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MICROSIMULATION OF ORGANISED CAR SHARING - MODEL PREDICTIONS AND POLICY IMPLICATIONS

by

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CONTENTS

ABSTRACT

BONSALL, P.W. (1979) Microsimulation of organised car sharing - model predictions and policy implications. Leeds: University of Leeds, Inst. Transp. Stud., WP 114 (unpublished).

This paper presents the results of a range of tests of organised car sharing schemes. The performance of the schemes is predicted using a sophisticated microsimulation model. A brief resume of the model is followed by a description of the tests and an analysis of their results. Conclusions are drawn on the place of organised car sharing within broader transport policies, the performance of the model when compared to the available empirical data and directions for public research.

The tests here presented include: a series of sensitivity analyses; tests of organisational strategies for car sharing schemes; tests of schemes in a variety of locations and at a variety of scales and finally a batch of tests which investigate the effect of major changes in the operating environment of car sharing schemes - changes in the price of fuel and public transport fares and the provision of parking space incentives for car sharers for example.

MICROSIMULATION OF ORGANISED CAR SHARING - MODEL MODEL PREDICTIONS AND POLICY IMPLICATIONS

1. INTRODUCTION

1.1 Aims of the study

The primary objective of this study, which was funded by TRRL on a contractual basis, was to provide a state of the art estimate of the likely performance of organised car sharing schemes in Britain. The performance of schemes being expressed both operationally and in terms of their effect on the transport system as a whole - particularly their effect on public transport patronage and private vehicle mileage.

It was hoped that some insight would be gained into the likely scale of these effects and how they might vary with changes in the nature of the schemes - changes in the location and size of the schemes and changes in their operating environment - the price of petrol and the provision of incentives to car poolers for example.

1.2 Other studies

Several studies have addressed themselves to the potential market for organised work journey car sharing (Tomlinson and Kellett 1977, Vincent and Wood 1979, Cambridge Systematics Inc 1976, Atherton et al 1976) but they have been concerned mainly with the potential and theoretical impact of car sharing given present journey-to-work patterns and characteristics. They have been able to contribute little to the estimation of likely impact because they could not estimate how many of the potential matches could or would be realised. Another line of research has been concerned with attitudes to car sharing in an attempt to understand the likely response at the micro level (Margolin et al 1976, Dobson and Tischer 1976, Levin et al 1978, Tomlinson and Kellett 1978, Hawker Siddeley Dynamics 1977). This attitudinal work has provided valuable insights into the likely behaviour of individuals but it is, in itself, not readily adapted for predictive purposes because it is concerned with individuals rather than populations.

It was the aim of this project to bridge the gap between theoretical modelling and attitudinal investigation by developing a model which, while being based on the attitudes and consequential decisions of individuals, could take into account the availability and characteristics of potential partners and could thus predict the impact of a carsharing scheme at both the micro and the macro level. The form of model best suited to this task is microsimulation. The resulting model seeks to represent the interactions between individual decision makers and the manner in which an organised car sharing scheme would operate.

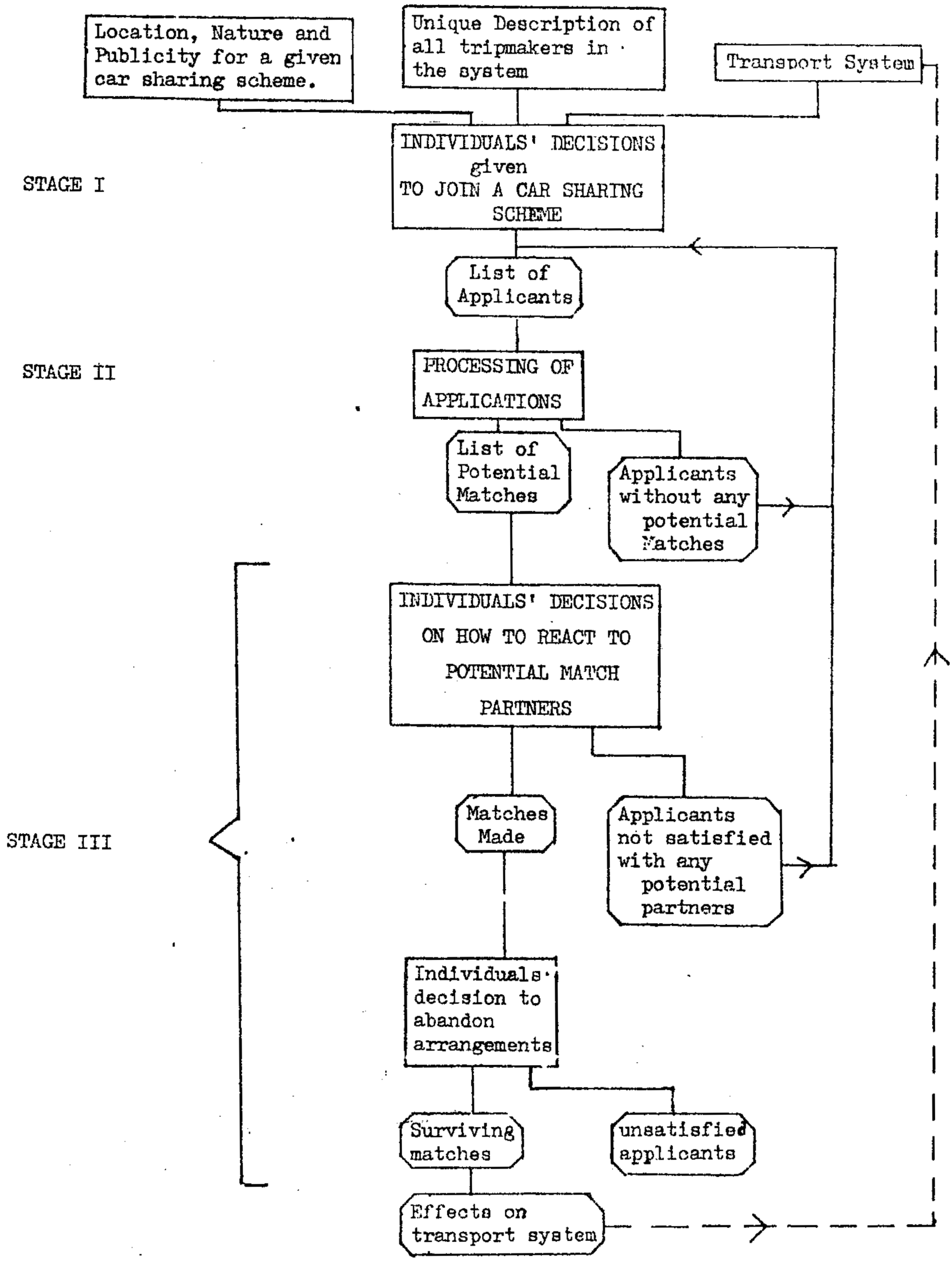
1.3 Summary of the model

1.3.1 The model and its calibration are fully described elsewhere (Bonsall 1979b) but, for convenience, a summary is reproduced here.

The model is based on microsimulation, a technique of computerised modelling within which the decision making process is replicated for individual decision makers within the system. These decision makers effectively become 'actors' within the modelled system. The model is driven by Monte Carlo type sampling.

The simulation suite has three stages, each representing a distinct process in the establishment of an organised car sharing scheme. These three stages are represented in figure 1.1. The first stage is concerned with the scope and intensity of the scheme being simulated and the decisions by members of the public to apply to join it. The second stage deals with the mechanics of matching up potential partners one with another. The third stage deals with the reactions of the participants in the scheme to their proposed partners.

Figure 1.1. OUTLINE STRUCTURE OF SIMULATION SUITE



An appendix to the main model translates the performance of the scheme into its effect on certain critical components of the transport system.

1.3.2 Microsimulation models require, as a fundamental input, a description of each of the actors in the system of interest. In the present case this means a description of all 180,000 peak period trip makers in our study area. Each of these individuals is uniquely identifiable by his identity number and the following characteristics:

- identity of household to which he belongs
- location of residence (6 figure grid ref)
- location of workplace (6 figure grid ref)
- sex
- age (3 age bands)
- employment category (3 types)
- whether head of household
- driving licence tenure
- normal mode of travel to work (7 modes, evening mode is not constrained to equal morning mode ∴ 49 modal combinations)
- whether car needed for business use
- work hours
- household telephone ownership
- number of household members with a driving licence
- number of household members without a driving licence
- a random number seed for Monte Carlo sampling.

The descriptions of these individuals were synthesised on the basis of combined probabilities from a household survey (WYTCONSULT 1976) and control totals from published census material (OPCS a,b). The method of synthesis is described elsewhere (Bonsall and Champernowne, 1979).

1.3.3 The first stage of the simulation suite itself allows the model user to define the scale and location of the car sharing scheme to be tested. This is achieved by defining a 'target population' in terms of their residential location, work location or some combination of the two. The user is also able to specify a 'threshold of interest' which may be taken to represent the intensity of an advertising campaign conducted among the target population.

1.3.4 A calibrated choice model then replicates the decisions by each individual member of the target population whether or not to apply to join the postulated car sharing scheme. These choices are represented by the evaluation of binary logit models for each member of the target population. These models are regression transformations of the form:

$$P_n = \frac{e^{\sum_{i=o}^{21} a_i x_{in}}}{1+e^{\sum_{i=o}^{21} a_i x_{in}}} \qquad 1.1$$

where P_n is the probability of that individual making a type n application to join the scheme (the various types of application being for pooling, driving or riding during the mornings and/or evenings).

a_i are the characteristics of the individual (see section 1.3.2)

x_{in} are calibrated coefficients

The calibration of the coefficients x_{in} was on the basis of a field survey of expressed desire to join an organised car sharing scheme. Details of the calibration procedure and the field surveys are to be found elsewhere (Bonsall 1979a,b).

The value of P_n derived for each individual in the target population is then compared with a random number drawn from a rectangular distribution between o and 1. The ratio of P_n to this number is taken to represent the individual's level of interest in joining an organised car sharing scheme. This interest is then compared with the 'threshold of interest' referred to in section 1.3.3 and if the individual's interest surpasses the threshold then a type n application from him is deemed made.

When all members of the target population have been considered in this way, those who are deemed to have made applications are passed on to the next stage of the simulation.

1.3.5 The next stage of the simulation represents the processing by the scheme organisers of all applications received from the target population. This processing involves the preparation, for each applicant, of a list of those of his fellow applicants whose home location, work location, work hours and type of application make him a potential travelling companion. There will, of course, be some applicants for whom no potential partners can be found.

1.3.6 The next stage of the simulation represents the consideration by each applicant, who has received a list of potential partners, of the worth to himself of entering an arrangement with any of those potential partners. This consideration is on the basis of a calibrated utility model of the form:

$$U_{AP} = \sum_{n=1}^{n} \sum_{m=1}^{m} a_n \, p_m \, x_{nm} + e_{Pn} + \text{feepaid} \qquad 1.2$$

where U_{AP} is the utility of arrangement A to person P

$a_1 \ldots a_n$ are characteristics of the arrangement A (see table 1.2)

$p_1 \ldots p_a$ are characteristics of the person P (see table 1.3)

$x_{11} \ldots x_{nm}$ are calibrated components of utility associated with any person with characteristic m engaging in an arrangement with characteristic n.

$e_{iP} \ldots e_{nP}$ are stochastic elements associated with the utility to person P of an arrangement with characteristic n.

feepaid is the net sum of money, if any, passing to person P in respect of his participation in the scheme.

The calibration of the components x was on the basis on a series of linear regression equations using data from a special survey. The calibration procedure leaves a residual term which we take to be normally distributed and from which we sample to impart a unique (stochastic) element to each of our decision makers. The calibration process and surveys are described elsewhere (Bonsall 1979a,b).

The simulation model is based on the assumption that each applicant will consider all the potential partners on his list and will evaluate the utility to himself of an arrangement with each of them. If any arrangements have a positive net utility to all participants (after the exchange of any fees) then the driver will choose, from among them, that one which has greatest net utility to him and that arrangement is deemed made.

The model proceeds through each of the applicants in turn and replicates their evaluation of the potential travelling partners included on their list.

1.3.7 The model does not attempt to derive a system optimum but to optimise from the point of view of the individual decision makers (in this respect it mirrors the real world). Once two individuals have contracted to travel together they are both out of the market · the model predictions will therefore be a function of the order in which bargains are struck. In the absence of any indication to the contrary, the model assumes that bargains will be struck in a random order.

1.3.8 The model thus has two stochastic elements (the residual term in evaluation of utilities and the order in which bargains are struck) and model results will therefore vary depending on which random number strings are used. In order to reach an average result the model is therefore run five times during each test and mean values of the various indicators are derived. (A confidence interval on this mean is also produced).

2 MODEL TESTS AND PREDICTIONS

2.1 <u>Introduction - scope and purpose of the tests</u>

The tests reported on in this paper are many and various, they include at one extreme, sensitivity analysis of the model and its calibration and, at the other extreme, scenario based policy testing.

Broadly, there are four groups of test. The first group comprises a number of sensitivity tests designed to investigate the significance of some of the assumptions made during the design and calibration of the model suite. The second group of tests examine how the performance of organised car sharing schemes are affected by the procedures adopted during the formation of match lists. The results of this group of tests should thus provide practical guidance for potential car pool organisers. The third group of tests is concerned with the location and intensity of the proposed car pooling schemes and should contribute to the formation of policy on the design and location of schemes. The final group of tests comprise a speculative analysis of the probable effect on car pooling schemes of changes in the broader policy environment - changes in transport costs and parking-space incentives for car poolers for example.

2.2 <u>The conduct of the tests</u>

The general framework for the tests reported on in this paper is adapted from the pivotal method of sensitivity analysis developed at Leeds in a previous project (Bonsall et al, 1977). Within this framework we begin by defining a pivotal model run - using the 'most likely' value of model parameters and the 'best estimate' values of model coefficients. Within the other runs, the model parameters and coefficients are systematically varied one by one - all other parameters and coefficients retaining their default values. Predictions by the pivotal model are then investigated in some depth before being used as the yardstick for analysis of other model runs.

In this way the effect of variation in the various model parameters and coefficients (some of which represent policy variables) can be compared with one another in magnitude and importance.

Table 2.1 lists the model parameters and coefficients which will be tested in the present paper, and shows their default values for use on the pivotal model run.

TABLE 2.1: PARAMETERS AND COEFFICIENTS OF THE SIMULATION MODEL (AND DEFAULT VALUES THEREOF)

Name	Function	Default values
POPULATION	the population base who act within the simulation model	'best' synthesised population as of March 1979
HOMESIN	defines which residence zones are valid for applicants	1 thru' 455 (entire study area)
WORKSIN	defines which employment zones are valid for applicants	1-13 (central Leeds)
THRESHOLD	threshold of interest	8 (level of publicity = that of survey)
APPLYCOEFS	coefficients of decision to make an application	'best' calibrated values as of March 1979
BATSIZE	number of applicants to be processed in current batch	1688 (all applicants)
NOONFORM	maximum number of potential partners to be included on each match list	10
TIMEWINDOW	extent, in time, of search for partners	± 15 minutes
SEARCH	extent and path of spatial search	spiral eliptical search routine as at March 1979
MATCHCOEFS	coefficients of utility of decision to match	'best' calibrated values as of March 1979
MAXFEE	car running cost per 1/10 kilometer upon which driver can base the maximum fee that he may charge his passengers.	unlimited

2.3 Output indicators

In order to provide both for sensitivity analysis and for policy testing a variety of indicators have been included in the model output. They are summarised in Table 2.2. The analysis package produces values and 90% confidence intervals for each indicator. Some of the indicators can, if necessary, also be displayed graphically on a base map of the study area.

The first group of indicators, profiles of applicants and participants, will be of particular interest to policy makers wishing to consider the distributional effects of a car sharing policy. The second group, descriptions of operational performance of the scheme, will be of use to the organisers and managers of schemes. The third group of indicators, however, are the ones of greatest general interest; they describe the effects that the scheme would have on the transport system as a whole.

TABLE 2.2: IMPORTANT MODEL OUTPUTS

Type	Indicator
PROFILE OF APPLICANTS AND PARTICIPANTS IN EACH TYPE OF ARRANGEMENT	Location of homes and workplaces* Length of journey to work Previous mode of travel to work Sex, age and employment status Household background (including cars owned, number of drivers, number of members and telephone ownership) Perceived utility of arrangements Fees changing hands Diversions and delays accepted
OPERATIONAL PERFORMANCE OF THE SCHEME	Number of applicants for each type of arrangement Number of applicants given a match list Number of arrangements initiated Computational cost of matching program
SYSTEM EFFECTS	Work journey public transport patronage numbers of passengers lost passenger kilometres lost Private vehicle usage: kilometres saved kilometres driven within car sharing arrangements* net saving in kilometres driven change in car occupancies vehicles 'liberated' for possible off-peak usage

* can be displayed on a base map.

3 DESCRIPTION, RESULTS AND INTERPRETATION OF THE PIVOTAL MODEL RUN

3.1 Introduction

This section deals with the pivotal model run which provides the yardstick against which all other runs will be considered. Subsequent sections will then consider the four groups of tests outlined in section 2.1.

3.2 The target population

The default values of parameters and coefficients which define the pivotal model run were given in table 2.1. We are using the 'best estimate' model coefficients to run a policy test of an organised car sharing scheme open to all peak period work trip makers employed in central Leeds. This part of Leeds was chosen to be typical of sites that might be considered for a large municipally organised car sharing scheme. It is a commercial area (shops, offices and some service industry) approximately 1 kilometer by ½ kilometer.

The location of the homes and workplaces of members of this target population are shown in figure 3.1. Salient statistics relating to this population are given in column one of table 3.1. It is clear that the population is not atypical of other groups of city-centre workers elsewhere in the country.

3.3 The applicants

When the decisions by each member of this target population whether or not to apply to join the scheme were simulated we found that 1688 individuals applied to join the scheme (=7.9% of the target population). Column two in table 3.1 contains a description of these applicants and may be compared with the target population as a whole which is described in column one.

Comparing these two columns we note that applications have been particularly forthcoming from: men, professional/managerial workers, car drivers, and from persons with a home telephone, peak period journeys or longer than average journeys to work. Conversely, women, manual/shop floor workers, people over 50, car passengers, public transport users, people with no car driving licence or a short journey to work and people from large households or households with no telephone or cars available were particularly reluctant to apply.

FIGURE 3.1 LOCATION OF TARGET POPULATION (PIVOTAL RUN)
- EACH DOT IS AT THE HOME OF AN INDIVIDUAL TRIPMAKER
- WORK LOCATION IS CROSS HATCHED

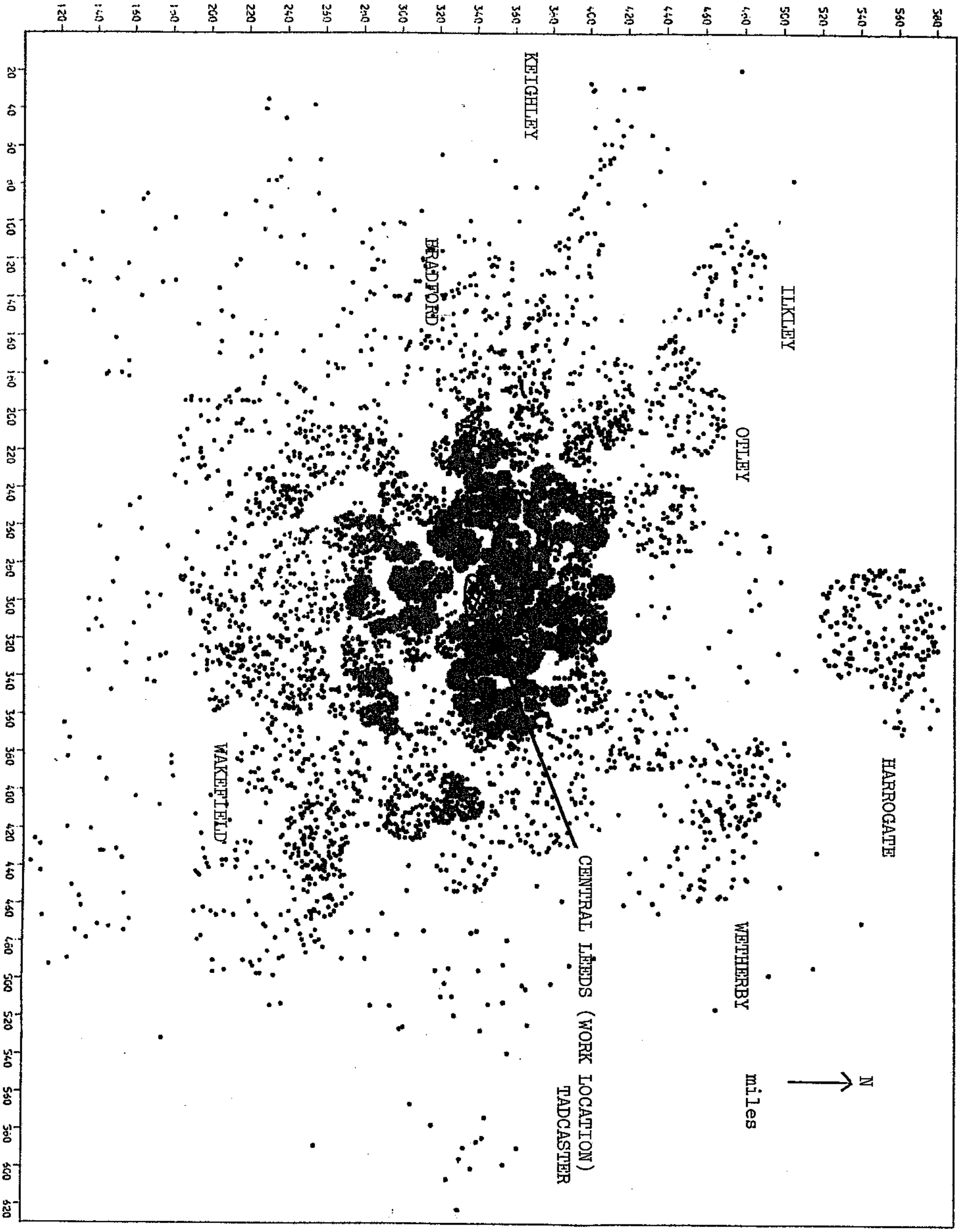


Table 3.1 SUMMARY DESCRIPTION OF PARTICIPANTS AT VARIOUS STAGES OF THE PIVOTAL MODEL RUN (Leeds City Centre Scheme).

	Target population	Applicants	Successful participants
Number	21,235	1,688	327
% male	53.12	64.45	65.46
% 'manual/shop floor' workers	33.84	12.62	11.09
% 'technical/clerical' workers	34.26	39.04	41.77
% 'professional/managerial' workers	31.91	48.34	47.14
% under 30 years old	31.50	32.29	30.20
% 30 to 50 years old	42.22	45.32	47.98
% over 50 years old	26.28	22.39	21.82
% previously solo car drivers (mornings)	24.23	40.4	36.72
% previously accompanied car drivers (mornings)	8.64	15.52	13.82
% previously passengers (mornings)	13.47	5.81	2.29
% previously public transport users (mornings)	47.83	35.07	41.10
% with no car available in hh.	39.65	26.05	30.34
% with 1 car available in hh.	49.53	59.53	56.04
% with 2+ cars available in hh.	10.82	14.42	13.62
% with household phone	60.66	73.65	72.2
% with a car driving licence	50.55	74.76	68.35
% from 1 person households	4.54	8.07	7.97
% from 2 person households	30.28	40.00	38.32
% from 3 person households	21.45	25.52	26.69
% from 4+ person households	43.73	26.73	27.02
% needing car at work	5.11	5.81	n.a.
% whose morning journey = on-peak*	77%	88%	94%
% whose evening journey = on-peak*	64%	79%	83%
average length of journey to work (kms)	5.97	9.10	9.26

* morning peak here defined as 0730 hrs → 0930 hrs, evening peak defined as 1600 hrs → 1800 hrs.

Although middle class males had a higher propensity to apply, the proportion of less affluent, predominantly public transport using people is far from insignificant because of their predominance in the target population. This fact is reflected in the not inconsiderable proportion of applicants who desired to receive rather than to give lifts.

The type of applications made is shown in table 3.2 from this table we note the following facts:

- Applications to receive lifts were the most numerous (561 + 117 + 18 = 696 = 38% of total applications).
  Applications to give lifts made up 32% of the total and the remaining 30% were applications to pool.
- Applications to pool and to take passengers came predominantly from people who were previously drivers.
- Applications to receive lifts came predominantly from public transport users.
- Applications to pool came from people with longer journeys to work than did applications to drive. Applications to ride came from people with even shorter journeys to work.
- Applications for car sharing at only one end of the day came from people with shorter journeys than did applications to share at both ends of the day. Evening-only applications were associated with particularly short journeys.

3.4 The match lists

The next stage in the simulation was the production of 'match lists' (lists of potential travelling companions) for each of the 1688 applicants. In this pivotal run, the production of match lists for all 1688 applicants was effected in one batch. The search for potential partners was carried out using the spiral-eliptical routine which terminates its search when the implied extra diversion for the driver reaches ½ of his journey to work distance. The routine was constrained to reject partners whose work hours were not within ¼ hour of those of the applicant in question. Up to 10 potential partners were sought for each applicant.

The matching process managed to produce match lists for 94% of the applicants. The average number of potential partners on each match list was 6.76. The computing costs of the matching process were about £15, (at commercial rates as charged by Leeds University).

Table 3.2 DESCRIPTION OF APPLICATIONS MADE IN PIVOTAL MODEL RUN.

type of application	Number of applications						average journey length of applicants (kms)
	from previously solo drivers	from previously accompan'd drivers	from previous passengers	from previous public transport users	from previous other mode users	Total	
to pool (alternate driving)	292	146	31	71	5	545	10.66
to drive - morning and evening	248	108	14	15	1	386	10.28
to drive - mornings only	143	31	1	13	9	197	9.86
to drive - evenings only	3	3	0	0	0	6	4.02
to ride - mornings and evenings	62	-	50	415	34	561	7.78
to ride - mornings only	24	-	6	82	5	117	5.55
to ride - evenings only	0	-	2	16	0	18	3.61
any type of application*	772	288	104	612	54	1830	9.19

* note that statistics relating to applications will not necessarily be equivalent to those for applicants because each applicant may make more than one application.

3.5 The decisions to form arrangements

3.5.1. The final stage in the simulation was the decision by each of the applicants who received a match list whether or not to form a car sharing arrangement with any of the people on his list. A description of those people who did decide to enter an arrangement is given in column 3 of table 3.1. It is interesting to compare this column with the preceding ones which describe the applicants and the target population respectively. Among other features we note the following:

- 327 people actually entered car sharing arrangements (= 19% of applicants or 1.5% of the target population).
- 'Technical/clerical' workers and persons between 30 and 50 years old were marginally more successful in finding compatible car sharing partners than were other people.
- If we consider the previous modes of travel of applicants and successful participants, we note that people previously travelling by car were less likely to find suitable travelling partners than were those who previously used public transport. (This is reflected in the higher success rate for people from non-car-owning and non-telephone-owning households).
- It is something of a surprise to note that the mean trip length of successful participants is longer than that of applicants. Presumably the geometrical relationship (which ensures that the greater the journey distance then the less the probability of finding a near neighbour with the same workplace), is swamped by the greater enthusiasm of long distance travellers for car sharing.
- People who travel in the main peak periods are more likely to find compatible travelling companions than are those with more eccentric work hours. The reason for this is obviously that they have more potential partners to choose from.

3.5.2 Table 3.3 compares applications made with arrangements eventually formed. The table is disaggregated by the type of arrangement and the previous mode of the participant. From this table it is apparent that lift requestors are slightly more likely to be satisfied than are lift offerers. Applicants for car pooling (alternate driving) are significantly less likely to be satisfied. Persons wishing to ride or drive for only one journey per day are less likely to be successful than those wishing for two journeys per day (the evening only applicant is particularly unlikely to succeed)½ Persons who were previously 'other mode' users

Table 3.3 Successful participants per 100 applications made

Type of arrangement	Previous mode of travel					Total
	Solo driver	Accompanied driver	Car passenger	Public transport	Other	
Pooling	9	8	8	11	-	9
Drive - morning and evening	23	27	17	11	-	23
Drive - morning only	10	10	-	9	12	10
Drive - evening only	3	11	-	-	-	9
Ride - morning and evening	28	-	26	25	15	25
Ride - morning only	25	-	26	23	28	24
Ride - evening only	-	-	-	3	-	2
Any type of arrangement	16	16	19	22	14	18

seem particularly unlikely to be sufficiently pleased with any of the arrangements offered to them to cause them to become car sharers. Persons who previously travelled by public transport however, appear more likely to be satisfied. (Previous public transport users make up 35% of applicants but 41% of participants).

3.5.3 Table 3.4 shows, for applicants and for successful participants, the relationship between their distance to work and their type of application.

Table 3.4 DISTANCES TO WORK (KMS) - APPLICANTS AND PARTICIPANTS.

type of application	applicants	successful participants
pooling	10.66	14.10
driving - mornings and evenings	10.28	10.58
driving - mornings only	9.86	10.21
driving - evenings only	4.02	8.10
riding - mornings and evenings	7.78	8.13
riding - mornings only	5.55	4.83
riding - evenings only	3.61	5.70
all types of application	9.10	9.26

We note that pooling is characterised by the longest distances and riding by the shortest. Arrangements for only 1 journey per day are generally preferred by people with much shorter journey distances. When the matches are actually made we find that long distance travellers are more successful overall and particularly within pools. The very short distance travellers requiring arrangements for only one journey per day tend not to be satisfied.

3.5.4 We must now consider the overall impact on the transport system of the organised car sharing scheme here modelled. The following results are of particular interest:

- The work journey modal split (AM peak) of the target population changes from 46.35% private car to 47.02% private car.
- The demand for city centre car park spaces falls from 6981 to 6957 (24 fewer spaces are required - a reduction of 0.34%).
- The weekly peak period work trip public transport patronage falls by 10,708 passenger kilometres from 600750 to 590042 - a reduction of 1.78%.
- The weekly peak period work trip private vehicle kilometres travelled falls by 1423 kilometres from 453,896 to 452,473 - a reduction of 0.31%.

Clearly the effect of this car sharing scheme on the transport system is marginal. Its most significant effect is the reduced demand for peak period public transport.

3.5.5 Turning from this global summary of the scheme's effect on the transport system to a more detailed analysis of the matches actually made, we find the following points of particular interest.

- Of total participants who actually join schemes; 52% are fee paying passengers, 33% are fee paid drivers and only 15% are true poolers (alternate driving - riding). We also find that 85% of aggreements are for two journeys per day.
- 54% of poolers, 63% of paid drivers and 13% of paying passengers were previously solo drivers.
- 15% of poolers, 3% of paid drivers and 74% of paying passengers were previously public transport users.
- Mean car occupancies within true car-pools and simple lift giving arrangements are 2.01 and 2.57 persons/car respectively. The comparatively low occupancies within true car pools is a result of the much lower probability which a driver has of finding two other drivers (whose home and work locations are such that any of the three could conveniently give a lift to the other two) than he has of finding two passengers whom he could pick up en route to work.

- The arrangements contracted involve 15 cars which were previously unused (9 of these are required by new car poolers only on those days when they act as driver in their pool).
- The arrangements contracted 'liberate' 47 cars which are no longer required (23 of these are liberated by new car poolers and are therefore available only on those days when not required within the pool).
- the arrangements contracted liberate 17 cars in households where there are more drivers than cars (6 of these are liberated by new car poolers).
- The net reduction in private vehicle usage of 1,423 kilometres per week is due almost entirely to pooling arrangements (within simple lift giving arrangements increased use by drivers is almost exactly offset by reduced use by passengers).
- The lift giving arrangements contracted involve a transfer of utility units from passengers to their drivers. In monetary terms the average driver receives £3.75 per week (= 3.7 pence per kilometer travelled) and each passenger gives £2.39 per week (= 2.98 pence per kilometer carried). The rates per kilometer travelled for arrangements involving only one journey per day are about 40% higher than for arrangements involving two journeys per day.
- The total utility (to participants) of matches made is £537 per week.*
- The utility* per person averages £4.71 for each pooler and £1.16 per participant in simple lift giving schemes.
- Diversions to pick up passengers cause the average pooler to drive an extra 4 kms. (2 kms. morning and 2 kms. evening) on each day that he is the driver - this represents an increase of about 14% on his distance travelled on those days.
- Diversions to pick up passengers cause the average paid driver to drive an extra 2 kms (1 km morning and 1 km evening) each day - this represents an increase of about 11% on his daily distance travelled. (It is partly as a result of these massive diversions that the net reduction in vehicle usage is so small).

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* This utility being the excess of what participants would have been willing to pay over what they actually did have to pay.

3.5.6 The policy implications of this pivotal model run will, no doubt, already be forming themselves in the minds of the perceptive reader. Before considering these implications, however, we will present the results of the other model tests. Discussion of policy issues is reserved for section 8 of this paper.

4. THE SENSITIVITY ANALYSES

4.1 Introduction

The tests included under this head were designed to investigate the sensitivity of model predictions to changes in certain model assumptions:

1. That the model of propensity to make an application should be calibrated on positive answers to the question "would you make use of an information system...." which was posed in our field survey (see Bonsall 1979a). An alternative assumption (tested here) is that we should assume applications from any eligible person expressing any interest at all in car sharing.

2. That we should disregard applications from people who appear unable to participate in the scheme in the stated manner (- eg because they have no car and yet are offering to give lifts). We will here test the effect of accepting all applications even if the applicants appear ineligible.

3. That the calibration of match utilities should be based on data from all respondents. We will here test the effect of excluding data which appears counter-intuitive (see Bonsall 1979b pp.34-36).

4. That the calibration of match utilities is best carried out on a transformed data set in order to maximise normality. We will here test the effect of not transforming the data, (see Bonsall 1976b section 3.3.3).

5. That a mechanism should be built into the microsimulation program to set counter intuitive valuations of match utility to zero (Bonsall 1979b pp. 36-39). We will here test the effect of omitting this mechanism.

6. In the pivotal run it was assumed that passengers would be willing to compensate their drivers with an amount* as great as their perceived utility of receiving the lift. We will here test the assumption that no passenger would be prepared to pay more than the bus fare.

* This compensation, although here expressed as a transferal of money might in practice involve gifts in kind or (rather difficult for us to quantify) friendship.

4.1.2 A sensitivity analysis was also carried out to examine the impact on model results of the order in which bargains are struck in the simulation model (see Bonsall 1979b, p.18). This analysis involved running the model five times with all inputs held constant except the random number string which determines the order in which bargains are struck. The conclusions from this test were that changing the order in which bargains are struck has a very marginal (≤ 2%) effect on model results. This conclusion being arrived at from inspection of the variances. Nevertheless, it remains quite probable that significant changes in system performance would result from a careful arrangement of the order in which bargains are struck. (A complex ordering might be devised in order to aim for a system optimum). However such an arrangement would not occur by chance on the field and is unlikely to be attempted as a matter of strategy. Its investigation and testing is therefore not warranted at the present time.

4.2 Results

Table 4.1 contains a summary of the results of the six tests described above. The table enables comparison of the value of each indicator from a given test with its value in the pivotal run. We will now consider the results of each test in turn.

4.2.1 The first test (propensity to apply calibrated on respondents expressing any interest at all in car sharing) results in a 17% increase in the number of applicants. This increase is most marked among people wishing to give lifts (because it is they who, in the survey, were particularly keen to make their own arrangements rather than to use a matching system).

The 17% increase in applications results in a 19% increase in participants (because the larger number of applicants allowed the matching system to work more efficiently).

The increased number of participants is associated with further reductions in demand for parking spaces, for peak period public transport and private vehicle kilometres travelled (VKT).

The less rigorous definition of 'applicants' within the calibration results in a lower mean trip length for applicants and for participants. The lower mean utilities and compensations result from the lower mean trip lengths and the increased number of drivers (reducing their competitive position and hence the compensation which they are offered).

Table 4.1 Results of sensitivity analyses (for description of tests see section 4.1)

Indicator	value of indicator for:								
	Pivotal run	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Pivotal run with confidence interval added	Pivotal run with confidence interval subtracted
total applicants	1688	1975	2269	These indicators will be unchanged for tests 3-6 because these tests do not involve rerunning the model which simulates the decisions to make applications					
applications for pooling	545	673	885						
applications to give lifts	589	742	831						
applications to receive lifts	696	760	859						
% of applicants who previously used public transport	35.07	33.52	31.78						
mean distance to work of applicants (kms)	9.10	8.80	9.54						
number of successful participants	327	388	455	402	257	437	279	348	306
number of participants in car pools	49	57	88	56	44	124	42	59	39
number of participants giving lifts	109	130	144	134	86	122	91	118	100
number of participants receiving lifts	169	201	223	212	127	191	146	184	153
mean car occupancy with arrangements	2.45	2.45	2.43	2.48	2.37	2.38	2.49	2.48	2.42
mean distance to work of participants (kms)	9.26	8.87	8.36	9.32	8.97	9.69	9.76	9.63	8.85
number of cars 'liberated' in households with more drivers than cars	17	19	36	17	15	38	15	20	15
number of participants who previously drove solo	120	131	174	147	95	177	105	130	110
number of participants who previously used public transport	135	162	178	180	108	159	117	144	126
mean diversion experienced by participants (kms. per week)	11.82	11.02	9.84	12.43	9.7	14.71	12.53	12.75	10.88
reduction in demand for peak period public transport (pass.kms.per week)	10708	12184	12376	14250	8043	12967	9562	11338	10077
net reduction in peak period use of vehicles (kms. per week)	1423	1528	3010	648	1288	3518	1711	1835	1012
net reduction in daily demand for parking spaces	24	28	63	18	15	49	24	28	21
compensation offered to average driver giving lifts morning and evening									
a) pence per week	375	364	343	391	355	440	322	n.a.	n.a.
b) pence per km,	3.70	3.66	3.62	3.66	3.71	4.31	2.99	n.a.	n.a.
total net utility of the scheme to participants (£ per week)	537	609	703	1007	376	1449	517	600	474
mean utility of the scheme to each participant (pence per week)	164	157	154	251	147	332	186	177	151

4.2.2 The second test (propensity to make an application calibrated on respondents' stated desire to use a matching system even if the respondents appeared ineligible to make an application of that type) resulted in a 34% increase in applicants. Particular increases are apparent among would-be poolers (62%) and would-be lift givers (41%) because it is amongst these that the eligibility constraint is most significant.

The 34% increase in applicants grows to a 39% increase in participants. The 80% increase in successful poolers reflects the importance of having an adequate population for the matching system to work effectively.

The number of car park spaces saved, cars liberated and peak period private vehicle kilometres saved all increase by at least 100%. Reduced demand for peak period public transport, on the other hand, increases by only 15% - this obviously reflects the reduced proportion of applicants who previously relied on public transport.

The reduced mean rates of compensation reflect the increased number of would-be drivers (⟶ reduced competitive position).

4.2.3 In the third test (match utilities calibrated on a data set from which counter-intuitive values have been removed), we find a 23% increase in the number of successful participants.

Mean diversions within arrangements are increased and this contributes to a less marked reduction in peak period VKT.

There is an increased reduction in demand for peak period public transport but a reduction in the number of parking spaces saved.

4.2.4 In the fourth test (match utilities calibrated without normalisation prior to the regression), we find a 21% reduction in the number of successful participants.

Participants have lower mean trip lengths. The reduction in demand for peak period public transport is less marked as is the saving in VKT and parking spaces.

4.2.5 In the fifth test (evaluation of match utilities not subject to a sieve for counter intuitive valuations), we find a 33% increase in the number of participants.

There is a higher proportion of true car pooling. The reduction in peak VKT is up 147% and there is a corresponding doubling in the number of parking spaces saved. There is only a 21% increase in the reduction of demand for peak period public transport.

4.2.6 In the sixth test (compensation greater than bus fare not allowed for), we find a 15% reduction in the number of participants.

Car occupancies are up (perhaps because fewer drivers feel that they get sufficient compensation to carry only one passenger).

Savings in peak VKT are increased by 20% and the reduction in demand for peak period public transport is 10% less.

The mean net utility to participants is increased because the reduced compensation (not included as a net utility because it is a transfer payment) does not tempt drivers to give lifts which are particularly irksome to them.

4.2.7 Having considered each of the six sensitivity tests in turn we will now compare the magnitudes of their impacts with one another and with the 90% confidence interval on the pivotal model run. (Column 9 in table 4.5 shows for each indicator the mean value from the pivotal run plus the confidence interval while column 10 shows the result of subtracting the confidence interval from the mean value).

We find that the number of participants varies from 455 (test 2) to 257 (test 4) whereas the 90% confidence interval on the pivotal run gives a variation from 348 to 306.

The number of true poolers varies from 124 (test 5) to 42 (test 6) - (pivotal run 90% confidence range = 59 to 39).

Cars liberated for possible off peak use varies from 38 (test 5) to 15 (test 6) - (pivotal run 90% confidence range 20 to 15).

Peak VKT saved varies from 3518 (test 5) to 648 (test 3) - (pivotal run 90% confidence range 1835-1012).

Reduction in peak period public transport patronage (pas kms per week) varies from 14250 (test 3) to 8043 (test 4) - (pivotal run 90% confidence range 11338 to 10077).

Reduction in demand for parking spaces varies from 62 spaces (test 2) to 15 spaces (test 4) - (pivotal run 90% confidence range 28 spaces to 21 spaces).

The conclusion from this analysis must be that certain of the model results are very sensitive to the model assumptions tested here. We must draw particular attention to the results of tests 4 and 5. Clearly there is a case for examining in more detail the whole question of the calibration of match utilities if we wish to reduce the margin of error of the model.

Table 4.2 Global results of sensitivity analyses (for description of tests see section 4.1)

Indicator	value of indicator before introduction of the scheme	value of indicator in:								
		Pivotal run	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Pivotal run plus confidence interval	Pivotal run minus confidence interval
applications as a % of target population	-	7.94	9.30	10.69	(not different from the pivotal run)					
successful participants as a % of target population	-	1.5	1.8	2.1	1.9	1.2	2.1	1.3	1.6	1.4
% of participants who previously used public transport	-	41	42	39	44	41	36	42	41	41
peak period work trip VKT per week	453896	452473	452368	540886	453248	452608	450378	452185	452061	452884
reduction in peak VKT as a % of the 'before' total	-	0.31	0.34	0.66	0.14	0.28	0.78	0.38	0.40	0.22
peak period work trip public transport patronage (pass.kms/week)	600750	590042	588566	588374	586500	592707	587783	591188	589412	590673
reduction in peak public transport usage as a % of the 'before' total	-	1.78	2.03	2.06	2.37	1.34	2.16	1.59	1.89	1.68
car parking spaces required (per day)	6981	6957	6953	6918	6963	6966	6932	6957	6953	6960
reduction in park space requirement as a % of the 'before'	-	0.34	0.40	0.90	0.26	0.21	0.70	0.34	0.40	0.30
modal split (% private)	46.38	47.02	47.15	47.24	47.25	46.89	47.13	46.92	47.06	46.97

4.2.8 Having considered the absolute magnitude of differences between the various sensitivity tests it is now important to put these differences in a proper perspective. Table 4.2 shows values for some of the system indicators which have particularly strong policy implications.

The Table shows how these indicators vary with each of the tests and allows comparison with the situation before the introduction of an organised car sharing scheme. The last two columns in the table show the range of values that fall within the 90% confidence interval for the pivotal run.

From this table it is quite clear that the results of all the sensitivity tests are very close to that of the pivotal run:

The application rate approximates to 10%.
The participation rate to somewhat under 2%.
About 40% of participants previously used public transport.
The reduction in VKT is considerably less than 1%.
The reduction in peak public transport patronage approximates to 2%.
The reduced demand for parking spaces is less than 1%.
........and so on.

Clearly none of the sensitivity analyses have caused a significant change in the variables which are most likely to be used in policy formulation.

5. TESTS OF THE ORGANISATIONAL STRUCTURE OF CAR SHARING SCHEMES

5.1 Introduction

In this group of tests we analyse how the performance of the car pooling scheme under investigation is affected by the procedures adopted during the formation of match lists. The procedural parameters tested here are:

The maximum number of potential partners to be included on any applicant's match list, and

the size of the 'time window' used in searching for prima-facie matches.

5.2 Results

Table 5.1 shows how certain important indicators are affected by changes in the maximum number of people on each match list and in the extent of the timeband within which the search for potential matches is made (Figures 5.1 and 5.2 show graphical representations of these).

Table 5.1 Effect of changes in matching system procedures
(values in parentheses indicate % change from pivotal value)

Indicator	test: Pivotal run	max number on form				extent of time window (each timeband = ¼ hour)	
		7	5	3	1	own timeband only	own timeband ± 2 timebands
number of participants	327	290 (-11)	253 (-22)	205 (-37)	120 (-63)	261 (-20)	333 (2)
reduction in peak period public transport usage	10708	9200 (-14)	7884 (-26)	5827 (-45)	3209 (-70)	9185 (-14)	10996 (3)
reduction in peak period car travel (kms/week)	1423	1637 (15)	1158 (-19)	1128 (-21)	771 (-46)	547 (-62)	1868 (31)
reduction in parking spaces required	24.48	22.6 (-8)	17 (-31)	13.8 (-44)	9.1 (-63)	18 (-26)	25.2 (3)
utility of the scheme to participants (£)	537	472 (-12)	406 (-24)	315 (-41)	173 (-68)	442 (-18)	543 (1)
cost* of the matching process	150	97 (-35)	72 (-52)	56 (-63)	37 (-75)	140 (-7)	180 (20)
cost* per park space saved	6.2	4.3 (-31)	4.2 (-32)	4.1 (-34)	4.1 (-34)	7.7 (24)	7.1 (15)
cost* per 100 peak period public transport passenger kms saved per week	1.44	1.1 (-21)	0.9 (-36)	1.0 (-29)	1.2 (-14)	1.5 (7)	1.6 (14)
cost* per 100 kms of peak period car use saved per week	10.5	5.9 (-44)	6.4 (-39)	5.0 (-52)	4.7 (-55)	25.5 (142)	9.6 (-9)

* 'cost' is here expressed in notional units derived from the computing costs of the matching process. This interpretation in monetary terms would be purely speculative since it should properly include elements for staff time, stationery and much else besides. We are here interested in the relative rather than the absolute, of the different sorts of scheme. Having said that, however, it would not be inappropriate to denote these units shown in the tables as pounds sterling.

FIGURE 5.1 Percentage Changes in Various Indicators Resulting from a Change in the Maximum Number of People on each Match List

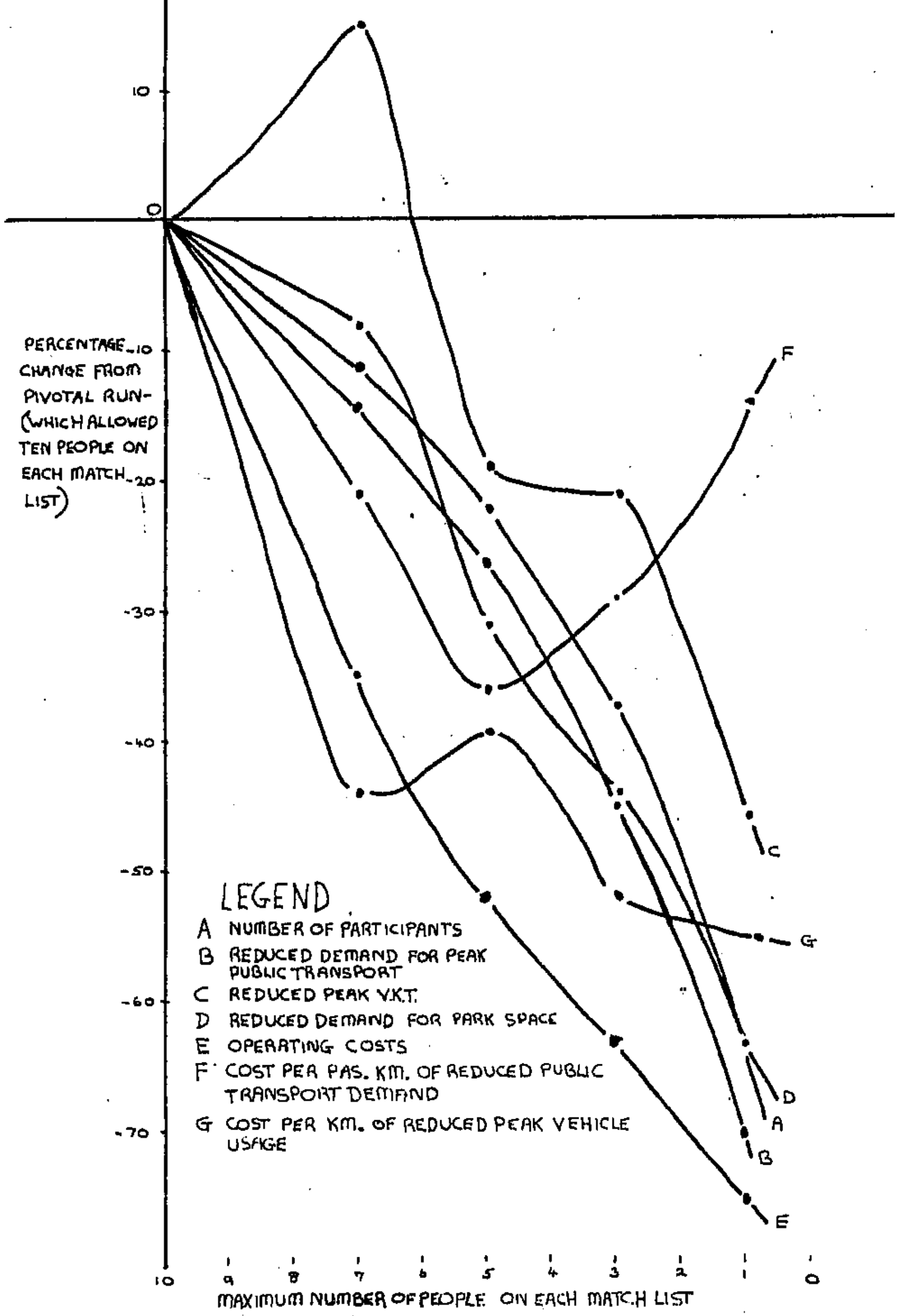
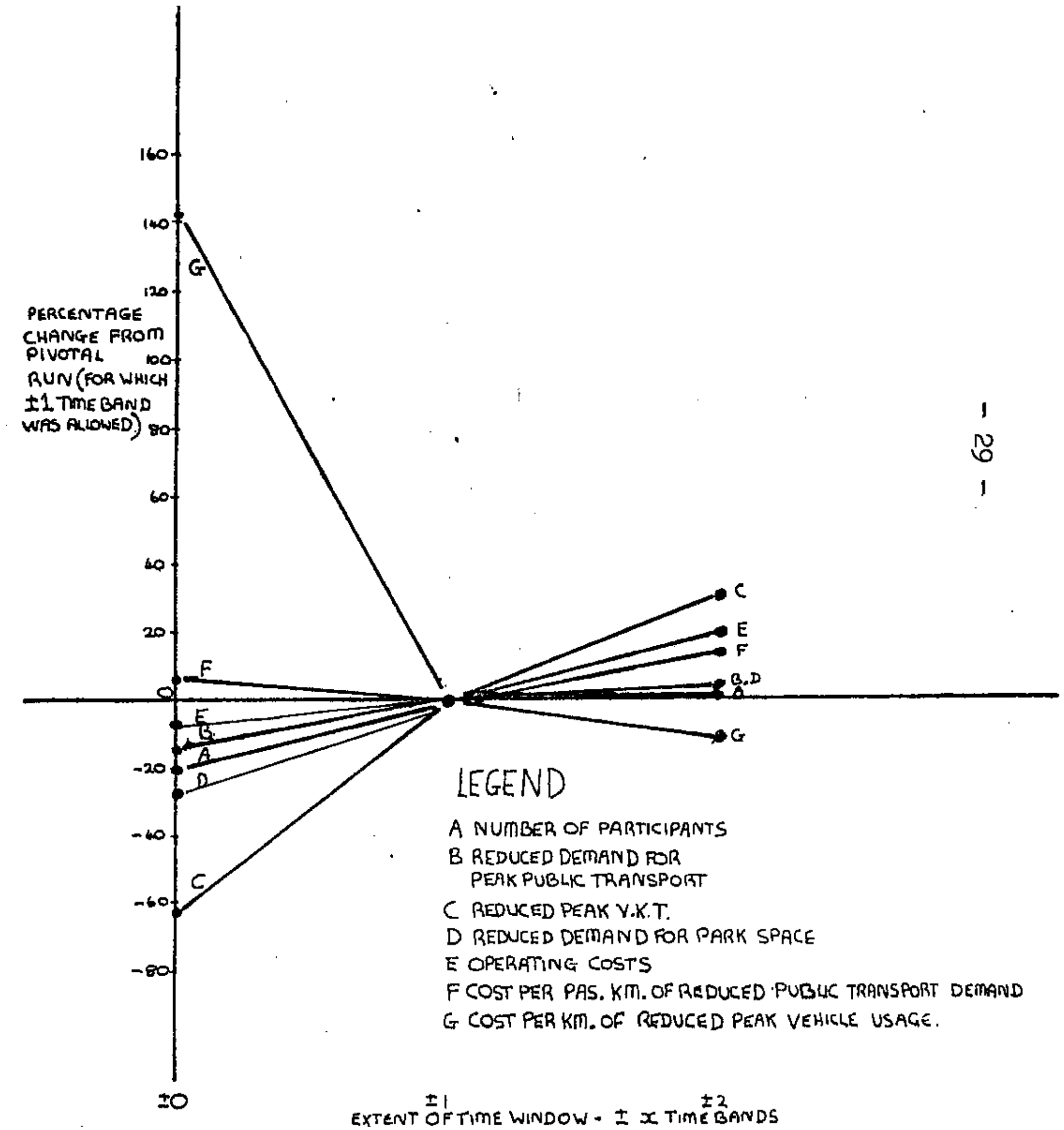


FIGURE 5.2 Percentage Changes in Various Indicators Resulting from a Change in the Extent of the Time Window



5.2.1 As expected, reducing the maximum number of people on the match list decreases both the effects of the car sharing scheme and its cost of operation. We note (with reference to Figure 5.1) that the reduction in costs tends to decelerate as we reduce the maximum number of persons per form (the cost difference between 7 and 5 is greater than between 3 and 1) while the reduced effectiveness of the scheme tends to accelerate. If we were concerned only with maximising the cost effectiveness of the matching system then clearly we will decide that the optimum maximum number of persons per form is between 3 and 5. In practice, however, the overall costs of a car sharing scheme will be dominated by staffing and publicity costs which are not proportional to the number of persons on a match list. When these costs are included the optimum number of persons per match list will rise from about 4 to about 10 (the precise number will obviously depend on the costs of publicity and staffing arrangements).

5.2.2 In examining the effect of extending or contracting the width of the time band within which the search is conducted (i.e. Figure 5.2) we note, with no surprise, that the measures of scheme impact (curves A to D) show decreases when the time band is contracted and increases when it is expanded. We note also that the reduction in cost (curve E) obtained by searching in one time band only is less than the consequently reduced effectiveness of the scheme (curves A, B, C and D). The increased costs incurred when 2 time bands are used are greater than the increased effectiveness except in respect of reduced VKT (curve C). In terms of cost-effectiveness, therefore, the optimum time window will approximate to ±1 ¼hr time band unless savings in VKT are thought to outweigh all other benefits of organised car sharing - if such be the case then a wider time window is to be preferred.

6. TESTS OF SCHEME LOCATION AND INTENSITY

6.1 Introduction

6.1.1 Our first group of tests under this heading was designed to investigate how the performance of a scheme is related to the characteristics of the target population. We tested schemes within which the target populations vary in size, location and composition. Schemes were tested for eight target populations (coded A-H):

A	city centre offices	employment based
B	inner suburb industrial	employment based
C	outer suburb industrial	employment based
D	inner suburb industrial	employment based
E	mid suburb industrial	employment based
F	Garforth	commuter oriented
G	Harrogate/Knaresborough	commuter oriented
H	Otley	commuter oriented

6.1.2 In our second group of tests we investigated how the performance of the scheme is affected by the strength of the public's reaction to a call for applications. (The strength of this reaction may result from variations in the intensity of any attendant publicity campaign but a discussion of this question is beyond the scope of the present paper). In this group of tests we are particularly interested in the relationship between the number and type of applications received and the effectiveness of the matching system.

These tests involved variation in the 'threshold of interest' which is used in the determination of applications (see sections 1.3.3. and 1.3.4). Note that it is not possible to estimate the intensity of publicity campgain represented by any given 'threshold of interest' (except that threshold 8 represents the level of publicity which accompanied our calibration surveys) (see Bonsall 1979a).

6.2 Descriptions of the Target Populations

Table 6.1 shows the target populations for each of the schemes tested. Figure 6.1 shows the location of these populations.

In comparing the various target population note in particular the following points:

The populations are all considerably smaller than that of the pivotal run.

The Scheme A (City Centre offices) population has a somewhat smaller proportion of manual workers and of males.

The Scheme B (inner suburb industrial) population has a much higher proportion of manualworkers, a high proportion of people walking to work, lower car ownership and telephone availability.

The Scheme C (outer suburb industrial) population has a high proportion of males and manual workers; short journeys to work and a consequent high proportion of walking.

The Scheme D (inner suburb industrial) population differs from the other inner suburb industrial population (scheme B) in having a very high proportion of females and of 'technical'/clerical' employees. This is associated with low licence tenure and car use.

The Scheme E (mid suburb industrial) population is overwhelmingly male and manual, has short journey lengths and a high proportion of walking.

FIGURE 6.1 LOCATIONS OF HOMES AND WORKPLACES OF VARIOUS TARGET POPULATIONS (FOR SCHEMES A TO E DOTS SHOW HOME LOCATIONS, FOR SCHEMES F TO H THEY SHOW WORK LOCATIONS)

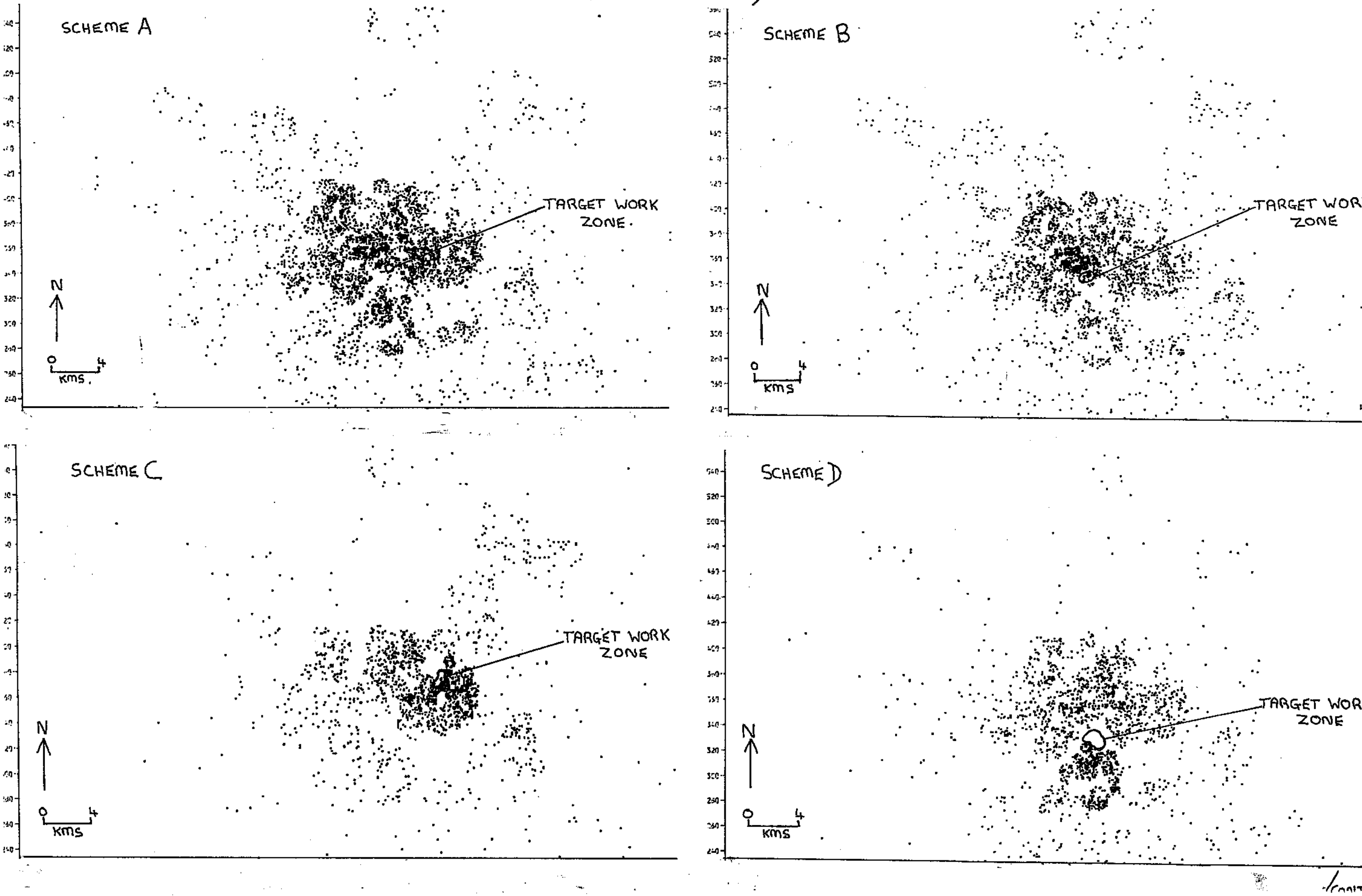


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FIGURE 6.1 (CONTINUED)

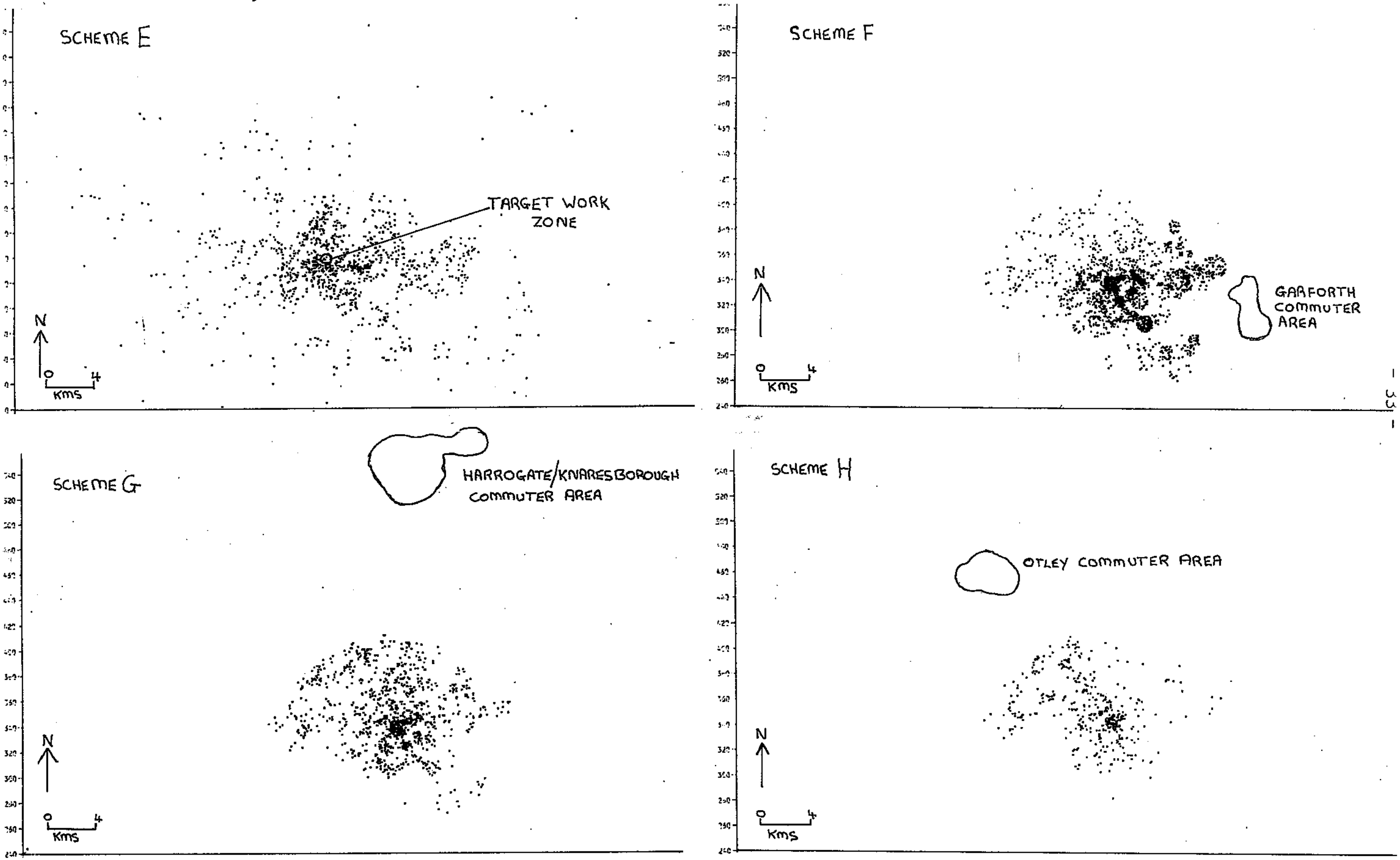

Table 6.1 Description of target populations for tests of scheme location and intensity

Indicator	value of indicator for: Pivotal study area	Scheme A (city centre offices)	Scheme B (inner suburb industrial)	Scheme C (outer suburb industrial)	Scheme D (inner suburb industrial)	Scheme E (mid suburb industrial)	Scheme F (Garforth)	Scheme F (Harrogate/ Knaresboro)	Scheme H (Otley)	The tests of scheme intensity
target population	21235	4985	3536	2292	2262	1246	2930	1579	521	2036
% 'manual'	34	32	48	46	36	62	49	49	53	36
% 'technical'	34	35	31	28	40	15	27	17	14	33
% 'professional'	32	33	21	27	24	23	24	34	33	31
% male	53	51	52	63	39	88	59	84	75	51
% 30 yrs old	32	31	33	32	32	29	30	29	31	31
% 30-50 yrs old	42	42	42	41	43	41	43	44	44	41
% 50 yrs old	26	26	25	26	25	30	26	27	25	28
mean distance to work (kms)	6.0	5.9	5.8	5.1	5.6	5.3	9.9	21.1	13.7	5.9
Prior mode:										
% solo driver	24	24	22	26	19	29	30	40	34	23
% accompanied driver	9	9	7	8	8	8	9	8	6	9
% car passenger	13	14	15	13	16	13	20	17	16	13
% public transport	48	48	45	37	50	38	37	35	43	49
% walk etc	6	5	11	16	8	13	3	1	2	6
% with driving licence	51	50	47	54	44	59	54	63	57	49
% with household phone	61	62	57	58	60	55	56	60	57	60
Household car availability:										
% no car	40	40	41	40	42	40	35	36	39	40
% 1 car	50	50	48	50	48	50	53	52	50	49
% 2 + cars	11	10	11	10	10	11	13	12	10	11

All three commuter populations tend to have longer work journeys, a higher proportion of males and of car drivers.

Compared to the other commuter populations, that in Garforth (Scheme F) has a relatively high proportion of females and of technical/clerical workers and to have shorter distances to work.

The Harrogate/Knaresborough commuter population (Scheme G) have particularly long journeys to work, have few 'technical/clerical' members, very high licence tenure and car use.

The Otley commuter group (Scheme H) has a high proportion of manual workers. Its outstanding feature is that it comprises only 521 individuals.

The target population used in the tests of scheme intensity comprises 2036 work trippers, it differs from the pivotal population in having a somewhat higher proportion of manual workers, males, people over 50 and users of public transport. Work journeys are somewhat shorter, licence tenure, phone ownership and car availability are also lower than that of the pivotal population.

6.3 Results of Tests of Scheme Location

Table 6.2 summarises the tests of scheme location.

6.3.1 Note that the target populations for the employment based schemes vary from just over 1200 to almost 5,000. None of the employment based schemes approach the success rate (successful participants per 100 members of the target population) achieved in the pivotal run. This is due in part to the lower application rates (8.0 per 100 in the pivotal run and between 5.6 and 7.8 in the test schemes), but more particularly it is due to the lower matching rates (% of applicants for whom potential partners are found). The matching rate, which is 94% in the pivotal run, varies from 36% to 79% in the test schemes. These much lower match rates cannot but reduce the effectiveness of the schemes. The lower match rates are clearly a function of the size of the target population. In the employment based schemes here tested the residential catchment area of the various schemes is similar in extent to that of the pivotal scheme but the density of employees within that area is considerably less; these lower densities obviously reduce the chances of finding potential partners.

Table 6.2 Performance of tests of scheme location (for definition of tests see section 6.1.1)

Indicator	value of indicator for;								
	Pivotal run	Scheme A	Scheme B	Scheme C	Scheme D	Scheme E	Scheme F	Scheme G	Scheme H
size of target population	21235	4985	3536	2292	2262	1246	2930	1579	531
number of applicants (total)	1688	387	230	129	160	75	268	394	75
number of applicants (as % of target population)	8.0	7.8	6.5	5.6	7.1	6.0	9.2	25.0	14.4
description of applicants:									
mean length of journey to work (kms)	9.2	9.0	8.8	7.8	8.1	8.1	10.6	21.6	14.8
% previously solo drivers	40	39	42	45	34	41	45	59	59
% previously public transport users	35	35	35	29	38	25	27	23	23
% 'manual'	13	11	24	19	21	37	19	25	23
% 'technical'	39	42	41	44	41	20	39	22	15
% 'professional'	48	46	35	36	38	43	42	53	63
description of applications:									
% which are for true pooling	30	31	26	31	33	31	36	36	31
% which are for driving	32	31	30	31	26	34	40	43	44
% which are for riding	38	38	44	38	41	35	24	21	24
number matched by matching system	1586	306	142	46	78	34	243	379	63
number matched as % of applicants	94	79	62	36	49	45	91	96	84
number of participants (total)	327	42	14	2	4	1	38	86	13
number of participants (as % of applicants)	19.4	10.9	6.3	1.6	2.3	1.6	14.3	21.7	17.1
number of participants (as % of target population)	1.5	0.8	0.4	0.1	0.2	0.1	1.3	5.4	2.5
reduction in demand for peak period public transport (work trip/pas.kms per week)	10708	1352	465	38	115	33	1773	6147	741
reduction in peak VKT (work trip VKT per week)	1423	54	-75	-11	7	-21	-238	1260	46
reduction in daily demand for parking spaces	24	2	0	0	0	0	1	7	1

Overall it is clear that the smaller the scheme then the lower will be the matching rate. We note, however, that the matching rate for scheme C is the lowest although it is not the smallest scheme. This is due to the exceptionally low mean trip length of workers and applicants from scheme C. Short journeys to work combine with low residential densities to reduce the matching rates.

6.3.2 The performance of the commuter oriented schemes follows a rather different pattern. The longer average work journeys within the target population result in higher application rates (as high as 25 per 100 in scheme G). The matching rates are also much higher than for the employment based schemes because of the 'dum bell' distribution of homes and workplaces of the applicants, (notice the distributions of homes and workplaces for schemes F-H in Figure 6.1). The overall success rates of these commuter oriented schemes compare well with that of the pivotal scheme - the pivotal scheme's rate was 1.5, that of scheme F was 1.3, that of H was 2.5 and that of scheme G a staggering 5.4. Once again we note that the performance of scheme F is held back by its having a shorter average journey to work than the other two schemes.

6.3.3 Closer examination of the performance of the individual schemes reveal several additional interesting features, among which we note the following:

- Application rates are well correlated with the mean work journey lengths of the target population.
- Several of the schemes actually result in increased peak period VKT (this increase is, however, infinitessimal when compared to the total peak period VKT within the target population). Unfortunately there is no clear relationship between quantifiable characteristics of the target population and the tendency of some car sharing schemes to have an adverse effect on VKT. (Further research is probably warranted on this question).
- Reduction of demand for peak period public transport is most marked on longer routes (partly because car sharing *per se* is more successful on longer routes).
- Careful choice of scheme location with respect to characteristics of the target population can profoundly affect the performance of the scheme - compare the performance of scheme G with that of scheme E (which is of similar size) or with the pivotal scheme which is 13 times the size.

- The effectiveness of scheme G is demonstrated by the calculation that it results in a 3.8% reduction in demand for peak period public transport (1.7% unpivotal run), a 1.2% reduction in peak VKT (0.3 in pivotal run) and a 1.4% saving in parking spaces (0.3% in the pivotal run).

6.4 Results of Tests of Scheme Intensity

Table 6.3 summarises the results of the tests of scheme intensity. (The first column contains a description of the target population, for ease of reference).

6.4.1 Examination of the characteristics of the applicants in each test shows some clear trends. As the 'threshold of interest' increases (i.e. as the intensity of the scheme decreases) we find that the number of applicants declines* and their characteristics alter. We find an increasing proportion of males, professional workers, long distance commuters, licence holders, phone owners and persons who previously drove to and from work alone. Conversely we find a decreasing proportion of manual workers, people over 50, people without access to a car and people who previously travelled to work by public transport. This change in the characteristics of the applicants is reflected in a decreasing proportion of applications to receive lifts and an increasing proportion of would-be poolers.

It thus appears that the more intensive the scheme (≏ the more persuasive the publicity?) the less exclusive in both senses of that word, it becomes. These tendencies are, of course, a function of the differeing propensities which people of different characteristics have of applying to join a car sharing scheme - these propensities having been derived in our calibration survey (see Bonsall 1979a).

6.4.2 We note that as the number of applicants decreases (from left to right in Table 6.3), then sotoo does the matching rate (% of applicants for whom a match list can be made). Note, however, that the matching rates achieved with the low thresholds of interest are higher than we would normally expect for schemes of this size. This is because the low thresholds have produced a population of applicants who have expressed interest in more than one type of car sharing⁄ and their catholic tastes make the matching process easier. It is interesting to note that the matching rate reaches a ceiling just above 95% however large and catholic the pool of applicants.

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* The rate of this decline is a function of the logit form of the choice model. As such it may or may not represent realistic rates of change. We are here concerned with the effect of this reduction in interest rather than in the reduction itself.

⁄ The model structure is such that lowered thresholds bring multimode applications e.g. for pooling, driving <u>and</u> riding, whereas more normal thresholds typically bring only one mode of application from each applicant.

Table 6.3 Results of tests of scheme intensity

indicator	value of indicator for: target population	test 1	test 2	test 3	test 4	test 5	test 6
threshold of interest used in test	n.a.	1	3	5	7	8	9
number of applicants (total)	n.a.	1859	1712	1464	905	146	19
number of applicants (as of target population)	100	91	84	72	44	7	1
type of applications made: % which were for the pooling	n.a.	8.9	9.6	9.9	11.3	28.4	65.0
% which were for driving	n.a.	33.5	33.4	34.2	34.1	33.6	25.0
% which were for riding	n.a.	57.7	57.0	55.9	54.6	38.1	10.0
description of applicants % previously public transport users	49.07	51	50	47	42	40	16
% previously solo drivers	23.08	25	26.	29	34	40	47
% male	51	52	52	54	59	63	79
% 'manual'	36	37	36	35	32	13	5
% 'technical'	33	33	32	32	32	36	42
% 'professional'	31	31	32	33	35	51	53.
mean length of journey to work (kms)	5.92	6.01	6.04	6.09	6.37	9.57	17.7
% under 30	31	30	31	31	33	36	37
% 30-50	41	41	42	41	41	44	53
% over 50	28	28	28	27	26	21	11
% phone	60	60	61	61	63	81	84
% licence	49	53	55	58	66	71	89
% with no cars available	40	38	37	35	31	27	11
% with 1 car available	49	50	51	52	55	60	63
% with 2+ cars available	11	12	12	12	14	13	26
total number matched	n.a.	1781	1639	1394	840	86	3
total as a % of applicants	n.a.	95.8	95.7	95.2	92.8	58	15
number of successful participants	n.a.	763	653	448	191	9.6	0
number as a % of target population	n.a.	37.47	32.07	22.00	9.37	0.47	0
reduction in peak period VKT (per week)	n.a.	476	460	430	14	-75.6	0
reduced demand for peak period public transport (pass km. per week)	n.a.	11134	10654	6564	3048	273.4	0
reduced demand for daily park spaces	n.a.	41	30	30	16	1	0
persons per arrangement	n.a.	2.8	2.8	2.6	2.5	2.3	0

6.4.3 The higher number of applicants and their greater catholicisity of taste in the low threshold tests brings greatly increased numbers of successful participants, and correspondingly larger system effects.

6.4.4 These measures of the operation and impact of schemes of differing intensity clearly show that the mechanisms of organised car sharing tend to magnify the level of interest extant among the target population; that is to say that a given increase in the number of applicants and their willingness to consider a variety of modes of car sharing, will produce a more than proportionate increase in the effectiveness of the schemes. This points to the value of publicity and incentives.

7. THE SCENARIO TESTS

7.1 Introduction

In this group of tests we investigate how the performance of the car sharing schemes might be affected by major changes in their operating environment. The tests included under this head are:

1. The effect of providing free reserved parking space in city centres for members of the scheme.
2. The effect of a doubling in the real price of petrol.
3. The effect of a doubling in the real price of public transport (fares).
4. The effect of a simultaneous increase in the real prices of both petrol and public transport.
5. The effect of enforcing the legal/insurance company stipulations on acceptable levels of compensation*.

7.2 Definition of the Tests

7.2.1 Tests 1 to 4 involve the recalibration of the model of decisions to join a car sharing scheme and some modification to the calculation of match utilities. The recalibration was on the basis of response to special questions in our calibration survey (see Bonsall 1979a). These special questions asked respondents whether they would apply to join a car sharing scheme under the scenarios postulated. Obviously we must retain a healthy scepticism as to the reliability of answers to such speculative questions.

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* This stipulation states that the 'hire and reward' exclusion on car insurance policies would not be invoked so long as compensation did not entail an element of 'profit' for the driver (see BIA (1978)).

7.2.2 The modification of the calculation of match utilities for the first four of the scenarios was as follows:

(a) For the test of free reserved parking we assume that half of the drivers in the scheme will already have access to the reserved parking and will thus not be affected by the availability of this special incentive for car sharers. (In the absence of data we chose arbitrarily whether a given driver will or will not fall into this unaffected group). For those drivers who are affected, we assume that the utility of the arrangement will be increased by the total value of parking fees saved. Thus we assume that lift givers will perceive their utilities increased by 5 daily parking fees per week while poolers, who drive only every other day will perceive increased utility of $2\frac{1}{2}$ daily parking fees per week. In the test whose results are presented here we assume the daily parking fee is 20 pence (December 1977 values). We have not attempted to quantify the value put by passengers on having a reserved parking space (rather than a walk from a bus stop for example) - it would be interesting to test the effect of including a benefit this type at a later date.

(b) For the test of a doubling in the real price of petrol we assume that all previous drivers who cease to drive as a result of joining the car sharing scheme will have an increase in utility equal to the increase in the amount that they would have had to spend on petrol had they continued to drive. Against this we assume that all drivers within car sharing schemes will perceive an increase in the disutility of having to divert in order to pick up passengers. This increased disutility being equivalent to the increased petrol cost of making that diversion. In the test whose results are presented here we assume that the increase in the price of petrol amounts to 3.4 pence per kilometre for all drivers (1977 prices). (An obvious refinement would be to make allowance for variation in car engine size but the necessary data was not available to us).

(c) For the test of a doubling in the real price of public transport we assume that all previous users of public transport, who cease to use it as a result of the car sharing scheme, will perceive an increase in utility equal to the increased fares that they would have had to pay had they continued to use public transport. In the test whose results are presented here we assume that the increase in fares amounts to 3.75 pence per kilometre (1977 prices).

(d) For the test of a simultaneous doubling in the real price of petrol and of public transport we combine the assumptions set out in paragraphs b and c above.

Please note that these tests were designed to show how the various scenarios would affect the performance of a given car sharing scheme; they do not attempt to quantify the effects of any other changes in mode or distribution that the scenarios might bring about.

7.2.3 For the test of enforcing the strictest interpretation of the insurance companies undertaking there is a modification to the algorithm within which the compensation paid by passengers to their drivers is worked out. This modification ensures that no driver shall receive a total compensation (from all passengers combined) exceeding 3.4 pence per kilometre (i.e. average car running costs at 1977 levels). Note that this test does not attempt to comment on how this regulation would be enforced but merely to comment on its effect on the performance of an organised car sharing scheme, if it were enforced. Also note that, for this test, we do not attempt to quantify the effect that existence of strict enforcement would have on individuals' desire to make an application to join a car sharing scheme (presumably the effect would tend to be depressive).

7.3 <u>Results</u>

Table 7.1 summarises the results of all five scenario tests. Clearly the tests are quite different from one another in character.

7.3.1 The free-reserved-parking test results in the greatest number of applicants (10.2% of the target population compared to 7.9% in the pivotal run and $\simeq$ 8.3% in the other scenarios). If we examine the characteristics of these applicants we find that they include an increased proportion of:

- Non-professional workers (who are presumably less likely to have free reserved parking already)
- Women
- People over 50
- People from small households (not shown in Table)
- Users of public transport and persons seeking someone to give them lifts to and from work. (This rather surprising result suggests that public transport users may be attracted by the idea of <u>reserved</u> parking spaces which might lessen their sometimes irksome walk from bus stop to workplace. Also, it might be argued, potential passengers might welcome the thought that their presence in someone's car would entitle that person to a benefit (free reserved parking) in return for which any free might be waived!).

Table 7.1 Results of scenario tests.

indicator	value of indicator in					
	pivotal run	free reserved parking	petrol prices doubled	public transport fares doubled	simultaneous doubling of petrol and fares	insurance company limit
number of applicants (total	1688	2176	1769	1761	1784	1688
number of applicants (as a % of target population)	7.9	10.2	8.3	8.3	8.4	7.9
description of applicants:						
% male	64	62	65	65	65	64
% 'manual'	13	13	13	13	13	13
% 'technical'	39	44	39	39	39	39
% 'professional'	48	42	47	47	47	48
% <30 years of age	32	31	31	31	31	32
% 30-50 years of age	45	46	45	45	45	45
% >50 years of age	22	24	24	24	24	22
previous mode:						
% solo drivers	40	28	40	39	40	40
% accompanied drivers	16	16	16	16	16	16
% car passengers	6	6	6	6	6	6
% public transport	35	45	35	36	35	35
% with ≥ 1 houshold car	74	74	75	74	75	74
% with household phone	74	68	75	74	75	74
% with driving licence	75	71	75	74	75	75
% needing car for business use	6	4	6	6	6	6
mean distance to work (kms)	9.1	9.1	8.9	8.9	9.0	9.1
Description of applications:						
% for true pooling	30	30	30	29	30	30
% for driving	32	28	33	33	33	32
% for riding	38	41	37	38	37	38
% of applications matched	94.0	91.4	94.4	93.9	94.5	94.0
Number of successful participants (total)	327	453	369	513	554	219
Number of successful participants (as % of target population)	1.5	2.1	1.7	2.4	2.6	1.0
Number of successful participants (as % of applicants)	19	21	21	29	31	13
mean car occupancy within arrangements	2.4	2.29	2.42	2.47	2.49	2.44
% of participants engaged in true pooling	15	20	20	9	15	19
% of participants previously solo drivers	37	29	43	30	35	40
% of participants previously public transport users	41	48	34	52	46	40
mean distance to work of all participants (kms)	9.3	9.4	9.6	9.1	9.3	9.6
reduction in demand for peak public transport (pass Kms per wk)	10708	16599	9619	20345	19743	6756
reduction as a % of system total	1.8	2.8	1.6	3.4	3.3	1.1
reduction in peak weekly VKT	1423	413	5063	-734	2933	1802
reduction as a % of system total	.3	.1	1.1	(+.2)	.7	.4
reduction in demand for daily parking spaces	24	2	51	8	37	21
reduction as a % of system total	.4	.0	.7	.1	.5	.3
cars 'liberated' for possible off peak use	17	20	30	15	30	14
total 'utility' of arrangements to participants (£)	537	864	734	995	1206	473
mean utility per participant (£)	1.6	1.9	2.0	1.9	2.2	2.2
mean per km compensation 'paid' to drivers (pence)	4	3	5	6	7	1

The increased number of applicants is not reflected in an improved matching rate because of the imbalance of lift seekers to lift offerers. (Although the density of applicants per km^2 is greater there is actually a smaller proportion of applicants whose journeys and type of application are compatible).

The provision of free-reserved parking spaces results in a 40% increase in participants (over the pivotal scheme) but the system effects of this policy are rather more complex. The fact that the spaces were available to all drivers in the scheme, no matter what their car occupancy, seems to have mitigated against high car occupancy and it has indeed declined to 2.29 from its value of 2.45 in the pivotal run. While the reduction in demand for peak period public transport is 57% greater, the reduction in private vehicle peak usage is only ¼ of what it was in the pivotal run. Similarly the reduced demand for city center parking spaces totals only 2 spaces compared to 24 in the pivotal run.

Clearly the types of arrangements being entered into are quite different - there is a much higher proportion of true pooling and a reduced proportion of lift giving. It is interesting to note that drivers are accepting passengers offering lower fees than in the pivotal run - do doubt because the drivers are getting some benefit already from the free park spaces. Most interesting of all, however, is the increased proportion of participants who were previously public transport users. It seems that the car parking incentive has appealed to a rather different section of the community than might have been envisaged.*

7.3.2 The petrol price increase scenario brings about a small (4.7%) increase in applications. The extra applications are particularly forthcoming from men, from people over 50 years of age and from people with shorter *(sic)* work journeys than those of applicants to the pivotal scheme. There is a particular increase in interest from people wishing to find passengers (presumably they are hoping for contributions towards the increased petrol costs).

The increased number of potential drivers helps to improve the matching rate - albeit only marginally.

The 4.7% increase in applicants is transferred into a 13% increase in successful participants - due no doubt to the particularly large increase in the number of people wishing to give lifts. There is less of a reduction in

* It is interesting to compare this test result with empirical evidence from Seattle where 40% of users of a high occupancy vehicle parking preference facility were found to have been tempted in from public transport.

peak period public transport patronage but a considerably increased saving in private vehicle usage and in demand for parking spaces. This reflects the higher proportion of true pooling and of participants who were previously solo drivers.

Thus it appears that, against a background of increased petrol prices, the conventionally expected system benefits of organised car sharing (reduced VKT and parking requirement) are more in evidence. Note, however, that even with a doubling of petrol prices the net effect of these two is still only marginal (a reduction of 1.11% in VKT and of 0.74 in parking requirement).

7.3.3 The public transport fare increase scenario brings about a 4.3% increase in applications. The extra applications are particularly forthcoming from women, people over 50 and public transport users.

The 4.3% increase in applicants becomes a 57% increase in successful participants. This high success rate is reflected in increased car occupancies and a much greater reduction in peak period public transport patronage. There is, however, a reduced saving of car park spaces and the marginal reduction in VKT is actually transformed into a marginal increase!

The fees being offered to drivers within the scheme are much enhanced and this reflects the general pattern of great inducement to become a driver which results in the poor VKT and park space savings mentioned above.

Against a background of increased public transport fares, an organised car sharing scheme proves a very attractive option to public transport users. The reduced demand for work trip peak period public transport is particularly marked (3.4%). The savings of VKT or parking spaces, however, are negligible.

7.3.4 The simultaneous increase of petrol costs and public transport fares brings about a 5.6% increase in applicants - a somewhat higher percentage than that due to either of the increases separately but certainly not as great as the two increases put together. This suggests that a substantial number of people would be persuaded to apply to join a car sharing scheme by <u>either</u> an increase in petrol costs <u>or</u> in public transport fares - one might have expected the populations affected by these two scenarios to be quite distinct.*

The larger number of applicants allows a more successful match rate (94.5%). The increase in successfully matched individuals is, at 69%, very significant and is substantially more than for either the petrol or the fare

* This counter-intuitive result prompts a reminder that the survey questions on which these scenario tests were calibrated were highly speculative and are unlikely to be as reliable as the questions on which the pivotal model was calibrated.

increase scenarios separately. The mean car occupancy is increased even higher than under the fare increase scenario. Reduction in demand for peak period public transport is substantial but not as great as under the fare increase scenario. Similarly the reduced peak period VKT and park space requirements are not as great as under the petrol price increase scenario.

The high success rate for the car sharing scheme under this scenario (2.6% of the target population become participants compared to 1.5% in the pivotal run, 1.7% under the petrol scenario and 2.1% under the fare scenario), is attributable to the fact that all the participants are clearly motivated to save money. In the case of the petrol scenario we found drivers more motivated than passengers and vice versa under the fare scenario.

7.3.5 The scenario under which we assume strict enforcement of the insurance companies limits on compensation results in a $\frac{1}{3}$ reduction in participants. We also note that mean car occupancies are down (there is little incentive for drivers to carry additional passengers if his compensation rates must be divided by car occupancy). Also we find a 40% less reduction in the demand for peak period public transport.

On the other hand, however, we notice a 27% greater reduction in peak VKT. This is related to the lower levels of compensation which lead more drivers to become poolers rather than lift givers (the compensation for giving lifts being artificially constrained). This switch from lift giving to true pooling (alternate driving) is responsible for the greater reduction in peak VKT.

The result of strictly enforcing the insurance company limits is thus seen to include the, at first sight, contrary elements of reduced car occupancies and reduced participation and yet increased reduction in peak VKT.

8. DISCUSSION AND CONCLUSIONS

8.1 Main Findings

The tests reported in this paper allow a number of conclusions to be drawn. The most significant ones are presented below.

8.1.1 The predictions produced by the microsimulation model are relatively stable when the model is subjected to sensitivity analysis. Certainly there is no cause to doubt the conclusions presented below. The reason for this stability is undoubtedly the microsimulation framework which imposes strong and realistic constraints on the actions of individual actors within the system. (This fact commends the use of microsimulation models).

8.1.2 In the absence of any special incentives and with transport costs at their 1977-78 levels, it seems that an organised car sharing would draw applications from some 8% of city centre workers. This proportion would increase if the target population were characterised by higher journey lengths. It also appears that populations with high telephone ownership, and a high proportion of males produce more applications than do others. Populations with a high proportion of manual/shop floor workers produce fewer applications.

Only $\frac{1}{3}$ of applications are for true car pooling (alternate driving) the remaining $\frac{2}{3}$ being for simple lift giving arrangements.

Answers to a very speculative question in the surveys suggested that a "doubling" of petrol prices or of bus fares would only lead to a marginal increase in the number of applications. A policy of free reserved parking spaces for car poolers in city centres would (also very speculative) lead to applications from 10% of city centre workers (i.e. an increase of 25%).

8.1.3 The success rate of a matching system (percentage of applicants for whom a realistic list of potential partners can be produced) is dependent on the number of applicants, their spatial distribution and the relative proportions of lift seekers, lift offerers and would-be car poolers. A 94% match rate can be expected from a target population of 21,000, in a primarily suburban hinterland. With a target population of 5,000 an 80% match rate could be expected, target populations of 2,000 and 500 might bring match rates of 60%, and 40% respectively. Below 500 the match rates decline sharply.

Concentration on a distinct group of commuters (e.g. from a given dormitory town to a given city centre) will result in much higher match rates - a match rate of 96% for a target population of 1,500 can be achieved for a group of commuters with average commuter length of 21 kms each way.

8.1.4 An organised car sharing scheme for a target population of 21,000 city centre workers is likely to result in about 1.5% of that population entering some form of car sharing arrangement. Only some 15% of these arrangements will be true car pools. Something between $\frac{1}{3}$ and $\frac{1}{2}$ of these participants are likely to have been previously users of public transport. The expected effect on the transport system is a reduction in demand for peak period (work trip) public transport of between 1.5 and 2% and reductions in peak period work trip VKT and parking space requirement of some 0.3%.

Figures for a scheme based on a group long distance commuters would be more dramatic. Over 5% of commuters could be expected to participate, work trip peak period use of public transport would decline by almost 4%, VKT and demand for parking spaces by over 1%.

There is evidence that, against a background of increased transport costs (a doubling in petrol prices and in public transport fares), reductions in peak period work trip VKT, park space requirement and public transport demand would be twice as great as would be the case without these increases.

Similarly, an incentive for car sharers, in the form of free reserved parking in city centres would seem to result in an increased reduction in peak public transport demand but in a very marginal reduction in peak VKT and parking space requirement.

It is clear that an increase in the number of applicants and their willingness to consider more than one type of car sharing arrangement, will bring about a more than proportionate increase in the effectiveness of the schemes.

8.1.5 It is interesting to compare these model predictions of the performance of organised car sharing schemes with such empirical evidence as exists. An evaluation of car pooling demonstration programmes in the United States (Wagner 1978) concludes that about 16% of employees exposed to intensive car sharing scheme publicity made applications to join that scheme. In two pilot schemes in West Yorkshire (Bonsall 1979c) response rates averaged 5% for non manual workers. The model prediction of 8% is clearly quite close to the British figure (particularly when it is revealed that the target populations for the West Yorkshire pilot schemes had a high proportion of females and short journey lengths). The US figure of 16% is high even when the longer journey lengths are allowed for. The more intensive publicity campaigns used in the US schemes is obviously a factor here.

In the US schemes it was found that 16% of applicants became car sharers as a result of the matching systems. Thus some 2½% of the exposed population had become sharers (16% x 16%). Of these it was observed that about ⅓ subsequently* reverted to their original mode. Thus leaving about 1.7% of the exposed population as new sharers. This figure of 1.7% is remarkably close to the 1.5% predicted by the model. Similarly, Wagner's estimate of a 0.3% saving in work trip VKT is identical to that predicted by the model. Clearly the more intensive advertising used in the US schemes attracted more applicants but much of the interest proved ephemeral.

* It is not clear from Wagner's paper for how long these people were car poolers before reverting to their original mode. Circumstantial evidence suggests that they had ceased to pool within the first 6 months.

The model prediction that some 40% of sharers would previously have been users of public transport is remarkably close to the finding in Seattle where 40% of users of new priority parking spaces for high occupancy vehicles were found to have been previously users of public transit.

8.2 Policy Implications

8.2.1 The major policy conclusion must be that voluntary car sharing schemes, even with the provision of parking incentives, will not make a major contribution towards reduction in urban congestion or energy use. A significant impact of the type of scheme represented here is a reduction in demand for peak period public transport - whether this is to be welcomed or not will, of course, depend on the ability of transport operations to reorganise their services more efficiently - also it will depend on the local conditions - whether the peak demand is currently being satisfied and the complex interaction of crew and vehicle scheduling for example. Clearly there will be cases where reduction in peak demand allows for a more efficient service and other cases where it would not. Suffice it to say that this is an impact of car sharing which deserves serious attention in the strategic and tactical planning of car sharing schemes.

8.2.2 It is apparent that the impact of a car sharing scheme can be manipulated by careful choice of the target population and by adjusting the mix of lift giving and true car pooling. Assuming that one wished to maximise reduction in VKT but minimise reduction in public transport use. It would not be possible to restrict entry to a car sharing scheme to private transport users exclusively* but it would be possible to aim the publicity at private rather than public transport users (application forms might be distributed in car parks for example). It would also be possible to exclude lift giving/receiving options from the application form and thus effectively to restrict the scheme to true car pooling which has a better record for saving VKT than does lift giving. Conversely, of course, if one wished actively to encourage the reduction in demand for peak period public transport, the publicity material and matching system could be adapted accordingly.

8.2.3 It is clear that the impact of a car sharing scheme will vary with the size and characteristics of its target population - larger schemes will be considerably more effective than smaller ones, commuter groups will respond more readily than will other groups of workers .... and so on.

* A device assumed purely for the purpose of the theoretical calculations performed by Vincent and Wood (1979).

Incentives, publicity and other methods of increasing interest in the various forms of car sharing offer the potential of greatly enhancing the effectiveness of the schemes.

8.2.4 The model suggests that a matching system ought to provide for up to 10 persons on each match list and ought to match within a $\pm\frac{1}{4}$ hour time window. If computerised matching is required, the eliptical search routine used in the model will prove extremely efficient.

8.3 Further Research

8.3.1 The microsimulation model used in the current project has indicated the scale of impacts that can be expected from organised car sharing schemes. If this result is all that is required by the policy makers then we can say the job is done and further work unnecessary. If, however, a greater insight is required into the mechanisms and impacts of car sharing then clearly there remains much work to be done.

8.3.2 The relationship between car sharing and public transport is obviously an extremely important issue about which we should wish to know more. The current model could be used to explore further the scope for restricting the car sharing schemes to car drivers or would-be poolers. It could also be used to test the impact of a scheme specifically designed to relieve pressure on a particular part of the public transport network.

A development of microsimulation modelling to explore the link between peak period mode choice and off-peak travel patterns is already underway in Leeds (SSRC grant) and is designed to contribute to an understanding of the relationship between car sharing schemes and use of public transport.

There is obviously scope for further examination of the behavioural factors affecting the choice between a car-sharing and a public transport journey.

8.3.3 Clearly there is a need for more detailed investigation of the effectiveness of publicity and various forms of incentives in increasing the effect and viability of car sharing.

8.3.4 More information is required about the performance and operation of car sharing schemes in the field in the UK. Experimental schemes already underway in Leeds should contribute useful information as should others being established elsewhere. The current model could be used to investigate the trade-offs between manual and computerised matching techniques and to provide recommendations as to the choice between them. The model could also test the impact of a car sharing scheme designed to ameliorate a particular traffic problem - a congested corridor for example, or to investigate the effect of additional incentives for car sharers - a subsidy from public funds to promote car sharing for example. The relationship between car sharing and flexitime cannot be realistically addressed by the current model but empirical work is already underway in Leeds (SSRC grant) which should help in this respect.

8.3.5 There is clearly room for further sensitivity analysis of the model and improvement in the calibration of the choice models. In particular we should investigate further the effects of changing the rationale of the algorithm within which the utilities of potential partners are evaluated. Similarly we would wish to investigate the effect of the (known) disparities between the real population of West Yorkshire and the synthesised one on which all the tests were run - a very important issue here, and one which has very wide application, is the divergence between data relating to 'normal' behaviour and the snapshot data from which our population was synthesised.

The case for these researches must, however, lie outside the context of predicting the effect of organised car sharing schemes because it is extremely unlikely that further refinement of the model or its calibration would cause a significant change in the model predictions. There is, however, a case for the development of microsimulation techniques in other areas of social science research because microsimulation is proving a valuable device for the improvement of modelling techniques in the three important areas of prediction, understanding and explanation.

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