The Implementation Of A Skid Policy To Provide The Required Friction Demand On The Main Road Network In The United Kingdom

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ABSTRACT

The United Kingdom skid resistance policy was published in December 1987 as Departmental Standard HD15/87 and was applicable to all Trunk Roads and Motorways. The policy required the whole of the network to be monitored using a Sideway-force Coefficient Routine Investigation Machine, SCRIM. The standard was innovative and introduced concepts of:-

- Investigatory rather than intervention levels;
- At any location on the network where the skidding resistance became equal to or fell below the investigatory level, an investigation was required to determine if treatment to improve its skidding resistance was justified;
- The recognition that the level of skidding resistance required to provide an equal risk of a wet road skid occurring would need to vary along a road depending on the geometry of the road and other factors. The varying characteristics were defined in terms of 13 SCRIM site categories e.g. dual carriageway no-event, single carriageway no-event, approach to major junction, bend of less than 250m etc.

These concepts have been proved and they remain features of the revised standard published as HD 28/04 in 2004. The new developments introduced in the revised standard are:-

- Development of SCRIM and survey procedure;
- Removal of slow speed testing at sharp bends and roundabouts (because of improvements to the measurement system on SCRIM);
- Rationalisation of the SCRIM site categories;
- Revision of some of the investigatory levels;
- Introduction of a range of investigatory levels for each site category.

A major feature of the new standard is the greater range and detail of the advice included to guide those responsible for providing adequate skid resistance in the application of the standard. Clear advice and guidance is provided in setting investigatory levels and carrying out investigations to determine if treatment is required.

This paper describes the development of the new standard, considers the main parameters to be considered when setting investigatory levels and carrying out site investigations and explains the costs and benefits that will accrue from its introduction.

1. INTRODUCTION

The UK skid resistance policy for trunk roads was introduced in 1988 through the standard HD28 in the Design Manual for Roads and Bridges, with the specific aim of managing road maintenance so as to equalise the risk of skidding accidents across the network. The standard was innovative and introduced concepts of:-

- Defined threshold levels of skid resistance ("Investigatory Levels") assigned to each part of the network, so that locations needing further investigation because of low skid resistance could be identified;

- A process of site investigation which was to be carried out wherever the skidding resistance fell to a level equal to or below the investigatory level, to determine if treatment to improve its skidding resistance was justified;

- The recognition that the level of skidding resistance required to provide an equal risk of a wet road skid occurring would need to vary along a road depending on the geometry of the road and other factors. The varying characteristics were defined in terms of 13 site categories e.g. dual carriageway no-event, single carriageway no-event, approach to major junction, bend of less than 250m etc.

While this approach is still valid, there have been a number of important developments since 1988 that meant it was appropriate to review how the policy is implemented. Specifically, traffic levels have increased and there have been changes to the network geometry and surfacing materials and to the vehicles using the network that could have influenced the requirements for skid resistance. The incidence of litigation had increased and, although the level of claims relating to the skid resistance of the road surface was not giving concern, the fear of litigation was leading to unduly conservative decision-making. In some cases, this was leading to proposals for maintenance that were felt to be poorly justified, in terms of the likely safety benefits.

The Highways Agency, an executive agency for the Department for Transport with responsibility for operating, maintaining and improving the strategic road network, was formed 1994. Since its creation, its role as a network operator has evolved to become increasingly customer focussed and accountable for the expenditure of budgets. The focus on customers, i.e. road users, has increased the emphasis on both minimising congestion and improving road safety, which has increased the need to scrutinise and justify the benefits of carrying out maintenance works.

All these factors combined to the need for a thorough review of the skid resistance policy and standard for today's conditions. This involved a number of parallel elements of work, which included:

- Developing the equipment used for measuring skid resistance (SCRIM) and the way in which data are gathered.

- A network level analysis of the influence of skidding resistance on accident risk, from which some changes were recommended to the way the network is categorised and the required levels of skid resistance are determined.

- A review of the guidance for investigating sites with low skid resistance and deciding if treatment is warranted. This included consideration of whether treatment should be

mandatory once a certain level of skid resistance is reached, or if it should continue to be based on engineering judgement through the use of thresholds that trigger further investigation.

- A review of the use of slippery road warning signs in connection with the skid resistance policy.

As a result of the review a revised standard was produced, which came into force in August 2004. This paper describes the development of the new standard, considers the main parameters to be considered when setting investigatory levels and carrying out site investigations and explains the costs and benefits that will accrue from its introduction.

2. DEVELOPMENTS TO SCRIM AND SURVEY PROCEDURE

Skid resistance surveys on UK trunk roads are carried out using SCRIMs (Sideways-force Coefficient Routine Investigation Machines). In England, surveys are carried out on Lane 1 of all trunk roads in both directions of travel – a total length of approximately 10,000km on motorways and dual carriageways and 3,500km on single carriageways. In the new standard there have been a number of changes to the SCRIM equipment and survey procedure required. These are described in the following sections.

2.1. SURVEY STRATEGY

The survey strategy has been changed from a pattern of Mean Summer SCRIM Coefficient (MSSC) surveys, whereby one third of the network is surveyed (three times) each year to enable calculation of the mean summer value, to a Single Annual Survey of the whole network each year, as illustrated in Figure 1.

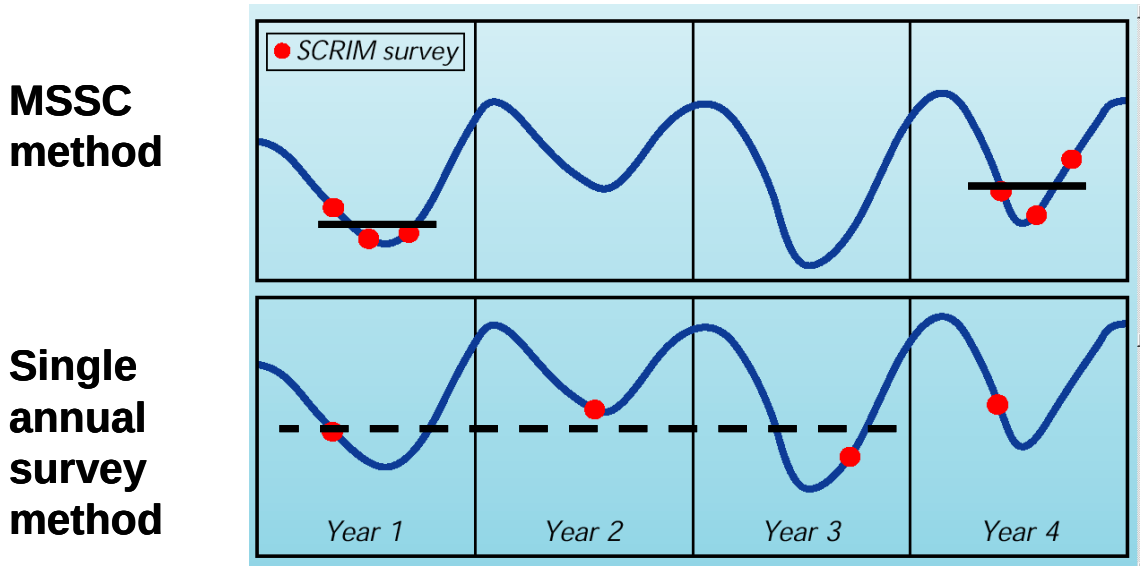

Figure 1 MSSC and new single annual survey strategy

In the single annual survey regime, the timing of the survey is rotated through the early, middle and late periods of the test season in successive years. In subsequent analysis, the mean value of the surveys recorded in the previous three years is used to determine whether the results from the current year are unusually high or low as a result of seasonal

effects, such as an unusually dry or wet summer. The new analysis procedures introduced correction for the effects of seasonal variation in skid resistance both from year-to-year and within individual years. The key changes, costs and benefits accruing from this change can be summarised as:

- Earlier and more reliable identification of sites with skidding resistance below specified levels through the reduced interval between skid resistance measurements and by minimising the effect of year to year variation in skid resistance. (The MSSC method minimises within year variation but does not address the problem of between-year variation).

- Associated improvement in the reliability of reporting network condition via Performance Indicators.

- Earlier maintenance at sites judged to present a potentially raised accident risk which should result in accident reductions. A reduction of up to 100 personal injury accidents per year was estimated, which translates to an annual cost saving of £10 million.

- One-off cost of approximately £300,000 resulting from the additional surveys necessary during the transition from the MSSC to the single annual survey strategy and £1.3 million for treatment of sites identified in the first year of operating the single annual survey that would not otherwise have been identified for a further 1 or 2 years.

- Thereafter, costs of approximately £40,000 per year resulting from additional surveys of a series of national benchmark sites as a safety net while the implementation of the new analysis method is bedded down.

- Nominal reduction in survey costs as a result of more efficient organisation achieved through central letting management of survey contracts. (The overall survey length is nominally the same under the single annual survey regime as under the MSSC regime.)

2.2. VERTICAL LOAD MEASUREMENT

All UK SCRIMs use a 200kg load on the test tyre (British Standards Institution, 1999) but the transfer of load to the tyre was not measured dynamically as part of the skid resistance measurement. It was known from annual checks that the load is within tolerance, that friction in the bearings could influence the load applied to the tyre and it was anticipated that this could be influencing the measurement of skid resistance, particularly on sites such as roundabouts and bends, where the survey vehicle leans to left or right when driving the site.

Prototype equipment for measuring vertical load was manufactured and evaluated, as described in detail in the paper by Roe and Sinhal (2005). As a result of the positive findings, all SCRIMs in the UK have been fitted with equipment to measure the vertical load applied to the test wheel from 2004.

2.3. TEST SPEED

Under the previous standard the target test speed was 50km/h, except for roundabouts and bends with radius of curvature less than 100m, where it was 20km/h. However, feedback

from survey crews indicated that this regime frequently brought them into conflict with other road users, particularly on larger roundabouts (e.g. at grade separated junctions) where the speed of traffic circulating and leaving the roundabout was significantly higher than 20km/h. The 50km/h test speed was also much lower than the speed of other traffic on motorways and derestricted dual carriageways. The traffic volume on trunk roads had increased substantially since the introduction of the standard and this was leading to increasing conflict between the slow-moving survey vehicle and other road users.

Therefore, for safety reasons, the target speed has been changed. The objective is now to test at 80km/h on dual carriageways where the posted speed limit is greater than 50mph, and 50km/h on all other roads. Where it is not safe to maintain the target speed, the SCRIM driver can vary the speed at his discretion. A single speed correction has been introduced to correct all measurements made between 20km/h and 85km/h to a standard speed of 50km/h:

$$SC(50) = SC(s) + (s * 2.18*10^{-3} – 0.109) \quad [1]$$

Where SC(50) is the SCRIM Coefficient corrected to 50km/h and SC(s) is the SCRIM Coefficient measured at the test speed, s.

Tests showed that the majority of the trunk road network could be tested safely at these speeds. Furthermore, although there is a greater degree of measurement variability at the higher test speeds, this effect is offset by the improvements resulting in from the installation of dynamic vertical load.

3. NETWORK ACCIDENT ANALYSIS

As well as its overall responsibility for building, operating and maintaining safe roads, the Highways Agency also has been set the specific objective of contributing to meeting the Department for Transport's national target for casualty reduction, set by the UK Government. On English trunk roads the target is to achieve, by 2010, the following reductions compared with 1994 values:

- A 33% reduction in casualties that are killed or seriously injured
- A 10% reduction in casualties with slight injuries
- A contribution to the national target of reducing child casualties by 50%.

An important component of the review of skid resistance policy was therefore to revisit the research into the link between skid resistance and accidents on which the original policy was based. The 1988 standard was based on the definition of 13 site categories, reflecting the different nature of network in terms of road geometry and the presence of junctions. For each site category, default "Investigatory Levels" of skid resistance were defined in the standard, which were based upon an analysis of the relationship between accidents and skid resistance on 1,000km of road. As part of the review, a new accident analysis was performed. The key results of the analysis for English trunk roads are summarised below, but a more comprehensive description can be found in Parry and Viner (2005). These results are also reported in Viner et al. (2004, 2005).

A key finding from the accident analysis was that, even within a single site category, substantial differences in accident risk are observed between different sites. This variability, and the finding that at the variation is, at least in part, systematic as opposed to random provided a clear argument for retaining the definition of "Investigatory Levels" as triggering an investigation, rather than switching to Intervention Levels that would automatically trigger treatment. The extent of variability for the "single carriageway non-event" site category is illustrated in Figure 2, and is typical of other site categories. The argument for retaining Investigatory Levels is discussed in more detail in the paper by Viner et al. (2005).

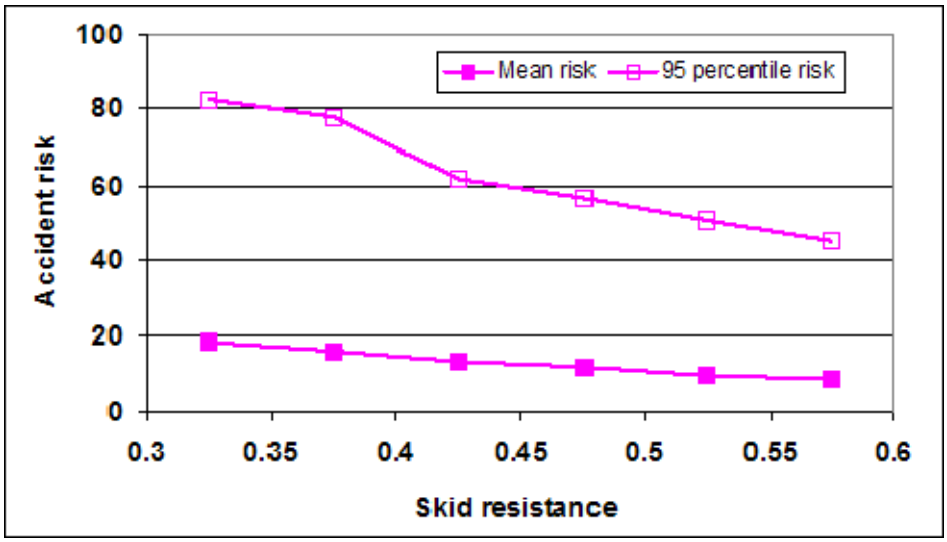

Figure 2 Range of accident risk observed for sites in the "single carriageway non-event" category

To be most effective, the skid resistance policy needs to distinguish between the sites where there could be greater benefits in providing a higher level of skid resistance because of the greater accident risk, and those sites where the accident risk is low and the scope for accident reduction is lower. While the definition of site categories provides an initial indication of accident risk, it is clear that the benefits of the policy could be improved by considering the individual characteristics of each site. This has been addressed in the revised policy through two key changes which are described in more detail in Section 4:

- Specification of a range of Investigatory Levels for each site category, plus detailed advice on the factors to consider when selecting an appropriate Investigatory Level from within the range. Sites that local engineers identify as having a greater potential accident risk will therefore be investigated sooner (i.e. while the skid resistance is still at a higher level) than for the lower risk sites within the category.

- Strengthening of the site investigation process to promote robust decisions on the need for treatment based on the overall site condition, observed accident history and nature of the specific site. This will mean that treatment is targeted effectively at the sites most likely to result in benefits in terms of accident prevention.

3.1. NEW SITE CATEGORIES AND INVESTIGATORY LEVELS

As a result of the accident analysis a number of changes were made to the site categories and Investigatory Levels, which are shown in Table 1. In addition to introducing a range of Investigatory Levels for each site category, the key changes are:

- Changes in Investigatory Level for site categories previously surveyed at 20 km/h to account for the effect of the change of speed on the skid resistance measurement.

- Combination of the major and minor junctions and approaches to roundabouts into a single site category.

- Extending the bend category to include bends with radii of curvature up to 500m (previously 250m) and separating bends on dual and single carriageways.

Table 1 Old and new recommended site categories and Investigatory Levels from HD28/94 and HD28/04 for trunk roads in Great Britain

Site category and definition		Investigatory level (at 50km/h) HD28/94 (preceding)	HD28/04 (current)
A	Motorway	0.35	0.35
B	Dual carriageway non-event	0.35	0.35-0.40
C	Single carriageway non-event	0.40	0.40-0.45
Q	Dual Carriageway (all purpose) - minor junctions	0.40	0.45-0.55
	Single Carriageway minor junctions & approaches to and across major junctions (all limbs)	0.45	
	Approach to roundabout	0.55	
K	Approaches to pedestrian crossings and other high risk situations	0.45	0.50-0.55
R	Roundabout	0.45*	0.45-0.50
G1	Gradient 5-10% longer than 50m	0.45	0.45-0.50
G2	Gradient >=10% longer than 50m	0.50	0.50-0.55
S1	Bend radius <500m – dual carriageway	0.45-0.50*	0.45-0.50
S2	Bend radius <500m – single carriageway		0.50-0.55

Table notes: 1. Category R and some sites in new categories S1 and S2 were previously tested at 20km/h. 2. A reduction in Investigatory Level of 0.05 is permitted for categories A, B, C, G2 and S2 in low risk situations, such as low traffic levels or where the risks present are well mitigated and a low incidence of accidents has been observed.

3.2. COSTS AND BENEFITS

An attempt was made to estimate the financial costs and benefits that would accrue as a result of the recommended changes to the site categories and Investigatory Levels, plus the improvements to the processes for carrying out site investigations. The length of the network likely to be affected by the changes was estimated based on up to date records of the existing site categories, the current distribution of measured skid resistance and the

percentage of the categories in the analysis database with geometry or accident risk that would imply a higher Investigatory Level would be selected. The cost estimates are based upon likely treatment lengths, the cost of resurfacing and traffic management and road user costs associated with delays at the works. Benefits are based upon the financial value assigned to accident reductions by the Department for Transport. Further details of this process are given in Parry and Viner (2005).

Depending on the assumptions made about the accident savings, it was found that the realisation period, i.e. the time at which the benefit associated with the accident saving would match the cost associated with treatment, varied from less than a year (best case) to between 3 and 16 years (worst case). For most site categories, even the worst-case realisation period was within the normal lifetime of the surfacing, assumed to be around 10 to 12 years. Based on this albeit simple analysis, it appears that in addition to assisting Highways Agency meet its targets for accident reduction, the costs of applying the recommended changes to the skidding resistance standard will be recovered in the financial value of the accident reductions that are estimated to result.

4. GUIDANCE ON SETTING INVESTIGATORY LEVELS AND CONDUCTING SITE INVESTIGATIONS

The results of the accident analysis highlighted the importance of local engineering judgement in setting appropriate Investigatory Levels for each site and in conducting site investigation to determine those sites most likely to deliver improvements in accident risk as a result of providing better skid resistance. Although the flexibility to change Investigatory Levels to suit local circumstances and advice about how to carry out a site investigation were both contained within the previous standard, experience from implementation had indicated that this part of the policy was not being applied robustly in practice. Feedback indicated a wish for clearer guidelines for decision-making and reluctance to reject treatment in case of a subsequent accident leading to litigation.

As a result, the advice on setting Investigatory Levels and on site investigation and accident analysis were substantially strengthened within the revised standard. The role of engineering judgement in maximising the effectiveness of the policy and the need to record the basis of decisions made are both made clear.

The revised standard specifies that the Investigatory Level set will normally be the lowest value in the range allowed, but that this will be increased for sites that might be expected to exhibit a higher accident risk, in comparison to other sites within the same category. For example, circumstances that would warrant setting a higher Investigatory Level include:

- Notable potential for conflict between road users, particularly at speed or where the outcome is likely to be severe.
- Road geometry departing substantially from current standards.
- Known incidence of queuing where the traffic speed is otherwise high.
- Presence of accesses onto the main carriageway, if they are busy, have poor advance visibility or create conflict between leaving or joining traffic.
- Low texture depth.

Exceptionally, a higher or lower Investigatory Level than indicated in the Table may be assigned if justified by the observed accident record and local risk assessment.
The guidelines for recommending treatment to improve the skid resistance are clearly set out, as is the fact of rejecting treatment if they are not met. The revised standard states that treatment will be justified where:

- The number of accidents is higher than average for the type of site being considered.
- A higher than average proportion of accidents occur when the road surface is wet or involve at least one vehicle skidding.
- The nature of the site and demands of road users mean that treatment is justified to pre-empt an increase in accidents.

A checklist of factors to consider in conducting a site investigation is included and, in England, the Highways Agency has reinforced these messages through a programme of training for engineers and through the Value Management process of maintenance prioritisation.

5. SLIPPERY ROAD WARNING SIGNS

The 1988 skid resistance policy required slippery road warning signs to be erected at locations where the skid resistance had been found to be at or below Investigatory Level. If subsequent investigation found that treatment was not required then the signs were to be removed, otherwise they were to be left in place until treatment was carried out. In practice, it had been found that, in contrast to the temporary measure that had been anticipated, slippery road warning signs were commonly left in place for long periods because treatment was not a priority, but nor had it been positively rejected.

It is believed that a lack of clarity of how to assess the need for treatment, combined with a fear of litigation contributed to this. The use of warning signs does provide highway authorities with a defence to litigation through the Highways Act (1980)[1] in force in England and Wales. For an engineer, the easy decision is to leave a sign in place rather than risk having to justify its removal in the event of a subsequent accident. However, as well as being expensive, signs have the disadvantages of contributing to visual roadside clutter and can present a collision hazard in the event of a vehicle leaving the road. Questions of whether the warning signs were really effective in reducing the risk of skidding accidents at sites where the skid resistance was low had also been raised.

A workshop of highway engineering professionals was held to discuss the issues surrounding the use of slippery road warning signs. The main conclusions of the workshop and the implications in respect of changes to the skid policy are as follows:

[1] Under Section 41 of the Highways Act 1980, which is applicable in England and Wales, a highway authority is placed under a duty "to maintain the highway". If claimants can demonstrate that the road was in a dangerous condition as a result of "failure to maintain", then the highway authority might be found liable for damages. However, if the highway authority had taken such care as could be reasonably expected then they can mount a defence under Section 58 of the Highways Act. In this case, if it is aware of the dangerous condition of the road, then the steps it has taken to warn the public of the danger, such as erecting warning signs, will be taken into account in determining the balance of liabilities.

- **Signs should be fewer in number but better targeted.** In the revised policy, the use of signs was therefore restricted to sites where site investigation has confirmed the need to improve the skidding resistance, except in Scotland where sites will be referred to the Overseeing Department on an individual basis for a decision on the provision of warning signs.

- **Warning signs should be erected as soon as possible following receipt of data.** The decision that signs would only be used following completion of a site investigation introduces a delay between the receipt of skid resistance measurements and the erection of signs, in order for the site investigation to be carried out. During this period, road users will not be warned of the potential risk associated with the low skid resistance. To minimise this delay, site investigations must be completed promptly and in a prioritised order. This is stressed in the revised policy. It was decided not to impose a rigid timetable because, while the most urgent investigations might be completed relatively quickly, it would inevitably be necessary to allow a longer period of time for all investigations to be completed.

- **Any change in procedure must be justified in terms of an overall improvement in effectiveness.** The proposed change would result in a reduction of the number of slippery road warning signs in place on the network. To give confidence that this would not lead to an increase in skidding accidents at sites requiring investigation, a new project was commissioned to assess the extent to which drivers responded to these signs.

5.1. TRIAL OF SLIPPERY ROAD WARNING SIGN EFFECTIVENESS

A trial site was established on a derestricted, two-way single carriageway trunk road with good skid resistance. The site contains a bend, which was chosen deliberately so drivers would be more likely to think the warning of a potentially slippery road surface would be important. Slippery road warning signs were erected immediately in advance of the bend and on the straight section beforehand.

Measurements of driver speed and headway indicated no statistically significant change in either parameter as a result of erecting the signs. Although there was a small reduction in vehicle speed observed during periods of moderate rainfall, there was no evidence that this reduction was affected by the presence or absence of warning signs. Driver interviews carried out a mile downstream showed that drivers were mainly aware of the meaning of the sign and proposed sensible measures in response to seeing it (e.g. slowing down or being more aware of potential hazards). However, very few drivers recalled having passed a slippery road warning sign, as indicated in Figure 3. It was concluded that the proposal to restrict warning signs to a more targeted selection of sites would be unlikely to result in an overall increase in skidding accidents. The strategy described above was therefore incorporated into the revision of the standard.

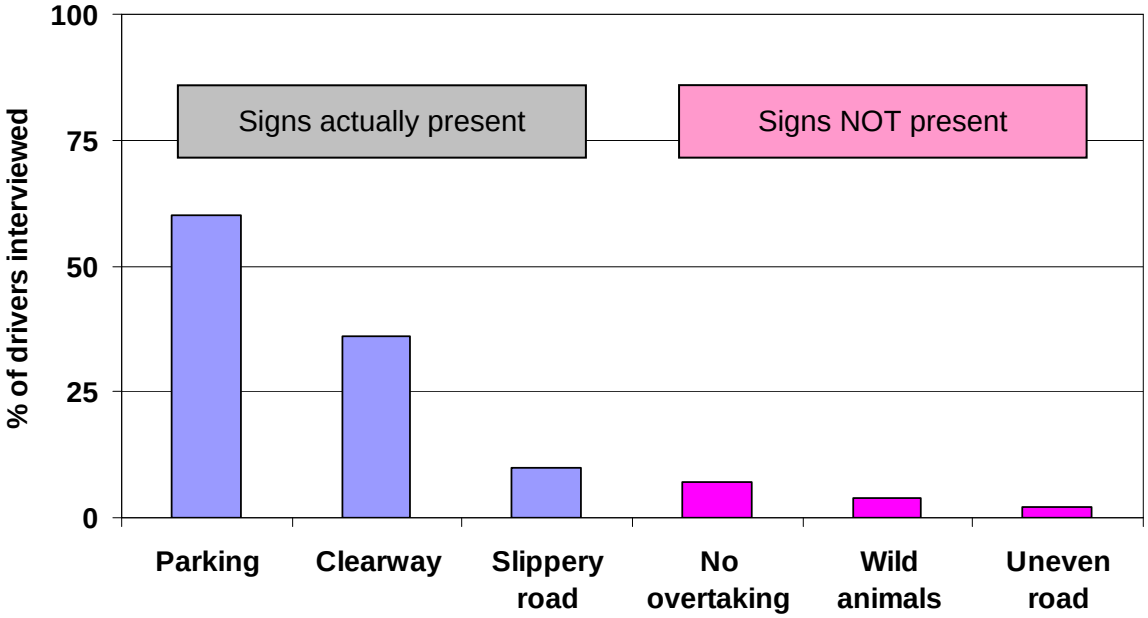

Figure 3 Percentage of drivers reporting having passed each road sign in the previous 2 miles

6. SUMMARY AND COMMENT

A revised standard for skid resistance measurement and interpretation was produced which came into force on UK trunk roads in August 2004. Changes introduced by the new standard include changes to the SCRIM equipment and survey strategy, revised site categories and the introduction of a range of Investigatory Levels for each category, improved site investigation guidance and targeted use of slippery road signs. It is believed that the revision will result in more robust decision-making, leading to more effective prioritisation of maintenance budgets. Furthermore, it is expected that the cost of bringing forward treatment at sites which would be assigned a higher Investigatory Level under the revised standard will be recovered through the reduced accident costs within the lifetime of the surfacings.

To realise the benefits of the revision to the standard, it will be important that all parties involved in its delivery implement it effectively. In England, this will be achieved through a combination of training programme for engineers, critical appraisal of proposals for maintenance through the Highway Agency's Value Management process and though implementation audits for which a framework is currently being delivered.

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