5th International Safer Roads Conference, 2017, Auckland, New Zealand
Hertfordshire Skid Resistance Strategy

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Abstract

Hertfordshire County Council (HCC) is recognised in the UK as an innovative highway authority that seeks to continually improve the manner in which it manages the highway network and appropriately prioritises spending of maintenance budgets. The paper describes the authors' involvement in developing a Skid Resistance Strategy (the Strategy) for HCC and using spatial analysis to apply the Strategy criteria to the Hertfordshire highway network. The Strategy was developed from skid resistance best practice in the UK, New Zealand, and Australia. While the Strategy includes detailed technical content, it is written to be accessible for all users (including policymakers) within the Council. Applying the Strategy to the network involved developing a set of automated spatial models in Geographic Information Systems (GIS) to leverage the relationships between spatial and non-spatial inputs through various geometrical, spatial, and tabulated relationships, queries, criteria, and constraints. Data limitations required additional steps to be taken in the GIS models to account for and/or mitigate the limitations. Developing an appropriate order of operations required a robust GIS analysis approach, collaboration with engineers, and a sound understanding of relevant GIS tools. The outputs demonstrate that even with data limitations a robust Skid Resistance Strategy can be applied to a local road network.

The primary objective of the paper is to share with road controlling authorities the approach that can be taken for developing and applying a skid resistance strategy for a local road network. The paper describes preparation of the Hertfordshire (UK) Skid Resistance Strategy and the use of automated spatial models to identify intervention levels for various site categories. It also describes how the approach better equips the Council to identify and prioritise those sections of highway requiring skid resistance maintenance in a manner that optimises spending of their maintenance budget.

1 Introduction

Hertfordshire County Council (HCC) is one of the leading highway authorities in one of the leading countries of the world for road safety performance. In terms of killed and seriously injured casualties per billion vehicle kilometres travelled (vkt), Hertfordshire casualty rates are typically 60 to 75% of the rates for all of England. However, HCC recognise that performing well from a road safety perspective is no reason for complacency.

For several years HCC collected skid resistance data for many of the higher-level roads on their 5000 km highway network; however, there was not a formal strategy in place for determining the adequacy of the measured skid resistance on the highway network. The Hertfordshire County Council Skid Resistance Strategy (the Strategy) was developed by a team of engineers and spatial modellers that brought experience and knowledge from the United Kingdom, Canada, Australia, and New Zealand.

This paper describes the approach used in developing the Strategy and demonstrates that other road controlling authorities with a suitably defined highway network can apply a bespoke skid resistance strategy to their network. One of the important aspects of the paper (and the

Strategy) is that a skid resistance strategy can be flexible to fit within operating budgets; the key thing is to have the Strategy in the first place. While texture depth and management of the highway surface to control ice, flooding, and detritus (such as fallen leaves) are important components of skid resistance, they are not specifically addressed in the Strategy because they are captured elsewhere in the HCC highway maintenance and management procedures.

A draft version of the Strategy was endorsed by Council in March 2014 and has been subject to ongoing refinement since then.

2 Developing the Strategy: Engineering

2.1 Introduction

Hertfordshire decision-makers (the elected councillors) maintain an interest in the performance of the County's highway network and have a good awareness of the road safety performance of the network. Skid resistance is arguably one of the most important road safety measures for a highway network because it provides road users with one of the key physical elements of the highway environment that assists them in controlling their vehicles.

The relationship between skid resistance and road safety is illustrated by the following sources:

- Highways England (2015, page A1/3) note that "… low skid resistance does not cause crashes although,… it may be a significant contributory factor… Higher skid resistance can therefore reduce crashes…".
- The NZ Transport Agency (2012, page 1) observe "Numerous studies internationally have shown that a skid resistance policy, which implements appropriate skid resistance … reduces crash rates and is a very economic, crash reduction tool …".
- Austroads (2011, page 5) states "Research undertaken in a number of countries is consistent in indicating that a disproportionately high number of crashes occur on road surfaces that have a low level of skid resistance …".

The engineering components of the HCC Skid Resistance Strategy address three fundamental aims:

- Providing an overview of skid resistance theory and practice;
- Optimising skid resistance for the highway network within budgetary constraints; and
- Defining the basis on which to determine the appropriate level of skid resistance for each portion of the highway network.

2.2 Skid Resistance Theory and Practice

The first portion of the Strategy provides an overview of the fundamentals of skid resistance theory and practice. The intention of including this material is to communicate the principles behind the Strategy to decision-makers and road users. The theory and practice material included in the Strategy addresses:

- What is skid resistance?
- Methods by which skid resistance can be measured.
- Approach used in Hertfordshire.

Although the overview provided is necessarily brief, it is a key foundation of the Strategy.

2.3 Budgets

Clearly, there must be budgets for carrying out any activity on a highway network, because there is not an inexhaustible supply of funds to deliver all possible projects and maintenance activities for the network.

Highway authorities need to prioritise spending on their highway network to deliver the most appropriate outcome for road users. HCC prioritise their spending for investigation and application of skid resistance on the network to balance risk against available funds. Funding constraints dictate that not all sites identified as potentially justifying skid resistance improvements can or will be investigated and/or treated. Therefore, the Council must prioritise skid resistance testing and remedial works for those highways at the higher level of the roading hierarchy, and those highways on which a potentially higher level of risk than normal has been identified, and on which it may be appropriate to undertake testing to determine whether skid resistance issues exist. The Strategy incorporates a trial prioritisation process for skid resistance remedial works that allows the Council to demonstrate that the funding available for skid resistance remedial works has been spent in the most appropriate manner.

2.4 Basis for Investigatory Levels

At the time the Strategy was first developed, the UK standard for the management of skid resistance was recorded in the Design Manual for Roads and Bridges (DMRB) document HD 28/04 Skid Resistance (the Standard). The objective of HD 28/04 "… is to manage the risk of skidding [collisions[1]] in wet conditions so that this risk is broadly equalised across the … road network. …" (Highways Agency, 2004). The Standard requires each subsection of highway to be categorised by key parameters. Since the Strategy was first endorsed by Council, Highways England (2015) has released an updated version of the Standard.

Notwithstanding that HD 28/04 (Highways Agency, 2004) 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 Hertfordshire network, it does not represent the most effective and/or appropriate framework for managing skid resistance on the network.

The Strategy built on the Highways Agency (2004) guidance and describes the specific requirements for the HCC highway network.

Similarly to many highway networks, Hertfordshire has a roading hierarchy; theirs includes:

- A-roads
- B-roads
- C-roads
- U-roads

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[1] In this paper, the terms "collision" and "crash" have the same meaning. At the time the Strategy was initially developed, the Highways Agency (2004) used the term "accident", while the Strategy used the term "collision". However, Highways England (2015) have started using the term "crash".

The hierarchy proceeds from A-roads at the top to U-roads (unclassified) at the bottom. Figure 1 provides an overview of the Hertfordshire highway network and its hierarchy, and illustrates the location of the County within the United Kingdom.

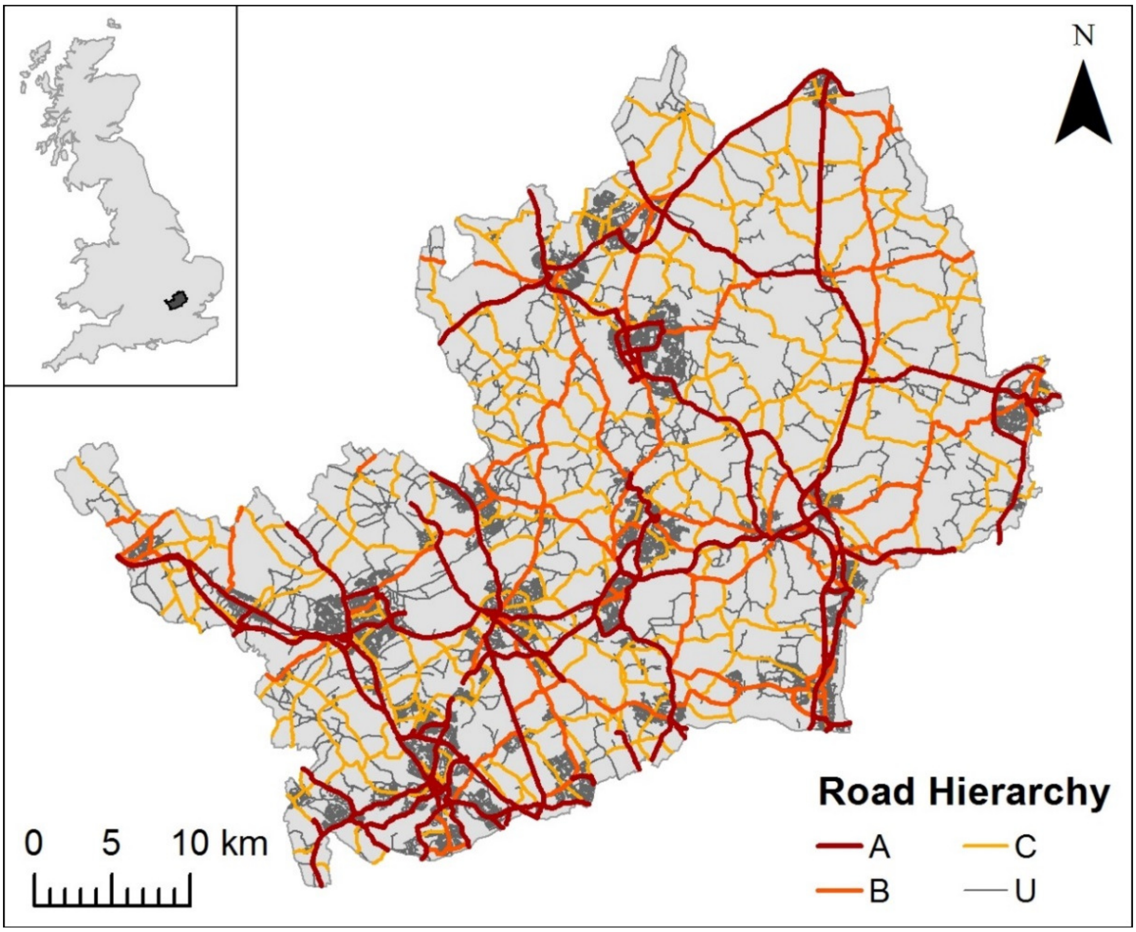

Figure 1: Hertfordshire County Council Road Network

2.5 Event Categories

HD 28/04 (and HD 28/15) describes 10 site categories that can be applied to a 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 matters addressed by the Hertfordshire categories that are not as fully covered in the Standard, are as follows:

- Consideration of speed limits above and below 30 mph (50 km/h)
- The skid resistance demand on the controlled approaches to junctions being greater than the skid resistance demand on the uncontrolled approaches
- Curve radii on the Hertfordshire network that are lower than curve radii likely to be encountered on the trunk road network
- The inclusion of skid resistance categories for “unclassified” roads (U-roads).

Table 1 below describes the skid resistance categories included in the Strategy.

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

2.6 Length of Skid Resistance Demand

A concern that the Strategy team identified with conventional skid resistance policies (such as HD 28/04) is the application of a standard 50 m length for specific site categories on the approach to a feature. While the Standard allows for extending the 50 m length when justified by local site characteristics, it does not take account of different approach speeds. The updated version of the Standard (HD 28/15, Highways England, 2015) retains the 50 m length criteria.

The Strategy adopts a variable length for the approaches to junctions and pedestrian crossings based on the speed limit in which the event exists. The adopted lengths were determined based on operating speeds for different speed limits, braking distances from the Highway Code

(DfT, 2014), and calculated stopping distances based on assumed surface friction and a range of speeds immediately prior to braking. While several jurisdictions adopt skid resistance lengths between 50 and 60 m, irrespective of the operating speed, the Hertfordshire Strategy has skid resistance lengths ranging from 25 m for a 30 mph speed limit to 130 m for a 70 mph speed limit. The range of lengths allows for the variation in the stopping distance required for a vehicle, depending on the likely operating speed of the vehicle.

2.7 Meeting Road User Expectations

2.7.1 High Friction Surfacing

For several years prior to the Strategy being developed, funding had been available for the widespread application of high friction surfacing (HFS) at many locations on the Hertfordshire (and United Kingdom) highway network. While there was generally a collision reduction basis for installing the high friction surfacing, there may not have been detailed analysis of the existing skid resistance of the highway surface at each site and consideration of the potential for an appropriate level of skid resistance to be provided using conventional surfacing materials (other than high friction surfacing). Since installation, the condition of the high friction surface on numerous lengths of highway has (not surprisingly) deteriorated. As a result, investment decisions have had to be made as to whether those surfaces are reinstated when maintenance is required or whether they are replaced with a surface of an appropriately high skid resistance, but one that does not incorporate the frictional or colour characteristics typical of high friction surfaces.

Because road users have developed an expectation of high friction surfacing for some site categories (such as the approaches to pedestrian crossings, curves, and junctions); on a case-by-case basis Hertfordshire County Council have explained to road users the reasons high friction surfacing has been replaced with conventional surfacing that nonetheless meets an appropriate level of skid resistance. Some road users appear to have developed an expectation that high friction surfacing is the only solution (or the best solution) for addressing the perceived or actual incidence of collisions at various locations. The Strategy specifically notes that “HFS will only be used where substantial personal injury collision reduction is anticipated…” (HCC, 2016). Therefore, while the Strategy has documented the appropriate and financially necessary reduction in the installation (and maintenance) of high friction surfacing, it also describes appropriate conventional highway surfacings to provide for the skid resistance needs of road users.

2.7.2 Curves

Many road users are unlikely to be aware of the specific radius of a curve on which they are travelling. However, from a skid resistance demand perspective, it is important to provide road users with appropriate levels of skid resistance, while at the same time identifying a practical means by which to deliver the skid resistance described by the Strategy. As demonstrated by the results of the 2015 National Highways and Transport Survey (NHT, 2016), road users regard “Safer Roads” as more important than any other component of the highway and transport services provided in Hertfordshire and the UK as a whole.

The team preparing the Strategy were concerned that if discreet minimum lengths for the application of a particular IL to a curve were rigidly followed, the potential existed for extensive lengths of curvilinear highway to be identified as non-event sections if consideration was not given to the proximity of nearby sections of highway that also constituted a curve. As a result, the team developed a series of criteria to ensure that a curve or series of curves, where the radii varied between the curve site categories (or incorporated short non-event lengths) was captured as a contiguous length of highway requiring the provision of a curve specific surface skid resistance demand, rather than the sections being identified as “non-event”, because there is not continuity of a specific site category throughout a series of curves.

From an engineering perspective, the Strategy team readily identified criteria by which to categorise lengths of highway comprising curves of varying radius. However, as discussed in the GIS portion of this paper, the application of the varying site categories to the highway network was more complicated.

2.8 Basis for Applying Strategy to the Network

2.8.1 Prioritisation

Having identified the sections of highway on which the skid resistance is at (or more than a nominal value below) the IL, a programme of works needs to be developed to address the skid resistance deficiencies. The decision-making process for any highway network involves optimising improvements in skid resistance across the network for a given budget. While the methodology has yet to be tested, the Strategy includes an objective risk based prioritisation process that considers a range of factors including:

- The amount by which the skid resistance is below the IL; the greater the difference between the measured skid resistance and the IL, the higher the priority for treatment
- Personal injury collision history in the vicinity of the sections identified. Those lengths with the most collisions obtain the highest ranking
- The classification of the highway; with those highways at the upper level of the hierarchy (A-roads) taking priority over highways lower in the hierarchy
- The speed limit for the highway
- Normalising the prioritisation value for each section by dividing by the section length.

The intention behind the prioritisation system is to allow practitioners to determine the lengths of highway on which it is most appropriate to address any skid resistance deficiencies. Through having an objective system, there is reduced potential for the decision-making process to be inappropriately influenced by input from stakeholders.

2.8.2 Polished Stone Value

The Design Manual for Roads and Bridges (DMRB: HD 36/06, Highways Agency, 2006) describes requirements for surfacing materials for new and maintenance construction. The document indicates that as commercial vehicle use per lane increases, the Polished Stone Value (PSV) of the aggregate used for the surfacing should also increase. Essentially, for a given skid resistance, HD 36/06 requires a greater PSV where the polishing demand (due to commercial vehicle use) is greatest.

The Strategy recognises that while the expectation of practitioners may be that a higher PSV produces a higher skid resistance, some studies (for example, Allen et al, 2008) have demonstrated that this is not necessarily the case. The need for research in Hertfordshire has been identified, with the aim being to determine the correlation between PSV and in service skid resistance for various aggregates available in Hertfordshire.

Notwithstanding the need for further research, the Strategy identifies the aggregate PSV to be applied based on the various site categories. Because of the lack of information available, the team developing the Strategy considered it inappropriate to expect practitioners to determine the most appropriate PSV to be used to achieve a specific skid resistance. Given the potential for litigation related to skid resistance, the Strategy provides a documented basis for practitioners to select a surfacing aggregate.

2.8.3 Accurately Informing Road Users

The Strategy recognises the appropriateness of using warning signs to advise road users that an upcoming length of carriageway may have lower than expected skid resistance. Because such signs can be overused and/or inappropriately left in place, the Strategy clearly defines the basis on which slippery road signage can be installed and (importantly) the basis on which they must be removed.

Although the installation of warning signage may be regarded as an inconsequential component of skid resistance management, it is important that road users are accurately informed of a lower than expected standard for the road surface and, as importantly, that road users are not incorrectly advised there is an issue with the highway when the issue has been resolved.

2.9 Macrotexture

The Strategy provides an overview of the two components of the road surface that contribute to the level of available friction on that surface; that is, macrotexture and microtexture. Cairney (2006, page 9) notes that "The evidence reviewed indicated a substantial difference in crash occurrence between sites with low macrotexture and sites with high macrotexture." He also observes (Cairney, 2006, page 2) there is a significantly more material that considers the relationship between pavement friction (measured by a range of devices including, but not limited to, SCRIM) and crashes, and that considering the relationship between macrotexture and crashes.

Austroads (2011, page 7) records that "… crash risk is greater at sites with low macrotexture,… although there was no close agreement about the precise value of macrotexture at which the crash risk began to rise…".

Macrotexture measurement in Hertfordshire is not carried out using SCRIM, but is undertaken separately using SCANNER (Surface Condition Assessment of the National Network of Roads). The macrotexture data is used for deterioration modelling, however, at present it is not specifically used for analysing texture depth on the network. Hertfordshire County Council recognise there is potential for combining the SCANNER macrotexture data with the SCRIM skid resistance data to improve the manner in which the macrotexture and microtexture components of skid resistance are combined and analysed to optimise skid resistance on the Hertfordshire network within available funding. Preparation of the Strategy has been a very significant first step in improving skid resistance management on the Hertfordshire highway network; incorporating analysis of texture depth into skid resistance management will be another important step.

3 Applying Strategy to the Network: GIS

3.1 Introduction

For the geospatial aspects of applying the Strategy to the network, the challenge was creating automated spatial models which would apply the logic from the Strategy to the spatial datasets to identify and classify the various extents of the network, based on the categories in Table 1, and a range of other uniquely specific criteria using data in a range of formats. With GIS, automated spatial models leverage the spatial, database, and geometry relationships and feature transformations between formats to identify the IL criteria extents in a standardised approach. This could not readily be achieved through manual digitisation, and certainly not within the same timeframe or to the same level of accuracy. The approach taken within GIS was to break the network down into its main components (base network; approaches to pedestrian crossings; approaches to junctions; curve radius; and gradient); each of which would have its own sets of models.

3.2 Models

3.2.1 Network

The first step in the GIS modelling was to build a base network that defined the road IDs, directions, speed limits, and start and end route positions. This involved extracting the A, B, C, and U-roads for Hertfordshire from the full network dataset, then compiling information from two other datasets to capture speed limit and direction. The direction information (CL1 and CR1) was required because single carriageways have skid resistance demands for both directions of travel, but are only represented by a single line feature. Therefore, information for each direction has to be treated independently in the spatial analysis. Speed limit was a variable required in a number of models; mainly for site category classification and determining appropriate approach lengths.

3.2.2 Non-Event Sections

Using the base network with reference to speed limit, road type, and hierarchy, the full base network was classified according to the criteria outlined in Table 1 for site categories B, C, D, U1, and U2. Non-event dual carriageway highways were all classed as site category “B”. For single carriageway A, B, and C-roads, the classification of each was dependent on whether the speed limit was >30mph (“C”) or ≤30 mph (“D”). U-roads were assigned the site categories U1 where the speed limit is ≤30 mph and U2 where the speed limit is >30 mph. Due to data limitations, U-roads were not covered in the analysis of the other factors (curve radius, gradient, pedestrian crossings, or junctions, except where a U-road intersects with an A, B, or C-road). Therefore, the ILs for U-roads are limited to the speed limit related categories (U1 and U2) and junction categories (QC and QU) where U-roads intersect with A, B, and/or C-roads.

3.2.3 Curve Data

The curve data was derived from a spreadsheet of 2013 data collected through an automated high-speed survey of A, B, and C-roads using SCANNER vehicles. In order to conduct spatial analysis the contents of the table had to be linear referenced using the base network to generate a spatial layer of curve radii across the network. Three immediate challenges were identified:

1. The recorded extents spanned lengths of ≤10 m and the curve site categories required contiguous ≥50 m extents
2. A single carriageway can have both directions of travel plotted along the same centreline
3. Single carriageway highways have three potential curve categories (S2, S3, and non-classified) whereas dual carriageway highways only have two (S1 and non-classified).

For these reasons the single and dual carriageways were independently analysed.

3.2.4 Single Carriageway Curves

For curves on single carriageway there are three possible IL categories when working in GIS: S3 (>-250 m and <250 m), S2 (≤-250 m and >-500 m OR ≥250 m and <500 m), and non-classified (<-500 m OR >500 m). While the curve radii are described as absolute values in the Strategy, the GIS analysis considered them as negative and positive values.

Unlike dual carriageways, which only have curve data for a single direction of travel, much of the single carriageway network has curve data for both directions. So for a single carriageway centreline there can be two curve extents sharing the same location. This added to the complexity because the analysis had to treat each direction independently of the other, while undergoing the same geospatial analysis. Careful analysis was required, along with a good understanding of how features, geometry, attributes, and spatial processes behave with different geospatial functions.

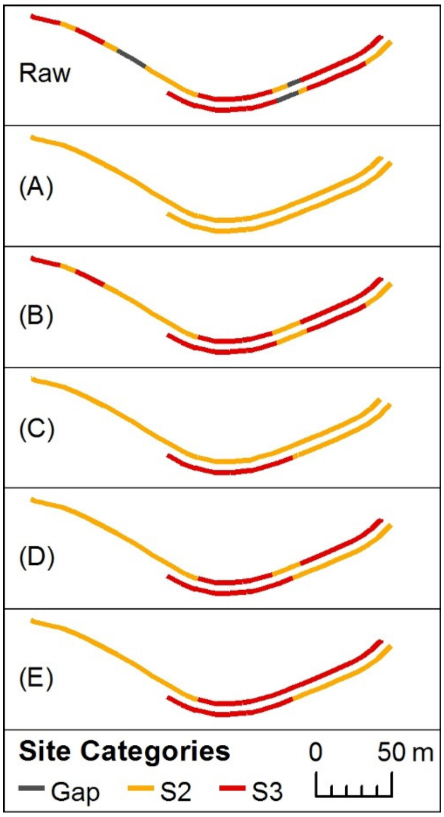

Figure 2: Curve radius site categories visual comparison

The order of operations for identifying and applying ILs was based on the curve categories outlined in Table 1. The differing results of each model step, from selection of initial extents contributing to a contiguous ≥50 m S2/S3 extent, through to its classification via steps (a) through to (e), are illustrated in Figure 2 and described in the following points:

a) Identify contiguous lengths ≥50 m where the absolute value of the curve radius is <500 m and assign the full length as “S2”
b) Within the contiguous ≥50 m extents identify all ≤10 m extents where the absolute value of the curve radius is <250 m and assign as “S3”
c) Where a series of curves have curve radii <250 m and these comprise an arbitrarily selected 70% of the S2/S3 extent, assign an “S3” site category to the full extent
d) If ≥50 m extents of S3 are present in any contiguous S2/S3 extent and the 70% threshold is not met, assign an S3 site category to the ≥50 m S3 extents
e) Where any gap of <50 m is present between two ≥50 m S3 extents, assign these gaps and the S3 extents on either side as S3
f) Where gaps <12 m exist between two contiguous ≥50 m extents, add these to the analyses and repeat steps (a) to (e).

The section of highway illustrated in Figure 2 is single carriageway and the data in each frame has been visually offset based on direction; where CR1 is the longer upper contiguous extent and CL1 is the shorter lower contiguous extent.

From a geospatial approach the <12 m non-classified sections (or gaps) were analysed at the beginning to make the process slightly easier and to avoid unnecessary repetition. There was also a requirement to extend curves across different highway sections; for instance A1000/10 and A1000/20 are different sections of the same highway (A1000), but have separate features in the network spatial data.

The first step was to add another field and populate this with the highway name to provide one of the fields to be used in matching data (along with direction and extent IDs). Identifying the <12 m extents of non-classified sections, that formed the gaps between sections of <500 m radius curves, involved applying a buffer (polygon of a specified radius around the full extent of a feature) and identifying the sections that fell within the buffer. Where the ends of the 6 m buffers overlapped (which could be an extent of up to 12 m) the gaps of <12 m that fell within the overlap were identified and included in the analysis. Any <12 m extents identified within the buffer area that did not fall between two sections of either S2 or S3 (i.e. located at the very end of a ≥50 m contiguous length) were excluded from the analysis as these belonged to gaps larger than 12 m. Further to that criteria, the non-classified sections also had to belong to the same highway (e.g. A1000) and direction (CL1 or CR1, not a mix of both) as the S2/S3 extents at either end. Step (a) was then applied so all nominal 10 m extents were assigned S2. Step (b) involved selecting features by query and classifying accordingly. Steps (c) to (e) required comparisons of combined lengths, spatial proximity, queries and classification.

3.2.5 Dual Carriageway Curves

Dual carriageways only have two curve categories; either S1, where the curve radius is ≤500 m (and ≥-500 m), or non-classified (>500 m or <-500 m); therefore, classification was not as complex as for the single carriageway curves. Dual carriageway curves also have a major difference in that they are unidirectional; that is, the centrelines only have one set of curve extents associated with them. As a result, the spatial modelling process was not as complicated. The approach to classifying dual carriageway curves followed the same approach of including gaps of <12 m between extents that fit the S1 criteria. The subsequent classification process was similar to that for single carriageway curves, but with a few minor differences. The sections were first classed as either S1 or Nil based on curve radius. For each contiguous S1/Nil subsection, the total lengths were then identified as S1, Nil, and S1/Nil combined. Using these lengths the percentage of S1 for each contiguous length was determined. If 60% of the contiguous length was classed as S1 the full extent was classed S1. Extents of ≥50 m based either on a pure contiguous S1 or contiguous ≥60% S1, were classified as S1.

3.2.6 Gradients

Gradient data for A, B, and C-roads was derived from a table within the spreadsheet containing the curve data. The initial conversion from tabulated data to spatial extents along the network followed the same process as the initial set up for curves. Consequently, gradient data extents were also ≤10 m.

Skid resistance classification for gradient falls within three potential categories; ≥50 m extent of ≥10% gradient (G2), ≥50 m extent with a gradient of 5-10% (G1), Gradient <5% (non-classified). Unlike the curve categories the gradient categories are not dependent on whether the highway is a dual carriageway or single carriageway. However, because of the number of categories and similar analysis issues, the process applied to identifying the gradient site categories was very similar to the method used for identifying curves on single carriageway highways. An adapted version of the (a) to (e) process used for single carriageway curves was applied to gradients to determine the G1 and G2 categories.

3.2.7 Junctions

The modelling of junctions was one of the most complex for which to establish a geospatial approach, given the detailed datasets feeding into it and the various criteria that had to be applied. Junctions include circulatory roundabouts, signalised roundabouts, mini roundabouts, signalised junctions, priority controlled junctions (e.g. stop and give way), and uncontrolled junctions, where control is typically based on road hierarchy. In addition to the base highway network, the data to be used included:

- Signs (points), which is a subset of the full sign inventory, to identify those signs that apply to junction control;
- Signals (points), which is a subset of just those traffic signal installations that pertain to junctions; and
- Mini roundabouts (points).

The approach taken was to decompile the highway network into “end points” on the assumption that where several roads meet end to end this defines the presence of a junction. However, this was not strictly the case as U-roads and, in some instances, A, B, and C-roads connect to A, B, or C-roads midblock, rather than at the end of a road section. The midblock locations had to be identified as point locations, with the correct associated information, that could be included in the analysis. The midblock points were duplicated so one represented the theoretical end of one section and the other the start of the next, which later helped with creating the directional based approach and departure extents. Each point then represents a road and its approach to, and departure from, any individual junction; these combined point datasets were collectively referred to as “end points”.

Identification of roundabouts with a defined circulatory carriageway was relatively easy because these could be identified in the base network. By singling out these features and applying a 12 m radius buffer around the centreline of the defined circulatory carriageway, the end points of the roads connecting to the roundabout could easily be identified; these connection points were used to identify the approaches to and/or departures from roundabouts. Approaches to mini roundabouts were based on the point location in the proximity of each mini roundabout. For signalised junctions the signals dataset only had one point feature per junction, which for an ordinary signalised junction could be spatially located in the middle of the junction, but for a signalised roundabout the point might be spatially located either inside the central island of the roundabout or somewhere to the side. In many instances the dataset contained a single point to represent more than one signalised approach (that is, the point was not necessarily located where the signals were located). Signs to define priority control for a junction contained a field that recorded the associated road ID; therefore, it was readily possible to identify which road/s at the junction were under priority control. All these junction types were identified using both spatial relationships and database query selections. All roundabouts with a defined circulatory carriageway were assigned an “R” site category, each controlled approach was assigned site category “QC”, and each uncontrolled approach to a junction, and the departure from roundabouts, was assigned “QU”.

For the junctions at which no control had been identified in a dataset, we assumed the junction had priority control based on the hierarchy of roads intersecting at the junction. This required identifying the hierarchy of each road (A, B, C, or U) based on its road ID, and identifying the other road hierarchies present at the same junction. The lower hierarchy (A > B > C > U) was assumed to be subject to priority control and assigned a “QC” site category, while the higher hierarchy road was assigned a “QU” site category. Any approaches to junctions that were not classified as “R” or “QC” were assigned “QU”. A process was set up to identify all “QU” only “junctions” and determine whether these were false junctions where only two sections of the same highway meet; these “junctions” were removed from the dataset. The process followed also identified any missed “QC” extents, which may have resulted from having roads of identical hierarchy intersecting at a junction, in which case the highway with the least number of intersecting road sections (such as occurs at a T or Y junction) was categorised as “QC”. In addition, if the end of one road section met midblock with another, where one end represents an end and the other two points represent the road on which the midblock occurs, the end point approach was categorised as “QC” and the midblock approaches were left unchanged as “QU”. Part of the challenge with this process was distinguishing whether the midblock was a junction or false junction, which could be distinguished based on the count of midblock points by the assigned junction ID. This process also eliminated some false junctions where the road either crossed under or over another road, which can be difficult to identify when working in a two-dimensional geospatial environment.

Creating the approach lengths on the network required identification of a start and an end position, as well as a matching route ID. The start and end route positions were calculated based on offsets from the route position of the end points. These offsets include the approach length, which was dependent on the speed limit (faster speed, longer approach length); an offset factor from the centre of the junction to kerb, based on road hierarchy and junction type; and a spatial geometry offset to account for where small gaps may exist between adjoining centrelines. The means of calculating start and end route positions using the offsets differed depending on whether the extent was an approach or a departure and whether it was for the increasing or decreasing direction (CL1 or CR1).

Whether the feature was an approach or a departure was determined based on the route position of the point and direction, this also meant the start and end route positions for the approach and departures were calculated slightly differently; as a result, one approach would be negative while the other would be positive. Once the approach, departure, and roundabout extents had been plotted as line features across the network, the dataset was reduced to focus on all approaches to roundabouts and the departures from roundabouts. All other departures from other junction types were excluded from the output.

3.2.8 Pedestrian Crossings

Establishing the skid resistance IL for the approaches to pedestrian crossings entailed identifying these as point features on the network then determining the approach for each direction of travel. The IL for the approach length is dependent on the speed limit. To create the extents the point attribute table was modified before the data could be spatially transformed to plot the approach lengths. This included splitting the table by road direction, adding route position fields for start and end positions, and populating them based on direction, point position, and approach length. The two tables were then combined before the extents were identified based on the route start and end positions.

3.3 Compiled Output

The modelled outputs for junctions, curves, gradients, pedestrian crossings, and non-event sections were brought together to create a compiled network-wide spatial layer of site categories and associated ILs. To achieve this, the IL extents in each of the outputs had a 5 m directional flat end buffer applied so that the CL1 extents were buffered 5 m to the left of the centreline, and CR1 extents were buffered 5 m to the right of the centreline. Each of the polygon outputs created by the buffers was then stripped of any attributes that were not required in the output, before being systematically combined into a single spatial layer. As polygons overlap there was a need to ensure that only those which share the same road ID and direction were combined; this ensured that only the information appropriate to each particular section of road was associated with that section. To address the possible issue of slithers and overlapping redundant features, a series of steps was included within the compilation process to identify these features where practicable and reclassify them based on the most appropriate larger adjoining feature which would ultimately absorb them.

ILs were assigned to the network based on the highest IL value present at the each site. This meant all sites were classed in order from highest to lowest IL. The result was a spatial layer of the different ILs based on the site categories. Figure 3 illustrates a portion of the network to which the individual site categories have been applied, with the highest IL plotted on the visible layer; Figure 4 illustrates the same portion of the network in the compiled output form showing the IL for each portion of the network. While the automated spatial models were carefully developed and compiled, the resulting output has some limitations. The quality and reliability of any GIS output is limited by the completeness and quality of the input data. Clearly, the GIS modelling process cannot identify whether isolated data is missing or whether any features have been located/recorded incorrectly.

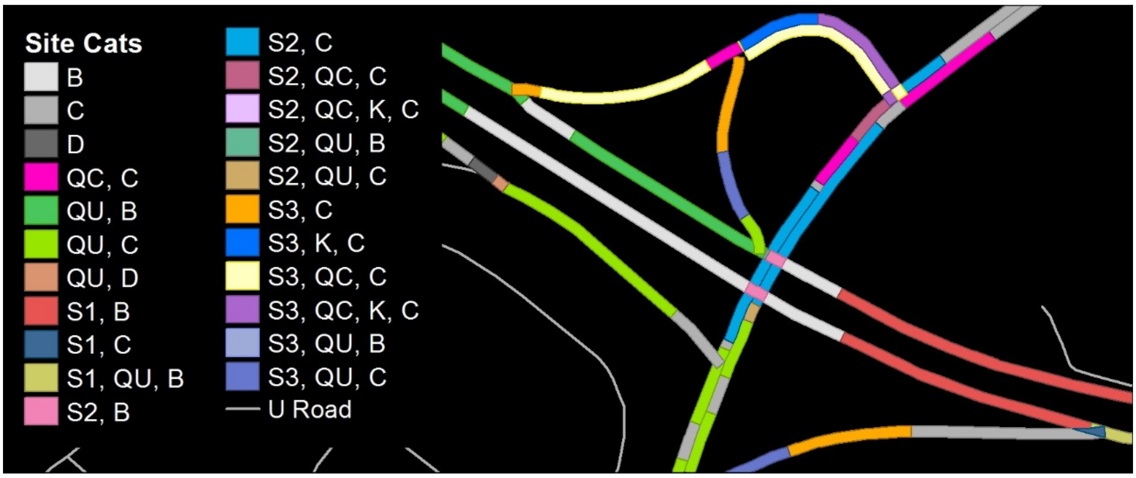

Figure 3: Example of the site category output

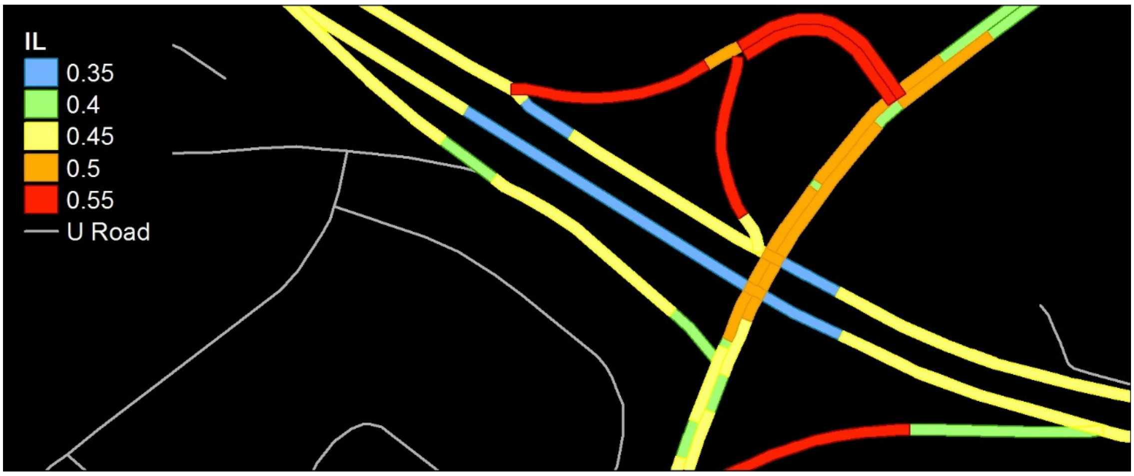

Figure 4: Example of the compiled output

4 Application of the Strategy

While it is a work in progress, the Strategy is being used for identifying and analysing the highest priority sections of highway on which to improve skid resistance. In addition, the Strategy is being refined to further improve its applicability for the HCC network.

Because the first comparison of skid resistance data with ILs produced a large number of sections that potentially required attention, the initial focus has been on sections of highway greater than 25 m long where the skid resistance is less than IL. Sections have then been ranked for treatment based on collision history, road class, speed limit, AAWT[2], and difference from IL. The identified lengths have also been compared with the HCC IWP[3] programme (current and future) to identify efficiencies for the timing of skid resistance works.

Tangible results road safety improvements directly linked to the Strategy have yet to be identified, however, the all-important first steps have been made and progress is continuing.

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[2] AAWT = Annual Average Weekday Traffic

[3] IWP = Integrated Works Programme

5 Conclusions

The team that developed, and are implementing, the Strategy have produced a bespoke approach to determining the skid resistance requirements for the Hertfordshire highway network. The engineering approach that has been adopted seeks to deliver skid resistance for the network that is aligned with road user needs, prioritisation of risk, and budgetary constraints.

The use of GIS to apply the Strategy to the network has been complex in that methods had to be developed to produce a spatial highway network on which the ILs have been assigned in accordance with the engineering requirements of the Strategy.

Notwithstanding the level of complexity involved, the key conclusions associated with developing the Strategy include:

- Skid resistance is arguably one of the most important and fundamental components of road safety for a highway network
- There is little point in measuring skid resistance on a network unless the findings of those measurements are applied to enhance skid resistance
- It is not necessary for a highway authority to adopt national (and potentially inappropriate) skid resistance standards for a local road network
- Provided a suitable spatial representation of the highway network can be obtained, it is readily possible to apply a bespoke skid resistance strategy to a highway network that will allow skid resistance risk across the network to be prioritised.

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Acknowledgements

The authors acknowledge with thanks the support and permission provided to them by Hertfordshire County Council for this paper to be prepared. They also acknowledge the involvement of their colleagues at Hertfordshire County Council and Opus International Consultants who worked with them on producing and applying the Skid Resistance Strategy.

Author Biographies

Renée Schicker is a Geographic Information Systems (GIS) Specialist at Opus with an MSc (Hons) Earth Sciences and nine years' GIS experience. Renée has a wide range of GIS skills which include advanced spatial analysis, automated spatial models/scripts, mobile data capture, web maps, and advanced cartography which enable her to provide a variety of high value GIS services for various projects and disciplines. She has worked collaboratively with Opus' road safety team to create various automated spatial models for skid resistance, crash analysis, quarterly network safety trend analysis, social cost analysis, and the identification of high risk rural roads.

Robert Swears is a Principal Transportation/Road Safety Engineer with Opus. His varied highway engineering experience ranges from investigation and planning for projects through to maintenance management. The projects Robert is involved with are predominantly funded by central and local government agencies. While most of his experience has been gained in New Zealand, from September 2012 to January 2015 he was responsible for road safety engineering activities on the 5000 km Hertfordshire County Council (HCC) highway network. Robert's involvement in preparing the HCC Skid Resistance Strategy allowed him to continue with his passion for using engineering to reduce road crash trauma.