Department for Transport

Motorcycles and Congestion: The Effect of Modal Shift

Phase 1 Report

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PREFACE

This report has been prepared for and funded by the UK Department for Transport (DfT) and Transport for London (TfL), and is one of the deliverables for the research project titled "Motorcycles and Congestion: The Effect of Modal Shift". The project's key objective was to determine how policy can affect motorcycle usage and what impacts increased motorcycle usage would have on traffic congestion.

The research project has been comprised of three main phases of work. The first phase related to the development of models to predict mode usage: particularly to predict motorcycle ownership and usage. The second phase of work involved enhancing existing transport models to incorporate the mode choice models defined in Phase 1 and finally Phase 3 involved a series of tests to determine the impacts of different policies on motorcycle usage and congestion. This report focuses on Phase 1 of the research project and provides details of the development of new motorcycle ownership and mode choice models. The development of these models has been undertaken by RAND Europe, with support from WSP and expert advice from Marcus Wigan of Oxford Systematics, Australia. The fieldwork to collect data for the usage models was conducted by Accent Marketing and Research.

This report will be primarily of interest to transport professionals and policy makers wishing to understand the drivers of motorcycle ownership and the subsequent choice of whether to use a motorcycle for peak period trips for those having access to a motorcycle. For a summary of the key findings the reader is directed to Chapter 4, which provides a concise overview of the general approach and the key policy implications that can be drawn from the models.

The report also contains technical information of interest to transport modellers who may wish to incorporate these new models describing the behaviour of motorcycle owners into an existing model system that has no explicit treatment of this mode. In this respect, the motorcycle ownership model has used a framework that is compatible with the current UK car ownership models and can therefore be incorporated within existing model systems that can accommodate disaggregate demand models. This report also provides detail on the design of a survey instrument to collect mode choice data, and the development of the model choice model for motorcycle owners. Information is provided on the implementation of the mode choice model, although more detail of these issues are available in the Phase 2 report that discusses the integration of the two new models into existing model systems for the London and Cambridge areas. Chapters 2 and 3 of this report are therefore aimed at the technical reader who wishes to understand the detailed development of the models and the subtleties of the model structures.

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1 INTRODUCTION TO PHASE 1 MODELS: MOTORCYCLE OWNERSHIP AND USAGE

1.1 In May 1999, the Government set up the 'Advisory Group on Motorcycling' as a means of investigating the potential of increased motorcycle use for reducing congestion and pollution. There were three primary terms of reference for the group:

- To look at the safety record of motorcyclists and agree measures that would improve safety
- To look at the environmental impact of motorcycles and if necessary agree measures to be taken
- To look at the role of motorcycles in integrated transport policy and to assess the scope for further enhancing their benefits through traffic management

1.2 The Advisory Group was set up after the Government's White Paper 'A new deal for transport' recognised that motorcycling had the potential to act as a viable alternative to car travel in certain circumstances. It also recognised that this brought with it potential for easing congestion, and improving the environment, although the associated safety issues also needed to be taken into account. The Advisory Group comprises various organisations with an interest in motorcycling, including road safety groups, motoring organisations, manufacturers, training associations and action groups. Since its inception, it has set up various Task Forces to examine specific issues.

1.3 The task forces' remits were wide ranging, from environmental and fiscal issues of motorcycling to advice and guidance on integration and traffic management. Within this last category, DfT commissioned a 6 month study into 'Motorcycling and Congestion', carried out by Halcrow Group Ltd. The main aim was to provide the Department with an initial appreciation of the potential effects of a mode shift to motorcycles, particularly from car. There were two specific objectives.

- To estimate the effects of such a shift on congestion and network performance
- To estimate the consequences of this on pollution, noise, interaction with other traffic, etc

1.4 To do this, Halcrow investigated the ways in which motorcycles are ridden in congested areas, and the extent to which motorcyclists benefit when compared to car or public transport travel. This was done by means of a literature review, surveys and observation of riding characteristics in congested conditions, and an efficiency assessment – the degree to which a transfer to motorcycle frees space, which in turn depends on the mode transferred from.

1.5 The aim of this study is to build on this work, and carry it forward by developing better methods to quantify the extent of mode share transfer to motorcycle.

1.6 There are two important choices that determine potential motorcycle use: motorcycle ownership and choice of motorcycle for travel. Both of these have been addressed in this study in order to predict reliably the impact of policy on motorcycle use and the related impact on road congestion. Because motorcycle owners form a small fraction[1] of the population, significant reductions in traffic congestion will come about only if that level of ownership increases.

1.7 Phase 1 of the research project therefore included the development of both the motorcycle ownership and mode split models. The following sections of this report document first the development of the ownership models, and then the development of motorcyclist mode-choice models.

1.8 The development of these models has been undertaken by RAND Europe, with support from WSP and expert advice from Marcus Wigan of Oxford Systematics, Australia. The fieldwork to collect data for the usage models was conducted by Accent Marketing and Research. We would also like to acknowledge the contribution of the representatives of the BMF[2], MAG[3] and MCIA[4] who assisted in developing and piloting the survey instrument for this study.

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[1] An estimate of 2.5% of the population owning 1 or more motorcycles has been obtained by pooling data from the 2000 & 2001 National Travel Survey and 2000 Family Expenditure Survey datasets, as shown in Table 7 later in this report

[2] British Motorcyclists Federation http://www.bmf.co.uk/

[3] Motorcycle Action Group http://www.mag-uk.org/

[4] Motor Cycle Industry Association http://www.mcia.co.uk/

2 MOTORCYCLE OWNERSHIP

Trends in Motorcycle Ownership 1993-2001

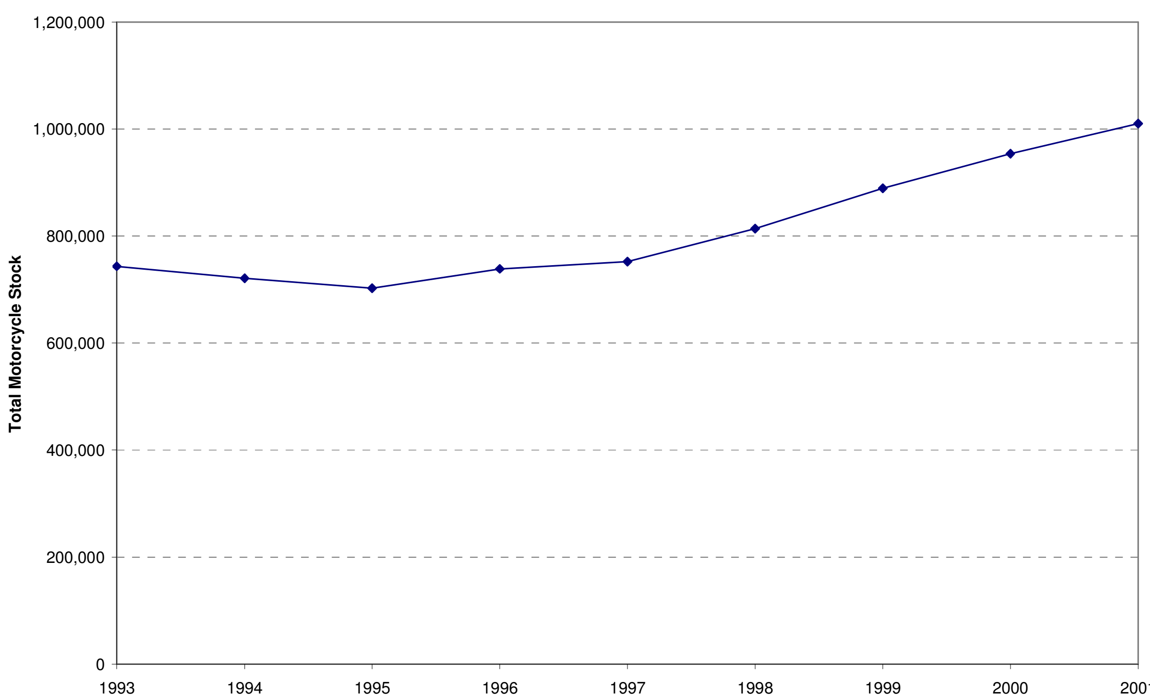
2.1 This section documents analysis of motorcycle ownership recorded in the Vehicle Information Database (VID) between 1993 and 2001. Data back as far as 1991 was requested, but only data from 1993 onwards was able to be provided.

2.2 Information was supplied by the DfT on the number of motorcycles registered in Great Britain (GB) broken down by:

- Engine size (16 bands)
- County/unitary authority
- Maker code (1996, 1998, 1999, 2000 and 2001 only)

2.3 Figure 1 shows the change in total motorcycle stock in GB between 1993 and 2001.

Figure 1: Change in Total Motorcycle Stock, 1993-2001



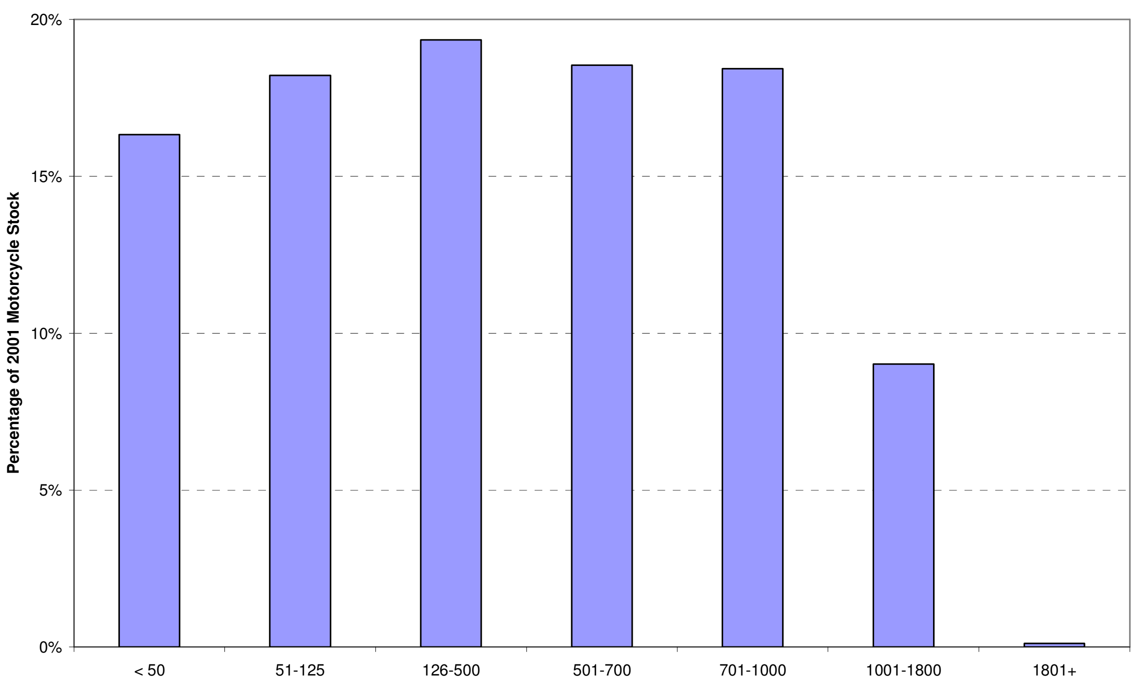
There has been a considerable increase in stock over the period; the 2001 stock represents a 36 % increase over the 1993 stock.

2.4 To analyse the changes in motorcycle ownership in more depth, the VID engine size banding was disaggregated into the following categories:

- < 50 cc
- 51 – 125 cc
- 126 – 500 cc
- 501 – 700 cc
- 701 – 1000 cc
- 1001 – 1800 cc
- 1801+ cc

2.5 The numbers of motorcycles registered in 2001 by each of the engine size bands is detailed in Figure 2.

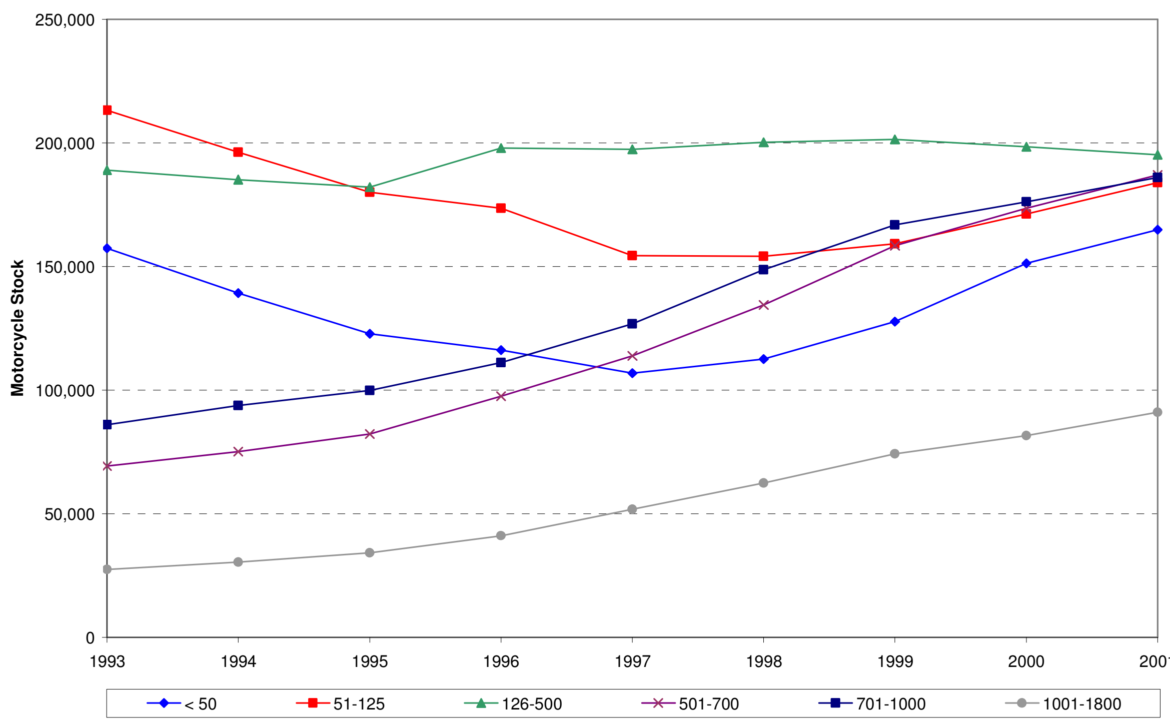
Figure 2: 2001 Motorcycle Stock by Engine Size Band



It can be seen that motorcycles are well distributed across the different engine size bands up to 1800 cc. The numbers of vehicles registered as a motorcycle and with an engine size in excess of 1800 cc is small. Historically this category has been composed predominately of vehicles such as trikes which are classified as motorcycles, but are not two-wheeled motorcycles in the conventional sense, although several new models of motorcycle with engine capacities over 1800cc have recently been announced and may become more widespread in the future. The call to tender stated that vehicles classified as motorcycles but with engine sizes exceeding 1800 cc should be excluded from the analysis and therefore for the purposes of this study such vehicles have been excluded from all subsequent analysis.

2.6 Figure 3 plots trends in motorcycle ownership by engine size band between 1993 and 2001.

Figure 3: Trends in Motorcycle Stock by Engine Size, 1993-2001



2.7 Considering first the smallest bikes (< 50 cc) it can be seen that a drop in numbers between 1993 and 1997 was subsequently reversed, and that 2001 stock is slightly above 1993 levels. The shape of the 51-125 cc band plot is similar, but in this case 2001 numbers have not returned to 1993 levels. In the 126-500 cc band numbers have remained much more stable over the period, with the 2001 stock slightly above 1993 levels. However the main trend that is shown here is that the overall growth in stock is driven by the large engine size bands. All three (501-700, 701-1000 and 1001-1800) show steady growth throughout the period.

2.8 The composition of each of these capacity bands varies by type of motorcycle. Two sub-categories of particular interest are mopeds (motorcycles with a capacity of 50cc or less, restricted to 30mph and weighing 250kg or under – historically these also had pedals, but this is not now necessarily the case) and scooters (motorcycles with step-through frames and small wheels).

2.9 Prior to the period assessed, mopeds rose to a peak and fell back, and during the period covered by this data scooters re-entered the market place and their sales rose swiftly. There are suggestions[5] that this too may soon peak, or may already have peaked. These scooters are concentrated in the capacity bands under 126cc and to a lesser extent up to 250cc with a few large scooters also entering the market place over the period. These two trends explain to some extent the U-shaped curves seen for the smaller capacity motorcycles. The purchasers of scooters tend to be rather different from those buying higher capacity motorcycles, for instance with this type of motorcycle attracting higher fractions of women than other types. Consequently the motivations and attitudes towards the two subdivisions of motorcycles are not necessarily the same. Although capacity bands are available (as described here) from the ownership data available from the VID database it is not possible to distinguish the full range of different motorcycle body types, so we are unable to separate out scooters from other motorcycles.

2.10 In this study we are specifically interested in motorcycle ownership in London and Cambridge, as the Phase 2 modelling will be undertaken in these areas, as well as national ownership. London can easily be identified in the data as 'Greater London'. Cambridge and its hinterland can only be identified as Cambridgeshire. In the 1994 and later data, data for Peterborough is separated from the rest of Cambridgeshire. However to plot trends back to 1993 data for all of Cambridgeshire is presented in this section.

2.11 Figure 4 compares trends in ownership in London and Cambridgeshire to the trend for GB as a whole. London stock has grown more rapidly than stock in GB as a whole, and furthermore the rates of growth by engine size band are different in London. Therefore the GB trend line has been plotted *excluding* the London data. Also plotted separately is the trend in total ownership for the South (South West, East Anglia and South East excluding London) and the rest of GB, to assess whether ownership has grown more rapidly in the South where incomes are higher on average. To account for the different magnitudes of the stock in each area, each line is plotted relative to 1993 ownership for that area. The absolute ownership levels in 1993 and 2001 in each area are summarised in Table 1.

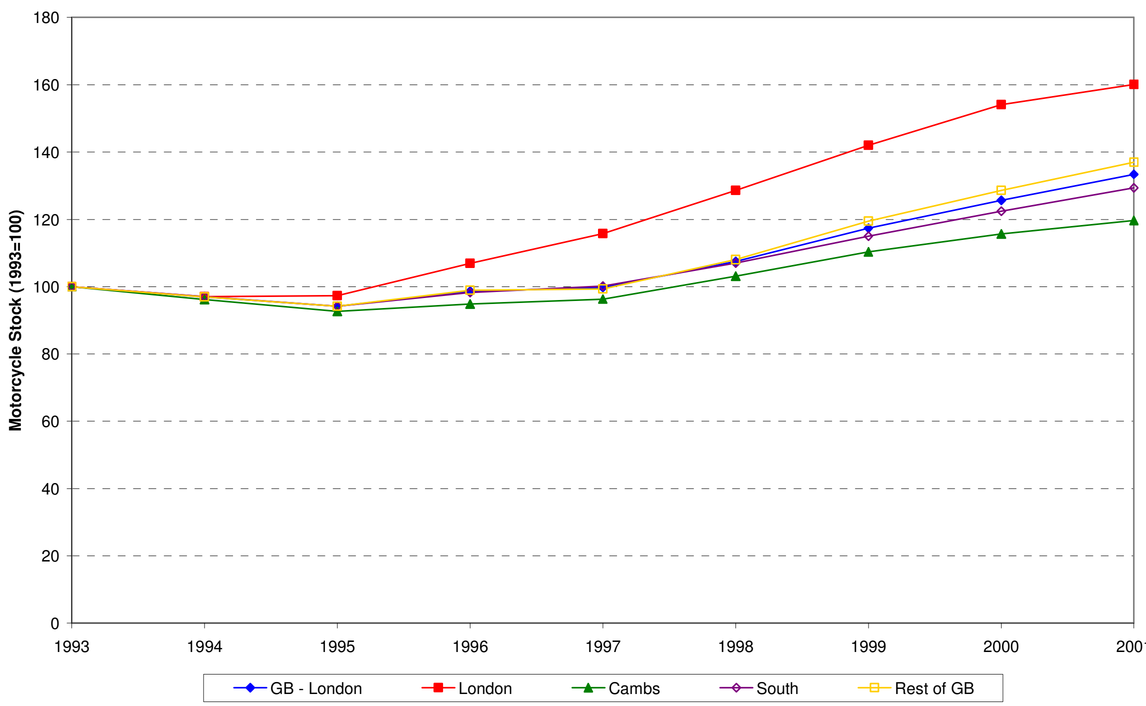
[5] From conversations between Marcus Wigan and sources in the UK motorcycle retail sector

Table 1: Absolute Ownership Levels by Region

Region	1993	2001	% increase
GB	743,071	1,009,511	35.9%
London	68,936	110,328	60.0%
Cambridgeshire	12,939	15,481	19.6%
South	317,313	410,418	29.3%
Rest of GB	356,822	488,765	37.0%

The 2001 London stock represents 10.9 % of the total GB stock levels. The 2001 Cambridgeshire stock represents 1.5 % of the total GB stock levels.

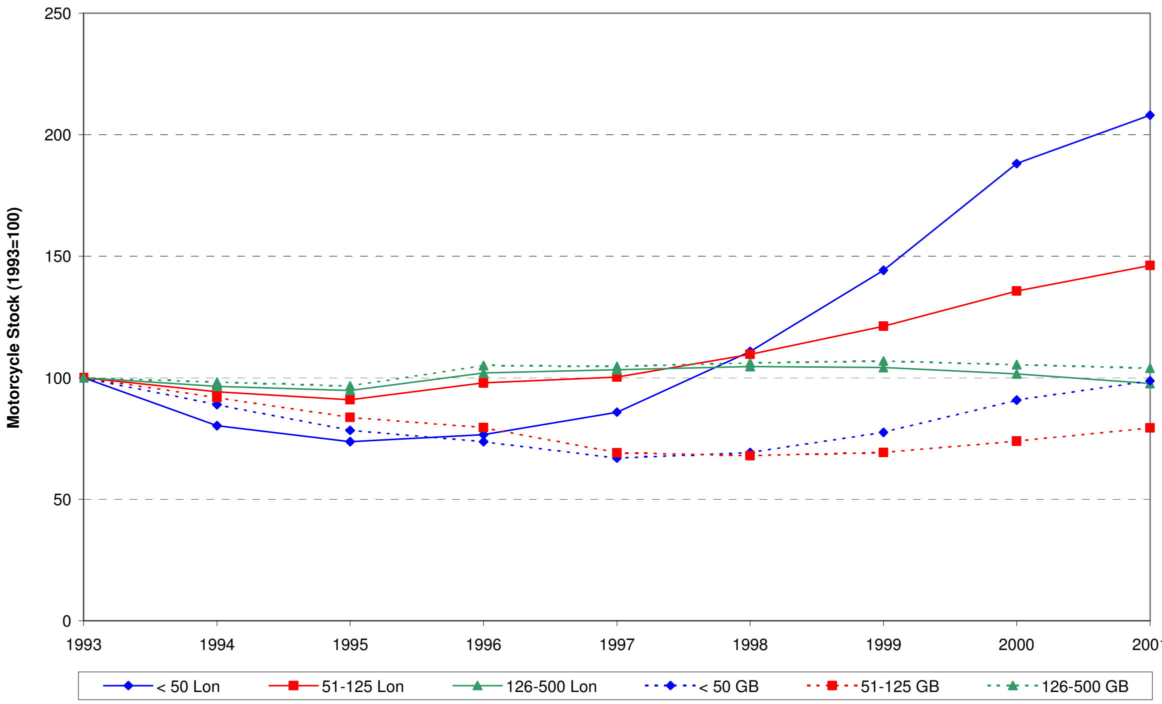
Figure 4: Changes in Motorcycle Stock by Region, 1993-2001



It can be seen that stock in London has grown considerably more than stock in the rest of GB over the period. By contrast stock in Cambridgeshire has grown noticeably less than GB stock. Stock in the South has not grown more rapidly than in the rest of GB, in fact it has actually grown slightly less. Given this result it is valid in subsequent plots to compare London and Cambridgeshire to the GB (excluding London) trends. Note that in all subsequent plots, the GB trend lines exclude Greater London data.

2.12 Figure 5 plots the change in stock in London for the three smallest engine size bands and compares the changes to the overall GB trends.

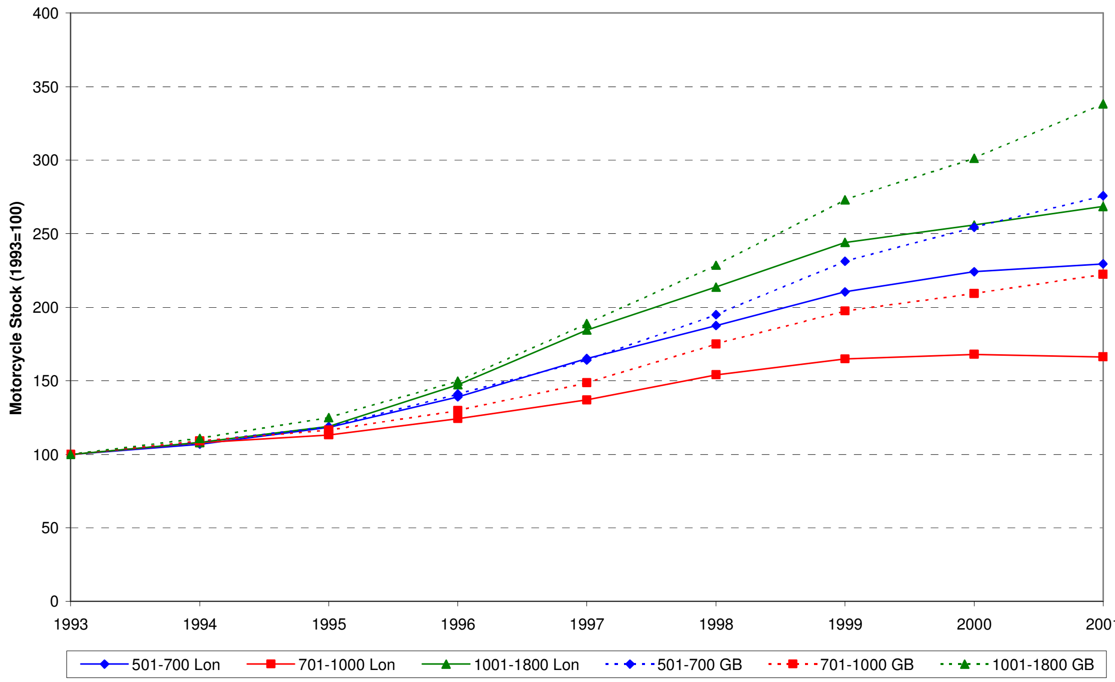
Figure 5: Changes in London Motorcycle Stock, Small Engine Bands, 1993-2001



The < 50 cc band in London has grown by over 100 % in the period, whereas the overall GB stock level in 2001 is close to 1993 levels. In the 51-125 cc band, London stock has grown by nearly 50 % whereas overall GB stock has shown a slight decline. Finally in the 126-500 cc band London stock has shown little change, a pattern consistent with the GB trend.

2.13 Figure 6 plots the change in stock in London for the largest engine size bands and compares the changes to the overall GB trends.

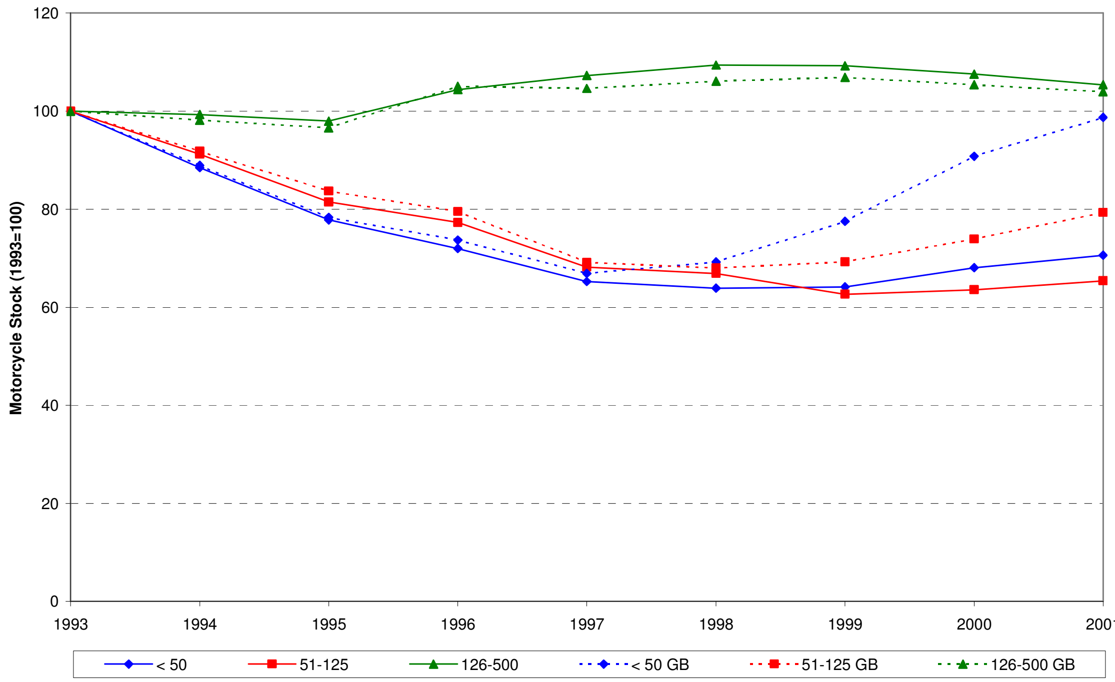
Figure 6: Changes in London Motorcycle Stock, Large Engine Bands, 1993-2001



While in London the growth in bikes under 125 cc has been much larger than across GB as a whole, for each of the three large engine size bands London stock has shown slower rates of growth than GB stock as a whole. Nonetheless the stock of large bikes in London has grown considerably over the period.

2.14 Figure 7 plots the change in stock in Cambridgeshire for the three smallest engine size bands and compares the changes to the overall GB trends.

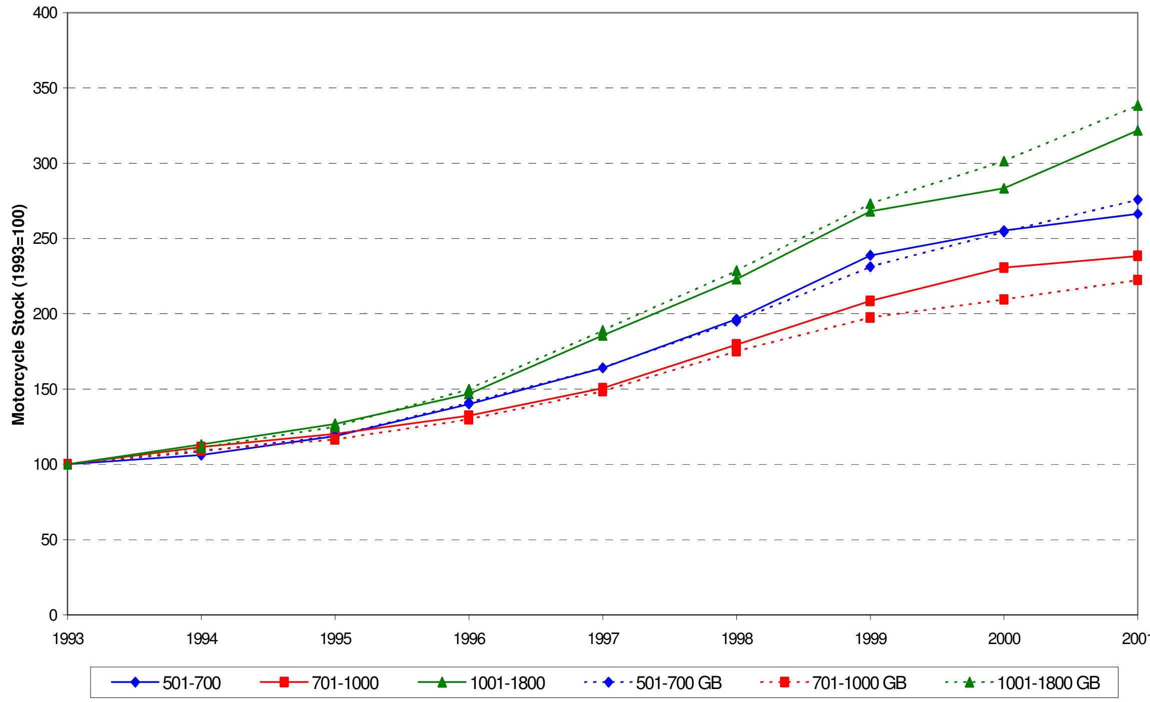
Figure 7: Changes in Cambridgeshire Motorcycle Stock, Small Engine Bands, 1993-2001



In contrast to London, in Cambridgeshire the numbers of motorcycles in the two smallest engine size categories have declined considerably more than across the GB as a whole. This difference is caused by the fact that post-1998 overall GB stock levels recovered significantly for these two engine sizes, whereas the numbers in Cambridgeshire remained more or less flat. Numbers in the 126-500 cc band have changed little over the period, consistent with the overall GB trend.

2.15 Figure 8 plots the change in stock in Cambridgeshire for the largest engine size bands and compares the changes to the overall GB trends.

Figure 8: Changes in Cambridgeshire Motorcycle Stock, Large Engine Bands, 1993-2001



Overall the numbers of large bikes in Cambridgeshire has grown significantly over the period, consistent with the overall GB trend. Bikes in the 701-1000 cc band have grown more than across GB as a whole, whereas the largest bikes (1001-1800 cc) have grown less.

Sample for Motorcycle Ownership Modelling

2.16 The motorcycle ownership models developed for this study reflect personal ownership. It is the opinion of the study team that the decision to purchase and use a motorcycle is a personal one, not a household one, although household characteristics, for example, presence of children may influence the decision.

2.17 Whilst the VID data is useful for understanding national trends in ownership at an aggregate level as it contains information on the characteristics of all currently registered motorcycles, the database contains no information on the characteristics of those owning each type of motorcycle. It is therefore necessary to consider other data sources to obtain information about "who" owns these motorcycles in order to build a disaggregate ownership model.

2.18 The ownership models have been estimated from two data sets. The first data set is the National Travel Survey (NTS) data, which provides information on the number of motorcycles each individual within the survey sample owns and the engine sizes of those motorcycles. Data from 1992 to 2001 has been used so as to identify a sufficiently large sample of motorcycle owners.

2.19 The second data set used is drawn from the 2000 Family Expenditure Survey (FES). Given the large changes in total stock between 1993 and 2001 (see previous section for details), it was felt to be important to boost the volume of more recent data, and the FES data provides a larger sample of households per year than the NTS. The FES data provides information on the number of motorcycles each individual within the sample owns but does not provide engine size information.

2.20 For both the NTS and FES samples, information was supplied at the person level (e.g. personal income, age, occupation), the household level (e.g. the number of adults and children in the household) and the location of the household (e.g. metropolitan area). The number of available NTS and FES person level observations (including both motorcycle owners and non-owners) by year of survey is tabulated in Table 2 (the percentages reflect the proportion of data in any one year).

Table 2: NTS and FES Data by Year

	NTS		FES		Total	
1992	6,852	11.2%			6,852	9.5%
1993	6,340	10.4%			6,340	8.8%
1994	6,363	10.4%			6,363	8.8%
1995	6,228	10.2%			6,228	8.6%
1996	5,994	9.8%			5,994	8.3%
1997	5,813	9.5%			5,813	8.1%
1998	5,426	8.9%			5,426	7.5%
1999	5,487	9.0%			5,487	7.6%
2000	6,203	10.2%	11,283	100.0%	17,486	24.2%
2001	6,207	10.2%			6,207	8.6%
	60,913	100.0%	11,283	100.0%	72,196	100.0%

It can be seen that the NTS data is well distributed between the different survey years.

2.21 The distributions of the NTS and FES samples by the number of motorcycles owned are presented in Table 3.

Table 3: Motorcycle Ownership Model Observations

Motorcycles	NTS		FES		Total	
	Obs.	%	Obs.	%	Obs.	%
Zero	60,021	98.54%	11,083	98.23%	71,104	98.49%
One	819	1.34%	160	1.42%	979	1.36%
Two Plus	73	0.12%	40	0.35%	113	0.16%
Total	60,913	100.00%	11,283	100.00%	72,196	100.00%

The percentages of observations with zero and one motorcycles are similar between the two datasets. The slightly lower percentage of zero motorcycle ownership in the FES data is consistent with the growth in registrations over the period – the NTS data reflects an average of the 1992-2001 situation, whereas the FES data reflects the 2000 situation. The percentage of individuals with two plus motorcycles is significantly higher in the FES data. It may be that some of the growth in motorcycle ownership between 1992 and 2001 is explained by existing motorcycle owners acquiring additional motorcycles. This could be associated with the growth in small machines, which are not seen to be substitutes in terms of function or use (such as commuting) to larger ones. However, the small sample sizes of multiple motorcycle owners make it hard to draw any firm conclusions here.

Motorcycle Ownership Model Structure

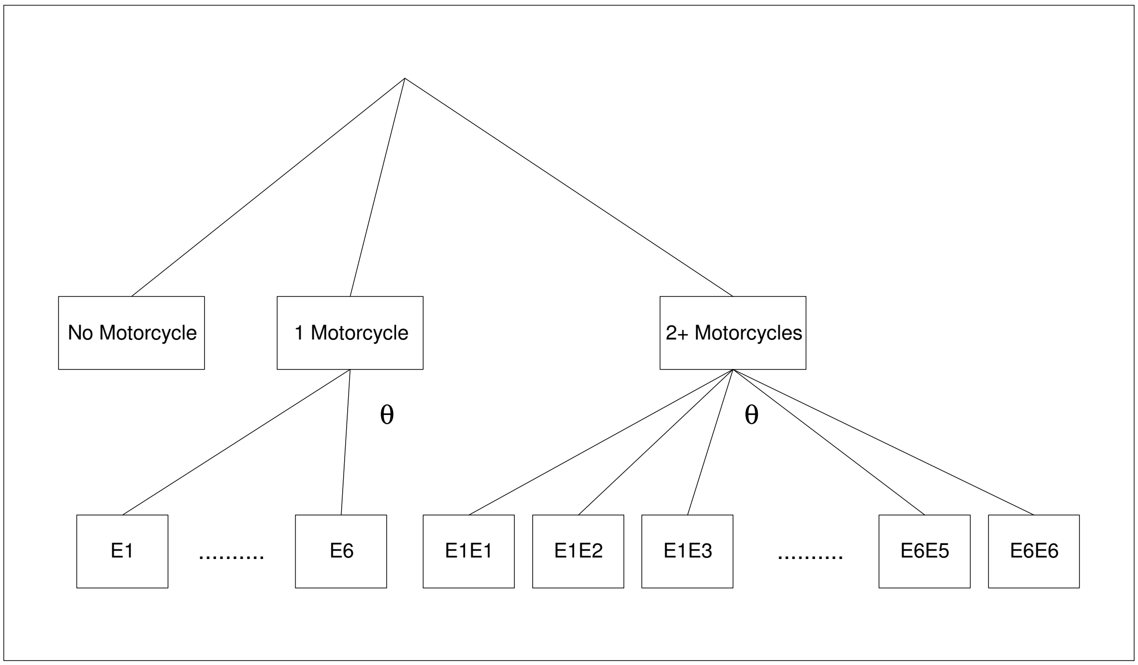
2.22 The motorcycle ownership model predicts both the number of motorcycles owned and the engine sizes of these motorcycles. In terms of numbers of motorcycles, zero, one and two-plus motorcycle alternatives are identified. The number of individuals owning more than two motorcycles is very small (17 / 60,913 = 0.03 % of NTS sample, 8 / 11,283 = 0.07 % of FES sample) and therefore there is insufficient data to distinguish ownership of more than two motorcycles in the models. Six engine size alternatives are also distinguished:

- E1: up to 50 cc
- E2: 51 – 125 cc
- E3: 125 – 500 cc
- E4: 501 – 700 cc
- E5: 701 – 1000 cc
- E6: 1001 – 1800 cc

For the two-plus motorcycles alternative, the choice of engine size for both of the motorcycles is modelled. Where an individual owns more than two motorcycles, then the engine sizes of the two motorcycles with the highest annual mileages are modelled.

2.23 The model structure is illustrated in Figure 9.

Figure 9: Motorcycle Ownership Model Structure



2.24 The parameter θ is used to account for the different error variation associated with the choice of engine size relative to the choice as to how many motorcycles to own. A value for θ less than one implies that there is more error in the model of the choice of the number of motorcycles compared to the model of choice of engine size.

2.25 Under the two-plus motorcycles alternative there are a total of 36 engine size alternatives, one for each possible combination of first and second motorcycle engine size band. It is assumed in the modelling that the utility of an engine size combination can be expressed as the sum of the utility of each of the two separate engine size alternatives; this assumption is necessary as there is relatively little data on multiple motorcycle ownership.

2.26 The NTS data provides engine size information, and thus allows choice to be specified at the bottom of the tree structure where six engine size alternatives are distinguished: The FES data only provides information on the number of motorcycles owned: the engine sizes of these motorcycles are not known. Therefore choice is specified higher up in the tree in the FES data, at the number of motorcycles level. The model structure used allows the NTS and FES data to be combined in a statistically efficient manner to provide joint coefficient estimates.

Motorcycle Ownership Model Results

2.27 The estimation of the discrete choice models for motorcycle ownership and engine size was undertaken using ALOGIT. A series of models were estimated to find the best explanation to describe the number of motorcycles and motorcycle engine size per person. For each model presented here, two sets of values are presented: (i) model summary statistics, and (ii) model coefficients and their associated approximate t-ratios.[6]. The model summary statistics are defined in Table 4 below.

Table 4: Model Summary Statistics

Statistic	Definition
Observations	The number of observations included in the model estimation.
Final log (L)	This indicates the value of the log-likelihood at convergence. The log-likelihood is defined as the sum of the log of the probabilities of the chosen alternatives, and is the function that is maximised in model estimation. The value of log-likelihood for a single model has no obvious meaning. However comparing the log-likelihood of two models with different specifications allows statistical tests to be made on the differences between the models
D.O.F.	Degrees of freedom, i.e. the number of coefficients estimated in this model. Note that if a coefficient is constrained to a fixed value (indicated by(*)) then it is not a degree of freedom.
$Rho^2(0)$	The rho-squared measure compares the log-likelihood (LL(final)) to the log-likelihood of a model with all coefficients restricted to zero (LL(0)): $Rho^2(0) = 1 – LL(final)/LL(0)$ A higher value indicates a better fitting model.

2.28 The coefficient values are then presented. If a coefficient is positive then it has a positive impact of utility and so reflects a higher probability of choosing the alternatives to which it is applied, for example, improved parking facilities. Conversely if a coefficient is negative then it has a negative impact on utility and so reflects a lower probability of choosing the alternative to which it is applied.

6 This ratio is an asymptotic approximation to the standard statistical Student’s t-ratio.

2.29 The terms in each model reflect preferences for the alternatives to which they are applied, for example the constant “inc<9k_1” with a negative value of about -0.43 in the one motorcycle utility implies that Persons with incomes under £ 9,000 p.a. (at 2001 prices) are less likely to own a motorcycle. The constants on the models are additive and more than one constant can be applied for each individual. A positive value for a constant indicates that the individual is more likely to choose that alternative, and a negative value for a constant indicates that the individual is less likely to choose that alternative.

2.30 Two sets of model results are presented in Table 5: the first set of results contain a purchase cost term (in 2001 indices), the second set of results exclude this term. The purchase cost information comes from National Statistics data on motorcycle sales. This data reflects unit costs of motorcycles split by engine size, from which the average cost of a motorcycle of each size can be determined for each year. The costs are industry costs, not retail costs. The data has been obtained from the National Statistics website:

http://www.nationalstatistics.gov.uk/StatBase/Product.asp?vlnk=7612&Pos=&ColRank=1&Rank=224

The purchase cost term significantly improves the fit of the model[7], but it may not be possible to forecast these costs.

Additional work was undertaken to try to obtain retail costs from motorcycle agencies, but the required data could not be provided within the timescale of the study.

2.31 A full explanation of each term in the model is provided in Table 6. These have been chosen to maximise model fit whilst maintaining plausibility and simplicity.

[7] A likelihood ratio test suggests that the inclusion of the additional cost term provides an improvement in model fit at the 95% level of significance, although it should be noted that some terms in the model become insignificant – these are retained for the purposes of comparison.

Table 5: Ownership Model Results

File	Motorcycle_Own_63.F12		Motorcycle_Own_64.F12	
Converged	True		True	
Observations	72196		72196	
Final log (L)	-6807.9		-6813.2	
D.O.F.	40		39	
Rho²(0)	0.975		0.975	
Estimated	20 Jun 03		20 Jun 03	
purch_cost	-3.3e-4	(-3.2)		
Terms on the One Motorcycle Alternative:				
one_bike	-6.20	(-30.5)	-6.37	(-28.9)
male_1	2.15	(16.7)	2.17	(16.5)
16_24_1	-0.469	(-2.9)	-0.469	(-2.8)
25_34_1	0.496	(5.2)	0.498	(5.2)
35_39_1	0.604	(5.3)	0.606	(5.3)
40_44_1	0.402	(3.3)	0.403	(3.3)
60_69_1	-0.991	(-6.1)	-0.991	(-6.1)
70_plus_1	-1.69	(-7.6)	-1.69	(-7.6)
one_car_1	0.322	(4.7)	0.321	(4.7)
no_child_1	0.340	(4.6)	0.341	(4.6)
inc<9k_1	-0.430	(-4.6)	-0.425	(-4.5)
SEG_1_1	-0.326	(-3.9)	-0.327	(-3.9)
Lon_1	-0.402	(-3.8)	-0.402	(-3.8)
Met_1	-0.783	(-6.6)	-0.782	(-6.6)
Scot_1	-1.01	(-6.1)	-1.01	(-6.1)
Terms on the Two Motorcycles Alternative:				
two_bikes	-11.3	(-14.1)	-11.6	(-14.1)
male_2	4.66	(6.1)	4.73	(6.2)
16_24_2	-2.12	(-3.6)	-2.11	(-3.6)
inc>15k_2	0.687	(3.1)	0.681	(3.0)
Lon_Met_2	-0.620	(-2.6)	-0.620	(-2.6)
Scot_2	-2.50	(-2.5)	-2.50	(-2.5)
Terms on the Engine Size Alternatives:				
51_125	-0.801	(-3.7)	-0.974	(-4.8)
126_500	-0.309	(-1.2)	-0.797	(-4.0)
501_700	0.197	(0.6)	-0.711	(-3.5)
701_1000	-0.778	(-1.2)	-2.05	(-4.2)
1001_1800	-2.04	(-3.2)	-3.31	(-6.6)
E1_eq_E2	0.713	(3.0)	0.705	(3.0)
male_E1	-1.98	(-8.9)	-2.01	(-9.3)
male_E56	1.14	(2.4)	1.11	(2.3)
16_19_E1	3.24	(7.6)	3.15	(7.5)
16_19_E2	1.72	(4.0)	1.66	(3.9)
50_pl_E1	0.670	(3.3)	0.657	(3.3)
50_pl_E456	-0.592	(-3.8)	-0.578	(-3.7)
inc<7_E456	-0.814	(-3.4)	-0.834	(-3.5)
inc>20_E56	0.701	(4.7)	0.706	(4.7)
SEG_4_E1	0.740	(3.7)	0.701	(3.5)
0_car_E12	0.670	(4.2)	0.650	(4.1)
Tree and Scaling Parameters:				
FES_Scale	0.632	(4.9)	0.568	(3.8)
theta	0.588	(4.9)	0.617	(4.7)

2.32 The model terms are defined in the following table.

Table 6: Motorcycle Ownership Model Terms

Term	Definition
purch_cost	The purchase cost reflects the unit costs of motorcycles, split by engine size. These are industry costs, not retail costs.
one_bike	Constant on the one motorcycle alternative
male_1	Males are more likely to own one motorcycle
16_24_1	Persons aged 16-24 are less likely to own a motorcycle than those aged 45-59
25_34_1	Persons aged 25-34 are more likely to own a motorcycle than those aged 45-59
35_39_1	Persons aged 35-39 are more likely to own a motorcycle than those aged 45-59
40_44_1	Persons aged 40-44 are more likely to own a motorcycle than those aged 45-59
60_69_1	Persons aged 60-69 are less likely to own a motorcycle than those aged 45-59
70_plus_1	Persons aged 70 plus are less likely to own a motorcycle than those aged 45-59
one_car_1	Persons in households with one car are more likely to own a motorcycle
no_child_1	Persons living in households without children are more likely to own a motorcycle
inc<9k_1	Persons with incomes under £ 9,000 p.a. (2001 prices) are less likely to own a motorcycle
SEG_1_1	Persons in the professional and managerial SEG group are less likely to own a motorcycle
Lon_1	Persons living in London are less likely to own a motorcycle than less likely to own a motorcycle than those living in Wales or non-metropolitan England
Met_1	Persons living in Metropolitan areas are less likely to own a motorcycle than those living in Wales or non-metropolitan England. This term is larger in magntude than the Lon_1 term, so the effect is stronger in non-London metropolitan areas
Scot_1	Persons living in Scotland are less likely to own a motorcycle than those in Wales or other non-metropolitan areas in England. This term is larger in magnitude than the Lon_1 and Met_1 terms, i.e. persons in Scotland are least likely to own one motorcycle
two_bikes	Constant on two motorcycle alternative
male_2	Males are more likely to own two motorcycles
16_24_2	Persons aged 16-24 are less likely to own two motorcycles than those aged 25-plus
inc>15k_2	Persons with incomes of at least £ 15,000 p.a. (2001 prices) are more likely to own two motorcycles
Lon_Met_2	Persons living in London and Metropolitan areas are less likely to own two motorcycles than those living in Wales or non-metropolitan areas in England

Term	Definition
Scot_2	Persons living in Scotland are less likely to own two motorcycles than those living in Wales or other non-metropolitan areas in England. This term is larger in magnitude than the Lon_ Met_2 term, i.e. persons in Scotland are least likely to own two motorcycles
51_125	Engine size dummy for 51-125 cc
126_500	Engine size dummy for 126-500 cc
501_700	Engine size dummy for 501-700 cc
701_1000	Engine size dummy for 701-1000 cc
1001_1800	Engine size dummy for 1001-1800 cc
E1_eq_E2	Constant reflecting higher probability of second engine size being equal to the first
male_E1	Males are less likely to own motorcycles < 50 cc in size
male_E56	Males are more likely to own motorcycles > 700 cc in size
16_19_E1	Individuals aged 16-19 are more likely to own motorcycles < 50 cc in size
16_19_E2	Individuals aged 16-19 are more likely to own motorcycles 51-125 cc in size
50_pl_E1	Individuals aged 50 plus are more likely to own motorcycles < 50cc in size
50_pl_E456	Individuals aged 50 plus are less likely to own motorcycles > 500 cc in size
inc<7_E456	Persons with incomes under £ 7,000 p.a. (2001 prices) are less likely to own motorcycles > 500 cc in size
inc>20_E56	Persons with incomes of at least £ 20,000 p.a. (2001 prices) are more likely to own motorcycles > 700 cc in size
SEG_4_E1	Persons with semi-skilled or unskilled manual occupations are more likely to own motorcycles < 50 cc in size
0_car_E12	Persons in zero car households are more likely to own motorcycles < 125 cc in size
FES_Scale	Scaling coefficient applied to the FES data relative to the NTS data.
theta	Structural tree coefficient (see Figure 9)

2.33 All model terms are significant at a 95 % confidence level in model 64, however some become statistically insignificant at this level once the purchase cost term is included.

2.34 The value for FES_Scale of less than one implies that there is more error in the FES data than the NTS data. The lack of engine size information in the FES data means that this result is plausible.

2.35 The value of theta implies that there is more error in modelling the decision of how many motorcycles to own compared to the decision of choice of engine size.

2.36 It is interesting to note that the positive value of E1_eq_E2 shows that multiple motorcycle owners have an increased probability of the second motorcycle being the same size as the first. This may be individuals that are comfortable with a certain level of performance but use an older bike for utilitarian trips such as commuting and a newer model for leisure – this would seem to fit with anecdotal evidence from multiple motorcycle owners expressing concerns about leaving their new motorcycles parked all day in areas where they may be subject to theft. This also suggests that these multiple motorcycle owners may not be strongly associated with the increase in purchase of smaller machines, although this has not been directly tested.

Motorcycle Ownership Model Recalibration

2.37 Because of the small number of observed motorcycle owners, the ownership models are estimated from a sample of households from 1992 to 2001. The VID trend analysis has revealed significant changes in stock over this period, and differential patterns of growth by engine size band and region. Consequently the models have been recalibrated so that they replicate the engine band shares in the 2001 VID data. This recalibration is described in the following section. First the recalibration method is presented in detail for the case of Great Britain as a whole. This is followed by the results from the recalibrations for other geographical sub-areas, each of which have used the same basic procedure but have used targets appropriate to each individual area.

2.38 The 2001 Census gives the total Great Britain (GB) population aged 16 and above in 2001 as 45,632,832[8]. The VID data gives the total number of motorcycles registered with an engine size of up to 1800 cc in 2001 as 1,008,324. This gives a mean 2001 ownership propensity of 0.022097. These two data sources allow an overall mean ownership propensity to be calculated, but they do not allow us to determine the split between one and two-plus motorcycles. For this, the disaggregate NTS and FES data sources used for model estimation have been analysed. To give a sufficiently large sample, data from the calendar years of 2000 and 2001 have been combined.

8 http://www.nationalstatistics.gov.uk/census2001/pop2001

Table 7: Multiple Ownership in NTS and FES Data

Motorcycles	NTS				FES		Total	
	Calendar Year 2000		Calendar Year 2001		2000			
0	6,218	0.9831	6,226	0.9853	10,890	0.9652	23,334	0.9752
1	96	0.0152	88	0.0139	323	0.0286	507	0.0212
2	7	0.0011	5	0.0008	49	0.0043	61	0.0025
3	2	0.0003	0	0.0000	17	0.0015	19	0.0008
4	1	0.0002	0	0.0000	4	0.0004	5	0.0002
5	1	0.0002	0	0.0000	0	0.0000	1	0.0000
	6,325	1.0000	6,319	1.0000	11,283	1.0000	23,927	1.0000

From this data it is possible to calculate the mean number of motorcycles owned by individuals with more than one motorcycle as 2.372, and the ratio p_1 / p_{2+} as 5.895.

We can then set up two simultaneous equations:

$$p_1 = 5.895\ p_{2+}$$

$$p_1 + 2.372 * p_{2+} = 0.022097$$

This gives:

$$p_1 = 0.0158$$

$$p_{2+} = 0.0027$$

Note that the values for p_1 and p_{2+} are not taken directly from Table 7 - all that Table 7 provides is the ratio p_1 / p_{2+} and the mean number of motorcycles owned by multiple owners, and then the final values of p_1 and p_{2+} are calculated to be consistent with the full VID sample. Comparison of these calculated probabilities from the VID data with the proportions observed in the FES dataset indicates that the FES overstates the total proportion of motorcycle ownership. Whilst interesting, this difference will have little impact on the recalibration if the FES data on the one motorcycle – multiple motorcycle split is representative.

2.39 The VID data gives the total number of registrations by engine size band for GB (including London) directly. Thus the probability of each engine size band is easily calculated as shown in Table 8.

Table 8: 2001 VID Engine Size Targets for GB

	< 50	51-125	126-500	501-700	701-1000	1001-1800	Total
Total	164,863	183,963	195,282	187,134	186,041	91,041	1,008,324
Probability	0.1635	0.1824	0.1937	0.1856	0.1845	0.0903	1.0000

2.40 Using the information from Sections 2.38 and 2.39 it is possible to determine the targets for recalibrating the sample in the Motorcycle_Own_63 model. Only the data for the years 2000 and 2001 have been used for the purposes of this recalibration as the interest is in obtaining a match with recent observed ownership levels; following the exclusion of outliers this provides a base sample of 23,693 observations. The targets to which these were matched are shown later in Table 9.

2.41 The targets were met by adding a constant to each alternative (zero motorcycles, one motorcycles, two-plus motorcycles and the six engine size band alternatives) using the following formula:

$$c_i = c_{i-1} + \ln(T/P)$$

where: c_i is the new correction factor

c_{i-1} is the correction factor for the last iteration

T is the target total demand for the alternative

P is the predicted total demand for the alternative

The correction factors were recalculated for each new iteration in the calibration until the absolute difference between the predicted demand and target demand for each alternative was less than one, which was a selected as appropriate in this context to indicate convergence.

2.42 Twelve iterations were required to achieve a good match between the targets T and predicted values P. The fit of the recalibrated model to the targets is detailed in Table 9.

Table 9: Fit To Targets, GB Recalibration

Alternative	Target	Original Model 63		Recalibrated Model 63	
		Predicted	Difference	Predicted	Difference
Zero	23,256.344	23,301.635	8.793	23,255.572	-0.772
One	373.327	347.618	5.496	373.899	0.572
Two	63.329	43.748	-14.288	63.529	0.200
< 50 cc	81.749	73.943	-0.972	81.903	0.154
50 - 125cc	91.220	86.570	2.975	91.400	0.180
125 - 500 cc	96.832	73.437	-15.301	97.023	0.191
500 - 700 cc	92.792	71.835	-13.201	92.971	0.179
700 - 1000 cc	92.250	95.108	10.569	92.434	0.184
1000 - 1800 cc	45.143	34.220	-7.150	45.227	0.083

2.43 The models have also been recalibrated for: London; London, South East and Eastern England; and Cambridgeshire. For the purpose of these recalibrations there is not sufficient data in the NTS and FES at a regional level to carry out the calculations detailed in Section 2.38 completely at regional level. Instead it has been assumed that the GB-wide proportions given in Table 7 are applicable, but VID and census data have been used at each regional level to determine mean ownership, so that p1 and p2+ are regional specific. Targets for engine size bands have also been determined on a regional level basis using the VID data. Table 10 presents the key information from the calibration of each of the three areas, which is followed by a series of tables presenting the fit obtained to the targets for each of the geographic areas.

Table 10: Calibration information for each sub-region

	London		London, South East and Eastern England		Cambridgeshire	
Census >= 16 years of age	5,723,855		16,435,660		445,355	
VID motorcycles registered	110,234		506,911		15,455	
Mean ownership	0.019259		0.030842		0.034703	
p1	0.0137		0.0220		0.0247	
p2+	0.0023		0.0037		0.0042	
Target - total (probability)						
< 50 cc	18,089	(0.1641)	81,590	(0.1610)	2,758	(0.1785)
51-125 cc	32,443	(0.2943)	109,349	(0.2157)	2,256	(0.1460)
126-500 cc	16,726	(0.1517)	88,191	(0.1740)	2,789	(0.1805)
501-700 cc	19,612	(0.1779)	94,627	(0.1867)	2,916	(0.1887)
701-1000 cc	15,824	(0.1435)	89,781	(0.1771)	3,221	(0.2084)
1001-1800 cc	7,540	(0.0684)	43,373	(0.0856)	1,515	(0.0980)
Total	110,234	(1.0000)	506,911	(1.0000)	15,455	(1.0000)
Iterations required	10		14		14	

Table 11: Fit To Targets, London Region Recalibration

Alternative	Target	Original Model 63		Recalibrated Model 63	
		Predicted	Difference	Predicted	Difference
Zero	23,312.425	23,301.635	-10.791	23,311.635	-0.790
One	325.379	347.618	22.238	325.965	0.586
Two	55.196	43.748	-11.448	55.400	0.204
< 50 cc	71.508	73.943	2.435	71.665	0.156
50 - 125cc	128.252	86.570	-41.681	128.561	0.310
125 - 500 cc	66.120	73.437	7.317	66.269	0.149
500 - 700 cc	77.529	71.835	-5.694	77.703	0.174
700 - 1000 cc	62.555	95.108	32.553	62.697	0.142
1000 - 1800 cc	29.807	34.220	4.413	29.870	0.063

Table 12: Fit To Targets, London, South East and Eastern England Recalibration

Alternative	Target	Original Model 63		Recalibrated Model 63	
		Predicted	Difference	Predicted	Difference
Zero	23,083.535	23,301.635	218.100	23,082.623	-0.912
One	521.073	347.618	-173.455	521.744	0.671
Two	88.392	43.748	-44.644	88.634	0.241
< 50 cc	112.324	73.943	-38.380	112.505	0.181
50 - 125cc	150.539	86.570	-63.969	150.796	0.257
125 - 500 cc	121.411	73.437	-47.974	121.613	0.202
500 - 700 cc	130.272	71.835	-58.437	130.485	0.213
700 - 1000 cc	123.600	95.108	-28.493	123.807	0.207
1000 - 1800 cc	59.711	34.220	-25.491	59.804	0.093

Table 13: Fit To Targets, Cambridgeshire Recalibration

Alternative	Target	Original Model 63		Recalibrated Model 63	
		Predicted	Difference	Predicted	Difference
Zero	23,007.238	23,301.635	294.397	23,006.269	-0.969
One	586.304	347.618	-238.687	587.014	0.710
Two	99.458	43.748	-55.710	99.717	0.259
< 50 cc	140.125	73.943	-66.182	140.342	0.217
50 - 125cc	114.620	86.570	-28.050	114.799	0.178
125 - 500 cc	141.700	73.437	-68.263	141.925	0.224
500 - 700 cc	148.153	71.835	-76.318	148.382	0.229
700 - 1000 cc	163.649	95.108	-68.541	163.913	0.265
1000 - 1800 cc	76.972	34.220	-42.752	77.087	0.114

2.44 These recalibrated models are the final models for each of the areas of interest and are recommended for use in subsequent policy analysis.

3 MOTORCYCLE USAGE

Introduction

3.1 Whilst Revealed Preference (RP) data was judged to be more appropriate given the nature of decisions for the ownership models, Stated Preference (SP) data was judged to be more appropriate for development of the usage models on the basis that the low incidence of motorcycle ownership in the population meant that RP travel databases, such as the NTS, did not provide adequate information on the choices that have been made. As a result it has been necessary to collect new sources of information on these aspects of travel behaviour in this study. Both Revealed and Stated Preference data about motorcycle usage was collected in this study. The benefit of this approach is that data on actual behaviour is collected and supplemented with a number of data-points relating to a range of controlled hypothetical situations. As a result a much richer data source, with multiple decision points for each respondent, is obtained at an economical cost.

3.2 The decision to collect Stated Preference data was also driven by the desire to investigate a number of potential policy responses, for example the effects of introducing motorcycle parking costs, changing lane widths and introducing parking security measures. The responses to such policies are difficult to measure from Revealed Preference sources as the incidence of the emerging policy measures are typically quite small, and in some cases the policies are still in consideration and as such have not reached implementation. The responses to some measures, such as changes in motorcycle usage as a result of changes in lane width, may also be too small to measure from revealed preference data.

3.3 One particularly important issue in setting the scope for the new data collection was the specification of who should be surveyed. In examining the potential for mode switching to motorcycle from other modes there are two distinct groups that can be considered. The first of these is existing motorcycle owners who can increase their existing use of motorcycle, the second is non-owners who would need to purchase a motorcycle and possibly even undertake additional training in order to use this mode for their travel. It was judged that the quantification of likely mode switches to motorcycle for non-motorcycle-owning respondents was simply too complex to undertake in this study and as such the usage modelling concentrated on usage for existing motorcycle owners. Ownership decisions are represented in the motorcycle ownership models.

3.4 Motorcycle owners as a group are far from homogeneous, with extremes of those who use their machines on a daily basis for commuting regardless of weather, through to those who use their machines solely for leisure purposes at weekends. There are also be significant differences in usage according to engine size, e.g. moped riders may be less likely to use their motorcycle for a touring holiday than an owner of a large capacity motorcycle.

3.5 The key point is that for those that own motorcycles it is possible to imagine using a motorcycle for other journeys; this is less likely to be the case for those that do not own motorcycles. As such, we have a pair of models that describe the two decision processes, one describes ownership and one describes use for owners. There is no explicit feedback from traffic quality variables into the ownership model to describe increases in ownership as a result of changes in congestion. However these effects are modelled in the description of use once an individual owns a motorcycle. An issue which therefore has not proved possible to address directly, but is of some significance, is any growth in the purchase of scooters and small motorcycles for commuter use in response to congestion charges by those who previously did not own another motorcycle.

3.6 The approach of collecting RP and SP information from the same respondents provides economy and efficiency in the data collection, but it does have the disadvantage that there are correlations between the RP and SP responses. The coefficient estimates within the joint models have therefore been corrected with a jack-knifing procedure.

Survey design

3.7 The main area of interest to the study is the relationship between motorcycles and congestion. The usage model therefore concentrated on the choice of mode for journeys made during the AM peak period. For the study "AM peak" was defined as between 7am and 10am, which is consistent with the definitions used within the mode choice and assignment models to be developed and applied to London and Cambridge within the project. The journeys were also required to include travel into or within an urban area.

3.8 Representatives from motorcycle groups were consulted during the questionnaire design phase in order to ensure that the survey questionnaire was appropriate for motorcycle users. This advisory group was consulted at two key points in the survey development. The first meeting was used as a brainstorming session to elicit their ideas on the factors that are likely to influence the decision of motorcyclists to travel in the AM peak. This session helped inform the variables for the SP exercises and provided useful clarification on the most appropriate definitions to use for a number of key concepts such as congestion and filtering. The second meeting with the representatives was held after the design of the survey instrument but before the formal pilot. This meeting provided an opportunity to work through the questionnaire and iron out issues of definition and presentation; it also provided useful insights on question wording and identified areas where the questionnaire could benefit from the addition or removal of certain questions.

3.9 A formal pilot survey with 40 interviews was also undertaken. This pilot led to a number of changes in the original design, mostly to the design of the SP experiments as a result of a lack of trading between modes. The changes for the main survey included: (i) the introduction of parking costs in the within-mode experiment (no cost term was included in this experiment in the pilot survey, which led to difficulties in estimating joint models from the within-mode and between-mode data sets), (ii) the introduction of different parking and congestion costs for respondents making journeys inside and outside of London in the between-mode experiment, and (iii) the inclusion of a cost variable for the PT alternative in the between-mode experiment. The details of the final survey structure are provided in the following section.

Survey structure

3.10 The survey was designed to collect both SP and RP information for a specific journey made in the AM peak for existing motorcycle owners. The survey contained a number of separate sections, which collected important information relating to both existing motorcycle ownership and use, and the constraints and personal circumstances that could influence the ability to modify the existing usage behaviour.

3.11 The first section of the questionnaire collected information on the respondent's motorcycle ownership and general usage profile. This started with questions about the respondent's experience of motorcycling, collecting both information on how long the respondent had held a motorcycle licence and details of any breaks the respondent may have had from motorcycling. This information provided measures of how important motorcycling had become in the respondent's life and included a self-classification scheme which allowed identification of inexperienced riders and "born-agains" returning to motorcycling after a significant break. The respondents' were then questioned about the number and types of motorcycle they owned and how they typically used them. If respondents owned more than one motorcycle they were asked to provide details on the two motorcycles they used most frequently. Respondents were also asked some questions to understand their driving behaviour in congested conditions, specifically with regard to filtering through traffic.

3.12 A series of questions were then presented to investigate whether the respondent had a car licence and/or access to a car, in addition to their motorcycle. For those that could use a car, subsequent questions were presented to determine the level of their car usage and the profile of trips for which car was used.

3.13 In the next section of the questionnaire, respondents were asked to focus on the most recent peak period weekday journey they had made in the previous two weeks. A number of details were collected about this trip, such as the trip origin and destination, the time of travel, the duration of the trip, whether there was any flexibility in the time at which they travelled and the purpose of the trip. The respondent was then asked to provide details of the mode they used for the trip and the associated journey time and costs by this mode. This was used as an input for the SP exercises and also provided RP data for subsequent model development.

3.14 If the respondent indicated that he or she had used their motorcycle for their journey, they were then asked to provide details about which mode they would have used if their motorcycle was not available for the journey. They were also asked to report the associated journey time and costs for this alternative mode. Respondents who indicated that they did not use their motorcycle for this journey were asked to provide information on the journey times and costs that they would encounter if they had used their motorcycle. Respondents therefore provided information on the level of service they would expect for both their motorcycle and a credible alternative mode for their journey. This data provided the base inputs for the subsequent SP experiments and the subsequent RP modelling.

3.15 Respondents were then presented with a 'within-mode' SP experiment in which they were asked to choose between two hypothetical motorcycle journeys. The variables in this experiment were specified to collect information relating to factors that could make one motorcycle journey better than another, for example because of increased lane widths or the availability of parking security. The full list of variables and levels are provided in Table 14.

Table 14: Within-mode experiment variables and levels

Variable	Levels
Congestion in general motor vehicle lanes	1 Freely flowing 2 Mild congestion 3 Subject to long stopped periods
Parking security	1 You will not know in advance whether you will find a space with security measures 2 You will be able to park at a location with no special security measures for motorcycles 3 You will be able to park at a location with an immovable object to lock your motorcycle to
Distance from parking to destination	1 On site 2 2 mins walk 3 5 mins walk 4 10 mins walk
General traffic lane width	1 Not wide enough for filtering, no access to alternative lanes 2 Wide enough for filtering
Advance stop lines	1 Legal access to advanced stop line 2 No advance stop line
Parking costs	1 Your motorcycle parking will be free 2 Your motorcycle parking will be free 3 Your motorcycle parking will be 50p per day 4 Your motorcycle parking will be £2 per day

3.16 Each respondent was presented with four choice pairs in this within-mode experiment. The Internet survey software required that fixed designs were used and sixteen different blocks of four choice pairs were specified, which were evaluated across the sample. Variables with levels that differed between the choices offered were highlighted in bold to help respondents focus on the key differences between the alternatives. A "neither" option was provided for cases where the respondent would not choose either of the alternatives offered. An example choice pair from the within-mode experiment is presented in Figure 10.

Figure 10: Example within-mode choice pair

Which option would you prefer for your journey in the AM peak period if you had to use your motorcycle?

Option A	Option B
The traffic in the general motor vehicle lanes will be subject to mild congestion **The general traffic lanes are not wide enough for filtering, you have no access to alternative lanes** You have legal access to advanced stop lines	**The traffic in the general motor vehicle lanes will be freely flowing** **The general traffic lanes are wide enough for filtering** You have legal access to advanced stop lines
You will be able to park your motorcycle within 5 minutes walk of your destination **You will be able to park at a location with no special security measures for motorcycles** **Your motorcycle parking will cost £2 per day**	You will be able to park your motorcycle within 5 minutes walk of your destination **You will be able to park at a location with an immovable object to lock your motorcycle to** **Your motorcycle parking will be free**

Prefer Option A ☐ **Prefer Neither** ☐ **Prefer Option B** ☐

3.17 This experiment was presented both to respondents who used their motorcycle for the AM peak period journey investigated in the survey and those who did not use their motorcycle for this journey.

3.18 Following the within-mode experiment, respondents were asked to participate in a 'between-mode' SP experiment. This experiment presented the respondent with choices between motorcycle and another credible mode alternative. The experiment was designed to provide information on the factors which may influence the decision of which mode to use for a journey, such as the influence of weather, journey times and costs. The full list of variables and levels are provided in Table 15.

3.19 There were three guiding principles for the specification of the variables and levels. Firstly, the levels were specified to evaluate possible future policy options, for example provision of motorcycle parking, road pricing, etc. Secondly, the variables were specified such that the levels and choices were reasonable, for example, distance to motorcycle parking locations was the same or closer than for cars, etc. Thirdly, the levels were specified to try to encourage trading between the alternatives.

3.20 It is noted that in the experiment the in-vehicle operating costs for both car and motorcycle were held constant, but the public transport in-vehicle costs were varied. Cost variation between the car and motorcycle modes was investigated through changes in parking costs and road user charging. Specifically, respondents who were making choices between motorcycle and car were presented with four choice pairs with varying parking charges and four choice pairs with varying road user charges. This framework would make most sense to riders well aware or actually with the experience of entering the central parts of London, in or near the road pricing cordon, where the relevance of road user charging and the levels of parking charges for motorcycles are generally the highest. However, it was judged that the London congestion charging scheme had been given sufficient national publicity for those motorcyclists in urban areas outside of London to be sufficiently familiar with the concept of the charges to be able to envisage circumstances in which their local towns may also consider introducing charges in the near to mid future.

Table 15: Between-mode experiment variables and levels

Variable	Motorcycle	Alternative
Expected weather for the day	1 Light intermittent rain 2 Heavy continuous rain 3 Dry, but strong gusty winds 4 Pleasant	
Journey time difference	1 Same as now	1 Same as now 2 5 minutes more than now 3 10 minutes more than now 4 20 minutes more than now
Reliability		1 You rarely have problems on your journey and nearly always arrive on time 2 There are often unpredictable delays causing you to be 10 minutes late 3 There are often unpredictable delays causing you to be 20 minutes late
Motorcycle parking security	1 You will not know in advance whether you will find a space with security measures 2 You will be able to park at a location with no special security measures for motorcycles 3 You will be able to park at a location with an immovable object to lock your motorcycle to	
Distance from parking to destination	1 On-site parking provided 2 within 5 minutes 3 within 10 minutes	1 Car parking in same location as motorcycle parking 2 Car parking 5 mins further than motorcycle parking 3 Car parking 10 mins further than motorcycle parking

Variable	Motorcycle	Alternative
Cost of Travel	1 As reported	1 As reported (for PT see next section)
PT fares		1 Your fare will be 50p cheaper than now (or remain free if currently so) 2 Your fare will remain the same as now 3 Your fare will be 50p more than now 4 Your fare will be £1 more than now
First 4 choices (motorcycle levels apply regardless of alternative mode; alternative mode levels only apply to car)		
Parking Costs (London)	1 Free 2 Free 3 £1 per day 4 £3 per day	1 Same as motorcycle 2 £5 more than motorcycle 3 £10 more than motorcycle 4 £15 more than motorcycle
(non-London)	1 Free 2 Free 3 £1 per day 4 £3 per day	1 Same as motorcycle 2 £3 more than motorcycle 3 £5 more than motorcycle 4 £10 more than motorcycle
Second 4 choices (motorcycle levels apply regardless of alternative mode; alternative mode levels only apply to car)		
Variable	**Motorcycle**	**Alternative**
Congestion Charging (London)	1 No charge 2 No charge 3 £2 per day 4 £5 per day	1 Same as motorcycle 2 Motorcycle charge + £2 3 Motorcycle charge + £3 4 Motorcycle charge + £5
(non-London)	1 No charge 2 No charge 3 £1 per day 4 £2.50 per day	1 Same as motorcycle 2 Motorcycle charge + £2 3 Motorcycle charge + £3 4 Motorcycle charge + £5

3.21 Each respondent was presented with eight choice pairs in this between-mode experiment. A fixed design approach was adopted and four different blocks of eight choice pairs were specified for each mode (car within London, car outside London, public transport, bicycle). The blocks were randomly distributed within each segment to provide variation across the sample. As in the within-mode experiment, a "neither" option was provided for cases where the respondent would not choose either of the alternatives offered. Example choice pairs from the MC-Car between-mode experiment are presented in Figure 11 and Figure 12. The first presents parking costs and the second shows the case where these are replaced by congestion charges. Figure 13 presents an example MC-PT choice pair.

Figure 11: Example between-mode choice pair: MC-car choice with parking costs

Which option would you choose for your journey in the AM peak period?

You expect there to be light intermittent rain during the day	
Motorcycle	**Car**
Journey takes the same time as by motorcycle now	Journey takes 5 minutes more than by car now There are often unpredictable delays causing you to be 10 minutes late
You will be able to park your motorcycle within 5 minutes walk of your destination You will not know in advance whether you will find a space with security measures	You will be able to park your car within 5 minutes walk of your destination
Your travel costs by motorcycle will stay at the level you reported Your motorcycle parking will be free	Your travel costs by car will stay at the level you reported Your car parking will be £15 per day

Choose Motorcycle ☐ **Choose Neither** ☐ **Choose Car** ☐

Figure 12: Example between-mode choice pair: MC-car choice with congestion charges

Which option would you choose for your journey in the AM peak period?

You expect there to be heavy continuous rain during the day	
Motorcycle	**Car**
Journey takes the same time as by motorcycle now	Journey takes 10 minutes more than by car now There are often unpredictable delays causing you to be 20 minutes late
You will be able to park your motorcycle within 5 minutes walk of your destination You will not know in advance whether you will find a space with security measures	You will be able to park your car within 15 minutes walk of your destination
Your travel costs by motorcycle will stay at the level you reported You will have to pay a congestion charge of £2 per day	Your travel costs by car will stay at the level you reported You will have to pay a congestion charge of £4 per day

Choose Motorcycle ☐ **Choose Neither** ☐ **Choose Car** ☐

Figure 13: Example between-mode choice pair: MC-PT choice

Which option would you choose for your journey in the AM peak period?

You expect it to be dry, but with strong gusty winds during the day

Motorcycle	Public transport
Journey takes the same time as by motorcycle now	Journey takes 10 minutes more than by public transport now You rarely have problems on your journey and nearly always arrive on time
You will be able to park your motorcycle within 10 minutes walk of your destination You will be able to park at a location with an immovable object to lock your motorcycle to	
Your travel costs by motorcycle will stay at the level you reported You will not have to pay a congestion charge	Your fare will be £1 more than now

Choose Motorcycle ☐ **Choose Neither** ☐ **Choose Public transport** ☐

3.22 Following the second SP experiment the respondent was asked a number of questions about factors that may have influenced their choice behaviour. This included a question on the maximum number of days that the respondent could use their motorcycle in a typical week, questions on their perception of risk of having an accident on their motorcycle at different times of the day, and their perception of the risk of their motorcycle being stolen from different locations.

3.23 Finally a series of questions were asked about the respondents' personal and household characteristics in order to provide data that may be useful in categorising the respondents and identifying potentially different behaviour according to background or circumstance. This included questions on age, gender, household composition, working status, socio-economic group, dress code, personal income (before tax), and membership of any motorcycling clubs.

3.24 In the design of the survey a number of psychometric scales were investigated in an effort to obtain an indirect measure of how different motorcycle owners generally approach risks in their lives, e.g. are they the sort of person that avoids situations where there may be dangers, or are they the sort of person that actively seeks out exciting situations. This was motivated by a wish to examine the influence that these personal characteristics may have on the willingness to use a motorcycle for peak period trips. As the scope for developing and verifying a new instrument was out of the scope of the existing study such a scale could only be incorporated if it had already been developed and accepted within the psychological literature. A number of potential scales were identified that had been validated for measuring arousal and other associated factors that could relate to the motorcycling experience, but each scale contained some questions which were deemed to be inappropriately worded for the context of the current study. The number of questions required to calculate each of the scales were also found to significantly lengthen the questionnaire and placed an undue burden on the respondents. As a result the decision was taken not to pursue such an approach in the main survey, although this is an area which merits further examination in the design of future studies of motorcyclist attitudes and behaviour.

3.25 Tables presenting the frequencies of the responses to each of the background questions in the survey are presented in the Appendix of this report.

Survey administration

3.26 Respondents were initially recruited by telephone from a sample frame of motorcycle owners whose contact details were available from an omnibus survey. Those that agreed to participate in the survey were given the option of a subsequent telephone interview (requiring the mail-out of the choice cards for the SP exercises) or a self-completion survey available through the internet. The access to the internet survey was strictly controlled with each respondent being given a unique identifier allowing a single interview to be completed; this avoided any potential sample bias from being introduced by interest groups distributing html links to the survey site.

3.27 Quotas were set for the recruitment to ensure that there was sufficient representation of each of the key groups that were to be examined within the model. This comprised of a split by geography (London, other metropolitan areas, and other areas) and a split by available mode pair. The quotas that were specified are presented in Table 16. In addition general quotas were set for vehicle size, with a requirement that there were at least 50 interviews of small, medium and large motorcycles in each of the three area types. For these purposes “small” was defined as an engine size of 125cc or less, “medium” was defined as an engine size between 126cc and 700cc, and “large” was defined as an engine size in excess of 700cc. A target of a total of 480 completed interviews was set.

3.28 For the purposes of this study “other metropolitan areas” were defined as the 36 metropolitan authorities. These are: Barnsley, Birmingham City, Bolton, Bradford, Bury, Calderdale, Coventry City, Doncaster, Dudley, Gateshead, Kirklees, Knowsley, Leeds City, Liverpool City, Manchester City, Newcastle upon Tyne City, North Tyneside, Oldham, Rochdale, Rotherham, St Helens, Salford City, Sandwell, Sefton, Sheffield City, Solihull, South Tyneside, Stockport, Sunderland City, Tameside, Trafford, Wakefield, Walsall, Wigan, Wirral, and Wolverhampton.

Table 16: SP Survey Quotas

Area Type	London	Other Metropolitan Areas	Other Areas
Main Mode = Motorcycle Alternative Mode = Car	40	40	40
Main Mode = Motorcycle Alternative Mode = PT or Bicycle	40	40	40
Main Mode = Car Alternative Mode = Motorcycle (by default)	40	40	40
Main Mode = PT or Bicycle Alternative Mode = Motorcycle (by default)	40	40	40
Total	**160**	**160**	**160**

3.29 Accent Marketing and Research started the data collection for the main survey at the end of June 2003. However, some difficulties were encountered with recruiting respondents within some of the quota categories from their sample frame. By the middle of July 2003 the sample frame of motorcycle owners purchased from the omnibus survey was exhausted, with a total of 342 completed interviews. This was 71% of the intended sample, and there were significant shortfalls in a number of key areas.

3.30 The most significant shortfalls were for London and the other metropolitan areas, with particular problems for those motorcycle users who used public transport for their last journey in the AM peak. Accent were unable to find any alternative commercially available sample frames of motorcycle owners, but Transport for London were able to assist by supplying a list of LATS respondents that were known to own a motorcycle and had indicated they would be happy to be contacted for future surveys. Using this list of contacts Accent were able to obtain a further 81 interviews with motorcycle owners from the London area. This fulfilled the original target for interviews in London and the split in the alternative to motorcycle between car and public transport was balanced. Within those asked about choices between motorcycle and public transport there were fewer interviews conducted with those currently using public transport than had been intended. These difficulties may to a certain extent reflect a preference for using a motorcycle over public transport within the motorcycling population.

3.31 In order to obtain more responses from public transport users in metropolitan areas, Accent attempted further recruitment of motorcyclists at rail stations. This approach seemed promising as there are significant numbers of motorcycles and scooters parked at many of the London termini stations and major commuting stations outside of London. This approach was piloted at Birmingham New Street station, but no respondents were successfully recruited so this strategy was abandoned. Whilst there are clearly a number of motorcycle riders using motorcycle as an access mode we did not find an economical approach to recruiting them for this study. However, during this extended period an additional 20 interviews were obtained from following up potential respondents that had already been contacted but had not previously been available to complete the SP telephone interview.

3.32 In total 443 completed interviews were collected from respondents by the end of the data collection phase. The breakdown of these by quota segment is provided below in Table 17.

Table 17: Details of completed interviews

		Area						Total	
		London		Metropolitan		Other			
Mode used	Alternative	Interviews	% Quota	Interviews	% Quota	Interviews	% Quota	Interviews	% Quota
Motorcycle	Car	47	117.5%	35	87.5%	52	130.0%	134	111.7%
Motorcycle	PT	66	165.0%	20	50.0%	28	70.0%	114	95.0%
Car	Motorcycle	42	105.0%	46	115.0%	70	175.0%	158	131.7%
PT	Motorcycle	19	47.5%	5	12.5%	13	32.5%	37	30.8%
Motorcycle		113	141.3%	55	68.8%	80	100.0%	248	103.3%
Other Mode		61	76.3%	51	63.8%	83	103.8%	195	81.3%
Total by Area		174	108.8%	106	66.3%	163	101.9%	443	92.3%

3.33 Of the 443 completed interviews, 22 interviews had to be excluded due to inconsistencies in the responses that meant that the context for the SP exercises were unlikely to be correct; this left a total of 421 completed interviews for further analysis.

Examination of trading behaviour

3.34 The first inspection of the data examined the number of times that each alternative was chosen by the 421 interviewees. The results are displayed in Table 18. In the within-mode experiment the two sides of the cards (choice A and choice B) are almost equally chosen, as is expected since the sides of the cards were randomly determined. The distribution of choices over the alternatives in the between-mode experiment is biased, since not all alternatives are available to each respondent. A more detailed distribution that takes this availability into account is shown in

Table 19. This table also shows the difference between respondents that used their motorcycle for their trip; and those who used an alternative mode.

3.35 Table 18 also shows the distribution of modes used for the RP model. It is noted that again these are not representative, because the SP survey sample was obtained from a quota-based and therefore not representative sample.

Table 18: Distribution of choices

	Choice A chosen	Choice B chosen			Neither chosen
Within-mode experiment (421 x 4 choices)	48.7%	45.7%			5.6%

	Motorcycle chosen	Car chosen	Public Transport chosen	Cycle chosen	Neither chosen
Between-mode experiment (421 x 8 choices)	74.2%	11.9%	5.3%	3.6%	5.0%

	Motorcycle chosen	Car chosen	Public Transport chosen	Cycle chosen	
RP model (421 choices)	55.5%	35.9%	5.5%	3.1%	

Table 19: Distribution of choices in the between-mode experiment

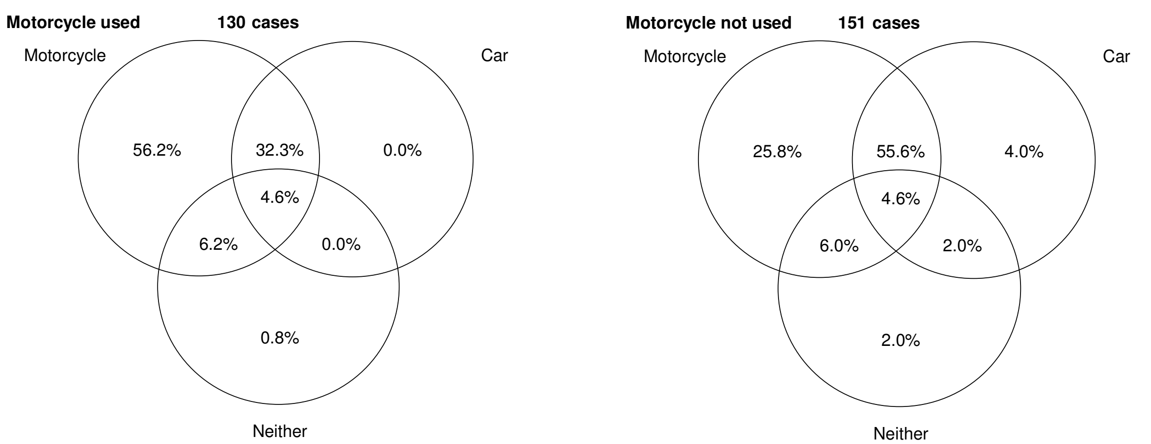
			Motorcycle used	Alternative used
Between-mode (motorcycle vs car)	Number of respondents	281	130	151
	Motorcycle chosen	77.5%	86.8%	69.5%
	Car chosen	17.8%	10.1%	24.4%
	Neither chosen	4.7%	3.1%	6.0%
Between-mode (motorcycle vs public transport)	Number of respondents	110	87	23
	Motorcycle chosen	73.3%	76.3%	62.0%
	Public Transport chosen	20.2%	15.9%	36.4%
	Neither chosen	6.5%	7.8%	1.6%
Between-mode (motorcycle vs cycle)	Number of respondents	30	17	13
	Motorcycle chosen	47.5%	61.0%	29.8%
	Cycle chosen	50.8%	38.3%	67.3%
	Neither chosen	1.7%	0.7%	2.9%

3.36 Table 19 shows that the motorcycle option was favoured in most cases, even when the motorcycle was not the chosen mode for the observed journey. Only when compared to cycling, for cyclists, was the motorcycle alternative chosen less frequently than the alternative. The experiments were designed to explore the impact of policy options (such as road charging, provision of parking, etc) but the alternatives offered were constrained to realistic situations, i.e. charges, parking costs and journey times for motorcycle would not be greater than for car[9].

3.37 The choices were also designed to explore the impact of increases in the travel time for modes other than motorcycle, to explore the potential switches to motorcycle if other modes became less attractive. As a result of these design aspects we are not surprised to see the motorcycle alternative generally favoured over other modes across the choices, although we did not anticipate quite this level of preference.

3.38 Next the data were examined to look at the detailed trading pattern across survey respondents. This analysis was only conducted for the between-mode experiment. The response patterns are presented as Venn diagrams, which show the percentage of respondents who always choose motorcycle, the alternative, neither and those who trade between the various alternatives.

Figure 14: Trading diagram for the between-mode experiment Motorcycle vs Car



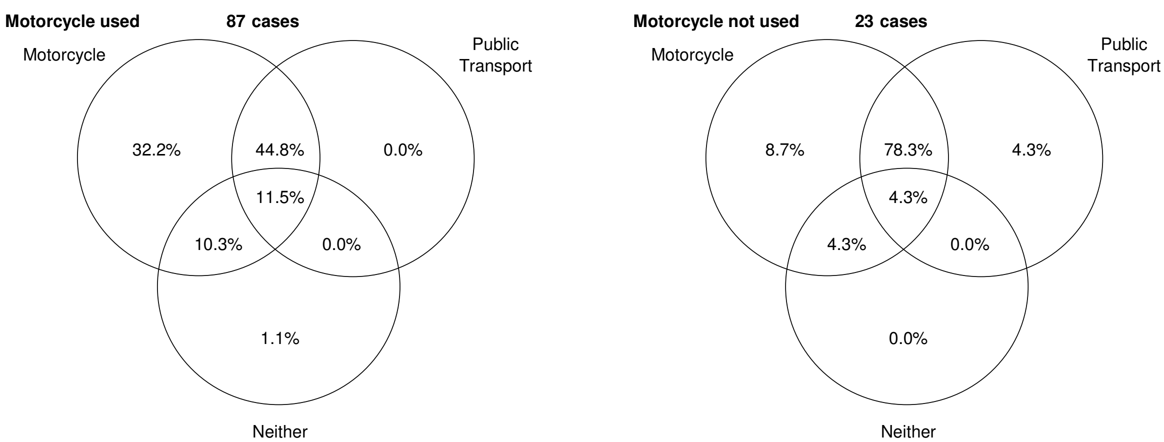
3.39 Figure 14 shows a Venn-diagram for the responses in the between-mode experiment Motorcycle versus Car. From this figure it is clear that respondents who did not use their motorcycle for their journey (diagram to right) traded more than respondents who did use their motorcycle (diagram to left) (60.2% of those who did not use their motorcycle made trade-offs between the modes compared to just 36.9% of those who used their motorcycle for the journey). This was not unexpected, as the alternative mode was typically made less attractive in the choices for all respondents. However, a surprisingly high number of the respondents who had not used

[9] There is evidence that this assumption is certainly sensible for the London context, where recent TFL bus lane monitoring studies have revealed that motorcycles can generally move 10% faster than other traffic in the main vehicle lanes – anecdote from David Tidley in conversation with Marc Wigan, May 2004

their motorcycle for their last AM peak period journey (25.8%) *always* chose the motorcycle alternative in the SP choices which compared motorcycle with car, their observed mode of travel. When asked why they had always chosen the motorcycle alternative, these respondents generally justified their choices by way of the lower travel time, lower cost, cheaper and easier parking, and overall enjoyment – little insight was gained from these responses as to why they did not use their motorcycle for the existing journey.

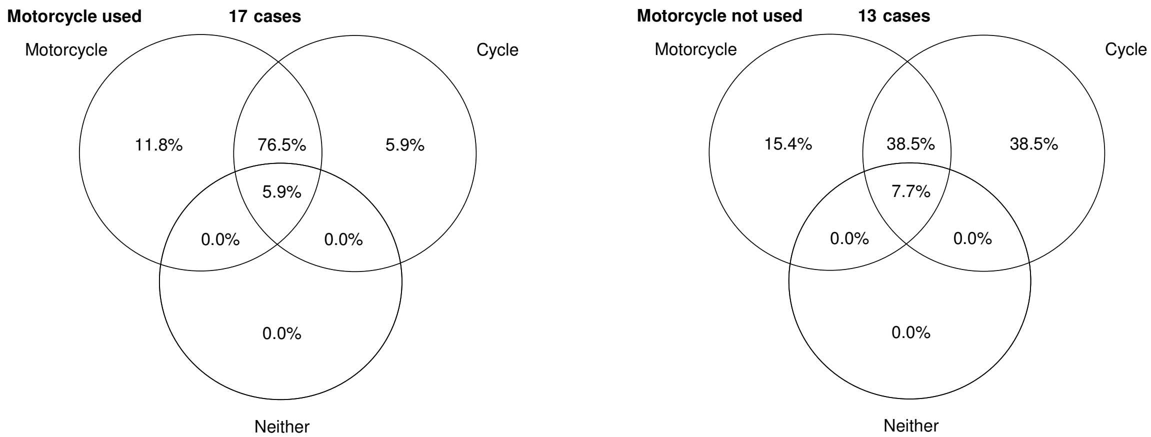
3.40 From the same figure it follows that the persons who used their motorcycle are less willing to use a car. This pattern was also observed in the pilot study and as a result an extra unfavourable motorcycle parking level was added to the experiment in the main study to stimulate the attractiveness of the alternative, but still the use of the motorcycle remained highly attractive.

Figure 15: Trading diagram for the between-mode experiment Motorcycle vs PT



3.41 Figure 15 shows the same diagrams for the Motorcycle versus Public Transport experiments. There is much more trading between the public transport and motorcycle alternatives, with over 80% of public transport users making trades between the motorcycle and public transport alternatives. Less trading is observed for those who used motorcycle for their journey (over 55% of respondents trade between alternatives), and again we see a general preference for motorcycle, although this is not as prevalent as for the car users.

Figure 16: Trading diagram for the between-mode experiment Motorcycle vs Cycle



3.42 Finally, Figure 16 shows the Venn diagram for the Motorcycle versus Cycle experiment. It is noteworthy that there are far fewer motorcycle versus cycle observations (30 in total) and there is much more trading for the respondents who used their motorcycle. Those who used their bicycle, show a general preference for bicycle.

3.43 In general we would have hoped to have seen more trading between modes, with the above results suggesting that many of those currently using their motorcycle are not particularly responsive to the policy changes that were examined. With the exception of the cycle respondents, we did not see a large proportion of those respondents not using their motorcycle for the trip in question staying with their current mode, but quite significant numbers moved over to always choosing the motorcycle alternative. This may suggest that the participating respondents may have viewed the changes to the alternative modes as quite large and more detailed information on trading may have been obtained by examining smaller changes in journey time etc. In interpreting these results it is important to remember that all of the respondents participating in these exercises owned a motorcycle and therefore had an inclination towards this mode already, albeit not always for AM peak period trips.

Exclusion of outliers and inconsistent observations

3.44 A close inspection of the data revealed a number of problems with some of the survey responses. Because of these problems, the answers to the stated preference experiment choices were deemed to be not credible for these respondents. For these reasons the responses were excluded from further analysis. An overview of excluded respondents (and the exclusion reason) is given in Table 20. The lower exclusion threshold used on running costs was set at a level that could only be obtained by the most economical of the 50cc class of machines. It should be noted that the number of rejected survey responses is presented cumulatively.

Table 20: Overview of excluded respondents

		Cumulative number of respondents rejected
1	Wrong cardset sent (card set alternatives do not match with actual available alternatives)	12
2	Chose Neither 6 or more times in the between-mode experiment	20
3	Journey time for current mode or with alternative mode is missing or invalid	26
4	Journey costs for travel by motorcycle are unrealistically low (<4 pence pm) or high (>50 pence pm)	57
5	Journey costs for travel by car are unrealistically low (<12 pence pm) or high (>80 pence pm)	66
6	Very long trip (> 50 miles; very few respondents in this range, so model variables difficult to estimate)	78

3.45 The total number of excluded respondents is quite high (about 19% of the 421 respondents). For this reason, we checked the effect of including certain groups again, after the model had been finalised. This was done for those people that were excluded on the basis of exclusion criterions 2, 4, 5 and 6. Each time any one or more of the exclusion criteria were dropped the model quality deteriorated. Leaving out exclusion criterions 1 or 3 led to errors when running the model. We therefore conclude that all these observations were excluded for valid reasons. 343 respondents were left in the final sample for model estimation.

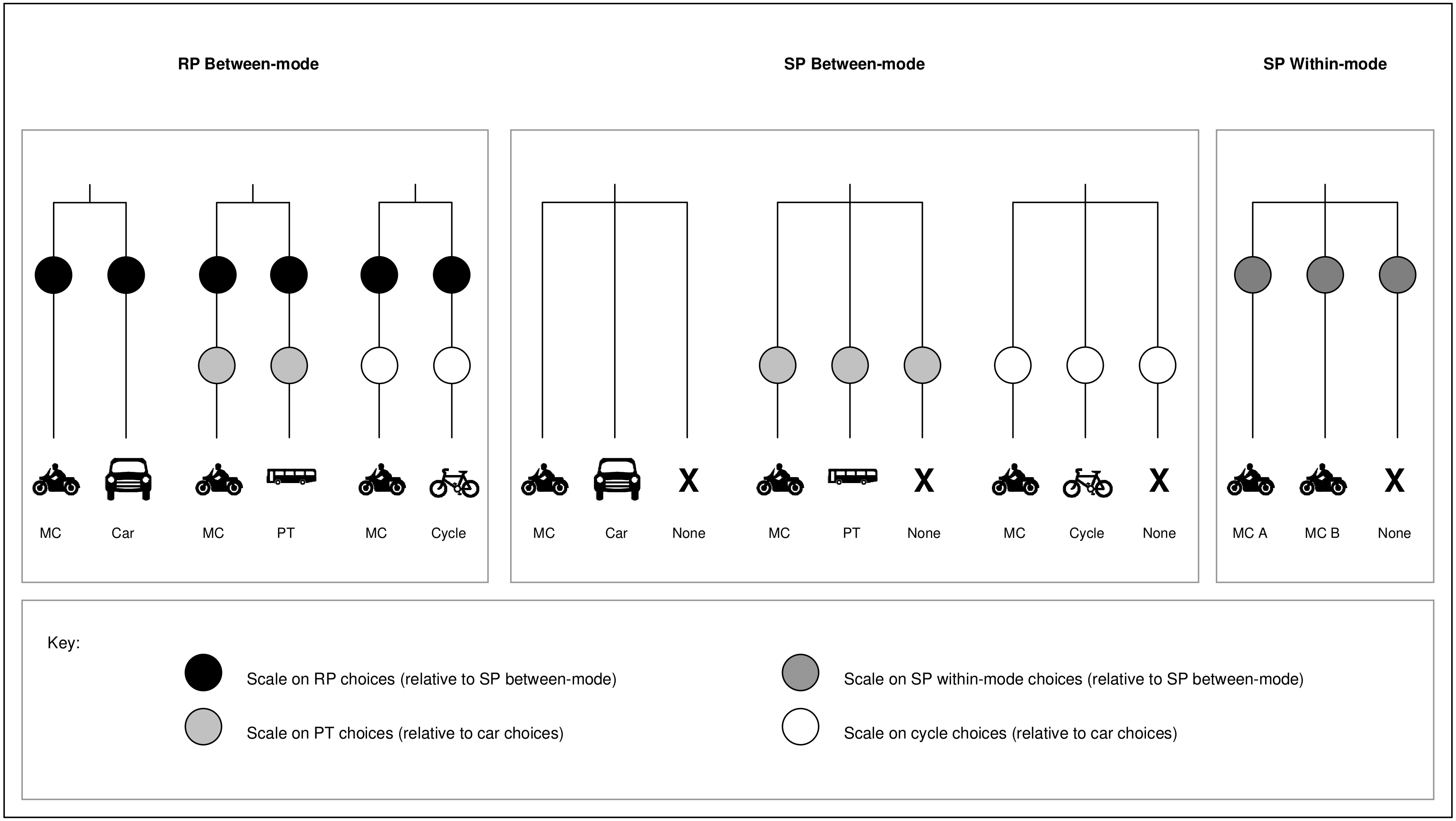
Overview of the usage model structure

3.46 The SP and RP data have been used to estimate the mode choice model parameters. The advantages of the joint analysis approach are essentially that RP and SP data are complementary, i.e. the strengths of the one cover the weaknesses of the other. In particular, the credibility and realism of the RP data combines well with the efficiency and flexibility of the SP data. The key aspect of this approach is the simultaneous estimation of the model coefficients from both RP and SP data. Two shortcomings of models based purely on SP data are that the scale of the SP models may not reflect that of RP models because of differences in the variance of the model error terms and that the alternative-specific constants do not reproduce the observed alternative shares (particularly when quota-based sampling is employed, as was done in the current study). Joint simultaneous estimation of SP and RP data identifies differences in SP and RP utility scales. A secondary estimation procedure to correct the alternative-specific constants is also required, but it has been proposed that this be performed using aggregate RP data, i.e. aggregate mode shares, during the model application.

3.47 The joint model included the RP data and the two SP data sources from the within-mode and between-mode experiments. These two experiments contain a number of common variables and the joint estimation allows the factors relating to the choice between motorcycle journeys to be combined with those relating to the choice between motorcycle and an alternative mode.

3.48 There are therefore a number of different scale parameters in the model estimation to combine the three separate, but correlated, sources of data. The structural form of the model is presented in the following figure. Separate scale parameters are applied to the utility equations for each data set to take account of differences in unexplained error in each data set: the SP between-mode data is used as the reference data set with an implied scale parameter of 1.0. Separate scale parameters are also used to examine differences in relative unexplained error variation between different mode combinations in the between-mode choices, i.e. for the MC-PT and MC-cycle between-mode utilities, with MC-car used as the base with an implied scale parameter of 1.0; these are estimated jointly from the RP and SP between-mode data. All the scales in the model are therefore relative to the SP between-mode MC-car choice.

Figure 17: Tree structure illustrating scaling applied to utility functions for each choice situation modelled



3.49 Utility functions have been specified for each of the possible mode alternatives. For the between-mode models (SP and RP) there are four possible mode alternatives, i.e.: motorcycle, car, public transport and bicycle. It is noteworthy that each respondent only evaluated two of these alternatives in the SP experiment, i.e. motorcycle and their best alternative. They also only provided service information for these two modes for the RP model. For the within-mode model there are two different abstract motorcycle alternatives. Each SP model also includes a "neither" alternative for each mode choice pair with an associated utility function. For each respondent, only the utilities for the alternatives actually specified in their pair-wise choices are included in their mode choice alternative set.

Model development and interpretation

3.50 The model is based on the assumption that the respondent chooses the alternative with the highest utility. An error term is included in the utility function to reflect the unobservable factors in the individual's utility. The estimation can therefore be conducted within the framework of random utility theory, i.e. accounting for the fact that the analyst has only imperfect insight into the utility functions of the respondent.

3.51 The most popular and widely available estimation procedure for data representing discrete choices is logit analysis. The logit model predicts choice probabilities as $p_1 = \exp V_1 / (\exp V_1 + \exp V_2 + \exp V_3)$, where the V's represent the utility functions of the alternatives and exp is the standard exponential function. The estimation procedure produces estimates of the model coefficients, such that the choices made by the respondents are best represented. The standard statistical criterion of Maximum Likelihood is used. Both the values of the coefficients (in utility terms) and the significance of the coefficients are output.[10]

3.52 A step-wise model development procedure was adopted in order to ensure that each of the model structures was working correctly before estimating models jointly with all data sets simultaneously. At first, only the choices made by the respondents in the within-mode experiment were considered. Parameters are added and removed until a satisfactory model for the utilities is generated. Then, the data from the between-mode experiment was added. When this joint model results were judged to be satisfactory, the data from the Revealed Preference experiment was added and again terms were added and removed until the final best model was produced.

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10 For further information about logit models, see Ben-Akiva, M. and Lerman S. R. (1985) Discrete Choice Analysis: Theory and Application to Travel Demand. The MIT Press, Cambridge, Massachusetts.

3.53 The estimation of the discrete choice models was undertaken using ALOGIT. For each model, two sets of values are presented: (i) model summary statistics, and (ii) model coefficients and their associated approximate t-ratios.[11]. The model summary statistics which are presented are defined in Table 21.

Table 21: Model Summary Statistics

Statistic	Definition
Observations	The number of observations included in the model estimation.
Final log (L)	This indicates the value of the log-likelihood at convergence. The log-likelihood is defined as the sum of the log of the probabilities of the chosen alternatives, and is the function that is maximised in model estimation. The value of log-likelihood for a single model has no obvious meaning. However comparing the log-likelihood of two models with different specifications allows the statistical significance of new model coefficients to be assessed properly.
D.O.F.	Degrees of freedom, i.e. the number of coefficients estimated in this model. Note that if a coefficient is constrained to a fixed value (indicated by(*)) then it is not a degree of freedom.
$Rho^2(0)$	The rho-squared measure compares the log-likelihood (LL(final)) to the log-likelihood of a model with all coefficients restricted to zero (LL(0)): $Rho^2(0) = 1 - LL(final)/LL(0)$ A higher value indicates a better fitting model.
$Rho^2(c)$	If we compare the log-likelihood (LL(final)) value obtained with the log-likelihood of a model with only constants (LL(c)) we get: $Rho^2(c) = 1 - LL(final)/LL(c)$ Again a higher value indicates a better fitting model.

3.54 The coefficient values are then presented. If a coefficient is positive then it has a positive impact of utility and so reflects a higher probability of choosing the alternatives to which it is applied, for example, improved parking facilities. Conversely if a coefficient is negative then it has a negative impact on utility and so reflects a lower probability of choosing the alternative to which it is applied, for example, increased parking costs.

3.55 Some coefficients are multiplied by continuous variables and therefore reflect the disutility per unit of the variable, e.g. cost, which reflect the relative disutility per Pound. Other coefficients are applied to categorical variables; these therefore reflect the total utility increase or decrease for that variable, relative to a base situation, e.g. the increase in utility as a result of a different weather type. In some cases, significant coefficients could not be identified for each discrete level for a variable and therefore valuations for some levels have been aggregated, e.g. for the car; public transport and cycle utilities no significant difference was observed when the unreliability in the arrival times was 5, 10 or 20 minutes; these levels have therefore the same model coefficient.

[11] This ratio is an asymptotic approximation to the standard statistical Student's t-ratio.

3.56 The constants in each model reflect preferences for the alternatives to which they are applied, for example the constant “Engine size > 900cc” with a positive value of about 0.4 in the motorcycle utility implies that respondents with a larger motorbike have a preference for choosing the motorcycle alternative. The constants on the models are additive and more than one constant can be applied for each individual. A positive value for a constant indicates that the respondent is more likely to choose that alternative, and a negative value for a constant indicates that the respondent is less likely to choose that alternative.

3.57 A neither option was included in the experiments for cases where neither option was acceptable to the respondent. In order to take account of the cases where respondents chose this option it is necessary to include a utility for this alternative. This typically contains a single constant to explain the preference for neither over all respondents, although differences in propensity to choose the neither option were found in some of the models, which is reflected in the separate constants.

3.58 In the models which pool the data from the within-mode, between-mode and the RP experiments to estimate jointly coefficients it is necessary to control for potential differences in unexplained model error. This is done through the application of a scaling parameter, which is applied to the utilities for one data set to bring them in line with the other.

Modelling of the within-mode motorcycle choice data

3.59 The development of the within-mode choice model started with a simple model with terms only for each of the variables presented in the SP exercise (see Table 22).

Table 22: Standard model terms for the within-mode usage model

Type of term	Model term		Remark
Standard motorcycle utility terms	$\beta_{Congestion}$	:	Different values for ▪ mild congestion ▪ heavy congestion Relative to 'no congestion'
	$\beta_{WideLanes}$	:	Relative to 'lanes are not wide enough for filtering'
	$\beta_{AdvancedStops}$	:	Relative to 'no legal access to advanced stop lines'
	$\beta_{WalkTime} \cdot$ WalkTimeParking	:	Continuous variable for the number of minutes it takes to walk from the parking location to the final destination
	$\beta_{ParkingSecurity}$	:	Different values for ▪ knowing to be able to park at a location with no specific security measures available ▪ knowing to be able to park at a location with an immovable object to lock your motorcycle to Relative to 'you do not know in advance whether you will be able to park your motorcycle at a secure location'
	$\beta_{ParkCost} \cdot$ ParkingCosts	:	Continuous variable for the parking costs (in Pounds) per day
Neither utility	$\beta_{Neither}$	:	Constant

3.60 Next, taste variation in the valuation of the model parameters was tested by comparing predicted and observed choices across different subgroups of the population, for example across age categories, occupation categories, reported road and traffic conditions during the journey, etc. A large number of tests were undertaken, but only a few gave significant improvements: the neither coefficient turned out to be different for respondents that were interviewed via the telephone and via the web; the preference for wide lanes depended on a combination of the arrival time and length of the trip.

3.61 The final model is presented in Table 24 (at the end of this section). All model coefficients are intuitive, that is, they have the expected signs and reasonable magnitude. The terms are discussed separately in the next paragraphs.

3.62 The walking time variable (walking time from the parking location to the final destination) was treated as a continuous variable. As expected, it is negative, i.e. motorcycle users prefer smaller walking times from their parking location to their final destination.

3.63 The value of the first security level of the parking location (i.e. "you will be able to park at a location with no special security measures for motorcycles") was not significantly different from the base level (i.e. "you will not know in advance whether you will find a space with security measures"). This coefficient was therefore set to zero and thus there is no associated term in the final model (the coefficient $\beta_{ParkingSecurity}$ is zero for these two levels).

3.64 The second security level of the parking location (i.e. "you will be able to park at a location with an immovable object to lock your motorcycle to") was significant, but it was correlated with the walking distance from the parking location: people did not mind the walking longer distances if it meant that they were able to park at a secure location. The combined coefficient $\beta_{WalkTimeSec}$ was significant. With this variable, a significant walking time variable remained, but a separate parking-security parameter could not be estimated

3.65 The advanced stop line coefficient ($\beta_{AdvancedStops}$, indicating that respondents would have legal access to advanced stop lines) was not significant in the final model, implying that respondents did not place value on this change in legislation within the context of the choices they were offered. This may in part reflect the lack of attention that motorcyclists receive from the police in practice for any use of advance stop lines.

3.66 The wide lane coefficient ($\beta_{WideLanes}$, indicating that the lanes are wide enough for filtering) was highly significant. After checking its size for several subsets of the respondents it turned out that is was valued less by people with short (less or equal to 6 miles) or long (more than 15 miles) travel distances, unless they were arriving in the end of the morning peak (between 8:30 and 9:00am) at their destination. This is likely to be a group of respondents that are not really in a hurry because they are travelling only short distances, or they are making longer-distance trips, but in either case do not have to be at their destination until around 9:00 am.

3.67 The congestion coefficients ($\beta_{Congestion}$, with different values for mild and heavy congestion) are behaving as expected. There is a large disutility for motorcycle use in heavy congestion, while the disutility for mild congestion is only small (and on the edge of significance).

3.68 The parking cost coefficient $\beta_{ParkCosts}$ is behaving as expected. A test was conducted to determine whether it was correlated with the parking distance, but this was not an improvement of the model (sign of combined parameter was reversed).

3.69 The Neither constants $\beta_{Neither}$ of the telephone-based interviews and web-based interviews were found to be significantly different, with the neither option being chosen less often for the Internet surveys for this within-mode experiment. No other significant differences in coefficient estimates were found on the basis of the survey method, so the data has been kept pooled with this constant representing the difference in propensity to choose the "neither" option.

Addition of the between-mode choice data

3.70 Next the data was included from the between-mode experiment, with the appropriate scaling as described earlier.

3.71 The variables in the between-mode experiment are summarised in Table 23 below.

Table 23: Standard terms for between-mode usage model

Type of term	Model term		Remark
Standard motorcycle utility terms	β_{MCCost}· MCTravelCost	:	Continuous variable for the costs of the journey by motorcycle (in Pounds)
	$\beta_{ParkCost}$ · ParkingCosts	:	Continuous variable for the parking costs (in Pounds) per day
	$\beta_{CongCost}$ · CongestionCharge	:	Continuous variable for the congestion charge (in Pounds) per day
	β_{MCtime}· MCTravelTime	:	Continuous variable for the number of minutes it takes for the journey by motorcycle
	$\beta_{WalkTime}$ · WalkTimeParking	:	Continuous variable for the number of minutes it takes to walk from the parking location to the final destination
	$\beta_{ParkingSecurity}$	:	Different values for ▪ knowing to be able to park at a location with no specific security measures available ▪ knowing to be able to park at a location with an immovable object to lock your motorcycle to Relative to 'you do not know in advance whether you will be able to park your motorcycle at a secure location'
Standard car utility terms	$\beta_{CarCost}$· CarTravelCost	:	Continuous variable for the costs of the journey by car (in Pounds)
	$\beta_{ParkCost}$ · ParkingCosts	:	Continuous variable for the parking costs (in Pounds) per day
	$\beta_{CongCost}$ · CongestionCharge	:	Continuous variable for the congestion charge (in Pounds) per day
	$\beta_{CarTime}$· CarTravelTime	:	Continuous variable for the number of minutes it takes for the journey by car (including possible extra travel time presented on the cards)
	$\beta_{WalkTime}$ · WalkTimeParking	:	Continuous variable for the number of minutes it takes to walk from the parking location to the final destination
	$\beta_{Weather}$	:	Different values when ▪ light intermittent rain is expected ▪ heavy continuous rain is expected ▪ the weather is dry, but strong gusty winds are expected Relative to 'pleasant weather'
	$\beta_{Unreliable}$	:	Variable indicating whether there are often unpredictable delays, causing the driver to be late (different values for 10 and 20 minutes)
Standard public transport utility terms	β_{PTCost}· PTTravelCost	:	Continuous variable for the costs of the journey by public transport (in Pounds). This includes any possible extra fares presented on the cards
	β_{PTTime}· PTTravelTime	:	Continuous variable for the number of minutes it takes for the journey by public transport (including possible extra travel time presented on the cards)
	$\beta_{Weather}$	:	Different values when ▪ light intermittent rain is expected ▪ heavy continuous rain is expected ▪ the weather is dry, but strong gusty winds are expected Relative to 'pleasant weather'
	$\beta_{Unreliabile}$	::	Variable indicating whether there are often unpredictable delays, causing the driver to be late (different values for 10 and 20 minutes)
Standard bicycle utility terms	$\beta_{CycleTime}$· CycleTravelTime	:	Continuous variable for the number of minutes it takes for the journey by bicycle
	$\beta_{Weather}$	:	Different values when ▪ light intermittent rain is expected ▪ heavy continuous rain is expected ▪ the weather is dry, but strong gusty winds are expected Relative to 'pleasant weather'
Neither	$\beta_{Neither}$	:	Constant

3.72 With the implementation of the between-mode data, a minor design error in the between-mode experiment was discovered. Two variables on the cards were correlated: motorcycle parking cost (or, congestion charge in the second half of the cardsets) and car (un)reliability times. Fortunately, the two variables were not perfectly correlated, and as such it was possible to estimate the variables as if they were independent. However, the errors in the estimates remain correlated.

3.73 The final model contains a generic cost coefficient, but mode-specific journey time coefficients, i.e. $\beta_{MCTime,}$, $\beta_{CarTime}$, β_{PTTime}, $\beta_{ParkTime}$, reflecting that travel time by mode is valued differently.

3.74 The fit of the models is significantly improved when distance terms are included on the non-motorcycle utilities. The positive coefficients for car and PT imply that these are more attractive compared to motorcycle, as the journey distance increases. We have also added a term proportional to the distance to the Neither utility as this was found to improve the model fit.

3.75 The unreliability coefficient, $\beta_{Unreliable}$, was insignificant, both for values of 10 and 20 minutes. This was not expected and the reason for this is not known. It might have to do with the correlation between these levels and the parking/congestion costs described in one of the previous paragraphs. Another possibility is that the respondents currently already experience similar unreliability levels and do not value the difference with the presented levels on the cards very much.

3.76 The walking time and the parking security terms for the motorcycle utility were again combined, as was done in the within model. This was done to be able to estimate both models simultaneously.

3.77 After the inclusion of all data from the between-mode experiment, separate models for commute journeys, business journeys and other-purpose journeys were tested. The purpose segmentation did not significantly improve the fit of the model and therefore the aggregate model across purposes was retained. It is noteworthy that this model does include some terms which differ by purpose.

3.78 Separate models were also tested for the different geographical areas, i.e. London, other Metropolitan areas and other areas, and again the model fit was not improved with this segmentation and the aggregate model was adopted, with some specific area-dependent constants.

3.79 The model developed from the within-mode and between-mode data is presented in Table 24 (at the end of this section). At this stage the revealed preference data was added. It was judged that it was better to include the RP data than to undertake further work on the SP models. For this reason, insignificant coefficients are still part of this model and some other terms are not consistent with those in the final model (e.g. the time coefficient for a cycle trip is still missing; it was added at a later stage).

Addition of the revealed preference mode choice data

3.80 The RP data was first modelled in isolation and was then added to the SP model, with appropriate scaling as described earlier. The utilities developed for the RP alternatives contained journey time, cost and distance terms, consistent with the between-mode experiment. Constants for heavy rain were applied to the utilities of the alternatives for the motorcycle, using the information that the respondents provided on their anticipation of the weather before their journey. Their coefficients were set equal to the heavy rain coefficients from the between experiment.

3.81 All terms that were insignificant in the final run after combining the RP data and undertaking the jack-knife analysis were removed from the model. This 'final' model is presented in Table 24.

Correction for correlation of responses

3.82 An important advantage of the SP approach is that several responses can be collected from each individual. This reduces substantially the cost of data collection and allows for more advanced experimental designs. However, the collection of multiple responses means that each respondent's basic preferences apply to the series of responses that he or she has given: those responses are therefore interdependent. 'Naïve' analysis methods that assume the independence of observations are therefore in principle invalid. This issue is compounded by the correlations that may exist between the RP and SP data, which in the case of this study are not independent.

3.83 While a number of methods can be used to correct for the interdependence of SP observations, experience has shown that a good practical method is to use the 'jack-knife' procedure[12]. This is a standard statistical method for testing and correcting model mis-specifications. RAND Europe has pioneered its use in connection with SP data and has found it to be effective and reliable in this context. In general, the application of the jack-knife procedure to SP data has confirmed that the coefficient estimates themselves are not greatly affected by the specification error of assuming independent observations. However, the significance of the

[12] For further information see (1) Bissell, A.F. and R.A. Ferguson (1975). 'The Jackknife: Toy, Tool or Two-Edged Weapon?'. Statistician. V. 24. pp79-100 and (2) Miller, R.G. (1974). 'The Jackknife: A Review'. Biometrica. V. 61. pp 1-14. The application of this technique to SP data has been studied by C. Cirillo, A. J. Daly and K. Lindveld (1998) "Eliminating Bias due to the Repeated Measurements Problem in SP Data" in *Operations Research and Decision Aid Methodologies in Traffic and Transportation Management*, M. Labbé et al. (eds.), Springer.

coefficient estimates is often substantially overstated by the naïve estimation. Thus when there is an important issue about the significance of a specific variable it is necessary to test that variable in a jack-knife procedure rather than in a naïve estimation. Generally it is found that when variables are significant at very high levels in a naïve estimation, they remain significant in the jack-knife estimation; but when the significance of a variable in the naïve estimation is marginal, a jack-knife estimation may show that it is not truly significant.

3.84 The development of the models is presented in Table 24 and the final model after jack-knifing is again presented in Table 25 with the definition of each variable provided in Table 26. This jack-knifed model reflects the usage of motorcycle compared with other mode alternatives, for persons who own motorcycles, for journeys made in the AM peak.

Description of the mode choice model

3.85 The utility equations for each of the mode alternatives are described below.

Motorcycle utility

3.86 The cost term is negative (as expected) and highly significant. It is generic across modes. In the motorcycle utility equation, the coefficient applies to all operating costs (operating costs, parking costs, congestion charges). The operating costs for motorcycle are calculated by multiplying the journey distance by a standard cost per mile (10 pence per mile for all types of trips). This works better than using the operating costs as calculated based on the answers given by the respondent (how many gallons in a tank, how many miles per tank). A different standard cost per mile was explored for business motorcycle journeys, but this did not improve the model.

3.87 The journey time term of the motorcycle utility was positive, suggesting that respondents enjoy time spent on their motorbike. This is relative to negative journey time terms for all other modes. This is in line with findings from previous work in Australia[13], which also suggest that motorcyclists have greater enjoyment of all driven modes than non-motorcyclists. This enjoyment of time spent on a motorcycle is also clear when looking at the remarks made by the respondents and their answers given to the introduction questions. In general these comments indicate that people use their motorbike mainly because they enjoy it and also because it is much more convenient than other transport mode (in many cases). The enjoyment aspect is clearly summarised by one respondent who reported: "I just love riding bikes. I get the same thrill throwing my leg over a bike as I do a beautiful woman".

3.88 Further investigation of this journey time parameter revealed that the enjoyment of the time spent on a motorbike (expressed by the corresponding coefficient) decreased as the journey distance increased. The valuation of the journey time by motorcycle is therefore represented by a piecewise linear function that changes gradient at a duration of 20 minutes:

*timeMCle20 * (min(EjTime_M,20)) + timeMCgt20 * (max(EjTime_M-20,0))*

- timeMCle20 is a positive coefficient

- timeMCgt20 is a negative coefficient

3.89 The time spent walking from the parking location to the final destination is only valued negatively when there are no specific security measures available at the parking location. If there are security measures, then the walking time has no impact on the utility.

3.90 The motorcycle utility is strongly dependent on the number of months per year that a person uses his bike. This is to be expected, since it is a good indicator whether a person is a real 'die-hard' user or a 'only-when-the-weather-is-nice-in-the-summer' user of his motorbike. 'Die-hard' users are more strongly inclined to use their motorbike. The effect is the biggest for commuting in London and other metropolitan areas.

3.91 There is a negative impact on the motorcycle utility for travellers living in London and other metropolitan areas, relative to the "other" areas. It is possible (though not further investigated) that this is because of risk of theft in these areas. This effect needs to be assessed in combination with the previous effect, since they cancel each other out in some cases.

3.92 Other terms show that people aged 60 and over are less likely to use their motorbike, as do people that are commuting and people whose dress code is smart or a smart uniform. Those who perceive a higher accident risk in the morning peak than on the rest of the day are less likely to choose a motorbike. Motorcycle owners with large motorbikes (> 900 cc) are more likely to choose to use the motorcycle alternative for the peak period journeys than those owning smaller motorcycles. In determining these effects a range of different model specifications were examined (e.g. different respondent ages, different engine size break-points) in order to determine the model specification that gave the best fit to the mode choice data available.

[13] Wigan, M. R. (2002) "Motorcycles treated as a full mode of transportation" Transport Research Record (181)

3.93 The RP experiment revealed a negative value attributed to a trip that was made for other purposes than commuting or business. This suggests that once all other effects have been accounted for, motorcycle is viewed less favourably for these purposes. These non-commuting and non-business trips will include journeys such as shopping and taking children to their place of education, so it is not entirely surprising that motorcycle is seen as less appropriate in such cases.

Car utility

3.94 In the car utility, the cost term multiplies the car operating costs, which were calculated using values of 16 pence per mile for non-business trips and 40 pence per mile for business trips.

3.95 The coefficient for the journey time is negative (as to be expected), but with a low level of significance. This is believed to be partly a result of general lack of trading in the SP exercises, but may also indicate the lower significance that motorcycle owners have been suggested to place on the travel time in driven modes (see 3.87). This car journey time coefficient also needs to be compared with the positive coefficient on the motorcycle journey time.

3.96 The negative standard term for the car utility (ASCcar) indicates that with all other factors being equal the respondents in the sample have a strong preference for using the motorcycle, although this may change when the models are recalibrated for a more representative sample.

3.97 The coefficient on the distance is positive. This indicates that cars are preferred relative to motorcycles, as distances increase. This might have to do with comfort levels and the ability to take passengers and luggage in cars.

3.98 It is important to note that unreliability was presented only on the non-motorcycle alternative in the SP experiments. Therefore this term does not appear in the motorcycle utility. Within the between-mode models we have been unable to estimate statistically significant terms for unreliability of 5, 10 or 20 minutes on car and PT journey time. Congestion also affects motorcyclists (though less than car users), so they will also perceive unreliability as a consequence of increased congestion. This is quantified in the within-mode experiment where the traffic in the general motor vehicle lanes was described as “free flowing”, “subject to mild congestion”, and “subject to long stopped periods”.

3.99 The weather coefficients have been applied to the car utility and they therefore reflect the preference for car relative to motorcycle given the specific weather alternatives. The coefficients clearly show that when the weather gets worse, the car becomes more attractive, as is to be expected.

3.100 Additionally, people who own two motorbikes or more are less likely to choose the car as represented by a negative term in the car utility. It was striking that this effect was only evident in the motorcycle versus car experiment (no explanation is known; it might be related to the low number of statistics for the other experiments). One possible explanation why those with more than one motorcycle are seen to be less likely to consider car choices could be that they have purchased specific types of bike (e.g. touring bike, sports bike, trail bike) on which to make specific types of journeys and as a result their mode choice decisions are heavily influenced by the availability of a motorcycle they consider as particularly fit for purpose.

Public transport utility

3.101 In the PT utility, the cost term multiplies the one-way fare for the journey in question. This fare was collected from respondents for cases where PT was either their used or alternative mode.

3.102 The door-to-door journey time and distance coefficients all behave as expected. The unreliability term applies both to the car and public transport alternatives: no differences in the valuation of reliability were observed between these modes.

3.103 There is a striking difference between the weather coefficients for car and public transport, relative to motorcycle. Light rain does not influence the choice between using a motorbike and public transport. With gusty winds, motorbikes seem to be preferred over public transport (although this has a low level of significance): it may imply dissatisfaction for waiting for public transport during windy conditions. Only with heavy rain is public transport clearly preferred.

3.104 The constants for the area of residence should be assessed only in combination with the standard constant for using public transport. In London and other metropolitan areas there seems to be an inclination towards the use of a motorbike. For commute and business trips there is no difference for London, metropolitan areas and other areas, though their public transport levels are clearly different. For other purpose journeys, there seems to be an inclination towards using public transport in the non-London and non-Metropolitan areas. This includes shopping journeys where motorcycle becomes a less attractive alternative due to the need to carry luggage on the motorcycle.

Cycle utility

3.105 No cost term is applied to the cycle alternative.

3.106 A negative distance term indicates that respondents are less likely to chose to travel by bicycle as the journey distance increases; this was found to provide a better model fit than a journey duration term.

3.107 All terms of the cycle utility are low in significance. This is due to the low number of respondents in this experiment. Those choosing between cycle and motorcycle do not distinguish a difference between light and heavy rain: in both conditions motorcycle is deemed to be more attractive which may be related to the ability to wear weather resistant clothing on a motorcycle without any impairment of movement. Gusty winds are not found to be an important factor in MC-cycle mode choice, possibly as both modes are susceptible to gusty conditions and there may be no difference in benefit from using either of the two modes under consideration in such circumstances.

Neither utility

3.108 Most striking in this utility is the difference between telephone and web respondents. Once all the experiments are considered together we can observe that web respondents are more likely to choose the neither option than people that are interviewed via the telephone. This may be because it is easier to give a "neither" response when it does not have to be justified another person as in a telephone interview situation, although it is difficult to make a judgement as to whether this results in better or worse quality data. We also see respondents are less likely to reject both of the modes offered as the length of their existing journey increases.

Scales

3.109 The scales relating to the SP within-mode data and the RP data act to control for differences in variance from the SP between-mode data. These demonstrate that the SP within-mode data has less variance than the SP between-mode data, and the RP data has more variance than the SP between-mode data.

3.110 The scales relating to different mode combinations within the model indicate that the motorcycle-cycle utilities have less variance than the motorcycle-PT ones, which in turn have less variance than the motorcycle-car ones. This suggests that there is greater cross-elasticity between motorcycle and cycle than motorcycle and PT, and greater cross-elasticity between motorcycle and PT than motorcycle and car. This tree structure has been adopted in the final model; the implications of this structure for implementation are discussed further in paragraph 3.119. The application of these scales is further discussed in paragraph 3.117 which discusses their interpretation for application.

Table 24: Coefficients of the best model for the within, combined between and within experiment, combined RP, between and within model and the final jack-knifed model

		Tree		Within model		Between + within model		RP, between + within model		Final model (Jack-knifed)		
	File			Main27_with.F12		Joint120.F12		SP_RP66.F12		JACK_SP_RP66		
	Observations			409		334 × 12		4459		4459		
	Final log (L)			-1145.0		-2224.1		-2520.6		-2520.6		
	D.O.F.			9		60		50		50		
	Rho²(0)			0.363		0.495		0.470		0.470		
	Rho²(c)			0.197		0.208		0.190		0.190		
				Scale	**T-ratio**	**Scale**	**T-ratio**	**Scale**	**T-ratio**	**Scale**	**T-ratio**	
Scale factors	MC-Car Between SP data.	**BC**				1	by def.	1	by def.	1	by def.	
	MC-PT Between SP data	**BP**				1.13	(6.0)	1.34	(6.7)	1.32	(3.9)	
	MC-Cycle Between SP data	**BB**				3.84	(5.2)	3.03	(5.4)	2.62	(2.8)	
	MC Within SP data	**W**				4.58	(7.6)	4.57	(8.1)	4.60	(5.9)	
	RP data	**RP**						0.52	(3.4)	0.47	(2.1)	
Type	**Model term**			**β**	**T-ratio**	**β**	**T-ratio**	**β**	**T-ratio**	**β**	**T-ratio**	**Remark**
All utilities	$\beta_{Cost} \cdot$ AllCosts	**All**	**=**					-0.1594	(-9.9)	-0.1541	(-7.2)	
			or			-0.167	(-8.9)					if purpose is business
			or			-0.157	(-8.5)					if purpose is commute or other
Motorcycle utility	$\beta_{ParkCost} \cdot$ ParkingCosts	**W**	=	-0.716	(-13.6)							
	$\beta_{MCtime} \cdot$ MCTravelTime	**not W**	=			-0.0047	(-1.3)					if purpose is commute or business
			or			0.0177	(4.2)					if purpose is other
								0.0154	(1.5)	0.0168	(0.8)	For each min of MC_JourneyTime <= 20 mins
								-0.0071	(-1.9)	-0.0053	(-0.9)	For each min of MC_JourneyTime > 20 mins
	$\beta_{WalkTime} \cdot$ WalkTimeParking	**W**	=	-0.109	(-9.7)							
	$\beta_{WalkTimeSec} \cdot$ WalkTimeParking	**W+B**	=	0.102	(5.2)	-0.0038	(-0.9)					if security measures are available on parking location

	$\beta_{WalkTimeNoSec}$· WalkTimeParking	B	=			-0.0258	(-6.3)	-0.0250	(-6.5)	-0.0241	(-4.7)	if no security measures are available on parking loc. or if you do not know in advance if security is available
	$\beta_{monthly\_use}$	B	=			2.65	(8.6)	2.32	(8.2)	2.27	(3.8)	if MC is used 6-12 mnth/yr for commuters in London & Metrop.
		B	or			0.785	(2.5)	0.89	(3.1)	0.87	(1.6)	if MC is used 6-11 mnth/yr for non-comm. in London & Metrop.
		B	or			2.31	(7.7)	1.79	(6.4)	1.76	(3.5)	if MC is used 12 mnth/yr for non-comm. in London & Metrop.
		B	or			0.977	(3.9)					if MC is used 6-12 mnth/yr for comm/bus. journeys in other areas
		B	or			0.855	(2.5)					if MC is used 6-11 mnth/yr for other journeys in other areas
		B				-0.0621	(-0.3)	-0.73	(-3.3)	-0.78	(-1.9)	if MC is used 12 mnth/yr for other journeys in other areas
	$\beta_{MC\_London+Metropolitan}$	B	=			-1.41	(-4.3)	-2.131	(-8.0)	-2.089	(-4.0)	if living area is London or Metropolitan
	$\beta_{commute}$	B	=			-0.347	(-2.0)	-0.668	(-4.1)	-0.654	(-2.1)	if journey purpose is commute
	$\beta_{60years+}$	B	=			-1.04	(-6.1)	-0.956	(-6.0)	-0.938	(-3.9)	if age of respondent is 60 years or older
	β_{smart_dress}	B	=			-0.393	(-3.1)	-0.489	(-4.0)	-0.440	(-1.7)	if dress code is smart or smart uniform
	$\beta_{perceive\_risk}$	B	=			-0.691	(-4.4)	-0.748	(-5.2)	-0.737	(-2.9)	if respondent perceives a higher risk of an accident in the AM peak period for a motorcycle journey than at other moments of the day and if this affects his decision to use his motorcycle for this journey
	β_{900cc+}	B	=			0.489	(3.9)	0.496	(3.9)	0.437	(2.3)	if the engine size of the motorcycle is 900 cc or more.
	$\beta_{Congestion}$	W	=	-0.180	(-1.7)	-0.0484	(-1.8)	-0.049	(-1.9)	-0.047	(-1.6)	if mild congestion
		W	or	-1.05	(-9.8)	-0.232	(-6.0)	-0.233	(-6.4)	-0.224	(-4.5)	if heavy congestion
	$\beta_{WideLanes}$	W	=			0.173	(6.3)	0.172	(6.5)	0.168	(4.6)	if lanes are wide
		W	or	0.339	(3.4)							if lanes are wide and if arriving outside the interval 8:30 – 9:00 am and if trip length is short (<6) or long (> 15 miles)
		W	or	1.27	(11.7)							if lanes are wide in all other cases
	β_{MC_Other}	RP	=					-1.60	(-2.5)	-1.58	(-2.0)	if purpose is not commute or business
Car utility	$\beta_{CarTime}$	not W	=			-0.0065	(-1.8)	-0.0140	(-3.8)	-0.0120	(-2.1)	
	$\beta_{WalkTime}$	BC	=			-0.0307	(-2.4)	-0.0310	(-2.5)	-0.0298	(-2.5)	
	$\beta_{CarDistance}$	not W	=			0.0235	(2.5)	0.0384	(3.6)	0.0376	(2.5)	if purpose is commute
			or			0.0595	(8.1)	0.0747	(6.0)	0.0728	(3.4)	if purpose is not commute
	$\beta_{Weather}$	BC	=			1.43	(5.3)	1.36	(5.3)	1.33	(4.2)	if light rain
		B+RP	or			2.75	(10.6)	2.59	(10.8)	2.52	(8.2)	if heavy rain

		BC	or		1.29	(4.7)	1.22	(4.8)	1.19	(4.0)	if gusty winds
	$\beta_{Unreliable}$	BC	=		-0.117	(-0.9)					if there are often unpredictable delays of 10 or 20 minutes
	β_{TwoMC}	BC	=		-0.842	(-3.5)					if respondent owns two motorcycles
	β_{Two+MC}	BC	=				-0.723	(-4.0)	-0.694	(-2.0)	if respondent owns two or more motorcycles
	ASC_{Car}	BC	=		-1.87	(-5.3)	-2.49	(-7.7)	-2.48	(-4.2)	alternative specific constant
	ASC_{Car_RP}	RP	=				0.004	(0.0)	0.007	(0.0)	alternative specific constant
Public transport utility	β_{PTTime}	not W	=		-0.0081	(-1.9)	-0.0074	(-2.3)	-0.0055	(-1.1)	
	$\beta_{PTDistance}$	not W	=		0.0082	(0.9)					
	$\beta_{Weather}$	BP	=		0.0272	(0.1)					if light rain
		B+RP	or		0.676	(2.6)	0.609	(3.2)	0.578	(2.9)	if heavy rain
		BP	or		-0.576	(-1.8)	-0.477	(-2.0)	-0.425	(-1.6)	if gusty winds
	$\beta_{Unreliable}$	BP	=		(see before)						(idem as unreliability coefficient $\beta_{Unreliable}$ in the car utility)
	$\beta_{PT\_London+Metropolitan}$	BP	=		-3.29	(-3.9)					if living area is London or Metropolitan
	$\beta_{OthArea\_Commute+Business}$	BP	=		-3.48	(-3.9)					if living area is not L or M and purpose is commute or business
							-1.942	(3.0)	1.481	(1.6)	If living area is not L or M and other purpose
	ASC_{PT}	BP	=		2.88	(3.0)	-1.312	(-4.3)	-1.296	(-2.4)	alternative specific constant
	ASC_{PT_RP}	RP	=				-1.523	(-1.8)	-1.376	(-1.4)	alternative specific constant
Cycle utility	$\beta_{Cuc;leTime}$	not W	=								
	$\beta_{CycleDistance}$	not W	=		-0.0653	(-6.2)	-0.0737	(-6.8)	-0.0647	(-3.5)	
							-0.2390	(-2.2)	-0.2475	(-1.5)	If rain
	$\beta_{Weather}$	BB	=		-0.204	(-1.6)					if light rain
		B+RP	or		-0.287	(-2.1)					if heavy rain
		BB	or		-0.0637	(-0.5)					if gusty winds
	ASC_{Cycle}	BB	=		0.741	(3.3)	-0.279	(-1.3)	-0.277	(-0.8)	alternative specific constant
	ASC_{Cycle_RP}	RP	=				0.121	(0.3)	0.139	(0.3)	alternative specific constant
Neither utility	$\beta_{MeitherDistance}$	BC	=		-0.0398	(-2.0)					If purpose is not business
			or		-0.17	(-3.5)					If purpose is business
			or				-0.0552	(-4.6)	-0.0522	(-2.9)	All purposes
	$\beta_{Neither}$	BC	=		-1.24	(-3.1)					if resp. via web and living in London or Metropolitan area
			or		0.413	(0.4)					if resp. via web and living in “other” areas and purp. is business
			or		-2.89	(-4.9)					if resp. via web and living in “other” areas and purp. is not bus.

							2.219	(7.0)	2.172	(5.4)	If resp. via web
		or			-3.9	(-10.9)					if respondent via telephone
							-4.849	(-15.3)	-4.721	(-9.0)	Alternative specific constant
$\beta_{MeitherDistance}$	BP	=			-0.0703	(-3.4)	-0.0552	(-4.6)	-0.0522	(-2.9)	
$\beta_{Neither}$	BP	or			-0.442	(-1.3)	1.357	(4.3)	1.296	(2.3)	if respondent via web
		or			-2.02	(-4.4)					if respondent via telephone
							-2.755	(-6.3)	-2.552	(-2.9)	Alternative specific constant
$\beta_{MeitherDistance}$	BB	=			(see before)		-0.0552	(-4.6)	-0.0522	(-2.9)	(idem as neither distance coefficient $\beta_{MeitherDistance}$ for PT)
							-1.614	(-4.4)	-1.422	(-1.7)	Alternative specific constant
$\beta_{Neither}$	BB	or			-0.188	(-0.7)					if respondent via telephone
$\beta_{Neither}$	W	=	-3.37	(-20.0)	-0.807	(-7.3)					if interview was done by telephone
	W	or	-1.82	(-9.9)			0.372	(5.0)	0.356	(3.3)	if interview was done by the Web
	W	or			-0.402	(-5.5)					if interview was done by the Web and living in L. or Metrop.
	W	or			-0.585	(-5.5)					if interview was done by the Web and not living in L. or Metrop.
							-0.812	(-7.7)	-0.777	(-4.9)	Alternative specific constant

Tree:

- B = all between-mode SP data;
- BC = MC vs car between-mode- SP data;
- BP = MC vs public transport between-mode SP data;
- BB = MC vs (bi)cycle between-mode SP data;
- W = MC within-mode SP data;
- RP = Revealed Preference data

Table 25: Final mode choice model after jack-knifing

	Motorcycle			Car			PT			Cycle		
	Coefficient	**Estimate**	**t-ratio**	**Coefficient**	**Estimate**	**t-ratio**	**Coefficient**	**Estimate**	**t-ratio**	**Coefficient**	**Estimate**	**t-ratio**
Costs		-0.1541	-7.2		-0.1541	-7.2		-0.1541	-7.2			
Journey time	for each min of MC journey < 20mins	0.0168	0.8	All respondents	-0.0120	-2.1	All respondents	-0.0055	-1.1	All respondents	0.0000	n/a
(coefficients applied to time in mins)	for each min of MC journey >20mins	-0.0053	-0.9									
Unreliability				All respondents	0.0000	n/a	All respondents	0.0000	n/a			
Journey distance				Commute	0.0376	2.5	All respondents	0.0000	n/a	All respondents	-0.0647	-3.5
				Non-Commute	0.0728	3.4						
Parking walk time	With no parking security	-0.0241	-4.7	All respondents	-0.0298	-2.5						
	With parking security	0.0000	n/a									
Weather				Light rain	1.3323	4.2	Light rain	0.0000	n/a			
				Heavy rain	2.5190	8.2	Heavy rain	0.5775	2.9	Rain	-0.2475	-1.5
				Gusty winds	1.1868	4.0	Gusty winds	-0.4245	-1.6	Gusty winds	0.0000	n/a
Monthly use	London & Metropolitan											
(under 6 month as base)	Commute											
	6-12 month users	2.2673	3.8									
	Non-commute											
	12 month users	1.7604	3.5									
	6-11 month users	0.8650	1.6									
	"Other" Areas											
	Not commute or business											
	12 month users	-0.7793	-1.9									
	6-11 month users	0.0000	n/a									
Constants (SP)				All respondents	-2.4750	-4.2	All respondents	-1.2961	-2.4	All respondents	-0.2772	-0.8
	London & Metropolitan	-2.0892	-4.0	Own 2+ MC	-0.6935	-2.0	"Other" Areas, not commute or business	1.4807	1.6			
	Commute	-0.6540	-2.1									

	Over 60 years old	-0.9382	-3.9									
	Smart dress required	-0.4398	-1.7									
	Perceive risk of MC accidents in peak period	-0.7371	-2.9									
	Engine size > 900cc	0.4374	2.3									
Constants (RP)				All respondents	-0.0073	0.0	All respondents	-1.3761	-1.4	All respondents	0.1392	0.3
	Non-business & non-commute	-1.5806	-2.0									
Scales				Car	1.0	n/a	PT	1.3163	3.9	Cycle	2.6178	2.8
				RP data to SP data	0.4693	2.1	RP data to SP data	0.4693	2.1	RP data to SP data	0.4693	2.1
Motorcycle specific values												
Advance stop lines	All respondents	0.0000	n/a									
Lane width	All respondents	0.1647	4.6									
Congestion	Heavy	-0.2235	-4.5									
	Mild	-0.0468	-1.6									
Scale	Within-mode data	4.5964	5.9									
Choice of "Neither" **separate neither utilities for each mode pair**												
Between-mode experiment				All respondents	-4.7207	-9.0	All respondents	-2.5523	-2.9	All respondents	-1.4218	-1.7
				Car web respondents	2.1721	5.4	PT web respondents	1.2956	2.3			
				Distance (per mile)	-0.0522	-2.9	Distance (per mile)	-0.0522	-2.9	Distance (per mile)	-0.0522	-2.9
Within-mode experiment	All respondents	-0.7769	-4.9									
	Web respondents	0.3558	3.3									

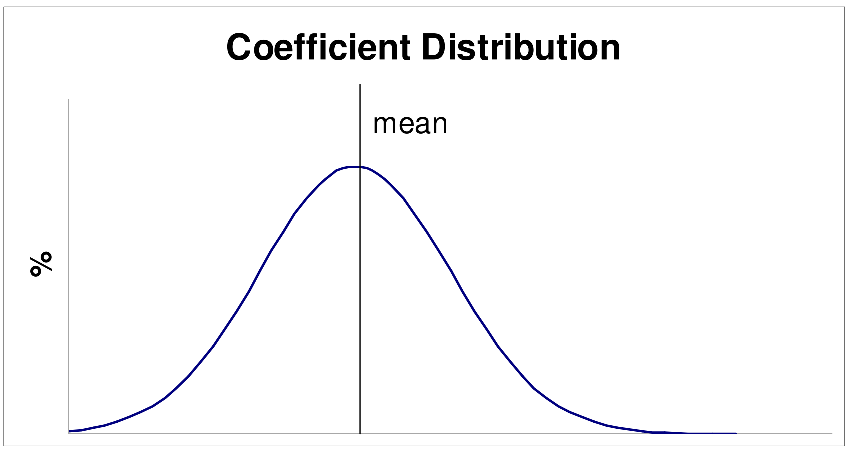
Table 26: Definition of terms in motorcycle usage model

	Motorcycle	Car	PT	Cycle
Costs (pounds)	Fixed operating cost (all purpose = 10p/mile) + Parking cost (varied) + Congestion charge (varied)	Fixed operating cost (business = 40p/mile) (non-business = 16p/mile) + Parking cost (varied) + Congestion charge (varied)	fare (varied)	n/a
Journey time (mins)	Existing journey time	Existing journey time + SP increment	Existing journey time + SP increment	
Unreliability		Unpredictable delays	Unpredictable delays	
Journey distance		O-D distance in miles	O-D distance in miles	O-D distance in miles
Parking walk time (mins)	walk time from destination in minutes	walk time from destination in minutes		
Weather relative to "You expect the weather to be pleasant"		You expect there to be light intermittent rain during the day You expect there to be heavy continuous rain during the day You expect it to be dry, but with strong gusty winds during the day	You expect there to be light intermittent rain during the day You expect there to be heavy continuous rain during the day You expect it to be dry, but with strong gusty winds during the day	You expect there to be light intermittent rain or heavy continuous rain during the day You expect it to be dry, but with strong gusty winds during the day
Monthly use	Months motorcycle used in year			
Scales			Scale compared to MC-Car choice	Scale compared to MC-Car choice

Investigation of distributed parameters

3.111 Because of the heterogeneous nature of the motorcycling population, there could be significant variation in parameter valuations, particularly the intrinsic 'enjoyment' that we appear to be picking up in the valuation of journey time by motorcycle, even after taking account of observed differences. We have therefore undertaken mixed-logit analysis to investigate random taste variation of motorcyclists. The introduction of distributional parameters (as illustrated in Figure 18) has the potential to increase model explanation and provides important information on the range of coefficient valuations observed in the sample.[14]

Figure 18: Distributional effects



3.112 The first stage in the development of a model with distributed parameters is to move from a tree-structure represented by scales applied to each of the utility functions (as shown in Figure 17) to a tree-structure represented by common coefficients on error component terms on groups of utility functions, which creates correlation among the utilities for different alternatives. This is required as the model estimation software cannot at this time combine error components for distributed parameters with scales on the utilities; all the correlations within the model need to be represented by error components within a mixed logit framework.

3.113 The error components used to replicate the tree structure must use the group of utilities that are observed to have the lowest variance as their reference; in the case of the existing model we can see that the within-mode SP data has the lowest variance. A

[14] For more details on mixed logit models, see Train, K. E. (2003) Discrete Choice Methods with Simulation. Cambridge University Press, Cambridge.

series of error components (taken from a Gumbel distribution using 1000 draws) were therefore applied to the other alternatives to replicate the correlations between utilities previously represented by the scale parameters; the allocation of these error components are detailed in Table 27 below.

Table 27: Error components to replicate model tree-structure

Data Source	Alternative1	Coefficient * EC	Alternative2	Coefficient * EC	Alternative3	Coefficient * EC
SP Within-mode	W_MC_A	(reference)	W_MC_B	(reference)	W_None	(reference)
SP Between-mode	MC_C	BETWSCALE * 20 CARSCALE * 46	Car_C	BETWSCALE * 17 CARSCALE * 47	None_C	BETWSCALE * 23 CARSCALE * 48
	MC_P	BETWSCALE * 21 PTSCALE * 11	PT_P	BETWSCALE * 18 PTSCALE * 12	None_P	BETWSCALE * 24 PTSCALE * 13
	MC_Cycl	BETWSCALE * 22 CYSCALE * 14	Cycl_Cycl	BETWSCALE * 19 CYSCALE * 15	None_Cycl	BETWSCALE * 25 CYSCALE * 16
RP Between-mode	RPMC_C	RPSCALE * 1 BETWSCALE * 26 CARSCALE * 44	RPCar	RPSCALE * 2 BETWSCALE * 29 CARSCALE * 45		
	RPMC_PT	RPSCALE * 3 BETWSCALE * 27 PTSCALE * 4	RPPT	RPSCALE * 5 BETWSCALE * 30 PTSCALE * 6		
	RPMC_Cy	RPSCALE * 7 BETWSCALE * 28 CYSCALE * 8	RPCycle	RPSCALE * 9 BETWSCALE * 31 CYSCALE * 10		

3.114 The mixed logit representation of the tree structure replicates the model results quite closely, although this is not exact as the mixed logit is estimated using simulation techniques and is not a closed form problem that can be estimated exactly like the nested model. The mixed logit structure results in an error component on cycle which is not found to be significantly different to the within-mode reference; this is consistent with the nested model which finds that these two scales are relatively close once the standard errors have been taken into account. The cycle-specific error components have therefore been dropped from the mixed logit model and this revised specification has been used as the basis for the investigation of distributed parameters.

3.115 Tests were run to examine whether model improvements could be obtained by specifying the time and cost terms within the model as distributed parameters to allow random taste variation. These error components were drawn from a normal distribution using 1000 draws. The error components on the time terms were not found to have significant coefficient estimates, indicating that they added no additional explanatory value to the model specification.

3.116 The error component on the cost term was found to be significant, indicating that there is taste variation with respect to cost across the sample. The coefficient for the mean of the cost distribution was –0.844 and the coefficient for the standard of the distribution was 0.514. However, the overall improvement in model fit with respect to the original nested model structure without a distributed cost parameter was marginal (log likelihood of -2517 units compared to –2520). As a result the additional complication of applying the distributed parameter was considered to out-weigh the relatively minor improvement in model fit obtained, and the original nested model has been retained for application.

Issues for application

3.117 To move from a model estimated from a series of separate data sources to a mode choice model for application it is necessary to interpret the meaning of the scale parameters and move to a more meaningful mode choice tree structure with the RP choice observations used as the base.

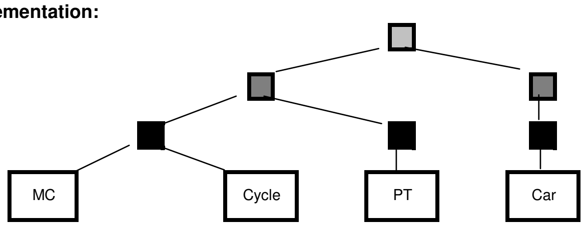
3.118 From estimation we obtain values for scale parameters which relate to the variance of the SP error term. In order to adjust the model to the RP data we multiply the SP coefficients by the RP scale parameter.

3.119 The scale parameters, which provide the magnitude of the variance of the error terms from each of the pairs of mode choice data, can then be used to define the tree structure. From the model, we see that the MC-Cycle utilities have less variance than the MC-PT ones, which in turn has less variance MC-Car ones. This defines a tree where MC and cycle are in the lowest branch, PT is next up the tree and car is at the highest level. In defining the tree parameters we can work backwards so that the correct values are obtained as we move up each level of the tree.

From Estimation:

Scales	
Car	1.000
PT	1.316
Cycle	2.618

For Implementation:



Tree parameter = 1.000 / 1.316 = 0.760

Tree parameter = 1.316 / 2.618 = 0.503

All coefficients multiplied by 2.618

Check:

MC-Cycle	-	Coeffs * 2.618			= Coeffs * 2.618
MC-PT	-	Coeffs * 2.618	* 1.316 / 2.618		= Coeffs * 1.316
MC-Car	-	Coeffs * 2.618	* 1.316 / 2.618	* 1.000 / 1.316	= Coeffs * 1.000

3.120 The following table provides the model for implementation following these corrections.

Table 28: Final model for implementation

	Motorcycle		Car		PT		Cycle	
	Coefficient	Estimate	Coefficient	Estimate	Coefficient	Estimate	Coefficient	Estimate
Costs		-0.1893		-0.1893		-0.1893		
Journey time	for each min of MC journey < 20mins	0.0207	All respondents	-0.0148	All respondents	-0.0067	All respondents	0.0000
(coefficients applied to time in mins)	for each min of MC journey >20mins	-0.0065						
Journey distance			Commute	0.0462	All respondents	0.0000	All respondents	-0.0794
			Non-Commute	0.0895				
Parking walk time	With no parking security	-0.0296	All respondents	-0.0366				
	With parking security	0.0000						
Weather			Light rain	1.6368	Light rain	0.0000		
			Heavy rain	3.0948	Heavy rain	0.7095	Rain	-0.3041
			Gusty winds	1.4581	Gusty winds	-0.5216	Gusty winds	0.0000
Advance stop lines	All respondents	0.0000						
Lane width	All respondents	0.2023						
Congestion	Heavy	-0.2746						
	Mild	-0.0575						
Monthly use	London & Metropolitan							
(under 6 month as base)	Commute							
	6-12 month users	2.7856						
	Non-commute							
	12 month users	2.1628						
	6-11 month users	1.0628						
	"Other" Areas							

	Not commute or business							
	12 month users	-0.9575						
	6-11 month users	0.0000						
Constants (SP)	London & Metropolitan	-2.5667	Own 2+ MC	-0.8520	"Other" Areas, not commute or business	1.8191		
	Commute	-0.8035						
	Over 60 years old	-1.1527						
	Smart dress required	-0.5404						
	Perceive risk of MC accidents in peak period	-0.9056						
	Engine size > 900cc	0.5374						
Constants (RP)			All respondents	-0.0090	All respondents	-1.6907	All respondents	0.1711
	Non-business & non-commute	-1.9420						
RECALIBRATION			**CONSTANT TO BE ESTIMATED**		**CONSTANT TO BE ESTIMATED**		**CONSTANT TO BE ESTIMATED**	
Tree parameters			Theta1	1.0	Theta2	0.8	Theta3	0.5

3.121 The terms from the within-mode motorcycle SP utilities can been incorporated in the between-mode motorcycle utility function as a result of the scaling of the two data sources. The "neither" utilities have been dropped for application, the current models control for the likelihood of not choosing either of the pair of alternatives offered in the SP choices but these neither alternatives are difficult to interpret in their own right for application.

3.122 The models as they stand are based on a stratified sample and still require calibration from network data to ensure the correct mode shares are obtained for the base situation for which the level of service for each mode will be known. The SP alternative specific constants have therefore been dropped for application, but the RP alternative specific constants have been retained to provide an initial start point for the recalibration. The models will require an additional constant on the car, PT and cycle utilities as indicated in Table 28. This calibration procedure should be conducted for each area to be examined to ensure the mode shares are appropriate for both the London and Cambridge models.

3.123 In order to conduct this calibration it will also be necessary to define the availability of each mode in the mode-choice model, specifically:

- Motorcycle should be available to all travellers in this segment, i.e. motorcycle owning persons;
- Car should only be available to those that have access to a car (within the survey data has been collected on both the number of cars in the household and the availability of these for use on a regular basis);
- Public transport should be available to those with public transport alternatives;
- Cycle should not be available as a viable mode for long journeys

3.124 The availability conditions that are defined for calibration should also be used in forecasting.

3.125 Additionally, there are a number of variables which are contained in the model utilities, which will not be available for application in the WSP models. We advise that average values be used in model application (to be multiplied by the relevant coefficients). These average values will be supplied to WSP from analysis of the RP survey data; tabulations of the data collected in the surveys is provided as an appendix to this report.

3.126 One of the factors that will need consideration in application is the weather aspect. The results suggest that wet weather and dry weather situations require separate modelling, which will need to include both congestion levels and speeds for both cars and motorcycles as these will also impact on the mode choice.

4 SUMMARY AND RECOMMENDATIONS

4.1 In May 1999, the UK Government set up the 'Advisory Group on Motorcycling'. One of their remits was to investigate the potential of increased motorcycle use for reducing traffic congestion and pollution. In response to this the Department for Transport commissioned a study to determine how policy could affect motorcycle usage and what subsequent impacts increased motorcycle usage would have on traffic congestion. The study was undertaken by a team comprising WSP, RAND Europe, Accent Marketing and Research and Marcus Wigan.

4.2 There are two important choices that determine potential motorcycle use: motorcycle ownership and choice of motorcycle for travel. Both of these decisions have been modelled in this study.

4.3 The motorcycle ownership model predicts personal motorcycle ownership, including number of motorcycles owned and the engine sizes of these motorcycles, depending on the characteristics of the person and the average purchase cost of a motorcycle. The ownership model has been estimated from two data sets: 1992 to 2001 National Travel Survey (NTS) data, which provides information on both personal motorcycle ownership and engine size, and the 2000 Family Expenditure Survey (FES), which provides information on personal motorcycle ownership only. The NTS data was necessary in order to be able to model choice of engine size. However, because of the small fraction of motorcycle owners in the NTS sample, even when data were aggregated across years, it did not provide enough data for development of the ownership models. The inclusion of the FES data was therefore important to boost the volume of more recent ownership data. For implementation, the models were calibrated against information on the total number of motorcycles registered by engine size and area.

4.4 The structure of the motorcycle ownership model is a disaggregate hierarchical logit model, with structural parameters to measure the sensitivity of choice of engine size relative to motorcycle ownership. Proper account is taken of differences in unexplained error between the NTS and FES data sets. The models contain a number of important explanatory variables describing motorcycle ownership, including age, gender, personal income, family structure, car ownership, location of residence and motorcycle purchase cost.

4.5 Whilst Revealed Preference (RP) data was judged to be more appropriate given the nature of decisions for the ownership models, Stated Preference (SP) data was judged to be more appropriate for development of the usage models on the basis that the low incidence of motorcycle ownership in the population meant that RP travel databases, such as the NTS, did not provide adequate information on the choices that have been made. Also, SP data allowed for further evaluation of how motorcycle usage may change as a result of policy, for example, increased lane widths, provision and pricing of parking, and other important influences, such as weather.

4.6 An SP survey was therefore conducted with 443 motorcycle owners in London, Metropolitan and other areas in the UK. Interviews were conducted by telephone and on the Internet. Respondents provided revealed preference mode choice information for a journey made in the AM peak. They then participated in two SP experiments: first a within-mode experiment to examine preferences for motorcycle travel and second a between-mode experiment to examine trade-offs between motorcycle and another model of travel, with varying travel conditions including changes in congestion, weather, provision of motorcycle/car parking, and journey cost changes. These RP and SP data were used to develop a model of mode choice from choices of motorcycle, car (driver), car (passenger), public transport and bicycle. Quotas were used to ensure that information was collected on a number of key dimensions which were pre-determined to be of interest for modelling. As a result the survey results are not representative of the motorcycling population, but do provide sufficient detailed information to allow the key differences in behaviour to be observed and accounted for in the mode choice models.

4.7 Joint models were estimated using the SP within-mode, SP between-mode and revealed preference data, with proper scaling by data source type and mode combination.

4.8 The final model indicates that, for journeys in the AM peak period

- costs are valued negatively, and are an important driver of mode choice for motorcyclists;
- journey time on motorcycles is perceived positively, but this decreases as the journey distance increases: the enjoyment is the greatest for short trips (up to 20 minutes);
- time in congestion is valued more negatively by motorcyclists than time in non-congested conditions;
- journey times on other modes, i.e. car and public transport, are viewed negatively relative to motorcycle;
- we observe a distance effect, which indicates that travel by car becomes more attractive, relative to motorcycle, as journey distances increase;
- bicycle, as an alternative to motorcycle, is less attractive as journey distances increase;

- for motorcycle travel, the time spent walking from the parking location to the final destination is only valued negatively when there are no specific security measures available at the parking location: if there are security measures, then the walking time has not been found to have an impact on the utility within the range examined within the experiments;

- wide lanes are highly valued by motorcyclists who can then use the additional width to filter through congested areas and reduce their travel time variability;

- legal access to advance stop lines is not found to be of significance in the choice process; possibly as these are already used due to low levels of enforcement, or possibly as they are simply not relevant: as long as the motorcyclist can position themselves level with the front car they can generally use their better acceleration to clear the junction before the rest of the traffic;

- the preference for motorcycle is strongly dependent on the number of months per year that a person uses his bike, possibly representing a life-style effect: the effect is the biggest for commuting in London and other metropolitan areas;

- there is a negative impact on motorcycle usage for travellers living in London and other metropolitan areas, compared to 'other' areas, in addition to that predicted by the model, taking into account journey times, costs, etc.;

- people aged 60 and over are less likely to use their motorbike, as are people who commute and people whose dress code is smart or a smart uniform;

- those who perceive a higher accident risk in the morning peak compared to the rest of the day are less likely to choose motorcycle;

- motorcycle owners with large motorbikes (> 900 cc) are more likely to choose to travel by motorcycle than those owning smaller motorcycles;

- motorcycle owners who own two motorbikes or more are more likely to choose to travel by motorcycle, compared to car;

- in general, motorcycle is less attractive for journeys for other purposes, compared to commuting and/or for business;

- car is more attractive to motorcycle owners in poor weather conditions; only with heavy rain is public transport preferred to motorcycle.

4.9 Because of the heterogenous nature of the motorcycling population, mixed-logit analysis was undertaken to investigate random taste variation in the model parameters. No significant random taste variation was detected in the time. The models indicate that cost varies in importance across the respondents in the sample, but the model incorporating these effects was not found to give a significant improvement in model fit and has therefore not been carried forward for application.

4.10 In a second phase of this study the ownership and usage models will be implemented in two existing transport models to allow an investigation of the impacts of a range of policies on motorcycle use and their impact on congestion.

4.11 The data we have collected clearly shows that motorcyclists enjoy using their motorcycles. From the models we can observe that motorcyclists are particularly sensitive to cost, and this acts as one of their primary drivers in mode choice.

Recommendations for further developments

4.12 In this section we make recommendations for further model development.

4.13 This study has restricted itself to investigating the propensity of existing motorcycle owners to change their travel behaviour. A further area of interest would be to investigate mode-switching to motorcycle by those that are not currently motorcyclists, this would require an ownership model that included travel quality variables as well as demographic variables.

4.14 In the ownership models, there is currently no linkage between motorcycle ownership and travel quality variables, such as increased congestion. It was not possible to easily obtain information on usual congestion levels for journeys made by travellers in the NTS or FES samples, and ideally the model would benefit from network accessibility information. It may be possible to investigate such a linkage in London, say, through LATS, where there may be enough motorcycle owning persons and where detailed information on journeys made is collected, such that detailed travel conditions could be approximated.

4.15 Additional benefits may be obtained from incorporating retail prices into the motorcycle ownership models, rather than manufacturing process. An attempt was made in this study, but the data did not become available over the course of the project.

4.16 In the mode-choice component, the RP models currently rely on self-reported level of service information for the current and alternative modes in the model. This was a practical approach as a survey was already being used to collect the SP data, however, practical restrictions make it difficult to collect data on more than two modes within such an instrument. Whilst the data collected has allowed RP information to be incorporated within the model and allows binary choice models for motorcycle against the next best mode, there could be potential benefits from estimating a model using network level of service data. This would also lift the practical restrictions of the existing survey and would allow more modes to be considered. Combined with availability information, this would provide the basis for a simultaneous mode choice model covering all available modes. This would require a sample of respondents who used motorcycle for an AM peak period journey for whom the LOS for a range of available modes, including motorcycle, could be obtained. Again we recommend LATS as a potential data source.