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THE EFFECT OF FREE PUBLIC TRANSPORT ON THE JOURNEY TO WORK

by

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ABSTRACT

The travel habits of public transport employees who had free travel concessions on public transport were compared with those of similar groups of workers who had to pay fares in seven provincial cities. The study used linear logit models to examine the effect of the many different travel and socio-economic factors on mode choice between car and public transport for the journey to work, on car availability for the journey to work, and on single and multiple car ownership.

The results suggested that socio-economic variables were very important in explaining car ownership and availability, but less so in influencing mode choice, while the difficulty and cost of the public transport journey appeared to have an important effect on mode choice and car availability, and less so on car ownership. The best estimate of the effect of providing free public transport for the control group is that car use by peak-hour commuters who do not need their car at work would be reduced by 22 per cent, that 10 per cent of those workers who had a car available for the work journey would no longer have the choice and would travel by public transport if it were free, and that car ownership among commuting households would be reduced by a statistically non-significant 3 per cent. Much additional information on the factors influencing travel behaviour was also obtained, including estimates for the value of travel time of 50p per hour for time spent walking or in a public transport vehicle, 13p per hour for time spent driving to work, and 200p per hour for time spent waiting for public transport, though this latter figure is known to be an over-estimate.

1. INTRODUCTION

The work described in this report was undertaken to try to determine the extent to which the use of car to travel to work is affected by public transport fares, and in particular the likely effect of free public transport. Previous information on these issues was drawn largely from a study by Goodwin[1], based on data collected in London from public transport employees (who generally enjoy free travel to work) and from other workers without this privilege. That study suggested that two-thirds of the commuters who travelled by car might divert to public transport if fares were eliminated. This dramatic result naturally gave rise to debate both about the validity of the finding for London and about its transferability to other cities.

Accordingly, in 1973 TRRL commissioned the Local Government Operational Research Unit (LGORU) to undertake a review of the literature on public transport demand elasticity[2], to set Goodwin's study in context and to determine whether there were any other studies bearing directly on this question. In this review, however, LGORU found no other study directly comparable with Goodwin's. Moreover, although Goodwin's analysis appeared sound, the value of his findings was much reduced by technical differences between the survey of the public transport employees and that of the other workers, which suggested that the two groups might not be strictly comparable.

LGORU were therefore commissioned to undertake a new survey and to analyse the data collected. The LGORU survey, like Goodwin's, was to cover both public transport employees and a 'control group'. The difference between these groups in the fares paid for the journey to work would permit an accurate assessment of the impact of fares, and, in particular, would enable an estimate to be made of the effects of zero fares on travellers' behaviour. The LGORU survey was, however, more extensive than Goodwin's in a number of ways: surveys were undertaken in seven English provincial cities; the surveyed population was much larger, partly because manual workers were included as well as clerical (although platform staff were excluded); and finally, each respondent was asked for extensive details about the journey he had made to work, permitting a more thorough analysis of the factors influencing his choice. Thus valuable information is available from the study on factors other than fares that are important in determining behaviour.

2. COLLECTING AND VALIDATING THE DATA

2.1 Design of the Questionnaire

The major aim of this study was to investigate the influence of public transport fares on four issues – mode choice, car availability, car ownership and multiple car ownership. The use of other modes, such as walk or cycle, was not investigated. In the circumstances of the survey, with voluntary completion of the questionnaire form by the respondents, and without the assistance of an interviewer, it was essential to design the form to be simple in presentation and quick to complete. These requirements very much limited the questions that could be asked to essentials only, and much information that would have been useful had to be omitted. One example of this was the omission of detailed information on trips to work made other than by public transport or by car. This was because questions on the use of other modes would have greatly increased the length of the questionnaire and possibly reduced the response in the primary area of interest of the study. For similar reasons, it was not possible to investigate any journeys other than those to and from work. The main questions asked were therefore concerned with the alternatives of car driving and public transport for the journey to work. This enquiry naturally involved a range of hypothetical questions and the questionnaire was designed in three parts to minimize complications.

The first part applied to all respondents, including those who did not use public transport or drive to work. Here we asked for full details of time spent on the journeys to and from work made by the respondent on the day preceding the survey. It was decided to ask for details of a specific day's journey rather than for a 'usual' journey partly to pick up a reasonable quota of unusual journeys and partly to avoid the difficulty of defining 'usual' journeys. This section of the questionnaire also collected the basic data on age, sex, car ownership and household income. Enquiring about income was expected to meet some resistance, so the question was phrased in such a way as to minimize the extent to which resentment to this question would damage response to other questions. The home address of each respondent was also obtained to help in checking the data.

The second part of the questionnaire applied only to respondents who drove a car or van to work. They were asked how far they drove, how much they paid for parking, and whether they took any passengers. Questions about car running costs were not asked because of the confusion between average costs, marginal costs and perceived costs which has been noted in so many studies. The drivers were asked for information on their alternative journey by public transport. To help in checking, they were also asked how often they used public transport and why they chose to drive on the day in question.

The third section applied to respondents who used public transport for most of their journey to work. These people were asked the cost of their journeys and the numbers of changes they had to make. Those who could have driven a car were then asked for details of the car journey they could have made. Not asking for car journey details from respondents who did not have a car available caused some problems in the analysis and its interpretation, but it was felt that these problems were preferable to those caused by asking purely hypothetical questions.

The questionnaire thus gave detailed information on the alternative car and public transport journeys to work, where both were available to the individual, and a full investigation of the choice between these two modes was possible. For modelling car ownership and availability some of the basic socio-economic data for the individual were available, but little apart from income for the household. The lack of measures of household size proved to be particularly detrimental to the multi-car ownership investigation.

Particular attention was given to the question of car availability for those travellers who used public transport: they were asked whether they could have driven to work if they had so wished and, if not, the reasons for it. All respondents were asked about household car ownership and this information made it possible to distinguish clearly in the analysis between household car ownership and individual car availability.

The questionnaire was set out on a single folded sheet of four pages, the first being a brief general introduction to the survey, the other three carrying the three sections as described above.* This format was tried out in a pilot survey in Newcastle and Sunderland, covering about one hundred staff of Tyne and Wear Passenger Transport Executive, and it proved generally satisfactory. The pilot study was also used to try out different formats for some questions, particularly where people were asked why they made the journeys they did. Here an 'open' format, giving maximum freedom for response, was found to work better than a 'closed' format, where people were asked to tick one or more reasons from a prespecified list. The pilot survey also showed that the general survey method was satisfactory, and the same approach was used in each of the other sites.

2.2 Selection of sites

In selecting sites for the survey, the major considerations were to find large and closely comparable groups of public transport employees and other workers. Close comparability of the groups was necessary to ensure that the effect of fares is not confused by other effects such as income differences and differences in the quality of public transport service to the workplaces.

The main difficulty was the availability of sufficient numbers of public transport employees. Approaches were initially made to all the Passenger Transport Executives and to the National Bus Company. Subsequently visits were made to selected undertakings to determine the numbers of staff who could be surveyed and to take note of the key indicators of transport provision to the workplaces, such as car parking and the convenience of the public transport service for access to the workplaces.

In the seven cities finally selected, it was anticipated that up to 3646 public transport employees could be surveyed at nine separate sites. This number gave a good margin for errors and low response rates. The numbers in each city are shown in Table 1, listed in the order in which they were subsequently surveyed.

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* The form of the questionnaire is contained in the Appendices to this report, which are not reproduced here but are available as a separate Working Paper WP/SRB4 on application to the Head of Special Research Branch, Transport and Road Research Laboratory. In the remainder of this report, the Working Paper will be referred to as reference 3.

TABLE 1

Public transport workplaces surveyed

City	Site	No. of staff anticipated		
		Clerical	Manual	Total
Liverpool (MPTE)*	Central Works	60	479	539
	Headquarters	227	–	227
Norwich	Eastern Counties	115	125	240
Bolton	Greater Manchester Transport	68	240	308
Stoke	Potteries Motor Transport	125	155	280
Sheffield (SYPTE)*	Headquarters	333	–	333
	Central Works	70	180	250
Bristol	Bristol Omnibus Company	200	200	400
Manchester (GMT)*	Ardwick Offices and Works	420	649	1069
	TOTAL	1618	2028	3646

* Abbreviations: MPTE Merseyside Passenger Transport Executive;
SYPTE South Yorkshire Passenger Transport Executive;
GMT Greater Manchester Transport.

The requirements for a site to be suitable for a control in the survey were rather stringent. First, the employees had to be comparable with the public transport employees in their distribution of income, type of work (i.e. clerical or manual†), and sex. Second, the workplace itself had to be comparable with the public transport workplace in the provision of parking, the quality and convenience of the public transport service and preferably in location. Finally, both management and workers had to be willing to cooperate in the survey.

The sites that were eventually surveyed are shown in Table 2, which also gives the number of staff expected at each site. The survey of manual control groups in Bolton and Manchester had to be abandoned because of a last-minute change of attitude by the workers involved, who refused to cooperate.

Thus a survey of up to 7,000 individuals was anticipated. In the event, just under half that number of questionnaires was completed. The reasons for this reduction are given in the following section.

† 'Clerical' and 'manual' proved to be terms that management could apply to their workers without ambiguity.

TABLE 2

Other workplaces surveyed

City	Site	No. of staff anticipated		
		Clerical	Manual	Total
Liverpool	City Council	250	–	250
	Plessey	60	500	560
Norwich	Colman Foods	150	150	300
Bolton	Borough Council	70	–	70
Stoke	City Council	150	–	150
	Spode Potteries	–	250	250
Sheffield	Yorkshire Water Authority	150	–	150
	GPO	150	–	150
	City Council	50	300	350
Bristol	SW Gas	250	–	250
	Wills	–	200	200
Manchester	ICL	500	–	500
	TOTAL	1780	1400	3180

2.3 Response to the survey

The sites listed in the previous section were surveyed between June 1975 and January 1976. In each city, the surveys at the public transport and control sites were all conducted on the same day. The numbers of questionnaires received from each site are shown in Tables 3 and 4.

TABLE 3

Questionnaires returned by public transport workers

City	Site	Clerical	Manual	Total
Liverpool	Central Works	53	96	149
	Headquarters	194	–	194
Norwich	Eastern Counties	95	63	158
Bolton	Greater Manchester Transport	47	40	87
Stoke	Potteries Motor Transport	79	85	164
Sheffield	Headquarters	152	–	152
	Central Works	15	92	107
Bristol	Bristol Omnibus Company	99	125	224
Manchester	Ardwick Offices and Works	250	203	453
	TOTAL	984	704	1688

TABLE 4

Questionnaires returned by other workers

City	Site	Clerical	Manual	Total
Liverpool	City Council	165	–	165
	Plessey	47	262	309
Norwich	Colman Foods	160	96	256
Bolton	Borough Council	68	–	68
Stoke	City Council	115	–	115
	Spode Potteries	–	117	117
Sheffield	Yorkshire Water Authority	141	–	141
	GPO	134	–	134
	City Council	29	47	76
Bristol	SW Gas	133	–	133
	Wills	–	58	58
Manchester	ICL	105	–	105
	TOTAL	1097	580	1677

The numbers shown in these tables are much less than those in Tables 1 and 2 for three main reasons.

First, the estimates given by the managements concerned were generally the total number of staff employed, rather than the number who were likely to be contacted by the survey. Thus not only those employees who were sick or on holiday were missed, but also those whose work took them away from the survey sites on the day of the survey.

Secondly, the survey was entirely dependent on the internal circulation systems of the firms surveyed to distribute and collect the questionnaires. In some cases, the management were enthusiastic about the survey, and achieved an excellent coverage of their staff, but in others many staff, or whole departments, did not receive forms at all.

Finally, some individuals simply refused to complete the survey forms. In some cases refusals were the result of organized opposition to the survey on a small scale, particularly connected with the income question. Refusals were more frequent from manual workers than from clerical.

For these reasons, it is difficult to calculate an exact response rate for the survey. We estimate that not more than two thirds of the staff shown in Tables 1 and 2 had an opportunity to complete the form, so that the response rate achieved was over 70 per cent of these staff. Altogether 3365 questionnaires were returned, which, while fewer than expected, promised quite a substantial body of data for analysis.

There is clearly the possibility of bias in the responses to the questionnaire, as with any self-completion survey. In this case, however, much of the loss of response was caused by factors not connected with the individuals themselves. Therefore, while some bias in response cannot be ruled out, it does not seem likely to be very important.

2.4 Preparation of data for analysis

The questionnaires collected were subjected to a rigorous process of validation before any analysis was done. The validation and subsequent analysis were mainly computer-based, so that the first stage in the process was to code, punch and verify the data to allow automatic processing. Frequent reference to the original questionnaires was, however, required.

Throughout these processes, the main problems that arose were caused when respondents failed to answer all the questions, particularly where there was confusion between an answer of zero and a non-answer. Extensive checks were therefore made to ensure that all the fields were correctly filled. A full validation was then carried out to check that all the answers fell within permitted ranges and that there were no illogicalities, and to indicate possible ambiguities which could then be resolved by reference to the questionnaires. About 100 checks were performed on each questionnaire returned.

A further investigation was carried out to try to determine how accurately the respondents had answered the questions. A sample was taken from the Sheffield data, and the journeys described by the respondents were compared with independent estimates of the times that would be taken and costs that would be incurred. These independent estimates were derived from bus timetables, highway maps, etc. Obviously there is some uncertainty about the accuracy of estimates derived in this way, but it was felt that the comparison should reveal any significant biases in the answers that had been given to the questionnaire. For components other than waiting time, this investigation showed a close correspondence between the respondents' answers for the journey actually made and the independent estimates, and apparent overestimation by 10–20 per cent of the components of the alternative journey[†]. In the case of waiting times for buses, there were no reasonable means of deriving independent estimates, because it was not possible to establish a clear relationship between the waiting times stated by the respondents and the headways of the bus services used. There was, however, a substantial difference between respondents' estimates for actual journeys and hypothetical alternative journeys: for the latter, estimates were about twice as great.

The results of this investigation were fairly encouraging for the assessment of components other than waiting time. The estimates of actual and hypothetical journeys were sufficiently close that errors would be within normal experimental accuracy. Most important, no significant differences were found between the public transport employees and the control group. For waiting time, however, the findings indicate that little weight should be attached to the results of analysis in which waiting time is compared with other components in the model, as in, for example, mode choice. This reservation may well apply to many other studies that have estimated values of waiting time from data collected from individual's own estimates.

The final investigation before starting the main analytical process was into the comparability of the public transport and control groups of workers in terms of income, sex, job type*, and the length of the journey to work. It should be noted that any differences revealed in this way would not necessarily affect the validity of a particular result, since these factors were allowed for in all the analyses, although it might affect the accuracy of the comparison since the modelling of these parameters inevitably contains random errors. Moreover, the length of the journey to work might itself be influenced by a zero fares concession. The results of these investigations showed no systematic differences between the two groups over all sites, although at some sites there are significant differences in particular factors. The overall distributions of income are shown in Table 5. This shows the close comparability of the two groups in income distribution.

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† A summary of the findings of this investigation is contained in reference 3.

* i.e. clerical or manual work

TABLE 5

Household income distribution (per cent)

Annual Income	PT Group	Control Group	Total
Up to £1000	0.3	0.3	0.3
£1000 – £2000	6.0	5.8	5.9
£2000 – £3000	13.4	15.4	14.4
£3000 – £4000	13.1	13.4	13.2
£4000 – £5000	8.2	10.7	9.5
Over £5000	12.5	12.6	12.5
No answer	46.5	41.9	44.2

In most other respects also the two groups were closely comparable. In the public transport group 26 per cent were women and 42 per cent manual workers; in the control group 29 per cent were women and 35 per cent manual workers. Although at some sites there were significant differences in the journey lengths between the groups*, in some cases the public transport employees lived closer to their work, on average, while in other sites the situation was reversed, and no trend covering all the sites could be established. It was not considered that any of these differences could adversely affect the analysis.

3. DETERMINING THE IMPORTANT FACTORS

This section discusses the results obtained from analysis of the data to determine the important factors in the four issues considered: mode choice, car availability, car ownership and multi-car ownership.

A total of 3365 questionnaires had been received, 1688 from public transport employees and 1677 from the control group. These were distributed as shown in Table 6.

TABLE 6

Overall distribution of respondents (per cent)

	All Respondents		Car Owners**		Car Ownership		
	Drive	Use PT	Drive	Use PT	No Car	1 Car	2+
PT Group	31.1	53.7	45.8	39.4	29.0	54.6	10.8
Control	42.7	31.9	58.2	19.6	23.0	56.6	14.7
TOTAL	36.9	42.8	52.2	29.1	26.0	55.6	12.7

** Including those who need their car at work.

* The details of this analysis of journey lengths are contained in reference 3.

The percentages do not add up to 100 because of the use of modes other than driving and public transport, and because some people failed to give their car ownership. Tests of χ^2 statistics show that the differences between the two groups in mode choice (for all respondents and for those who were car owners) and in non-car ownership are all significant at much less than the 0.1 per cent level. The difference between the groups in multi-car ownership (among car owners) is significant at the 2 per cent level.

Of course presentation at this level discards a large amount of information that is interesting in itself and that might add to the accuracy of estimation of the effect of zero fares. It is for this reason that the detailed information on journey characteristics was collected. The analysis of this more detailed information is discussed below.

3.1 Method of analysis

The four issues analysed can each be put into a binary form. That is, only two results are possible in each case, thus:

mode choice – car or public transport (all other choices were ignored)

car availability – yes or no

car ownership – yes or no

multiple car ownership – yes or no (non-car owners were excluded).

This structure of the issues meant that binary models could be applied to investigate the factors influencing them.

In this study, the type of binary model selected was the linear logit model:

$$\Pr(m = 1) \quad = \quad \phi(a_1 x_1 + a_2 x_2 + \ldots + a_n x_n)$$

where the probability of the result m taking the first value (e.g. for mode choice, car chosen) is represented by the logit function ϕ defined by

$$\phi(z) \quad = \quad 1/(1 + \exp(-z))$$

and $x_1 \ldots x_n$ are the values of the independent variables, such as income, fare, etc. The parameters $a_1 \ldots a_n$ are weights attached to these variables by the travellers, and may be estimated from the data by standard statistical processes. Conversely, the probability of the result m taking the second value (e.g. in the mode choice, public transport chosen) is simply $1 - \Pr(m = 1)$.

Models of this type are the most commonly used in transportation planning. It was not within the scope of the study to investigate alternative model forms, nor was it felt that significantly different results would have been obtained by different forms. Consequently, the standard methodology was adopted, except that special procedures had to be developed to deal with incomplete data records, where an individual had failed to answer some of the questions.

In previous studies the standard procedure has been to omit all incomplete records. Here, however, this would have given an unacceptable loss of data; for example, as shown in Table 5, 44.2 per cent of the respondents had not given their household income. For this study, therefore, statistical techniques for analysing incomplete data were developed. These techniques, described in reference 3, allow incomplete data to be incorporated in the analysis and given weight appropriate to their completeness.

The large volume of data collected and the number of calculations required, particularly for the iterative method adopted for dealing with incomplete data, meant that the use of a computer to analyse the data was inevitable. This study used the LGORU program SLOGIT, a development of a program used in previous LGORU studies[4,5], which incorporates the missing-data techniques. The function of the program is to derive estimates of the parameters $a_1 \ldots a_n$ of the model that best describe the choices observed in the data*. The program also produces standard errors and other statistics relating to the estimates, so that confidence limits can be calculated. Thus the primary results available from the analysis are the estimates of the parameters $a_1 \ldots a_n$. Each parameter gives an estimate of the importance of the corresponding variable in influencing the issue being studied. For example, a parameter estimate significantly† different from zero (at a defined level of significance) implies that the corresponding variable has an influence on choice that is significant (at the defined level). Throughout, these results are given on the logit scale, which unfortunately is unfamiliar to non-specialists and impossible to transform to a more familiar scale. It has a direct interpretation+, but non-specialists may find it easier to assess the results by comparing the magnitudes of the coefficients in a looser way, which will not generally be misleading.

The issues investigated, although binary in themselves, are more accurately seen as parts of more complicated models. Thus in the models of car availability and mode choice the individual is more accurately represented as being in one of three categories: no car available, car available and driven, or car available but public transport used. In this study, this three-way split was modelled as two two-way choices: first, between car availability and no car availability; then, for those with a car available only, between car use and public transport use. It is possible that the structure of modelling used could be improved by taking explicit account of the three-way structure (possibly along the lines of reference 5), but such an investigation was beyond the scope of the study. For similar reasons, a conditional two-stage structure was used for car ownership modelling. First, the split between non-car owners and those who owned any number of cars was modelled. Then, for car owners only, the split between those whose households owned one car and those who owned two or more cars was modelled. Again this modelling structure might possibly have been improved by further investigations, but such investigations were beyond the scope of the study.

In studying each of the issues, as much of the data as possible was used, pooling information from all the sites to get the most accurate estimates possible. Variables were included (as outlined in Section 3.3) reflecting the differences between sites that were not measured in the data: differences in public transport reliability, for example. Although the missing data techniques allowed the inclusion of incomplete data, it was necessary to exclude a number of records, for two main reasons. First, records were excluded that were felt to describe behaviour not covered by the models; for example, travellers who needed their car at work or who travelled at unusual times. Second, records were excluded that contained unusual answers which might otherwise have distorted the estimates. Details of the exclusions and of the populations used for investigating each issue are given in reference 3.

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* Technically, the criterion of best description of the data used by the program is the maximum likelihood criterion.

† 'Significant' is used throughout this section in its statistical sense.

\+ The logit scale may be interpreted as showing differences in logarithmic odds. Thus an increase of 1.10 ($= \log_e 3$) would shift a probability of 0.5 (= 1:1) to one of 0.8 (= (1+3):1).

The variables taken from the data and used as the x variables in the model fell into two clases. First, there were variables describing the journey made by an individual and his alternative journey. These variables are generally measured in minutes or pence. Second, there were variables describing the individual himself or his household, such as age or income. These variables are generally included as 'dummy' variables, as explained in Section 3.3. The following two sections present the results obtained for all four issues, first for the journey variables, then for the other variables.

3.2 Journey variables

The investigation of the effects of journey variables was the key phase of the study, since it was concerned with the link between the issues of car ownership, car availability and mode choice, and measures of the cost and convenience of car and public transport journeys to work.

For the mode choice investigation, only travellers who had a car 'available' were included†, and the analysis was based on 1167 individual records. These people had been asked the full range of questions on their two alternative journeys so that both car and bus journey variables could be included in the analysis. For car ownership and availability it was necessary to exclude the car journey variables, since travellers who did not have a car available had not been asked questions about a hypothetical car journey. It was possible, however, to investigate the impact of the public transport journey variables on these issues. The analysis of car availability was based on 2016 individual replies, while the analyses of car ownership were based on 2280 individuals for the non-car owner/car owner split, and on 1584 individuals for the single-car-ownership/multiple-car-ownership split.

The results of this analysis are given in Table 7. Six variables were used to describe the public transport journey. Four of these were walking time (at both ends of the journey and at any intermediate interchanges); the waiting time for all the stages of the journey; the time spent in public transport stages of the journey; and the total cost of the public transport journey. Times were measured in minutes and the cost in pence, and included the journey to work and the journey home. A further variable (the 'PT Vehicles' variable) counted the total number of public transport vehicles used in the round journey (i.e. buses + trains + ferries). Finally, a 'dummy variable' (the 'PT Employment' variable) was included, taking the value one for public transport employees and zero for the other workers. This variable was initially included to allow for inherent differences in attitude towards using public transport between public transport employees and other workers, but it was found to assume a 'proxy' role which allowed for some complicated interactions of the cost variables, as explained in detail later.

Three variables were used to describe the car journey. Two of these were the driving time (in minutes) and the parking and/or toll cost (in pence), both for the round journey to and from work; the third was the driving distance (in miles) for the one-way journey to work. In some cases, respondents had had to walk as part of a journey that was primarily by car. In these cases this walking time was subtracted from the walking time on the alternative public transport journey, so that the variable actually used represented the difference between the alternatives.

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† An individual was assumed to have a car available unless: *either* the number of cars or vans in regular use by the household is zero; *or* he went to work by public transport and stated that he could not have driven to work or that he did not drive because someone else required the car. This definition avoids any dependence on a decision by the respondent whether he 'could have driven' in spite of the requirements of another household member. Details are given in reference 3.

TABLE 7

Logit coefficients for the journey variables
(Standard errors are given in brackets*)

	Choose Car	Car Available	Car Owned	More than one Car Owned
Public Transport Journey				
Walk Time (mins)	.041† (.012)	.0129 (.0053)	.0064 (.0053)	−.0004 (.0055)
Wait Time (mins)	.153 (.015)	.0552 (.0063)	.0357 (.0059)	.0164 (.0054)
Travel Time (mins)	.044 (.007)	.0136 (.0026)	.0120 (.0026)	−.0027 (.0027)
Fare (pence)	.042 (.010)	.0157 (.0045)	.0242 (.0050)	.0016 (.0026)
PT Vehicles (number)	−.33 (.14)	−.124 (.070)	−.137 (.068)	−.067 (.082)
PT Employment (dummy)	.62 (.43)	−.13 (.20)	−.62 (.20)	.22 (.19)
Car Journey				
Drive Time (mins)	.011 (.010)			
Drive Distance (one-way miles)	.266 (.049)			
Park and Toll Cost (pence)	.063 (.014)			

* The distribution of the estimates is approximately normal.

† In the mode choice investigation, walking time for the car journey has been subtracted from walking time for the alternative public transport journey.

The models were set up in such a way that the logit coefficients would be positive when the measured effect acted in the direction which would be expected intuitively. Thus, with the exception of the multi-car-ownership analysis, all the variables but two, the 'PT vehicles' variable and the 'PT Employment' variable, have the intuitively correct sign. The values obtained for the two variables for which this is not true suggest, apparently, that the use of more than one public transport vehicle (i.e. by interchange) makes public transport relatively more attractive, and that public transport employees are more likely than the control group to choose car travel, or to have a car available, or to own a car, other things being equal. This seems unlikely, and an explanation, which depends on these two variables acting as proxies for other effects, is given later in this section.

Summarizing these results, with the exception of the two variables mentioned, the coefficients are significantly positive in mode choice (except for driving time), car availability and car ownership (except for walking time). The multi-car ownership investigation, however, does not seem to have been successful in detecting a connection between this issue and journey costs: only the waiting time variable is significantly non-zero. Thus in general the results for most of the variables are satisfactory. For the two variables for which the results are difficult to interpret, the following explanation is given.

The public transport employment variable is, it appears, fulfilling a corrective role. The public transport fare for journeys to the central sites gives a reasonable measure of the overall accessibility of the home of the respondent. This overall accessibility is of course connected with car ownership (and thus, to a lesser extent, with availability). For public transport employees, however, the respresentation of accessibility by fare is absent since this group has free travel, and the analysis uses the public transport employment variable to compensate for the lack of such an accessibility variable.

That the public transport employment variable is used only partly to compensate for the absence of an accessibility relationship is illustrated by the graph in Fig. 1. This shows the relationship of the control group employees' car ownership with the round trip fare as specified by the model and a hypothesized 'true' relationship of public transport employees' car ownership with the 'payable' fare. The model, which does not have the information on payable fares for public transport employees, can only represent the accessibility relationship by the horizontal line meeting the true line at the average fare. The average 'payable' fare can reasonably be assumed to be the same for the two groups; the figure is about 40p. The increase in log odds of car ownership at this average fare is calculated from the logit coefficients of Table 7. The coefficient for fare is 0.0242 and the control workers pay a fare of 40p on average: thus the increase in log odds is 40 x 0.0242 = 0.97. The public transport workers pay no fare, but the explanation of car ownership falls on the PT employment dummy variable, which takes the value 1 for these workers. Its coefficient is –0.62, where the sign indicates an *increase* in the probability of owning a car (ie the effect is counter intuitive), so that at the average fare payable the adjustment required in the log odds is +0.62. At this average fare, however, the other employees' probability of owning a car is considerably higher (at 0.97). A similar graph could be drawn for car availability.

Thus the fare coefficients postulated in Table 7 serve two functions: first as a proxy for accessibility, then as a true reflection of the behavioural impact of fares. These separate effects are shown by the separate sloping lines in Fig. 1, and given numerically (for the mean fare) in Table 8: the true reflection of the behavioural impact of the fares (the 'Non-proxy Effect') is assumed to be the difference between the increase in log odds for the non-public transport employees (at their mean fare) and that given by the hypothesized 'true relationship' for public transport employees at the same fare.

TABLE 8

Proxy and non-proxy contributions to the logit coefficients for fares

	Ownership	Availability
Proxy for Accessibility	0.62	0.13
Non-proxy Effect	0.35	0.50
TOTAL	0.97	0.63

The figures shown in this table seem plausible. A similar calculation can be done for mode choice, again giving plausible results: a negative accessibility proxy effect (−.62) but a very large non-proxy effect (2.30). One must beware, however, of reading too much into these figures, which as Table 7 shows are subject to fairly large errors.

The results for the interaction of fares and public transport employment have been dealt with at length, since the findings here are fundamental to predicting the diversions that would be occasioned by universal zero fares. Since the PT employment variable cannot be used to measure any difference in attitude between public transport workers and others, the calculation of diversions must be subject to the assumption that there is no difference in attitudes (or information) from the other workers other than those measured in the data. This assumption is, however, essential in a study such as this and it cannot be tested on the data available because of the proxy effects described above. In the case of car ownership, where it can be assumed with reasonable confidence that the accessibility proxy effect is strictly positive, it can be inferred that any attitude difference is small (otherwise the coefficient would have taken a positive sign), but for car availability and mode choice no such inference can be made.

For the public transport vehicles variable, which also takes a sign that is intuitively implausible, a similar explanation involving the waiting time variable is suggested. In this case the effects are rather more complicated, and the detailed explanation is contained in reference 3. Briefly, it appears that in the surveys those who used car consistently overestimated the waiting time of their alternative public transport journey, so that the waiting time seems to be a particularly important discriminator between public transport users and car users. Consequently the model overestimates the importance of the waiting time component, and assigns too high a value per unit time to it. This high value of waiting time is, of course, also applied to the time spent waiting for interchange, in those journeys involving interchange, and the deterrent effect of interchange becomes exaggerated to the point that a negative value must be assigned to the coefficient of the PT vehicles variable in order to compensate for this exaggeration. ı his complicated proxy effect is not discussed further here because the waiting time variable is not so central to the purpose of the study in predicting the response to fares.

3.3 Non-journey variables

The variables investigated that related to the individual traveller, rather than his alternative journeys, were concerned with age, sex, income, the type of work done by the respondent (ie clerical and administrative or manual work) and the location where he worked.

The data in each case were not available as a continuous series of values, as were the journey data, but rather as an indication of a category into which the individual fell. The model parameters estimated thus gave indications of the differences between the categories. In the case of sex and work type, there were only two categories for each variable, and the parameter estimated for each represents the difference between the two.

In the case of income, age, and location, there was a range of possibilities; these were dealt with by arbitrarily selecting one of the categories (eg age 31–50) and estimating the difference between this category and each of the others.

In practice, there were insignificant differences between some of the categories. Therefore, a number of preliminary investigations were made to determine the appropriate number of categories for each of the four issues. Only the final results are presented in Table 9.

Preliminary investigations

The results for modal split were rather different from those found for the other issues. There was no evidence that age or sex had any effect on mode choice (for travellers with a car available). Moreover, the mode choice results for income seemed to show a threshold at £2000 per annum, with insignificant effects on choice above this amount. Accordingly, in the final results given in Table 9 only two non-journey variables are shown for mode choice.

For car availability, on the other hand, both age and sex were found to be highly significant. Income also showed an increased significance, but when five ranges (four variables) were used, the differences between the second and third ranges and the fourth and fifth were not significant and had anomalous signs. The groupings as shown in Table 9 are thus probably the best.

TABLE 9

Logit coefficients for the non-journey variables
(Standard errors are given in brackets)

<table>
<tr><th>Variable</th><th>Choose Car</th><th>Car Available</th><th>Car Owned</th><th>More than one Car Owned</th></tr>
<tr><td>Age*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Under 21</td><td>–</td><td>–1.26 (.21)</td><td>–0.40 (.19)</td><td>0.88 (.24)</td></tr>
<tr><td>21–30</td><td>–</td><td>–</td><td>–0.19 (.15)</td><td>0.03 (.17)</td></tr>
<tr><td>Over 50</td><td>–</td><td>–0.37 (.13)</td><td>–0.50 (.14)</td><td>–0.51 (.21)</td></tr>
<tr><td>Income*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>£2000–£3000 pa</td><td rowspan="4">1.49 (.71)</td><td rowspan="2">1.14 (.26)</td><td>1.16 (.23)</td><td>–0.06 (.55)</td></tr>
<tr><td>£3000–£4000 pa</td><td>1.57 (.25)</td><td>0.29 (.54)</td></tr>
<tr><td>£4000–£5000 pa</td><td rowspan="2">1.76 (.28)</td><td>2.19 (.29)</td><td>1.20 (.53)</td></tr>
<tr><td>Over £5000 pa</td><td>2.68 (.30)</td><td>2.06 (.53)</td></tr>
<tr><td>Sex (Female)</td><td>–</td><td>–1.50 (.16)</td><td>–0.27 (.14)</td><td>0.24 (.18)</td></tr>
<tr><td>Work Type (Manual)</td><td>0.80 (.29)</td><td>–0.33 (.16)</td><td>–0.23 (.14)</td><td>0.30 (.20)</td></tr>
</table>

* Age variables represent differences from the 31–50 age category, income variables represent differences from the under £2000 per annum category.

For both car ownership studies, a full range was used for both age and income variables. For multi-car ownership, the distinction between ages 21–30 and 30–50 and the distinction between incomes less than £2000 per annum and £2000–£3000 might both have been dropped, but this investigation was not pursued fully because of the poor results on the journey variables discussed in the preceding section.

Main results

As with the journey variable results, the distribution of the coefficient estimates is approximately normal, so that the usual test of significance, comparing an estimate with its standard error, is reasonably applicable. Caution should be used, however, in assessing the significance of differences between these estimates, since the correlations of errors are not shown. For example, in each investigation all the income coefficients are significantly different at the 5 per cent level, because of high positive correlations between the estimates†.

Age and sex

Perhaps the most interesting results in Table 9 are those for the age and sex variables. The car availability results show that people under 21 or female are much less likely to have a car available. By contrast, the car ownership investigation shows much smaller values of the variables. It may be deduced that the low car availability results more from competition within the household than from the household not owning a car. By contrast, the multi-car ownership investigation shows positive values for these variables. These positive values are probably caused by the fact that households with an employed person who is under 21 or female are more likely to be households with several employed people, and thus more likely to be multi-car owners.

The results obtained for the other age groups are less striking. The over 50 group clearly owns fewer cars than the 31–50 group, and the car availability result is probably simply a reflection of this low ownership. The 21–30 group may own fewer cars than the 31–50 group, but this result is not significant. Note that all age groups seem equally likely to use cars, given availability.

Income

The results for income variables are fairly straightforward. For car ownership, the relationships with household income seem linear, with a step around £2000 per annum for single car ownership and very low multi-car ownership below £3000 per annum. The results are more accurate relative to each other than they appear from the standard errors in the table, since most of the standard error can be attributed to estimating the zero on the scale. These results are shown diagrammatically in Fig. 2. The increase in car availability with increasing income is also consistent with the increase in car ownership, though any direct relationship between availability and ownership is complicated by increasing competition with the household, as household sizes tend to be larger in the higher income groups.

Location

All the models used in the analyses included nine variables to account for locational factors. These variables reflected influences on car ownership, availability and use that varied from site to site but that were not reflected in any of the explicitly measured variables. The coefficients found for these variables* are difficult to interpret usefully, but seem to show a general preference for car use in the smaller cities, above the preference indicated by the journey variables. The trends are not at all clear, however, and this interpretation should be treated with caution.

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† Correlations between the estimates are given in reference 3.

* The results for the location variables are given in detail in reference 3.

3.4 Discussion

The prime objective of the study was to investigate the impact of public transport fares on travellers' behaviour. Before turning to discuss this impact in detail in the next section, it is useful to draw together a number of the other findings of the study that are important for transport planning in a broader context.

The results given in Table 9 and discussed above show a clear distinction between individual car availability and household car ownership. In many of the models commonly applied in transport studies, this distinction is blurred or non-existent. The results of this study, however, indicate that the distinction is quite important, and can be linked with factors such as age and sex that relate to the individual's position in the household. Thus these results not only indicate a need to improve the modelling of car availability, but suggest directions that this improvement might take.

The distinction between car ownership and availability is found mainly in the age and sex variables. The dependence on income, however, is also interesting for the threshold effects shown in the graph of Fig. 2. This graph shows a large increase in ownership of one car around an income of £2000 per annum (at 1975/6 values) after which increases with income are less rapid. Multiple ownership, however, increases rapidly only for incomes over £3000 per annum. Apart from these thresholds, however, the relationships with income are approximately linear.

The second aspect of the results that has importance in a broader context is the investigation of journey variables. Some of the results shown in Table 7 are contrary to currently accepted thinking, and it may be that these results could be helpful in refining this thinking. In particular, in mode choice modelling in-vehicle times are commonly given equal weight whether travel is by public transport or by car, but here the mode choice model implies that public transport time is valued four times higher than driving time. This result has most important implications for policy, but has not been investigated in detail in many previous studies. An important associated result is that walking time and public transport time have very similar values. Additionally, walking time is valued much below waiting time, though this may result (at least in part) from the problems of valuing waiting time mentioned in section 3.2, which imply that the values obtained here are likely to be overestimated.

TABLE 10

Estimates of values of travel time (per hour)
(Coefficients of variation* are given in brackets)

	Mode Choice	Car Availability	Car Ownership
Walking Time	47.3p (.39)	49.3p (.52)	15.9p (.86)
Waiting Time	177p (.26)	211p (.32)	88.5p (.26)
PT Time	50.7p (.27)	52.0p (.35)	29.8p (.31)
Driving Time	12.6p (~1)	–	–

* The coefficient of variation is the ratio of the standard error of the estimate to the estimate itself. It is used here rather than the standard error to emphasize that the estimates are not normally distributed.

Values of time may be estimated from these results; the estimates are set out in Table 10. They are obtained from the ratios of the estimated weights of the time variables (given in Table 7) to the public transport fare variable, and the average values of these times and costs.

The reason for using this method of estimation is given elsewhere[4]. Note that much of the error in these estimates is caused by the error in estimating 'the value of money', corresponding to the relatively large errors in the public transport fare weights in Table 7. This estimate of the value of time, although used in many other studies, may contain distortions because of the proxy effects identified above, which certainly seem to apply to the cost variable, and may or may not also apply to the various time variables. If so, there is no way of identifying the proxy effects in the time variables and correcting for them.

The difference in the weights attached to the many variables in Table 7 is interesting, though it is not significant. In the mode choice analysis, it seems strange that the public transport fare weight should be *lower* than that for private transport costs, since the data include drivers who took passengers, with whom they might expect to share some of the costs. In fact, in an analysis excluding passenger takers* the ratio of these cost weights increased, suggesting that cost sharing is relevant. The difference in the cost weights remains unexplained.

Driving costs were not required on the questionnaire, but are represented in the model by the driving distance. Relative to the public transport cost, the coefficient of drive distance in Table 7 implies a cost per kilometre of 2.0p (coefficient of variation 0.29), assuming that the round trip distance is twice the one-way distance. This is slightly more than petrol cost for an average car at the time of the survey, and seems a reasonable estimate of marginal cost. If this suggestion that car drivers account reasonably for marginal driving cost is true, it could be inferred that some of the problems found with this variable in other studies were the result of its strong correlation with the driving time, which previous studies had not considered in enough detail.

4. ESTIMATING THE EFFECTS OF ZERO FARES

The preceding section presented the results of analyses to find the significant factors influencing mode choice, car availability and car ownership. Of special interest in this study were responses to public transport fares, and particularly to zero fares, and this section discusses estimates of the changes in car ownership, availability and use which would occur if public transport were made free.

4.1 Assumptions required

A change to zero public transport fares on any significant scale would have impact well beyond the transport sphere. This study made no investigation of these wider changes, nor can it comment on the desirability or otherwise of fare changes. An outline of the likely effects of zero fares can be found elsewhere.[6,7]

Even within the transport sphere some changes would be likely to result from zero fares that are beyond the scope of the present study. For example, a fare reduction that caused some car drivers to transfer to buses would reduce traffic congestion, thus making the car journey more attractive again. Similarly, increased bus patronage might justify increased bus frequencies (with, of course, increased operating costs), and the elimination of fare collection might lead to increased bus speeds, both of which would make bus travel more attractive. Such effects, involving operational aspects of the transport systems, fall outside the purely behavioural investigations carried out in this study.

Further restrictions on the applicability of deductions drawn from these data are imposed by the information collected, in that it concerns only the journey to work, it excludes people who travelled other than at usual times, it refers only to central workplaces in a limited range of provincial cities, and the study considers only the choice

* The results of this analysis are tabulated in reference 3.

between public transport and car driving. Inferences drawn from the data are strictly applicable only in circumstances of which the data are representative. Such circumstances, nevertheless, include the important problems of peak hour traffic congestion and bus patronage, and relate strongly to car ownership. Intuitively, however, it might be expected that measures aimed at causing mode shift from car to bus would have their greatest impact on work trips to city-centre locations, since these are particularly well served by public transport. It should also be realised that where such mode shift causes cars to be left at home, where they may be available for use by other members of the household, the mode shift does not necessarily imply any overall reduction in private travel.

The basic analysis reported in section 3, on which the projections of this section are based, applied only to a population who:

- travelled to and from work at normal times;*
- drove to work or used public transport;
- did not need their car at work.

Technical details of these exclusions and a discussion of their importance are given in reference 3. The data then contained information on 2361 individuals. Each of these exclusions improves the accuracy and reliability of inferences drawn from the data, but reduces the range of applicability of these inferences. For example, zero fares would presumably attract present walkers, cyclists and car passengers to public transport, but no predictions of the extent of this transfer could be made. Other exclusions were made for specific analyses where individuals had failed to answer crucial questions (eg the car ownership question in the car ownership analysis) or who had given answers so unusual that they threatened to distort the model.† Two further systematic exclusions were also made from the car availability and mode choice models, however, that are important for inference from these data.

The first of these was the exclusion of individuals who had made 'impure' public transport journeys (8.8 per cent of the 2361). These people had made part of their journey by a mode other than public transport or walking, usually getting a lift home in the evening after coming to work by public transport, or driving or being driven to and from railway stations. It was considered that such people would not respond in the same way to fare changes as would people whose trips were purely by car or purely by public transport.

The second and more difficult problem concerned car drivers who took passengers (about 50 per cent of the drivers did). It is reasonable to suppose that drivers who take passengers will be less willing than those who do not to divert to public transport if fares are reduced. But to investigate this effect would have required information from public transport users who would have taken passengers had they driven. Thus if travellers who took passengers are excluded from the analysis an unnecessary bias will be introduced. Accordingly the main predictions are made including passenger takers, but the results that would be obtained for car availability and mode choice, were these people excluded, are also presented, on the assumption that car drivers who take passengers will continue to drive to work irrespective of any reductions in public transport fares: this, of course, is unrealistic since some passenger takers would change to public transport if it were free, but the calculation puts a lower bound on the likely diversion.

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* Times were restricted to journeys to work between 06.00 and 10.00 and from work between 15.00 and 20.00.

† One individual, who had made an exceptionally unattractive public transport journey, rather than driving, stated that he had done so purely as an experiment and would never do it again.

4.2 Derivation of estimates

The diversions that would be likely to follow from zero fares were estimated using information on the non-public transport employees represented in the data and the models reported in section 3. Because of the 'proxy' function of the public transport cost variable, explained in that section, this variable was also adjusted to take a value appropriate to public transport employees rather than that for other workers.**

The results of these calculations are set out in Tables 11–13, which refer to the studies of mode choice, car availability and car ownership respectively. In each case, an estimate is given for the diversion which would be caused by free public transport, expressed as a percentage of the number of individuals included in each study. Changes were not estimated in multiple car ownership since that issue did not show a clear relationship with public transport costs.

TABLE 11

Estimated mode choice changes when public transport is made free
(for travellers with a car available)

	Passenger Takers	
	Excluded	Included
Currently car users*	80.3	89.1
Estimated diversion*	14.7	12.4
Standard error*	2.4	1.6
Number of individuals	340	613

TABLE 12

Estimated car availability changes when public transport is made free

	Passenger Takers	
	Excluded	Included
Currently car available*	53.4	67.2
Estimated diversion*	5.4	6.2
Standard error*	2.5	2.0
Number of individuals	661	939

** This adjustment emphasizes the need for the assumption that there is no basic attitudinal difference between the two groups of workers. It is slightly inaccurate, in that some of the public transport workers pay fares for parts of their journeys, but this effect is very small.

* As a percentage of the number of individuals given.

TABLE 13

Estimated car ownership changes when public transport is made free

Currently car owners*	75.9
Estimated diversion*	2.4
Standard error*	1.8
Number of individuals	1043

The effects indicated in Tables 11 and 12 can be combined to give estimates of overall mode changes, as shown in Table 14.

TABLE 14

Estimated mode choice changes when public transport is made free
(all travellers)

	Passenger Takers	
	Excluded	Included
Currently car users*	42.3	59.9
Estimated diversion*	10.8	13.1
Standard error*	2.0	1.8
Number of individuals	661	939

A more common way of expressing the results of Table 14 would be to state that 21.9 per cent of the existing car users would be expected to divert to public transport use (using the figures that include passenger takers). This represents the best estimate of the effect of free public transport which the model can provide, but it must be remembered that the model cannot treat passenger takers differently from drivers who travel alone. If passenger takers are excluded from the model, it predicts that 25.5 per cent of the modelled car users (ie single drivers) would divert, but this would be only 12.2 per cent of all car users. However, this latter case certainly underestimates the diversion, since some of the car drivers who take passengers are likely to switch to free public transport.

The calculations on which these tables are based are outlined in reference 3, which also gives the technical assumptions on which their accuracy rests.

It is interesting to note that although Table 7 in section 3 shows a very strong connection between car ownership and public transport fare, Table 13 predicts a very small (and technically insignificant) diversion consequent on the elimination of fares. This is a further illustration of the substantial proxy effect discussed in section 3. The diversions of Table 14, however, are significantly different from zero at all normal statistical levels.

Sensitivity of public transport demand to fare changes is often expressed as an elasticity, as defined in the economic literature.† This measure is fraught with technical and other difficulties, as outlined by Daly and Gale[2],

* As a percentage of the number of individuals given.

† Elasticity at a point on a demand curve q = q(p), where p is some 'price' measure, is defined by

$$\eta = \frac{dq}{dp} \cdot \frac{p}{q}$$

and in this case further confused by the proxy variable effects. Table 14, however, shows a 33 per cent change in public transport use (19 per cent excluding passenger takers), which is predicted to result from a 100 per cent change in fares. These figures seem consistent with elasticities commonly quoted (typically for 10 per cent to 30 per cent fare increases) of –0.3 overall or slightly lower (in absolute magnitude) for peak hour travel.

4.3 Discussion

Two main aspects of the results presented in the previous section are considered here: first, the reliability and applicability of the results that have been presented, and secondly their relevance to an understanding of traveller behaviour and to transport policy.

Throughout the presentation of model results in this section and section 3, the statistical error associated with the estimates has been given. These errors, however, are 'internal', in the sense that they take account only of errors arising from the fact that the data on which the models were calibrated are a finite set. In setting more realistic confidence levels for the results, it is necessary to take account of the possibility that the models are incorrect or that the data are biased.

The choice of the logit model is of course somewhat arbitrary, but there now exists an extensive literature concerning this form that shows it to be reasonable, and indeed well based in economic theory. The most likely causes of inaccuracy in this model are the omission of relevant variables and the inclusion of faulty data. Some relevant variables have been omitted, as seen in the analysis of section 3 where the household size could not be included in the car ownership analysis. Care is therefore required in interpreting the results for variables closely associated with those omitted. Where no included variables are closely associated with a relevant excluded variable, the effect of the exclusion will simply be to increase the variance of all the estimates, and this will be shown in the error estimates. Even faintly suspicious data has been excluded wherever it was detected. The automatic exclusion of unusual and extreme cases reduces the possibility of one individual influencing the model calibration to an excessive extent.

Systematic exclusions of groups of travellers from the data may of course bias the results. On the other hand the inclusion of groups for whom considerations not included in the model are paramount (eg those who need their car at work, who accounted for about 7 per cent of completed questionnaires) may cause still worse distortion. In each case attempts have been made to balance distortion against loss of information, and although the arguments are not always conclusive, it is unlikely that a reasonable treatment of the data would lead to radically different results.

A definite loss results from the exclusion of data in that the scope of applicability of the models is reduced. Thus the models described in this report referred only to peak-hour work trips by car or public transport (principally central locations) for those workers who had a clear choice between car and public transport. Of course, it is in a sense regrettable that the conclusions are limited in this way, but a study of this specific situation gives more information about the travel choice mechanisms than might be obtained from investigating a more aggregated set of journeys and, in a study which must necessarily be constrained for practical reasons, the journey to centrally located workplaces is arguably the most important situation to consider.

Within these limitations, however, the results that have been obtained are substantial. Most of the numerical estimates that form the basis of the findings are significant at the usual levels of statistical significance. Moreover, although the results are limited in the ways that have been described, the specific situations that are analysed are of considerable interest.

5. SUMMARY AND CONCLUSIONS

The study described in this report examined the way in which travellers chose between using private car or public transport for the journey to work: it compared the travel habits of public transport employees, who could travel free on public transport, with those of a control group of workers in other industries who were chosen to be similar to the public transport employees, but who did not have the free travel concession. A self-completion questionnaire was administered to workers in bus companies and in other industries at nine separate sites in seven cities between June 1975 and January 1976. Response at most sites was excellent, but in two cities there was some organised resistance to the survey and the response at one location in each was very poor. Nevertheless, altogether 3365 useful questionnaires were returned, and these permitted a valid investigation of travel behaviour on one specific day in each of the seven cities.

The data were subjected to careful validation and testing prior to analysis, and these checks showed that a true comparison could be made between the public transport employees and the control group, in that there were no systematic differences in the characteristics of the groups. Testing of the questionnaire replies against independent estimates of the travel times and distances involved also showed good agreement between the values estimated by the respondents and the independent measurements except for the times spent waiting for buses. Statistical techniques were developed to permit incomplete records to be incorporated into the analyses with appropriate weight given to them by comparison with complete records; this was particularly useful, since many records contained much useful information but gave no reply to one or two of the questions (especially the income question) and without this technique such records would have had to be omitted from some of the analyses.

The study examined four related issues:

a) For those respondents who have a car available, what determines whether they go to work by car or by public transport? This mode choice was modelled and calibrated against data from 1167 individuals who were considered to have a free choice of mode.

b) What determines whether a respondent will have a car available? In the survey special attention was paid to the distinction between car availability and household car ownership. Whether or not the analysis assumed that an individual had a car available was based largely on whether or not the individual had said he could have driven to work if he so wished, but this was qualified in some cases by the respondent's answers to questions concerning the reasons for a car not being available, or for his choice of mode. The car availability analysis was based on 2016 individual replies.

c) What determines whether a respondent's household will own a car? This analysis was based on data from 2280 individuals.

d) For those households owning a least one car, what determines whether they will own two cars or more? This analysis was based on data from 1584 individuals.

In each case a linear logit model was set up to represent the choices made by individuals or households. These models represented the influences of various socio-economic factors on the choices made, as well as the influences of the characteristics of the journey to work by both the mode chosen and the alternative mode.

The results obtained from these investigations suggest that:

- socio-economic variables (eg income, age, sex) are very important in explaining both car ownership and availability, but, for respondents who have a car available, much less important in influencing mode choice;

- the difficulty and cost of the public transport journey to work is a very important influence on car availability and use; there is an effect on car ownership also, but it is probably smaller;
- these findings apply equally well in each of the cities surveyed.

To give the results concerning fares a more concrete form, estimates were derived for the changes that might result if fares were to be eliminated for all workers as they are for public transport employees. These estimates are naturally based on a number of assumptions, which are given and discussed in Section 4, but subject to the validity of these assumptions the best estimate is that car use by peak-hour commuters who do not need their car at work would be reduced by 22 per cent (± 3 per cent). The best estimate is that car ownership among commuting households would be reduced by 3 per cent (± 2 per cent). Although the effect of public transport fares on car ownership is small (and not statistically significant) the effect of fares on car availability is much more marked: if public transport were made free, some 10 per cent of those in the control group who had a car available for the journey to work would no longer have the choice and would travel by public transport. Presumably this is because, with concessionary travel, the nature of the competition for the car within the household will change. This finding underlines the importance of distinguishing between car ownership and availability.

Additional valuable information was derived on the other journey factors influencing behaviour and their relative importances, including the values of time spent in different parts of the journey. The values of time suggested by this study were approximately: for time spent walking or travelling on public transport 50p per hour; for time spent waiting for public transport 200p per hour; and for time spent driving 13p per hour. The perceived cost of running a car was 2.0p per kilometre. These values, particularly the wide divergence between driving time and public transport time[†], are somewhat contrary to currently accepted values and it may be that improvements could be made in the time values used in transport scheme evaluations. The value quoted for waiting time is subject to a number of difficulties and reservations, however, and the figure given above is almost certainly overestimated.

The estimates of the diversion to public transport caused by free travel to work, although much less than those given by Goodwin in a similar study[1], still represent a substantial transfer of traffic and this runs counter to much recent thinking which has tended to stress the insensitivity of car use to the characteristics of public transport travel (see, for example, Heggie[8]).

As with any statistical results the findings of this study are applicable only in circumstances of which the data are representative. Particularly important in this context is that the data relate only to peak hour commuters who do not need their car for work, mainly working in city centre locations. Although any policy aimed at attracting car users to public transport might be expected to have its greatest impact on this type of travel, because of the convenience of public transport for peak travel to central locations, such travellers are a vital group to consider in urban transportation planning. The corollary of the effect of free public transport on car availability should also be noted, however, in that cars left at home during the day may well be used by other members of the household, and a shift from car to bus for particular types of journeys does not necessarily imply an overall reduction in car use.

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† Also noted in other studies[4].

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Spode Limited
The Plessey Company Limited
Sheffield City Council
City of Stoke on Trent District Council
International Computers Limited
Yorkshire Water Authority
General Post Office
South West Gas
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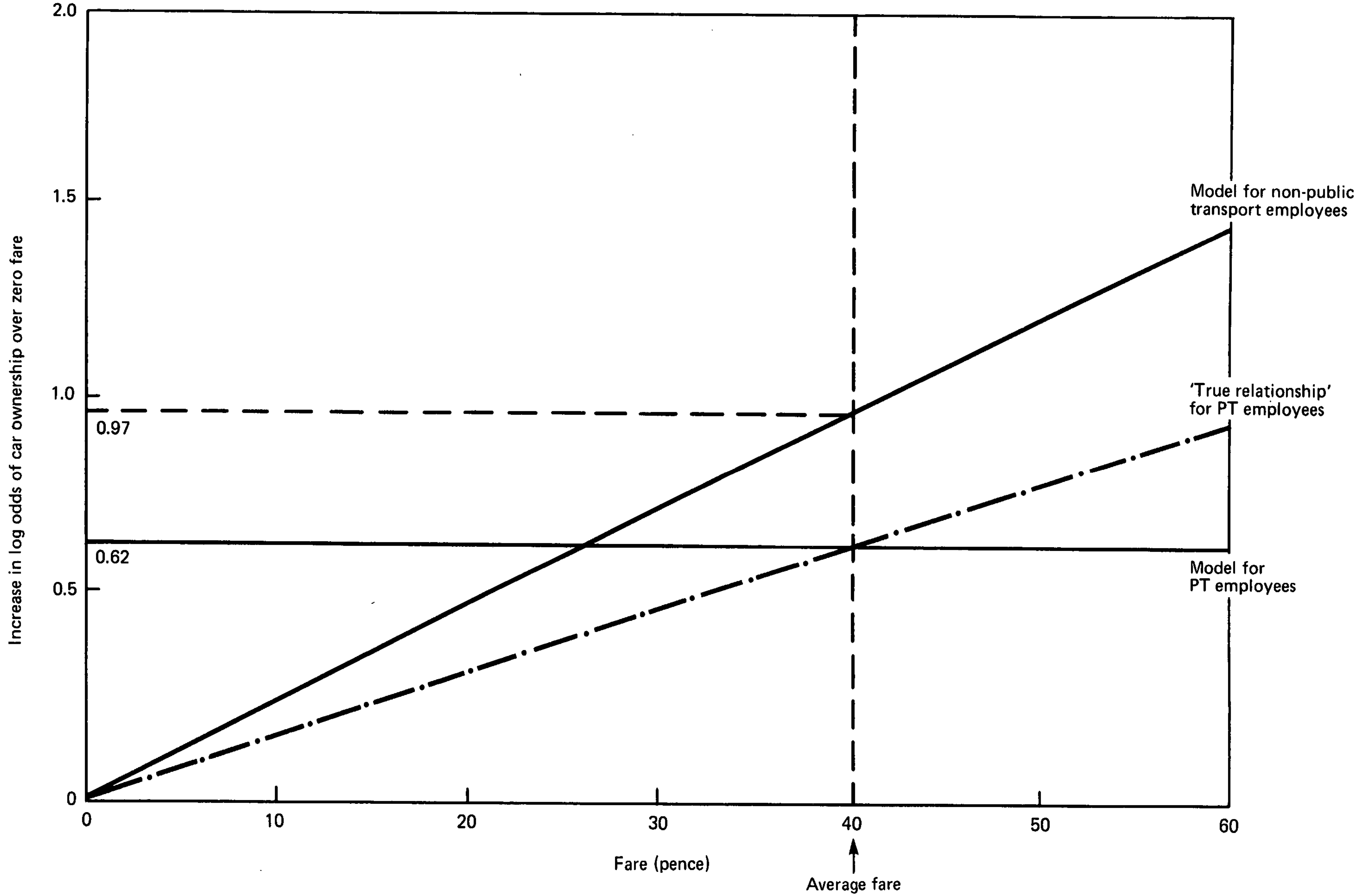

Fig. 1 DEPENDENCE OF CAR OWNERSHIP ON PUBLIC TRANSPORT FARE

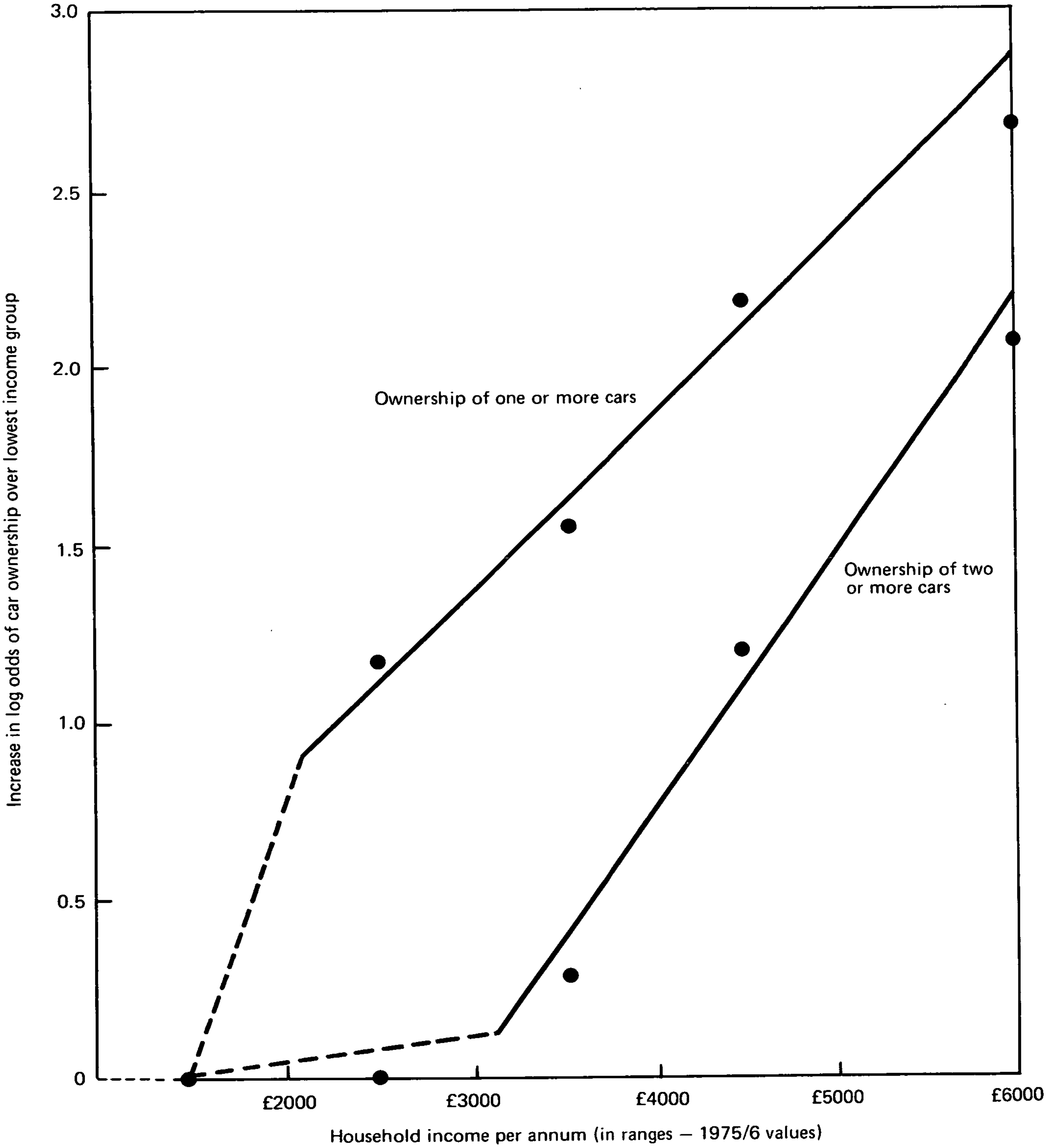

Fig. 2 DEPENDENCE OF CAR OWNERSHIP ON HOUSEHOLD INCOME

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ABSTRACT

The effect of free public transport on the journey to work: A J DALY and S ZACHARY: Department of the Environment Department of Transport, Supplementary Report 338: Crowthorne 1977 (Transport and Road Research Laboratory). The travel habits of public transport employees who had free travel concessions on public transport were compared with those of similar groups of workers who had to pay fares in seven provincial cities. The study used linear logit models to examine the effect of the many different travel and socio-economic factors on mode choice between car and public transport for the journey to work, on car availability for the journey to work, and on single and multiple car ownership.

The results suggested that socio-economic variables were very important in explaining car ownership and availability, but less so in influencing mode choice, while the difficulty and cost of the public transport journey appeared to have an important effect on mode choice and car availability, and less so on car ownership. The best estimate of the effect of providing free public transport for the control group is that car use by peak-hour commuters who do not need their car at work would be reduced by 22 per cent, that 10 per cent of those workers who had a car available for the work journey would no longer have the choice and would travel by public transport if it were free, and that car ownership among commuting households would be reduced by a statistically non-significant 3 per cent. Much additional information on the factors influencing travel behaviour was also obtained, including estimates for the value of travel time of 50p per hour for time spent walking or in a public transport vehicle, 13p per hour for time spent driving to work, and 200p per hour for time spent waiting for public transport, though this latter figure is known to be an over-estimate.

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