prices and acquisition costs is more difficult, since we should expect individuals to face very different effective prices because of different opportunities for bulk buying, bulk carrying
and bulk storage, and other possible sources of discrimination such as the availability of credit. However, we would expect these to vary systematically in some way with household income or socio-economic group and with car ownership/availability; so for this model we have to subsume them into the more general explanatory factors.

A final problem which we have ignored so far is the level of observation: individual or household. The basic utility formulation is essentially valid only at the individual level, unless the household has a single dictatorial decision maker. However, individuals make many trips, especially for shopping, on behalf of the household as a whole, and who makes the trip may be decided quite arbitrarily. It was felt better, therefore, to concentrate on total household production of trips and to include household size as an explanatory factor, the coefficient of this variable reflecting any economies of scale involved.

Having established the basic approach and the issues to be resolved, we turn in the next section to some alternative empirical estimates of the models.

EMPIRICAL EVIDENCE OF THE STRUCTURE OF SHOPPING BEHAVIOUR

The data used for empirical investigation in this study were collected as part of an earlier research project on shopping travel (see Robinson and Vickerman, 1976, for details). We had available weekly shopping diaries, collected in 1972, giving full details of purchases, expenditure and travel for a sample of 1,074 households in 25 sample districts in the County of Sussex. Because expenditure data for certain trips were incomplete, and we needed expenditure records for aggregation, this sample reduced to 851 households which could be used for analysis.

The earlier analysis had been confined to the estimation of simple trip generation equations, and the information on expenditure had not been used. Three versions of a basic model had been tried (all with \( T_h \) as the dependent variable). A pure generation model included only household factors; a location specified model included in addition dummy variables indicating whether the household lived in an urban area, a semi-urban developed rural area, or a totally rural area or small village; and an attraction and accessibility specified model replaced these dummy variables with more sophisticated aggregate measures of location of shops and the quality of the associated transport facilities. The two main features which emerged from the results of these models were the importance of household size as the dominating household variable and the significance of the locational variables as proxies for shopping costs; these improved the overall performance of the models. Typically the best results were obtained from the attraction and accessibility specified model, and this specification is used for ease of comparison throughout this paper.

The initial test of the model described in the previous section was to produce an 'expenditure generation model' for direct comparison with the earlier trip generation model, using the same set of explanatory variables. Essentially this meant estimating equation (3) with \( E_h \) and \( T_h \) as alternative dependent variables. It should be noted here that, as in the previous model, expenditure comprises
just expenditure on goods purchased on the trip, excluding any travel or acquisition costs and excluding any expenditure on goods not requiring a shopping journey (for example, goods bought through mail order). These results are presented in equations (a) and (b) of Table 2. Not surprisingly, given the rather greater variations in total expenditure than in trip making, the results for the expenditure equation are rather poorer in terms of overall fit. Nevertheless, the relative importance of certain variables did show some interesting changes: car ownership became more important, and to a lesser extent income also, and household size relatively less important. The shopping attraction and accessibility variables became less significant, particularly the index of travel costs. The next step was to try to separate the trip and expenditure equations in the way suggested by equations (3) and (4). The insignificant variables in equations (a) and (b) in Table 2 were dropped; the results are given in equations (c) to (e) in Table 2. The addition of expenditure improved the trip generation equation (c) and also marginally improved the significance of the income variable, highlighting the rather low association between income and shopping expenditure. The zero-order correlation between these two variables is as low as 0.19, suggesting that, despite the evidence in Table 1 for variations between groups, there is little systematic variation within those groups and between individual households with different incomes. Income is more likely to have an independent influence on trip making through variations in non-recurrent shopping expenditures such as that on housing (and thus on residential location) and on household durable goods such as refrigerators, freezers and telephones (which make cheaper searches possible) and by making shopping cheaper through variations in the prices and acquisition costs discussed above. The coefficients of the attraction and accessibility variables also changed very little, demonstrating that these too had little influence on expenditure; that is, location appears not to play an important role in determining expenditure levels. Turning to the expenditure generation equations, we estimated two, equations (d) and (e), the latter being a move towards a recursive explanation and including the level of trip making as an independent variable. This did lead to some improvement in the overall performance of the equation, but again without greatly disturbing the values or significance of other variables. The precise relationship between the level of expenditure and trip making is thus far from clear from these estimates — certainly there is a positive association, and it is largely independent of income or location. This would reinforce the view expressed in the previous section that the determination of E and T is a simultaneous rather than an independent exercise. Thus the versions of the model embodied in equations (c) and (e) in Table 2 were re-estimated simultaneously, using two and three stage generalised least squares. These results for two and three stage estimations are presented in equations (a) to (d) in Table 3. The main problem with this simultaneous estimation is that, because of the relatively poor overall level of explanation of the equations, when T and E are both made endogenous they lose significance. The effects of the exogenous variables are virtually unchanged in size of coefficient, except for some loss of significance of the income variable in the trip equations. Broadly similar results were obtained for other specifications of the model; for example, equations (e)
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R. W. Vickerman and T. A. Barmby

TABLE 2

Single Equation Trip and Expenditure Generation Models

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<tr>
<th>Equation</th>
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Figures in parentheses are t-statistics.

Variables:
- \( T \) = Total household shopping trips in diary week
- \( E \) = Total expenditure on goods on shopping trips in week
- \( C \) = Number of cars owned or available for use
- \( N \) = Number of persons in household
- \( Y \) = Total household income
- \( SA \) = Shopping attraction index (weighted sum for \( n \) nearest centres, \( n \) varies so as to include 95% of all trips from that area)
- \( SC \) = Shopping travel cost index (weighted sum of travel costs to same \( n \) centres)
and (f) in Table 3 omit the recursion of $T$ into the $E$ equation.

These results would suggest that, though there are strong links between trip making decisions and expenditure levels, they are largely independent or recursive ones. Expenditure is principally determined by factors outside our model; income has only a small role to play, and location/accessibility factors virtually none. It is interesting that car ownership is a much more important determinant of expenditure than it is of trip making; this suggests that its role may be rather to make shopping more efficient by increasing expenditure per trip than to induce any great variation in the level of trip making. Car ownership may also reflect other variations in socio-economic status better than household income. On the other hand, it is interesting to note that household size affects trip making more than the level of expenditure, but that there are obvious economies in trip making in large households, since the elasticity of trip making with respect to changes in household size is only of the order of 0.11 at the means.

Locational factors, both the level of provision of shops in the locality and their accessibility, are the most important determinants of variations in trip making, with elasticities of 0.21 and $-0.27$ at the means respectively. People with access to a better range of facilities do appear to spend more in total, but the effect is of little significance.

We are therefore of the opinion that trip generation equations can be modelled without taking an expenditure relationship into account simultaneously, but that it is important to incorporate expenditure as an explanatory variable, recognising that such a key determinant of travel behaviour as car ownership is an important determinant of the level of expenditure. We are left, however, with the difficulty that decisions on trip making are largely discrete ones, to which the method of regression analysis may not be the most appropriate estimational technique. We shall turn in the next section to consider the basis of an alternative approach which may avoid this problem.

A number of questions on aggregation arise from this examination of the structure of shopping behaviour. We have considered all shopping travel, regardless of destination or type of purchase. The sample sizes available in particular locations, or for purchases of particular goods or types of goods other than foodstuffs, rendered any disaggregation on these lines impossible. Also, there might be some problem of zero trip bias for the disaggregate groups (see Vickerman and Barmby, 1983, for a further discussion of this problem). Secondly, we have problems of aggregation over groups of households with very different travel behaviour and response patterns.

We also recognise the need to overcome some problems caused by observations with either low trip or low expenditure generation, or both. We need to recognise further explanations for these, in addition to those based on socio-economic factors and travel cost. Any diary period may exclude some household who shop less frequently or make only marginal purchases in the period covered (one week here). Furthermore, it is possible to buy goods without shopping trips as defined here: for example, through travelling shops or mail order. Since we only recorded expenditure during shopping trips this may also upset the relationships here. We have considered the implications of these biases in more detail elsewhere (Vickerman and Barmby, 1983).
### TABLE 3

*Simultaneous Estimation of Generation Models*

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Figures in parentheses are $t$-statistics

Variables are as in Table 2

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**FURTHER DEVELOPMENTS**

The model developed and estimated here cannot be regarded as a totally satisfactory explanation of shopping trip behaviour; but it has pointed out some important limitations of more conventional approaches, and offers some illustration of the complexity of the relationships involved in this area of decision making. We have restricted the empirical analysis in this paper to the use of least
squares regression techniques, because they are familiar, but it is clear that the
discrete nature of the choices involved in decisions on numbers of trips does pose
certain estimational problems. However, as we have also seen, the complexity of
the way in which trips can be ordered and the rather different ways in which their
significance could be assessed in relation to a utility-maximising hypothesis would
also pose problems for a simple model of discrete choice between well defined,
mutually exclusive alternatives. This is clearly an area in which further develop-
ments are needed (see Vickerman and Barmby, 1983, for an attempt to solve
some of these problems).

The investigations of both the independent single equation models and the
simultaneous equation models do reveal something of the complexity of the inter-
relationships between choices on expenditure and on trip levels. In particular,
there are clear indications that car ownership operates on expenditure levels more
than on trip levels, indicating economies of scale in purchasing, and that house-
hold size operates more on trip making, demonstrating the potential economies
of scale there. There remains some difficulty in interpreting the results for the
effects of income, because there is an apparently inconsistent relationship
between income and expenditure generation. The results here do, however,
explain some of the problems encountered in conventional formulations of trip
generation. On the other hand, there is some clarification of the role of attraction
and accessibility factors. These influence both expenditure levels and trip making,
showing that improved shopping facilities within easy reach may have an effect on
total spending. Only travel costs affect trip making consistently. It appears that
there is little trade-off between travel and non-travel expenditures, and the sign
indicates a very significant tendency to save travel costs by reducing shopping
trips as costs increase.

In all these explanations, however, we have a feeling that the level of aggrega-
tion over all shopping activity is hiding some relatively important aspects of the
composition of expenditures on different goods on different journeys, and the
relationship between shopping and other activities. These points could not be
considered with a sample of this size, and indeed it must be doubted whether even
increased sample sizes would be able to solve the problem of disaggregated ex-
penditures. Much more thought will also need to be given to the underlying
behavioural model to accommodate such information. There is, however, enough
evidence in the results reported here to counter the view that the level of activity
is completely independent of the spatial and transport environment, and that trip
demands can therefore be treated as purely derived demands.

For transport and retail planning also there are some lessons to be learned from
this. Accessibility and attraction do play key roles. The data on which this study
was based were collected before the rapid rise in fuel prices and before the con-
siderable increases in one-stop out-of-town shopping which occurred in the mid-
1970s. It is interesting to note, however, that rising incomes did not affect the
level of trip making as much as increases in expenditure, and, since expenditure
on goods for which regular shopping is undertaken tends to be less income
elastic than other expenditures, we would not expect the net situation to have
changed markedly over the past decade. We have treated all trips as equal here,
regardless of destination; a further stage of development will need to incorporate
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elements of choice of destination. A wide range of potential destinations was available in this sample, because of the need to capture wide variations in access costs; this makes our data set unsuitable for looking at the precise elements of destination choice in the context of an expenditure and trip generation model.

REFERENCES


