TRANSPORT RESEARCH LABORATORY

A survey of the effectiveness of ABS in reducing accidents

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Executive Summary

An Anti-lock Braking System (ABS) is a primary safety feature designed to prevent roadwheels from locking under conditions of hard braking, such as those experienced during emergencies.

A number of track and simulator studies have assessed the potential accident savings that might be expected from ABS. The results of these encouraged the expectation that ABS will reduce accidents, and a study of accidents in Germany estimated that the universal fitting of ABS could reduce accidents involving heavy damage and/or injuries by 10-15% in Germany.

Studies in the USA have indicated that ABS may not be achieving its potential as a primary safety feature. It has been suggested that this could result from deficiencies in drivers' knowledge and use of the system, which would imply a need to train or inform drivers about ABS and how to use it effectively.

This study has been carried out to assess the effectiveness of ABS in reducing accidents in Great Britain. Previous studies have analysed existing sets of accident data, comparing fleets of vehicles that are known to be equipped with ABS with other fleets which are known *not* to be equipped; however, that approach was not feasible as no suitable accident data existed in this country. In addition, the comparisons made by these studies may have been biased by factors that could not be taken into account because of the nature of the data analysed.

The approach adopted for this project was to survey a sample of the registered keepers of cars, enquiring about their driving experience over the previous year and any accidents in which they had been involved. A postal self-completion survey was designed to collect information about the drivers and their mileage, as well as their cars.

Questionnaires were sent to registered keepers of cars with registration prefix P. This group of cars was selected to provide information about modern cars (so that relatively many ABS-equipped cars would be included) which had been in use for sufficiently long to be involved collectively in a reasonably large number of accidents. 80 thousand questionnaires were sent out and about 21 thousand were returned. These responses provided details of 1,684 accidents, of which 198 involved personal injury.

An initial analysis of the data revealed that drivers of ABS cars reported about 10 per cent fewer accidents per year than drivers of non-ABS cars. The two groups of cars and drivers clearly differed in several respects, however; for example, ABS cars tended to have larger engines and higher annual mileages, and their drivers were more likely to be middle-aged and male. Consequently, a more sophisticated statistical approach was required to make an unbiased comparison of the accident rates of the two groups of car.

A statistical model was developed to relate the number of accidents reported per questionnaire to details of the driver (e.g. age, sex and experience of driving), of the driver's mileage (e.g. distance travelled, percentage on motorways) and of the car (e.g. whether it was equipped with ABS). This allowed the effects of ABS to be established free of bias induced by these other factors. The results for all accidents showed that driving an ABS car was associated with:

- about 16 per cent fewer accidents among men up to 55 years old (the 90% confidence interval is from 1 to 28 per cent);
- about 10 per cent more accidents among older men (the 90% confidence interval is from 11 per cent *fewer* to 36 per cent *more* accidents);
- about 18 per cent more accidents among women (the 90% confidence interval is from 1 per cent *fewer* to 40 per cent *more* accidents);
- about 3 per cent fewer accidents overall (the 90% confidence interval is from 12 per cent *fewer* to 7 per cent *more* accidents).

The reduction among younger men is statistically significant at the 90% level, and the increase for women approaches significance. The results for injury accidents were less precise; they were broadly consistent with the results for all accidents, although the increase among older men was more marked - and statistically significant.

The responses showed a poor level of knowledge about ABS, but younger men did tend to score higher than older men, who in turn scored higher than women. Drivers of ABS cars tended to score higher than drivers of non-ABS cars. When these scores were introduced into the modelling, it emerged that the number of accidents reported by drivers of ABS cars fell as their level of knowledge rose, but there were differences between the three groups of drivers.

- Among men up to 55 years old, drivers of ABS cars who were ignorant about ABS reported about the same number of accidents as drivers of non-ABS cars. The reduction in accidents as knowledge improved meant that drivers in this group who knew something of ABS tended to benefit from the equipment.
- Among older men, drivers of ABS cars reported more accidents than drivers of non-ABS cars. Despite the reduction in accidents as knowledge improved, even the drivers with most knowledge of ABS still tended to report more accidents,
- Among women, drivers of ABS cars reported more accidents than drivers of non-ABS cars. The reduction in accidents as knowledge improved meant that the drivers with most knowledge of ABS tended to report as many accidents as drivers of non-ABS cars.

The increase in accidents among older men and women driving ABS cars suggests that there are aspects of ABS as currently implemented that prevent a significant part of the driving population from deriving its benefits – even when they are knowledgeable about ABS. Various explanations can be advanced for this. For example, it could be that younger men tend to be physically better able to exert the necessary force on the brake pedal, or that they respond better to the feedback provided by ABS, or that they are more likely to perceive an emergency in sufficient time to be able to benefit from the system.

The study has shown that ABS has the potential to reduce the number of accidents, but that this has not been fully achieved – in part because many drivers have little or no knowledge of ABS. Lack of knowledge contributes to the increased accident risk among older men and women, but it will be important in future to identify the other factors which contribute to this increase.

1 Introduction

Antilock Braking Systems (ABS) are fitted to many new cars with the aim of preventing the brakes from locking under conditions of heavy braking. Evidence from track studies indicates that they can:

- reduce stopping distances, especially on low adhesion surfaces;
- improve lateral stability and ability to keep within lane during braking on curves; and
- improve steering, stability and average braking decelerations in lane-change and braking manoeuvres on ice.

Such evidence encourages the expectation that ABS will reduce accidents, and a study in Germany to estimate the proportion of crashes that could be avoided by ABS concluded that the universal fitting of ABS in Germany could reduce accidents involving heavy damage and/or injuries by 10-15% (Langweider, 1986).

A literature review that was carried out as part of this project found, however, that previous studies of accident data have reached conflicting conclusions about the influence of ABS upon accident risk. These studies indicate that ABS leads to an decrease in fatalities among cyclists, pedestrians and others not in the vehicle of up to a fifth, but an increase in vehicle occupant fatalities by perhaps a quarter - largely as a result of more single vehicle and rollover crashes. The net effect of ABS on fatalities appears to be either zero or, for older vehicles, an increase.

The evidence is inconclusive for non-fatal accidents - the most optimistic indication being that there is a 10 per cent reduction overall, with larger reductions on wet roads than on dry: some types of single-vehicle accidents, especially rollovers, may increase when ABS is fitted.

This evidence has largely come from studies carried out in the United States of America and their applicability to conditions in the United Kingdom is unclear, but they do indicate that the potential benefits of ABS have not been demonstrated in practice to date. One reason could be the technical problems associated with conducting a successful study of this topic. Alternatively, it is possible that ABS has not achieved its potential for accident reduction in practice, and if this were true then there would be a number of possible explanations, including:

- some inherent characteristics of ABS, e.g. the higher decelerations achieved by ABS vehicles may increase the risks of them being struck from behind while braking;
- certain characteristics of the drivers, e.g. do ‘typical’ drivers of ABS-equipped cars know how to use ABS and do they actually use it correctly in an emergency? Support for this doubt comes from demonstrations that training can improve drivers’ performance with ABS;
- the possibility that expectations (perhaps unrealistic) about the performance of ABS may influence driving behaviour, e.g. by leading some drivers to drive with smaller headways and to brake later and more fiercely.

A wide variety of factors may influence the risk of a car being involved in an accident, in addition to whether or not it is equipped with ABS; these include the age, sex and driving experience of the driver, also the distance travelled and the types of road used. Any investigation of the effects of ABS upon accident risk needs to take as many of these factors as possible into account.

This emphasises the need for a *multivariate* analysis that examines simultaneously the influence of several factors on accident risk, including whether the car was equipped with ABS. If an important detail is lacking from a particular accident data set, there must be concern that its effect might mask the actual effects of ABS.

All but one of the studies reported in the literature review are essentially *univariate*, comparing the number of accident-involvements of paired groups of cars, one group being ABS-equipped and the other not. The results of such analyses will be misleading if the groups are not matched overall in other respects, such as mileage and type of drivers (a recent paper (Hertz et al, 1998) has gone some way to address this concern, using a simpler version of the model that will be presented in Section 3). Furthermore, no car sold in large numbers on the British market has followed the pattern found with several US models, and switched directly from ‘ABS not available’ to ‘standard fitting of ABS’. Thus, it would not be feasible to carry out such a paired comparison of accident risk in this country, even if it appeared to be desirable.

The alternative approach adopted for this project was to survey a focussed sample of ‘registered keepers’ of cars, enquiring about their driving experience over the previous year – and in particular about any accidents in which they had been involved. A postal self-completion survey was designed to collect sufficient information to assess the influence of ABS upon accident risk. A large sample was required to obtain details of enough accidents to carry out a multivariate analysis of risk with reasonable prospects of achieving statistically convincing results. The survey was designed to collect a wide range of descriptive information that would allow an assessment of the factors that may be preventing ABS from achieving its potential for accident reduction.

Questionnaires were sent to a sample of ‘registered keepers’ of cars with registration prefix P. This criterion was imposed in order that the selected cars would be modern (so that relatively many ABS-equipped cars would be included), yet the cars would have been in use for sufficiently long to be involved collectively in a reasonably large number of accidents.

Details of the survey are given in Section 2, together with some results from exploratory analyses of the data collected. A series of statistical models has been fitted to the data, to assess the influence of ABS on accident risk and to relate it to the level of knowledge about ABS. The models are described in Section 3 and the results are presented in Section 4. Section 5 then brings together the conclusions that may be drawn from this investigation.

2 The survey of drivers

2.1 Survey design

The aim of the survey was to investigate the influence of ABS on the number of accidents involving equipped cars by, in essence, estimating the ratio of the number of accidents involving *equipped* cars to the number of accidents involving *unequipped* cars, once allowance has been made for any differences in the exposure to risk of the two groups of cars. Consequently, the survey included both equipped and unequipped cars. It was judged that a minimum of one thousand accidents was required to test the influence of ABS properly. The rate of accident-involvements per car per year is low, so a large survey was required: to be confident of collecting details of sufficient accidents, given the possibility of a poor response rate, questionnaires were sent to 80 thousand car owners. 20,973 of them provided useable responses (a 26 per cent response rate) and they provided details of 1,684 accidents. Only 198 of these accidents involved an injured person.

To achieve the project's goals, the accident survey had to collect information about relatively new cars, to maximise the number of ABS-equipped cars included. On the other hand, the cars had to have been in use for some time in order that they had been exposed to a significant level of accident risk. The Vehicle Registration Mark (VRM) system in use in Great Britain at the time of the survey allows a car's 'year of first registration' to be readily identified. Any car with a VRM beginning with P was first registered between August 1996 and July 1997. The survey was carried out in March 1999, by which time any P-registered car would have been in use for 19-30 months. It was judged that this group of cars offered a good compromise between 'newness' and 'exposure'.

Another advantage of this sampling strategy is that the cars would be equipped with modern types of ABS since the cars are modern. Thus, the results should not be affected by the performance of older and possibly less effective equipment.

A computer file was provided by the Driver Vehicle and Licensing Agency (DVLA) which contained the names and addresses of 'registered keepers' of P-registered cars; registered keeper is a technical term which is almost synonymous with 'owner', so the more familiar term 'car owner' is used below. A sample of 80 thousand car owners was extracted. Two groups of car owner which could be identified from the registration details were excluded from the sample:

- any company, since it appeared unlikely that many companies would respond: in addition, company-owned cars often have multiple drivers and the statistical model described in Section 3 could not be applied in these cases;
- any owner whose car was registered under a scheme that assists disabled drivers to buy cars, since it seemed possible that their experience of accidents might not be typical.

The exclusion of company-registered cars does not affect the large number of vehicles that are company-owned but registered with an individual driver. Thus, the sample should include many 'company car drivers'.

In the interval between the receipt of the DVLA data and the dispatch of the questionnaires, some owners had replaced their P-registered cars. The questionnaire requested them to supply details of their current car, not of the car that had been replaced. These 'replacement' cars will have been driven less than average, but otherwise the responses should be typical of equivalent P-registered cars. Nevertheless, the possibility that the P-registered and newer cars might differ will be examined by repeating the analyses of the full data set with data for P-registered cars alone. 12 per cent of respondents had replaced their cars: this included 5 per cent with 'personalised' VRMs that did not allow the age of the replacement car to be determined.

The questionnaire is reproduced in Appendix B. Previous studies (e.g. Maycock et al, 1991) have demonstrated that the expected number of accident-involvements of a particular driver is influenced by factors such as the drivers' age, sex and experience, as well as their annual mileage and the types of road condition under which the journeys are made. The incidence of the reported accidents will have been influenced by these factors, so they were included. The questionnaire asked for:

a details of the current car, such as whether it was equipped with ABS;

b limited personal details of the owner (e.g. age, sex, length of driving career);

c details of car mileage in the past 12 months, such as the distance driven and the proportion of the mileage on motorways;

d details of any accident that occurred in that period;

e details of any ABS training received, also knowledge about ABS such as the appropriate method of braking with ABS.

When the current car had been owned for less than 12 months, (c) and (d) related to the period since the car was acquired. Other research projects have used a longer period of recall, such as 3 years, to increase the number of accidents reported. A 'memory loss' has generally been found, however: respondents tend to remember accidents two or three years earlier less reliably than accidents in the past year. It is possible to compensate for this loss but, in view of the focus of this project on newer cars, it was judged preferable to limit the reporting period to 12 months.

When analysing the accidents reported by any group of respondents, a crucial item of data is the 'exposure' of that group; this is defined as the number of car-years covered by their responses. A car that has been owned for more than one year contributes 1.0 to the exposure of the group, while a car that has been owned for $x<1.0$ years contributes x.

2.2 Exploratory analyses of the data

This section presents an initial exploration of the questionnaire responses. The results will guide the more elaborate statistical analyses presented in later sections, which take account of the multivariate nature of accident risk. The following tables present two sets of data for each group of cars or drivers:

- the percentage of total exposure in car-years (this makes allowance for those cars which had been owned for less than one year);
- the relative accident rate, defined as:

$$\frac{\text{rate of accidents per year of exposure for the group}}{\textit{overall}\text{ rate of accidents per year of exposure}}$$

Two relative accident rates are presented, one for injury accidents and another for all accidents. The smallness of the number of injury accidents reported, however, limits the precision of the relative injury accident rates.

Many questionnaires were not completed fully, and so cannot be used for specific analyses. The minimum requirement is that the period that the car had been owned should be reported, for otherwise the exposure cannot be calculated. The first table includes all questionnaires that meet this requirement, including those that failed to answer the question about whether ABS was fitted. ‘Not knowns’ provide no useful information for the final analysis, so later tables include only those questionnaires that responded to the relevant question(s). For example, Table 2 excludes questionnaires that do not provide the driver’s sex, and it can be seen that this leads to the omission of 4 of the accidents that appeared in Table 1 (2 involved injury).

Table 1 ABS equipment

Is car equipped with ABS?	*Exposure (%)*	*Relative accident rate (injury accidents)*	*Relative accident rate (all accidents)*
Yes	39.9	0.96	0.95
No	43.7	0.99	1.05
Not known	16.4	1.13	1.00
Number of accidents		194	1646

Results for groups with limited exposure will be rather imprecise, and it is possible to calculate nominal standard errors and confidence intervals that would appear to show whether the difference between two rates is real or whether it might have arisen by chance. These estimates would probably be too low, however, since they would not allow for the interacting factors that influence the accident rate, so they could be misleading. The statistical analyses of the effects of ABS that are reported in Section 3 will include confidence intervals that have been calculated appropriately.

It is unfortunate that approximately one sixth of respondents failed to report whether their cars were fitted with ABS. There is no way of inferring the correct response, so the data that they did supply cannot contribute to the investigation of the effects of ABS. These preliminary results suggest that ABS reduces the accident rate by approximately 10 per cent overall and the injury accident rate by approximately 3.5 per cent. More detailed analyses in Section 4 will identify the effects of ABS more reliably, taking account of the influence of other factors on accident rates.

If ABS were uniformly distributed across the sample of cars then much of the need for these more detailed analyses would disappear, but it seems likely that ABS is more frequently fitted to more expensive cars. This is supported by Figure 1, which shows that the fitting rate increases rapidly with engine capacity until about 2.2 litres. Engine capacity could have been used as an explanatory variable in the statistical analyses that are reported in Section 3; however, its value appeared to be limited and another approach was actually used to examine possible differences in the accident risk of car models (see Section 3.1).

Several questions were asked about any ABS training that the driver might have received. In order to introduce this information into the accident analysis, a single data item was generated: ‘Has any ABS training been received?’. The proportion of drivers who reported that they had received training was, however, very low: ABS-trained drivers accounted for only 3.8 per cent of exposure, compared with 12 per cent for those who had not received training. 84 per cent of respondents did not reply to these questions, generally because they had received no driver training since learning to drive. Little more than half of the drivers with ABS training were driving cars equipped with ABS. This level of trained drivers is too low for any analysis of the effects of ABS training on accident risk to succeed. Instead, Section 4.2.2 examines whether a

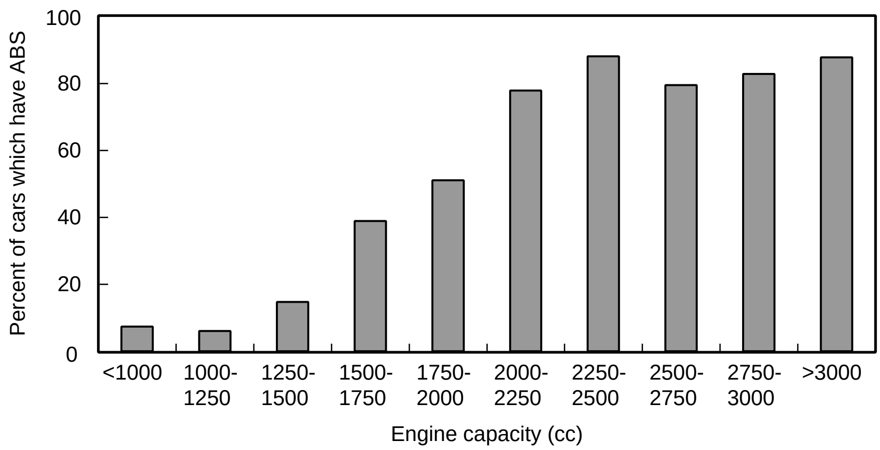

Figure 1 The percentage of cars equipped with ABS, by engine capacity

driver's level of knowledge about ABS may be linked to the level of benefit provided by the equipment.

Table 2 analyses the data by age and sex of driver. The rates for all accidents follow the pattern found in other studies, falling until about the age of 70 and then rising. The male rates for injury accidents follow a different pattern, which may be the result of the relatively small number of injury accidents reported. The proportion of exposure accounted for by the youngest and oldest age groups is lower than would be found in a survey of randomly selected drivers. This is probably caused by the relatively new – and hence expensive – group of cars used to select the sample.

Table 2 Driver details

Age and sex of driver	*Exposure (%)*	*% of cars with ABS*	*Relative accident rate (injury accidents)*	*Relative accident rate (all accidents)*
Men				
17-25	1.4	29	3.69	2.28
26-40	11.6	49	0.81	1.21
41-55	21.5	57	0.82	1.01
56-70	22.2	56	0.82	0.70
71-	8.4	47	0.44	0.79
Not known	0.2	44	0.00	1.22
Women				
17-25	2.1	25	2.72	2.20
26-40	10.6	35	1.63	1.35
41-55	13.6	37	1.23	1.06
56-70	6.8	38	0.69	0.60
71-	1.5	32	0.70	0.86
Not known	0.3	39	2.07	0.72
Number of accidents			192	1642

Drivers of unknown sex are excluded from the table
Cars with unknown ABS status are excluded from the third column

Men are more likely than women to drive ABS-equipped cars, and 41-70 year olds are more likely than the other age groups to drive ABS-equipped cars. Because of these associations between the incidence of ABS and the age and sex of the driver, it was necessary to include age and sex in the statistical models that were developed to analyse the effects of ABS.

Previous research has shown that a driver's accident risk increases with annual mileage, but less than proportionately. The questionnaire asked for the mileage in the particular car in the previous 12 months or, if the car was obtained less than 12 months previously, the mileage in that period. For cars obtained less than 12 months previously, the annual mileage has been estimated as the reported mileage divided by the period of use (in years).

Table 3 shows the results. Men reported driving farther than women, with almost one-fifth driving more than 12,000 miles per year. The relative accident rate broadly follows the expected pattern for all accidents, but not for injury accidents (perhaps because of the relatively small number of injury accidents). Both rates are higher for women than for men in each mileage range. The percentage of cars with ABS rises with mileage.

Table 3 Mileage details

Annual mileage and sex of driver	*Exposure (%)*	*% of cars with ABS*	*Relative accident rate (injury accidents)*	*Relative accident rate (all accidents)*
Men				
0-4000	5.6	45	0.38	0.50
4001-6000	8.7	47	0.30	0.68
6001-8000	10.3	51	1.12	0.86
8001-10000	12.1	52	0.87	0.95
10001-12000	9.9	54	0.59	0.86
12001-20000	12.8	57	1.11	1.13
20001-	6.3	64	1.26	1.51
Women				
0-4000	5.6	31	0.84	0.80
4001-6000	6.4	31	0.58	0.80
6001-8000	5.3	36	1.58	1.08
8001-10000	5.9	36	1.43	1.13
10001-12000	4.6	36	1.71	1.37
12001-20000	4.7	40	1.58	1.50
20001-	1.8	44	2.61	1.71
Number of accidents			190	1607

Drivers of unknown sex or annual mileage are excluded from the table
Cars with unknown ABS status are excluded from the third column

Previous research has shown that a driver's accident risk falls with the length of time that they have been driving, as they acquire experience. The age distribution of Table 2 suggests that this will have limited effect with the present data set, however, since there were relatively few young drivers among the respondents. This is confirmed by the results in Table 4. The analysis also shows that the relative accident risk falls with experience, although the strong correlation between age and experience makes it difficult to know which is more influential. The table also shows that more experienced drivers are more likely to drive ABS-equipped cars, although this is likely to be closely linked to the age-related variation shown in Table 3.

Table 4 Length of driving career

Length (years)	*<2*	*2-2.99*	*3-4.99*	*5-7.49*	*7.5-10*	*>10*
Exposure (%)	0.3	0.5	1.4	2.3	4.2	91.2
% with ABS-equipped cars	19	24	23	29	33	49

The questionnaire asked for the colour of the car. The possible effect of colour on accident risk is poorly understood, and a question was included because of the possibility of a genuine effect that might bias the estimation of the effect of ABS. A wide range of colours was reported, and the responses were grouped as shown in Table 5. This inevitably involved some simplification; the colour 'red' for example will include many different shades. The relative accident rates of the more popular colours (for example, those that account for more than 5 per cent of exposure) should be reasonably precise in view of the number of responses. The 'all accidents' rates range from 0.83 for white cars to 1.28 for black cars, with a large group that includes green, brown, red and blue around the mean value of 1.0.

Table 5 Colour of car

Colour	Exposure (%)	% of cars with ABS	Relative accident rate (injury accidents)	Relative accident rate (all accidents)
Yellow	0.5	45	3.40	1.33
Black	5.3	61	1.31	1.28
Grey	4.4	51	0.97	1.21
Multi-coloured	0.6	67	0.93	1.10
Green	19.2	50	1.14	1.02
Brown	0.4	53	1.43	1.01
Red	24.0	41	1.04	1.00
Blue	26.1	45	0.90	0.98
Silver	11.0	61	0.92	0.91
White	7.8	38	0.62	0.83
Gold	0.9	45	1.24	0.80

Cars of unknown colour are excluded from the table
Cars with unknown ABS status are excluded from the third column

The nature of the influence of colour on accident rate is debatable: it might be physical, linked perhaps to conspicuity, or it might be behavioural (e.g. certain types of driver may tend to choose certain colours). Whatever the underlying cause, these data indicate that certain colours are associated with relatively high or low accident rates, and this will be taken into account during the analyses.

The questionnaire asked for the make and model of the car. If there were sufficient data for certain models, this would have allowed model-specific effects of ABS to be analysed. In practice, given the wide range of new cars on sale in this country, this was not a feasible goal for the survey. The most common car model was found to be the Ford Fiesta, with 5.7 per cent of the exposure and 4.1 per cent (67) accidents; the second most common model was the Ford Escort, with 4.8 per cent of the exposure and 4.7 per cent (77) accidents.

With just these two examples, it is immediately clear that the relative accident rate does vary between models: it is 0.71 for the Fiesta and 0.98 for the Escort. The differences may be explained by factors such as the characteristics of the drivers, but it seems desirable to group models according to their raw accident rates in case there are genuine differences. This was done by defining three groups of models:

‘low-risk’ – the raw relative accident rate (all accidents) ≤ 0.90.

‘medium-risk’ – the raw relative accident rate (all accidents) >0.90 and ≤ 1.08.

‘high-risk’ – the raw relative accident rate (all accidents) >1.08.

The values of 0.90 and 1.08 were selected to yield approximately equal levels of exposure in the three groups: the exact distribution was 33.8 per cent (low), 33.0 per cent (medium) and 33.1 per cent (high).

Table 6 compares the relative accident rates for ABS-equipped and unequipped cars according to their risk group. With the one exception of high-risk cars in injury accidents, rates are lower for ABS-equipped than for unequipped cars. The table also shows that the ABS-equipment rate is relatively low among high-risk cars.

Table 6 Comparison of risk groups

	Relative accident rate (injury accidents)		Relative accident rate (all accidents)		
	Cars with ABS	Cars without ABS	Cars with ABS	Cars without ABS	% of cars with ABS
Low-risk models	0.52	0.72	0.61	0.64	49
Medium-risk models	0.91	1.00	0.98	1.05	54
High-risk models	1.67	1.27	1.34	1.38	40

Cars of unknown ABS status are excluded from the table.

3 The statistical model

3.3 Development of the model

Section 2 mentioned various factors that may, according to the exploratory analyses, influence the likelihood of a car being involved in an accident. The presence or absence of ABS was one of these factors, and its influence will be examined by developing a suitable statistical model.

If a factor that significantly influences accident risk is omitted from an analysis, the omission could well lead to a misleading estimate of the effects of ABS. Table 3 provides a clear illustration. High-mileage cars are involved in relatively many accidents, and relatively many of them are equipped with ABS. Any analysis of the accident data that omitted the mileage data would tend to attribute the relatively high number of accidents to the presence of ABS, not to the effects of high mileage.

Clearly, the same risk applies with other influential factors. Thus, the analyses need to be *multivariate*, examining simultaneously the influence of several factors on accident risk, including whether the car was equipped with ABS.

Numerous analyses of the survey data have been carried out, following a structured approach that is described in Appendix A. The same *dependent* variable was used in each analysis: the number of accidents reported (parallel analyses were made for ‘all accidents’ and ‘injury accidents’). In each analysis, a group of *independent* variables such as age of driver and mileage of car was selected and tested to see how well the variables might - in combination - explain the dependent variable. The overall aim was to identify the selection of independent variables that gave the best model of the dependent variable, then to examine the contribution to this model of the ABS-equipment variable.

Appendix A explains how Generalised Linear Models (GLMs) were fitted to the data to relate the incidence of the reported accidents to a range of potential explanatory factors. This is a well-established technique for investigating the factors which affect accident liability, used for example by Maycock et al (1991). The explanatory factors included details of the driver and the car mileage, also features of the car such as whether it is equipped with ABS. The coefficient associated with the presence of ABS will show how much more or less likely an ABS-equipped car is to be involved in an accident than another car which is in all respects identical *except that it is not equipped with ABS*. Diagnostic statistics will show the strength of the evidence in support of the suggestion that these factors do affect the rate of accident involvement.

One major advantage of this approach is that the question of control groups, which afflicts many studies of this type, is dealt with automatically. The control for the ABS-equipped cars of a particular model in the survey consists of the non-equipped cars of that model in the survey. The two groups of car may not be matched in terms of number, driver and trip characteristics, but the necessary adjustments are made automatically when the GLM is fitted.

The model-building process is basically experimental, guided by logic and the results of previous research. Independent variables are added or removed from the model and the effects on the representation of the number of accidents per year examined. This continues until the most satisfactory model had been identified.

The results of this modelling are presented in Section 4, with the extent of knowledge about ABS being introduced as an explanatory variable in Section 4.2.2. Section 4.3.2 then applies a simpler approach to examine the details of the accidents that were reported for ABS and non-ABS cars.

The ABS-equipment variable was included at all stages of the development of the model. To this were added the principal driver-related factors, as indicated by previous research and the exploratory analyses of Section 2.2:

- sex and age of driver (age groups of 17-25, 26-40, 41-55, 56-70, 71- were used);
- annual mileage (groups of 0-4000, 4001-9000, 9001-12000, 12001-20000, >20000 were used);
- percentage of total mileage driven on motorways (0-25, 25-50, >50);
- percentage of total mileage driven on rural roads (0-25, 25-50, >50).

The ranges were chosen experimentally to optimise the model fit with the fewest categories. It quickly became clear that results for male and female drivers differed, so separate series of models for male and female drivers were developed in parallel. The early results found a similar ABS effect in each of the three younger male age groups, and another effect in the two older male age groups. Consequently, to obtain clearer estimates of the effects of ABS, separate analyses were made for men aged 17-55 and men aged 56-; most of the tables of results presented below treat younger men and older men separately. Equally detailed models were fitted for women but there was no such consistent variation with age and they are treated as a single group in the tables.

Driving experience was added to the models and had the expected effect, but this achieved only a small improvement in the fit of the model – presumably because of the relatively small number of drivers with limited experience. Consequently, driving experience was not retained during the further development of the model, although it was reintroduced experimentally to check that its omission was not affecting the estimated effects of ABS.

Two ‘engineering’ variables were then added to the model for ‘all accidents’: the three risk groups for car models that were defined in Section 2.2 (rather than engine capacity) and three colour groups that were defined on the basis of Table 5. Ideally, the influence of the independent variables already present in the model would be taken into account when forming the risk groups, but this is not feasible because of the number of car models represented in the data. The diagnostic statistics from the model-fitting will indicate whether the effects suggested by Table 6 have been explained by these variables, or whether they remain influential.

The number of colour group is relatively small, so it was possible to conduct a re-analysis. This led to a reallocation of some of the less common colours, and the final groups were:

1 white, silver, yellow, green;

2 red, blue, gold;

3 black, grey, brown, multi-coloured.

The injury accident model did not incorporate the colour groups because of the relatively small number of these accidents.

The resulting models fit the accident data well, and should provide reliable indications of the effects of ABS on accident risk. Many of the questionnaires were returned incomplete, yet only those that supplied all of the requisite data could be used to fit the models. Consequently, the final ‘all accidents’ model used only 67 per cent of the questionnaires and accidents, and the ‘injury accidents’ model used 68 per cent.

3.4 Statistical significance

The modelling results are not precise; they are the most appropriate values that can be estimated from the data, but the *true* values may well differ from the *estimates*. The reason for this lies in the variability in the data, arising from the random nature of accidents and the wide variety of experiences of the respondents. The program that fits the models produces diagnostic statistics that measure the precision of the estimates.

It is important to know the likelihood that an apparent effect is genuine rather than the result of chance. Effects that have a high probability of being genuine are said to be ‘statistically significant’, and the minimum value for significance used in this report is 0.9. The choice of 0.9 as the appropriate minimum is made in the light of the context: if the level were to be set unrealistically high (e.g. 0.99) then it is quite likely that genuine effects would be rejected as having arisen by chance.

Two methods of presentation are used in the following tables to show the likelihood of an apparent effect being genuine. The t-value is the ratio of the estimated coefficient to its standard error, but this can only be interpreted by reference to a standard statistical table. For example, a value of ±1 shows that the probability of the result arising by chance is 0.32, i.e. the odds of the effect being genuine are slightly better than 2-in-3. With a t-value of ±2, the probability is 0.046 and the odds of a genuine effect are better than 19-in-20.

The second method of presentation is the confidence interval: in addition to the t-value, the tables will include 90% confidence intervals, i.e. the range about the central estimate within one can know with 90% confidence that the true value lies. The confidence interval and the t-value are alternative ways of presenting the same information; each has its own advantages, the main advantage of the confidence interval being that it is easily interpreted by the lay reader.

4 Results

4.1 ABS and accident risk

This section will present the principal results from the final models. While the estimates of the driver-related coefficients are of interest, they will not be presented as they do not relate to the engineering issues that are the focus of this project. However, the general agreement with the findings of previous research helps to establish confidence in the integrity of the data that have been collected. Results relating to the colour and risk groups are presented in Section 4.3.1.

One aspect of the driver-related coefficients is worthy of mention. The variable ‘percentage of total mileage driven on motorways’ would be expected to have a negative coefficient: motorways have low rates of accidents per kilometre travelled, so the more that a driver with a certain annual mileage uses motorways, the lower would be the number of accidents expected. This is the pattern found for male drivers. Comparing a man with more than 50 per cent of his total mileage on motorways with a man who drives less than 25 per cent on motorways but is otherwise comparable (i.e. same annual mileage, age etc.), the former has on average 24 per cent fewer accidents per year (90% confidence interval (6, 38)). The reverse is found for women, however; instead of 24 per cent fewer accidents, the analysis shows there to be on average 38 per cent *more* accidents (90% confidence interval (4, 81)). Moreover, when the male data are examined by age, a reduction of 39 per cent (90% confidence interval (22, 53)) is found for drivers up to the age of 55, but an *increase* of 32 per cent (90% confidence interval (-8, 93), i.e. not significant) among older drivers. There is no clear variation with age among women. These results may reflect the relative success of the different groups of driver in coping with the demands of motorway driving, or it could relate to the types of driver who make frequent use of motorways.

Table 7 presents the results from the final models for the effects of ABS on accident risk. The ‘all accidents’ models included the variables described in Section 3.1, namely sex and age of driver, annual mileage, percentage of total mileage on motorways and rural roads, car model risk group and colour group; the ‘injury accidents’ models excluded colour group. A negative result in the table indicates that an ABS-equipped car has *reduced* risk compared to an otherwise identical car that lacks ABS, and a positive effect indicates that it has *increased* risk. Results are presented for younger and older male drivers because the evidence for the effects in the two groups being different is reasonably strong; the age-related differences are much less for females, so only results for all female drivers are presented. The final column presents results from a final series of models where data for male and female drivers were analysed together to examine the overall effects of ABS.

The table shows that there is reasonably strong evidence that ABS reduces the risk of an accident of any severity among younger men by about 16 per cent. There is, however, some evidence that ABS might increase the risk among older men by about 10 per cent, and stronger evidence of an increase among women of about 18 per cent. ABS appears overall to reduce risk by about 3 per cent. The reduction among younger men is statistically significant at the 90% level, and the increase for women approaches significance.

The small number of injury accidents recorded in the survey makes it more difficult to draw conclusions in this case, as demonstrated by the much wider confidence intervals. The results for younger and older men again appear to differ, and this time the size of the increase among older men is sufficient to be statistically significant and to lead to an overall increase for men. There appears to be no effect among women.

There is no way of obtaining more precise estimates of the effects of ABS from the data that have been collected. The limited level of precision arises from the inherent unpredictability of accidents and the consequent variability of data that have been collected. As a rule of thumb, it would be necessary to quadruple the number of responses to halve the t-values and (approximately) the width of the confidence intervals. Section 4.2.2 will examine whether these results can be explained in terms of drivers’ knowledge about ABS and its correct mode of operation.

Section 2.1 mentioned that the drivers in the sample had all owned P-registered cars at the time when the DVLA file

Table 7 Estimated effects of ABS

	Male drivers			*Female drivers*	*All drivers*
Age	*17-55*	*56-*	*All*	*All*	*All*
All accidents					
Effect of ABS	-15.6%	9.9%	-7.4%	17.8%	-2.8%
90% conf interval	(-28%,-1%)	(-11%,36%)	(-18%, 5%)	(-1%, 40%)	(-12%, 7%)
t-value	-1.81	0.73	-1.01	1.54	-0.47
Injury accidents					
Effect of ABS	-13.3%	150%	25.8%	-4.7%	3.3%
90% conf interval	(-47%,41%)	(25%, 403%)	(-15%, 85%)	(-1%, 40%)	(-23%, 39%)
t-value	-0 .48	2.17	0.98	-0.17	0.18

was prepared. Almost one-eighth of cars had been replaced by the time that the questionnaires were dispatched. To see whether the analyses that produced Table 7 might have been influenced by the inclusion of these generally newer cars, they were repeated with data specifically for P-registered cars. The estimated coefficients were scarcely changed but their precision was reduced slightly because of the smaller numbers. Thus, it is appropriate to use the full data set in the subsequent analyses.

4.2 Knowledge about ABS

4.2.1 The extent of knowledge about ABS

No research into drivers' knowledge and use of ABS appears to have been conducted to date in the United Kingdom. A number of surveys elsewhere have demonstrated that drivers are unaware of the correct technique for activating the system in an emergency braking situation (Williams and Wells, 1994; Hans, 1995). They may be startled by the feedback, causing them to remove pressure from the brake pedal in an emergency (Collard and Mortimer, 1998).

To achieve the full safety benefits of ABS, the driver needs to:

- Use the correct braking technique,

  For ABS to work properly the driver must apply sufficient force to the brake pedal to activate the system and then maintain sufficient force to sustain its activation. Reducing or removing pressure from the brake pedal will disengage the system, as will cadence or pulse braking – techniques that are recommended during advanced driver training in non-ABS vehicles to reduce wheel lock and help maintain steering control. For the purposes of questionnaire surveys, such techniques are commonly referred to as 'pumping' the brakes.

  Although drivers must use the correct technique if ABS is to operate properly, it does not necessarily follow that they need to know what this technique is. For some drivers at least, the natural reaction in an emergency in any car will be to stamp hard on the brakes, irrespective of what they may have been told about skid avoidance in non-ABS cars.

- Not to be startled by the activation of ABS

  When activated, many systems are accompanied by unfamiliar and potentially unnerving feedback in the form of vibration or pulsation from the brake pedal and car body, and audible feedback from the brakes themselves. Consequently, some drivers may be startled into reducing or removing pressure from the brake pedal altogether, thus disengaging the system. Knowledge of what to expect when the system activates, practice with ABS and routine experience of its coming into operation are likely to help to reduce any startle effect.

- Understand the performance characteristics of vehicles fitted with ABS

  A main potential benefit of ABS is to allow the driver to maintain steering control during emergency braking. Being aware of this might be expected to increase the probability of a driver making use of the facility to steer in an emergency. It also seems desirable that drivers should be aware of the limitations of ABS, including the facts that it does not allow effective steering and braking in *every* situation, and it may not have much effect on stopping distances on good, dry surfaces - and can even increase stopping distances on loose surfaces.

The survey was designed to gauge driver's knowledge about ABS as a possible explanation of any observed differences in accident rates between drivers of cars with and without ABS.

Three questions were included to assess drivers' knowledge of ABS:

Question 33 – How do you think ABS should be used?

Pump the brakes fast in an emergency

Keep your foot hard on the brakes in an emergency

Same as ordinary brakes

Don't know

The correct answer is 'Keep your foot hard on the brakes in an emergency'.

Question 34 – How do you think stopping distances during emergency braking differ between cars with and without ABS, on the following road conditions?

(a) dry roads

(b) wet roads

(c) icy roads

(d) loose surfaces, e.g. snow/gravel

Six alternatives were given, ranging from 'ABS much shorter' to 'ABS much longer' and 'Don't know'. The correct answers, based on the available research evidence, are:

(a) slightly shorter or no different
(b) slightly shorter
(c) much shorter or slightly shorter
(d) slightly longer

Question 35 – Compared with non-ABS fitted cars, how effective do you think ABS fitted cars are at allowing you to steer while braking in an emergency, on the following road conditions?

Conditions (a)-(d) from question 34 were repeated, and six alternative answers ranging from 'ABS much more effective' to 'ABS much less effective' and 'Don't know'. The correct answers are:

(a) much more effective *or* slightly more effective
(b) much more effective
(c) much more effective
(d) slightly more effective

Questions 34 and 35 each had four parts to answer, i.e. one answer per condition. A score was calculated for each part by awarding one mark per correct answer – so the maximum score was four.

The results for Questions 33-35 are summarised in Tables 8 and 9 for four groups of driver; the percentages in each column add to 100. The analyses are confined to the responses from drivers who knew whether or not their car was fitted with ABS.

Table 8 Distribution of responses to Question 33

Response	Male drivers: Cars with ABS	Male drivers: Cars without ABS	Female drivers: Cars with ABS	Female drivers: Cars without ABS
'Pump the brakes'	4%	3%	10%	7%
'Hard on the brakes'	49%	32%	34%	21%
'Same as ordinary'	45%	51%	48%	44%
'Don't know'	2%	14%	8%	28%

A few questionnaires had multiple responses, these have been excluded
The second is the correct response for ABS

Table 9 Distribution of responses to Questions 34 and 35

	Male drivers: Cars with ABS	Male drivers: Cars without ABS	Female drivers: Cars with ABS	Female drivers: Cars without ABS
Score for question 34				
0	10%	20%	19%	29%
1	35%	29%	39%	30%
2	34%	33%	26%	25%
3	20%	18%	16%	15%
4	1%	0%	0%	0%
mean	1.66	1.50	1.39	1.28
standard deviation	0.94	1.02	0.98	1.05
Score for question 35				
0	10%	22%	21%	32%
1	16%	13%	16%	12%
2	28%	23%	25%	21%
3	42%	38%	35%	33%
4	4%	4%	3%	3%
mean	2.13	1.89	1.84	1.64
standard deviation	1.06	1.24	1.21	1.30

The responses show a limited level of knowledge about the operation of ABS and its effects. Drivers of ABS cars tend to have slightly more knowledge of ABS than other drivers. It is interesting to find that drivers are better informed about the ability to steer during braking with ABS (Question 35) than about its effects on stopping distances (Question 34). This arises principally from an increase in each of the four groups in the number of drivers who scored 3 and a reduction in the number who scored 1. A more detailed analysis by age among men shows that younger men (up to 55) tend to be more knowledgeable about ABS than older men (over 55) – who tend in turn to be more knowledgeable about ABS than women.

There is a poor correlation between the responses to the two questions, so they appear to be testing different aspects of drivers' knowledge about ABS. Table 10 shows the correlation coefficients by sex and whether or not the cars were equipped with ABS. The relatively high coefficients for drivers of cars not equipped with ABS arise in part because of the numbers of drivers with zero scores to both questions: 23 per cent in the case of women.

Table 10 Correlation coefficients for the scores for Questions 34 and 35

	Male drivers	Female drivers
Cars with ABS	0.10	0.28
Cars without ABS	0.33	0.40

4.2.2 The influence of knowledge about ABS

One possible explanation of the results of Table 7 could be that younger men are relatively knowledgeable about ABS and are benefiting from the technology, whereas women and older men are less knowledgeable and may be using the equipment incorrectly. In order to test whether the estimated effects of ABS are linked to the driver's level of knowledge about ABS, the response was introduced – for each question in turn - as an independent variable into the modelling. Because of the relative complexity of the responses, the full model was only used for a final check: the colour and risk group variables were omitted for the remainder of the modelling.

Table 11 relates accident risk to drivers' responses to Question 33. The results are presented using the format of Table 7, except that the t-value appears in brackets after the estimated effect; the 90% confidence interval is immediately below. The basis of comparison in each case is the set of drivers of non-ABS cars, irrespective of how they responded to this question. Thus, the first row compares the accident risk of drivers of ABS cars who thought they should 'pump the brakes' to the risk of matching drivers of non-ABS cars: negative values indicate reduced risk and positive values increased risk.

Table 11 Estimated effects of ABS related to the response to Question 33

Age	Male drivers: 17-55	Male drivers: 56-	Male drivers: All	Female drivers: all
'Pump the brakes'	-12% (-0.38) (-48%, 51%)	1% (0.02) (-50%,102%)	-6% (-0.23) (-38%, 46%)	44% (1.52) (-3%, 114%)
'Hard on the brakes'	-17% (-1.63) (-32%, 0%)	-4% (-0.29) (-27%, 25%)	-13% (-1.48) (-25%, 2%)	17% (0.96) (-11%, 52%)
'Same as ordinary'	-19% (-1.74) (-34%, -1%)	-3% (-0.20) (-26%, 26%)	-14% (-1.53) (-26%, 1%)	9% (0.58) (-14%, 37%)
'Don't know'	3% (0.06) (-55%,137%)	233% (3.45) (88%,493%)	97% (2.40) (24%,215%)	9% (0.27) (-36%, 86%)

The small number of questionnaires with multiple responses has been excluded
The second is the correct response

The results relate to ‘all accidents’: results are not presented for injury accidents because of their low precision.

There is no evidence to suggest that male drivers who know the correct braking technique with ABS fare any worse than those who (wrongly) think that they should brake as normal, but some suggestion that those who pump the brakes do fare worse. Those men who have no opinion appear to fare worst of all. There are weak indications that female drivers who know the correct ABS braking technique fare worse than those who (wrongly) think that they should brake as normal.

It should be remembered that a driver’s natural reaction in an emergency may well be to stamp hard on the brakes, irrespective of whether their car has ABS, so some respondents with ABS cars could well react correctly in an emergency in spite of answering the question wrongly.

The same analytical approach was applied initially to relate the effects of ABS to the scores for Questions 34 and 35; in particular, the basis of comparison in each case is the set of drivers of non-ABS cars, irrespective of how they responded to the particular question. The results are presented in Table 12.

The table shows fairly clear evidence, at least among men, that greater knowledge of ABS as indicated by higher scores is linked to greater benefits from the technology. No knowledge (score=0) is associated with a higher accident rate than in a non-ABS car, but knowledge (score>0) is generally associated with a lower rate. The results begin to suggest that ignorance about the effects of ABS can lead to faulty braking and increased risk, while knowledge allows the potential benefits to be realised.

To provide more precise results, Table 13 shows the results of a simple grouping of the scores.

The results shown in the table are still somewhat unclear, and the data have been reanalysed to give a clearer picture. A linear model is fitted, which assumes that effect of ABS among a particular group of drivers can be expressed as:

$$\text{effect of ABS for driver with score } s = A + B.s \qquad (1)$$

where A and B are coefficients to be estimated: A is the average effect for drivers with score=0 and B is the average change in the effect of ABS when the score increases by 1. The estimation of these coefficients automatically takes account of the number of drivers with each score.

To illustrate this model with one example from Table 14 (below), female drivers of ABS cars who score 0 for Question 34 have on average 15 per cent more accidents than female drivers of non-ABS cars. Those who score 1 have on average 15-9=6 per cent more accidents, while those who score 2 have on average 15-9-9= -3 per cent more (i.e. 3 per cent fewer).

An objection to this simplifying assumption could only arise if there was reason to think that the benefits of moving from score 0 to score 1, say, might differ from the benefits of moving from score 2 to score 3. There are no theoretical grounds for an objection and the (admittedly imprecise) results of Tables 12 and 13 do not indicate any such non-linearity. Table 14 presents the estimated coefficients from this reanalysis. To be consistent with the previous results, a negative value of A indicates a beneficial effect and a negative value of B indicates that an increasing score (i.e. greater knowledge about ABS) is

Table 12 Estimated effects of ABS related to scores for Questions 34 and 35

	Male drivers			*Female drivers*
Age	*17-55*	*56-*	*All*	*all*
Score for question 34				
0	1% (0.03) (-31%, 47%)	25% (0.99) (-14%,83%)	11% (0.62) (-15%, 44%)	43% (1.90) (5%, 94%)
1	-11% (-0.94) (-27%, 9%)	10% (0.61) (-16%,45%)	-4% (-0.38) (-18%, 13%)	11% (0.75) (-12%, 42%)
2	-25% (-2.26) (-39%, -7%)	-15% (-0.88) (-37%,15%)	-21% (-2.32) (-34%, -7%)	2% (0.12) (-24%, 36%)
3	-31% (-2.27) (-48%, -10%)	-6% (-0.31) (-33%,32%)	-23% (-2.03) (-38%, -5%)	13% (0.57) (-21%, 61%)
4	-27% (-0.45) (-77%, 134%)	-99% (-0.63) (-100%,*)	-45% (-0.84) (-83%, 76%)	-97% (-0.56) (-100%, *)
Score for question 35				
0	30% (1.41) (-4%, 78%)	38% (1.41) (-5%, 101%)	32% (1.92) (4%,68%)	26% (1.31) (-6%,70%)
1	-44% (-2.89) (-60%, -22%)	-5% (-0.21) (-34%, 38%)	-31% (-2.49) (-46%,-12%)	11% (0.47) (-22%,58%)
2	-5% (-0.39) (-23%, 18%)	-21% (-1.17) (-43%, 10%)	-10% (-0.96) (-25%, 8%)	30% (1.62) (-1%,70%)
3	-28% (-2.74) (-41%, -12%)	10% (0.62) (-15%, 42%)	-16% (-1.79) (-28%, -1%)	-4% (-0.24) (-26%, 26%)
4	-27% (-0.95) (-59%, 27%)	-59% (-1.28) (-87%, 30%)	-37% (-1.50) (-62%, 5%)	18% (0.37) (-43%,146%)

** Denotes that a meaningful value could not be calculated*

Table 13 Estimated effects of ABS related to grouped scores for Questions 34 and 35

	Male drivers			*Female drivers*
Age	*17-55*	*56-*	*All*	*all*
Score for question 34				
0	1% (0.03) (-42%, 75%)	26% (0.99) (-14%, 85%)	10% (0.62) (-15%, 42%)	42% (1.90) (5%, 93%)
1-2	-18% (-2.02) (-30%, -4%)	-2% (-0.13) (-24%, 27%)	-13% (-1.67) (-24%, -0%)	8% (0.61) (-12%, 33%)
3-4	-31% (-2.30) (-47%, -10%)	-9% (-0.45) (-36%, 29%)	-24% (-2.13) (-39%, -6%)	11% (0.50) (-21%, 57%)
Score for question 35				
0	30% (1.41) (-4%, 77%)	38% (1.40) (-6%, 102%)	32% (1.92) (4%, 68%)	26% (1.31) (-6%, 69%)
1-2	-17% (-1.86) (-30%, -2%)	-15% (-0.98) (-35%, 12%)	-18% (-2.07) (-30%, -4%)	23% (1.48) (-2%, 55%)
3-4	-28% (-2.82) (-41%, -13%)	5% (0.32) (-18%, 35%)	-17% (-2.06) (-29%, -4%)	-2% (-0.13) (-24%, 27%)

Table 14 Estimated coefficients for Questions 34 and 35

	Male drivers			*Female drivers*
Age	*17-55*	*56-*	*All*	*All*
Question 34				
A	-18% (-2.21) (-30%, -5%)	3% (0.23) (-16%, 27%)	-11% (-1.60) (-21%, 0%)	15% (1.34) (-3%, 37%)
B	-15% (-3.39) (-21%, -8%)	-12% (-2.09) (-21%, -3%)	-14% (-3.87) (-19%, -8%)	-9% (-1.89) (-17%, -1%)
Question 35				
A	-19% (-2.32) (-30%, -6%)	-0% (-0.01) (-19%, 23%)	-12% (-1.81) (-22%, -1%)	15% (1.31) (-3%, 36%)
B	-6% (-1.42) (-12%, 1%)	0% (0.08) (-8%, 10%)	-3% (-0.98) (-8%, 2%)	-3% (-0.77) (-9%, 4%)

associated with greater benefit or reduced disbenefit.

The confidence intervals are generally tighter than in Table 13, so a clearer picture emerges. The estimates of A for the two questions agree well, but the responses to increasing scores differ. This difference is not surprising, in view of the lack of correlation between the two sets of scores (Table 10).

A broadly similar pattern emerges when the analysis is repeated for injury accidents, although the increase among older men from Table 7 is confirmed. The confidence intervals are much wider, however, so the picture is less clear than in Table 14.

With one exception, Table 14 indicates that drivers with more knowledge of ABS derive greater benefit from the equipment (i.e. B is negative in all but one case). It does not necessarily follow, however, that the extra benefit is the result of the extra knowledge; the two questions could actually be assessing something else about drivers. In other words, drivers who are well informed about ABS may also tend to have other characteristics that tend to reduce their accident risk. For example, they may be knowledgeable about and interested in driving safely, and this might be the cause of the lower accident risk. This can be tested by fitting ‘parallel’ linear models for the accident risks of drivers of ABS cars and of non-ABS cars. If the drivers of non-ABS cars have similar accident risks irrespective of their score (i.e. B is approximately 0) then the benefits associated in Table 14 with higher scores can legitimately be attributed to greater knowledge about ABS.

The results of this test are shown in Table 15, and they differ markedly for Questions 34 and 35. For Question 35 (which asks how effectively ABS allows the driver to steer while braking), introducing the split between drivers of cars with and without ABS improves the fit of the model significantly in each case. Moreover, the results in the table have the expected pattern, i.e. the effect is very slight among drivers of cars without ABS (shown by small values of B) but increases with the score among drivers of cars with ABS (shown by negative values of B). By contrast, with Question 34 (which asks about the effect of ABS on stopping distances), introducing the split has no effect upon the fit of the model. The results in the table for this question have a counterintuitive pattern, i.e. the effect of increased knowledge among drivers of cars without ABS appears to be at least as great as the effect among drivers of cars with ABS.

This analysis suggests strongly that Question 35 is assessing drivers’ knowledge about ABS rather effectively,

Table 15 Estimates of B for drivers of cars with and without ABS

	Male drivers			Female drivers
Age	*17-55*	*56-*	*All*	*All*
Question 34				
Cars without ABS	-17% (-2.91) (-25%, -8%)	-12% (-1.39) (-8%, 2%)	-14% (-3.00) (-21%, -7%)	-10% (-1.57) (-19%, 1%)
Cars with ABS	-12% (-1.37) (-1%, -25%)	-12% (-1.09) (-28%, 7%)	-13% (-1.81) (-23%, -1%)	-9% (-0.84) (-23%, 9%)
Question 35				
Cars without ABS	-3% (-0.49) (-11%, 6%)	7% (0.90) (-5%, 21%)	1% (0.27) (-6%, 9%)	-1% (-0.23) (-9%, 7%)
Cars with ABS	-9% (-1.22) (-21%, 4%)	-6% (-1.22) (-21%, 12%)	-8% (-1.33) (-17%, 2%)	-6% (-0.63) (-18%, 8%)

and is a more discriminating test of drivers' effective knowledge about ABS than Question 34. The knowledge tested by Question 34 may be associated with general aspects of braking performance - which is as valuable to drivers of non-ABS cars as to drivers of ABS cars. Alternatively, it may be associated with other factors that reduce a driver's accident liability. The results do not show that knowledge of the effect of ABS on stopping distances is not beneficial to drivers of ABS cars, rather that such knowledge (or something associated with it) also tends to benefit drivers of non-ABS cars.

In contrast, knowledge that ABS allows the driver to steer while braking does appear to be of special value to drivers of ABS cars, since it has little effect on the accident liability of drivers of non-ABS cars. This knowledge presumably increases the likelihood that drivers of ABS cars will use this characteristic of ABS effectively, while not encouraging unrealistic expectations of what the equipment can achieve.

Attention is now focussed on the relation between the effect of ABS and Question 35, as the more reliable test of drivers' knowledge about ABS. Table 13 indicated that drivers scoring 0 were at increased risk in ABS cars, but do the linear models confirm this? Table 16 shows the relative risk of these drivers, calculated from the coefficient A from model (1).

Figure 2 illustrates the relationship between the score for Question 35 and the relative risk that is implied by the coefficients in Tables 15 and 16. The figure has been prepared from the best estimates of the coefficients and does not indicate the uncertainty involved.

Although the results are not exact, since the issue studied is rather detailed, the degree of parallelism of the fitted lines suggests that a real effect has been detected. It appears that younger men benefit from ABS with any score over 0, but among women and particularly older men even knowledgeable drivers tend to be at greater risk in ABS cars.

Finally, the risk group variable was added to the model that produced Table 14, to check whether the estimates might have been biased by omitting this variable. The changes in the estimated coefficients were only slight in proportion to the standard errors. Overall, the omission of the risk group variable had only a minor effect on the results and did not affect the conclusions that were reached.

4.2.3 Summary

Knowledge that ABS allows the driver to steer while braking does appear to be of special value to drivers of ABS cars in reducing their accident liability. Presumably it increases the likelihood that they will use this characteristic of ABS effectively, while not encouraging unrealistic expectations of what the equipment can achieve.

Drivers who know about the effects of ABS on stopping distances also tend to have reduced accident liability – irrespective of whether their cars are actually equipped with ABS. Such knowledge may be associated with other beneficial knowledge about braking performance – knowledge that also tends to benefit drivers of non-ABS cars. Alternatively, it may be associated with other factors that reduce a driver's accident liability. Thus, it is not clear whether knowledge of the effect of ABS on stopping distances is of itself beneficial to drivers of ABS cars.

Table 9 has shown that the level of knowledge about ABS indicated by the scores for Questions 34 and 35 varies through the driving population. These variations explain, at least in part, the differences between the results in Table 7 for the various groups of drivers. Nonetheless, it still appears that only one group derives benefits from the technology: younger men (up to 55 years old). Among the

Table 16 Relative risk of drivers of cars with ABS with score 0 for Question 35

	Male drivers			Female drivers
Age	*17-55*	*56-*	*All*	*All*
Relative risk with score 0	1% (0.04) (-35%, 56%)	45% (1.13) (-16%, 152%)	17% (0.77) (-17%, 65%)	32% (1.12) (-12%, 99%)

A positive relative risk indicates greater risk in an ABS car than a non-ABS car

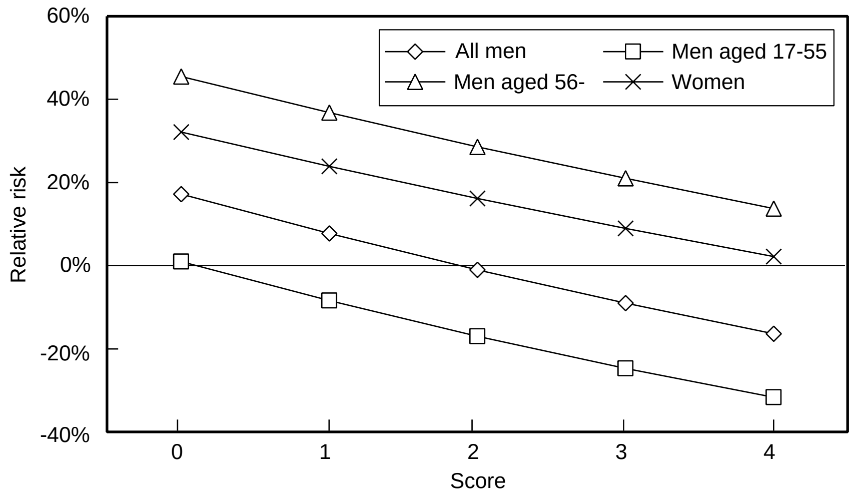

Figure 2 Relative risk as a function of the score for Question 35

other groups, only the most knowledgeable of women do not suffer a disbenefit from ABS. The group of older men appears to suffer a disbenefit from ABS, even the most knowledgeable.

Various hypotheses can be advanced to explain these differences. For example, it could be that younger men tend to be physically better able to exert the necessary force on the brake pedal, or that they respond better to the feedback provided by ABS, or that they are more likely to perceive an emergency in sufficient time to be able to benefit from the performance of ABS. Research into these differences is needed in order to allow all groups of driver to benefit from ABS.

4.3 Supplementary results

The following sections bring together various results from the survey that are secondary to the principal questions concerning the effectiveness of ABS.

4.3.1 Colour and risk group

The full models that produced Table 7 included a number of variables, but only the main results have been presented so far. Table 17 now presents results from the full models that relate to the risk groups for car models and the colour groups. The same form of presentation is used, but the basis for the comparison is now the ‘low-risk’ group of models and colour group 1. Thus, cars in the medium risk group with male drivers have about 73 per cent more accidents than those in the low risk group, rising to 112 per cent for cars in the high risk group. The model effects are almost as strong with injury accidents as with all accidents. The colour effects are weaker than the risk group effects, and the effects for men and women appear to differ.

4.3.2 Accident details

The questionnaire asked for details of accidents in which the car owner had been involved in the previous year. This section analyses the responses to examine whether the accidents involving ABS cars and non-ABS cars may differ.

Table 17 Estimated variation of accident risk with risk groups of car models and colour

	Male drivers	*Female drivers*
All accidents		
‘Medium-risk’ group	73% (5.4) (46%, 104%)	63% (3.3) (27%, 108%)
‘High-risk’ group	112% (7.6) (80%, 150%)	137% (6.3) (89%, 197%)
Colour group 2	11% (1.33) (-3%, 27%)	-11% (-1.02) (-25%, 7%)
Colour group 3	25% (1.92) (3%, 52%)	-1% (-0.09) (-26%, 31%)
Injury accidents		
‘Medium-risk’ group	21% (0.62) (-28%, 103%)	81% (1.57) (-3%, 240%)
‘High-risk’ group	108% (2.54) (29%, 236%)	115% (2.12) (19%, 290%)

The colour variable was not included in the injury accident model

Only simple analyses are presented, as it is not possible to apply the detailed statistical techniques of Section 3 to these data. Consequently, differences between the results for ABS and non-ABS cars could well be explained by differences between the two samples of cars and drivers, rather than any effect of ABS. For example, Table 18 examines the times when the accidents occurred and finds relatively many accidents involving ABS cars between 6pm and midnight, compared with non-ABS cars. It would be difficult, however, to explain this result in terms of the operation of ABS: it seems far more likely to be a consequence of the relative number of trips made by the two groups of cars at that time of day.

Consequently, it is not possible to assess any differences reliably and to infer statistically whether they might represent a significant effect of ABS. The comparisons may indicate issues that could be studied in future research, but definite conclusions cannot be drawn at present.

The basic results presented in the following tables are the number of accidents reported per 100 driver-years. There

Table 18 Accident rates by time of day and lighting condition

Time of day	*6.00-12.00*	*12.00-18.00*	*18.00-0.00*	*0.00-6.00*
Rate for cars with ABS	3.12	3.86	1.44	0.11
Rate for cars without ABS	3.43	4.31	1.48	0.14
ABS%	-9%	-10%	-2%	-20%
Lighting condition	*daylight*	*twilight*	*darkness*	
Rate for cars with ABS	6.59	0.53	1.41	
Rate for cars without ABS	7.41	0.71	1.26	
ABS%	-11%	-25%	12%	

were 8.55 accidents reported per 100 driver-years for ABS cars, compared with 9.40 for non-ABS cars. When particular groups of accident are studied below, the rates for ABS and non-ABS cars will be compared by calculating:

$$\text{ABS\%} = \frac{\text{rate for ABS cars}}{\text{rate for non-ABS cars}} - 1.0\ (\%)$$

The figure for all accidents is (8.55/9.40)-1 = -9%, so overall ABS cars have 9 per cent fewer accidents than non-ABS cars. The following tables will check whether this percentage varies between groups of accidents, for variations might indicate that ABS is more or less effective in specific circumstances. A figure less than -9% might indicate that ABS is *more* effective than usual, while a greater figure might indicate that ABS is *less* effective.

Table 18 combines two comparisons, by Time of day and by Lighting condition. The results for Lighting condition raise the possibility that ABS may be more effective than usual in the twilight, but less effective in the darkness. It is difficult to think of a plausible explanation, however, and this may well be the result of differences between the trip patterns of the two samples of cars.

Table 19 compares accident rates by Weather and Road surface conditions. Earlier studies have found that ABS is more effective on wet roads than on dry. This is consistent with the result that cars with ABS are involved in relatively few accidents in the rain, but not with the results for wet and dry roads.

Table 19 Accident rates by weather and road surface conditions

Weather conditions	*Dry-sun*	*Dry-cloud*	*Rain*	*Snow*	*Fog/mist*
Rate for cars with ABS	2.48	3.96	1.25	0.08	0.23
Rate for cars without ABS	2.70	4.29	1.51	0.14	0.29
ABS%	-8%	-8%	-18%	-40%	-19%
Road surface conditions	*Dry*	*Wet*	*Icy*	*Snowy*	
Rate for cars with ABS	6.04	2.06	0.30	0.04	
Rate for cars without ABS	6.81	2.00	0.35	0.05	
ABS%	-11%	3%	-14%	-18%	

Table 20 compares accident rates by Road type and Traffic condition. The fact that cars with ABS appear to be involved in relatively many accidents on motorways could well be explained by the use made of these cars. Table 3 showed that high-mileage cars are more likely than low-mileage cars to have ABS, so cars with ABS probably drive a disproportionately high proportion of the total mileage on motorways.

Table 20 Accident rates by road type and traffic condition

Road type	*Motorway*	*Urban road*	*Rural road*
Rate for cars with ABS	0.82	5.51	1.93
Rate for cars without ABS	0.58	6.53	2.15
ABS%	43%	-16%	-10%
Traffic condition	*No traffic*	*Light*	*Heavy*
Rate for cars with ABS	1.97	3.95	2.51
Rate for cars without ABS	2.25	4.29	2.76
ABS%	-12%	-8%	-9%

Drivers were asked to report their speed before the accident, and Table 21 shows the results. The high ABS% for speeds over 60mph could well be linked with the relatively high number of accidents on motorways involving ABS cars that was shown in Table 20.

Table 21 Accident rates by pre-accident speed

Speed (mph)	*Stationary*	*<20*	*20-40*	*40-60*	*60-70*	*>70*
Rate for cars with ABS	2.78	3.71	1.30	0.40	0.26	0.05
Rate for cars without ABS	3.39	3.39	1.88	0.58	0.13	0.04
ABS%	-18%	10%	-31%	-31%	108%	46%

Drivers were asked to summarise the accident by asking them to choose the most appropriate from a list of eleven descriptions. More than one-tenth failed to do so; Table 22 analyses the responses of those who did, including only the seven types with rates exceeding 0.1 accidents per 100 driver-years. The final two rows group the data to show whether the driver's role in the accident was active or passive.

Table 22 Accident rates by type of accident

Summary description of accident	*Rate for cars with ABS*	*Rate for cars with-out ABS*	*ABS%*
Your[1] car hit the rear of another vehicle	1.23	1.43	-13%
Your car hit the side of another vehicle	0.89	0.85	5%
Another vehicle hit the rear of your car	2.14	2.51	-15%
Another vehicle hit the side of your car	1.84	2.10	-13%
Your car was hit by an oncoming vehicle in your lane	0.27	0.36	-24%
Your car hit a road side object	0.66	0.73	-9%
Your car left the road without hitting any other object	0.05	0.14	-60%
Your car hit another vehicle or object (*active* role)	2.99	3.19	-6%
Another vehicle hit your car (*passive* role)	4.25	4.98	-15%

[1] *'You' refers to the respondent*

Thus, relative to the average value of ABS% of –9%, the accident-involvement of ABS cars is slightly more likely to be in the *active* role than non-ABS cars, and slightly less likely to be in the *passive* role. Other studies have found the opposite, and this may well be a case where differences between the ABS and non-ABS samples of drivers and cars have influenced the comparison.

Where the accident involved an impact with another vehicle, drivers were asked to categorise that vehicle and to indicate whether it was moving. The results are summarised in Table 23.

Table 23 Accident rates by details of the other vehicle

Vehicle type	*Car*	*Van/ lorry*	*Bus/ coach*	*Motor- cycle*	*Other*
Rate for cars with ABS	5.45	1.16	0.10	0.10	0.33
Rate for cars without ABS	6.36	1.03	0.13	0.09	0.41
ABS%	-14%	14%	-23%	10%	-20%
Other vehicle's movement	*Par- ked*	*Mov- ing*	*Stati- onary*		
Rate for cars with ABS	0.52	5.45	1.08		
Rate for cars without ABS	0.54	6.08	1.30		
ABS%	-3%	-10%	-17%		

Thus, relative to the average value of ABS% of –9%, ABS cars are slightly less likely than non-ABS cars to collide with other cars, but more likely to collide with vans, lorries and motorcycles. They are less likely to collide with stationary vehicles, but more likely to collide with parked vehicles.

Drivers were also asked whether they had attempted any avoiding action, and Table 24 analyses the responses of those who answered that they had. The results suggest that drivers of ABS cars may be more likely to take avoiding action, in particular 'positive' action such as acceleration and swerving. The increase in swerving as an avoiding action is to be expected since improved control during braking is one of the recognised benefits of ABS. The increase in acceleration is more difficult to explain, and may be related to drivers' beliefs about the improved control and stability provided by ABS.

Table 24 Accident rates by attempted avoiding action

	None/n.k.	*Accelerated*	*Braked*	*Swerved*
Rate for cars with ABS	5.00	0.29	1.42	0.42
Rate for cars without ABS	5.68	0.14	1.89	0.31
ABS%	-12%	109%	-25%	36%

The results of Table 24 may help to explain the results in Table 23 for stationary and parked vehicles. When drivers of ABS cars swerve to avoid stationary vehicles ahead, they may sometimes collide with a parked vehicle.

Finally, drivers were asked to supply details of any injuries sustained during the accident, and this information has been used in earlier sections to identify injury accidents. As was anticipated when planning the survey, the number of casualties was relatively small: 198 in total. This means that the casualty rates per 100 driver-years are too low to compare usefully. The injuries were predominantly minor: 77% were slight cuts and bruises, 7% were serious cuts and bruises and 17% were more serious (one death was reported, a pedestrian or pedal cyclist who was in collision with an ABS car).

4.3.3 Reported experience of skidding

One of the benefits expected from ABS is to reduce the risk of skidding. The survey sought drivers' experiences of skidding at different speeds and on different road surfaces. Table 25 shows that drivers who reported that their car was fitted with ABS were significantly less likely to report that they had experienced skidding for all specified road surfaces when travelling at both low and high speeds, compared with drivers of non-ABS cars. The difference in responses is particularly noticeable for the category of low speed and icy road conditions.

Table 25 The percentage of drivers who reported having skidded, by road condition

Speed/road surface	*Car with ABS*	*Car without ABS*	*Difference*
High speed/icy	6%	9%	-3%
High speed/wet	9%	15%	-6%
High speed/dry	6%	10%	-4%
Low speed/icy	22%	36%	-14%
Low speed/wet	13%	20%	-7%
Low speed/dry	6%	7%	1%

4.3.4 ABS operation in near misses and accidents

Drivers of cars with ABS were asked if they were aware of the system coming into operation during near misses or actual accidents. 30 per cent of ABS drivers reported that they had been aware of the operation of ABS in a near miss. Of all ABS drivers who reported having been involved in an actual accident, 8 per cent said that they had been aware of ABS in operation during the accident.

ABS drivers were also asked if ABS has worked in an unexpected way when driving at high and low speed. Only 2 per cent said that there had been occasions when ABS had not worked as they had expected when driving at high speed, while 4 per cent made the same response with respect to low speed.

5 Conclusions

Antilock Braking Systems (ABS) are fitted to many new cars with the aim of preventing the brakes from locking under conditions of heavy braking, thereby avoiding accidents or mitigating their severity. Almost one half of P-registered cars surveyed during this project were equipped with ABS, so conditions are now favourable for assessing the effectiveness of ABS in reducing accidents in this country.

Most previous studies of this topic have been carried out in the USA, and have compared the number of accident-involvements of paired groups of cars, one group being

ABS-equipped and the other not. There are theoretical problems with such an approach, since the results can be misleading if the groups are not matched overall with respect to factors such as mileage and type of driver. Moreover, the approach is impractical in this country: only one car model sold in large numbers on the British market has followed the pattern found with several US models and switched directly from 'ABS not available' to 'standard fitting of ABS' at a certain time.

The alternative approach adopted for this project was to survey a focussed sample of car owners, enquiring about their driving experience over the previous year and any accidents in which they had been involved. A postal self-completion survey was designed to collect information about the drivers and their mileage, as well as their cars. This information has not been available in earlier studies, and its use has avoided the type of problem mentioned above.

Questionnaires were sent to owners of cars with registration prefix P. This group of cars was selected to collect information about modern cars (so that relatively many ABS-equipped cars would be included) which had been in use for sufficiently long to be involved collectively in a reasonably large number of accidents. 80 thousand questionnaires were sent out and about 21 thousand were returned. These responses provided details of 1,684 accidents, only 198 of which involved personal injury. Unfortunately, one sixth of the respondents did not report whether or not their car was equipped with ABS, so the information they supplied could not contribute to the analysis of the effects of ABS.

An initial analysis of the data revealed that drivers of ABS cars reported about 10 per cent fewer accidents per year than drivers of non-ABS cars. The two groups of cars and drivers clearly differed in several respects, however; for example, ABS cars tended to have larger engines and higher annual mileages, and their drivers were more likely to be middle-aged and male. Consequently, a more sophisticated statistical approach was required to make an unbiased comparison of the accident rates of the two groups of car.

A statistical model was developed to relate the number of accidents reported per questionnaire to details of the driver (e.g. age, sex and experience of driving), of the driver's mileage (e.g. distance travelled, percentage on motorways) and of the car (e.g. whether it was equipped with ABS). The results for all accidents showed that driving an ABS car was associated with:

- about 16 per cent fewer accidents among men up to 55 years old (the 90% confidence interval is from 1 to 28 per cent);
- about 10 per cent more accidents among older men (the 90% confidence interval is from 11 per cent *fewer* to 36 per cent *more* accidents);
- about 18 per cent more accidents among women (the 90% confidence interval is from 1 per cent *fewer* to 40 per cent *more* accidents);
- about 3 per cent fewer accidents overall (the 90% confidence interval is from 12 per cent *fewer* to 7 per cent *more* accidents).

The reduction among men up to 55 years old is statistically significant at the 90% level, and the increase for women approaches significance. The results for injury accidents were less precise; they were broadly consistent with the results for all accidents, although the increase among older men was more marked (and statistically significant).

One possible explanation of these results could be that younger men are relatively knowledgeable about ABS and are benefiting from the technology, whereas women and older men are less knowledgeable and may not be using the equipment correctly. The survey had asked questions to test respondents' knowledge about the operation and effectiveness of ABS. The responses to these questions showed a poor level of knowledge about ABS, but younger men did tend to score higher than older men, who in turn scored higher than women. Drivers of ABS cars tended to score higher than drivers of non-ABS cars.

When these scores were introduced into the modelling, it was found that knowledge about the ability conferred by ABS to steer while braking is of special value to drivers of ABS cars in reducing their accident liability. Presumably it increases the likelihood that they will use this characteristic of ABS effectively, while not encouraging unrealistic expectations of what the equipment can achieve. The number of accidents reported by drivers of ABS cars fell as their level of knowledge rose, but differences were found between the three groups of drivers.

- Among men up to 55 years old, drivers of ABS cars who were ignorant about ABS reported about the same number of accidents as drivers of non-ABS cars. The reduction in accidents as knowledge improved meant that all drivers in this group who knew something of ABS tended to benefit from the equipment.
- Among older men, drivers of ABS cars reported more accidents than drivers of non-ABS cars. Despite the reduction in accidents as knowledge improved, even the drivers with most knowledge of ABS still tended to report more accidents.
- Among women, drivers of ABS cars reported more accidents than drivers of non-ABS cars. The reduction in accidents as knowledge improved meant that drivers with most knowledge of ABS tended to report as many accidents as drivers of non-ABS cars.

This raises the possibility that there are aspects of ABS as currently implemented that prevent a significant part of the driving population from deriving its benefits – even when they are knowledgeable about ABS. Various hypotheses can be advanced. For example, it could be that younger men tend to be physically better able to exert the necessary force on the brake pedal, or that they respond better to the feedback provided by ABS, or that they are more likely to perceive an emergency in sufficient time for the system to act effectively.

Finally, the details of the accidents involving ABS and non-ABS cars were compared. The results could only provide general pointers about the effects of ABS since the comparison could not allow for the differences between the two populations of drivers and possible differences between the types of trip that they made. One unexpected finding was that the ABS cars were involved in relatively many accidents on wet roads, although they were involved in relatively few accidents during rain. They were involved in relatively many accidents in an active role (e.g. hitting another vehicle); conversely, they were involved in relatively few in a passive role (e.g. hit by another vehicle). ABS cars were far less likely than non-ABS cars to leave the road without hitting any other object, although this was very uncommon even for the non-ABS cars. ABS cars were slightly more likely than non-ABS cars to attempt avoiding action during the reported accidents, by accelerating or swerving rather than by braking.

To summarise, this project has investigated the effects of ABS using a novel approach. Previous studies have analysed existing sets of accident data, but no suitable accident data existed in this country and the comparisons made by these studies may have been biased by factors that could not be taken into account because of the nature of the data analysed. Instead, a large survey of drivers of modern cars has been carried out, which has provided the extra level of data and has allowed more detailed analyses to be made. These have shown that ABS has the potential to reduce the number of accidents, but that this has not been fully achieved at present. Part of the explanation is that many drivers have little or no knowledge of ABS: ignorance of ABS can increase the risk of accidents in cars equipped with ABS. Moreover, it appears that the way in which many women and older men use the equipment may be increasing their risk of accidents.

6 Acknowledgements

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Appendix A: Modelling the accident data

Section 4 presented the results from a series of statistical models that had been fitted to the survey data. This section presents the accompanying technical details.

When choosing the appropriate analytical approach to apply, guidance was provided by related research that has been carried out previously, and reference has already been made to the key research of Maycock et al (1991). The focus of that work, however, was on the role of the driver rather than the car, so the guidance could only be followed in general terms.

The *dependent* variable in the modelling is the number of accidents. Accidents are rare and independent events, so statistical models of the incidence of accidents normally assume that the error distribution is Poisson. The goal is then to develop the best model to explain variations in the dependent variable (accidents) in terms of variations in the *independent* (or explanatory) variables selected from the data collected during the surveys.

The question of which is the 'best' model involves several considerations, most of which can be resolved technically. One that involves judgement is whether, at a particular stage in the model development, to add another variable. This may improve the fit of the model marginally, but at the expense of reducing the number of data records since records can only be retained for the analysis if they include satisfactory data for the additional variable. The ideal is a *parsimonious* model that satisfactorily explains the dependent variable with the minimum number of independent variables.

The variables are generally taken directly from the survey data. X, the exposure, was defined in Section 2.1 and has a special role as independent variable in the analysis. For a particular group of responses, it is the period of time for which the accident data had been collected, i.e. the number of years that these drivers had owned their cars (but counting 1.0 for cars which had been owned for more than a year). Suppose that, in addition to exposure, the particular set of data contains I independent variables $x_1, x_2..x_I$. The model states that the expected number of reported accidents is

$$A(X,x_1, x_2..x_I) = X.\exp[\beta_0 + \beta_1 x_1 + \beta_2 x_2 + .. +\beta_I x_I] \qquad (1)$$

The coefficients $\beta_0 .. \beta_I$ are estimated to provide the best representation of A on the basis of the independent variables. This is done using the GLIM program (Francis et al, 1993). The unit of analysis is the set of responses which have x_1, x_2..x_I in common, so as I increases the number of units rises and the actual number of accidents per unit falls. This, together with the loss of incomplete records as I increases, restricts the degree to which it is feasible to elaborate the model. Since there are relatively few injury accidents, this limit is reached sooner when A is the number of *injury* accidents.

The process of model development has the following steps:

1 Select a promising group of independent variables, guided by logic and the results of the exploratory analyses.

2 Prepare a suitable file of data for analysis, based on this selection of independent variables.

3 Fit a standard statistical model to these data.

4 Assess the explanatory power of the fitted model using standard statistical procedures.

5 If a suitable model has not been achieved, return to Step 1 and continue the analysis, otherwise terminate.

TRANSPORT RESEARCH LABORATORY

CAR PERFORMANCE AND SAFETY SURVEY

Ref No: 9988

TRANSPORT RESEARCH LABORATORY

CAR PERFORMANCE AND SAFETY SURVEY

We would be grateful if you would kindly complete this questionnaire by either ticking the appropriate box(es) or writing in the required details it will only take about 15 minutes to complete. Not all questions will apply to you. Any information that you give will of course be treated in the **strictest confidence** and will be used for statistical purposes only.

SECTION A: YOUR CAR AND DRIVING EXPERIENCE

In this section we are interested to find out about your driving experience with your current car. Please answer the following questions in relation to the car you *currently* drive in which you do the *most* miles.

(1) What is the make and model of your *current* car? (*eg, Vauxhall Vectra*)

____

(2) What is the engine size and specification of your car? (*eg, 1.3LS, 2.0Sri*)

____

(3) What colour is the car?

____

(4) What registration year is your car? (*eg, 'P', 'R', 'S'*)

____

(5) How long have you been driving this car?

☐☐ Months ☐☐ Years

(6) When you got this car, was it new or used? (*Please tick one box only*)

New ☐1

Used ☐2

(7) Where did you purchase this car? (*Please tick*)

Dealership ☐1

Private garage ☐2

From member of the public ☐3

Company provided/purchased ☐4

Other (*please specify*) ☐5

____

(8) Please indicate which of the following features your *current* car is fitted with?

	Yes	No	Don't know
Power assisted steering	☐1	☐2	☐3
Side impact protection	☐1	☐2	☐3
Driver airbag	☐1	☐2	☐3
Passenger airbag	☐1	☐2	☐3
Side airbags	☐1	☐2	☐3
Seat belt pretensioners	☐1	☐2	☐3
ABS	☐1	☐2	☐3
Traction control	☐1	☐2	☐3
Centre high mounted brake light	☐1	☐2	☐3

(9) How important are the following features to you when selecting a new car?

	Very important	Fairly important	Not very important	Not at all important
Driver airbag(s)	☐1	☐2	☐3	☐4
ABS	☐1	☐2	☐3	☐4
Traction control	☐1	☐2	☐3	☐4
Top speed	☐1	☐2	☐3	☐4
Acceleration	☐1	☐2	☐3	☐4
Fuel economy	☐1	☐2	☐3	☐4

(10) a) How many miles have you driven in your *current* car over the past 12 months? (*Or since obtaining it, if driven for less than 12 months*)

☐☐☐☐☐☐ Miles

b) If you regularly drive another vehicle, how many miles per year do you drive in total?

☐☐☐☐☐☐ Miles

(11) In your *current* car, what percentage of your mileage do you estimate that you drive for the following:

	Percentage
Business	☐
Private	☐
Commuting	☐
Other	☐
Total	100%

(12) In your *current* car, what percentage of your mileage do you estimate that you drive on the following?

	Percentage
Motorways	☐
Urban Roads (Speed limit 40mph or less)	☐
Rural Roads (Speed limit greater than 40mph)	☐
Total	100%

Now go to Section B

SECTION B: NEAR MISSES AND ACCIDENTS IN YOUR CURRENT CAR

In this section we are interested to find out about any near misses and/or accidents you have been involved in during the past 12 months while driving your current car, which you described in section A. If you have had this car for less than 12 months please answer in relation to any near misses and/or accidents you have been involved in since getting the car.

(I) NEAR MISSES

(13) Many drivers have had the impression of only just avoiding an accident (i.e. of having a 'near miss'). How many times would you say that this has happened to you in your current car in the past twelve months *(Or since getting the car if driven for less than 12 months)*?

Never	☐1
Once or Twice	☐2
3 to 5 times	☐3
6 to 10 times	☐4
On more than 10 occasions	☐5

(II) ACCIDENTS

By accident, we mean any incident which occurred on a public road (not on private property) which involved damage to property, damage to your car or someone else's vehicle, or injury to yourself or another person.

(14) Have you had any accidents while driving your *current* car during the *last 12 months*? *(or since getting the car if driven for less than 12 months).*

Yes	☐1
No	☐2

If NO go to Section C

(15) How many accidents have you had in your *current* car during the *last 12 months*? *(or since getting the car if driven for less than 12 months).*

Please write in number: ☐☐

The rest of this section asks questions relating to the two most recent accidents you have been involved in while driving your current car during the past twelve months (or since obtaining your current car if you have been driving it for less than 12 months). If you answered '1' in question 15 please describe only this accident. Please answer the following questions as honestly as you can, remembering all answers you give will be treated in the strictest confidence. Whilst question 30 will offer you the chance to describe what happened in more detail, please answer questions 16-29 with the response that most closely fits what happened.

(16) When did the accident(s) happen (Date)?

	Month	Year
Most recent accident	☐	☐
Next most recent accident	☐	☐

(17) At what time did the accident(s) occur? (*Please tick*)

	Most recent accident	Next most recent accident
6am-12 noon	☐1	☐2
12noon- 6pm	☐1	☐2
6pm- 12 midnight	☐1	☐2
12 midnight- 6am	☐1	☐2

(18) Did the accident(s) occur in daylight or darkness? (*Please tick*)

	Most recent accident	Next most recent accident
Daylight	☐1	☐2
Twilight	☐1	☐2
Darkness	☐1	☐2

(19) What were the conditions of the road surface at the time of the accident(s)? (*Please tick*)

	Most recent accident	Next most recent accident
Dry	☐1	☐2
Wet	☐1	☐2
Icy	☐1	☐2
Snow covered	☐1	☐2

Other (please specify) ____________________

(20) What were the weather conditions? (*Please tick*)

	Most recent accident	Next most recent accident
Dry - Sunny	☐1	☐2
Dry - Cloudy	☐1	☐2
Raining	☐1	☐2
Snowing	☐1	☐2
Foggy/Misty	☐1	☐2

Other (please specify) ____________________

(21) On what type of road did the accident(s) occur? (*Please tick*)

	Most recent accident	Next most recent accident
Motorway	☐1	☐2
Urban roads (Speed limit 40mph or less)	☐1	☐2
Non-Urban roads (Speed limit greater than 40mph)	☐1	☐2

(22) What was the traffic like at the time of the accident(s)? (*Please tick*)

	Most recent accident	Next most recent accident
No other traffic	☐1	☐2
Light traffic	☐1	☐2
Heavy traffic	☐1	☐2

(23) At what speed were you travelling just before the accident(s) occured? (*Please tick*)

	Most recent accident	Next most recent accident
Stationary	☐1	☐2
Less than 20 mph	☐1	☐2
20-40 mph	☐1	☐2
40-60 mph	☐1	☐2
60-70 mph	☐1	☐2
Above 70 mph	☐1	☐2

(24) Below is a list of possible statements describing what may have occurred during the accident(s). Please read *all* of the alternatives and tick which statement *best* describes the *first* impact in each accident? (PLEASE TICK ONLY ONE PER ACCIDENT)

	Most recent accident	Next most recent accident
a) your car hit a pedestrian	☐1	☐2
b) your car hit a cyclist	☐1	☐2
c) your car hit the rear of another vehicle	☐1	☐2
d) your car hit the side of another vehicle	☐1	☐2
e) another vehicle hit the rear of your car	☐1	☐2
f) another vehicle hit the side of your car	☐1	☐2
g) your car was hit by an oncoming vehicle in *your* lane	☐1	☐2
h) your car hit an oncoming vehicle in *their* lane	☐1	☐2
i) your car hit a road side object	☐1	☐2
j) your car left the road without hitting any other object	☐1	☐2
k) your car rolled over	☐1	☐2

l) Other (*please specify*)

____

If the first impact in either of the accidents involved another vehicle please answer questions 25&26. If the first impact did not involve another vehicle please go straight to question 27.

(25) What was the other vehicle?

	Most recent accident	Next most recent accident
Car	☐1	☐2
Van/Lorry	☐1	☐2
Bus/Coach	☐1	☐2
Motorcycle	☐1	☐2
Other (*Please specify*)		

____

(26) Was the other vehicle stationary, moving or parked at the time of the accident?

	Most recent accident	Next most recent accident
Stationary (but not parked)	☐1	☐2
Moving	☐1	☐2
Parked	☐1	☐2

(27) Before this first impact in either of the accident(s), did you feel that you had time in which to attempt any avoiding action?

Yes	☐1
No	☐2

If NO go to Question 29

(28) What avoiding action, if any, did you attempt? (*Please tick all that apply*)

	Most recent accident	Next most recent accident
I accelerated	☐1	☐2
I braked	☐1	☐2
I swerved	☐1	☐2
Other (please specify)		

____

(29) What injuries (if any) were received by anyone involved in the accident(s)? (*Please tick only those that apply*)

	Most recent accident	Next most recent accident
You		
None	☐1	☐2
Slight cuts/bruises	☐1	☐2
Serious cuts/bruises	☐1	☐2
Serious injuries (e.g. broken bones, or any permanent damage)	☐1	☐2
Your passenger		
No passenger	☐1	☐2
None	☐1	☐2
Slight cuts/bruises	☐1	☐2
Serious cuts/bruises	☐1	☐2
Serious injuries (e.g. broken bones, or any permanent damage)	☐1	☐2
Fatal	☐1	☐2
Driver/passenger in other vehicles		
No other vehicle involved	☐1	☐2
None	☐1	☐2
Slight cuts/bruises	☐1	☐2
Serious cuts/bruises	☐1	☐2
Serious injuries (e.g. broken bones, or any permanent damage)	☐1	☐2
Fatal	☐1	☐2
Pedestrian/cyclist		
No pedestrian/cyclist involved	☐1	☐2
None	☐1	☐2
Slight cuts/bruises	☐1	☐2
Serious cuts/bruises	☐1	☐2
Serious injuries (e.g. broken bones, or any permanent damage)	☐1	☐2
Fatal	☐1	☐2

Motorcyclist/Pillion		
No motorcyclist involved	☐[1]	☐[2]
None	☐[1]	☐[2]
Slight cuts/bruises	☐[1]	☐[2]
Serious cuts/bruises	☐[1]	☐[2]
Serious injuries (e.g. broken bones, or any permanent damage)	☐[1]	☐[2]
Fatal	☐[1]	☐[2]

(30) Please briefly describe and/or draw a diagram of what happened in the accident(s).

Most recent accident:

Next most recent accident:

Now go to Section C

SECTION C: ABS

ABS is now fitted to many cars. In this section we are interested to find out how much drivers know about ABS. We would be grateful if you could answer these questions even if you do not currently drive an ABS fitted car.

(31) What do you *think* the initials ABS stand for?

A __________ Don't know ☐1

B __________

S __________

(32) Would you prefer the car you drive to have ABS fitted or not?

Prefer to have ABS ☐1

Prefer not to have ABS ☐2

No preference ☐3

Don't know ☐4

Please state why:

____

____

____

(33) How do you *think* ABS should be used? (*tick as many as you think apply*)

Pump the brakes fast in an emergency ☐1

Keep your foot hard on the brakes in an emergency ☐2

Same as ordinary brakes ☐3

Don't know ☐4

Other (*please specify*)

____

Please add any further comments here:

____

____

____

____

____

(34) How do you *think* stopping distances during emergency braking differ between cars with and without ABS, on the following road conditions? *(please tick one box for each road condition)*

	ABS much shorter	ABS slightly shorter	No different	ABS slightly longer	ABS much longer	Don't know
a)dry roads	☐1	☐2	☐3	☐4	☐5	☐6
b)wet roads	☐1	☐2	☐3	☐4	☐5	☐6
c)icy roads	☐1	☐2	☐3	☐4	☐5	☐6
d)loose surfaces eg. snow/ gravel	☐1	☐2	☐3	☐4	☐5	☐6

Please add any further comments here:

____

____

____

(35) Compared with non- ABS fitted cars, how effective do you *think* ABS fitted cars are at allowing you to steer while braking in an emergency, on the following road conditions? *(please tick one box for each road condition)*

	ABS much more effective	ABS slightly more effective	ABS no different	ABS slightly less effective	ABS much less effective	Don't know
a)dry roads	☐1	☐2	☐3	☐4	☐5	☐6
b)wet roads	☐1	☐2	☐3	☐4	☐5	☐6
c)icy roads	☐1	☐2	☐3	☐4	☐5	☐6
d)loose surfaces eg. snow/ gravel	☐1	☐2	☐3	☐4	☐5	☐6

Please add any further comments here:

____

____

____

(36) Compared with non- ABS fitted cars, how effective do you *think* ABS fitted cars are at reducing skidding while braking in an emergency, on the following road conditions? *(please tick one box for each road condition)*

	ABS much more effective	ABS slightly more effective	ABS no different	ABS slightly less effective	ABS much less effective	Don't know
a)dry roads	☐1	☐2	☐3	☐4	☐5	☐6
b)wet roads	☐1	☐2	☐3	☐4	☐5	☐6
c)icy roads	☐1	☐2	☐3	☐4	☐5	☐6
d)loose surfaces eg. snow/ gravel	☐1	☐2	☐3	☐4	☐5	☐6

Please add any further comments here:

____

____

____

(37) If you have ever seen or heard anything about what ABS does or how to use it, please tick all of the boxes that apply.

	What it does	How to use it
Magazine/Newspaper	☐1	☐2
Car handbook	☐1	☐2
Internet website	☐1	☐2
Driving textbook	☐1	☐2
Television/Radio	☐1	☐2
Driver training course	☐1	☐2
Friend	☐1	☐2
Salesperson	☐1	☐2
No information seen/heard	☐1	☐2

(38) Have you ever been aware of skidding/ locking the wheels during braking, whilst driving your *current* car? *(tick all that apply)*

	Yes	No
At high speed on an icy road	☐1	☐2
At high speed on a wet road	☐1	☐2
At high speed on a dry road	☐1	☐2
At low speed on an icy road	☐1	☐2
At low speed on a wet road	☐1	☐2
At low speed on a dry road	☐1	☐2

If your current car is not fitted with ABS please go to Section D. If your current car is fitted with ABS please go to question 39.

(39) While driving your *current* car have you ever been aware of the ABS coming into operation

a) during a 'near miss' incident (*as described in question 13*).

Yes ☐1

No ☐2

Don't know ☐3

If yes, how many near miss incidents? ☐☐

Please describe how you were aware and what happened:

____

____

____

b) during the accident(s) you may have described in section B (*If you have not been involved in any accidents and did not fill in section B, please go straight to question 40*).

Yes ☐1

No ☐2

Don't know ☐3

If yes, please describe how you were aware and what happened:

Most recent accident:

____

____

____

Next most recent accident:

____

____

____

(40) Have there ever been occasions when the ABS has not worked as you expected?

	Yes	No
a) At high speed	☐1	☐2
b) At low speed	☐1	☐2

(*please comment*)

____

____

____

(41) Have you ever practised using the ABS on your car?

Yes ☐1

No ☐2

If yes, please describe what you did and where:

____

____

____

Now go to Section D

SECTION D: TRAINING

(42) Have you been on any driver training courses since passing your L-test?

Yes ☐1

No ☐2

If NO go to Section E

(43) Who was the training provided by? (*Tick all that apply*)

Institute of Advanced Motorists (IAM) ☐1

Royal Society for the Prevention of Accidents (RoSPA) ☐2

Employer ☐3

Other (please specify)

____

____

____

____

(44) How long was the training course?

☐☐ days ☐☐ hrs per day

(45) Which of the following were included during the training? (*Tick all that apply*)

Lecture/presentation by trainer ☐1

Group discussion ☐2

Demonstration drive by trainer ☐3

Trainer assessment of your driving ☐4

Training on public roads ☐5

Training on closed/private site ☐6

Commentary drive by you ☐7

Training of skid control ☐8

(46) Did the training course cover braking techniques?

Yes ☐1

No ☐2

(47) Did the training cover ABS? (*Tick all that apply*)

	Yes	No
Discussion	☐1	☐2
Demonstrated by trainer	☐1	☐2
Practice by yourself	☐1	☐2

We would be grateful for any other information you would be willing to give regarding any ABS training.

____

____

____

____

____

____

Now go to Section E

SECTION E: ABOUT YOU

(48) Are you?

Male ☐[1]

Female ☐[2]

(49) What was your age last birthday?

☐☐

(50) How long have you been driving?

☐☐ years ☐☐ months

(51) Please state your occupation.

____

(52) Please tick the box best describing your occupation.

Senior managerial, administrative or professional ☐[1]

Junior managerial, administrative or professional, supervisory and clerical ☐[2]

Skilled manual work ☐[3]

Semi-skilled and unskilled manual work ☐[4]

Student, housewife/husband, retired, unemployed ☐[5]

(53) If you have any comments about this survey, please comment below:

____

(54) If you would like to be involved in any follow up to this research in the area of 'car performance and safety', please write your name and address below:

Name: ____

Address: ____

Post code: ____

Please return your completed questionnaire using the envelope provided

MANY THANKS FOR YOUR HELP

Abstract

Antilock Braking Systems (ABS) are fitted to many new cars and can improve the driver’s ability to steer while braking heavily; they can also reduce stopping distances under many conditions. This report presents the findings from a project that has been carried out to assess the effectiveness of ABS in reducing accidents in Great Britain.

A large postal survey was carried out of the owners of P-registered cars, asking for details of any accidents in which they had been involved during the previous year. A wide range of factors might influence the likelihood of being involved in an accident, and the survey covered these factors in some detail. Questions were also asked to test respondents’ knowledge of ABS.

A preliminary analysis of the data showed that drivers of ABS cars had reported about 10 per cent fewer accidents per year than drivers of non-ABS cars. The two groups of cars and drivers clearly differed in several respects, however, so that a more sophisticated analysis was required to provide unbiased estimates of the effectiveness of ABS. These indicated that ABS does have the potential to reduce the number of accidents, but that this has not been fully achieved. One reason is that many drivers have little or no knowledge of ABS.

Related publications

TRL332 *Road layout design standards and driver behaviour* by G Maycock, P J Brocklebank and R D Hall. 1998 (price £35, code H)

RR340 *A study of various car anti-lock braking systems* by B J Robinson and B S Riley. 1991 (price £20, code B)

RR315 *The accident liability of car drivers* by G Maycock, C R Lockwood and J F Lester. 1991 (price £20, code C)

RR306 *Individual differences in accident liability: a review of the literature* by J Lester. 1991 (price £20, code B)

CT74.1 ABS braking systems update (1993-1996) *Current Topics in Transport: selected abstracts from TRL Library's database* (price £20)

Prices current at May 2000