

A Probability-based approach for assessing the relationship between road crashes and road surface conditions

Piyatrapoomi, N.¹, Weligamage, J.², Bunker, J.¹

¹ School of Urban Development
Faculty of Built Environment and Engineering
Queensland University of Technology
Brisbane, Australia

² Road Asset Management Branch
Department of Main Roads
Queensland Government
Brisbane, Queensland
Australia

ABSTRACT

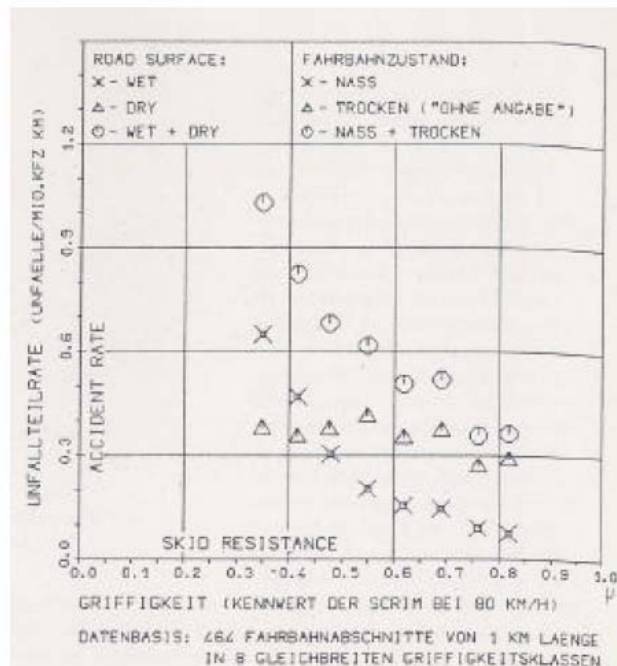
Skid resistance is a condition parameter characterising the contribution that a road makes to the friction between a road surface and a vehicle tyre. Studies of traffic crash histories around the world have consistently found that a disproportionate number of crashes occur where the road surface has a low level of surface friction and/or surface texture, particularly when the road surface is wet. Various research results have been published over many years and have tried to quantify the influence of skid resistance on accident occurrence and to characterise a correlation between skid resistance and accident frequency. Most of the research studies used simple statistical correlation methods in analysing skid resistance and crash data.

Findings from research projects do affirm various levels of correlation between skid resistance and accident occurrence. Studies indicate that the level of skid resistance at critical places such as intersections, curves, roundabouts, ramps and approaches to pedestrian crossings needs to be well maintained.

Management of risk is an integral aspect of the Queensland Department of Main Roads (QDMR) strategy for managing its infrastructure assets. The objectives of this paper are to explore current issues of skid resistance in relation to crashes, to provide a framework for a probability-based approach to be adopted by QDMR in assessing the relationship between crash accidents and road surface conditions.

INTRODUCTION

Skid resistance is one of the most important surface characteristics because it has a direct effect on traffic safety (Fulop et al., 2000). International research shows that the number of crashes increases as the skid resistance of a road decreases. Skid resistance of road surface is shown to be highly increased in wet conditions when compared with dry conditions. Figure 1 shows an example of the relationship between crashes and skid resistance found in 1983 where skid resistance of 464 intervals of 1 km length were measured and plotted against accident rates (Seiler-Scherer 2004).



J. Kamplade, H. Schmitz,
Erfassen und Bewerten der
Fahrbahngriffigkeit; Mai 1983

Figure 1 Relationship between skid resistance and accident rate (Source: Seiler-Scherer 2004)

Current practice in managing skid resistance by road authorities is based on comparing the actual skid resistance data with established investigatory skid resistance levels. The investigatory level is used to trigger site investigation. When recorded skid resistance data are below the investigatory levels, site investigation will be conducted. A threshold value which is usually set at 0.1 below the investigatory level is the trigger value for determining priority for treatment.

Skid resistance investigatory levels were firstly introduced by the UK Highway Agency Standard in 1988. Understanding the relationship between road crashes and skid resistance has become the subject of further research studies over many years. However, the outcomes of the road crashes/skid resistance relationship found by those researches provided mixed and inconclusive results.

EXISTING RESEARCH STUDIES

UK study

In the UK, as part of the review of skid resistance policy, network accident analysis and its relationship with skid resistance were conducted on a network of approximately 5800 km.

In this analysis, the network was divided into intervals of 500-metre for motorways and 200-metre for other roads. Within these lengths, surface conditions were reasonably homogenous. They divided skid resistance into different bands and accident risk for each skid resistance band and for each site category was statistically assessed. Mean and 90th percentile accident risk were calculated for different band of skid resistance and for each site. Accident risk was defined as the total number of accidents per 100 million vehicle km driven. In this study, although 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 accurate reporting of the surface condition at the time of accident (Viner et. al. 2005).

The results of the study indicated that accident risks for all skid resistance bands were found to be similar except within the lowest skid resistance band for the motorway site category. For dual carriageways non event category, accident risk was found statistically significant at locations with lower skid resistance. Non-event sites have no junctions, crossings, notable bends or gradients, but may have commercial or residential accesses. For single carriageway non-event category, the trend in accident risk was more significant when decreasing in skid resistance. For major junctions, the result indicated that accident risk was greater than the non-event site categories, but also indicated variation in the results. For roundabouts, the accident risk was higher than the other two categories, but also indicated variability in the relationship since the results did not show a clear trend in reducing accident risk for higher skid resistance.

Swiss study

In this study, a skid resistance survey was conducted between 1999 and 2000 on all the traffic lanes on Switzerland's national highway using the SCRIM (Sideway-force Coefficient Routine Inspection Machine). The measuring speeds were 60 km/h for junctions and on routes with speed limitations and 80 km/h for other general roadways. The skid resistance data were aggregated to mean values for intervals of 100 metres.

Accident data between 1994 and 1998 were collected and classified according to number, severity, accident in dry and wet road surface and accident type. The accident level was determined across the network for intervals of 500 metres. Annual average daily traffic (AADT) was also aggregated for intervals of 500 metres.

Since the skid resistance was aggregated for 100-metre intervals but accidents and AADT were aggregated for 500-metre intervals, the smallest skid resistance values in each 500-metre interval were assigned to the accident intervals of 500 metres.

Regression analyses were used in the analysis. The study concluded that no quantifiable correlation could be found between accidents and skid resistance (Seiler-Scherer 2004).

US study

In the US, skid resistance is generally quantified using some form of friction measurement such as a friction factor or skid number.

Friction factor (like a coefficient of friction): $f = F/L$ (1)

Skid number: $SN = 100(f)$ (2)

Where: F = frictional resistance to motion in plane of interface; L = load perpendicular to interface

Kuttesch (2004) conducted an extensive study in quantifying the relationship between skid resistance and wet weather accidents for data from Virginia. He used skid data measured between 2000 and 2003. The skid resistance were made with a locked-wheel trailer using a slip speed of 64 km/h. These data were reported as SN(64)S. The data were aggregated into 3,243 one-mile sections. For each section, the lowest value of SN(64)S was selected for use in the analysis. The data records of 3,243 sets were developed containing crash data, skid resistance data and traffic data (AADT). A total of 22,232 accidents occurred

at the study sites. The total accident rate per 10 million vehicle-miles travelled (VMT) and the wet accident rate per 10 million VMT were computed for each site.

The overall wet accident rate for the 3,243 sites was calculated to be 1.83 wet accidents per 10 million VMT (vehicle-mile travels). The traffic data (AADT) for the 3,243 sites for the state of Virginia were obtained for the analysis.

In his conclusion, the author pointed out that there was a statistically significant effect of skid resistance on wet accident rate, i.e wet accident rate increased with decreasing skid number. However, skid resistance information alone did not explain the variability in the wet accident rates.

Australia Study

Clague (2005) conducted wet road crash analysis and studied causations and relationships between skid resistance and pavement parameters including surface types, texture depth, seal age, traffic environment, pavement roughness and speed in the Mackay district of Queensland in Australia. Clague 2005 pointed out that data obtained in the analysis were imperfect and could contain a high degree of subjective assessment. The following measures were used in analysing crash data.

- Data were filtered to remove crashes that occurred in dry weather. Levels of severity of crashes were grouped. Unknown fog conditions were retained for consideration as crashes may occur in wet conditions.
- Police accident reports were reviewed to establish whether skidding was a contributory factor in the accident.
- It was identified whether the accidents had occurred on skid deficient sections or not.
- It was identified whether the accidents had occurred on asphalt or chip seal road surface.
- It was identified whether the accidents occurred due to deficient texture depth.
- Road surface condition was confirmed by viewing digital video.
- Comment was made on any issues identified and whether any actions had been required.
- Any apparent accident clusters were identified.

The author pointed out that analysis of other factors mentioned above had allowed the identification of other issues for minimum additional effort. Conclusions drawn from his wet crash analysis are summarised below.

- From 293 wet accidents, 166 accidents appeared to have a skidding component and 53 accidents appeared to occur on possibly skid deficient sections.
- High proportion of accidents involved some skid resistance components, a significant number of accidents involved other factors.
- Only 26 accidents of the 293 accidents occurred where texture depth was considered inappropriate.
- Speed and fatigue were cited as factors that likely caused fatal accidents, two were considered to be related to skid resistance and one occurred on a possibly skid deficient surface.
- Of the 293 accidents, 120 accidents were identified to have occurred around dawn or dusk. The lower number of accidents occurring at night possibly reflected lower traffic volume at night.
- Accidents involving learners and provisional licence holders were also investigated and 19% of accidents involved these types of drivers.

New Zealand Study

A study was conducted in New Zealand in attempting to combine detailed information of road geometry (i.e. horizontal curvature, gradient and cross-fall),

road surface condition (i.e. roughness, rut depth, texture depth and skid resistance), carriageway characteristics and crash data in crash risk analysis (Cenek & Davies 2003). They used annual surveys of 22,000 lane-km of New Zealand's State Highway network since 1997 in the analysis. The skid resistance data were measured using SCRIM. Four types of road crashes were investigated including:

- All reported injury and fatal crashes
- Selected injury and fatal crashes covering loss of control events
- Reported injury and fatal crashes occurring in wet conditions, and
- Selected injury and fatal crashes occurring in wet conditions.

One and two-way tables and Poisson regression modelling were used in the analysis in identifying critical variables and their relationships with crashes. The critical variables that are common to all crash types were traffic flow (ADT), horizontal curvature, skid resistance and to a lesser extent lane roughness (Cenek & Davies 2003). One and two-way tables were used for identifying trends in crashes. The one-way tables compared crashes with one critical variable, whilst the two-way tables compared crashes with two critical variables. The authors pointed out the trend shown in the one-way table that crash rates increased as horizontal curvature decreased; crash rates increase as skid resistance values decrease; and crash rate increased whilst traffic volumes decreased. The last case happened because low ADT suggested more challenging roads with narrower lanes, more tortuous alignment than roads with high volumes of ADT, hence leading to higher crash rates.

By using two-way tables, the results showed the trend of all crashes when compared with critical variables. The authors pointed out that there was a trend of wet crashes with horizontal curvature and SCRIM skid resistance coefficient. The crash rate increased as the curvature decreased but the apparent effect of ADT was reduced when the horizontal curvature was considered in the two-way table study. Crash rate increased as the skid resistance decreased and when the horizontal curvature decreased. However, the author observed that the crash rate for the wet condition showed greater statistical error because crash numbers were smaller than when all crashes were considered.

German Study

A Germany study was conducted on an approximately 8,000 km national routes from the states of Bayern and Nordrhein – Westfallen each having the road lengths of around 4,000 km. This study found that (Seiler-Scherer 2004):

The level of skid resistance of areas with wet accidents differed slightly from the level of skid resistance from other areas in the networks.

There was no evident correlation between accidents and skid resistance either in dry or wet condition in the areas that accidents significantly occurred.

However, it could be shown that the average skid resistance over all "accident-remarkable intervals" was lower than the one over the rest of the network.

PROPOSED RISK-BASED APPROACH

Road engineers and researchers recognise that low skid resistance is an important factor causing road crashes especially during wet conditions. However, the outcome of those studies did not provide conclusive results. In a joint research project of the Queensland University of Technology, Queensland Government Department of Main Roads and the Corporative Research Centre for Integrated Engineering Asset Management (CRC CIEAM), a method is being developed based on probability theory in assessing the relationship between crashes and road surface conditions (e.g. skid resistance, roughness, texture, etc.). The main objective in this analysis is to establish the probability distributions of the road surface condition variables for the small sections and

assess whether there are certain characteristics in the probability distributions of the road surface condition variables that cause crashes. The outcome of the analysis will be probability distributions of road surface conditions (e.g. skid resistance, texture etc.) that represent the boundary of acceptable crash rates (or zero crash rates) Figure 2 shows an example of the cumulative probability distributions of texture depth that divide road crashes into high, medium and low crash rates. The cumulative probability distribution that represents the boundary of acceptable crash rates (or zero crash rates) can be identified. The probability distribution represents the variability of the pavement surface condition and can be used for managing and controlling the pavement surface condition.

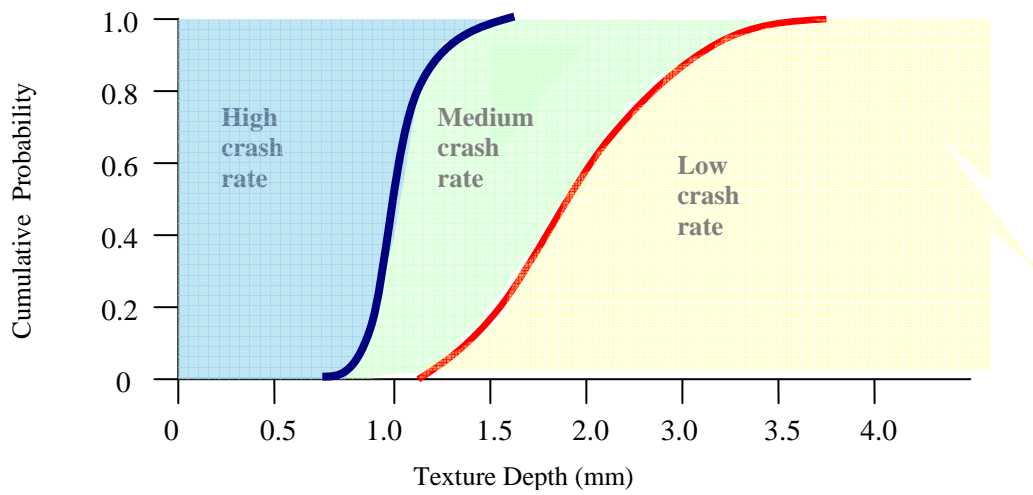


Figure 2 Example of the cumulative probability distributions that divide three supposed intensity rates of crashes

Steps of the analysis are given below.

- Step 1: Categorise road network
- Step 2: Identify road surface condition variables
- Step 3: Obtain historical road data from database
- Step 4: Divide total road length into small road sections
- Step 5: Quantify probability distributions of road surface condition variables of the divided small road sections
- Step 6: Mapping crash data in the probability distributions of small road sections for a road category
- Step 7: Divide and quantify crash rates according to the characteristics of the probability
- Step 8: Establish the characteristics of probability distributions for the identified crash rate intensities
- Step 9: Repeat the analysis for remaining variables

For a road category, the analyses of step 4 to step 8 are repeated for the remaining variables that were identified to be investigated in Step 2. In this study, the relationships between crashes and road surface condition variables including skid resistance; texture depth; roughness and rut depth were identified

to be assessed. The relationship between crashes and the road surface condition variables as presented in Figure 2 will be produced for skid resistance variable; texture depth variable; roughness variable and rut depth variable.

Step 10: Repeat the analysis for remaining road categories

The analyses of Step 4 to Step 9 are repeated for all road categories identified in step 1. The relationships as shown in Figure 2 between crashes and the road surface condition variables for all road categories are obtained.

Step 11: Assess investigatory levels

From the information as shown in Figure 2 of the crashes and specific skid resistance variable, appropriate cumulative probability distributions that represent the boundary of acceptable crash rates (or zero crash rates) can be identified for each road category.

Step 12: Establish investigatory levels

From the information of the cumulative probability distributions that represent the boundary of acceptable crash rates for all road categories, investigatory levels can be established in accordance with the Queensland Government Department of Main Road's safer road/safer community policies.

Step 13: Establish safer road/safer community measures for other road surface variables

From the characteristics of the probability distributions that represent acceptable crash rates obtained from Step 10, appropriate management plans will be developed to manage texture depth, roughness and rut depth in relation with crashes for safer road/safer community policies.

CONCLUSIONS

This paper presents a 13-step methodology in assessing the relationship of crash accidents and road surface conditions. This method is based on probability theory. In this method, the variability of road surface condition (e.g. skid resistance, texture, roughness, etc) of road sections is quantified by probability distributions. The numbers of crashes and rates of crashes can be assessed against each of these probability distributions. The characteristics of probability distributions of road surface conditions where high number of crashes occur can be developed. Probability distributions of road surface conditions of road surface for acceptable road crash rate can be chosen. This method is simple and the overall variability of road surface conditions can be assessed with crashes. The analysis should be conducted to compare all crash data and wet crash data. The probability distributions of road surface conditions for acceptable crash rates that are obtained from the analysis can be used as criteria for controlling and managing the road surface.

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