

Scottish Roads Research Board (SRRB)

SCRIM Investigatory Level Review
Transport Scotland

09 July 2020



Notice

This document and its contents have been prepared and are intended solely for Transport Scotland's information and use in relation to future considerations for the management of SCRIM across the Transport Scotland Trunk Road network.

Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 47 pages including the cover.

Document history

Job number: 5161547			Document ref: 5161547/TAM/001			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	Draft for Review	MM/CR/RA/ABF	AF	MM	LCT	16/02/18
Rev 1.1	Complete Draft for Review	MM/CR/RA/ABF	AF	MM	LCT	21/03/18
Rev 1.2	Updated based on TS feedback	MM	AF	MM	ABF	18/06/20
Rev 1.21	Updated based on TS feedback	MM	AF	MM	ABF	07/07/20
Rev 1.22	FINAL	MM	AF	MM	ABF	09/07/20

Client signoff

Client	Transport Scotland
Project	Scottish Roads Research Board (SRRB)
Document title	SCRIM Investigatory Level Review
Job no.	5161547
Copy no.	1
Document reference	Scottish Roads Research Board SCRIM Task Draft v1.22.docx

Table of contents

Chapter	Pages
Executive summary	5
1. Introduction	7
1.1. Background	7
1.2. Methodology	7
2. Assessment of Current Network Condition and IL's	8
2.1. Recommendations (Current SCRIM IL's)	9
3. Best Practice Review	10
3.1. Methodology	10
3.2. Local Authority Practices	10
3.3. Recommendations (Best Practice Review)	14
4. Risk Acceptance	15
4.1. Methodology	15
4.2. SCRIM History	15
4.3. Site Category/Accident Analysis	15
4.4. Transport Scotland Aggregate Performance Study	16
4.5. Transport Scotland HD28 Review 2015	16
4.6. SCRIM Site Category vs Wet Injury Road Traffic Collision Review	17
4.7. Recommendations (Risk Acceptance)	31
5. Traffic Speed and SCRIM	32
5.1. Introduction	32
5.2. Data	32
5.3. Traffic-speed data	32
5.4. Recommendations (Risk Acceptance)	34
6. International Practice Review	35
6.1. Methodology	35
6.2. Literature Review	35
6.3. European Skid Resistance Practices	35
6.4. International Skid Resistance Practices outside Europe	40
6.5. Recommendations (International Practice Review)	40
7. Conclusions and Recommendations	42
7.1. Conclusions and Recommendations	42
Appendices	44
Appendix A. Skid Resistance Investigatory Level	45
A.1. New Zealand	45
A.2. Australia VicRoads	46
Tables	
Table 2-1 TS Network SCRIM Analysis (whole network XSP CL1 only)	8
Table 3-1 Warwickshire County Council Site Category and Investigatory Level Table	11
Table 3-2 Hertfordshire County Council Site Category and Investigatory Level Table	12
Table 3-3 Cornwall County Council Site Category and Investigatory Level Table	14
Table 4-1 SCRIM Bands	17
Table 4-2 SCRIM Site Categories vs. wet injury RTC rates (RTC/100MVehKm)	18
Table 6-1 Skid resistance measuring device categories	35
Table 6-2 Typical Skid Number thresholds	40

Figures

Figure 4-1	Motorway Non-Event - CSC Band vs. wet injury RTC rates	19
Figure 4-2	Dual Non-Event - CSC Band vs. wet injury RTC rates	19
Figure 4-3	Single Non-Event - CSC Band vs. wet injury RTC rates	20
Figure 4-4	Approach to Junction - CSC Band vs. wet injury RTC rates	21
Figure 4-5	Approach to Junction - CSC Band vs. wet injury RTC rates	21
Figure 4-6	Gradients 5% to 10% - CSC Band vs. wet injury RTC rates	22
Figure 4-7	Gradients >10% - CSC Band vs. wet injury RTC rates	23
Figure 4-8	Pedestrian Crossing & Other High Risk Sites - CSC Bands vs. wet injury RTC rates	24
Figure 4-9	Roundabout - CSC Band vs. wet injury RTC rates	25
Figure 4-10	Dual Bend <500m - CSC Band vs. wet injury RTC rates	26
Figure 4-11	Dual Bend <500m - CSC Band vs. wet injury RTC rates (updated)	26
Figure 4-12	Single Bends – Curvature 500m to 250m vs. CSC Band vs. Wet injury RTC rates	27
Figure 4-13	Single Bends – Curvature 250m to 100m vs. CSC Band vs. Wet injury RTC rates	27
Figure 4-14	Single Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates	28
Figure 4-15	Single Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates (updated)	28
Figure 4-16	Dual Bend <500m - CSC Band vs. wet injury RTC rates	29
Figure 4-17	Dual Bends – Curvature 500m to 250m vs. CSC Band vs. Wet injury RTC rates	30
Figure 4-16	Dual Bends – Curvature 250m to 100m vs. CSC Band vs. Wet injury RTC rates	30
Figure 4-19	Dual Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates	31
Figure 5-1	Average Speed on the A82 to the east of Loch Achriochtan	32
Figure 5-2	A82 Site Categories (CL1)	33
Figure 5-3	A82 Road Traffic Collision Data (2014 – 2016) – Sourced from DfT website	33
Figure 6-1	Map illustration Primary Skid Resistance Measurement device	36
Figure 6-2	Routine Survey Frequency (years)	37
Figure 6-3	Survey Season	37
Figure 6-4	Number of Skidding Resistance Thresholds	38
Figure 6-5	Warning Signs - remedial option if skidding resistance below Warning or Threshold	38
Figure 6-6	Speed Limit – remedial option if skidding resistance below Warning or Threshold	39
Figure 6-7	Action plan safety measures in the case of RWS maintenance advice and in the case of DBFM	39

Executive summary

Atkins was commissioned by the Scottish Roads Research Board (SRRB) to review the appropriateness of the current SCRIM Site Categories and their associated Investigatory Levels. The purpose of this review was to explore the suitability of the Investigatory Levels for the Transport Scotland (TS) road network, particularly on more lightly trafficked roads. To deliver this task Atkins completed the following was undertaken:

- an assessment of the current network SCRIM condition and Investigatory Levels (IL)
- reviewed best practice techniques that have been adopted in the UK
- an assessment of the risk acceptance in respect to current SCRIM CSC values and Accident Rates
- assessed the relationship between traffic speed and SCRIM data
- a review of International skid resistance management practices.

As a result of this research task several conclusions can be drawn, and recommendations have been developed for consideration by the SRRB and TS.

The main conclusions and recommendations of this review task are identified in the following sections and are provided for consideration by TS.

Analysis of the current condition of the network in respect to SCRIM and IL's determined that approximately 28% of the TS network in CL1 is below the IL. Roads in the North West appear to be worse with approximately 35% of the CL1 network below the IL. Several recommendations have been identified that may assist in the management of SCRIM on the network including:

- Full review of all the IL's currently held on the TS IRIS system to ensure that they are correct and appropriate. If this is restricted by available budgets, then focus on a one area and base any further recommendations on these findings.
- In association with the above recommendation conduct an analysis of the currently assigned IL's using shapefiles to ensure that they are all correctly and accurately positioned.
- Review how accident rates are developed and applied to the network and apply any potential changes to the network to understand the opportunity to re-calculate data for lowering of current IL bands.
- Identify any potential gaps in the SCRIM data and ensure that a process is in place to manage these locations. This could include the assessment of high-risk areas, undertake a risk analysis to see if alternative methods of achieving skid resistance and/or road condition are required.
- Complete a data cleansing exercise of the crash data by reviewing the causality factors, ensuring that an incident is attributable to the road surface and/or skidding issue before applying it. The results may impact on the Accident Rates and adjust the risk rating of individual locations of negative SCRIM difference.

The best practice review identified that HD28/15 (as well as its predecessors) is not intended for the management of skid resistance on local roads, although similar principles may still apply. For this reason, Local Authorities (LA's) throughout the UK, have been developing and using their own skidding resistance strategies as they generally have a lower volume of traffic (including lower commercial vehicles) as well as many 'rural' evolved roads that are not designed to current standards. A number of LA's have developed their own bespoke SCRIM Category and IL tables following research into the crash rates and alignment of their network.

This review recommends that TS investigate the potential for a bespoke Site Category and Investigatory Level Table that better suits the rural "evolved" sections of the TS network.

With traffic speed data becoming more accessible, road authorities are able to undertake a risk-based approach to managing the skidding resistance of the road network, particularly on high speed bends where current practices identify vehicle speed as a key component to wet skid incidents.

Analysis of CSC data vs. wet injury RTC rates has identified that for the majority of the site locations the current IL is considered appropriate. The analysis highlighted four recommendations for consideration by TS, as follows:

- Merging 'Gradient 5%-10%' (G1) and 'Gradient >10%' (G2) into a unified 'Gradient \geq 5%' site category.

- Undertake a more detailed review to establish the impact of reducing the Single and Dual Bend radius from 500m to 250m.
- Examining wet injury RTC's within the boundaries of 'Approach to Junction' site categories, analysing if there are trends based on junction type (Traffic Signal, Give Way, Stop Line, Roundabout, etc), carriageway type, Speed Limit, visibility and vehicle speed (average and 85th percentile).

Through the review of traffic speed and its relationship with SCRIM it is recommended that analysis is undertaken on the S1/S2 bends along a route, or in a particular Operating Company area, to determine if actual traffic speed and the bend radii has an impact on the likelihood of wet skid road traffic incidents. This analysis should consider:

- SCRIM Site Category & Investigatory Level data
- Speed Limit
- Vehicle speeds
 - Mean vehicle speed
 - 85th Percentile vehicle speed
- Traffic Count Data
- SCANNER data
 - Alignment
 - Crossfall
- Injury Road Traffic Collision Data

It has been concluded from the international practice review that the primary method of surveying skid resistance is using side-ways force types surveys, such as SCRIM and the SKM skid resistance measurement devices utilised by Germany, Switzerland and Netherlands. Research has determined that there is consistency between the SCRIM and SKM readings when the machines utilise the same test tyres.

Additionally, the international practices review indicates that it is widely accepted that speed is a major factor when considering the skidding resistance of road surfaces, with several international road authorities reducing the speed limits on lengths of road which have below acceptable skidding resistance to manage the risk.

It is recommended that the potential to consider traffic speed data in the assignment of Site Categories and Investigatory Levels is investigated as identified through the traffic speed and SCRIM investigations.

In summary, several recommendations have been identified for consideration by both SRRB and TS that present potential opportunities to improve the way in which the network is managed in terms of skidding resistance. It is also recommended that if any of these findings are taken forward, they should be considered in respect to the ongoing investigations into the performance of aggregates on the network to ensure that any changes consider the findings of these studies.

1. Introduction

1.1. Background

Design Manual for Roads and Bridges Volume 7 Part 3 HD28/15 is the current UK standard for managing skid resistance on the Scottish trunk road network. Some local authorities also adopt the principles contained therein. The standard defines a system of categorisation for roads based primarily on their geometry and location situation.

Each category defines a series of Investigatory Levels (IL's) against which measured SCRIM values can be compared to identify areas of potentially increased risk. The standard then sets out a process of investigation to consider the risk at specific sites to support the prioritisation of maintenance works and investment.

SCRIM surveys indicate that a relatively large proportion of the trunk road network (around 25-30%) is below Investigatory Level (IL). This does not however mean that these sections of road are unsafe, and this would appear to be supported by the relatively low numbers of wet skidding related collisions being recorded.

A statistical examination of the relationship between SCRIM and frequency of skid related collisions formed the basis for the establishment of IL's in HD28, last examined before the 2004 publication, building on earlier studies by TRL. Since the original research, there have been repeated incremental improvements in vehicle technology, including braking systems and tyre manufacture resulting in a significantly altered vehicle fleet. Road surfacing materials have also changed dramatically over the past fourteen years which combines to mean that the tyre/road interface and the demands placed upon the surface course by road users has changed.

The following report presents the findings of research into the following areas:

- Assessment of SCRIM MSSC and IL's - assess the current condition of the Transport Scotland (TS) network in relation to the range of Investigatory Levels that are assigned to a Site Category as documented in HD28/15 Table 4.1 Site categories and Investigatory Levels. The approach will be to assess the impact of a reduction in IL by 0.05 would have on the quantity of the network below IL;
- Best Practice Review - to identify best practice approaches to the management of SCRIM that have been utilised across the UK;
- Risk Acceptance - understand the concepts and philosophy behind setting of the IL and how much risk is deemed acceptable by TS;
- Traffic Speed and SCRIM - research and report on technologies that exist where data is gathered that provide the potential to determine the speed of travel across the network
- International Practice Review - review international practices that are utilised to assess skidding resistance and how thresholds are determined.

1.2. Methodology

Atkins divided the initial assessment and research into five key elements and assigned these tasks to technical experts in each of those areas to deliver. The five areas are:

Section 2	Assessment of Current Network Condition and Investigatory Levels (IL)
Section 3	Best Practice Review
Section 4	Risk Acceptance
Section 5	Traffic Speed and SCRIM
Section 6	International Practice Review

2. Assessment of Current Network Condition and IL's

The Transport Scotland (TS) SCRIM data is held on WDM's Integrated Roads Information System (IRIS) system.

For the purposes of this task the network being considered includes the five Operating Companies (North East, North West, South East, South West and Forth Bridge). The overall length of the CL1 (lane 1) network (as this cross-sectional position should be common to all sections) was 3884km.

As a result of the analysis it is identified that approximately 8km of SCRIM IL's are not tagged as High (H), Medium (M) or Low (L) within IRIS and therefore for consistency it is recommended that these are updated.

The key driver for this study is the level of SCRIM readings that are currently below the designated IL on the TS network. From the available data received in August 2017, approximately 1077km (CL1) is negative, that's approximately 28% of the overall network. TS reported that they have undertaken some initial studies and found that by reducing sites with no accident history in last 3 years to the 'Low' category could reduce the negative SCRIM readings by 6%.

Having looked at the available data overall only 7% currently falls into the 'Low' category (Table 2-1). Therefore, as a result it is believed that there is further potential for reducing the SCRIM difference by lowering the IL's where safe to do so and within the bounds of HD28.

Table 2-1 TS Network SCRIM Analysis (whole network XSP CL1 only)

SCRIM Cat Band	Positive SCRIM Difference				Negative SCRIM Difference				Total
	L	M	H	Total	L	M	H	Total	
?	-	-	-	-	0.07	0.00	-	0.07	0.07
A	0.71	-	428.36	429.07	0.00	-	53.00	53.00	482.07
%	0%	-	11%	11%	0%	-	1%	1%	12%
B	0	760.9	3.95	764.85	0.00	201.68	4.05	205.73	970.58
%	0%	20%	0%	20%	0%	5%	0%	5%	25%
C	8.94	1290.48	2.57	1301.99	1.24	345.77	3.12	350.13	1652.12
%	0%	33%	0%	34%	0%	9%	0%	9%	43%
G1	58.33	-	0.14	58.47	51.96	-	1.42	53.38	111.85
%	2%	-	0%	2%	1%	-	0%	1%	3%
G2	0	1.11	0.00	1.11	0.00	1.93	0.00	1.93	3.04
%	0%	0%	0%	0%	0%	0%	0%	0%	0%
K	5.66	-	0.75	6.41	3.32	-	1.18	4.5	10.91
%	0%	-	0%	0%	0%	-	0%	0%	0%
Q	23.72	48.3	0.05	72.07	29.08	96.12	0.17	125.37	197.44
%	1%	1%	0%	2%	1%	2%	0%	3%	5%
R	4.79	-	0.00	4.79	17.23	-	0.30	17.53	22.32
%	0%	-	0%	0%	0%	-	0%	0%	1%
S1	29.02	-	0.40	29.42	22.65	-	0.16	22.81	52.23
%	1%	-	0%	1%	1%	-	0%	1%	1%
S2	4.02	133.55	0.48	138.05	2.01	240.33	0.61	242.95	381.00
%	0%	3%	0%	4%	0%	6%	0%	6%	10%
Total	135.19	2234.34	436.70	2806.23	127.49	885.83	64.01	1077.33	3883.64
%	3%	58%	11%	72%	3%	23%	2%	28%	100%

It is important to note that sites indicating SCRIM values currently approaching the IL, could become 'negative' following the next round of surveys. It should also be noted that there can be variances in the SCRIM results from year to year which can affect the reporting of these results.

A key element here appears to be the interpretation of crashes and in particular the calculations that relate to the changing of IL's, detailed by TS as an 'Accident Rate'. These Accident Rates are applied across the entirety of a road based on similar road types. However, if you look in detail at the wet crashes (skidding included) there are only wet crashes on only 4% (160km) of the CL1 network.

Looking at the North West (NW) Unit in more detail, the Unit has a length of 1443km in CL1. Of this 1443km length, 511km has negative SCRIM readings equating to approximately 35%. Only 20km of those 511km have crashes detailed within its sub section lengths, showing a similar level to the overall network, with crashes only occurring on 4% of the actual network.

This highlights a potential area for further detailed investigation in how Accident rates have been applied in deciding whether to reduce or increase the level of IL's (H/M/L) and understanding the potential for a more detailed application.

To provide an example, taking Section 12430/05 on the A90 at a detailed level, the section is over 4km long and has its IL's set at Medium, these are detailed as not to be lowered due to the calculated Accident rate. The accident variance applied for this road/section is 215%, however there are no recorded wet crashes on this section, this presents the potent to lower the IL by applying a more localised accident rate.

It is noted that the reported 511km of negative SCRIM values reported in the NW unit, does have 92km where the SCRIM Difference values >0.10. These sections would appear to be beyond any assistance from reducing an IL within the bounds of HD28 and would be recommended for further investigation, accident analysis and potential remedial action in line with the TS Skidding Policy.

In terms of the available SCRIM results, there is missing data, particularly on roundabouts. It is understood that these and some other high-risk areas are difficult to survey and therefore may have no data available, however this doesn't remove them from the issue of risk.

Within the network negative SCRIM values, approximately 640km of 1077km has SCRIM figures between 0.00 and 0.04 below IL, that's approximately 60% of the network. In theory, some of this could be removed if the IL's were reduced by 0.05 and the assumption is that along with other identified recommendations this could potentially be by more than 6% currently estimated by TS.

2.1. Recommendations (Current SCRIM IL's)

- Full review of all the IL's currently held on the TS IRIS system to ensure that they are correct and appropriate. If this is restricted by available budgets, then focus on a one area and base any further recommendations on these findings.
- In association with the above recommendation conduct an analysis of the currently assigned IL's using shapefiles to ensure that they are all correctly and accurately positioned.
- Review how accident rates are developed and applied to the network and apply any potential changes to the network to understand the opportunity to re-calculate data for lowering of current IL bands.
- Identify any potential gaps in the SCRIM data and ensure that a process is in place to manage these locations. This could include the assessment of high-risk areas, undertake a risk analysis to see if alternative methods of achieving skid resistance and/or road condition are required.
- Complete a data cleansing exercise of the crash data by reviewing the causality factors, ensuring that an incident is attributable to the road surface and/or skidding issue before applying it. The results may impact on the Accident Rates and adjust the risk rating of individual locations of negative SCRIM difference.

3. Best Practice Review

3.1. Methodology

For the purposes of this review we have undertaken a literature review to understand best practice approaches in the management of network skid resistance from around the UK to identify potential opportunities to be considered by Transport Scotland (TS).

3.2. Local Authority Practices

HD28/15 (as well as its predecessors) is not intended for the management of skid resistance on local roads, although similar principles may still apply, and for this reason Local Authorities (LA's) throughout the UK, have been developing and using their own skidding resistance strategies as they generally have a lower volume of traffic (including lower commercial vehicles) as well as many 'rural' type roads.

It was in the early 1990's that saw the need for LA's to have a formal skidding policy of their own to protect against unnecessary claims by the public which has been increasing in number. Generally, LA's in England undertake SCRIM on their 'A' principal roads and on some 'B' and 'C' roads as determined by route criticality and traffic volume considerations.

Warwickshire, Hertfordshire and Cornwall County Councils have been chosen for the purposes of this review as they are considered to be front runners in the asset management and the management of network skidding resistance.

3.2.1. Warwickshire County Council (WCC)

Warwickshire County Council (WCC) have developed their own skid strategy, based on HD28/04, to manage their network following detailed assessment of their network.

Historically, in Warwickshire, skid resistance testing has been undertaken on the roads that carry the highest volumes of heavy traffic. A Roads are tested as the most important network routes and are generally the more heavily trafficked parts of the network.

They recognise that deterioration in skidding resistance is accelerated primarily by commercial vehicles. Therefore, in addition to testing the A Road network, B Roads where traffic counts indicate more than 100 commercial vehicles per lane per day (cv/l/d), or crash investigations show a need, are routinely tested.

Most of the WCC local network has evolved over many centuries of use, rather than having been designed to particular standards, any designed maintenance work will have invariably been undertaken to fit the available space and may not always have met any national criteria.

Consequently, for Warwickshire's roads there are many bends on the network with radii less than 500m. HD28/04 was designed primarily for use on Motorways and Trunk Roads where sudden bends are unusual. At such unexpected locations, a higher skidding resistance is appropriate whereas on local County roads, curvature is more commonplace and less unexpected.

As a method of managing the variable risk for the bends present WCC have developed additional IL's to separate the bends into two categories (Bends 500m to 250m radius and Bends <250m radius). This approach has taken account of the change that occurred between HD28/94 and HD28/04 where the Site Category for bends was changed from <250m in HD28/94 to <500m in HD28/04 and re-introduced the parameters to enable them to better manage the risk.

The following Figure 3-1 identifies the Site Category table for WCC.

Table 3-1 Warwickshire County Council Site Category and Investigatory Level Table

Site category and definition		Investigatory Levels at 50 kph.					
		0.30	0.35	0.40	0.45	0.50	0.55
	<i>Risk Rating</i>	1	2	3	4	5	6
B	Dual carriageway non-event		B				
C	Single carriageway non-event		C-	C			
Q	Approaches to and across minor and major junctions, approaches to roundabouts			Q*	Q-	Q	
K	Approaches to pedestrian crossings and other high risk situations			K*	K-	K	
M	Approaches to single carriageway minor junctions (D roads and heavily trafficked private accesses)		M*(i)	M-	M		
R	Roundabouts		R*(ii)	R-	R		
G1	Gradient 5-10% longer than 50m		G1*(ii)	G1-	G1		
G2	Gradient >10% longer than 50m			G2*(ii)	G2-	G2	
S1	Bend radius <500m - dual carriageway		S1*(ii)	S1-	S1		
S2	Single carriageway 40 mph or above Bend radius 500m - 250m		S2*(ii)	S2-	S2		
S3	Single carriageway 40 mph or above Bend radius <250m - 100m			S3*(ii)	S3-	S3	
S4	Single carriageway all speeds (i) Bend radius < 100m			S4*(ii)	S4-	S4	

(i) Bends on single carriageways in 30mph zones will only be categorised when less than 100m radius. Bends above 100m radius in 30mph areas will be categorised "C" - non-event.

(ii) May only be used after appropriate assessment AND when the preceding IL is lower or equal. NOT to be used if the preceding IL is greater.

Figures in dark shading are to be used as starting point when setting an IL for the first time. They reflect the initial IL values in Paragraph 4.9 and Table 4.1 of HD28/04. Minus (-) values represent one risk rating below the initial IL value. Star (*) values represent two risk ratings below the initial IL value.

This approach could be considered a potential appropriate change for the TS network as a number of the single carriageways are evolved and therefore are not designed to standards.

3.2.2. Hertfordshire County Council (HCC)

Hertfordshire County Council (HCC) have also developed their own Skid Resistance Strategy after detailed consideration of their network and the risks.

HCC determined that notwithstanding the fact that HD 28/04 was developed to describe management of skid resistance for trunk roads (typically motorways), the principles in the Standard are applicable to non-trunk roads; such as the Hertfordshire network. However, local authority highway networks tend to have developed from roads with lower geometric standards than those on the trunk road network and include extensive urban lengths. While HD 28/04 was identified as the best place to start for establishing the intervention levels for the HCC network, it was determined that it does not represent the most effective and/or appropriate framework for managing skid resistance on the network.

The Strategy was built based on the HD28 guidance and was developed to consider the specific requirements of the HCC highway network.

For the Hertfordshire network the Strategy team extended the DMRB range to include 16 site categories. While there are some direct parallels between the Strategy investigatory level (IL) categories and the HD 28/04 categories, the Hertfordshire site categories allow for lower and higher risk situations than are likely to be encountered on the trunk road network.

The main changes that could be considered of interest for the TS network include:



- Expansion of the range of IL's in some categories i.e. roundabouts
- Introduction of two Site Categories for Bends, 500m to 250m radius and <250m radius

The following Figure 3-2 identifies the Site Category table for WCC.

Table 3-2 Hertfordshire County Council Site Category and Investigatory Level Table

Table 1: HCC Site Categories and Investigatory Levels

Site category and definition		Investigatory Level (IL)							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway class	Not Applicable							
B	Dual carriageway non-event								
C	Single carriageway non-event, speed limit >30 mph								
D	Single carriageway non-event, speed limit ≤30 mph								
QU	Across all junctions and uncontrolled approaches to junctions								
QC	Controlled approaches to junctions, including approaches to roundabouts								
R	Roundabout circulatory carriageway								
K	Approaches to controlled pedestrian crossings								
G1	Gradient 5-10% longer than 50 m								
G2	Gradient ≥10% longer than 50 m								
S1	Bend radius ≤500 m – dual carriageway								
S2	Bend radius ≥250 m and <500 m – single carriageway								
S3	Bend radius <250 m – single carriageway								
U1	Unclassified road with speed limit ≤30 mph	0.35 for all locations except where site categories QC, K, and/or US apply							
U2	Unclassified road with speed limit >30 mph	0.40 for all locations except where site categories QC, K, and/or US apply							
US	Unclassified Specific; IL site on unclassified road for which specific intervention level has been set	IL will be determined from risk analysis for site, based on site categories above.							

 Left hand dark grey box is used as default IL value
 Selectable if risk analysis has been carried out

3.2.3. Cornwall County Council (CCC)

Cornwall County Council (CCC) have based their skid resistance policy on HD 28/04 and HD 36/06 documents, however the results from a separate study that compared the wet accident rates against skid resistance levels indicated that changes should be made to the investigatory levels specified in HD 28/04 to optimise the risks for local roads in Cornwall. In addition, there are occasions where certain parts of the HD 28/04 standard are not considered appropriate for Cornish local roads, in these cases the areas of the standard that were considered inappropriate have been clearly identified and the rationale for not following the standard has been provided.

Cornwall commissioned a study to compare the wet accident rate at various skid resistance values at different site categories. The results from this study provided the information to set investigatory levels for each of the site categories for local roads in Cornwall. It was found from the study that the accident rates were higher on the approaches to roundabouts rather than on approaches to junctions and for bends with radii <100m than for bends with larger radii.

The main change that could be considered of interest for the TS network is the separation of bends into three Site Categories, <500m and >250m, <250m and >100m and <100m.

CCC also introduced some additional changes where it was considered that the HD28 standard was not considered appropriate for local Cornish roads. Specifically, it is recommended that the 50m approach to bends and gradients are not included within the policy.

The philosophy is that on county roads in areas such as the south west of England a significant proportion of the length of the network surveyed by SCRIM will be categorised as less than 500m radius and or gradient at or above 5%, compared with the proportion on the motorway and trunk road network. The approaches to the bends and gradients will not therefore be so much of a surprise to a driver and unless there is evidence of accidents it is not considered that the approach to bends or gradients present a high risk of wet road skidding.

Another interesting aspect is the allocation of three shadings of Low, Default and High Investigatory Levels associated with each Site Category with the upper and lower thresholds being based upon risk assessment. This is a very similar approach to the methodology developed for the TS network and therefore considered to be good practice that is used by others in setting IL's.

The following Figure 3-3 identifies the Site Category table for CCC.

Table 3-3 Cornwall County Council Site Category and Investigatory Level Table

Site category and definition		Investigatory level at 50km/h							
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65
A	Motorway class								
B	Dual carriageway non-event								
C	Single carriageway non-event								
Q1	Approaches to and across minor and major junctions,								
Q2	Approaches to roundabouts								
K	Approaches to pedestrian crossings and other high risk situations								
R	Roundabout								
G1	Gradient 5-10% longer than 50m								
G2	Gradient >= 10% longer than 50m								
S1	Dual carriageway bend radius < 500m								
S2<100	Single carriageway bend radius < 100m								
S2>100<250.	Single carriageway bend radius > 100m <250m								
S2>250<500.	Single carriageway bend radius > 250m <500m								

Lowest IL threshold (based on risk assessment)	
Default IL	
Upper IL threshold (based on risk assessment)	

3.3. Recommendations (Best Practice Review)

HD28/15 (as well as its predecessors) is not intended for the management of skid resistance on local roads, although similar principles may still apply, and for this reason Local Authorities (LA's) throughout the UK, have been developing and using their own skidding resistance strategies as they generally have a lower volume of traffic (including lower commercial vehicles) as well as many 'rural' type roads.

The rural parts of the TS network are generally old evolved carriageways that are not designed to current standards. Therefore, it is recommended that TS investigate the potential for a bespoke Site Category and Investigatory Level Table that better suits the TS network.

4. Risk Acceptance

4.1. Methodology

This element of the task was completed to understand the concepts and philosophy behind setting of the Investigatory Level (IL) and how much risk is deemed acceptable when assessing and setting the IL requirements for the network.

4.2. SCRIM History

The current skidding resistance guidance, HD28/15, was issued in July 2015 and superseded the previous versions HD28/04 and HD28/94. Prior to that there was Road Note 27. Issues relating to skidding resistance on roads even brought about a published paper (Report Paper 52) in October 1956 by Cyril George Giles titled 'Skidding Resistance of Roads and the Requirements of Modern Traffic', part of which investigated and considered the relationship between skidding resistance and the risk of skidding crashes. It further stated that the risk of skidding crashes would be greatly reduced with coefficients above 0.6 and that 0.5 would be acceptable in most cases and that below 0.4 the risk would increase 'rapidly'.

It is fair to say that the road layout, volume of traffic and changes to vehicles have all changed beyond recognition from 60 years ago. One of the objects of TRRL Report LR510 A Guide to Levels of Skidding Resistance for Roads, which was published in 1973, was to define levels of resistance to skidding. Up to that point in time, skidding sites had been classified rather simplistically into 3 tables with a (sideway force) coefficient of 0.55 for the 'difficult' sites (i.e. roundabouts, bends, gradients and approaches to traffic signals), 0.45/0.50 for the 'average' sites (i.e. motorway/trunk/principal roads) and 0.40 for 'other' sites. LR510 recommended four site categories but which also included a risk rating from 1 to 10 for each site. LR510 further recommended minimum PSV's for aggregates that would achieve a certain sideway-force coefficient level, and which was based on daily commercial vehicle volumes.

HD28/15 para 1.6 states that the objective is to maintain a consistent approach to the provision of skid resistance (strategic network) and to provide a level of skid resistance appropriate to the nature of the road environment at each location. The latter being determined from a combination of crash history, the friction demands of road users (the site category) and local judgement of site-specific factors.

4.3. Site Category/Accident Analysis

Before any accident analysis is undertaken, it is paramount that all the Site Categories and their respective IL's on the network have been set up correctly. The practice of checking the Site Categories and IL's is a requirement of HD28/15 and should be undertaken every 3 years (or 1/3 of the network annually).

The accuracy of the location of crashes has always been slightly contentious and although this has improved due to better technology, location errors persist and it is for this reason that as a rule of thumb, the skid site is extended by 200m in both directions with regards to searching for crash data for that site.

Skidding resistance research and crashes in various forms have been around since the 1930's. The New Zealand Transport Agency (NZTA) which is responsible for 11,000km of 'state highway', produced a report "The NZ Skid Resistance Policy and Crash Rate and Skid Resistance Trending for the Different Site Categories" in 2014 to determine the effectiveness of their skid resistance policy, in terms of the reduction in wet skidding crashes over a 10-year period (2003-2012). The conclusion was that in relation to fatal and serious injury crashes, the trend was down when considering the entire network, however, in looking at their regional locations, a few locations indicated an increase. Through this research project it was established that there is a strong relationship between wet surface friction and vehicle speed with regards to crashes on bends. In addition, NZTA research showed that they were having many crashes on bends between 250-400m radius but now have assigned a 'H', 'M' or 'L' risk rating based on their crash prediction model which considers the approach speed, bend speed difference and bend geometry. As a result, NZTA have looked at reducing speed limits to support lower skid resistance IL's particularly on high risk bends – a trial was undertaken on State Highway 58 and concluded that if the IL could be maintained at 0.4 (average skid resistance level achieved on State Highways when local aggregates are used), a 10kph reduction in max operating speed was sufficient to give the same level of crash risk. See Section 5 for further details regarding traffic speed and SCRIM.

Another factor in relation to risk of crashes, is whether to include a site where there has only been 1 reported wet crash. The rationale behind this is that if there has only been 1 (within the previous 3 years), this could be considered a random occurrence, although it should be stated that details of the police crash report should be carefully read before dismissing any crash as random or otherwise.

4.4. Transport Scotland Aggregate Performance Study

The Transport Scotland (TS) Skid Policy Research Aggregate Performance Study: Stage 2 was developed by WDM, to assess the SCRIM performance of local aggregates being used on the TS network. The main conclusions from this report include:

- i. The data indicates the anticipated increase in SCRIM coefficient as the stated PSV increases, however the increase does not appear to be as high as those reported in LR332 that are applied in HD36/06.
- ii. Recommendations to select the higher PSV requirements for sites where more than one PSV is required in accordance with HD36/06.
- iii. An assessment of the aggregate source suggests that some aggregates are performing 'better' than expected for the stated PSV.
- iv. Some aggregates are performing well on highly trafficked routes and some aggregates have been used in locations where a higher PSV is required in accordance with HD36/06.
- v. The investigation identified a number of less frequently used aggregates that appear to be performing well that present the opportunity to encourage their wider use.

The report presents data that suggests approximately 18% of the surface courses that were installed on Single Non-Event carriageways with the PSV as identified through HD36/06 are below the IL. This is considered a significant factor that may be influencing the overall network condition in terms of SCRIM.

It is recommended that potential areas for further investigation identified through this report will need to be considered in line with the recommendations of this report to ensure that a thorough methodology is developed.

4.5. Transport Scotland HD28 Review 2015

The Transport Scotland HD28 Review May 2015 (updated January 2016) was developed by WDM Ltd, to assess the impact of TS's Skid Policy as well as how it is being implemented by the Operating Companies (OC). In the conclusions, the affect was broken down into 3 sections:

- i. Accident record - the review concluded that the number of 'wet' crashes had reduced between 2009-13.
- ii. Accident Rate v SCRIM - the review concluded that the analysis showed a good correlation within the default Investigatory Levels (IL) for most categories. This showed the anticipated increase in accident rate as SCRIM reduces and that accident rates vary significantly between site categories except for roundabouts where a high proportion were below IL and which suggests a relaxation of the IL could be justified.
- iii. Site Reviews - the review concluded that due to the different characteristics of the TS network, some of the OC's only investigated P1 (where $CSC < IL + \text{a minimum of 1 wet crash over 3 years}$) sites, concluding that the site prioritisation be refined so that the same criteria is used by all OC's. The review further concluded on the speedy update of the Integrated Road Information System (IRIS) database, clearly define 'monitor' of sites, follow up of 'treated' sites and checking of accident sites not on the priority list.

The final recommendations from the review stated:

- i. The principles of prioritising sites, undertaking investigations and implementing treatments be continued.
- ii. The trend in accident numbers and skid resistance established within the report be monitored on an annual basis.
- iii. Develop a revised prioritisation system (subject to any contractual constraints) that defines a 'single network' criteria for investigation
- iv. Update the Guidance Document to provide more advice on setting IL's where more than one category applies, encourage OC's to capture more information for 'other' recommendations and provide guidance on interpreting crashes.
- v. A detailed assessment of the 2012-13 investigations should be undertaken to assess the number, location and nature of these sites. The OC's should then assess these sites and determine whether action is required.
- vi. The system used to manage sites should be developed to provide better information to inform investigations. This should also include a need to track and close out recommendations.

4.6. SCRIM Site Category vs Wet Injury Road Traffic Collision Review

4.6.1. Introduction

As part of this task Atkins undertook a desktop review of the wet accidents against SCRIM Site Category, replicating the methodology contained in 'Implementing a Revised Skid Policy into Scotland' produced by Morrison D., Grant W., and Donbavand J., 2008.

The review focused on comparing the Characteristic SCRIM Coefficient (CSC) and the number of wet Road Traffic Collisions (RTC) per 100 million vehicle kilometres (100MVehKm) for each Site Category. Transport Scotland provided Atkins with the Site Category, SCRIM Summary, Network, Traffic flow, SCANNER Alignment and RTC Data from IRIS.

4.6.2. Methodology

Atkins utilised GIS to plot the RTC data utilising the Ordnance Survey Grid References (OSGR) supplied. SCRIM Summary data, containing the complete Transport Scotland network, however **only XSP CL1 2016 SCRIM CSC and Site Category data**, was plotted against the network, using a GIS query, each RTC was referenced to the nearest SCRIM Summary subsection.

Applying the outputs from the GIS analysis and utilising the Traffic Flow data provided by TS, the number of wet RTC/one hundred million vehicle kilometres (Acc/100MVehKm) was calculated and summarised based on the Site Category and CSC Bandings. The results are presented later in this document under Section 4.6.3.

Table 4-1, below, was utilised to band the CSC values; it should be noted that the table below differs to Table 2 MSSC Bands contained in 'Implementing a Skid Policy in Scotland'.

Table 4-1 SCRIM Bands

Atkins CSC Banding	CSC Band
≤ 0.24	0.225
0.25 - 0.29	0.275
0.30 - 0.34	0.325
0.35 - 0.39	0.375
0.40 - 0.44	0.425
0.45 - 0.49	0.475
0.50 - 0.54	0.525
0.55 - 0.59	0.575
0.60 - 0.64	0.625
0.65 - 0.69	0.675
0.70 - 0.74	0.725
0.75 - 0.79	0.775
≥ 0.80	0.825

In addition, utilising the latest alignment data from the SCANNER survey, Atkins have undertaken a spatial query in GIS to determine the minimum bend radius for each of the bends with radius ≤ 500m; the bends have been split into three bands for the analysis:

1. ≤500m to >250m radius
2. ≤250 to >100m radius
3. ≤100m radius

The outputs from the analysis of the impact of the bend radius on the Acc/100MVehKm are contained in Section 4.6.3.7 Single Carriageway Bends and Section 4.6.3.8 Dual Carriageway Bends.

It is standard practice to analyse SCRIM with wet skid RTC's; however, as the 'Implementing a Skid Policy into Scotland' paper states "skidding accidents are significantly underreported, therefore it was decided to incorporate all accidents that occurred on wet/damp road surfaces", therefore this report has adopted this approach for comparison purposes.

4.6.3. Results

From the RTC data received from Transport Scotland, there were 3,391 unique injury RTC's recorded between 1st January 2015 and 30th September 2017. 1,235 of these injury RTC's recorded the road surface to be wet/damp, of which 1,045 of the injury RTC's were within 10 metres radius of the SCRIM Summary GIS polyline.

The SCRIM Site Categories have been grouped together into individual charts where the CSC bands (banded based on table 4-1) have been compared to the wet injury RTC rates (Acc/100MVehKm) calculated from the 1,211 wet/damp injury RTC's. Where correlation exists, trendlines have been generated utilising the same technique as the 'Implementing a Skid Policy into Scotland' paper. Where possible, trendlines have been based on the "Power" or "linear" (based on the which provides the best fit [R²]) trendline function to keep parity with 'Implementing a Skid Policy into Scotland' paper.

Individual CSC bands containing less 3% of the total Site Category length have been excluded from the trendline analysis, which can have a disproportional impact on the analysis.

4.6.3.1. Network Summary

For comparison purposes, the wet injury RTC rates have been calculated for all site categories and contained in table 4-2, below.

Table 4-2 SCRIM Site Categories vs. wet injury RTC rates (RTC/100MVehKm)

SCRIM Site Description	Wet Injury RTC rates	Total Site Length	Investigatory Level (IL) Band	Wet Injury RTC rates by IL	Total Site Length
Motorway Non-Event	1.97	497.666	Lower	0.00	0.712
			Higher	1.97	496.954
Dual Non-Event	1.64	946.685	Middle	1.61	930.965
			Higher	3.26	15.72
Single Non-Event	2.47	1642.212	Lower	1.52	6.44
			Middle	2.45	1623.139
			Higher	5.62	12.633
Gradient 5% - 10%	4.09	106.089	Lower	4.11	104.559
			Higher	0.00	1.53
Gradient >10%	0.00	2.27	Middle	0.00	2.27
Approach to Crossings	9.24	9.652	Lower	8.18	8.382
			Higher	17.00	1.27
Approach to Junctions or Roundabouts	9.30	191.473	Lower	7.03	56.845
			Middle	10.25	134.458
			Higher	54.32	0.17
Dual Bend <500m	3.10	55.478	Lower	3.12	54.883
			Higher	0.00	0.595
Single Bend <500m	8.90	367.386	Lower	10.51	3.718
			Middle	8.90	363.348
			Higher	0.00	0.32
Roundabout	13.39	21.585	Lower	13.39	21.585
Network	2.73	3840.496			

Roughly 80% of the Transport Scotland network is categorised as Non-Event; table 4-2 indicates that the risk of wet injury RTC occurring on Motorway, Dual and Single Carriageway Non-Events are below the network

average. Data indicates that the highest risk locations (Wet Injury RTC rates) are Roundabouts, the Approaches to Junctions/Roundabouts and the Approaches to Crossings and other high-risk sites.

4.6.3.2. Motorway Non-Event

Figures 4-1, 4-2 and 4-3 (below) provide the Motorway, Dual Carriageway and Single Carriageway 'Non-Events' CSC Band plotted against the wet injury RTC rates. Outliers (<3% of Site Category Total length) were removed from the trendline analysis.

Figure 4-1 Motorway Non-Event - CSC Band vs. wet injury RTC rates

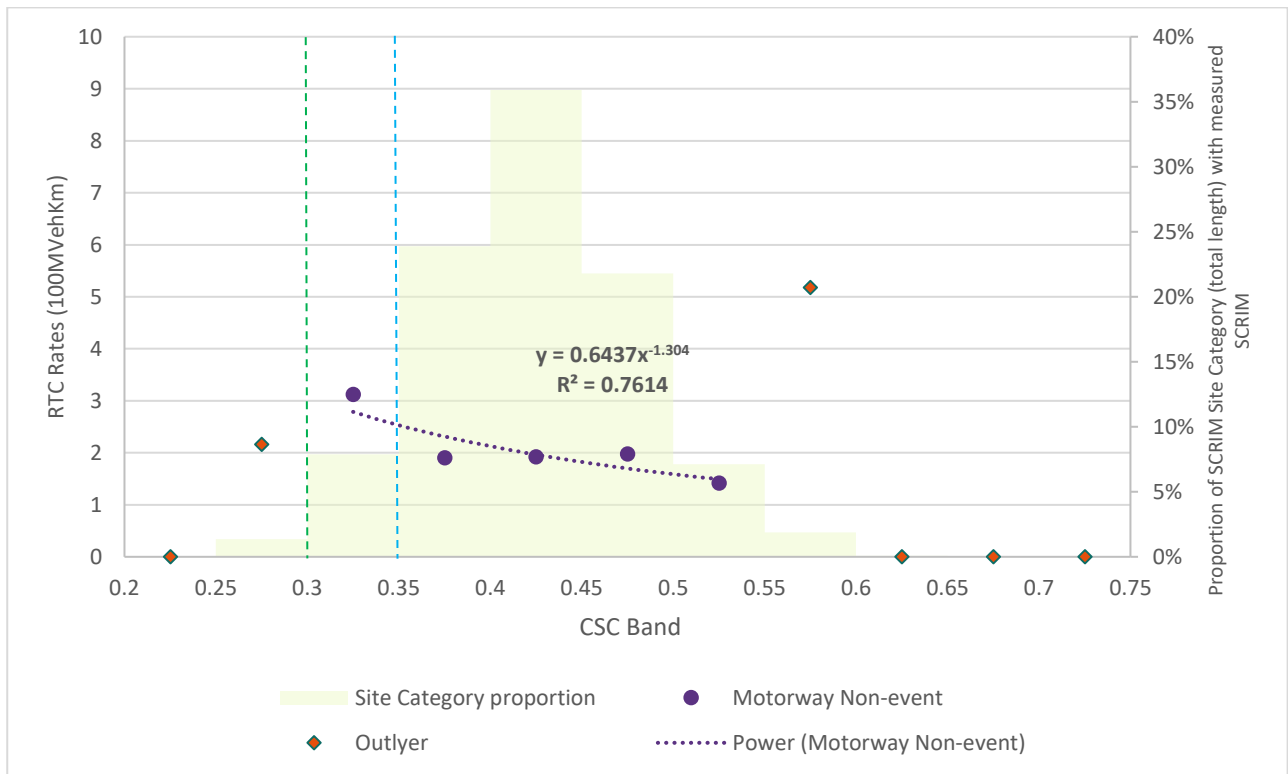


Figure 4-2 Dual Non-Event - CSC Band vs. wet injury RTC rates

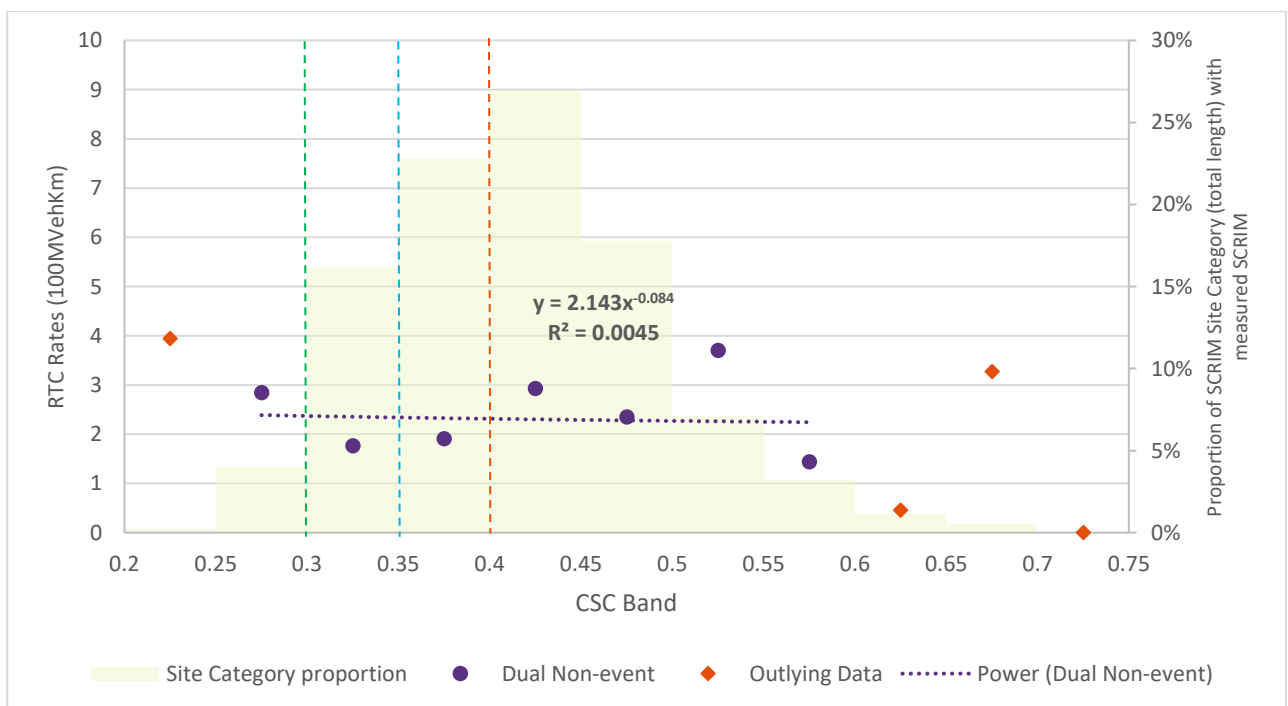


Figure 4-3 Single Non-Event - CSC Band vs. wet injury RTC rates

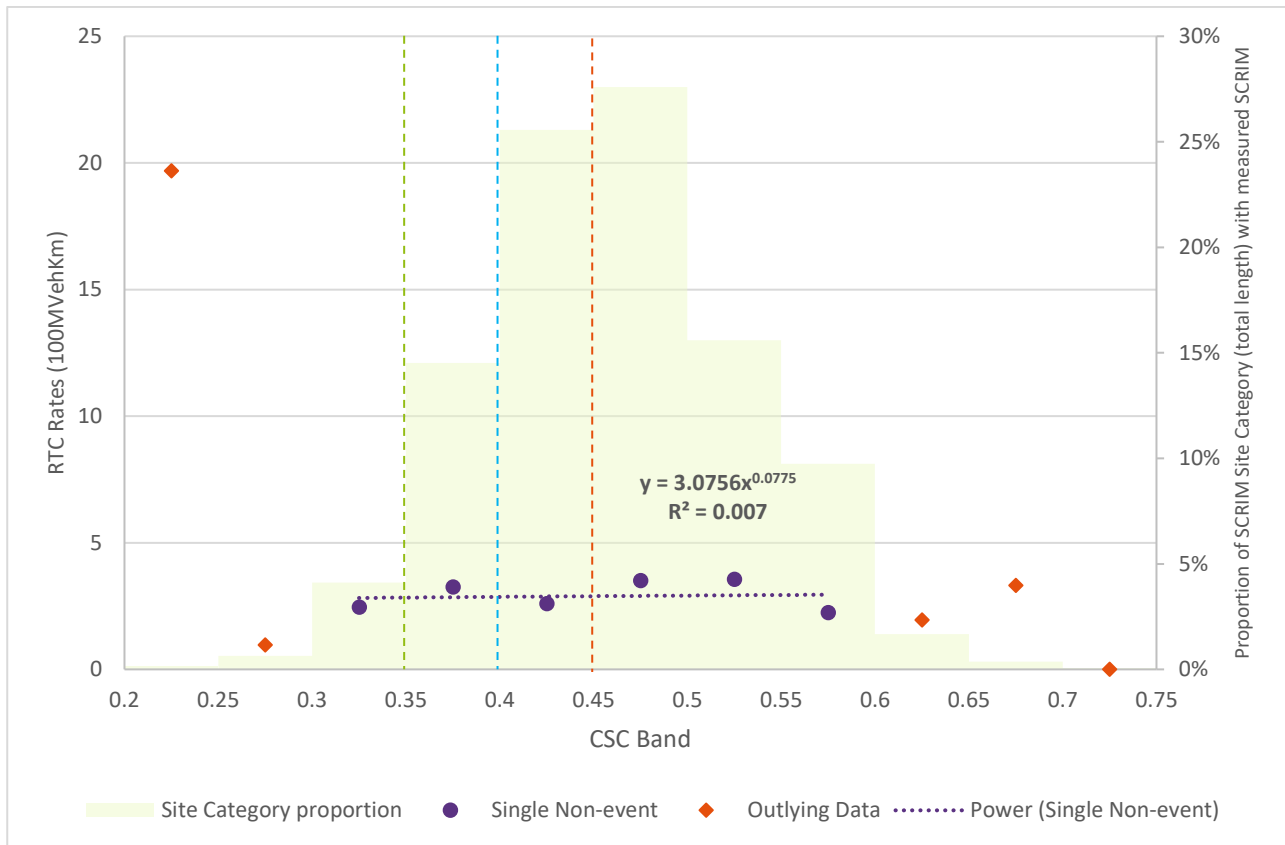


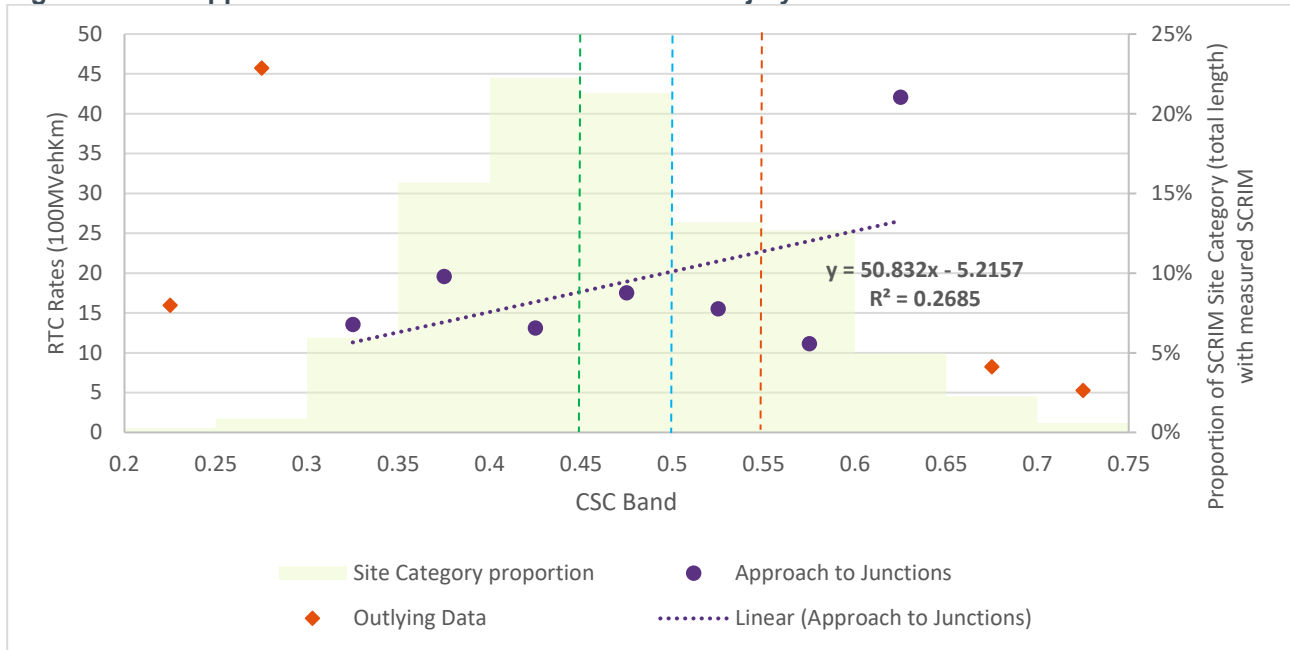
Figure 4-1 indicates that the risk increases slightly for CSC below 0.35, which is consistent with the existing recommended Investigatory Level or 0.35. For all CSC bands at and above the Motorway Non-Event recommended Investigatory Level of 0.35, the wet injury RTC rates are constant, which is indicative of skid resistance of the road surface not being a primary driver of wet injury RTC's on the Motorway Non-Events.

Figures 4-2 and 4-3 trendlines indicate that the injury RTC rates are generally constant (signified by the flat trendline) across all CSC bands, therefore as with the Motorways, the skid resistance of the road surface is not a major driver in Single and Dual Non-Event injury RTC's.

4.6.3.3. Approach to Junctions

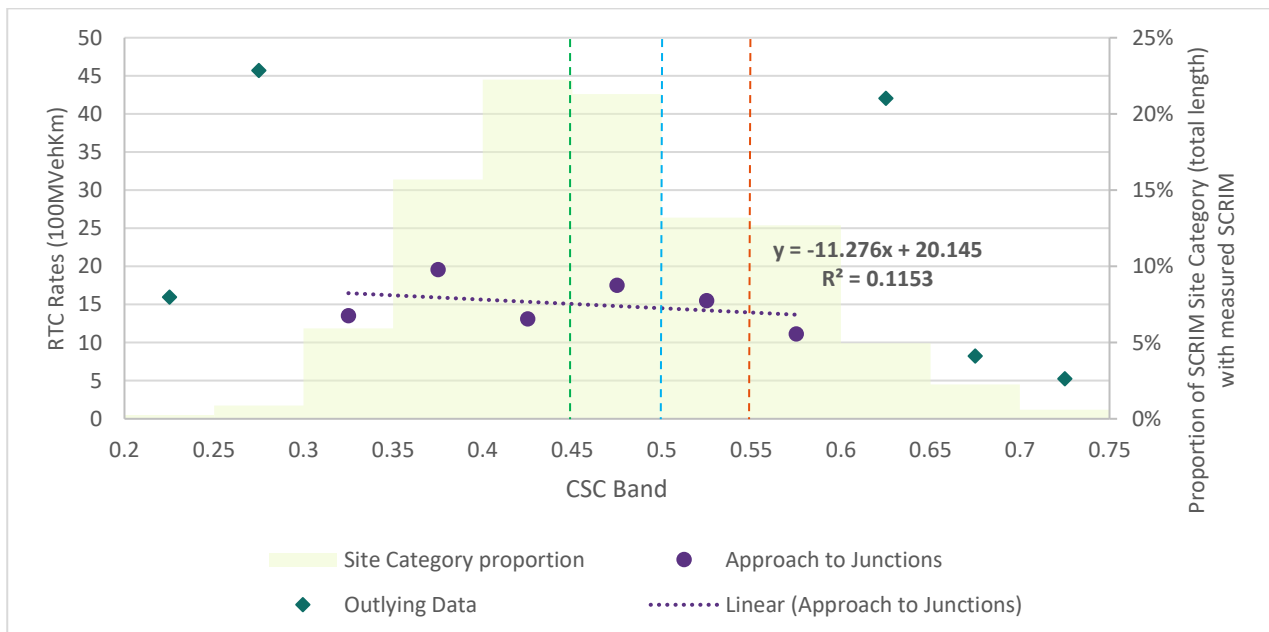
Figure 4-4 provides a comparison of CSC Bands vs. wet injury RTC rates for Approach to Junction and Roundabout sites. Outliers (<3% of Site Category Total length) were removed from the trendline analysis.

Figure 4-4 Approach to Junction - CSC Band vs. wet injury RTC rates



As a result of the high RTC rate for CSC band 0.6, the trendline indicates that accident rates increase as skid resistance increases; to achieve this level of skid resistance it is probable that the surface type is HFS. Due to the existing high skid resistance, it has been concluded that the main driver for these incidents are non-skid resistance factors such as visibility, speed, junction alignment/geometry or insufficient warning of queuing traffic. Consequently, this data point has been assumed to be an outlier and the trendline has been recalculated with this data point removed, see figure 4-5, below.

Figure 4-5 Approach to Junction - CSC Band vs. wet injury RTC rates



Removing the 'outlier' at CSC 0.6 from the trendline analysis, figure 4-5 trendline indicates a slight improvement in the wet injury RTC's as the carriageway skid resistance increases, however there is not a strong relationship between the wet injury RTC rates and the skid resistance. Therefore, it is recommended that Transport Scotland maintain the existing Investigatory Levels of 0.5 and 0.55.

However, further analysis of wet injury RTC rates vs skid resistance could be undertaken to determine if there are differences when considering speed limits, Junction types (e.g. Roundabouts, Give Way, Stop, etc), etc.

4.6.3.4. Gradients 5% to 10%

Figure 4-6 provides a comparison of CSC Bands vs. wet injury RTC rates for Gradient 5% to 10% sites. Outliers (<3% of Site Category Total length) were removed from the trendline analysis.

Figure 4-6 Gradients 5% to 10% - CSC Band vs. wet injury RTC rates

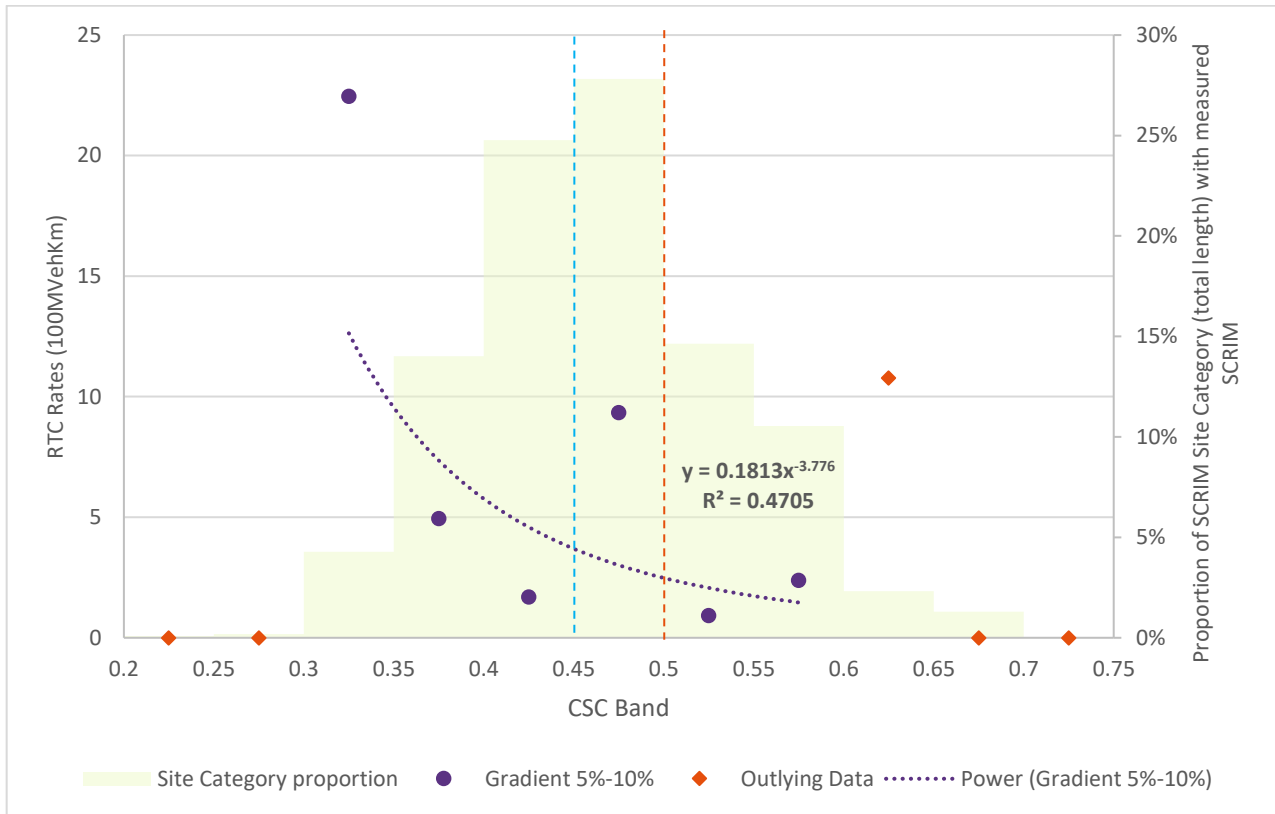


Figure 4-6 illustrates a correlation between wet injury RTC rates and skid resistance, indicating that generally, improvement in skid resistance reduces the RTC rates. The 'Gradient 5% to 10%' Site Category Investigatory Level (IL) range is 0.45 to 0.50, it is recommended that the existing IL range is maintained. However, further review is recommended into the increase in wet injury RTC rates in the 0.45 CSC band, considering if speed, uphill/downhill and proximity to Gradient >10% site are influencers.

4.6.3.5. Gradients >10%

Figure 4-7 provides a comparison of CSC Bands vs. wet injury RTC rates for Gradient >10% sites. Outliers (<3% of Site Category Total length) were removed from the trendline analysis.

Figure 4-7 Gradients >10% - CSC Band vs. wet injury RTC rates

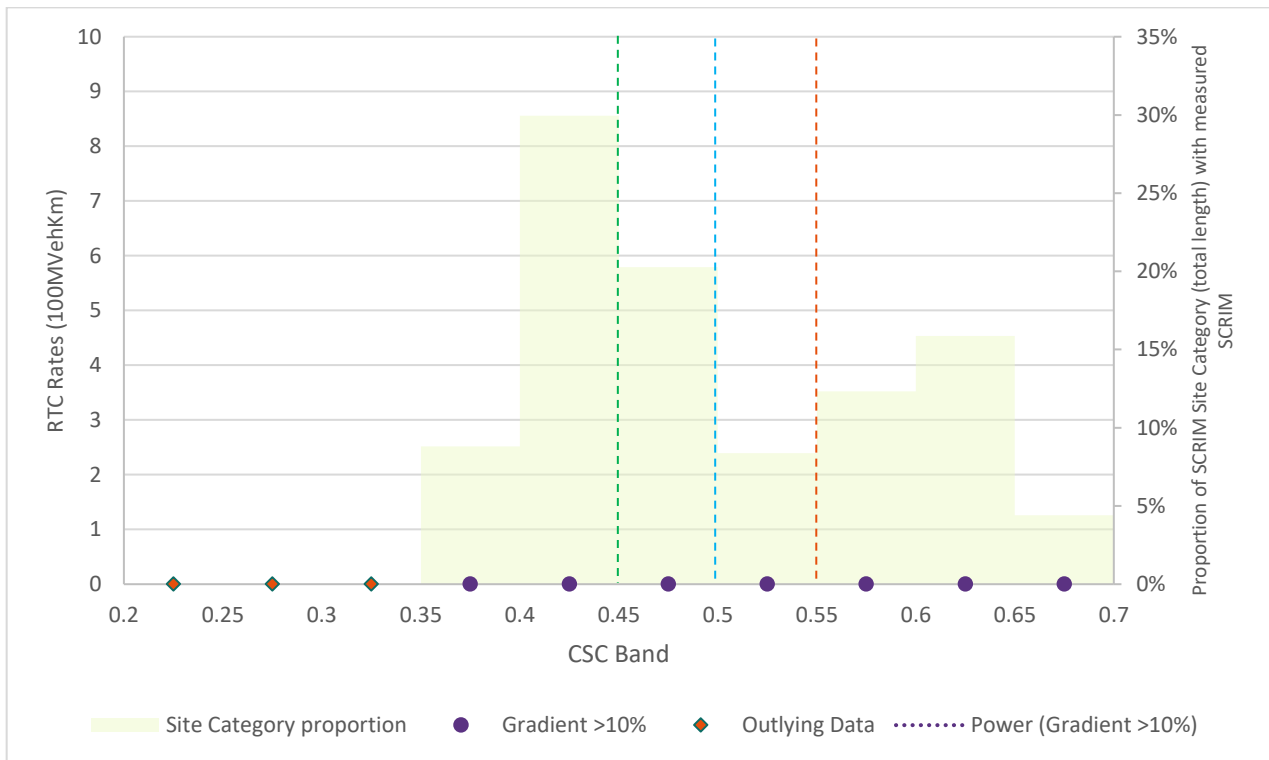


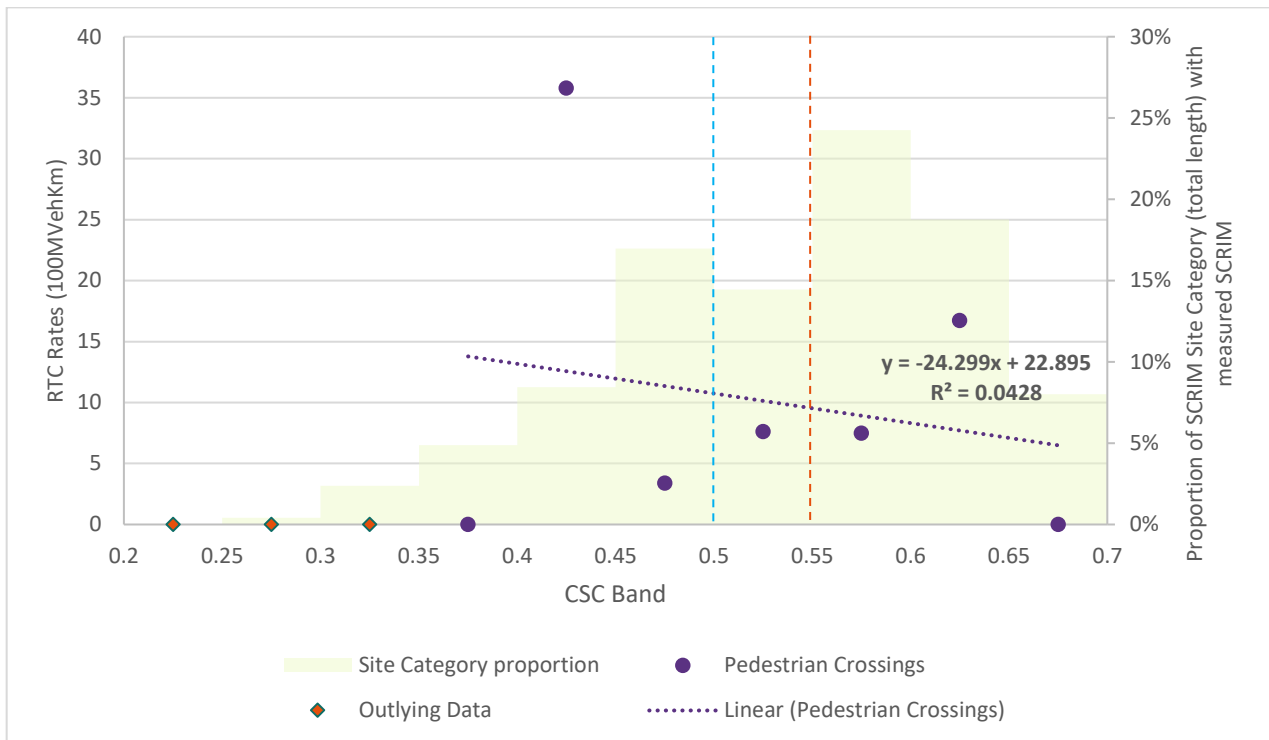
Figure 4-7 illustrates that no wet injury RTC occurred during the analysis period. It is recommended that Transport Scotland undertakes a review over a larger analysis period (e.g. 5 years or more) to determine the risk of wet injury incidents occurring on the 'Gradient >10%' sites. Additionally, during this review, consideration should be made for wet injury RTC's that have been referenced to neighbouring Gradient 5%-10% sites, where the Gradient >10% could have contributed to the loss of control.

If this review indicates that the risk is low, Transport Scotland could consider merging the two Gradient Site Categories into a single Site Category with an Investigatory Level range of 0.45 to 0.50.

4.6.3.6. Approach to Pedestrian Crossing and other High-Risk sites

Figure 4-8 illustrates the wet injury RTC rates for the 'Pedestrian Crossing and other high risk' sites; records indicate over the analysis period, there were nine incidents in total over the 9.652km total site category length.

Figure 4-8 Pedestrian Crossing & Other High Risk Sites - CSC Bands vs. wet injury RTC rates



The trendline analysis indicates an improvement in wet injury RTC rates as the skid resistance improves, however an anomaly with a higher than expected wet injury RTC rate within the 0.6 band prompted a quick review of the individual RTC records, due to the small number of incidents. The review found that most of the incidents that occurred on CSC Bands ≥ 0.50 were due to human errors, such as:

1. Pedestrians crossing the road within 50m of the pedestrian crossing, but not utilising the pedestrian crossing facilities and emerging from between parked cars, therefore reducing the pedestrians and driver's visibility.
2. Failure of the driver to look properly.

Based on the limited data available for the review, it is recommended that Transport Scotland maintain the existing Investigatory Level range of 0.50 to 0.55.

4.6.3.7. Roundabout sites

Figure 4-9 illustrates the wet injury RTC rates for the 'Roundabout' sites; the Transport Scotland IL range for roundabouts is 0.45 to 0.50.

Figure 4-9 Roundabout - CSC Band vs. wet injury RTC rates

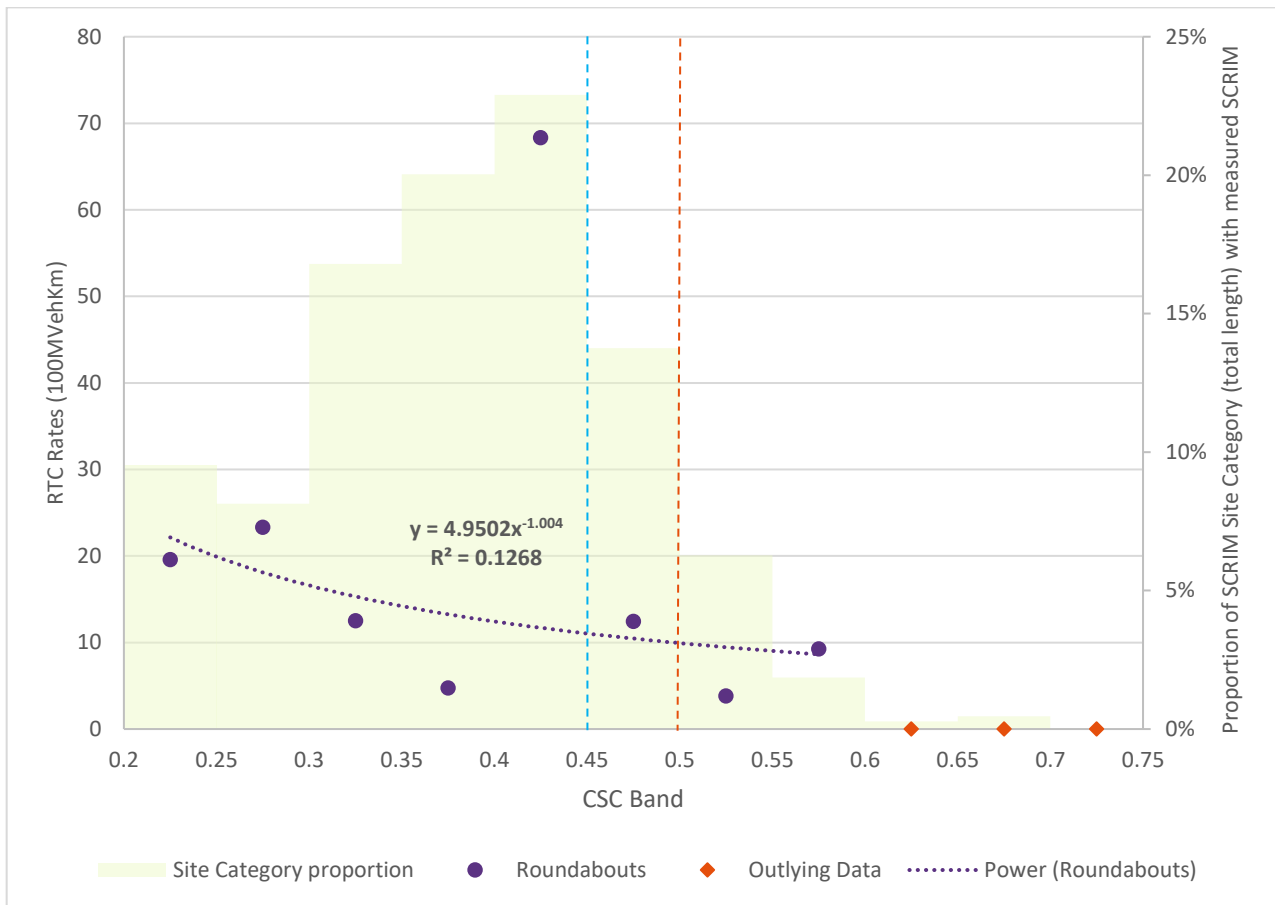
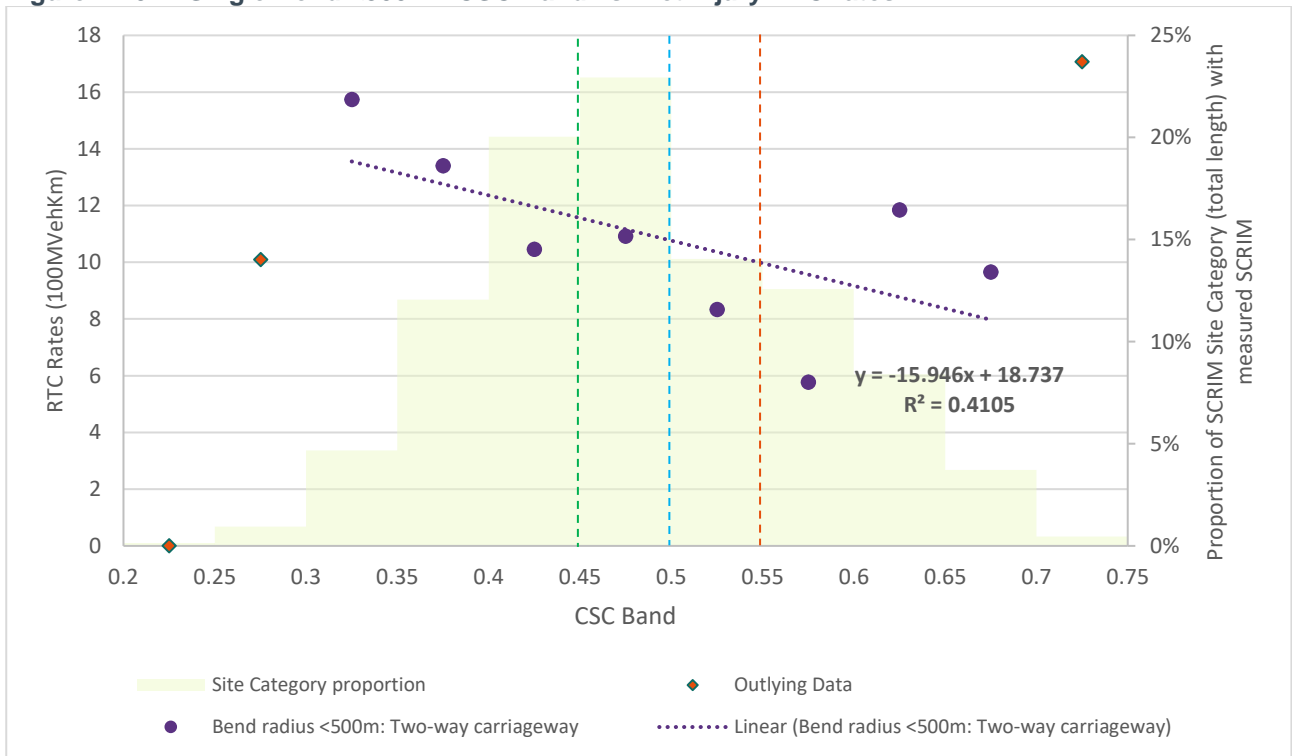


Figure 4-9 indicates that the wet injury RTC rate reduces with an improvement in skidding resistance, with lower rates of wet injury RTC's at the Lower Investigatory Level (0.45) and continue to reduce as the skid resistance improves. It is recommended that Transport Scotland continue with the existing IL range of 0.45 to 0.50.

4.6.3.8. Single Bend <500m radius

Figure 4-10 illustrates the wet injury RTC rates for the 'Single Bend <500m' sites; the Transport Scotland IL range for single bends with a radius below 500m is 0.45 to 0.55. Figure 4-10 indicates that based on the wet injury RTC rate trendline, the risk of a wet injury RTC occurring on a 'single bend <500m' radius with a CSC= 0.45 is approximately three time higher than the benchmark 'single non-event' with a CSC = 0.40.

Figure 4-10 Single Bend <500m - CSC Band vs. wet injury RTC rates



As a result of the high RTC rate for CSC band 0.6 and above, the trendline indicates that accident rates increase as skid resistance increases; to achieve this level of skid resistance it is probable that the surface type is HFS. Due to the existing high skid resistance, it has been concluded that the main driver for these incidents are non-skid resistance factors and consequently, this data point has been assumed to be an outlier

Figure 4-11 Single Bend <500m - CSC Band vs. wet injury RTC rates (updated)

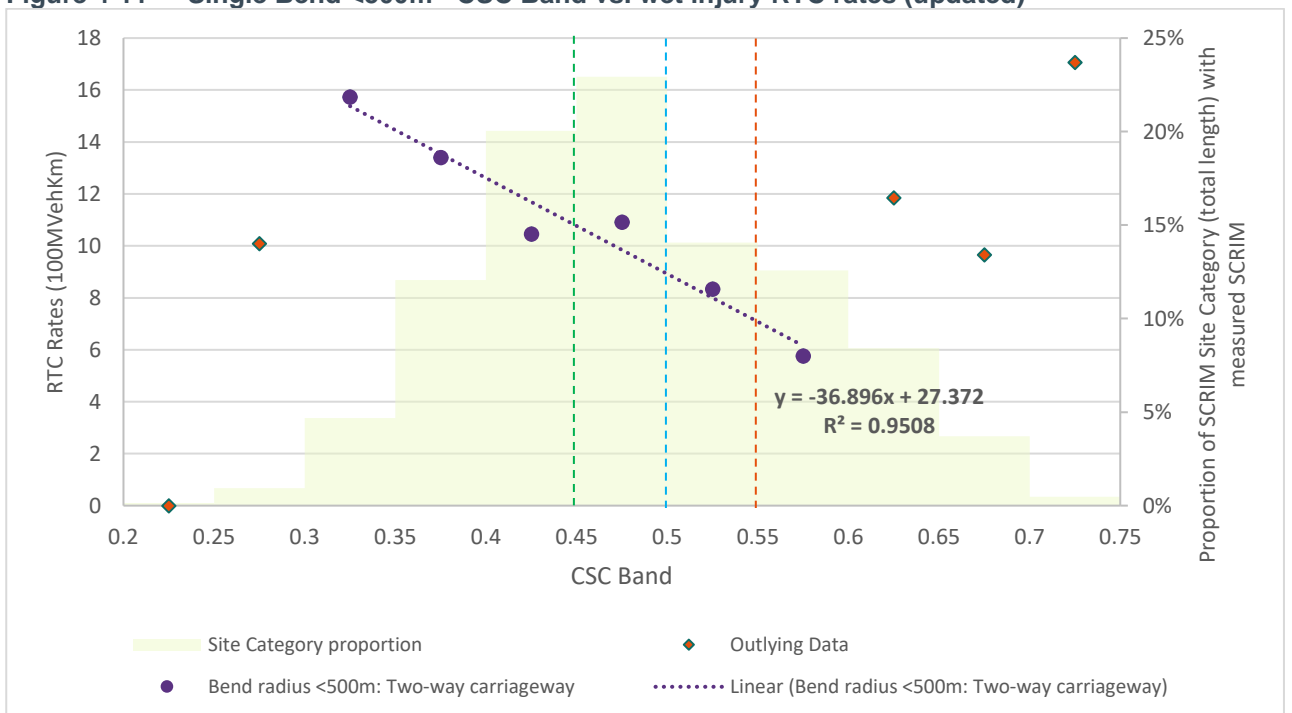
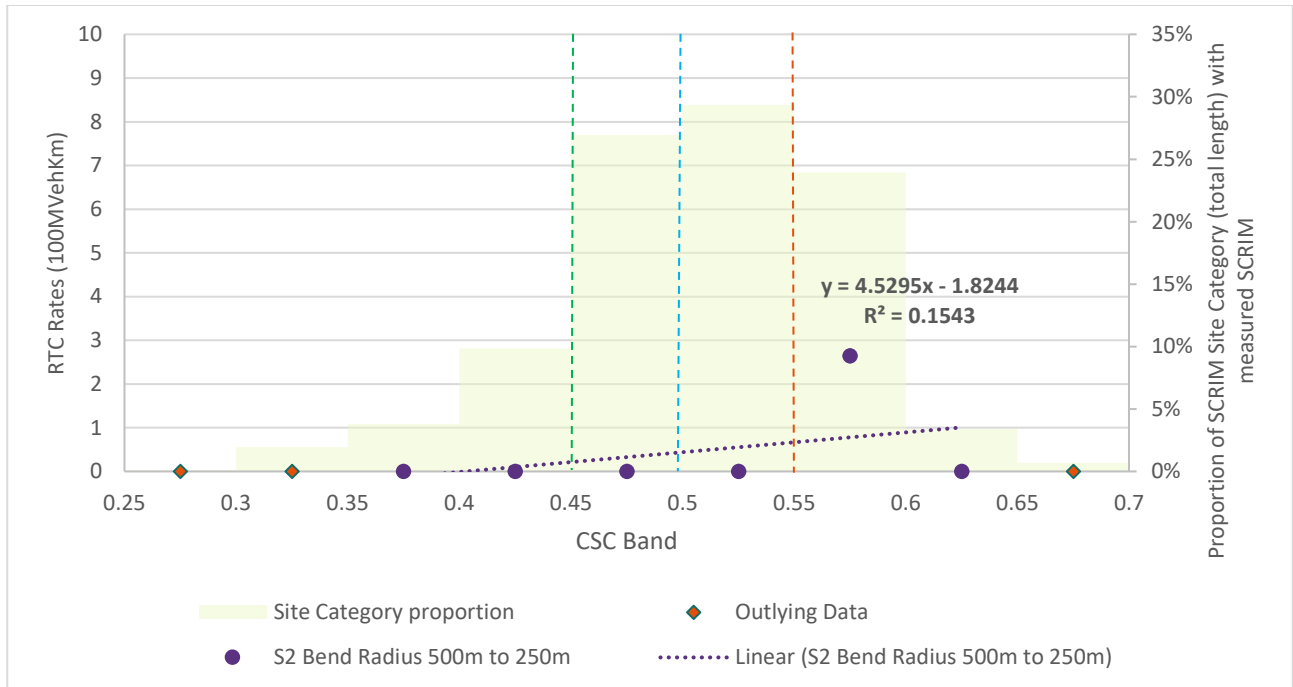


Figure 4-11 indicates that there is a strong link between wet injury RTC rates and skid resistance, after categorising the RTC rates for CSC Bands 0.6 and above as outliers.

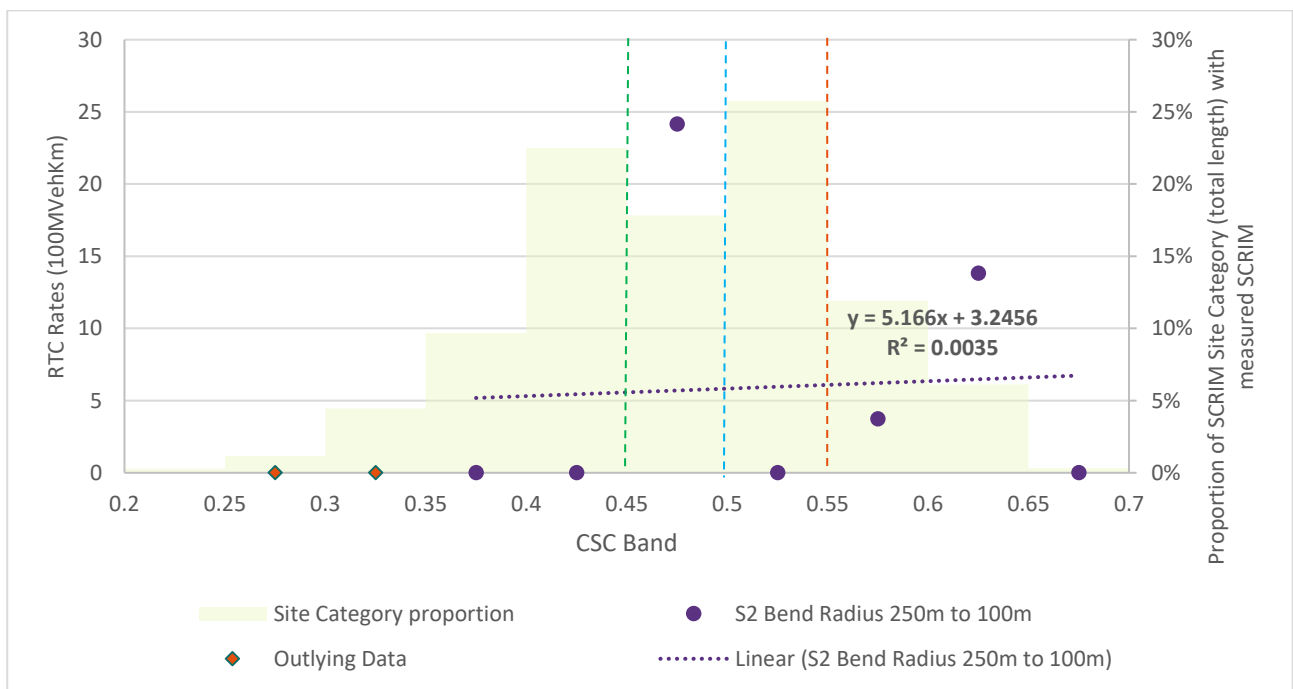
The SCANNER Curvature data was banded into <500m to 250m, <250m to 100m and <100m groups and then analysed in GIS with each SCRIM Summary Data to determine the minimum radius for each subsection and finally cross-referenced to the wet injury RTC data. The results are contained in figures 4-12, 4-13 and 4-14, below.

Figure 4-12 Single Bends – Curvature 500m to 250m vs. CSC Band vs. Wet injury RTC rates



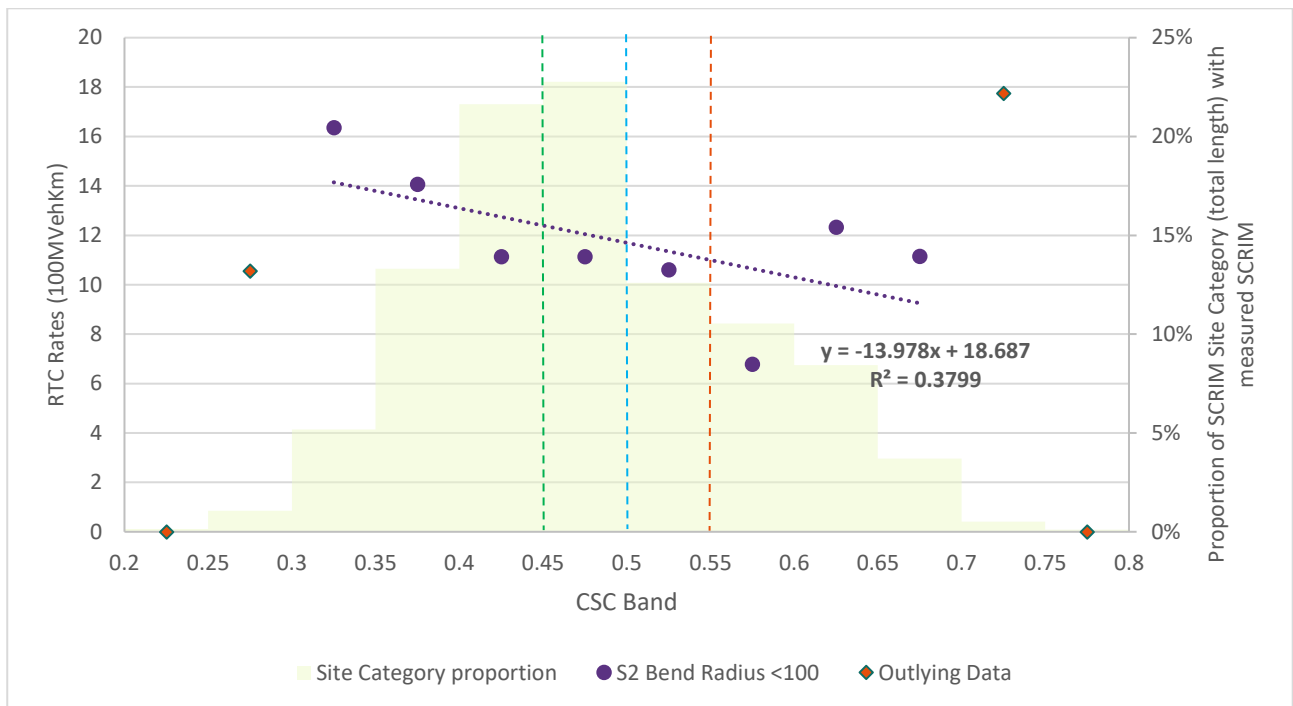
The 'Single Bends – Curvature 500m to 250m vs. CSC Band vs. Wet injury RTC rates' data contained in figure 4-12 indicates a poor relationship between wet injury RTC rates and Skid Resistance, which is based on only one incident that occurred over the analysis period.

Figure 4-13 Single Bends – Curvature 250m to 100m vs. CSC Band vs. Wet injury RTC rates



The 'Single Bends – Curvature 250m to 100m vs. CSC Band vs. Wet injury RTC rates' data contained in figure 4-13 indicates a poor relationship between wet injury RTC rates and Skid Resistance; however the trendline is influenced by the low RTC rates across the CSC bands below 0.45 and the higher RTC rates across CSC band 0.45 and above.

Figure 4-14 Single Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates



Similar to the figure 4-10, the radius charts have comparatively high wet injury RTC values in some of the 0.6 and above CSC bands; due to the high skid resistance values, these high rates are considered outliers, therefore have been removed from the trend analysis; the updated charts are below.

Figure 4-15 Single Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates (updated)

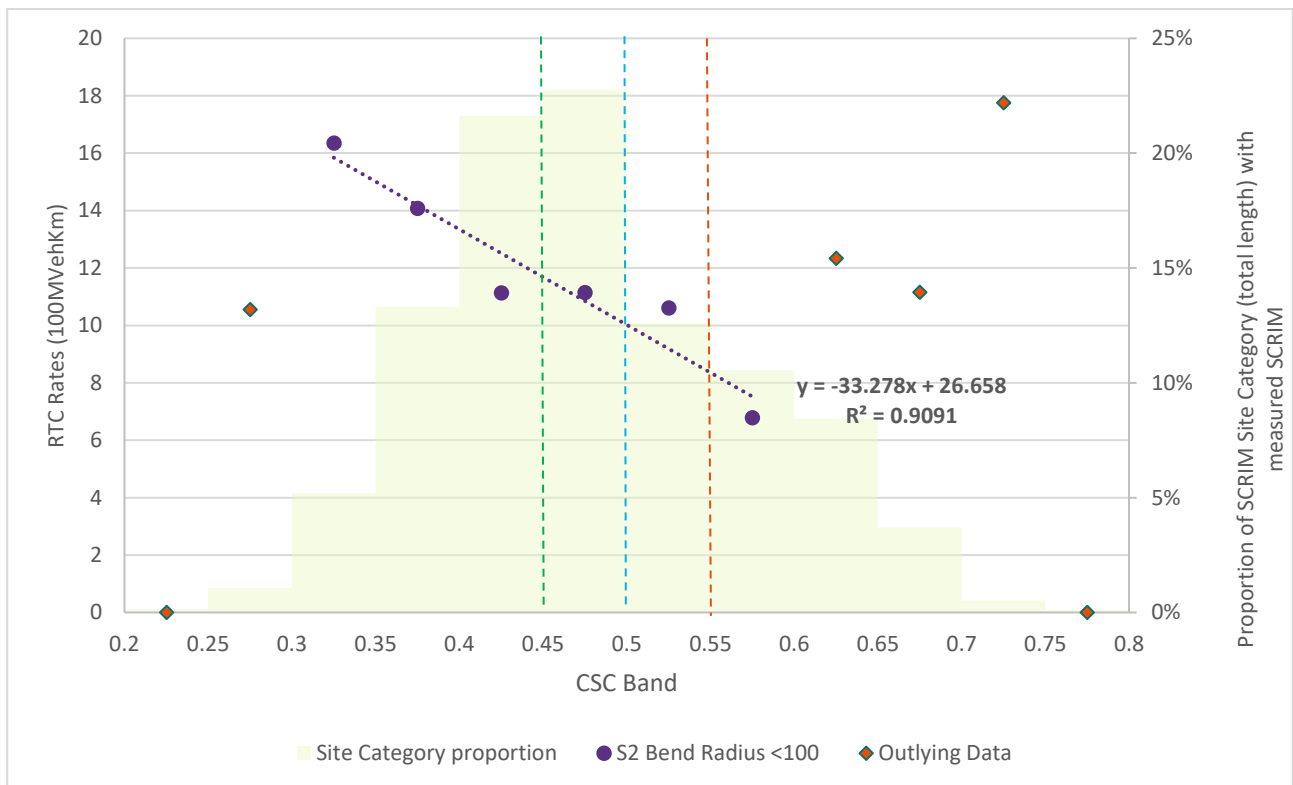


Figure 4-14 and 4-15 indicate that there is a strong relationship between skid resistance and RTC rates for bends with a radius below 100m.

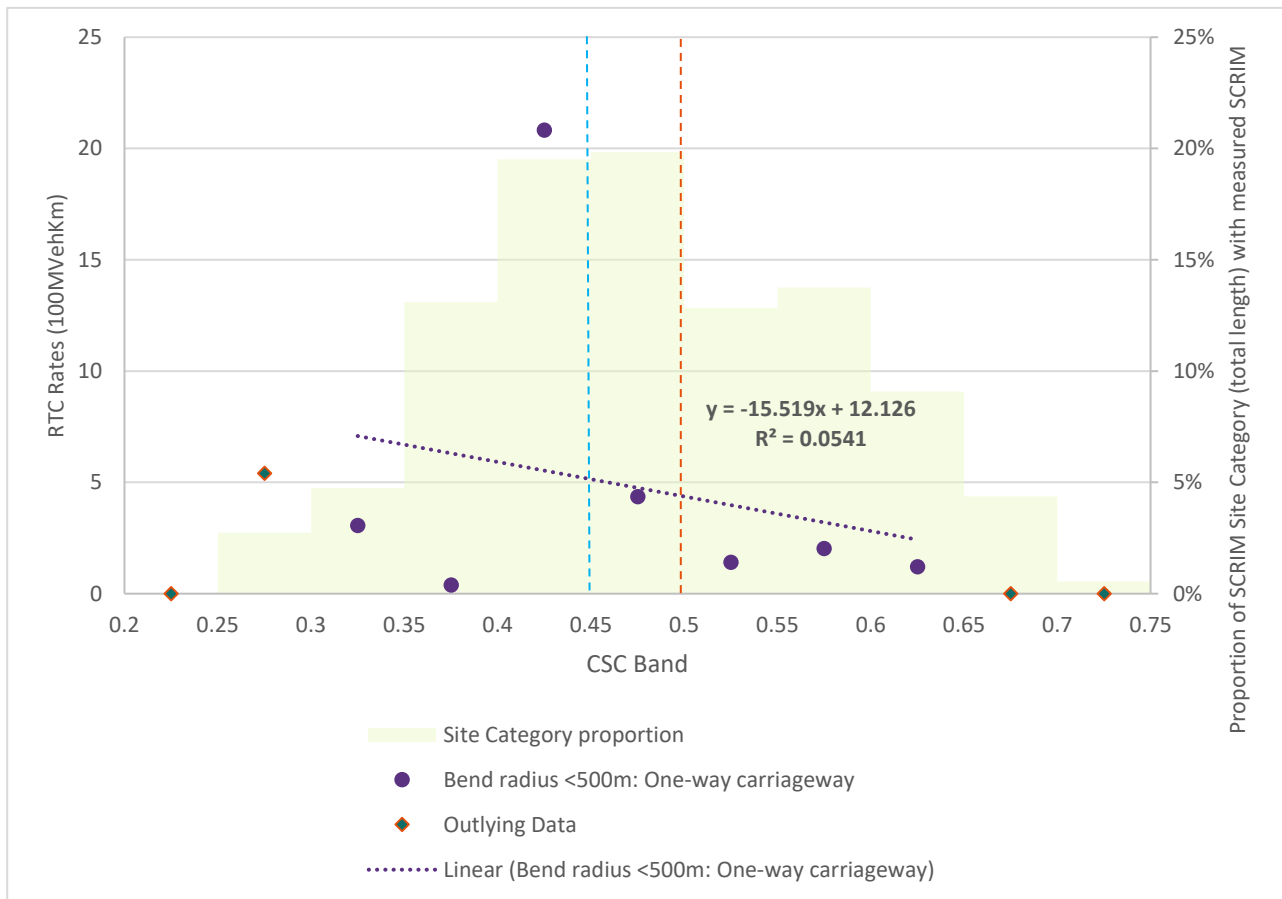
It is recommended that Transport Scotland conducts a more detailed study of the wet injury RTC over a large analysis window (5+ years), review the STATS19 records (local/tourist, day/night and other factors) and other available data, such as and not limited to, speed limits, traffic speed (average & 85th percentile), road geometry approaching site, road alignment, road marking condition, signage, etc to determine any other influences which may be impacting the wet injury RTC rates. Additionally, the study should investigate the impact on wet injury RTC rates if the bend radius is reduced from 500m to 250m, allowing Transport Scotland to reclassify any bends with a radius between 500m and 251m as the next lowest Investigatory Level/Site Category or reclassify any bends with radius >250m as Single Non-Event site category.

In the interim, it is recommended that the Investigatory Levels are maintained at their existing level of 0.45 to 0.55.

4.6.3.9. Dual Bend <500m radius

Figure 4-16 illustrates the wet injury RTC rates for the ‘Dual Bend <500m’ sites; the Transport Scotland IL range for single bends with a radius below 500m is 0.45 to 0.50. Figure 4-16 trendline indicates a slight relationship between wet injury RTC rate and skid resistance.

Figure 4-16 Dual Bend <500m - CSC Band vs. wet injury RTC rates



The SCANNER Curvature data was banded as follows:

- <500m to ≤250m radius
- <250m to ≤100m radius
- <100m radius

These groups were then analysed in GIS with each SCRIM Summary Data to determine the minimum radius for each subsection and finally cross-referenced to the wet injury RTC data. The results are contained in figures 4-17, 4-18 and 4-19, below.

Figure 4-17 Dual Bends – Curvature 500m to 250m vs. CSC Band vs. Wet injury RTC rates

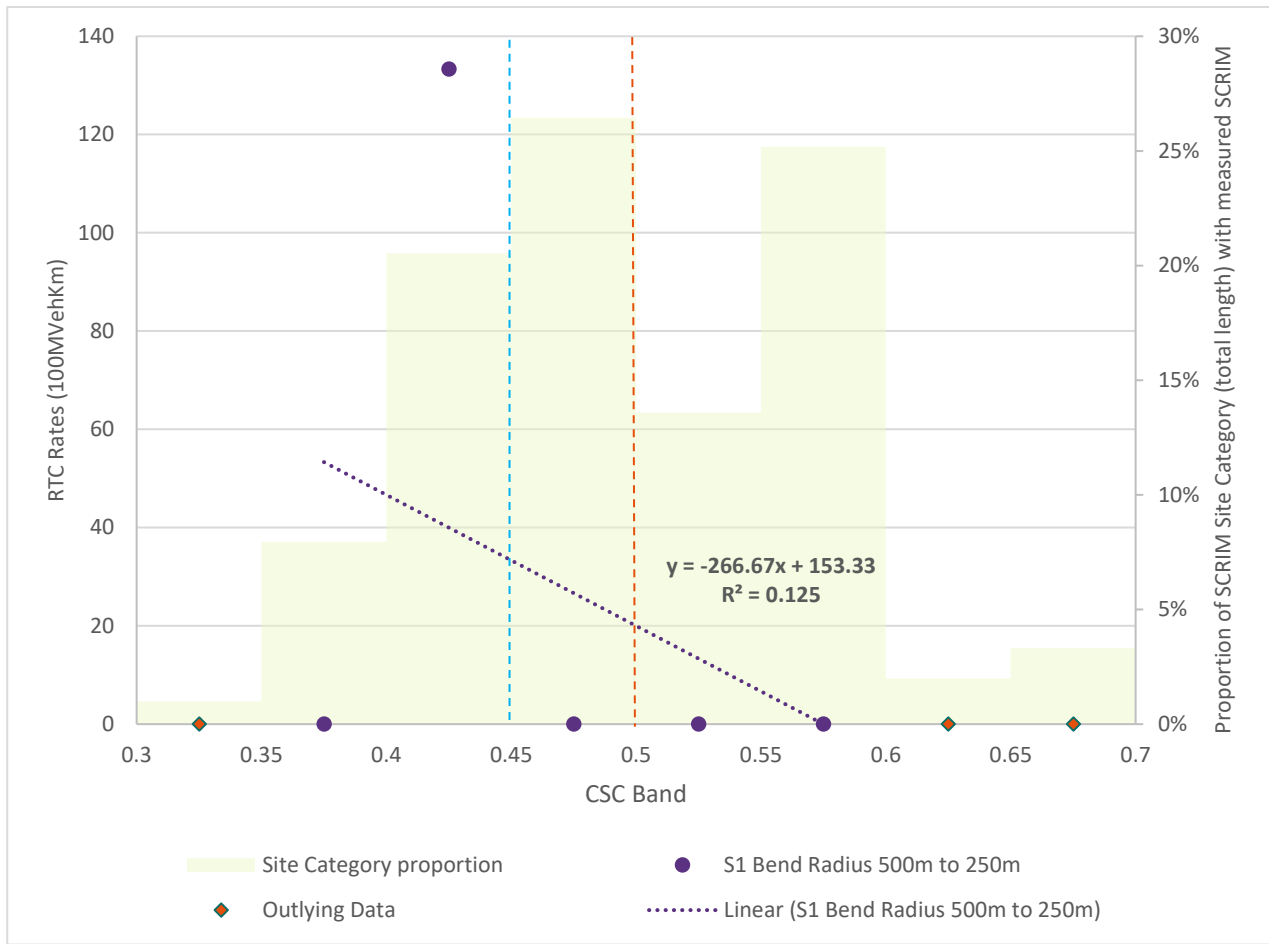


Figure 4-18 Dual Bends – Curvature 250m to 100m vs. CSC Band vs. Wet injury RTC rates

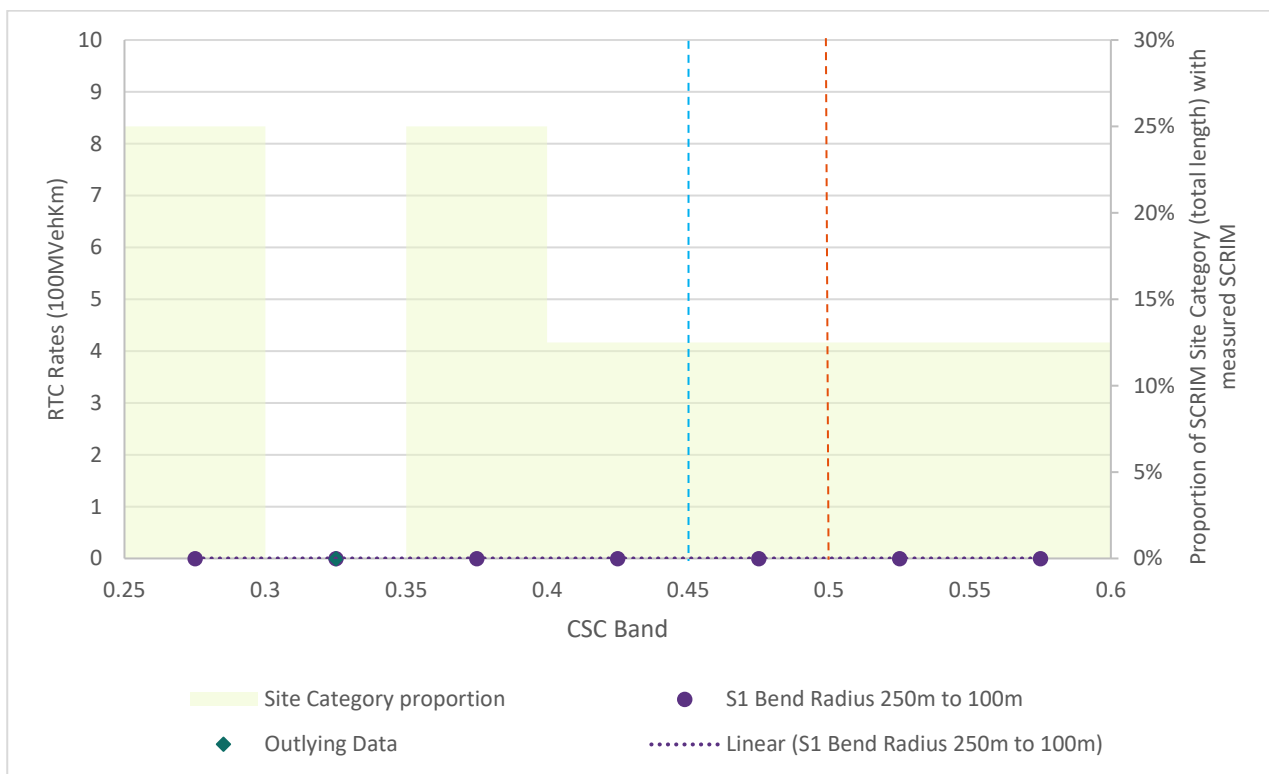
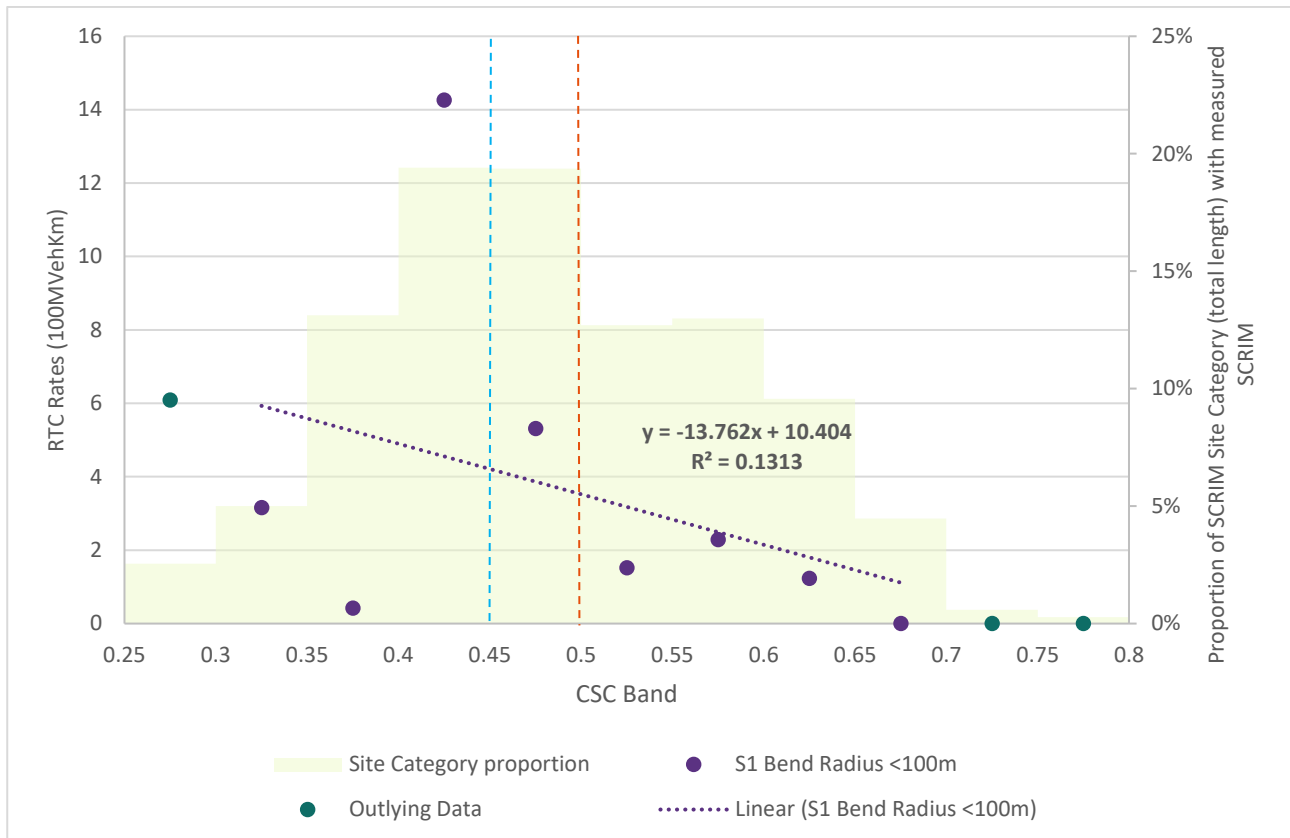


Figure 4-19 Dual Bends – Curvature <100m vs. CSC Band vs. Wet injury RTC rates



The analysis in figure 4-17 indicates that there was one wet injury RTC for minimum bend radius between 500m and 250m, which occurred on a length of road within the 0.40 CSC Bend. However, the figure 4-18 analysis indicates that there were no wet injury RTC’s that occurred on bends with a minimum bend radius between 250m and 100m; most incidents occurred on bends where minimum radius was < 100m (see figure 4-19).

The trendline in figure 4-19 indicates a relationship between wet injury RTC rates and skid resistance; it is recommended that the existing Investigatory Level range is maintained at 0.45 to 0.50; however, Transport Scotland should consider extending the single bend <500m study to the dual bend <500m to determine the impact of reducing the bend radius from <500m to <250m.

4.7. Recommendations (Risk Acceptance)

Review of the CSC Bands vs wet injury RTC rates based on Site Categories has highlighted four recommendations, which are:

1. Merging ‘Gradient 5%-10%’ (G1) and ‘Gradient >10%’ (G2) into a unified ‘Gradient ≥ 5%’ site category.
2. Undertake a more detailed review to establish the impact of reducing the Single and Dual Bend radius from 500m to 250m.
3. Examining wet injury RTC’s within the boundaries of ‘Approach to Junction’ site categories, analysing if there are trends based on junction type (Traffic Signal, Give Way, Stop Line, Roundabout, etc), carriageway type, Speed Limit, visibility and vehicle speed (average and 85th percentile).

5. Traffic Speed and SCRIM

5.1. Introduction

Traffic speed can be a major contributor to the risk of Road Traffic Collisions occurring, however when assessing the risks, overseeing authorities assess the risk based on the speed limit due to the expense required to gain traffic speed data across the network. This section discusses the use of crowdsourced data to assist Transport Scotland (TS) to intelligently assess and manage the skidding resistance risks across the network.

5.2. Data

Atkins partner, INRIX, purchase and crowdsource anonymised data from multiple different sources, such as the INRIX Traffic mobile application, vehicle manufacturers, mobile operators, mobile operating software suppliers and Satellite Navigation software/hardware suppliers. The level of granularity of the data varies across the supplier's data sources; INRIX gather data, undertakes some data cleansing to remove outliers, such as passengers travelling on trains and finally analyses the data ensuring data consistency and quality across the combined data repository.

5.2.1. Reports

INRIX have a repository of data from 2012 onwards, covering the whole of the UK that can be queried for trends, plus is collected live data.

INRIX provides various standard reports via their on-demand, cloud-based analytics suite, provide various Roadway Analytics information, such as live/historical traffic congestion, average queue times at junctions, journey origin-destination and traffic speeds, plus able to design ad-hoc reports, if required.

The INRIX traffic speed data can be collated with high-speed bends on the Transport Scotland Network to assess the risk and impact of reducing the Investigatory Levels or speed limit at these locations.

5.3. Traffic-speed data

As highlighted in Section 4, traffic-speed can be a large contributor to the risk of Road Traffic Collisions occurring at a location; historically these have been assess based on the roads speed limit due to challenges and expense of collecting this data. With the advent of mobile data and GPS, it has enabled car manufacturers to collect engine management data, which includes vehicle telemetry data from most modern cars fitted with GPS receivers. Additionally, Satellite Navigation software/hardware suppliers collect anonymised telemetry data to assist with determining the traffic congestion levels and providing the best route to the destination. Realising the value of this data, these companies now sell this data, providing Highway Authorities with traffic data covering the whole network at a fraction of the cost of collecting the data via speed studies.

Figure 5-1, below, has been created based on information supplied by INRIX the location is on A82 to the east of Loch Achriochtan, which is a National Speed Limit (60mph) single two-lane carriageway. The layer provides the average speed travelled by all vehicles in February 2017 between 9am and 6pm.

Figure 5-1 Average Speed on the A82 to the east of Loch Achriochtan

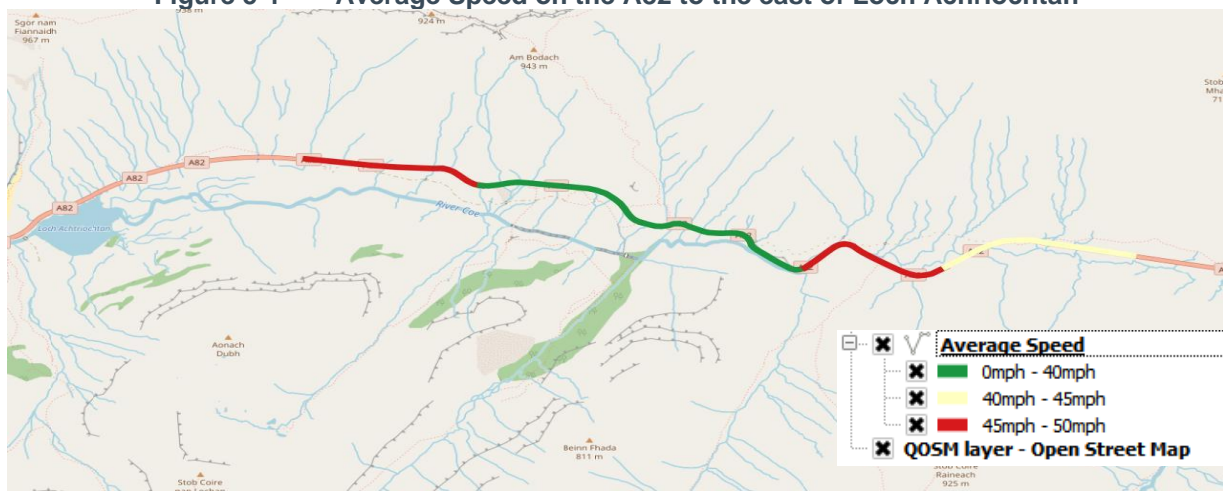


Figure 5-1 illustrates that the average speeds in February 2017 through the sample length was below 50mph, with the average speed below 40mph through the middle section (highlighted Green [0 to 40mph]) through the bends. The speed data also indicated that the 85th percentile speed through the middle section was 41mph over the analysis period.

Figure 5-2 A82 Site Categories (CL1)



Figure 5-2 provides the SCRIM Site Categories assigned to the westbound lane extracted from Transport Scotland's (TS) IRIS; the red lengths are locations which have been assigned Single carriageway bend with radius less than 500m, which has an Investigatory Level of 0.50.

Figure 5-3 A82 Road Traffic Collision Data (2014 – 2016) – Sourced from DfT website

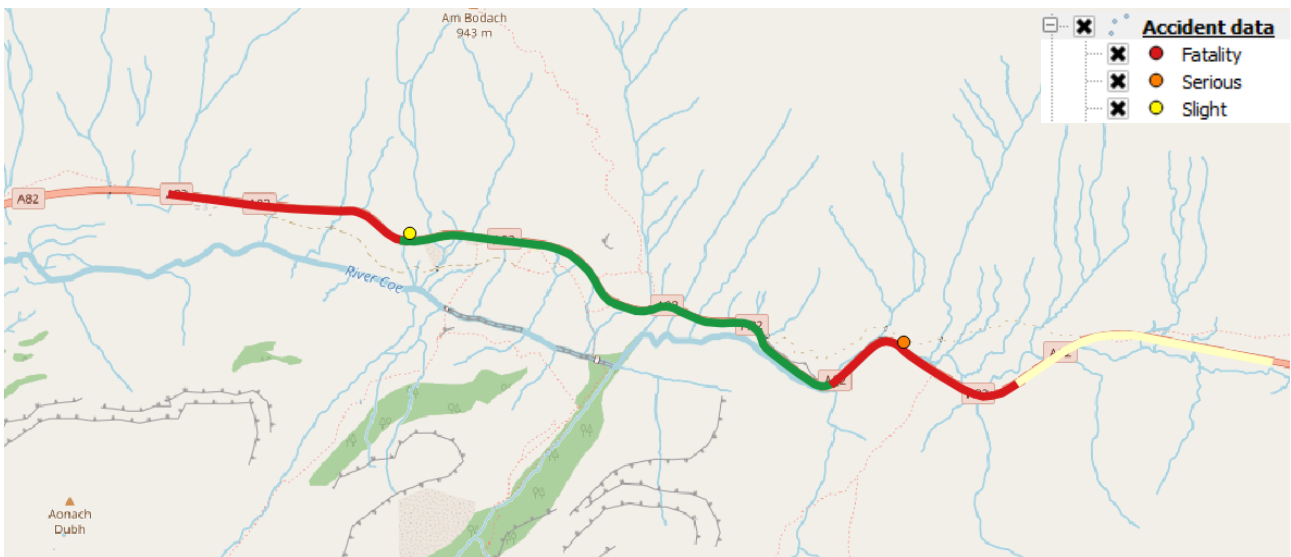


Figure 5-3 illustrates the injury road traffic collisions (RTC) which occurred along this length of road; RTC data was downloaded from the data.gov.uk website.

Figure 5-3 shows two RTC's occurred within the boundaries of the speed data we have available, both RTC's occurred when the road surface was categorised as wet; the injuries were categorised as a serious and a slight injury. The slight involved a motorcycle failing to negotiate a right-hand bend at night and leaving the carriageway on the offside; the weather was categorised as fine and there were no signs of skidding from the motorcycle. The serious occurred during the daytime while it was raining, and the road surface was wet.

5.3.1. Traffic-speed vs Skidding Resistance

HD28/15 indicates that the skidding resistance of the road surface reduces as the vehicle speeds increase; the reduction in the skidding resistance depends on factors, such as the speed of the vehicle and the macro-texture depth of the road surface.

HD28/15 Annex 5 provides detailed guidance on selecting the appropriate Site Categories and Investigatory Levels, advising that in many of the circumstances where the speed limit is 50mph or above the top Investigatory Level should be allocated. However, HD28/15 does indicate that if the actual traffic speeds are lower than 50mph due to the nature of the site, the Highway Authority can apply the Investigatory Level to the middle (Lower dark grey) band.

In similar circumstances to this example where the average vehicle speed is below 40mph, a reduction in speed limit to 40mph would have little or no impact on journey times and reduce the risk of wet skidding incidents occurring. Therefore, if Transport Scotland reduced the speed limit to 40mph, in accordance with HD28/15 the Site Category could be changed to Single Non-Event for all bends with a radius > 100m, reducing the Investigatory Levels from 0.50 to 0.40, which would improve the SCRIM difference, reduce the liability, reduce the need for high friction surfacing, reducing maintenance costs and the environmental impact of maintaining the skidding resistance.

5.4. Recommendations (Risk Acceptance)

With traffic speed data becoming more accessible, road authorities are able to undertake a risk-based approach to managing the skidding resistance of the road network, particularly on high speed bends where current practices identify vehicle speed as a key component to wet skid incidents.

It is recommended that analysis is undertaken the S1/S2 bends along a route or in an area to determine if actual traffic speed and the bend radii has an impact on the likelihood of wet skid road traffic incidents. It is recommended that the analysis should consider:

- SCRIM Site Category & Investigatory Level data
- Speed Limit
- Vehicle speeds
 - Mean vehicle speed
 - 85th Percentile vehicle speed
- Traffic Count Data
- SCANNER data
 - Alignment
 - Crossfall
- Injury Road Traffic Collision Data

Through the analysis, it will highlight locations where it could be acceptable to reduce the speed limit without impact travel times, due to traffic being unable to reach the speed limit due to road geometry. Additionally, the analysis would utilise the information above to identify the attributes in the bends which increase the likelihood of incidents occurring, allowing Transport Scotland to manage their asset more efficiently and effectively by adopting a risk-based approach which caters for their local stakeholders.

6. International Practice Review

6.1. Methodology

For the purposes of this study we have undertaken a literature review to identify methods used outside the UK to assess skidding resistance; this was an internet-based study. The following resources were utilised:

- *IHS* - an online suite of products that includes comprehensive collections of full-text publications, technical standards and an extensive range of product information; and
- Common internet search engines.

6.2. Literature Review

Various research papers and other documents were reviewed, and our literature review found two prime sources of information regarding international skidding resistance practices:

- Forum of European National Highway Research Laboratories (FEHRL) projects including:
 - TYROSAFE
 - ROSANNE
- International Safer Roads Conference

However, additional documents were sourced from other locations and have referenced in this report.

6.3. European Skid Resistance Practices

6.3.1. TYROSAFE and ROSANNE Projects

The TYROSAFE (Tyre and Road Surface Optimisation for Skid resistance and Further Effects) project is funded by the European Community and began on 1st July 2008. The project is composed of numerous national strategic highway and research organisations. The main objective of the TYROSAFE project was to increase safety and support the greening effect (reduction of CO₂ and noise emissions) through research of tyre/road interactions. The TYROSAFE project ended in June 2010, identifying the need for further research in the fields of skid resistance, rolling resistance and tyre/road noise emissions.

After the completion of the TYROSAFE project, the partner organisations have continued the work independently as a follow-on project, ROSANNE. The three-year ROSANNE project began in November 2013, building upon the research conducted as part of the TYROSAFE project.

6.3.2. Skid resistance measurement device

Information extracted from the TYROSAFE research project indicates that there are 11 different types of skidding resistance measurement devices utilised within Europe. However, the different devices can be split into two categories, see Table 6-1 below.

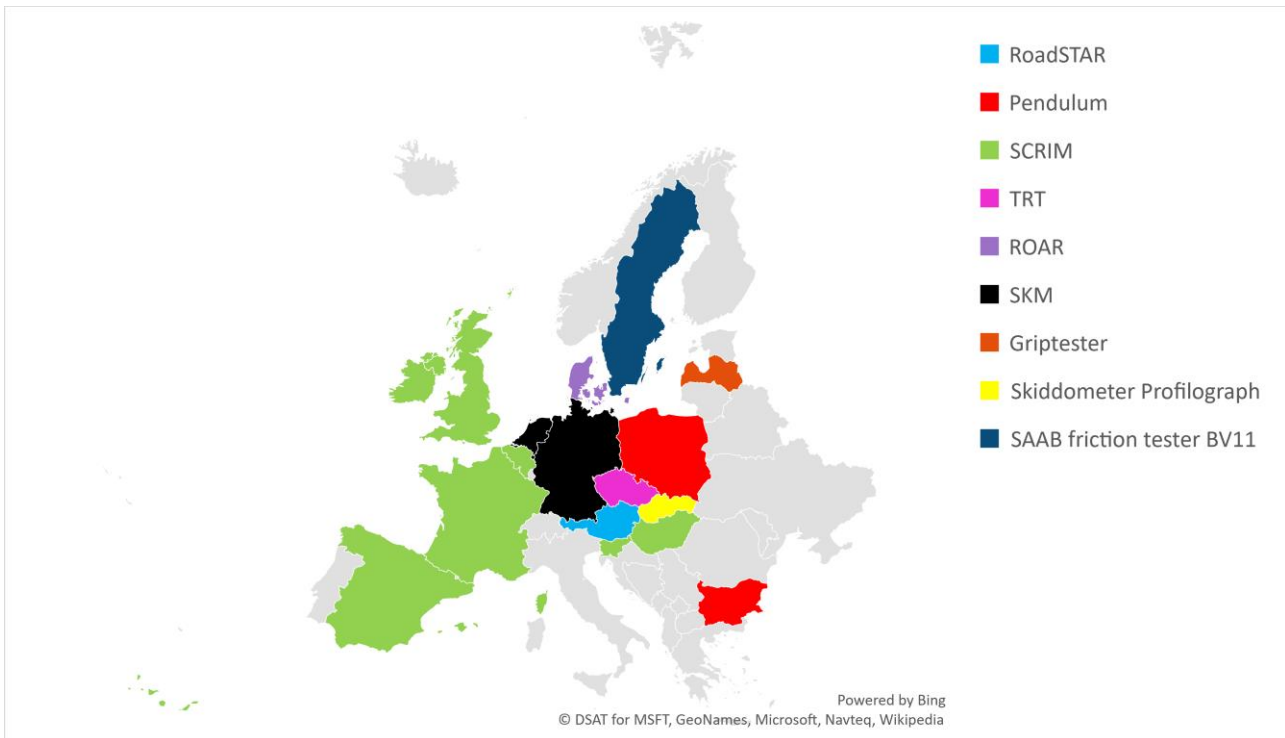
Table 6-1 Skid resistance measuring device categories

Group	Device
Side-force	Odoliograph
	PaveTesting
	SCRIM device family
	SKM
Longitudinal – low slip	Griptester (Lyon)
	Griptester
	IMAG
	OSCAR
	RoadSTAR
	Road/ViaFriction device family
	TRT

Report on policies and standards concerning skid, Deliverable D06, TYROSAFE, 2009

Figure 6-1 provides the primary skidding resistance device based on the information collected as part of the TYROSAFE project and extracted from “Report on policies and standards concerning skid, Deliverable D06, TYROSAFE, 2009” document.

Figure 6-1 Map illustration Primary Skid Resistance Measurement device



* Netherlands in the TyroSafe report utilised RWS trailer, however additional research indicates that Netherlands have transitioned to utilising the SKM device in 2017.

6.3.2.1. SKM vs SCRIM

SKM skid resistance measurement devices are utilised by Germany, Switzerland and Netherlands; the SKM survey vehicle is similar to the SCRIM vehicle, with the test wheel at a 20° to the direction travelled and the machine recording the Side-way Force Coefficient. However, there are five differences:

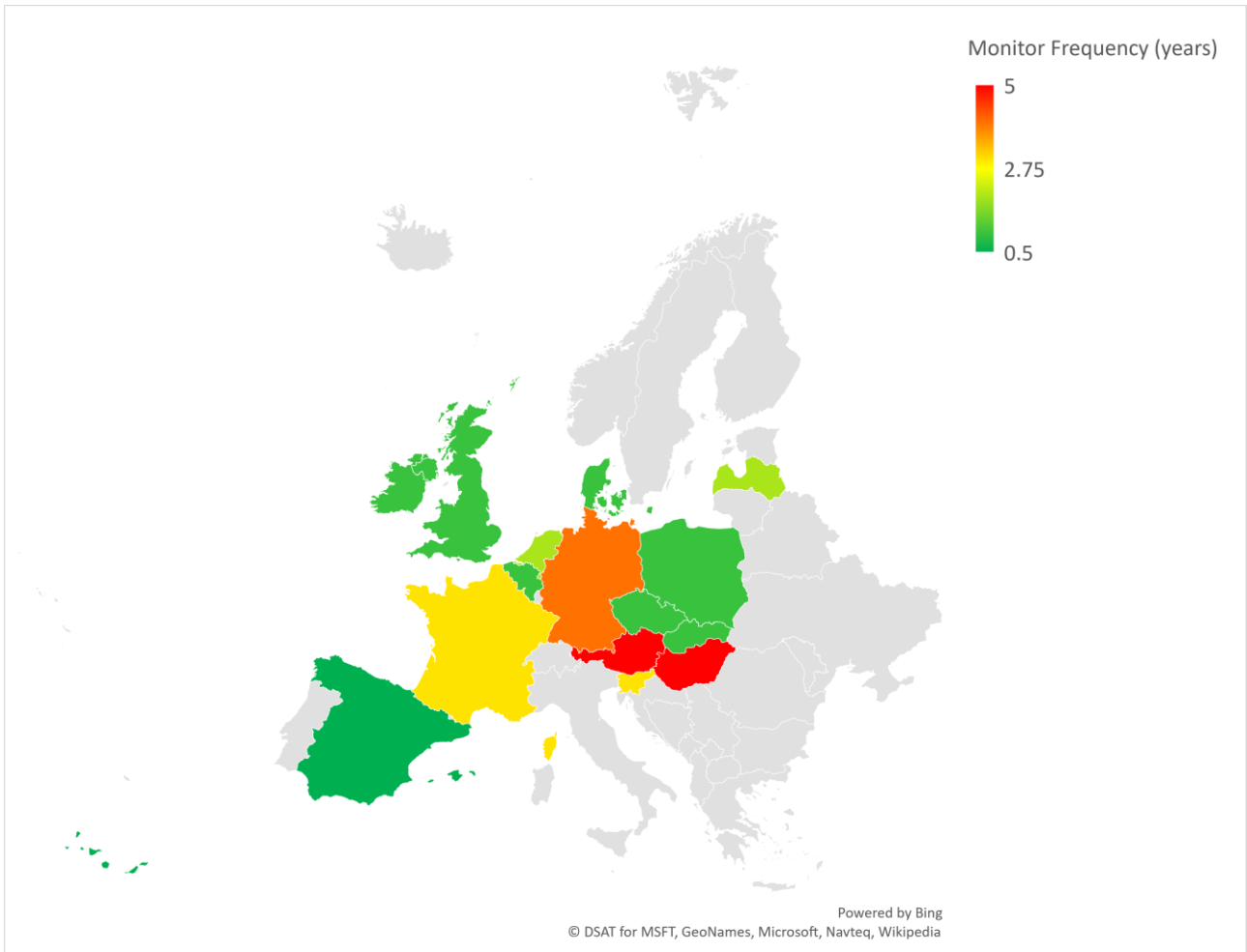
1. The SKM wheel is statically loaded; SCRIM is dynamically loaded.
2. The method of water delivery in front of the test wheel; SKM uses a guided water shoe, while SCRIM utilises a nozzle.
3. Temperature measurement; SKM measures air, surface, water and tyre temperatures; temperature measurement sensors are not mandatory on the SCRIM.
4. The SKM wheel is on the right-hand side of the vehicle; SCRIM is on the left.
5. The SKM test tyre has a lower resilience compared to the SCRIM tyre.

TRL Published Project Report PPR702 – Comparison of SCRIM and SKM sideway-force skid resistance devices concludes that the two survey types provide consistent results when fitted with the same test tyres and the different tyres was the main contributor to differences in results. It was also concluded that if the SKM was adopted on the UK network, it would require the test wheel moving to the left-hand side, for the test wheel to be dynamically loaded and for a test tyre to comply with BS 7941-1.

6.3.3. Survey Frequency

Figure 6-2, illustrates the routine survey regime of each country, based on information from the TYROSAFE research project.

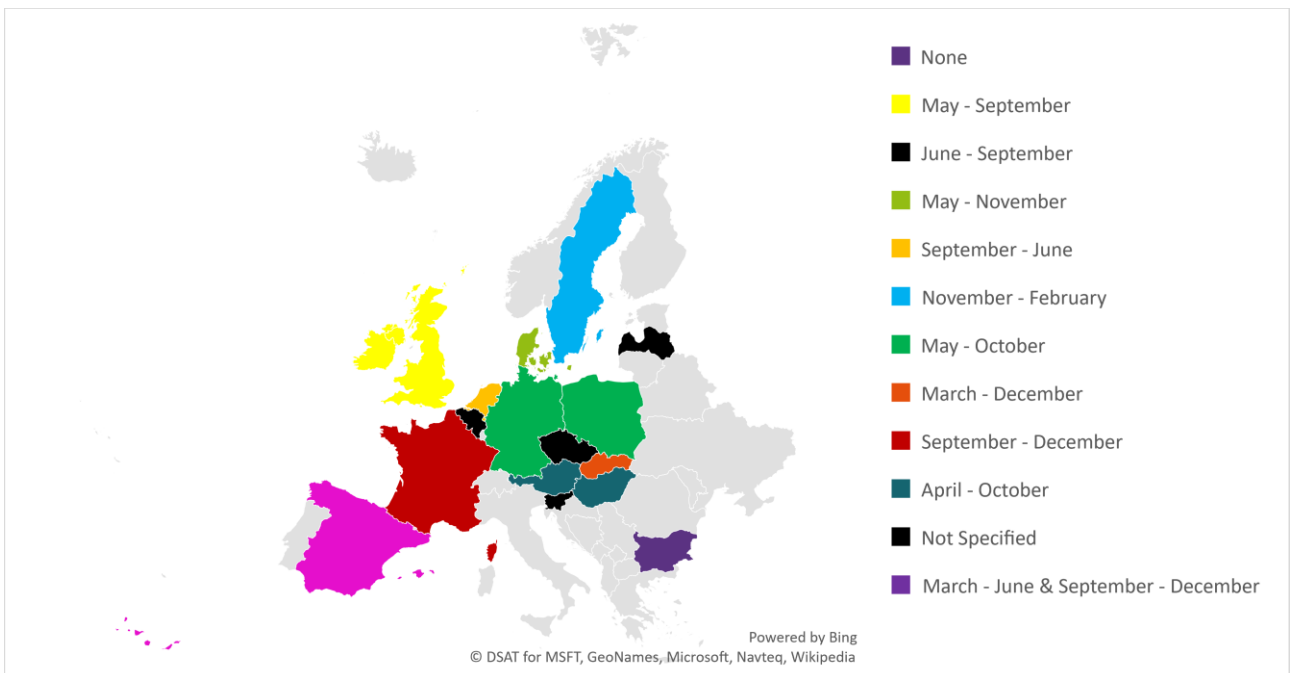
Figure 6-2 Routine Survey Frequency (years)



6.3.4. Survey Season

Figure 6-3, illustrates the survey season for each country, extracted from the TYROSAFE research project.

Figure 6-3 Survey Season

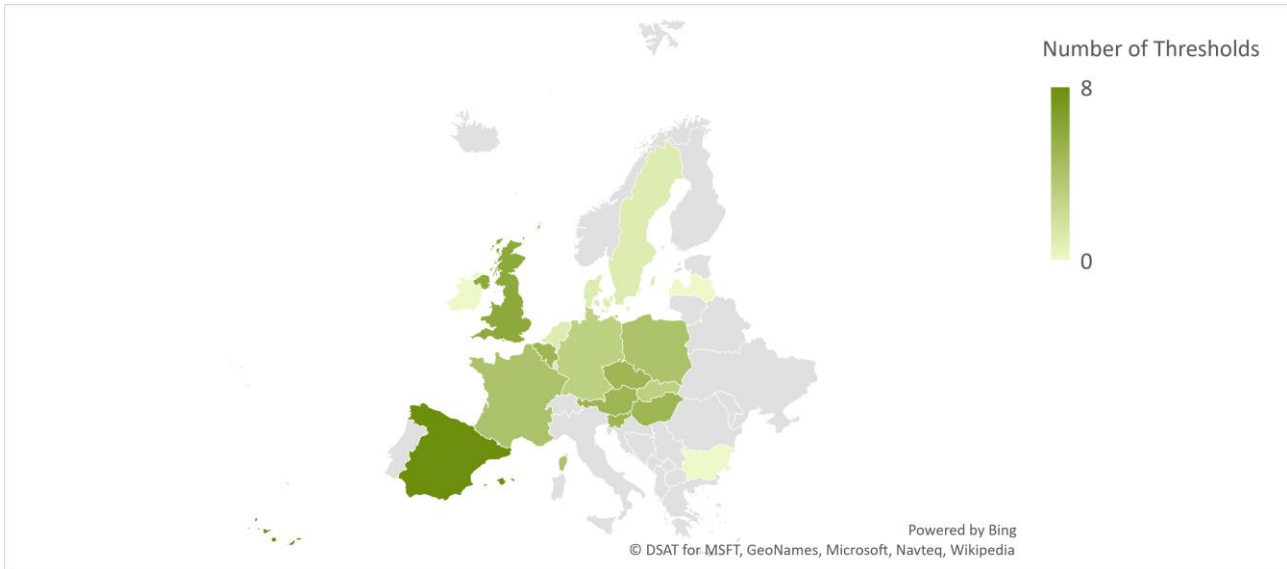


The information from the TYROSAFE research indicates that the survey seasons vary slightly, due to different climates, however the majority of countries survey season is during the spring/summer months.

6.3.5. Skidding Resistance Thresholds

Figure 6-4 illustrates the number of bands utilised by each country, based on information from the TYROSAFE research project.

Figure 6-4 Number of Skidding Resistance Thresholds



The TYROSAFE research indicates that the EU countries which replied to the Skid Resistance survey on policies and standards, there is a variety of different thresholds, with four countries without thresholds. Out of the remaining countries that do have national thresholds, several countries have determined the thresholds through statistical analysis of the skidding resistance data and a few countries have based the thresholds on analysis of road traffic collision data.

6.3.6. Remedial Actions

The TYROSAFE research project investigated the remedial actions which countries conducted if the skidding resistance values were worse than warning and threshold levels. The majority (82%) of respondents indicate that remedial works would be undertaken to improve the skidding resistance if the values were below the threshold level. Over 50% of respondents indicates that they utilised the options of erecting warning signs (Fig 6-5) and applying a speed limit (Fig 6-6), when skidding resistance levels fell below warning or threshold levels.

Figure 6-5 Warning Signs - remedial option if skidding resistance below Warning or Threshold

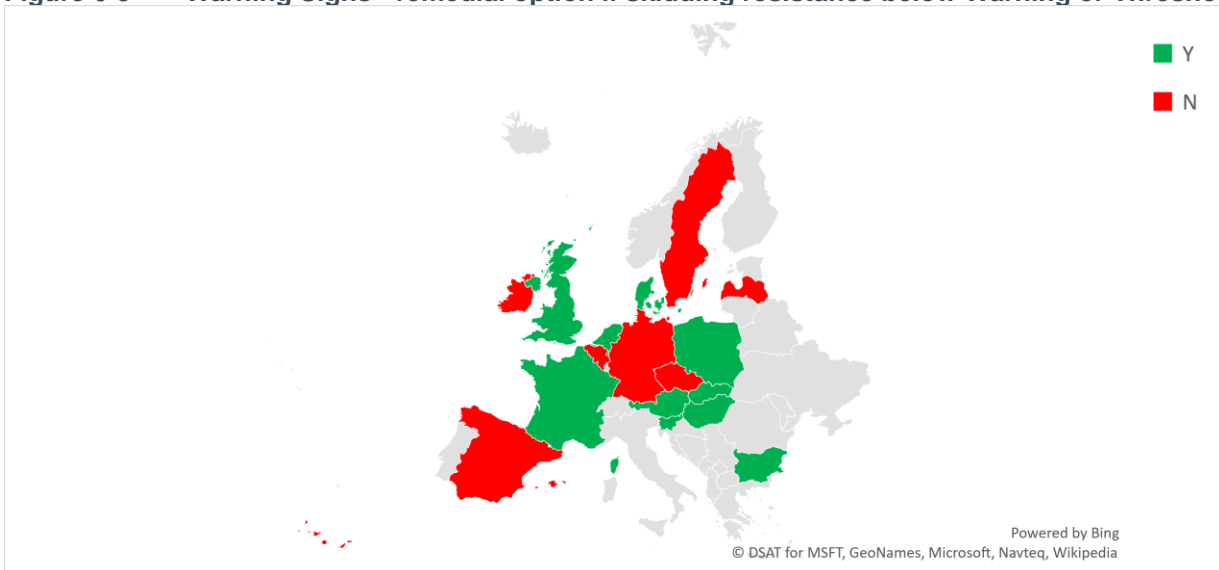
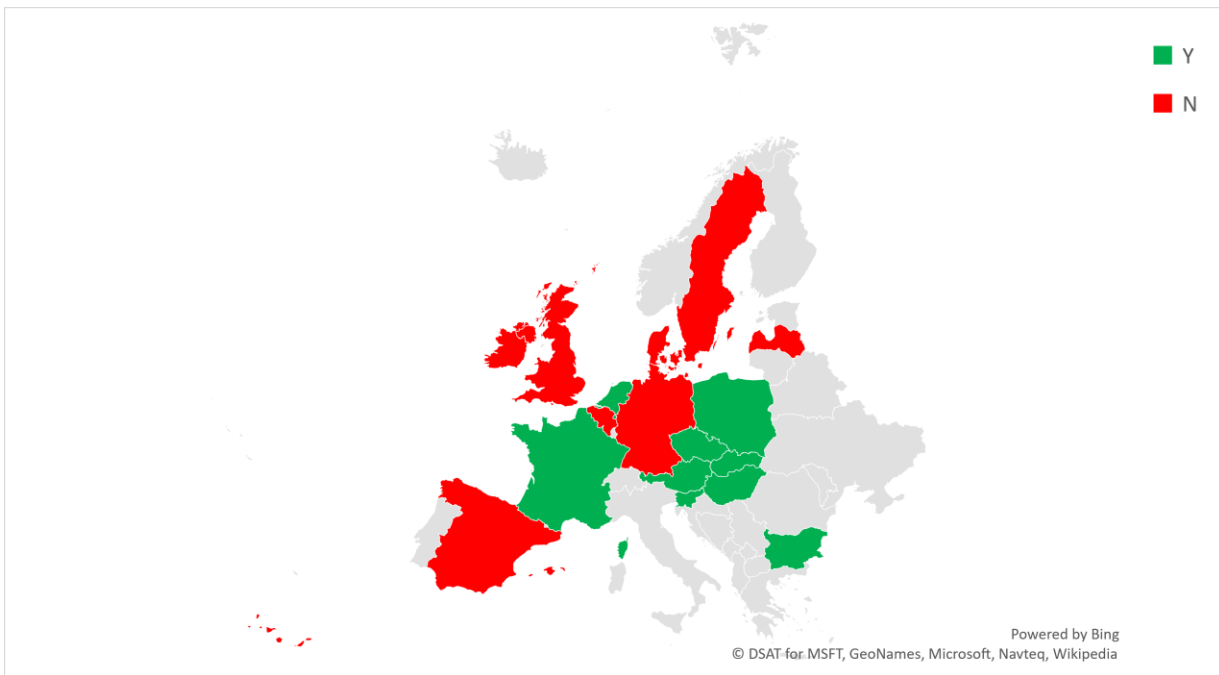


Figure 6-6 Speed Limit – remedial option if skidding resistance below Warning or Threshold



6.3.7. Holland – Managing Skidding Resistance

Rijkswaterstaat (RWS) published “skidding resistance on national roads” in 2015, which contains the action plan safety measures for managing the skid resistance of the network for a Design Build Fund and Maintain (DBFM) contract and this can be seen in the diagram illustrated in figure 6-7.

Figure 6-7 Action plan safety measures in the case of RWS maintenance advice and in the case of DBFM

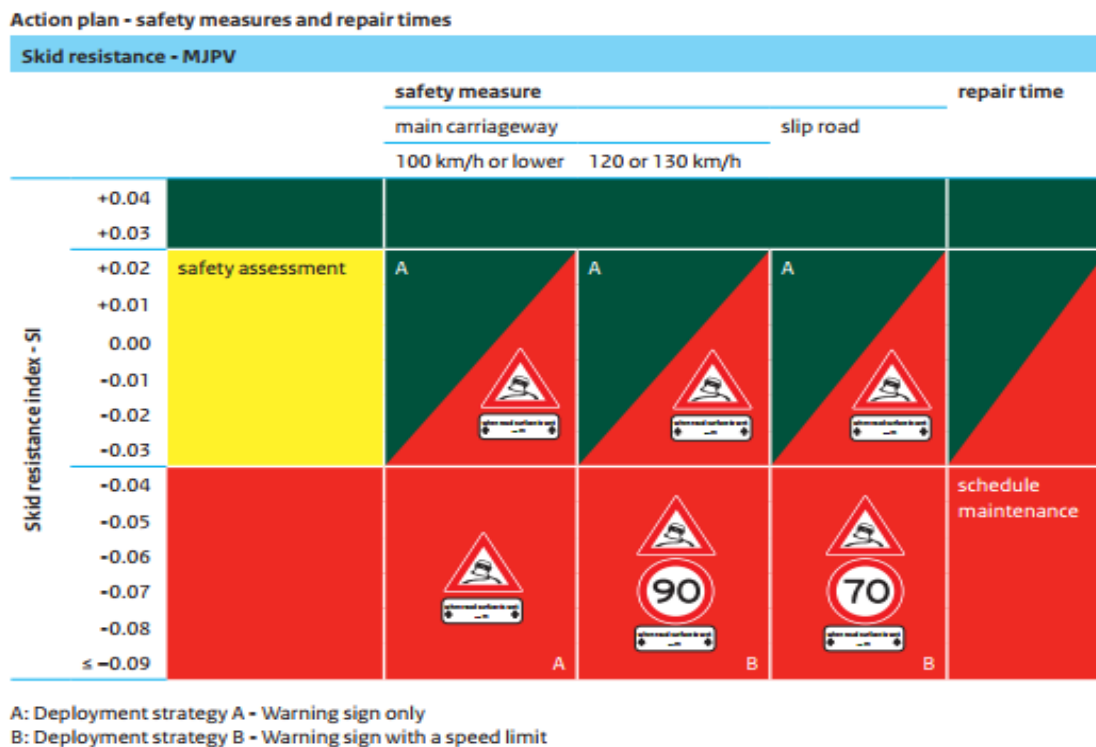


Figure 6-7 illustrates that if a road surface SCRIM difference is ± 0.03 , slippery road signs are erected with text explaining “only in the wet”. If the SCRIM difference is ≤ 0.04 , the actions depend on the speed limit of the

road and if it is a slip road or not; 100km/h (62 miles/h) or less speed limit locations are managed by using signs and higher speed limit roads have temporary speed limits applied until works are completed.

6.4. International Skid Resistance Practices outside Europe

6.4.1. New Zealand and Australia

Australian Department of Infrastructure and Regional Development and New Zealand Transport Agency have adopted a similar philosophy as the UK to the measurement and management of the highway skidding resistance, conducting annual SCRIM surveys, correcting the readings based on the prior three year's surveys and assessing the SCRIM against Investigatory Levels based on the assigned Site Category.

The difference in Australian and New Zealand standards are that the survey machines survey both the left and right wheel paths; New Zealand average the results to determine the Equilibrium SCRIM Coefficient (ESC) [NZTA T10 Specification:2013 – Specification for state highway skid resistance management]. Australian Roads Corporation of Victoria (VicRoads) Technical Note 110: Measurement and Interpretation of Skid Resistance using SCRIM, November 2015 indicates that the Side-way Force Coefficient (SFC) from each wheel path is considered individually against the assigned Investigatory Level, plus the Differential Friction Level (DFL) reviewed to ensure the difference between the two-wheel paths does not increase the risk of vehicle rotating when braking or manoeuvring.

A copy of the New Zealand Transport Agency and VicRoads Skid Resistance Investigatory Level Table is contained in Appendix A.

New Zealand Transport Agency (NZTA) have looked at reducing speed limits to support lower skid resistance IL's particularly on high risk bends – a trial was undertaken on State Highway 58 and concluded that if the IL could be maintained at 0.4 (average skid resistance level achieved on State Highways when local aggregates are used), a 10kph reduction in max operating speed was sufficient to give the same level of crash risk. The findings of this trial indicate that a reduction in speed could also be used to enable the use of locally sourced aggregate due to reducing the need for a high PSV aggregate and which in turn would lead to cost savings through transport costs.

6.4.2. United States

The ASTM E-274 locked-wheel skid test is used in 49 of the 50 states; the survey machine comprises of a vehicle or trailer with one or more test wheels that measure the longitudinal friction force. The survey measures the friction force by locking the test wheel brakes when at testing speed (typically 40mph) and recording the force exerted from the interaction between the tyre and road surface as the test wheel is dragged.

Due to the nature of the test wheel locking, this means that measurements are taken at intervals instead of continuously throughout the survey; typically, whole cycle of measurement takes at 3.5 seconds which is approximately a measurement every 63 metres.

The results are used to derive a Skid Number and then the skid number thresholds, typical examples of the thresholds are contained in Table 6-2.

Table 6-2 Typical Skid Number thresholds (<http://www.pavementinteractive.org/skid-resistance/>)

Skid Number	Comments
<30	Take measures to correct
≥30	Acceptable for low volume roads
31 – 34	Monitor pavement frequently
≥35	Acceptable for heavily travelled roads

The Federal Highway Authority (FHWA) has purchased a SCRIM which arrived in June 2015 and are presently working with Virginia Tech Transportation Institute to compare the SCRIM and ASTM E-274 locked-wheel skid test results.

6.5. Recommendations (International Practice Review)

It can be concluded that internationally, the primary method of surveying skid resistance is using side-ways force types surveys, such as SCRIM and SKM. Additionally, there is consistency between the SCRIM and SKM readings when the machines utilise the same test tyres. However, to allow the adoption of SKM on the

UK network, changes would have to be made to allow skidding resistance machines to be statically loaded and changes would be needed to either BS 7941-1 or to the SKM test tyre to make it BS 7941-1 compliant.

Additionally, the international practices review indicates that it is widely accepted that speed is a major factor when considering the skidding resistance of road surfaces, with several international road authorities reducing the speed limits on lengths of road which have below acceptable skidding resistance to manage the risk.

Investigate the potential to consider traffic speed data in the assignment of Site Categories and Investigatory Levels (see Section 4 – Traffic Speed and SCRIM).

7. Conclusions and Recommendations

The main conclusions and recommendations of this review task are identified in the following sections and are provided for consideration by Transport Scotland (TS).

7.1. Conclusions and Recommendations

7.1.1. Assessment of Current Network Condition and IL's

The review of the current network condition and Investigatory Levels identified the following recommendations for consideration by TS:

- Full review of all the IL's currently held on the TS IRIS system to ensure that they are correct and appropriate. If this is restricted by available budgets, then focus on one area and base any further recommendations on these findings.
- In association with the above recommendation conduct an analysis of the currently assigned IL's using shapefiles to ensure that they are all correctly and accurately positioned.
- Review how accident rates are developed and applied to the network and apply any potential changes to the network to understand the opportunity to re-calculate data for lowering of current IL bands.
- Identify any potential gaps in the SCRIM data and ensure that a process is in place to manage these locations. This could include the assessment of high-risk areas, undertake a risk analysis to see if alternative methods of achieving skid resistance and/or road condition are required.
- Complete a data cleansing exercise of the crash data by reviewing the causality factors, ensuring that an incident is attributable to the road surface and/or skidding issue before applying it. The results may impact on the Accident Rates and adjust the risk rating of individual locations of negative SCRIM difference.

7.1.2. Best Practice Review

HD28/15 (as well as its predecessors) is not intended for the management of skid resistance on local roads, although similar principles may still apply. For this reason, Local Authorities (LA's) throughout the UK, have been developing and using their own skidding resistance strategies as they generally have a lower volume of traffic (including lower commercial vehicles) as well as many 'rural' evolved roads that are not designed to current standards.

It is recommended that TS investigate the potential for a bespoke Site Category and Investigatory Level Table that better suits the TS network as the rural parts of the TS network are generally old evolved carriageways that are not designed to current standards.

7.1.3. Risk Acceptance

Review of the CSC Bands vs wet injury RTC rates based on Site Categories has identified that for the majority of site locations the current IL is considered appropriate. The analysis highlighted four recommendations for consideration by TS, as follows:

1. Merging 'Gradient 5%-10%' (G1) and 'Gradient >10%' (G2) into a unified 'Gradient \geq 5%' site category.
2. Undertake a more detailed review to establish the impact of reducing the Single and Dual Bend radius from 500m to 250m.
3. Further investigation into Single Bends < 100m radius, to establish the factors that influence the wet injury RTC rate, as these do not appear to decrease as the skidding resistance improves.
4. Examining wet injury RTC's within the boundaries of 'Approach to Junction' site categories, analysing if there are trends based on junction type (Traffic Signal, Give Way, Stop Line, Roundabout, etc), carriageway type, Speed Limit, visibility and vehicle speed (average and 85th percentile).

7.1.4. Traffic Speed and SCRIM

With traffic speed data becoming more accessible, road authorities are able to undertake a risk-based approach to managing the skidding resistance of the road network, particularly on high speed bends where current practices identify vehicle speed as a key component to wet skid incidents.

It is recommended that analysis is undertaken the S1/S2 bends along a route or in an area to determine if actual traffic speed and the bend radii has an impact on the likelihood of wet skid road traffic incidents. It is recommended that the analysis should consider:

- SCRIM Site Category & Investigatory Level data
- Speed Limit
- Vehicle speeds
 - Mean vehicle speed
 - 85th Percentile vehicle speed
- Traffic Count Data
- SCANNER data
 - Alignment
 - Crossfall
- Injury Road Traffic Collision Data

Through the analysis, it will highlight locations where it could be acceptable to reduce the speed limit without impact travel times, due to traffic being unable to reach the speed limit due to road geometry. Additionally, the analysis would utilise the information above to identify the attributes in the bends which increase the likelihood of incidents occurring, allowing Transport Scotland to manage their asset more efficiently and effectively by adopting a risk-based approach which caters for their local stakeholders.

7.1.5. International Practice Review

It can be concluded that internationally, the primary method of surveying skid resistance is using side-ways force types surveys, such as SCRIM and SKM. Additionally, there is consistency between the SCRIM and SKM readings when the machines utilise the same test tyres. However, to allow the adoption of SKM on the UK network, changes would have to be made to allow skidding resistance machines to be statically loaded and changes would be needed to either BS 7941-1 or to the SKM test tyre to make it BS 7941-1 compliant.

Additionally, the international practices review indicates that it is widely accepted that speed is a major factor when considering the skidding resistance of road surfaces, with several international road authorities reducing the speed limits on lengths of road which have below acceptable skidding resistance to manage the risk.

It is recommended that the potential to consider traffic speed data in the assignment of Site Categories and Investigatory Levels is investigated (see Section 4 – Traffic Speed and SCRIM).

Appendices



Appendix A. Skid Resistance Investigatory Level

A.1. New Zealand

Table 1 Skid resistance investigatory levels

Site category	Skid site description	Investigatory level (IL), units ESC					
		0.35	0.40	0.45	0.50	0.55	0.60
1	Approaches to: a) Railway level crossings b) Traffic signals c) Pedestrian crossings d) Stop and Give Way controlled intersections (where state highway traffic is required to stop or give way) e) Roundabouts. One lane bridges: a) Approaches and bridge deck.						
2	a) Urban curves <250m radius						
	b) Rural curves <250m radius			L	M	H	
	c) Rural curves 250–400m radius		L	L	M	H	
	a) Down gradients >10%. b) On ramps with ramp metering.						
3	a) State highway approach to a local road junction. b) Down gradients 5–10% c) Motorway junction area including on/off Ramps d) Roundabouts, circular section only.						
4	Undivided carriageways (event-free).						
5	Divided carriageways (event-free).						

Notes to Table 1:


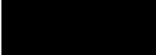
- When using seasonally corrected data, ILs are for mean skidding resistance within the appropriate averaging length. This is referred to as the Skid Assessment Length (SAL). The SAL for each site category is detailed in table 2
- the curve risk rating on rural curves with radii 0-400m is shown as H, M or L (high, medium or low-risk curves) in the appropriate greyed IL band under site categories 2b and 2c. Two options are available for rural low-risk sites with radii between 250m and 400m. Urban curves with a radius less than 250m are site category 2a
- the units for IL in table 1 are ESC, being the average of the left and right wheelpaths. Where seasonally corrected data is not available, SCRIM coefficient (SC) may be used as an approximation to ESC with further checks undertaken when seasonal corrections are available
- where the length of the feature is less than the SAL, the actual length shall be averaged and considered.

A.2. Australia VicRoads

Site Category	Site Description	Investigatory Levels of SFC ₅₀ at 50km/hr						
		0.30	0.35	0.40	0.45	0.50	0.55	0.60
1	<ul style="list-style-type: none"> Signalised intersections Pedestrian/school crossings Railway level crossings Roundabout and approaches 	INVESTIGATION					ADVIS	
2	<ul style="list-style-type: none"> Curves with tight radius $\leq 250\text{m}$ Gradients $\geq 5\%$ and $\geq 50\text{m}$ long Freeway, highway; on and off ramps 	ADVIS				INVESTIGATION		
3	<ul style="list-style-type: none"> Intersections 	ADVIS			INVESTIGATION			
4	<ul style="list-style-type: none"> Manoeuvre-free areas of undivided roads 	ADVIS		INVESTIGATION				
5	<ul style="list-style-type: none"> Manoeuvre-free areas of divided roads 	ADVIS	INVESTIGATION					

Site Category	Site Description	Investigatory Levels of SFC ₂₀ at 20km/hr						
		0.30	0.35	0.40	0.45	0.50	0.55	0.60
6	<ul style="list-style-type: none"> Curves with radius $< 100\text{m}$ 	INVESTIGATION						ADVIS
7	<ul style="list-style-type: none"> Roundabout and approaches 	ADVIS					INVESTIGATION	

Key To Thresholds At Or Below Which Investigation Is Advised

	Roads with less than 2,500 vehicles per lane per day
	Roads with more than 2,500 vehicles per lane per day

NOTES:

- The difference in Sideways Force Coefficient values between wheel paths (Differential Friction Levels) should be less than 0.10 where the speed limit is greater than 60km/hr; or less than 0.20 where the speed limit is 60km/hr or less.
- Investigatory levels are based on the minimum of the four point rolling average skid resistance for each 100 metre section.
- Investigatory Levels for Site Categories 1 and 3 are based on the minimum of the four point rolling average skid resistance for the section from 50 metres before to 20 metres past the subject site, or for 50 metres approaching a roundabout.

Matthew Miller
Atkins
The Exchange
2nd Floor
3 New York Street
Manchester
M1 4HN

matthew.miller@atkinsglobal.com

© Atkins Ltd except where stated otherwise.

The Atkins logo, 'Carbon Critical Design' and the strapline
'Plan Design Enable' are trademarks of Atkins Ltd.