Review of UK Skid Resistance Policy

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ABSTRACT

The skid resistance policy for UK trunk roads has been reviewed after fifteen years of operation. As a result, a revision to the policy is being implemented in 2004, which is described in this paper. A key part of the review has been a re-examination of the link between skid resistance and accidents. This confirmed the importance of skid resistance but also the site specific nature of the effect. As a result the advice on determining Investigatory Levels of skid resistance has been strengthened to promote better engineering judgement of skid resistance requirements and more robust investigation of sites where the skid resistance measurements are found to be below the Investigatory Level. The review has also resulted in changes to the survey strategy, use of slippery road warning signs and on-going monitoring of the effectiveness of the policy.

RÉSUMÉ

La politique de la résistance des frottements pour les routes nationales, au Royaume Uni, a été révisée après quinze d’application. Ceci a résulté dans l’implémentation d’une révision de la politique en 2004, cette dernière est décrite dans ce papier. Un des points clés a été de re-examiner les liens entre la résistance de frottement et les accidents. Ceci a confirmé l’importance de la résistance de frottement mais aussi les effets engendrés par la nature spécifique des sites. En conséquence, la recommandation pour déterminer les seuils d’investigation de la résistance de frottement a été augmentée pour promouvoir un meilleur jugement des exigences de cette dernière (la résistance de frottement) et des investigations plus robustes des sites ayant des mesures de résistance de frottement en dessous des seuils d’investigation. Cette révision a aussi résultée dans le changement de stratégie pour les études, l’utilisation de panneaux de signalisation pour chaussées glissantes et le monitorage de l’efficacité de la politique.
1- INTRODUCTION

The UK has implemented a policy for managing the skid resistance of its trunk road network since 1988. The policy was developed following observation of a link between skid resistance and the risk of wet skidding accidents on a 1000km sample of roads [1] and aims to equalise the risk of skidding accidents across the network by providing levels of skid resistance appropriate to different locations. It consists of two elements:

- Routine measurement of skid resistance using SCRIM [2], carried out on a three-year rolling programme, plus associated advice about the interpretation of these measurements. This includes advice on Investigatory Levels (ILs) for skid resistance and the process for investigating sites where the skid resistance falls at or below this threshold.
- Specification of surfacing material characteristics that will deliver the required level of skid resistance in different situations [3].

By 1999, a number of developments were pointing to the need for a review: several significant research projects had been concluded, e.g. on high speed friction and texture depth [4-6]. Improvements in road design and vehicle performance had also occurred since the introduction of the policy and it was therefore relevant to re-examine the link between skid resistance and accident risk. Furthermore, some maintenance schemes being proposed to rectify low skid resistance as a result of this policy were felt to be poorly justified in terms of the likely safety benefits. Engineers making unduly conservative decisions about the need for maintenance treatment out of fear of litigation, contributed to this effect. Consequently it was recognized that there was a need for clearer advice on interpretation of skid resistance and accident data, which could be robustly defended if necessary.

The Highways Agency therefore commenced a review to examine all aspects of the skid resistance policy. This paper describes the results of the accident analysis, which has led to a revision of the site categories and ILs and changes to the way that potential maintenance schemes will be evaluated. These changes will be implemented in a revision to the policy this year, 2004 [7].

2- APPROACH

A database of pavement condition, road geometry, traffic flow and accident data for English trunk roads was constructed for an accident analysis. In the database, the network was divided into lengths of around 500m (motorways) or 200m (other roads) to which the other data were assigned. These lengths represented a compromise between needing a long length to be confident in assigning accidents to the correct length and preferring short lengths so that the condition was reasonably homogeneous. Shorter lengths were created where necessary, e.g. around features such as junction approaches or bends. A summary of the data available for analysis is given in Table 1, broken down by the site categories defined in the current policy.

Pavement condition and road geometry data was available from routine surveys of the English trunk road network. Details of over 100,000 personal injury accidents recorded in the period...
between 1994 and 2000 were extracted from the UK “STATS19” database. A GIS package was used to assign the accident locations, recorded as 10 digit grid references, to individual road lengths. Selected details from the accident records were extracted, including whether the road was wet at the time of the accident and whether skidding was recorded.

Table 1. Summary of data available for analysis

<table>
<thead>
<tr>
<th>Site category</th>
<th>Number of lengths with data</th>
<th>Median length (m)</th>
<th>Total length (km)</th>
<th>Data coverage (% of whole network)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorway</td>
<td>3979</td>
<td>500</td>
<td>1901</td>
<td>56</td>
</tr>
<tr>
<td>Dual c/way non-event</td>
<td>8246</td>
<td>200</td>
<td>1648</td>
<td>59</td>
</tr>
<tr>
<td>Single c/way non-event</td>
<td>9026</td>
<td>200</td>
<td>1711</td>
<td>67</td>
</tr>
<tr>
<td>Dual c/way minor junction</td>
<td>359</td>
<td>93</td>
<td>41</td>
<td>40</td>
</tr>
<tr>
<td>Single c/way minor junction</td>
<td>2096</td>
<td>70</td>
<td>202</td>
<td>73</td>
</tr>
<tr>
<td>Major junction</td>
<td>909</td>
<td>57</td>
<td>80</td>
<td>49</td>
</tr>
<tr>
<td>Gradient 5 to 10%</td>
<td>708</td>
<td>200</td>
<td>126</td>
<td>82</td>
</tr>
<tr>
<td>Gradient steeper than 10%</td>
<td>14</td>
<td>190</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Bend &lt;250m</td>
<td>453</td>
<td>120</td>
<td>62</td>
<td>46</td>
</tr>
<tr>
<td>Approach to roundabout</td>
<td>57</td>
<td>75</td>
<td>6</td>
<td>22</td>
</tr>
<tr>
<td>Approach to signals, crossings etc.</td>
<td>402</td>
<td>53</td>
<td>22</td>
<td>42</td>
</tr>
<tr>
<td>Bend &lt;100m</td>
<td>534</td>
<td>50</td>
<td>31</td>
<td>59</td>
</tr>
<tr>
<td>Roundabout</td>
<td>286</td>
<td>196</td>
<td>52</td>
<td>42</td>
</tr>
</tbody>
</table>

A combination of approaches was taken to analyse the data. Taking the current site categories individually, the mean and 95 percentile accident risk were calculated for different bands of skid resistance. Accident risk is defined here as the total number of accidents per 100 million vehicle km driven. Although improvements to skid resistance will particularly influence skidding accidents in wet conditions, it was decided to include all accidents in the analysis because of the difficulty with accurately reporting the surface condition at the time of the accident, particularly if only damp, and whether skidding occurred.

This approach allowed the overall effects of skid resistance to be analysed, but it was recognised that other factors, such as traffic flow, road condition and geometry, also affect the accident risk and could introduce a bias to the analysis. To consider the effect of multiple factors on the accident rate, accident models were developed using a Generalised Linear Modelling (GLM) approach. The relevant variables - traffic flow, skid resistance, texture depth, high speed friction (estimated from SCRIM and texture data), rut depth, longitudinal profile variance, curvature and gradient - were tested individually for significance in a model for the number of accidents in each road length. All variables that were significant individually were then combined in a model of the form:

\[ R = kQ^\alpha L^\beta \exp(a_1 x_1 + a_2 x_2 + \ldots + a_i x_i) \]

Where \( R \) is the number of accidents, \( Q \) is the traffic flow, \( L \) is the length of the road section, \( x_1 \) to \( x_i \) are the other variables including the skid resistance and \( k, \alpha, \beta \) and \( a_1 \) to \( a_i \) are parameter
values determined in the modeling process. This form of model has been shown to be effective in other accident studies [8,9]. In this case the value of $\beta$ was fixed to 1 because the road lengths in the analysis were nearly constant and so the effect of length could not be reliably determined in the model. Any variables that were found not to be significant in the combined model were dropped, starting with the least significant, until a final model was reached and the contribution of skid resistance could be assessed for each site category.

3- SKID RESISTANCE AND ACCIDENT RISK

3.1- “Non-event” lengths

“Non-event” lengths are those with no junctions or crossings or notable bends or gradients, although they may have other accesses, e.g. commercial or residential properties. Figure 1 shows the relationship observed between mean accident risk and skid resistance for motorways and non-event lengths on dual and single carriageway all purpose trunk roads. In the current standard, these have default ILs of 0.35, 0.35 and 0.40 respectively.

![Figure 1. Mean accident risk by skid resistance for non-event lengths](image)

It is clear that there is a distinction between these three categories that justifies them remaining separate. In the accident model for motorways, the trend with skid resistance is not significant, although Figure 1 suggests there may be a small increase in mean accident risk below 0.35. For dual carriageway non-event lengths there is a significant but weak trend with skid resistance and for single carriageway non-event lengths the relationship is stronger, justifying the higher IL.
3.2 Junctions

Corresponding plots for the junction categories defined in the current standard are shown in Figures 2 and 3. The accident risk for these categories is generally higher than for non-event sections. For dual carriageway minor junctions the accident risk is relatively low, except for the striking trend at low skid resistance. The high value for the band 0.35 to 0.40 is driven by a relatively small number of sites where a very high accident risk was recorded, demonstrating the range in accident risk for different sites within a single site category. For single carriageway minor junctions there is a marked trend with skid resistance – in the accident models this trend was found to be stronger than for any other category. Conversely, for major junctions, the trend with skid resistance was not found to be significant in accident models.
In the current standard, major junctions and single carriageway minor junctions both have default ILs of 0.45, compared with 0.40 for dual carriageway minor junctions. These levels are consistent with the overall level of the accident risk, i.e. the lower accident risk for dual carriageway minor junctions than for the other two categories, but are not consistent with the much stronger effect of skid resistance observed for single carriageway minor junctions.

A possible explanation for these observations is that the design of major junctions has improved since the skid resistance standard was introduced, to cater for increased traffic flows, and that the associated reduction in conflict between road users has resulted in fewer instances where better skid resistance influences whether an accident occurs. Conversely, at minor junctions on single carriageways, there remains greater potential for traffic joining the two-way traffic on the main road to misjudge the manoeuvre, leading to an emergency situation where the level of skid resistance can influence the outcome. However, in both cases, a relatively high accident risk is observed for sites with skid resistance above 0.55, suggesting that increasing the skid resistance may not always reduce the accident risk to the level of the mean trend. Other road safety engineering measures may be more appropriate in these circumstances.

The current standard requires roundabouts and bends less than 100m radius to be tested at 20km/h, compared with 50km/h for most other site categories, but this distinction has been removed in the revised standard for safety reasons. In Figure 3, the skid resistance values have been adjusted to compensate for the different test speed and allow a direct comparison between the categories. For roundabouts and the approach to traffic signals, the mean accident rates and the trends with skid resistance fall approximately between the trends observed for minor junctions on dual and single carriageways. For roundabout approaches, the mean accident risk is clearly higher than for the other two categories, but the trend with skid resistance is rather ambiguous due to the small amount of data. The current default IL for all three categories is 0.55.

3.3 Bends and gradients

For bends and gradient categories, the GLM approach was used to review the threshold level of curvature or gradient that defines a bend or gradient. For bends, models were developed to describe the accident risk for road lengths with a radius of curvature less than 2000m. For dual and single carriageway all purpose trunk roads, although not for motorways, the trend for accident risk to increase with skid resistance was found to be strong and highly significant. The predicted effect of skid resistance and radius of curvature for single carriageways carrying typical traffic flows is given in Figure 4. From this analysis it was concluded that the ILs shown in Table 2 would be required to maintain a similar level of accident risk to that on straight roads.

<table>
<thead>
<tr>
<th>Radius of curvature (m)</th>
<th>Dual carriageway</th>
<th>Single carriageway</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>250-500</td>
<td>0.45</td>
<td>0.50</td>
</tr>
<tr>
<td>100</td>
<td>0.50</td>
<td>0.50-0.55</td>
</tr>
</tbody>
</table>
A similar analysis for gradients gave ambiguous results, possibly because of the lack of roads with steep gradients in the database. However, the trend for accident risk with skid resistance for sections with gradients in the existing 5 to 10% gradient category was strong and highly significant. It was concluded that the current IL of 0.45 for this category remains appropriate, and it was assumed that for the small number of sites with higher gradient, the higher IL of 0.50 would also continue to be appropriate.

4- RANGE OF ACCIDENT RISK

The accident risk for road lengths in the same site category and with similar skid resistance approximately follows a Poisson distribution, with typically half the lengths having no accidents and a long tail of sites with higher accident risk. The mean and 95 percentile accident risk for single carriageway non-event sections is shown in Figure 5. This behaviour is typical of all the categories.

The observation of a wide range of accident risk within a single category, at all levels of skid resistance, confirms that threshold levels should be set for Investigation, rather than Intervention, so that maintenance budgets can be prioritised at the most appropriate sites. In Figure 5, at whatever level a threshold is set, there will be sites with a high accident risk immediately above the threshold that might justify improvement to the skid resistance better than sites with very low accident risk immediately below the threshold. The consequences of this range of accident risk, in terms of targeting maintenance treatments effectively, are considered in Sections 5 and 6.
5- IMPORTANCE OF TEXTURE DEPTH

Accident models showed texture depth to be a significant variable in a number of categories. Figure 6 shows the combined effects of skid resistance and texture depth in the accident model for single carriageway non-event lengths. It is clear that the highest accident risk arises from a combination of low skid resistance and low texture depth and that the trend with skid resistance is even more pronounced at low texture depth.

In general, for this site category, the increase in risk when comparing a site with a moderate texture depth of 0.8mm to one with a higher texture of 1.3mm SMTD (a root-mean-square measure of texture depth [10]) is similar to the increase in risk for reducing the skid resistance by 0.05 units SFC. As a result, in the revised skid resistance policy the Investigatory Level will be increased by 0.05 for surfaces with texture depths below 0.8mm SMTD and the combination of low skid resistance and low texture depth will receive greater priority for maintenance than low skid resistance alone.

6- NEW SITE CATEGORIES AND INVESTIGATORY LEVELS

As a result of the analysis, the following changes have been made to the site categories and ILs in the revised UK skid resistance standard. These are summarized in Table 3, where dark shading indicates the normal range of ILs and light shading indicates a lower IL appropriate for low risk situations e.g. very light traffic.
Figure 6. Accident model for skid resistance and texture depth on single carriageways

<table>
<thead>
<tr>
<th>Site category and definition</th>
<th>Investigatory level at 50km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>A Motorway class</td>
<td></td>
</tr>
<tr>
<td>B Dual carriageway non-event</td>
<td></td>
</tr>
<tr>
<td>C Single carriageway non-event</td>
<td></td>
</tr>
<tr>
<td>Q Approaches to and across minor and major junctions, approaches to roundabouts</td>
<td></td>
</tr>
<tr>
<td>K Approaches to pedestrian crossings and other high risk situations</td>
<td></td>
</tr>
<tr>
<td>R Roundabout</td>
<td></td>
</tr>
<tr>
<td>G1 Gradient 5 to 10% longer than 50m</td>
<td></td>
</tr>
<tr>
<td>G2 Gradient &gt;10% longer than 50m</td>
<td></td>
</tr>
<tr>
<td>S1 Bend radius &lt;500m – dual carriageway</td>
<td></td>
</tr>
<tr>
<td>S2 Bend radius &lt;500m – single carriageway</td>
<td></td>
</tr>
</tbody>
</table>
For most site categories, a range of ILs has been introduced in place of the single default value. This is regarded as critical because of the range of accident risk observed for different sites within the same category. The flexibility to change the IL is available in the current standard but was not used in practice, partly because engineers were unwilling to specify a value other than the "recommended" value. This will be addressed by specifying that the normal IL will be the lowest value in the dark shaded band, and by strengthening the advice on the circumstances that will justify it being increased.

The existing motorway and non-event categories have been retained, but with the option to give a higher default IL for dual and single carriageways. The higher level would be specified, for example, for bends with radius of curvature less than 1000m or texture depths below 0.8mm.

Junctions, with the exception of roundabouts and pedestrian crossings, have been combined into a single category with a range of ILs between 0.45 and 0.55. This allows an IL to be chosen appropriate to each junction layout and the associated advice stresses the need to raise the IL for sites with notable potential for conflict between road users, particularly where the outcome is likely to have severe consequences. It is anticipated that this will result in some single carriageway minor junctions being assigned a higher IL than at present (0.45), reflecting the strong trend with skid resistance found in the accident analysis. Major junctions would continue to be assigned an IL of 0.45, the lowest in the band, unless the site characteristics justify an increase. This reflects the lack of a strong trend for skid resistance for this category overall. For approaches to roundabouts and traffic signals, currently assigned a default IL of 0.55, it is envisaged that the IL will be reduced over time for sites that do not exhibit a notable accident pattern.

Roundabouts will remain a separate site category, because skid resistance data is reported differently (at 10m intervals rather than 50m intervals), with a range of ILs between 0.45 and 0.50. This is consistent with the current standard, given the change in test speed to be applied. Pedestrian crossings have been retained in a separate “high risk” category, with IL of 0.50 or 0.55, because of the serious consequences of accidents involving pedestrians.

For bends, the site category has been extended to include radius of curvature values up to 500m and separate ILs are given for dual and single carriageways, consistent with Table 2.

7- DELIVERING VALUE FOR MONEY

Section 3 demonstrated the wide range in levels of accident risk present for different sites within the same site category. As a result, it was recognized that targeting maintenance treatment to improve skid resistance at sites where there is greatest potential to reduce the accident risk would require better site investigation procedures. This was seen as a key opportunity to improve the implementation of the current standard and the site investigation procedure has been substantially strengthened.

Engineers are now required to consider the overall surface condition, including but not limited to skid resistance and texture depth, the observed accident history and the potential for accidents
due to the nature of the individual site. For high-value schemes this process is reviewed centrally as part of the Highways Agency's Value Management procedure for critically evaluating and prioritizing maintenance schemes.

To assist in the interpretation of accident data, national and route control data is supplied for comparison with the site under investigation. Any site where the accident risk was above average, or involved an above average proportion of accidents in wet conditions or where skidding was reported will receive greater priority. Sites with low skid resistance but no observed accident problem will also receive priority where the engineer reports that the nature of the site could make it prone to skidding accidents. This point is important because it provides the facility to pre-empt an increase in accident risk at high risk sites. However, if there is neither an observed or potential accident problem, then the priority will be low and the normal course of action would be to review the site again following the next skid resistance measurement. If successive investigations continue to indicate that no treatment is necessary then the IL for the site will be lowered.

8- OTHER CHANGES

A number of other changes are being implemented within the same revision to the standard:

- Maintenance schemes identified as a result of this policy will be monitored to ascertain whether they deliver the expected safety improvements and to support continuing improvement in the advice about targeting treatments.
- A single survey of the entire network will be carried out each year in England, in place of the current three-yearly cycle.
- The use of slippery road warning signs will be restricted to sites confirmed as needed treatment to improve the skid resistance, as opposed to all sites undergoing investigation, to reduce proliferation.

9- SUMMARY

A new skid resistance policy is being implemented on UK trunk roads in 2004, which will build upon the existing policy by providing more effective targeting of maintenance treatments to improve skid resistance and reduce accident risk.

10- ACKNOWLEDGEMENTS

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11- REFERENCES


