LONG DISTANCE DAY TRIPPING
IN GREAT BRITAIN

By S. L. Edwards and S. J. Dennis*

1. Little is known of the number and distribution of long-distance trips for recreation purposes in Great Britain. Yet the Department of the Environment, the Countryside Commission, the National Parks Authorities and many local planning authorities are influenced in their policies towards stretches of countryside, historic towns and ancient monuments by the existing and potential level of demand for day trips to these places from, mainly, urban agglomerations. Existing demand and its variation by time of year and over a period of years can be measured by on-site surveys; but in the assessment of potential demand, with which policies are usually concerned, information is also required about the generation end of the trip. Only thus can be calculated the effects of population change, better communications, increasing leisure time, changing living standards and levels of car ownership, which are some of the determinants of demand on areas of recreation.

2. The purpose of this paper is mainly to examine long-distance recreational trips, i.e. those of more than 25 miles each way. Reference is also made to shorter distance trips where this is relevant or unavoidable. Existing sources of data on day tripping are investigated and the information they give extracted. This is then used first to build up the national pattern of long-distance day tripping: average journey length, mode of transport, number of trips made per annum, etc. and the influence of such variables as car ownership, income and age on the propensity to make a day trip. Second, though it is not possible to examine recreational flows for the whole country, it is possible to do so for the South West Region of England. Models are constructed for various destination areas in that region, from which assessments are made of the effect on day tripping of, on the one hand, road improvements affecting the Region and, on the other, increases in the price of petrol in recent years.

3. Data extracted from the various sources have been restricted to that category of a trip as defined in each source which was nearest to the concept of a day trip for sightseeing purposes. In the National Travel Survey [3] this was the journey purpose category "day trip", defined as "journeys for pleasure purposes within a single day (i.e. no overnight stop) not cadable as social entertainment, etc.".† It applied where the journey itself was the pleasurable activity (e.g. scenic drive) and also to a day trip made "to the coast" or "into the country", etc. Where a person used a horse,

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†The current definition is thus quite different from that used by Vickerman in [1] and [2]; his "recreation" included sport and entertainment, and his "pleasure" included holidaymaking. The narrowing of the definition does mean however that cross elasticities between, e.g., short distance trips for entertainment and longer distance trips for recreational purposes cannot be established in the current work.
boat or aeroplane merely for the pleasure of that activity rather than for a definite journey it was excluded from the survey. In the Mersey/Yorkshire Survey the category taken was "pleasure trip"; and, since the survey was by postal questionnaire and no definitions were included on the form, the interpretation must be that these are journeys not otherwise covered by the purposes which the respondent could choose from, i.e. work, shopping/personal business, to or from holiday or Forces' leave, sport or entertainment, visiting friends or relatives, or some "other" purpose which had to be specified. The definition is looser than in the National Travel Survey, but it is not unreasonable to suppose the bulk would fall into the equivalent category chosen from the N.T.S. In the South West Survey, which was a roadside origin and destination survey, the trip purpose chosen was "a trip between place of recreation and permanent home" by non-holidaymakers. This is an even looser definition of day tripping than that adopted in the Merseyside/Yorkshire Survey, since social, entertainment and sporting trips could have been included. However, evidence from the National Travel Survey shows that the bulk (over 80%) of the latter types of trips are of very short distance (not more than ten miles), and as the screen lines in the South West Survey were in the countryside it can be assumed that most trips included would be for the purpose with which this article is concerned.

**SOURCES OF DATA**

4. Apart from ad hoc site surveys, which though useful for yielding information about the demand for particular sites tell little about overall recreational demand, few sources of information are available on long-distance day tripping. The most detailed is the National Travel Survey [3] conducted by the Department of the Environment. Although this is not an ideal source, since it is not reliable in its estimates of numbers of recreational (and holiday) trips, it at least yields acceptable information on the characteristics of recreational tripping. The latest (1973) survey covered some 7,000 households and recorded details of about 800 long-distance day trips.

5. A better source of data will be the DOE's 1974/5 long distance travel survey [4]. This covers some 30,000 individuals aged over 16 in Great Britain and includes information on some 15,000 long-distance trips for various purposes, of which perhaps a third are for recreation. The results of this survey were not available when this paper was written. In the meantime, two further sources are available for restricted geographical areas. These are the long-distance travel survey of the Merseyside/Selnecc and West and South Yorkshire areas, which together constitute a fairly large part of northern England [5], and the information on day tripping contained in the 1970 Transportation Survey of the South West Region [6].

**THE NATIONAL PATTERN**

**Journey length and mode**

6. Perhaps the first lesson to be learnt from the National Travel Survey about recreational trips in general is that the bulk (83%) are short—of under 25 miles each way. Moreover, more than half the longer ones are in the 25-50 mile bracket.

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Thus, relatively few recreational trips are of very long distance. Few are inter-regional, but this may occur when a major urban area in one region lies close to a major recreational area in another, e.g., the Merseyside conurbation and North Wales. But recreational trips are on average longer than shopping trips and journeys to and from work (97% of which are under 25 miles). Hence there is a need for a different approach to modelling from that customarily used for examining shopping and commuting patterns.

7. A high proportion (75%) of recreational trips by rail and long-distance coaches are of over 25 miles. Almost all recreational trips by stage buses and three-quarters of those made by car are under 25 miles (see Table 1). The main means of transport used for recreational trips is a car (strictly, a 3-4 wheeled vehicle), but public transport is used almost as frequently for the very long-distance trips of 100 miles or more. Road public transport had (in 1973) a significantly greater share than rail for trips of 50 to 100 miles, but rail had a greater share than road for trips of 200 miles or more. There would thus seem to be some relation between choice of mode by users and journeys of varying lengths, with greater use of public transport for journeys of over 50 miles; road passenger transport predominates for medium distance trips and rail for very long distance trips. This is much the same pattern as was found in freight transport [7]. (See Table 2).

8. Recreation forms a significant portion (about 1 in 5) of passenger trips made for all purposes between 25 and 100 miles and about 1 in 8 of all trips between 100 and 200 miles. It constitutes about 1 in 5 of rail passenger journeys between 100 and 200 miles, and half of all journeys between 50 and 100 miles by long-distance coaches (see Table 3).

9. Thus far, the discussion has been based on numbers of trips made. To measure use of resources (petrol, road space, rail passenger mileage capacity, etc.) it is more useful to study recreational trip mileage. So expressed, longer distance trips of over

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**Table 1**

Recreational Trips by Journey Length

<table>
<thead>
<tr>
<th></th>
<th>Rail</th>
<th>Bus (A)</th>
<th>Bus (B)</th>
<th>Car</th>
<th>Walk</th>
<th>Other private transport</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25 miles</td>
<td>25</td>
<td>94</td>
<td>27</td>
<td>74</td>
<td>100</td>
<td>97</td>
<td>83</td>
</tr>
<tr>
<td>25 &lt; 50</td>
<td>22</td>
<td>3</td>
<td>27</td>
<td>16</td>
<td>—</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>50 &lt; 100</td>
<td>26</td>
<td>3</td>
<td>34</td>
<td>9</td>
<td>—</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>100 &lt; 200</td>
<td>24</td>
<td>—</td>
<td>11</td>
<td>1</td>
<td>—</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>200 +</td>
<td>3</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Source: National Travel Survey

(A) = London Transport and other stage buses, taxis, hire cars.

(B) = Tour, express and works buses.
## Table 2

<table>
<thead>
<tr>
<th>Length each way</th>
<th>Rail (A)</th>
<th>Bus (B)</th>
<th>Car</th>
<th>Walk</th>
<th>Other private transport</th>
<th>ALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25 miles</td>
<td>6</td>
<td>1</td>
<td>45</td>
<td>41</td>
<td>7</td>
<td>100</td>
</tr>
<tr>
<td>25 &lt; 50</td>
<td>3</td>
<td>1</td>
<td>7</td>
<td>88</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>50 &lt; 100</td>
<td>5</td>
<td>2</td>
<td>14</td>
<td>78</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>100 &lt; 200</td>
<td>20</td>
<td>1</td>
<td>21</td>
<td>53</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>200 +</td>
<td>27</td>
<td>—</td>
<td>18</td>
<td>55</td>
<td>—</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: National Travel Survey

## Table 3

<table>
<thead>
<tr>
<th>Length each way</th>
<th>Rail</th>
<th>Long distance bus</th>
<th>Car</th>
<th>Walk</th>
<th>All modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25 Miles</td>
<td>1</td>
<td>13</td>
<td>3</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>25 &lt; 50*</td>
<td>6</td>
<td>29</td>
<td>19</td>
<td>—</td>
<td>18</td>
</tr>
<tr>
<td>50 &lt; 100</td>
<td>10</td>
<td>51</td>
<td>22</td>
<td>—</td>
<td>23</td>
</tr>
<tr>
<td>100 &lt; 200</td>
<td>18</td>
<td>36</td>
<td>9</td>
<td>—</td>
<td>13</td>
</tr>
<tr>
<td>200 +</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>—</td>
<td>4</td>
</tr>
</tbody>
</table>

* Strictly 30 < 50

Source: National Travel Survey

## Table 4

<table>
<thead>
<tr>
<th>Length each way</th>
<th>Rail</th>
<th>London Transport, other stage buses, taxis</th>
<th>Long distance buses</th>
<th>Car</th>
<th>Other private transport</th>
<th>Walk</th>
<th>All modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25 miles</td>
<td>5</td>
<td>81</td>
<td>6</td>
<td>33</td>
<td>53</td>
<td>100</td>
<td>34</td>
</tr>
<tr>
<td>25 &lt; 50</td>
<td>11</td>
<td>9</td>
<td>19</td>
<td>29</td>
<td>14</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>50 &lt; 100</td>
<td>25</td>
<td>7</td>
<td>48</td>
<td>29</td>
<td>10</td>
<td>—</td>
<td>28</td>
</tr>
<tr>
<td>100 &lt; 200</td>
<td>48</td>
<td>3</td>
<td>23</td>
<td>8</td>
<td>23</td>
<td>—</td>
<td>11</td>
</tr>
<tr>
<td>200 +</td>
<td>11</td>
<td>—</td>
<td>4</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: National Travel Survey

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25 miles account for about two thirds of all recreational trip mileage, but very long-distance ones of over 100 miles are still a small part of the total (13%)—see Table 4. The share of each mode in each distance bracket is about the same as that shown by trips.

**Frequency and distribution**

10. The frequency with which trips are made is low. Ninety-two per cent of the individuals sampled in the Mersey/Yorkshire Study made no long-distance recreational trip in the fortnight over which they recorded their journeys; 7% made one trip, 1% made more than one.

11. The daily and annual distribution of recreational trips by car can be shown over all distances only from the National Travel Survey, but the data can be given in terms of journey mileage, so the information is probably representative of the longer-distance recreational tripping. Sunday is the predominant day for a recreational trip throughout the year, with a share of from 40 to 60% in total weekly recreational trips in most months. Recreational journeys account for about a quarter of all journeys made over all distances on Sundays from March to October. About 15 to 20% of recreational trips are made on Saturdays, and these form about a tenth of total car traffic on Saturdays from March to October. On weekdays it is only in July and August that recreational trips tend to be a significant (about 10%) part in total car traffic. Taking the week as a whole, recreation forms a tenth or more of all journeys by car in the months of May to August and about 5% in March, April, September and October, while its share is negligible from November to February.

12. The Mersey/Yorkshire survey shows that recreational trips are about 45% of long-distance car traffic on Sundays on a year-round basis, which means a higher proportion during the spring and summer. On other days, the share of recreation in total long-distance car traffic is 20 to 30%. Visiting friends and relatives also accounts for 20 to 30% of all long-distance journeys on most days, but it does not have such a marked Sunday peak. The only other journey purposes which account for more than 20% of all long-distance journeys are those connected with work on Mondays to Thursdays and holiday journeys on Saturdays. Thus the relative importance of recreation in long-distance travel is clearly illustrated (see Table 5).

**Occupancy and subsidisation**

13. As one might expect, a car is used to carry more people on a recreational trip (over all distances) than on, say, a journey to work. Vehicle occupancy is four persons or more on over a quarter of recreational trips and two or more on over 80% of them; on over 80% of journey-to-work trips only one person is in the car. The vehicle is subsidised, the driver having tax relief or mileage or other expenses, on about a quarter of trips, compared with about 90% of trips in course of work and about 40% of trips to or from work. Clearly, subsidies affecting fixed costs on a car inescapably subsidise all types of journeys, but it is somewhat strange that allowances related to variable cost are shown to subsidise recreational trips—unless of course such allowances are also ones that fail to discriminate between journey purposes:
Table 5

Long Distance Trips by Purpose

<table>
<thead>
<tr>
<th>Purpose</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pleasure</td>
<td>32</td>
</tr>
<tr>
<td>Visit friends etc.</td>
<td>25</td>
</tr>
<tr>
<td>Sport/entertainment</td>
<td>7</td>
</tr>
<tr>
<td>Holiday/forces leave</td>
<td>14</td>
</tr>
<tr>
<td>Shopping/personal business</td>
<td>6</td>
</tr>
<tr>
<td>Work</td>
<td>14</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td>All</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Mersey/Yorks Survey

e.g. free petrol rather than a mileage allowance, or payment of the cost of servicing and repairs. The incidence of subsidy for recreational trips is however less than for holiday trips, over 40% of which enjoy a subsidy of some form.

Influences on trip generation

14. The Mersey/Yorks survey shows that age (of persons 16 or over) is not an important influence on recreational trip generation, apart from a falling off of trip making by retired people and a tendency for young males (20–24) to make relatively more trips than their numbers in the population would suggest. And, apart from that exception, sex is not an important influence either.2

15. Socio-Economic Group of head of household, however, does influence recreational trip generation. Manual workers and junior non-manual workers undertake fewer trips than would be expected from their share of the population, while intermediate non-manual workers do significantly more trips. This suggests that income (probably more than Socio-Economic Group) is a significant determinant of long-distance trip making, but its influence is probably non-linear (i.e., the number of trips made does not increase progressively with an increase in household or individual income). Moreover, there is probably an overlap of influence with car ownership, so that income affects recreational tripping not directly but indirectly, by increasing the ability to afford a car. The influence of the car is in fact undoubtedly strong, even after allowing for the greater number of households with a car; households with cars make 2 to 3 times as many recreation trips as those without cars. They have an even greater propensity to make trips of over 25 miles (5 times greater than a no-car household), but these are mainly in the 25-50 mile bracket.

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2The findings on the influence of sex must be qualified for the possible effect of the household unit on trip decision making. For example, although males and females make trips in the numbers expected given their respective shares of the population, this may be because the decision for the household is made by the male head of the household.
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Car owners use their cars for 90% of their long-distance recreational trips, while non car owners use a bus on half the journeys made, a car on a third of all trips and rail on just over a tenth.

Numbers of trips
16. Applying grossing factors to the trips picked up in the National Travel Survey yields an estimated 100 million long-distance recreational trips made per annum in Great Britain. However, as indicated earlier, the NTS is not a particularly reliable source of numbers of recreational trips. The Mersey/Yorks survey was more successful in picking up long-distance recreational trips, yielding information on 2,600 trips. Grossing up for the population of the area covered yields an estimate of 13 million. If we assume that the propensity to make a recreational trip is the same in the rest of the country as in the area covered by that survey, we arrive at an estimate of about 80 million recreational trips for the country as a whole.

17. Finally, the South West survey shows the number of recreational trips to the Region and its parts from the rest of the country and from the South West itself. A distance decay function operates; trips per head are significantly higher from areas closest to the South West. For example, trips per head from the northern part of the Region to those parts of the Region at least 25 miles away were some 40 times more numerous than those from Scotland and Northern England. Thus, were it to be assumed that the share of the South West in the total recreational trips made by an area is the same as its share of the holidaymakers from that area, then recreational trip rates (per head) for a given area times the national population times the allowance for the fact that only a proportion of all recreational trips are made to the South West would yield an estimate of total recreational trips nationally. Naturally, the range is wide, varying from 5 million if we use Scotland and Northern England values to 155 million if we use those for the northern part of the South West. The mean, 80 million, is not unlike the estimates shown by alternative sources. It corresponds to an estimated 70 million derived in this fashion for the western part of the Outer South East, perhaps a “typical” area of long-distance recreation trip generation. (It is largely urban, close to the South West, but has alternative sources of recreation both within its boundaries and in adjoining parts of the South East.) The methods used for determining the global figure for long-distance trips for recreational purposes have been rough, but as a broad generalisation it would be fair to say that such trips are about twice as numerous as trips for holiday purposes.

RECREATION DEMANDS ON THE SOUTH WEST

18. The South West has long been recognised as one of Britain’s main tourist regions. Of late, particularly with the recently completed motorways, it has also been thought of as a potential, if not actual, major recreational area serving the needs of Industrial South Wales, the Midlands and the South East. Since much of the argument has been speculative, it was decided to re-analyse the road-side origin and destination data\(^3\) collected in the course of the 1970 South West Road Transportation

\(^3\)Since no socio-economic information has been collected, the approach in this paper is necessarily rather aggregative.
Survey to provide information on numbers of day trips to various recreational areas in the South West from other parts of Britain. Then, having established the (largely pre-motorway) pattern of recreational trips, given the travel cost savings due to the motorways, it would be possible to predict the growth in recreational trips to particular parts of the Region arising from communication improvements. A number of methods could have been used (for example see [8]), but partly as a result of previous work the gravity model was used. In its simplest form this can be expressed as:

$$T_{ij} = Gi Aj f(Cij)$$

where:

- $T_{ij}$ = number of trips from origin $i$ to destination $j$,
- $Gi$ = capacity of origin $i$ for generating trips,
- $Aj$ = attraction factor for destination $j$,
- $Cij$ = "generalised" cost of travel from $i$ to $j$, and
- $f(\cdot)$ = cost deterrence function.

19. The friction to be overcome in travelling between areas ($f(Cij)$) is measured by a generalised cost variable which incorporates elements of time and vehicle operating costs. Values of the cost variable were derived using the following formula:

$$\text{Generalised Cost} = \left[ \frac{\text{Vehicle operating costs per gallon of petrol consumed}}{\text{Gallons of petrol consumed per mile}} \times \text{Average person per car} + \frac{\text{Value of time per hour}}{\text{Travel time in hours}} \times \text{Average miles travelled} \right]$$

20. For modelling purposes account should be taken only of those costs which are perceived, and it is assumed here that non-petrol vehicle operating costs such as oil, tyre wear, repairs, general wear and tear, and so on are not important. The average price of (4 star) petrol during 1970 was 35 pence per gallon. Fuel consumption of 30 miles per gallon is assumed, this being the value implied by AA figures for 1970 relating to cars with engine capacities between 1000 and 1500 cc. The average car occupancy for leisure trips is about 3 persons. Some of these may be children whose influence on the trip-making process may not be commensurate with that of adults. In order to account for this a range of values from 2 to 3 persons per car is assumed. Average overall speeds are likely to vary considerably and are assumed to lie between 30 and 40 miles per hour. No allowance has been made for the possibility that congestion during peak periods may feed back to reduce average speeds and hence increase generalised cost. This factor will be of less importance because recreationists are probably ignorant of potential traffic bottlenecks.

21. The value of time savings on leisure trips is a controversial subject—see [9] [10]. Empirical work suggests that the value attached by travellers to saving leisure time is below the wage rate of the traveller concerned, and a large number of results fall in a range between 20 and 30% of hourly incomes [11]. It therefore seems reasonable to
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adopt the current practice of the Department of the Environment and assume that the value of time savings on leisure trips is 25% of the average hourly wage rate; this implies a figure of about 15 pence per hour per person in 1970.

22. These assumptions about costs lead to generalised costs per hour (per person) in the range of 26 to 37 pence. The matrix of intra-zonal travel times, available from the South West Transportation Survey, was therefore multiplied by 31 to obtain generalised costs (in pence). This implied that the vehicle operating and time costs each accounted for about half the total travel cost.

23. Several possible forms could be chosen for the deterrence function, but the most commonly used are the exponential function and the power function. The latter possesses the disadvantage that its value is extremely sensitive to small changes in costs in the range of lower values. This is particularly undesirable here, since origin and destination areas are of extensive size and there is more scope for error in locating zone centroids. These disadvantages are less acute with the exponential function, and it is therefore that form which is assumed in this paper.

24. The attraction factors \( A_j \) represent the aggregate of the opinions of all day trippers on the inherent recreational value of the corresponding areas. They depend upon such variables as climate, area size, and topography; but, since opinions may differ between individuals, overall relative attraction indices are best estimated by investigating preferences revealed by the trip data\(^4\). The potential of a destination for attracting trips will depend upon how attractive it is and upon the costs incurred in reaching it. A suitable measure is therefore obtained by weighting the attraction factor, \( A_j \), by the deterrence value, \( f(C_{ij}) \), so that:

Recreation potential of destination \( j \) as perceived from origin \( i = S_{ij} = A_j f(C_{ij}) \).

To obtain the total recreation potential perceived from origin \( i \), values for each individual area are summed so that:

Total recreation potential perceived from origin \( i = S_i = \sum_j A_j f(C_{ij}) \)

25. In order to examine more fully the impact of recreation potential upon trip patterns, it is useful to split the trip-making process into two stages; generation and distribution. Then, a competing opportunities interpretation of the distribution mechanism would suggest that the share of a destination in trips from a given origin would be the same as its share of recreation potential, so that:

\[
T_{ij} = T_i \frac{S_{ij}}{S_i} \tag{2}
\]

where \( T_i = \sum_j T_{ij} = \) total trips generated from origin \( i \).

26. The sum of recreation potential may also influence the total number of trips generated. Combining this with some of the other factors mentioned above as important influences on trip generation, a trip generation equation may be written as:

\[
T_i = g (P_i, S_i, V_i) \tag{3}
\]

where, in addition to those symbols already defined,

\(^4\)Attempts have been made to identify various attributes which people find attractive and to combine these in an "objective" composite index—see [12] and [13] for example. The factors included and the relative weights accorded to them are, however, essentially arbitrary. A more fruitful approach might be to relate indices estimated from revealed preferences to a set of area attributes, using an appropriate multivariate technique—see [14] for example.
$Vi =$ vehicle ownership per head at origin $i$,
$Pi =$ population at origin $i$.

A Cobb-Douglas specification for the generation function would seem appropriate, so that (3) becomes:

$$Ti = Pi \cdot S_i^{1+\beta} \cdot Vi^\gamma$$

(4)

where parameters $(1 + \beta)$ and $\gamma$ may be interpreted as trip generation elasticities. No additional parameter is associated with the population variable, since its principal role is one of normalisation. Combining trip distribution and generation equations, the basic model of (1) may be written as:

$$T_{ij} = Pi \cdot Si^\beta \cdot Vi^\gamma \cdot Aj \cdot f(C_{ij})$$

(5)

Any constant of proportionality may be absorbed into the attraction factors, $Aj$. One consequence of this specification is that if the recreational opportunity elasticity is unity, so that, ceteris paribus, trip generation is directly proportional to recreation potential, then the value of $\beta$ is zero and the only trip cost relevant to explaining flows between any pair of areas is the cost of travel between those two areas. Symbolically, for $j \neq k$, \[\delta T_{ij} / \delta C_{ik} = 0 \] if $\beta = 0$.

27. Suppose that stochastic elements enter the model multiplicatively and that the logarithm of the error term follows a normal distribution with zero mean and constant variance. Taking logarithms yields the following equation:

$$rij = aj + \beta \cdot i + \gamma \cdot vi - \delta C_{ij} + U_{ij}$$

(6)

where $rij = \log T_{ij} / Pi$, $aj = \log Aj$, $si = \log Si$, $vi = \log Vi$ and $U_{ij}$ is the error term.

Provided the last is uncorrelated with the explanatory variables, best linear unbiased estimates could normally be obtained by ordinary least squares regression of the logarithm of trips per head on the logarithm of recreational opportunities, the logarithm of cars per head, generalised cost and a set of dummy variables, one for each destination. The estimate for $aj$ would appear as the coefficient of the jth dummy variable, which would consist of ones wherever trips to the jth destination occurred and zeros elsewhere. In this case, however, the recreational opportunity variable, $si$, is not known before the estimation, since it depends partially upon a set of unknown parameters:

$$si = g(C_{i1}, \ldots, C_{in} | A_1, A_2, \ldots, An, \delta)$$

Unknown

28. A method of estimation which attempts to circumvent the difficulty highlighted above is to run an initial regression excluding the recreational opportunity variable. Initial estimates, $\hat{\gamma}_1(1), \ldots, \hat{\gamma}_n(1), \hat{\beta}(1)$ and $\hat{\delta}(1)$, of all parameters except $\beta$ are then obtained, and from these estimates can be obtained of the attraction factors, and then of the recreational opportunity variables. Hence:

$$Aj(1) = \exp [\hat{\gamma}_j(1)] \quad \text{for} \ j = 1, \ldots, n$$

and

The regression would be run without a constant term.
LONG DISTANCE DAY TRIPPING

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\( \hat{s}(1) = \log(\sum_j \hat{A}_j(1) \exp[-\hat{\delta}(1) C_{ij}]) \quad \text{for} \ i = 1, \ldots, m \)

The regression is now re-run, this time with the initial estimates of the recreational opportunity variable included, and a second set of estimates of all the model parameters obtained. Denoting these by \( \hat{\alpha}_1(2), \ldots, \hat{\alpha}_n(2), \hat{\beta}(2), \hat{\gamma}(2) \) and \( \hat{\delta}(2) \), corresponding values for the attraction factors and the recreational opportunity variables can be obtained as above. The process can be repeated until consecutive sets of estimated parameters are arbitrarily close. Since interest centres principally on the relative pattern of attraction factors, as a convenient measure of closeness the correlation coefficient between successive sets of attraction estimates can be used.

29. Using the correlation criterion, the procedure described above converged very rapidly (at step 2) and the estimated value of the deterrence function parameter was \( \hat{\delta} = 0.04404 \) with an estimated standard error (using the usual OLS formulae) of 0.001923. Although this parameter was highly significant (with a t-value of 22.9) neither the \( \beta \) nor the \( \gamma \) estimate was significantly different from zero. This does not imply that car ownership, for instance, is not an important influence upon leisure trip making; it is rather a reflection of the level of aggregation. The result for the \( \beta \)-coefficient would suggest a unitary elasticity of opportunity (at this level of aggregation).

30. As the analytical properties of the estimation procedure were not investigated thoroughly, some simulation experiments were undertaken to ascertain whether or not the method was capable of accepting an hypothesis of non-unitary opportunity elasticity when this was in fact true. Although such an exercise cannot be regarded as anything more than a preliminary back-up for the method, the results were encouraging and cases where the true elasticity was above and below one were detected successfully. In all cases, the deterrence function parameter was estimated with high precision.

31. These results provided some justification for looking at a simplified model with a unitary elasticity of opportunity embodied as an assumption and with no car ownership variable included. With such a simplified structure it is also easier to consider an alternative stochastic specification with additive instead of multiplicative errors. Such a model may be written as:

\[ T_{ij} = P_i A_j \exp(-\delta C_{ij}) + U_{ij} \quad (7) \]

where it is assumed that the error term obeys a normal distribution with zero mean and a variance which is allowed to differ with each origin-destination pair

\[ (i.e. \ U_{ij} \sim N (0, \frac{\sigma^2}{w_{ij}})) \]

32. Given these assumptions, maximum likelihood estimators may be obtained by setting to zero the partial derivatives of the likelihood function with respect to each of the model parameters. A more detailed account of the method of estimation is provided in the technical appendix, while estimated values of the attraction factors for areas in the South West are shown in Table 6. The accompanying map serves to define the various areas to which these estimates refer. In addition to estimates derived from a maximum likelihood procedure, direct least squares (obtained by assuming that the additive errors are homoskedastic) and log-linear regression estimates are presented for comparison purposes.
Table 6
Estimates of Normalised Attraction Factors*

<table>
<thead>
<tr>
<th>Area j</th>
<th>Log-Linear Regression Estimates</th>
<th>Direct least squares estimates</th>
<th>Maximum likelihood † estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.3</td>
<td>10.3</td>
<td>10.4 (1.6)</td>
</tr>
<tr>
<td>2</td>
<td>17.3</td>
<td>16.8</td>
<td>16.9 (1.0)</td>
</tr>
<tr>
<td>3</td>
<td>5.3</td>
<td>9.6</td>
<td>9.1 (0.9)</td>
</tr>
<tr>
<td>4</td>
<td>7.9</td>
<td>7.4</td>
<td>7.0 (1.1)</td>
</tr>
<tr>
<td>5</td>
<td>23.9</td>
<td>20.7</td>
<td>19.8 (1.0)</td>
</tr>
<tr>
<td>6</td>
<td>13.7</td>
<td>16.7</td>
<td>17.5 (1.2)</td>
</tr>
<tr>
<td>7</td>
<td>1.5</td>
<td>0.7</td>
<td>1.1 (0.7)</td>
</tr>
<tr>
<td>8</td>
<td>1.9</td>
<td>2.2</td>
<td>2.2 (0.6)</td>
</tr>
<tr>
<td>9</td>
<td>7.6</td>
<td>10.5</td>
<td>11.0 (0.8)</td>
</tr>
<tr>
<td>10</td>
<td>7.7</td>
<td>5.1</td>
<td>5.0 (0.5)</td>
</tr>
</tbody>
</table>

South West 100.0 100.0 100.0

* All figures have been rounded to one decimal place.
† Figures in brackets indicate estimated standard errors.

APPLICATION OF THE MODEL

Estimating the effect of road improvements and increases in travel cost

33. Estimates obtained from the South West Transportation Study showed that in 1970 nearly 6 million person day-trips were made by persons resident in all parts of England and Wales to areas within the South West Region (excluding Gloucestershire and sections along the Region’s eastern boundary outside the Transportation Study screen line). Residents within the South West also made about 1 million trips for recreational purposes to destinations outside the region. Perhaps the most significant feature of the pattern of recreation day trips was the strong influence of travel costs. Given a uniform spatial distribution of population, the estimated relationships suggested that about 50% of all trips to any destination involved a round trip costing 50 pence per person or less (1970 prices), or in distance terms less than about 30 miles each way. On the same basis round trips costing £1.00 per person or less (i.e. trips of around 60 miles or less each way) accounted for about 85% of total trips. (For particular destinations these proportions will be greater when large concentrations of population are located nearby, and smaller in the converse case). Thus it is not surprising that, apart from recreational areas in the east of the Region, very few (less than 1 million) trips originated from outside the Region.

34. The 1970 pattern can be roughly equated with the pre-motorway situation. Using the model developed above, the effects of particular road improvements that have occurred since then can be taken into account and the post-motorway situation
predicted. The road improvements include the completion of the M4 from London to Bristol, the extension of the M5 from Gloucester to Exeter with the upgrading to motorway standards of the A38 between Exeter and Plymouth, and the completion of the M3 from Kingston-on-Thames to a point just south-west of Basingstoke. Changes in generalised cost arising from motorway extensions can be estimated by referring to the model of generalised cost suggested in para 19. Dividing the generalised cost per hour by average road speed gives a coefficient of generalised cost per mile. Several such coefficients may be distinguished, since average vehicle speeds may vary between different road categories. Total generalised costs may be obtained by multiplying each coefficient by journey distance on the corresponding road type, and then summing over all road categories. A simple version of this approach results if just two road categories are distinguished: motorways and non-motorways. Generalised costs then become a function of the extent of the motorway network, and the impact of new construction upon generalised cost can therefore be assessed.

35. Report 651 of the Transport and Road Research Laboratory suggests that in 1968 average speeds for light vehicles were 58 m.p.h. on motorways and 40 m.p.h. on single two-lane highways. These estimates refer to unrestricted rural roads, so to account for the presence of road junctions and other obstacles, as well as for the likelihood that people drive more slowly on leisure trips, speeds on non-motorways are assumed to lie in a range of 30 to 35 miles per hour. As an example of the magnitude of cost savings implied by these assumptions, if in the initial situation there are no motorways, construction of a motorway over one quarter of the journey distance leads to a small cost saving of about 6%. If the road improvement enables the whole journey to be made on a motorway, however, there may be savings of up to 30%.

36. Applying the model to the 1970 data shows that the effect of road improvements on numbers of day-trippers to the various parts of the region would on the 1970 base have meant an increase of between $\frac{1}{2}$ and 1 million, or 11 to 17%. However, between 1970 and the first quarter of 1975 petrol prices rose by about 120%, from 33-3p to 73-5p, and in real terms (i.e. relative to the general index of retail prices) by about a third. Assuming that all vehicle costs entering into the above model also rose by 33%, this translates into an increase in generalised travel cost of about 16%. The effect of this increase on numbers of day-trippers would, on the 1970 base, mean a reduction of about $\frac{1}{2}$ million, or 30%.

37. The combined effect, therefore, of road improvements and relative increases in travel costs is that in practically every part of the South West the impact of petrol price increases more than outweighs that of motorway improvements, leading to an estimated overall decline in recreational trips of nearly 1 million on the 1970 level, or about 15% on average. The decline varies between the different parts of the region—see Table 7.

**Estimation of net benefits**

38. The model may also be used to estimate net benefits accruing to day trippers. Since there is no market for day trips, it is not immediately clear how such benefits can be measured. One method, first suggested by Clawson [15], is to treat the estimated relation between trips per head and generalised costs as a quasi-demand curve and then to use the Marshallian consumer surplus as a monetary measure of net benefit. Although this method is not without its theoretical shortcomings it is
### Table 7

<table>
<thead>
<tr>
<th>Destination</th>
<th>Estimated Total Trips in 1970 (000)</th>
<th>Estimated Net Reduction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) West Cornwall</td>
<td>260</td>
<td>16</td>
</tr>
<tr>
<td>(2) Mid Cornwall</td>
<td>620</td>
<td>15</td>
</tr>
<tr>
<td>(3) Plymouth/Dartmoor</td>
<td>490</td>
<td>14</td>
</tr>
<tr>
<td>(4) North East Cornwall/North West Devon</td>
<td>190</td>
<td>31</td>
</tr>
<tr>
<td>(5) South Devon</td>
<td>1,330</td>
<td>5</td>
</tr>
<tr>
<td>(6) North Devon/Exmoor</td>
<td>570</td>
<td>21</td>
</tr>
<tr>
<td>(7) Bridgewater/Taunton</td>
<td>80</td>
<td>—</td>
</tr>
<tr>
<td>(8) West Dorset</td>
<td>220</td>
<td>23</td>
</tr>
<tr>
<td>(9) Rest of Dorset excluding Poole/Bournemouth</td>
<td>970</td>
<td>31</td>
</tr>
<tr>
<td>(10) Avon/East Somerset/West Wiltshire</td>
<td>1,030</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>5,760</td>
<td>15</td>
</tr>
</tbody>
</table>

It is thus found that each person derives on average a net benefit of about 45½ pence (in 1970 prices) from each trip, regardless of its origin or destination. (A standard error of nearly 2 pence was estimated for this figure.) That the personal net benefit per trip does not depend either on the trip origin or on its destination is a direct consequence of the (exponential) form chosen for the deterrence function; it would not be true in the case of the power form, for example.

39. An estimate of the total net benefit accruing to all people from day tripping in the South West during 1970 may be obtained by multiplying the personal net benefit per trip by an estimate of total trips. The value thus obtained is about £2¼ million (in 1970 prices), with an estimated standard error of about £200,000. These figures imply that the net benefit derived from the average car day trip (with 3 people per car) was about £1·36. A more formal account of the way in which these figures have been derived is presented in the technical appendix.

---

6For a fuller discussion see [16], [17], [18].
I. A maximum-likelihood procedure for estimating the parameters of the simplified trip model

1. The simplified trip model suggested in para 31 takes the form of an unconstrained gravity model with an additive, heteroskedastic error term:

\[ T_{ij} = P_i A_j \exp(-dC_{ij}) + U_{ij} \]
where \( U_{ij} \sim N(0, \sigma^2_w) \) \hspace{1cm} (1)

Estimates are needed for the attraction factors \((A_j)'s\) and the deterrence parameter, \(d\).

2. Multiplying equation (1) by \(\sqrt{wij}\) transforms the error to the homoskedastic case:

\[ \sqrt{wij} T_{ij} = \sqrt{wij} P_i A_j \exp(-dC_{ij}) + V_{ij} \] \hspace{1cm} (2)
where \( V_{ij} = \sqrt{wij} U_{ij} \), and is normally distributed with zero mean, and constant variance, \(\sigma^2\).

3. Assuming an independent random sample of size \(N\), the log-likelihood function is given as:

\[ \log L = -\frac{N}{2} \log 2 \Pi - \frac{N}{2} \log \sigma^2 - \frac{1}{2\sigma^2} \sum_i \sum_j V_{ij}^2 \] \hspace{1cm} (3)

Maximum likelihood estimating equations may then be obtained by setting to zero the partial derivatives of (3) with respect to each of the parameters. Hence for each of the attraction estimates the following is obtained:

\[ \hat{A}_j = \frac{\sum_i wij T_{ij} P_i \exp(-\hat{d} C_{ij})}{\sum_i wij P_i^2 \exp(-2\hat{d}C_{ij})} \] \hspace{1cm} (4)

Note that if other estimates, \(A_j^*\) and \(d^*\), are available, and if \(\hat{d} = d^*\), then equation (4) may be written as:

\[ \hat{A}_j = A_j^* \frac{wij T_{ij} T_{ij}^*}{\sum_i wij T_{ij}^*} \] \hspace{1cm} (5)
where \( T_{ij}^* = P_i A_j^* \exp(-d^* C_{ij}) \). If it is assumed that a regression of the log of trips per head on generalised cost and a set of 0-1 dummy variables, one for each destination, yields a good estimate of the deterrence parameter, \(\hat{d}\), then equation (5) may be interpreted as a method of modifying the log linear attraction estimates.

4. No direct formula for the estimate of the deterrence function parameter can be obtained; but instead, when \(\frac{\delta \log L}{\delta \hat{d}}\) is set to zero, the following condition results:

\[ \frac{\sum_i \sum_j wij c_{ij} T_{ij} P_i \hat{A}_j \exp(-\hat{d} C_{ij})}{\sum_i \sum_j wij c_{ij} P_i^2 \hat{A}_j^2 \exp(-2\hat{d}C_{ij})} = 1 \] \hspace{1cm} (6)
or, writing \( \hat{T}_{ij} = P_i A_j \exp(-\hat{\delta} C_{ij}) \), which is the maximum likelihood estimator for \( T_{ij} \),

\[
\frac{\sum_i \sum_j w_{ij} C_{ij} \hat{T}_{ij}}{\sum_i \sum_j w_{ij} \hat{T}_{ij}^2} = 1
\]  

(7)

5. The maximum-likelihood estimator for the error variance of the transformed model (2), obtained by setting \( \frac{\partial \log L}{\partial \sigma^2} \) equal to zero, is given by:

\[
\hat{\sigma}^2 = \frac{1}{N} \sum_i \sum_j \hat{V}_{ij}^2 = \frac{1}{N} \sum_i \sum_j w_{ij} (T_{ij} - \hat{T}_{ij})^2
\]  

(8)

6. Asymptotic standard errors may be estimated by applying conventional theory associated with the maximum likelihood technique. If the model parameters are denoted by \( \theta_j = A_j \) for \( j = 1, \ldots, n \), \( \theta_{n+1} = \sigma^2 \) and \( \theta_{n+2} = \delta \) then the inverse of the asymptotic variance-covariance matrix for the parameter estimators may be expressed as:

\[
V(\hat{\theta})^{-1} = \left[ -E \left( \frac{\partial^2 \log L}{\partial \theta_i \partial \theta_j} \right) \right]
\]  

("E" is the expectations operator).

The elements of this (symmetric) matrix are shown below:

\[
\begin{align*}
-E \left( \frac{\partial^2 \log L}{\partial A_j^2} \right) &= \frac{1}{\sigma^2} \sum_i w_{ij} P_i^2 \exp(-2\delta C_{ij}) \quad \text{for } j = 1, \ldots, n \\
-E \left( \frac{\partial^2 \log L}{\partial \delta^2} \right) &= \frac{N}{2\sigma^4} \\
-E \left( \frac{\partial^2 \log L}{\partial A_k \partial \delta A_j} \right) &= \frac{1}{\sigma^2} \sum_i w_{ij} \frac{\partial C_{ij}}{\partial \delta} A_k A_j \exp(-2\delta C_{ij}) \\
\text{and } -E \left( \frac{\partial^2 \log L}{\partial \delta^2} \right) &= \frac{-1}{\sigma} \sum_i w_{ij} \frac{\partial C_{ij}}{\partial \delta} \exp(-2\delta C_{ij}) \quad \text{for } j = 1, \ldots, n
\end{align*}
\]  

(10)

7. The last \( n \) equations of (10) represent the only non-zero off-diagonal elements of the inverse of the full variance-covariance matrix. To simplify matters, the value of the deterrence parameter, \( \delta \), is taken as given (by the estimate obtained from a log-linear regression procedure) so the matrix (reduced by one in dimension) becomes diagonal and is therefore straightforward to invert. The asymptotic variances of the attraction factors (conditional upon the fixed value, \( \delta^* \), assumed for \( \delta \)) may then be obtained as:

\[
V(\hat{A}_j) = \frac{\hat{\sigma}^2}{\sum_i w_{ij} P_i^2 \exp(-2\delta^* C_{ij})}
\]  

(11)

which may also be expressed as:
\[ V(\hat{A}_j) = \frac{\hat{\sigma}^2 \hat{A}_j^2}{\sum_i w_{ij} \hat{T}_{ij}^2} \]  

(12)

if it may be assumed that \( \hat{S} = S \).

8. Each of the origin-destination trip flows, \( T_{ij} \), may be regarded as a sample from a binomial distribution where a “success” is defined as a trip from \( i \) to \( j \) and a “failure” is a trip from \( i \) to some other destination. The total number of trials is given by the sum of all trips emanating from the \( i \)th origin (i.e. \( T_i \)) and the probability of a “success” as postulated by the model is the share of destination \( j \) in the total of recreational opportunities. Denoting the latter by \( \lambda_{ij} = \frac{S_{ij}}{S_i} \) and noting that when the number of trials becomes large the Binomial tends to normality, the error term in the simplified model may be considered as a normal random variable with zero mean and variance given by:

\[ V(U_{ij}) = \lambda_{ij}(1 - \lambda_{ij}) T_i \]  

(13)

Direct comparison of (13) with (1) reveals that:

\[ w_{ij}^{-1} = \lambda_{ij}(1 - \lambda_{ij}) T_i \]  

(14)

and it may be shown that a reasonable approximation to (14) is provided by the following function of the sample data:

\[ w_{ij}^{-1} = K \frac{P_i}{C_{ij}} \]  

(15)

where \( K \) may be set equal to 1 without loss of generality.

II. Estimation of net benefits

1. The estimated consumer surplus arising from trips made during 1970 from \( i \) to \( j \) by the typical recreation day-tripper is given by:

\[ \hat{M}_{ij} = 2 \int_{C_{ij}}^{\infty} \hat{A}_j \exp(-\hat{\delta}c) \, dc \]  

(1)

where the integral is multiplied by two so as to account for costs associated with the complete round trip. From this may be derived the personal net benefit per trip from \( i \) to \( j \):

\[ \hat{b}_{ij} = b = \frac{2}{\hat{\delta}} \]  

(pence, 1970 prices)

(2)

and the total net benefit accruing to all people from day tripping in the South West during 1970:

---

7The implied value of \( \sigma^2 \) is 1.

8The effect is to reintroduce a non-unitary value for \( \sigma^2 \).
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\[ \hat{B}_{sw} = 0.02 \frac{\hat{T} \cdot \cdot}{\delta} \quad (\text{\pounds 000's, 1970 prices}) \]  

(3)

where \( \hat{T} \cdot \cdot = \sum_i \sum_j \hat{T}_{ij} \).

2. Approximate standard errors may be found by applying first order Taylor Series Expansions to functions of random variable (See [19]). Then:

\[ SE(\hat{\delta}) \simeq \frac{2}{\delta^2} SE(\hat{\delta}) \]  

(4)

and\(^9\)

\[ SE(\hat{B}_{sw}) \simeq 0.02 \left[ \frac{V(\hat{T} \cdot \cdot)}{\delta^2} + \frac{\hat{T} \cdot \cdot^2 V(\delta)}{\delta^4} - \frac{2 \hat{T} \cdot \cdot \sqrt{V(\hat{T} \cdot \cdot) V(\hat{\delta})}}{\delta^3} \text{Corr}(\hat{\delta}, \hat{T} \cdot \cdot) \right] \]

(5)

To obtain the variance of estimated total trip flows, if it is assumed that variation in the deterrence function parameter does not contribute significantly, it may be shown that:

\[ V(\hat{T} \cdot \cdot) = \frac{\sum_i (\sum_j \hat{T}_{ij})^2 V(\hat{A}_j)}{\hat{A}_j^2} \]  

(6)

The correlation between the deterrence estimate, \( \hat{\delta} \), and total trips, \( \hat{T} \cdot \cdot \), is not known. If it is assumed to be zero, a value of 142 results for the standard error of total net benefits, whereas in the extreme case when the coefficient of correlation is minus one, the standard error becomes 199, which is still small compared with the net benefit estimate.

REFERENCES


\(^9\)Corr. (a, b) \( \equiv \) product moment coefficient of correlation between a and b.