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The relationship between vehicle data, collision risk and skid resistance

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Executive Summary

This aim of this study was to understand the potential of vehicle data to help manage skid resistance on the road network and to consider whether vehicle data could be used in the future to measure skid resistance.

An algorithm has been developed by Synaptiv to identify skidding events using vehicle telematics data. The algorithm was validated using a track trial and it was found that the algorithm correctly identified skidding events during braking 97% of the time across different road surface at speeds above 50km/h. Identification of other types of skidding events (those during acceleration and whilst the vehicle was travelling at constant speed) have not been validated.

Vehicle data was gathered by a fleet of vehicles travelling on the Strategic Road Network (SRN) during an 18 month period and 220 skidding events were identified using the algorithm developed by Synaptiv; 92 of these events were during braking, 98 during acceleration and 30 whilst the vehicle was travelling at a constant speed.

These 220 skidding events of all types were analysed using a clustering algorithm and then the initial list of clusters was refined using additional criteria. As a result of this process, four clusters of skidding events were identified. This was not sufficient data to carry out statistical modelling so these four clusters were used in case study analysis to gain further understanding into the characteristics of the cluster sites.

The case study analysis involved reviewing key measures calculated for each cluster from a number of different data sources which provided data about the road surface characteristics at the cluster site, collisions that happened at that site and traffic flow. In addition, vehicle telematics data for all vehicles (both skidding and non-skidding) which travelled through the clusters was collated and analysed.

Two clusters were located on roundabouts, one on a motorway and one on a dual carriageway. The number of skidding events in a cluster varied from three to eight. The speeds at which most braking skidding events occurred were greater than 50km/h which is within the speed range where the skidding algorithm is known to be reliable. This means that clusters where the majority of events were braking events are likely to be robust. However, the two clusters on roundabouts where the majority of skidding events were not during braking are likely to be less reliable.

In general, the case study analysis showed that the road surface at the cluster sites did not have characteristics that would normally warrant further investigation. This suggests that clusters of skidding events from vehicle data are identifying sites with potential skidding risk which would not have been identified using current methods. However, further analysis of these sites would be needed in order to establish whether the skidding events are likely to have been caused by the road surface or other factors.

It is important to note that the conclusions of this study are severely limited by the lack of data and a larger study is recommended to form more robust conclusions. However, the results suggest that there may be potential value in using vehicle data to identify sites with high skid risk that are not currently being identified. Further investigation of some of the cluster sites identified is recommended.

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1 Introduction

The current Highways England skid resistance policy uses accurate measurements of road surface properties (e.g. skid resistance and texture depth) and identifies sites where a surface treatment may reduce the risk of skidding, based on these characteristics. The aim of the current policy is to broadly equalise the risk of skidding accidents across the network, and to identify sites where maintenance to improve skid resistance would be beneficial.

The current skid resistance standard, CS228 (CS 228 Pavement inspection and assessment - Skidding resistance, 2019), defines the approach to managing appropriate levels of skid resistance using routine (typically annual) measurements of the road network. The data from these measurements trigger investigations of individual sites where the skid resistance is low. The thresholds to trigger site investigations (Investigatory Levels, IL) are based on the type of carriageway (e.g. motorway, approach to junction, roundabouts, gradients, bends etc.). The concept is that higher IL are assigned at locations where the risk of collisions involving skidding is greater, thereby attempting to achieve an equalisation of risk. The current skid resistance policy uses IL to identify areas which might need improvement and then uses an investigation process that includes a review of accident data, to decide whether any change is required.

An alternative approach may be a system whereby vehicles directly report the risks on the network. If data on the location of skidding events (e.g. anti-lock braking system (ABS) activations, and the precursors to these activations) can be collected then this could be used to build up a picture of areas where these events are clustered. A cluster may indicate that there is an increased risk at that location.

1.1 Objectives

The primary objective of the work outlined in this report was to:

Understand the potential of vehicle data to help manage skid resistance on the road network.

As part of this project, TRL have worked with Synaptiv, a data analytics company who are focused on generating value from connected car data. Synaptiv have access to in-vehicle data from a fleet of Jaguar Land Rover vehicles being driven on the road network. Broadly, the aim was to use these data to identify skidding events on the Strategic Road Network (SRN), in order to provide a larger dataset with which to evaluate risk than the number of road accidents.

A secondary objective was to consider whether vehicle data could be used in the future to measure skid resistance, reducing (or perhaps eliminating) the need to carry out routine surveys of the network.

1.2 Contents of this report

This report describes the work carried out by TRL and Synaptiv to achieve these objectives. Specifically:

- Section 2 outlines the project tasks and disaggregation of these
- Section 3 presents the results of the analysis
- Section 4 summarises the conclusion and presents a discussion of next steps.

1.3 Acronyms/abbreviations

Table 1 contains a list of acronyms and abbreviations used in this report and their definitions.

Table 1: Acronyms/abbreviations

Acronym/abbreviation	Definition
ABS	Automatic Braking System
CAN	Controller Area Network
CSC	Characteristic Skid Coefficient
DBSCAN	Density-based Spatial Clustering of Applications with Noise
DfT	Department for Transport
HAPMS	Highways England Pavement Management System
HGV	Heavy Goods Vehicle
HMVM	Hundred Million Vehicle Miles
IL	Investigatory Level(s)
OBD	On-Board Diagnostics
PFT	Pavement Friction Tester
SCRIM	Sideway-force Coefficient Routine Investigation Machine
SLWG	Straight Line Wet Grip
SMTD	Sensor Measured Texture Depth
SRN	Strategic Road Network
TRACS	Traffic-speed Condition Surveys

2 Method

Figure 1 presents a summary of the project tasks. The methodologies for each of these tasks are described in more detail in the following sections.

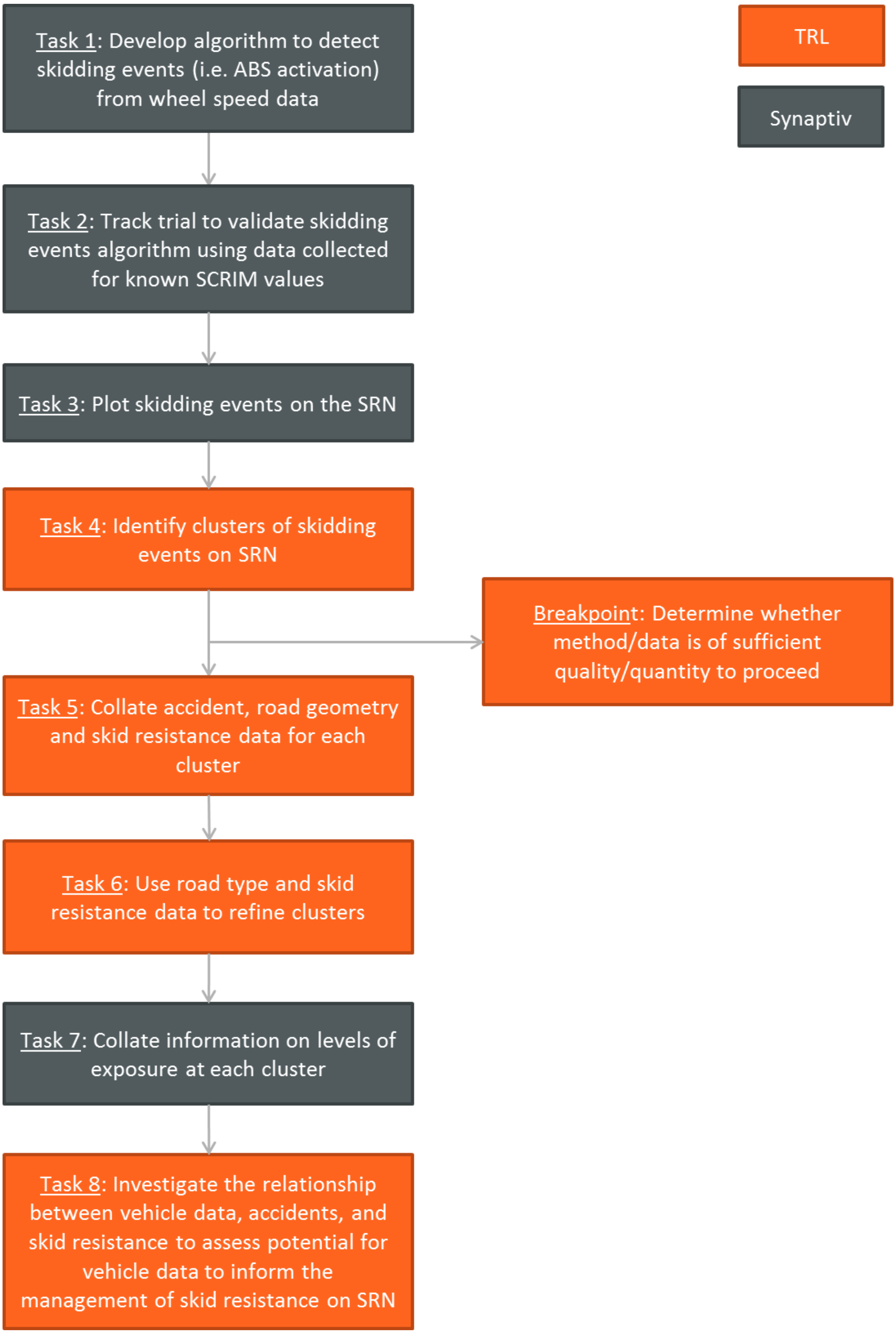


Figure 1: Summary of project tasks

2.1 Task 1: Develop algorithm to detect skidding events

In the first task, Synaptiv used wheel speed data, accessed through the vehicle's On-Board Diagnostics (OBD) port, to develop an algorithm to detect skidding events. The wheel speed data was recorded for each vehicle at 1Hz frequency. Instances where the wheel speed differentials (i.e. differences in the rate of change between the front or rear wheel speeds of the vehicle) were above a certain threshold were identified as potential skidding events. Differentials between the left and right wheels which were the result of cornering were not flagged as skidding events.

Wheel speed data were selected for this purpose as this information is more readily available than Automatic Braking System (ABS) activation signals, which require direct access to the vehicle's Controller Area Network (CAN) bus.

2.2 Task 2: Track trial to validate algorithm

2.2.1 Objective of the track trial

The objective of the track trial was to collect data from the in-vehicle sensors, specifically those pertaining to wheel rotational speed and brake activation, during a straight line braking manoeuvre. These data were used to identify ABS activation events (and the pre-cursors to this) and understand the performance of vehicles on different materials in order to validate the skidding algorithm developed in Task 1 (Section 2.1).

2.2.2 Facilities and equipment

For the purposes of the trial, Synaptiv supplied a Jaguar XF fitted with two data loggers. These recorded data from the vehicle (brake sensors, vehicle speed, wheel speed and ABS activation) at 1Hz and accelerometer data in all three directions at a higher frequency (10Hz).

Highways England's Pavement Friction Tester (PFT) was used by TRL to collect data on the friction properties of each of the surfaces during the braking manoeuvres.

The trial was carried out at the HORIBA-MIRA proving ground on the Straight Line Wet Grip (SLWG) area (Figure 2). This area has a number of surface materials with a range of reported friction values (red[1]). Skid resistance levels measured using the PFT[2] have also been provided for comparison (black).

[1] As measured using the Portable Skid Resistance Tester (PSRT) and reported as values of Mean Pendulum Test Value (Mean PTV).

[2] Measurements made at a test speed of 65km/h.

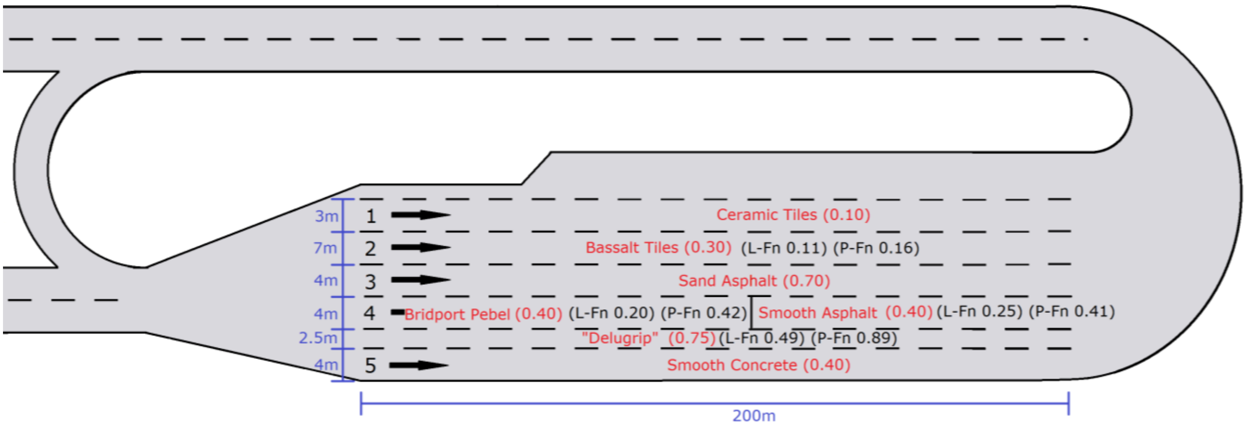


Figure 2: The SLWG Area, advertised friction values and section names given in red, measured skid resistance levels given in black, approximate distances given in blue

2.2.3 Trial procedure

The trial involved a number of runs by both the car and PFT at a range of speeds, across three different surfaces and in different conditions (wet or dry). Table 2 shows the combination of scenarios tested. Typically, 3 to 5 runs were completed for each scenario.

Table 2: Combinations of scenarios for test track trial

Speed		Surface & condition
30 km/h 50 km/h 70km/h	X	Sand asphalt, dry Sand asphalt, wet Basalt tiles, wet[3] Bridport pebble, wet

For each run, measurements were made using the PFT peak friction "chirp" protocols[4]. On longer sections the PFT was able to conduct multiple measurements in a single run. For the wet measurements, the SLWG spray bars were used instead of the PFT water flow system so that water depths were the same for both the PFT and vehicle tests.

During each run the car conducted a straight line braking manoeuvre: approaching the surface at the desired test speed, applying maximum braking once all four wheels were in contact with the surface and ensuring that the vehicle came to a full stop before accelerating away again for the next run. All data were collected with ABS activated.

[3] Testing of the Basalt tiles and Bridport pebble sections were not carried out under dry conditions owing to testing restriction from the test track owner.

[4] Peak friction protocols apply the brake until peak friction, the maximum friction provided by the road surface at the test speed, is reached. The brake is then released and the tyre allowed to rotate freely before a second test is made. This approach is analogous to the activation of ABS on the test car.

2.2.4 Validation of skidding algorithm

In order to validate the algorithm, the sensitivity (true positive rate) and specificity (true negative rate) of the skid events identified by the skidding algorithm were compared to ABS activations recorded in the data[5]. The results of this validation are presented in Section 3.1 of this report.

2.3 Task 3: Plot skidding events on SRN

Following validation of the skidding algorithm, this was applied to all the vehicle fleet data collected by Synaptiv between June 2017 and mid-November 2018. A total of 220 skidding events were identified on the SRN.

Each event was mapped to the SRN based on a nearest neighbour approach, with the restriction that the event had to be within 15m of at least one point on the link.

2.4 Task 4: Identify clusters of skid events on the SRN

Clusters of skidding events were identified using a Density-based Spatial Clustering of Applications with Noise (DBSCAN) algorithm (Ester, Kriegel, Sander, & Xu, 1996). In this algorithm, events are clustered based on location and two parameters: minimum number of events within a cluster and maximum distance between adjacent events 'as the crow flies'.

Sensitivity testing was performed in order to establish the most appropriate values for the DBSCAN parameters. This involved running the DBSCAN algorithm numerous times for different values of the two parameters; the results of this can be seen in Table 3.

Table 3: Number of clusters produced by DBSCAN algorithm for different combinations of parameters

		Minimum number of points in cluster							
		3	4	5	6	7	8	9	10
Max distance (metres) between adjacent points	**10**	0	0	0	0	0	0	0	0
	100	4	1	0	0	0	0	0	0
	200	6	4	2	1	0	0	0	0
	500	13	5	2	2	2	1	1	0

After discussions between TRL and Highways England, it was decided to set the minimum number of events to three and the maximum distance between events to 500m for the clustering identification process. The main reason for this was to preserve as high a number of viable clusters as possible.

[5] Note that due to the sampling frequency of the data (1Hz) it is possible that some ABS activations were missed. However, typically for each braking event the ABS was shown to activate more than once so the likelihood of missed events affecting the results presented here is considered to be low.

Before the DBSCAN algorithm was applied to the 220 skidding events identified on the SRN, the dataset was split by road number. This was to avoid events on different roads being grouped into the same cluster. The algorithm was then run on each dataset in order to find clusters on that road.

The resulting clusters were defined as groups of skidding events and so did not have any identifiable shape or boundary. In order to link the clusters with the other datasets in Task 5, it was necessary to define a boundary for each cluster. An example of this box and how it was defined is shown in Figure 3.

For each cluster, a box was defined using the minimum easting and northing coordinates of all the events in the cluster as the coordinates for the bottom left-hand corner and the maximum easting and northing coordinates of all the events as the coordinates for the top right-hand corner (blue dotted line in Figure 3). This box was then expanded by 100m on all sides and the resulting box (red line in Figure 3) was used to link to clusters to the datasets in Task 5.

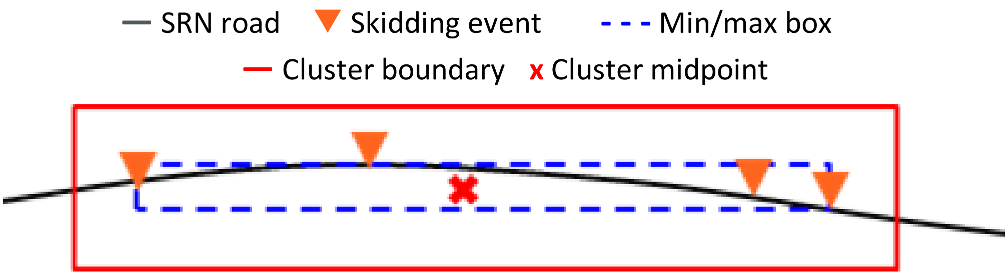


Figure 3: Diagram of cluster boundary process

2.5 Task 5: Collate linked datasets

There were three datasets that were linked to the skidding event clusters in order to gather further information about the road surface and geometry, collisions and traffic in the clusters.

1. Highways England Pavement Management System (HAPMS) which contains data about road characteristics for the SRN.
2. Stats19 collision data.
3. Traffic flow data published by Department for Transport (DfT).

The HAPMS data linking was performed before the cluster refining task (Task 6, section 2.6) because the information was needed in the cluster refining process but the linking of the Stats19 and traffic data was only done for the clusters used in the final analysis. The following sections describe each dataset and how they were linked to the clusters.

2.5.1 HAPMS data

HAPMS is the Highways England database where results of all the road condition surveys and other information about attributes of SRN roads are stored. The SRN is split into sections and data is recorded for each section. GIS software was used to gather data from HAPMS for the roads in the clusters. Relevant HAPMS sections were identified using the following criteria; sections which intersected the cluster boxes defined in Task 4 (see section 2.4) and for which the road number for the section matched the road number for the events in the cluster. Data was then extracted for these sections. This included the following key variables to be used in analysis of the clusters.

- Characteristic Skid Coefficient (CSC) – Measure of overall level of skid resistance on the road.
- Texture depth – Sensor Measured Texture Depth (SMTD). Indicative characterisation of the road surface macrotexture.
- Site category – Type of road e.g. motorway, non-event dual carriageway, roundabout.
- Section length – Length of road section.
- Investigatory level – Used to interpret CSC values.

2.5.2 Stats19 data

Stats19 is a database of injury collisions on public roads in Great Britain. Data is recorded for the collisions, the vehicles and casualties involved and factors which the police believed contributed to the collision. To identify collisions within clusters, GIS software was used to plot collisions for the period 2013 to 2017 on a map together with the cluster boxes. The collisions that had been assigned to each cluster were then reviewed manually to ensure that the all the collisions identified were on the same road as the cluster and that no collisions on nearby roads had been assigned to the cluster incorrectly. Key Stats19 variables extracted for the collisions in each cluster included:

- Road surface condition – whether the road was dry, wet, icy etc. at the time of the collision.
- Vehicle manoeuvre – what the vehicles involved were doing when the collision happened.
- Skidding/overturning – whether the vehicle skidded or overturned at some point during the collision.
- Contributory factors – factors which the police felt contributed to the collision.

2.5.3 DfT traffic data

DfT publish traffic flow estimates for all the major roads in Great Britain each year (DfT, 2019). These are calculated from a combination of observed and estimated traffic counts at count points across the road network and are split by vehicle type. As there is usually only one or two count points on each road link (a link is usually defined between two major junctions), it was not possible to use the cluster boxes to identify the count points needed to calculate traffic in the clusters. Instead, count points on links where there were clusters were identified manually and the data from these was used to calculate traffic through the cluster. For clusters on roundabouts, the count points on all the roads feeding into the roundabout were identified and the data from these were used to calculate the flow on the roundabout (for more detail, see section 3.3.1.3).

2.6 Task 6: Refine clusters

The clustering algorithm takes only maximum distance between adjacent skidding events and minimum number of events in a cluster as input parameters. This means that information such as which road type each skidding event was on or the road distance between events was not considered in the initial clustering process. Therefore it was necessary to go through a cluster refining process in order to ensure that the final clusters were meaningful in the context of this analysis.

Factors considered in the cluster refining process included:

- Road surface
- Road type
- Carriageway
- Distance between furthest events

Skidding events which were on a different road type (e.g. roundabout, main carriageway, approach to roundabout) or substantially different road surface type to other events in their cluster were removed from the cluster.

For clusters on motorways and dual carriageways, where carriageways were sufficiently far apart and therefore the carriageway the skidding event happened on could be trusted with reasonable confidence[6], skidding events on a different carriageway to the other events in their cluster were also removed. Clusters which had three or more skidding events remaining after this process were added to the final set of clusters for further analysis. The clustering algorithm initially identified 13 clusters and this was reduced to four after the cluster refining process.

Further description of the cluster refining process and justifications for the decisions about each cluster can be found in Appendix A. The resulting final set of clusters is described in section 3.2.

2.7 Task 7: Collate levels of exposure at each cluster

In addition to providing skidding event data, Synaptiv also provided vehicle telematics data for all the vehicles which travelled through each cluster that did not record a skidding event. An advantage of this exposure data is that it enables the calculation of the proportion of vehicles that skid whilst travelling through each cluster. This is a useful additional metric when comparing clusters and assessing whether any particular cluster is of a higher risk than another.

For all vehicles where a skidding event was recorded, telematics data for 10 seconds before and after the skidding event was extracted. For all vehicles that travelled through clusters but did not skid, telematics data was extracted for an appropriate period of time as the vehicle passed through the cluster. The way this time period was defined differed slightly for non-roundabout and roundabout clusters.

[6] Based on Synaptiv's reported GPS error of 5 metres

For clusters which were not on roundabouts, telematics was extracted for all non-skidding vehicles for 10 seconds[7] before and after the vehicle passed the midpoint of the cluster. This enabled a similar amount of data to be extracted for the non-skidding vehicles as was extracted for the skidding vehicles. The midpoint of each cluster was defined as the mean easting and northing coordinates of the bottom left-hand and top right-hand corners of the cluster box as defined in section 2.4 (example shown by the red x in Figure 3).

For clusters on roundabouts, a different approach was required. Telematics data was extracted for all vehicles that travelled on the relevant roundabout. However, data was also extracted for the 10 seconds before each vehicle entered the roundabout and 10 seconds after they exited. This approach was used because it was desirable to capture a vehicle's entire journey 'through' the roundabout but vehicles were on the roundabout for varying lengths of time depending on traffic lights and which exit they were taking (i.e. vehicles turning right spent longer on the roundabout than vehicles turning left). This approach ensured that no relevant data was removed from the analysis.

Both approaches for identifying vehicles travelling through the clusters resulted in journeys being identified which were on different roads or different carriageways to the events in the cluster. In order to filter out these incorrect journeys, the bearing for each journey was calculated and this was used to identify journeys which were travelling in a different direction to the road or carriageway that the cluster was on and exclude them.

2.8 Task 8: Case study analysis

As a result of the small number of skidding events identified on the SRN, the number of clusters in the final set (four) was not sufficient to carry out in-depth statistical modelling to investigate the relationship between vehicle data, skid resistance and collisions. As an alternative, a case study analysis was performed on the final set of clusters.

The case study analysis involved reviewing key measures calculated for each cluster from the vehicle data and linked datasets. The purpose of this was to further understand the characteristics of each cluster and whether there was any potential relationship between the skidding events, collisions and road surface and skid resistance data. The results of the case study analysis and discussion of each cluster are presented in section 3.3 and detailed definitions of the key measures calculated can be found in section 3.3.1.

[7] In some cases more than 10 seconds of data was extracted because the telematics data was not recorded at consistent one second intervals

3 Results

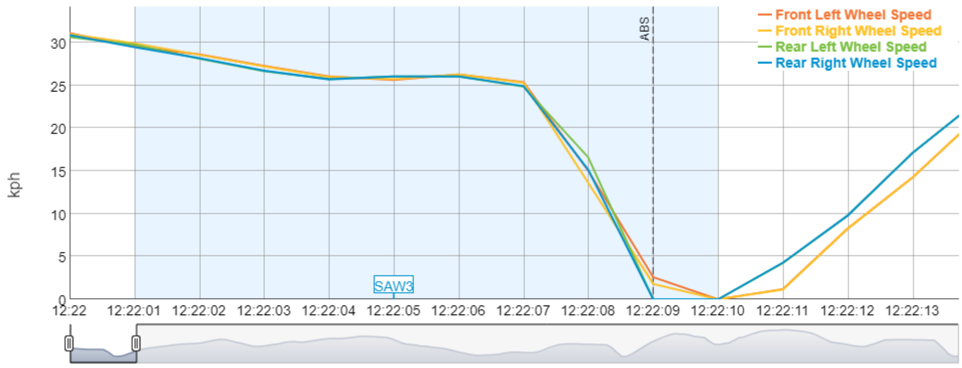
3.1 Skidding algorithm validation

In order to validate the skidding events algorithm, the sensitivity (true positive rate) and specificity (true negative rate) from the data collected at the track trial were calculated by comparing the occurrence of ABS events and skidding events on each run. In this context, the sensitivity is defined as the percentage of runs with ABS events that were correctly tagged as having a skidding event, and the specificity as the amount of non-ABS runs where there was also no skidding event flagged.

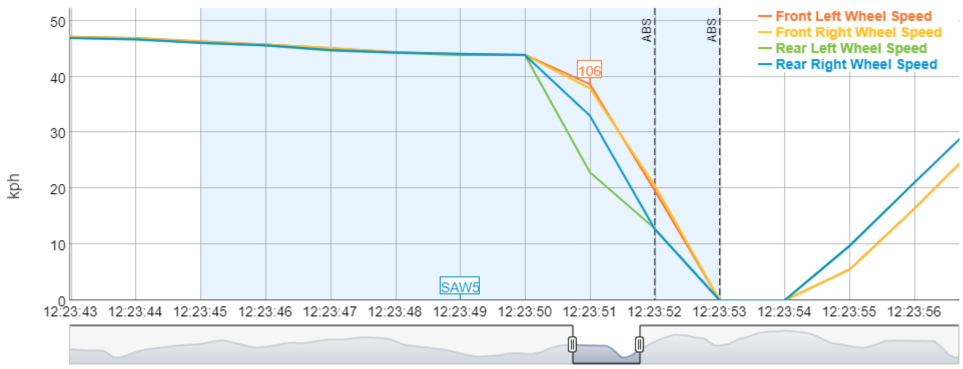
Figure 4 shows an overview of the data gathered for three consecutive runs (at 30km/h, 50km/h and 70km/h respectively) on the Sand Asphalt surface during testing in the wet. In each chart, the four lines represent the wheel speeds of the respective wheels; the orange boxes represent skidding events as indicated by the wheel speed algorithm (labelled numerically as they appear in the dataset) and the black dotted vertical lines are the ABS events reported on the CAN bus[8].

[8] Note that traction control activation was also identified and shown to correlate well with skidding events resulting from fast acceleration. However, since accelerations were not of interest for this testing these events were excluded from the analysis.

(a) 30km/h



(b) 50km/h



(c) 70km/h

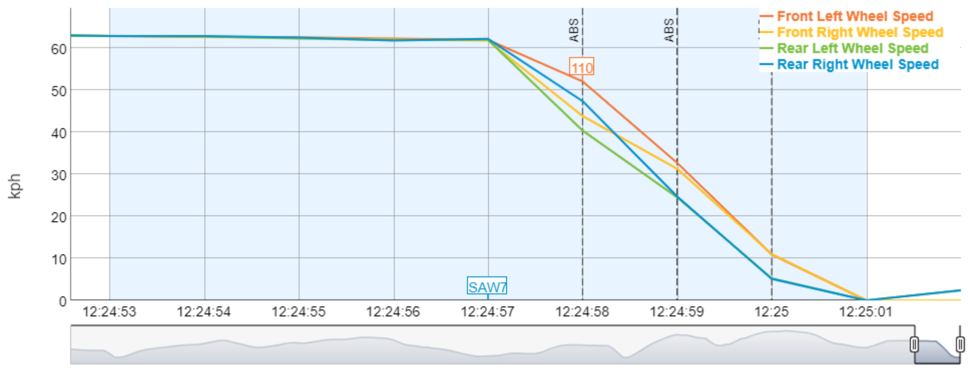


Figure 4: Data collected on the Sand Asphalt wet runs at (a) 30km/h, (b) 50km/h and (c) 70km/h

In this example the two runs at 50km/h and 70km/h represent true positives: there were ABS signals and skidding events detected in both. The 30km/h run however, was a false negative as a skidding event was not correctly identified where the ABS signal was reported. This may be because on this run the entire deceleration from 30 to 0kph only took around one second; the wheel speed data are only sampled once per second so in some cases this represents too long a sample period for accurate analysis.

Table 4 summarises the results from the 54 runs by surface type, condition and speed.

Table 4: Summary of results by surface type, condition and speed

Surface & condition	Speed	ABS activated		ABS did not activate	
		Skidding event identified (true positive)	No skidding event identified (false negative)	Skidding event identified (false positive)	No skidding event identified (true negative)
Basalt tiles, wet	30km/h	1	3	0	0
	50km/h	5	0	0	0
	70km/h	3	0	0	0
Bridport pebble, wet	30km/h	2	2	1	0
	50km/h	2	1	1	0
	70km/h	3	0	0	0
Sand asphalt, dry	30km/h	2	1	2	1
	50km/h	7	0	0	0
	70km/h	6	0	0	0
Sand asphalt, wet	30km/h	2	1	0	1
	50km/h	2	0	0	0
	70km/h	5	0	0	0
Total		**40**	**8**	**4**	**2**

As described above, the sensitivity is defined as the percentage of runs with ABS events that were correctly identified as having a skidding event. This was the case in 40 runs out of 48, resulting in a sensitivity score of 83%.

The specificity as the number of non-ABS runs where there was also no skidding event flagged. Out of the 6 runs without an ABS event, no skidding was detected in 4 of them, giving a specificity of 67%. Both of the false positive skidding observations happen at decelerations from 30km/h which could be a result of the 1Hz granularity of the data, or may mean that ABS was not required for these fairly small decelerations, even though there was some amount of skidding detected.

When this analysis is limited to decelerations from high speed tests (i.e. from 50 or 70km/h), which are more typical of those likely to be experienced on the faster speed roads on the SRN, the sensitivity rises to 97% and specificity to 100% (see Figure 5).

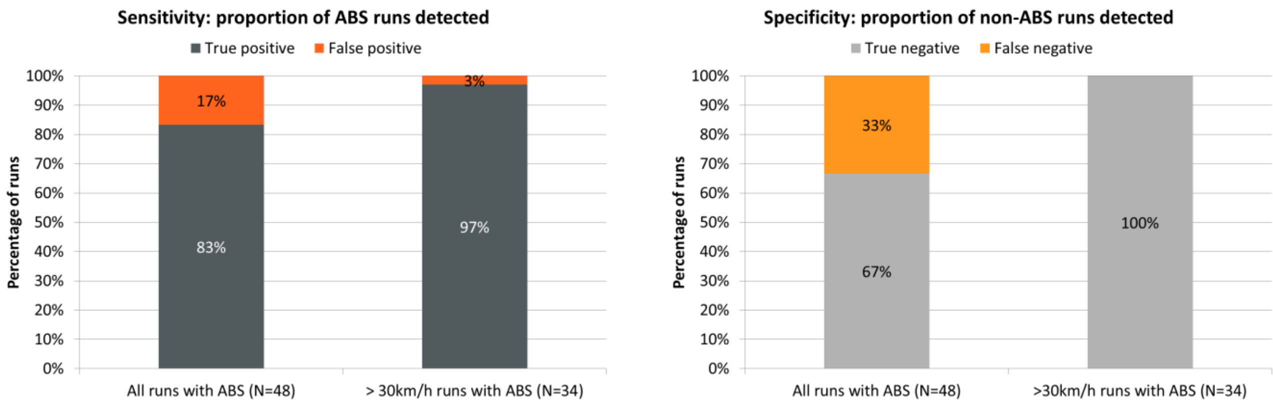


Figure 5: Sensitivity and specificity of the skidding detection algorithm by speed of test

These results suggest that the algorithm to detect skidding events does not perform as well at lower speeds (i.e. 30km/h). However, there was little difference in the results by surface type and condition, suggesting that the algorithm performs equally well across different road surfaces (with different levels of friction).

3.2 Skidding event clusters on SRN

In total, 220 skidding events were identified on the SRN; 92 of these were during braking, 98 during acceleration and 30 whilst the vehicle was travelling at a constant speed.

Figure 6 shows all 220 skidding events identified on the SRN. The majority of the skidding events are located around the Birmingham and Coventry area. This is most likely due to the vehicle fleet travelling more miles around that area than other areas of the UK - rather than as a result of the road surfaces on those roads.

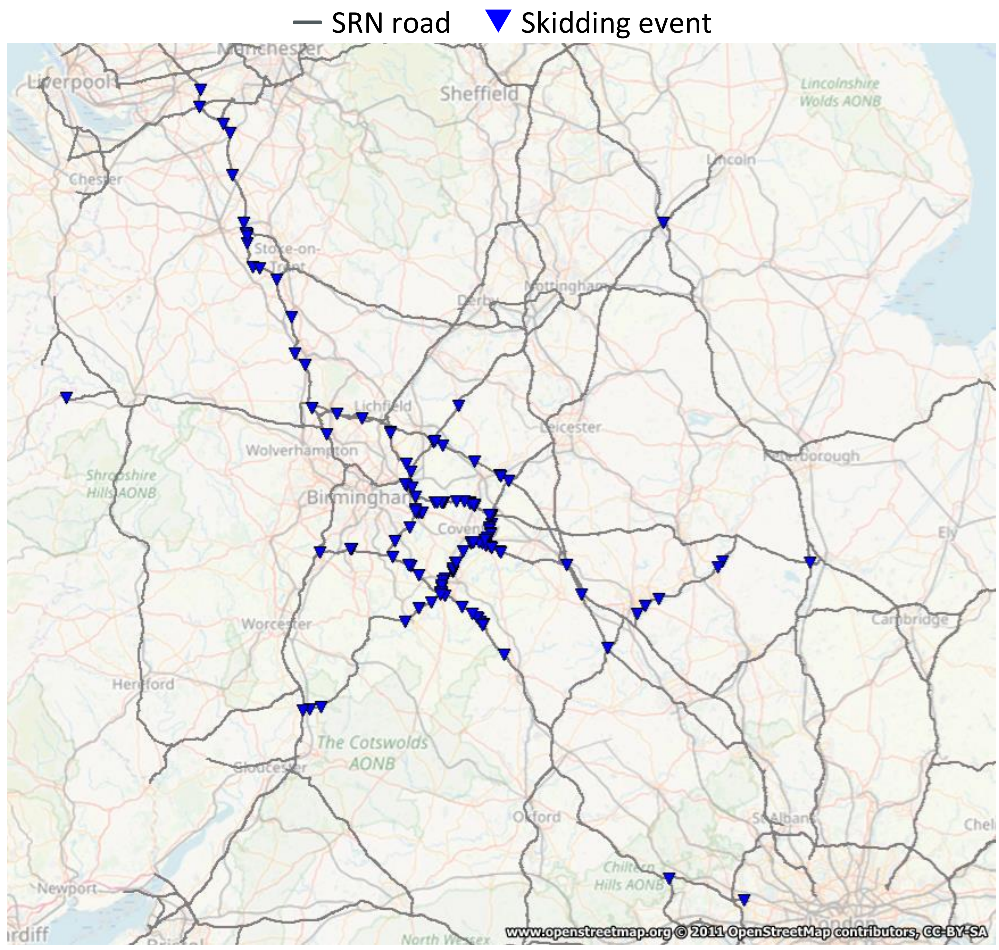


Figure 6: Map showing skidding events identified on the SRN

Only the skidding events from braking events were validated in the track trial (section 3.1). However, analysis of these braking skidding events only produced one cluster. Therefore it was decided to use all the skidding events (220 in total) for the cluster analysis in order to try and identify more clusters.

The initial clustering process identified 13 clusters from the skid events shown in Figure 6. After the cluster refining process described in section 2.6 had been carried out there were four clusters remaining to be included in the final analysis. The locations of these four clusters are shown in Figure 7. A detailed description of the outcomes of the cluster refining process including descriptions and reasons for exclusion can be found in Appendix A.

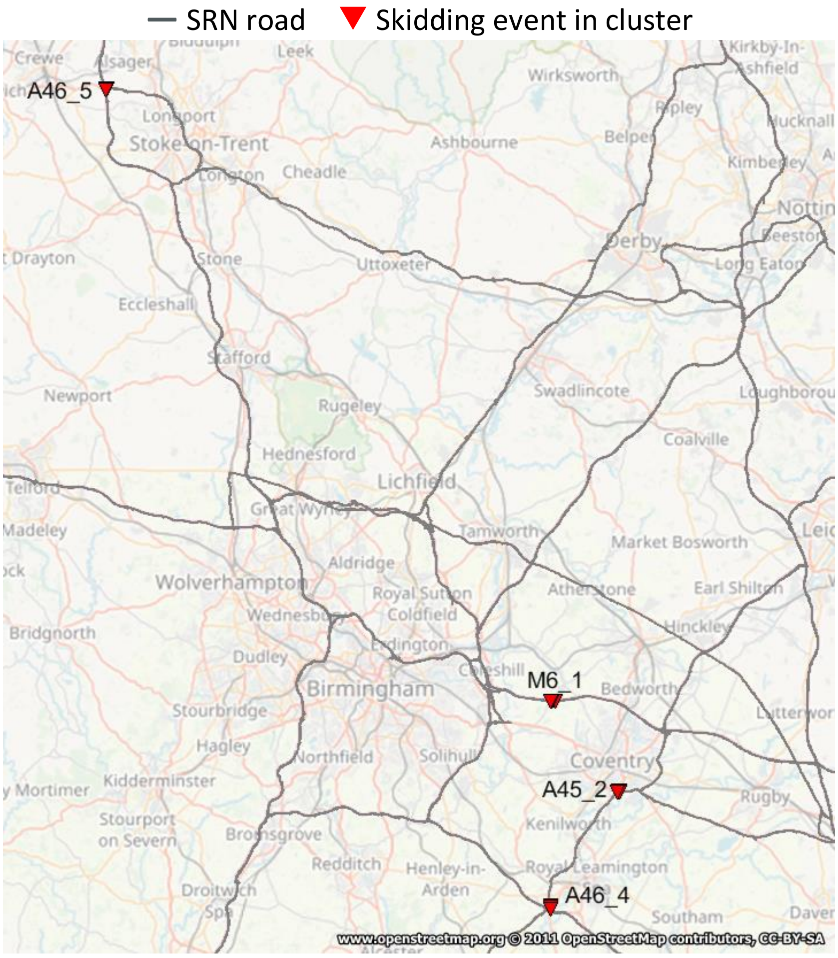


Figure 7: Map showing skidding events in final clusters

The four clusters included in the final analysis were located around Coventry, Warwick, Birmingham and Stoke-on-Trent. Two of these clusters were on roundabouts (A46_5 and A45_2), cluster M6_1 was on a motorway and A46_4 on a dual carriageway approaching a roundabout. The number of skidding events in a cluster ranged from three (M6_1) to eight (A45_2). It should be noted that some of the skidding events in these clusters are acceleration or constant speed skidding events and the skidding algorithm has not been validated for these types of skidding events (see previous section).

A detailed case study analysis was performed on each cluster to understand more about the skidding events in each cluster and any relationships between skidding events, collisions and road surface data from HAPMS. The results of this analysis are presented in the next section.

3.3 Case study analysis of clusters

This section presents the results of the case study analysis for each of the clusters shown in Figure 7 in section 3.2. For each cluster, a number of different measures from analysis of the following four different sources of data are presented:

- Vehicle telematics data from Synaptiv's fleet
- HAPMS data

- Stats19 collision data
- DfT traffic flow data

Section 3.3.1 defines the measures used in the case study analysis and how they were calculated from the different datasets. A description of how these measures can be interpreted is also presented.

3.3.1 Definitions of case study measures

3.3.1.1 HAPMS data

Mean CSC (see section 2.5.1) was calculated for each section and then across the cluster as a whole. For each section, the CSC value was averaged over varying numbers of years of data depending on the age of the road surface. This is recommended when calculating mean CSC values.

- Road surface less than 3 years old – most recent CSC value used
- Road surface between 3 and 5 years old – most recent 2 years of data used
- Road surface between 5 and 10 years old – most recent 3 years of data used
- Road surface greater than 10 years old – most recent 5 years of data used.

Once a mean CSC value had been calculated over the correct number of years for each section, the average of all the mean CSC values for all the sections in the cluster was calculated and this is presented in the overview tables for each cluster. CSC values are interpreted by comparing them to the IL for that type of road (site category) as defined in CS228 (CS 228 Pavement inspection and assessment - Skidding resistance, 2019); if the CSC value is above the IL this means no further investigation is needed. The IL for the specific HAPMS sections included in this analysis are shown in Table 5.

Table 5: Investigatory levels (ILs) for CSC used in this analysis (CS228, (CS 228 Pavement inspection and assessment - Skidding resistance, 2019)

Site category	IL for sections included in study
A – Motorway	0.35
B – Non-event carriageway with one-way traffic	0.35
Q – Approaches to and across minor and major junctions, approaches to roundabouts and traffic signals	0.55
R – Roundabout	0.45

The **proportion of road with mean CSC above IL** measure was calculated by comparing the mean CSC of each section in the cluster to the IL for that section and calculating the proportion of the total road length in the cluster that was above the IL.

Average texture depth was calculated for clusters by calculating the mean of the SMTD (see section 2.5.1) values for all the sections in the cluster. Texture depth is collected as part of the TRACS surveys and these are not carried out on roundabouts so average texture depth was only available for two of the four clusters included in the final analysis. There are four condition categories for texture depth defined in CS229 (CS 229 Data for pavement assessment, 2020) and these are shown in Table 6 below. The average texture depth for the cluster was compared to the thresholds to determine which condition category the cluster was in.

Table 6: Texture depth condition categories (CD229, (CS 229 Data for pavement assessment, 2020))

Condition category	Threshold	Definition
1	1.1	Sound – no visible deterioration
2	0.8	Some deterioration – lower level of concern. No further investigation needed unless extends over long lengths
3	0.4	Moderate deterioration – warning level of concern. Deterioration needs to be investigated.
4	-	Severe deterioration – intervention level of concern. Investigation should be carried out as soon as possible and action taken if appropriate

High speed friction for each section was calculated for each cluster where both mean CSC and average texture depth were available using the following formula (Roe, Parry, & Viner, 1998).

$$\text{High speed friction} = 0.00367SR + 0.411(1 - e^{-SMTD}) - 0.151$$

Where:

SR is raw SCRIM coefficient (mean CSC for the cluster divided by 0.0078)

$SMTD$ is average texture depth for the cluster

In order to provide a baseline to compare the high speed friction values to, an 'ideal' high speed friction value was defined. The ideal high speed friction value for a cluster was defined as the value generated by the equation above with SR equal to the IL for the cluster (divided by 0.0078) and SMTD equal to the threshold for texture depth condition category 1.

If a cluster had a high speed friction value above the ideal value then this meant that it was likely that no further investigation would be required on the road in that cluster. High speed friction values were also compared to the 5th and 95th percentiles for measured locked wheel friction at 100km/h. These represent the 90th percentile range of several thousand measurements made on surfaces of these types. They have been included for context only and do not imply safe, or acceptable, performance.

3.3.1.2 Vehicle data

Distance between furthest events was measured along the road between the two most distant skidding events in the cluster. Where the cluster was on a roundabout, this metric is the distance between the two adjacent events that have the greatest road distance between them, measured using the route around the roundabout that passes through all the remaining skidding events.

Average speeds for journeys (skidding and non-skidding) which travelled through the cluster were calculated using the telematics GPS speed collected by the vehicle. Where telematics GPS speed was missing, the mean of the four wheel speeds was used instead. The average speed was calculated for each journey individually and these were used to create histograms for each cluster showing the distribution of average speeds for journeys in that cluster.

A **relevant window** of time was defined for each skidding event in order to analyse wheel speed difference. The beginning of the relevant window was defined as the last point prior to the skidding event where the acceleration (or deceleration) of all four wheels was equal. The end of the relevant window was the time at which the skidding event occurred.

Skid severity was defined as the maximum difference in acceleration (or deceleration) between any pair of wheels within the relevant window. A higher skid severity means that there was a greater difference in the acceleration (or deceleration) between the wheels and therefore the skid was more severe.

Mean speed at start of skidding event for each cluster was calculated by taking the mean of the speeds at the start of the relevant windows across all the skidding events in the cluster. Similarly to the calculation of average speed for journeys (described above), the speed at the start of the relevant window for each skidding event was telematics GPS speed or mean wheel speed where telematics GPS speed was unavailable.

3.3.1.3 Traffic data

Average yearly traffic was calculated across the period 2013-2017. For roundabouts, it was assumed that any vehicle entering the roundabout was equally likely to exit at any of the exits apart from the one they had just entered from. Traffic figures are presented in hundred million vehicle kilometres (10^8 vehkm).

3.3.2 Cluster M6_1

This cluster comprises three skidding events on the westbound carriageway of the M6 between junctions 3 and 4. Figure 8 shows the skidding events and collisions in the cluster.

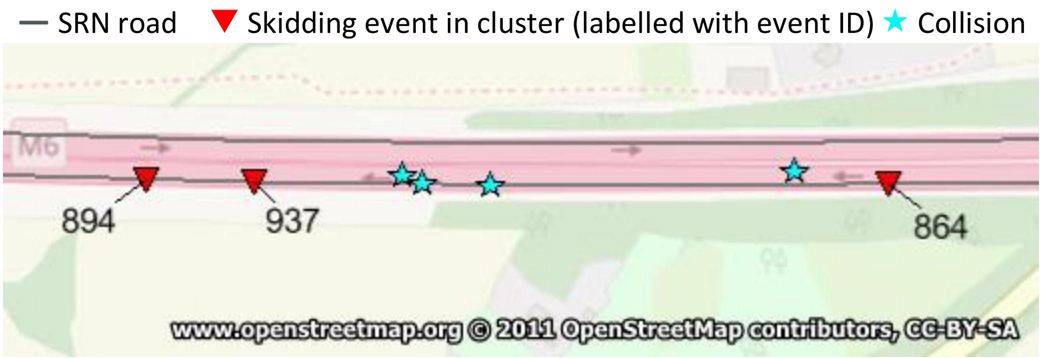


Figure 8: Map showing skid events and collisions in cluster M6_1

Two out of the three skidding events (events 937 and 864) were during braking - the scenario for which the skidding algorithm has been validated. The other (event 894) occurred while the vehicle was travelling at constant speed.

Table 7 gives an overview of the results from the case study analysis for cluster M6_1.

Table 7: Results from case study analysis for cluster M6_1

Data source	Measure		Value for M6_1
Vehicle data	Number of skidding events	Braking	2
		Acceleration	0
		Constant speed	1
	Distance between furthest events (metres)		414
	Mean speed at start of skidding event (km/h)		54.9
	Mean skid severity (km/h/s)		1.5
HAPMS	Road type		Motorway
	Mean CSC		0.40
	Proportion of road with mean CSC above IL		100%
	Average texture depth		1.01
	High speed friction		0.30
Stats19	Number of collisions		4
Traffic	Average yearly traffic through cluster (10^8vehkm)		2.7
	HGV proportion		17%

In total, Synaptiv recorded 259 journeys which travelled through cluster M6_1, of which the three journeys where a skidding event occurred accounted for 1.2%. Figure 9 shows the distribution of average vehicle speeds for journeys in the cluster with/without a skidding event.

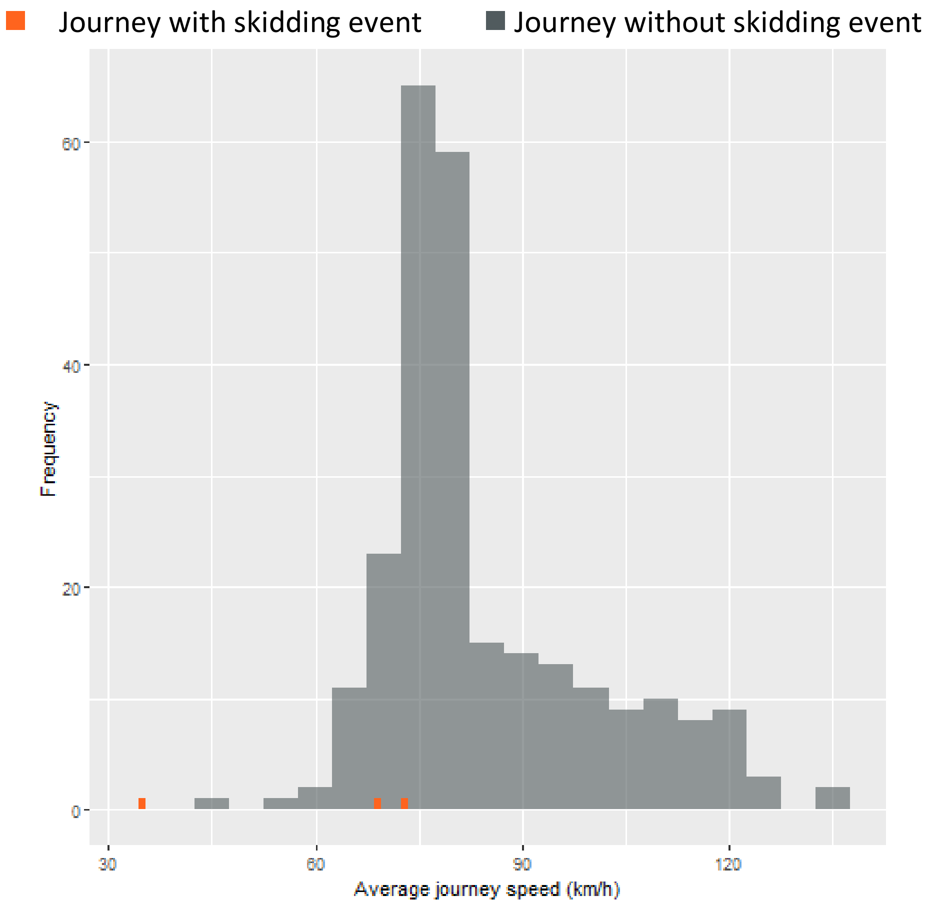


Figure 9: Distribution of average speeds for journeys in cluster M6_1

As seen in Figure 9, the distribution of average speeds for non-skidding journeys is heavily skewed. For this type of distribution, relying solely on the mean average can be misleading and it is worthwhile considering also the mode average. The mode average is the most common value – for Figure 9 this is around 75km/h. Vehicle speeds at the start of the 3 skidding events are lower than both the mean and mode of speeds for non-skidding event journeys.

The mean speed at start of skidding event (54.9km/h) presented in Table 7 is much lower than the mode average speed for non-skidding journeys. This is likely to be because this constant speed skidding event happened at a much lower speed (21.3km/h) than the two braking skidding events (which happened at 74.0km/h and 69.5km/h). This same pattern is seen in Figure 9; the orange bar to the far left of the chart represents the average speed for the journey with the constant speed skidding event whereas the average speeds for the journeys involving the braking skidding events are much closer to the most common speed for journeys without skidding events. Also, the speed at which the constant speed skidding event happened is outside the range where the skidding algorithm was found to be most reliable (see section 3.1).

The range of skid severities was small for the skid events in cluster M6_1 compared with the other clusters. The maximum skid severity across the skidding events in this cluster was

4km/h/s (braking skidding event) and the other events had skid severities of 0km/h/s [9] (braking skidding event) and 0.5km/h/s (constant speed skidding event). The mean skid severity for cluster M6_1 was 1.5km/h/s.

As shown in Table 7, the mean CSC across all the sections in cluster M6_1 is 0.40. The Investigatory Level for all the sections in this cluster is 0.35 and 100% of the sections in this cluster have a CSC above this Investigatory Level. This means that under normal circumstances further investigation of the road where the skidding events occurred would not be carried out following the SCRIM survey. In addition, the average texture depth value of 1.01 would put the road in this section into condition category 2 for texture depth and it would therefore be unlikely to warrant further investigation.

The 'ideal' high speed friction value for this cluster was calculated to be 0.29 and Table 7 shows that the actual high speed friction was 0.30. In addition, the high speed friction value falls between the 5th and 95th percentile values for locked wheel friction at 100km/h which means that the road in this section is fairly typical when compared to other measurements on a similar surface. Similarly to the mean CSC and texture depth analysis, this suggests that the skidding events in this cluster have happened on a section of road that would not have warranted further investigation under any of the criteria currently used.

Stats19 collision analysis identified four collisions which happened within 100m of the boundary of the cluster between 2013 and 2017 (note that this period does not overlap with the period of vehicle data collection and none of the Synaptiv vehicles which reported skidding events were involved in collisions). Of these collisions, one involved a car which was recorded to have skidded but Stats19 does not record whether the skidding was a cause or a result of the collision. Two of the four collisions had the contributory factors "following too close" and "sudden braking" recorded which suggests that these collisions may have been caused by tailgating, possibly in queueing traffic. However, the number of collisions in the cluster is too small to draw any robust conclusions.

3.3.3 Cluster A46_4

Cluster A46_4 contains five skidding events on the A46 southbound carriageway approaching the roundabout at junction 15 of the M40 (Longbridge Interchange). Figure 10 shows the skidding events and collisions in the cluster.

[9] Difference in wheel speed acceleration of 0 likely to be because wheel speed in data received from Synpativ were integer values and therefore very small differences could not be identified.

Figure 10: Map showing skid events and collisions in cluster A46_4

Of the five skidding events shown in Figure 10, one occurred during acceleration (event 879) and the other four occurred during braking. The acceleration skidding event is further away from the others and nearer to the roundabout, suggesting that it may have occurred whilst the vehicle was moving off to enter the roundabout. Also, the speed at start of skidding event for event 879 was very low (5.1km/h) which further supports the theory that the vehicle was moving off in a queue of traffic when the skidding event occurred.

Events 723 and 724 were both part of the same journey; the vehicle skidded twice within 100m. In addition, events 637, 716 and 724 are very close together, within 40 metres of each other. This may suggest that there is something on this particular stretch of road that is causing people to skid at a similar place.

Table 8 presents an overview of the results from the case study analysis for cluster A46_4. The cluster comprises road lengths with two different site categories: B (non-event carriageway with one-way traffic) and Q (approach to roundabout). The two site categories have different IL and therefore the mean CSC and high speed friction values for this cluster are reported separately for the different site categories.

Table 8: Results from case study analysis for cluster A46_4

Data source	Measure		Value for A46_4
Vehicle data	Number of skidding events	Braking	4
		Acceleration	1
		Constant speed	0
	Distance between furthest events (metres)		348
	Mean speed at start of skidding event (km/h)		86.0
	Mean skid severity (km/h/s)		4.7
HAPMS	Road type		Dual carriageway
	Mean CSC	Site category B	0.49
		Site category Q	0.55
	Proportion of road with mean CSC above IL		91%
	Average texture depth		0.96
	High speed friction	Site category B	0.33
		Site category Q	0.34
Stats19	Number of collisions		2
Traffic	Average yearly traffic through cluster (10^8vehkm)		0.19
	Proportion of traffic that is HGVs		6%

Synaptiv recorded 459 journeys which travelled through cluster A46_4, of which four journeys (0.9%) involved a skidding event (there was one journey where two skidding events occurred). Figure 11 shows the distribution of average vehicle speeds for journeys in the cluster with/without a skidding event.

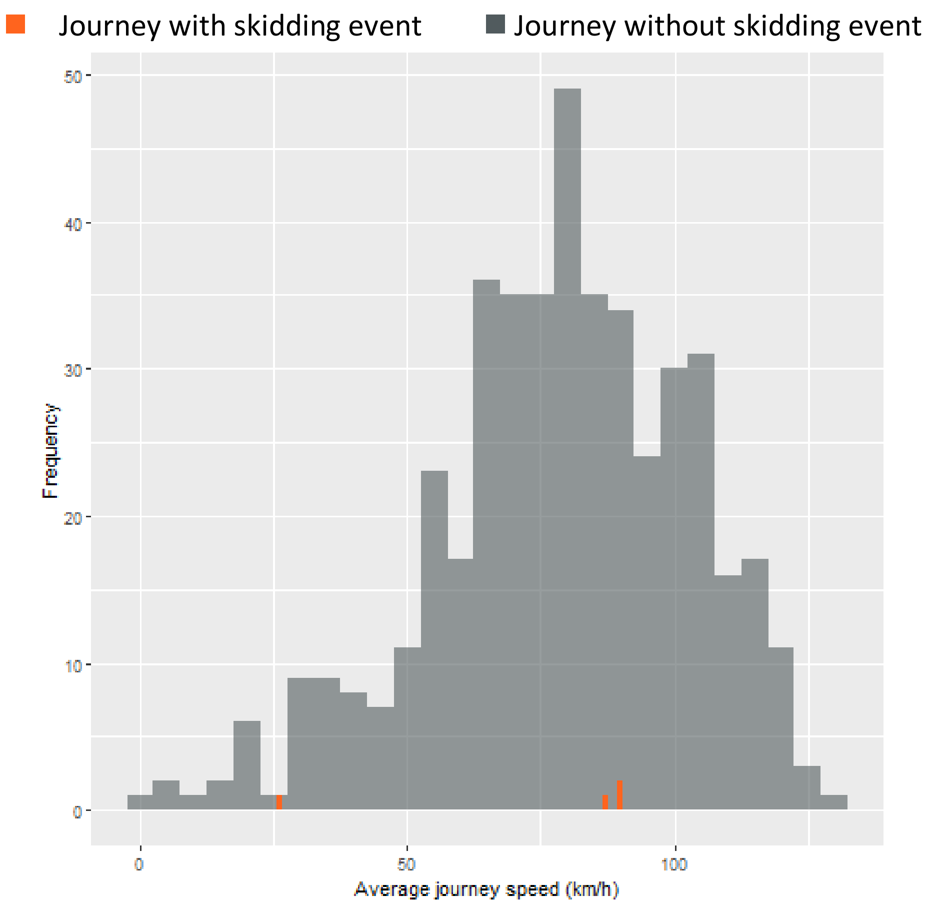


Figure 11: Distribution of average speeds for journeys in cluster A46_4

Figure 10 shows that the mode average, the most common speed for non-skidding journeys in cluster A46_4, was around 80km/h and the mean was 78.7km/h. The average speeds for journeys involving skidding events in cluster A46_4 are slightly higher than this with the exception of the acceleration skidding event mentioned above. When the acceleration skidding event is excluded, the mean speed at start of skidding event across all the events in the cluster was 106.2km/h which is higher than both the mean and mode averages for journeys where the vehicles did not skid.

The mean skid severity for this cluster was 4.7km/h/s and all the braking events had skid severities between 4km/h/s and 8km/h/s. The skidding event with the lowest skid severity was the acceleration skidding event.

The HAPMS analysis results for site category B sections shown in Table 8 indicates that there are no obvious signs of high skid risk on these sections when considering mean CSC and high speed friction values. The mean CSC of 0.49 for site category B sections is above the IL of 0.35 and the high speed friction value is above the ‘ideal’ value of 0.28.

The results are slightly different for the site category Q section. The high speed friction value of 0.34 is below the ‘ideal’ value of 0.38. This is likely to be because, although the mean CSC for the site category Q section is equal to the IL (as recorded in HAPMS for this section), the texture depth value is 0.84 which is in condition category 2 but very close to threshold for condition category 3. However, the high speed friction value is between the 5th and 95th percentile values for locked wheel friction at 100km/h which would suggest that the road in this section is fairly typical when compared to other measurements on a similar surface.

Despite the fact that the HAPMS analysis indicates that the site category Q section of cluster A46_4 may warrant further investigation, only the skidding acceleration event (for which the skidding algorithm has not been validated) occurred on this section. All of the four braking skidding events happened on the site category B sections. Since the HAPMS analysis does not explain these events, this suggests that there may be additional factors influencing skid risk on the road in this cluster that either have not been identified by the current process or are unrelated to the road surface (e.g. people needing to brake harshly on approach to roundabout because of inadequate signage or the slight bend).

There were only two collisions in cluster A46_4 in the period 2013-2017. In both collisions, one vehicle was waiting to go ahead and the other was slowing or stopping. This suggests that these are low speed collisions which happened in queues on the immediate approach to the roundabout. Also, both collisions happened close to the roundabout and not near to the braking skidding events (see Figure 10).

3.3.4 *Cluster A45_2*

Cluster A45_2 has the most skidding events of any of the clusters included in the case study analysis. The cluster (shown in Figure 12) encompasses the whole of the Stivichall Interchange roundabout at the junction of the A45 and A444 on the outskirts of Coventry and contains eight skidding events.

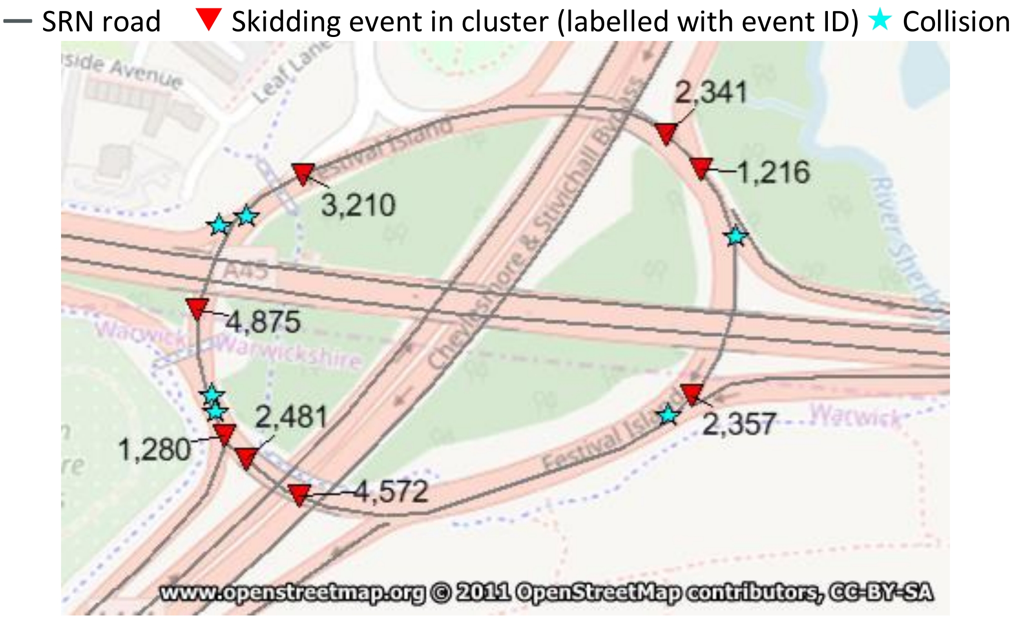


Figure 12: Map showing skid events and collisions in cluster A45_2

Most of the skidding events in this cluster were skidding events which occurred during acceleration. Only two of the skidding events (events 4875 and 4572) happened during braking, one event (event 3210) occurred whilst the vehicle was travelling at constant speed and the remaining five were all acceleration skidding events. This is unsurprising because cluster A45_2 is on a roundabout and it is likely that skidding events are occurring as people try and move off when traffic lights change.

An overview of the results from the case study analysis for cluster A45_2 is shown in Table 9. Average texture depth and high speed friction values were not calculated for this cluster because TRACS surveys are not carried out on roundabouts so texture depth data was not available.

Table 9: Results from case study analysis for cluster A45_2

Data source	Measure		Value for A45_2
Vehicle data	Number of skidding events	Braking	2
		Acceleration	5
		Constant speed	1
	Distance between furthest events (metres)		660
	Mean speed at start of skidding event (km/h)		22.9
	Mean skid severity (km/h/s)		4.1
HAPMS	Mean CSC		0.52
	Proportion of road with mean CSC above IL		87%
	Average texture depth		N/A
	High speed friction		N/A
Stats19	Number of collisions		6
Traffic	Average yearly traffic through cluster (10^8vehkm)		0.96
	Proportion of traffic that is HGVs		5%

Figure 13 shows the distribution of average vehicle speeds for journeys in the cluster with/without a skidding event. There were 346 journeys recorded which travelled through the cluster; of which the eight journeys where skidding events were recorded make up 2.3%.

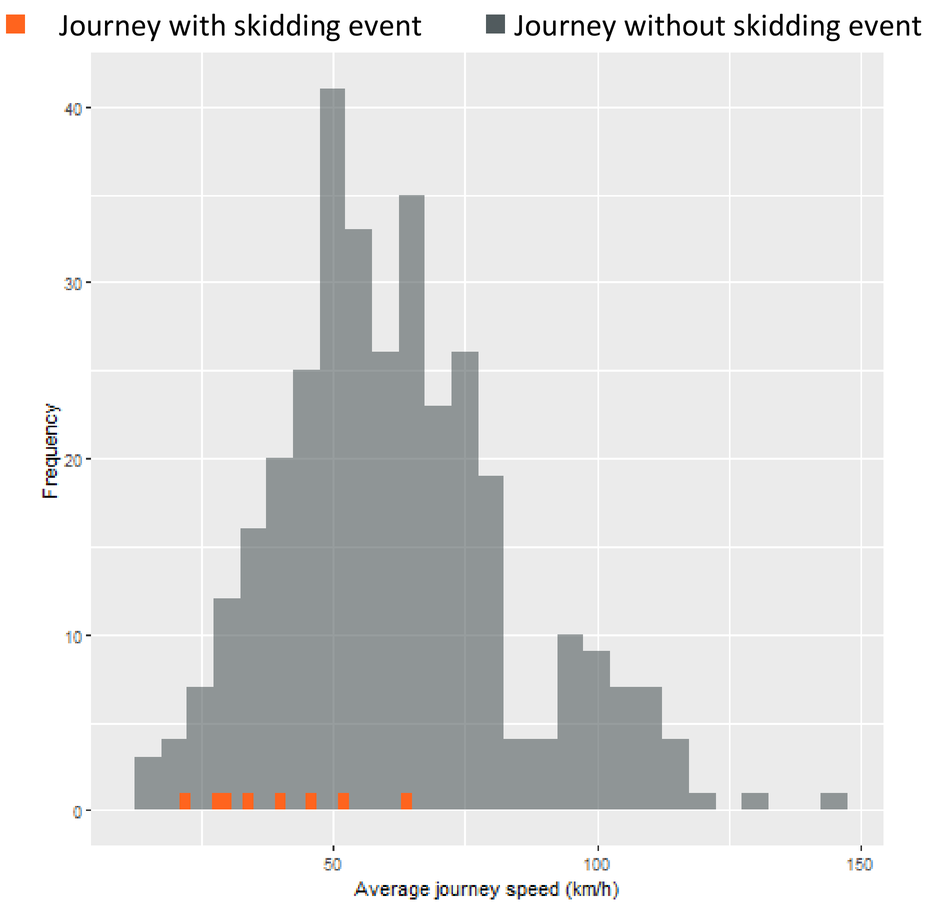


Figure 13: Distribution of average speeds for journeys in cluster A45_2

As shown in Figure 13, the average speeds for journeys in cluster A45_2 are lower than in clusters M6_1 and A46_4 because the cluster is on a roundabout rather than the main carriageway. The most common average speed for non-skidding journeys is around 50km/h which is the lower end of the range for which the skidding algorithm is most reliable (see section 3.1). The majority of journeys with skidding events have average speeds lower than the most common average speed for non-skidding journeys. This is because five of the skidding events are during acceleration and therefore likely to be happening when moving off from very low speeds (for four out of the five acceleration skidding events the speed at start of skidding event is 0km/h).

The speeds at the starts of the two braking skidding events are 56.4km/h and 57.0km/h which are above the most common average speed for non-skidding journeys and slightly below the mean average speed for journeys (61.6km/h). Both speeds are only just within the reliable range for the skidding algorithm. The skid severities of the skidding events in this cluster range from 1.5km/h/s to 10km/h/s with a mean of 4.1km/h/s and the skidding event with the highest skid severity was a braking skidding event.

The proportion of cluster A45_2 with mean CSC above the IL was 87% which is the lowest of all the clusters. Also, the mean CSC across the whole cluster is 0.52 which is slightly lower than the mean CSC for the other roundabout cluster (0.55 for cluster A46_4, see section 3.3.5) but still above the IL of 0.45. Therefore it is unlikely that further investigation would be warranted on the road in this cluster based on the annual skid resistance survey data.

Collision data analysis identified six collisions in the cluster in the period 2013 to 2017. None of them reported that the vehicles involved had skidded although one listed 'sudden braking' as a contributory factor (but did not indicate whether the sudden braking had led to skidding). An analysis of the collision data reveals nothing that would suggest a link between the collisions in the cluster and the skid risk. In addition, any links would be questionable as the collision numbers are too small to be able to draw robust conclusions.

It is important to note that six of the eight skidding events in this cluster do not occur during braking. The skid detection algorithm is therefore less reliable as it has not been validated for these types of events.

3.3.5 Cluster_A46_5

This cluster is on the roundabout at the junction of the M6 and the A500 at the M6 junction 16. The cluster comprises four skidding events and is shown in Figure 14.

— SRN road ▼ Skidding event in cluster (labelled with event ID) ★ Collision

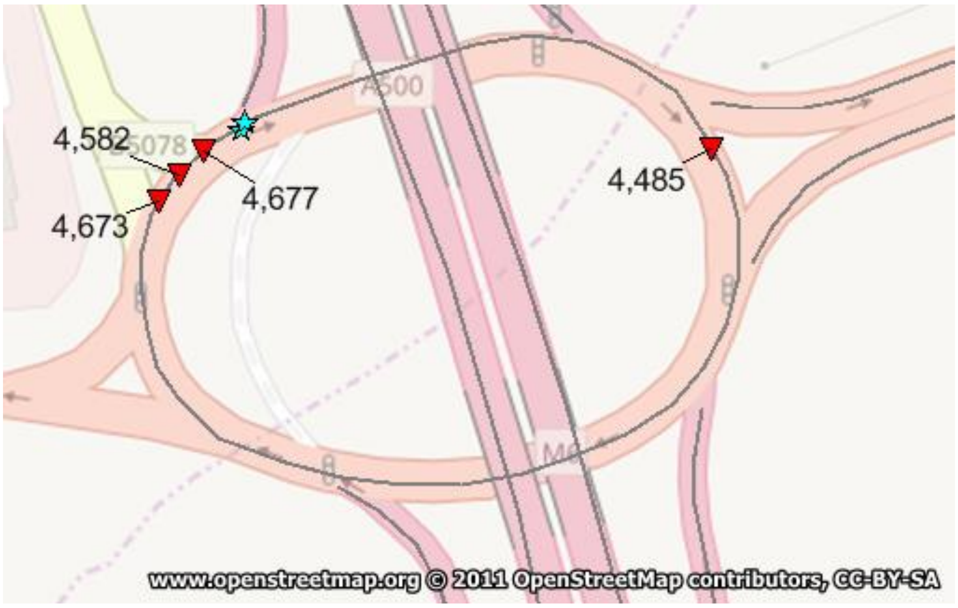


Figure 14: Map showing skid events and collisions in cluster A46_5

Three of the skidding events in this cluster are within 20m of each other and one is approximately 170m away on the other side of the roundabout. However, all four of the skidding events in this cluster were skidding events which happened during acceleration. As mentioned previously, the skidding algorithm has not been validated for this type of skidding event and therefore the identification of this cluster may not be as reliable as some of the others.

Table 10 presents an overview of the results from the case study analysis for cluster A46_4. Similarly to cluster A45_2, average texture depth and high speed friction values were not calculated for this cluster because TRACS surveys are not carried out on roundabouts so texture depth data was not available.

Table 10: Results from case study analysis for cluster A46_5

Data source	Measure		Value for A46_5
Vehicle data	Number of skidding events	Braking	0
		Acceleration	4
		Constant speed	0
	Distance between furthest events (metres)		188
	Mean speed at start of skidding event (km/h)		1.0
	Mean skid severity (km/h/s)		9.3
HAPMS	Mean CSC		0.55
	Proportion of road with mean CSC above IL		100%
	Average texture depth		N/A
	High speed friction		N/A
Stats19	Number of collisions		2
Traffic	Average yearly traffic through cluster (10^8vehkm)		2.9
	Proportion of traffic that is HGVs		17%

Cluster A46_5 had the fewest number of vehicles travelling through it recorded by Synaptiv (176) and of these, the journeys where skidding events occurred accounted for 2.3%. The distribution of average vehicle speeds for journeys in the cluster with/without a skidding event is shown in Figure 15.

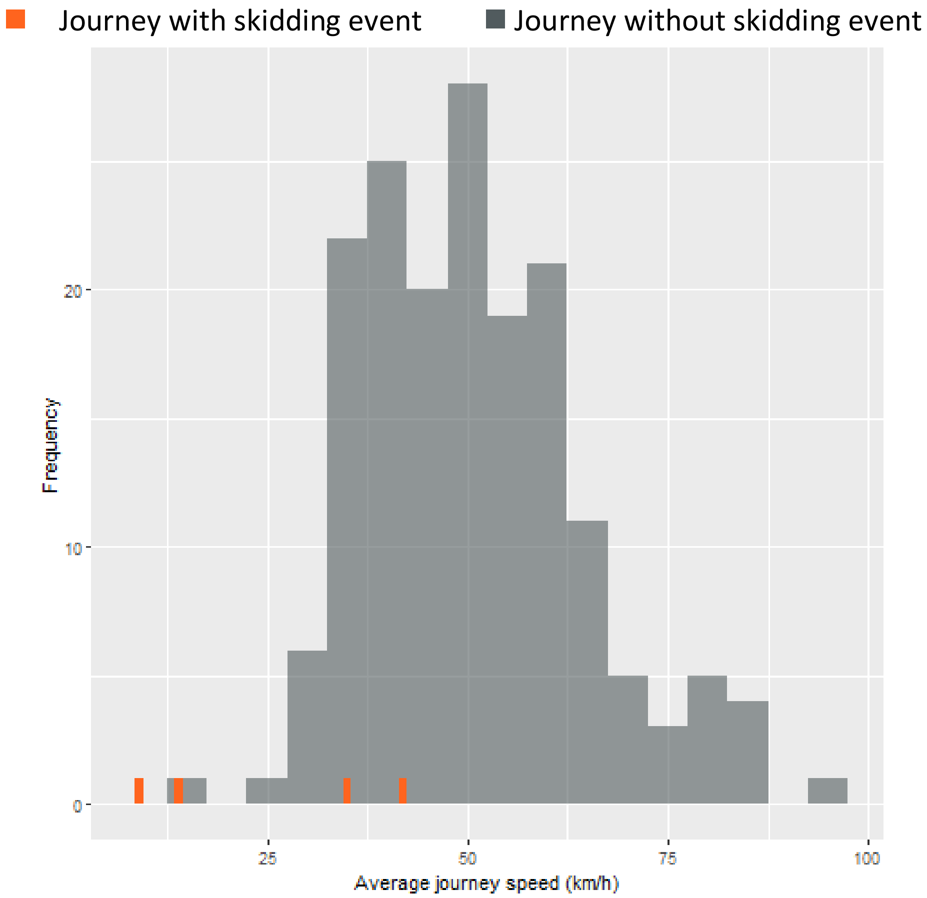


Figure 15: Distribution of average speeds for journeys in cluster A46_5

Similarly to the other roundabout cluster (A45_2, section 3.3.4), the most common speed for journeys made by non-skidding vehicles in cluster A46_5 was around 50km/h and the mean average speed for these journeys was 50.6km/h. The journeys where skidding events occurred have lower average speeds than the mean and mode for non-skidding journeys. This is to be expected because all these journeys contain acceleration skidding events and the mean speed at start of skidding event across all four skidding events in this cluster is only 1.0km/h.

Interestingly, this cluster had the highest mean skid severity (9.3km/h/s). The skid severities for the skidding events in the cluster were 5km/h/s, 7km/h/s, 12km/h/s and 13km/h/s so this is also the highest range of skid severities. However, since these skid detections all occurred during acceleration (rather than braking) and at lower speeds than 50km/h, we have less confidence in the reliability of the skid detection algorithm for these events.

One hundred percent of the sections in this cluster had a mean CSC value above the IL and the mean CSC across the whole cluster was 0.55 which is above the IL of 0.45. This means that the road surface in this cluster would not normally warrant further investigation.

There were only two collisions which happened on the road in the cluster during the data period considered. One involved a vehicle making an illegal U-turn and the other involved an HGV which overturned. Neither of the collisions reported skidding, sudden braking or defective road surface.

4 Conclusions and discussion of next steps

4.1 Conclusions

The aim of this project was to understand the potential of vehicle data to help manage skid resistance on the road network and to consider whether vehicle data could be used in the future to measure skid resistance.

The track trial to validate the methodology for identifying skidding events during braking from vehicle telematics data concluded that the algorithm performs better at higher speeds than lower speeds and equally well across different road surfaces. Skidding events were correctly identified 83% of the time across all runs but when the analysis was limited to higher speed runs (50 or 70km/h) this figure rose to 97%. The majority of the SRN has a speed limit greater than 50km/h (approx. 30mph). Although it is noted that vehicles do not always travel at the speed limit, especially in congestion, it is likely that the majority, or at least a large proportion, of vehicles are travelling at greater than 50km/h and therefore skidding events during braking identified using this algorithm would be expected to be reliable. The identification of skidding events that occur whilst the vehicle is travelling at constant speed or accelerating has not been validated in the track trial.

Cluster analysis identified four clusters from the 220 skidding events (during braking, constant speed and acceleration) identified on the SRN as part of this project. The number of clusters was too small to carry out statistical modelling as originally planned. Therefore case study analysis was performed as an alternative. This analysed vehicle telematics data, HAPMS road surface data and collision data in order to evaluate the cluster and attempt to identify any relationships between the data from the different sources. An overview of the main results from the case study analysis for each cluster is shown in Table 11.

Table 11: Overview of cluster case study analysis

Measure	Cluster			
	M6_1	A46_4	A45_2	A46_5
Road type	Motorway	Dual carriageway	Roundabout	Roundabout
Total journeys through cluster	259	459	346	176
Number of skid events	3	5	8	4
Number of braking skid events	2	4	2	0
Proportion of total journeys with skidding event	1.1%	0.9%	2.3%	2.3%
Proportion of total journeys with braking skidding event	0.7%	0.9%	0.6%	0.0%
Mean speed at start of skidding event (km/h)	54.9	86.0	22.9	1.0
Mean skid severity (km/h/s)	1.5	4.7	4.1	9.3
Proportion of length with mean CSC above IL	100%	91%	87%	100%
Condition category for average texture depth	2	2	N/A	N/A
Number of collisions	4	2	6	2

The skidding events in the two roundabout clusters (A45_2 and A46_5) mainly occurred when not braking; 75% and 100% of the events respectively. As noted in the case study, the skid detection algorithm has not been validated for non-braking events. In addition, the algorithm was shown to be less reliable at lower speeds. The mean speeds at the start of skidding is low for both these clusters (22.9 and 1.0 km/h respectively) – considerably lower than the reliable range of 50-70km/h. Therefore, results for these two roundabout clusters must be considered to be less reliable than for the other two clusters, since there is less certainty of how genuine the detected skidding events are.

In contrast, the other two clusters (M6_1 and A46_4), both have mean speeds (54.9 and 86.0 km/h respectively) that lie within the reliable range from the track trial. In addition, the majority of their skidding events occurred during braking (66.7% and 80% respectively). All the braking skidding events in these clusters occurred at speeds within the reliable range and are therefore more likely to be valid. Hence, the conclusions drawn from these clusters are more robust.

In the case studies, for the histograms comparing the vehicle speeds at the start of the skidding event with speeds from non-skidding events, for all clusters except A46_4, all or almost all of the skidding event speeds were lower than both the mean and the mode of the non-skidding event speeds. This would suggest that these skid events were not caused by excessively fast driving. For cluster A46_4 the skid speeds for the braking skidding events were above both the mean and mode average speeds for non-skidding journeys but below the speed limit of the road. Again, this suggests these skidding events are not a result of excessive speed.

The number of collisions in each cluster was too small to be able to draw robust conclusions about any relationship between collisions and skid resistance and vehicle data. In addition, no common factors or patterns were identifiable from looking at the details for individual collisions in the clusters.

In general, the clusters did not have road surface data characteristics that would normally require further investigation at the site. The vast majority of road in each of the clusters has a mean CSC value above the IL. In addition, for the two non-roundabout clusters where it was available, average texture depth was in condition category 2 but close to the threshold for condition category 1, indicating that there may be some deterioration in the road surface but it was not likely to warrant further investigation under normal circumstances.

For the two non-roundabout clusters (M6_1 and A46_4), the road surface data, combined with the not excessively high speeds of the skidding events and the relatively small distances between the skidding events, suggests that the clusters may be identifying sites with potential skidding risk which would not otherwise have been identified. Cluster A46_4 is of particular interest. This has the highest percentage of total journeys which involved a braking skidding event (approximately 0.9%) and includes three braking skid events within 40 metres. However, further analysis of these sites would be needed in order to establish whether the skidding events are likely to have been caused by the road surface or other factors.

It is important to note that the conclusions of this study are severely limited by the lack of data and a larger study would be necessary in order to form more robust conclusions. A larger dataset would also reduce the possibility that the clusters have been formed “by chance”. However, the results suggest that there may be potential value in using vehicle data to identify sites with high skid risk that are not currently being identified.

The secondary objective was to consider whether vehicle data could be used in the future to measure skid resistance, reducing (or perhaps eliminating) the need to carry out routine surveys of the network. With such limited data available for analysis, it is not possible to comment on the viability of this.

4.2 Next steps

For the sites where a cluster of skidding events has been identified in this study, further investigation could be carried out into the likely causes. This is less important for the roundabout clusters because the majority of skidding events are non-braking and therefore less reliable. Cluster A46_4 contained four braking skidding events close together and so further investigation of this cluster in particular is recommended. This investigation would determine whether it is likely that the skidding events can be attributed to the road surface characteristics or whether there are other factors such as signage, bends or sight lines which are causing skidding events at this site.

It is also recommended that in order to test the approach investigated in this study further, more vehicle data should be collected to increase the size of the dataset to include more skidding events. This would likely result in an increased number of clusters. With a greater number of skidding events and clusters, it would not be necessary to include the (so far unvalidated and therefore less reliable) non-braking events in the analysis.

In addition to a larger dataset, another track trial could be implemented in order to test the validity of the skid detection algorithm when vehicles are accelerating or travelling at constant speed. If the algorithm is validated for these non-braking events, this would further increase the number of reliable skidding events detected for analysis. Sufficient reliable skidding events detected would enable a more robust analysis to be performed that would investigate the relationship between vehicle data and skid resistance.

5 References

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Appendix A Cluster refining outcomes

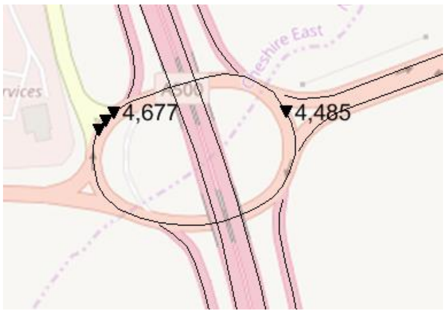
This appendix describes the 13 initial clusters identified using the clustering algorithm and the decisions made about including them in the final list of clusters for case study analysis.

Map key[10]

- Black upside-down triangle = skid event
- Lines = HAPMS network
- Labels = Event ID for each skid event (sometimes not visible if events are too close together)

A.1 Clusters kept

A.1.1 Cluster A46_5

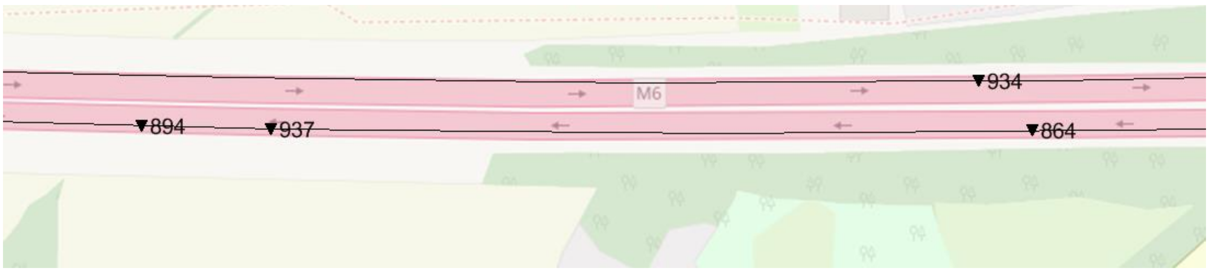


Decision: No need to remove any events

Justification: All events are on same roundabout within 500m of each other

Outcome: Keep cluster with all points

A.1.2 Cluster M6_1



Decision: Remove event 934

Justification: Event is on other side of the carriageway to the other three

Outcome: Keep cluster with 3 events

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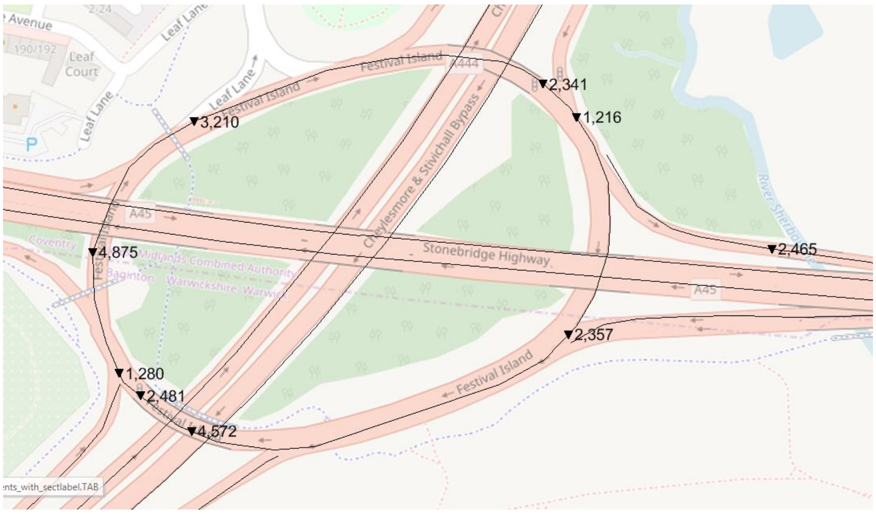
[10] All background map images are from www.openstreetmap.org © OpenStreetMap contributors, CC-BY-SA

A.1.3 Cluster A45_2



Decision: Remove event 2465

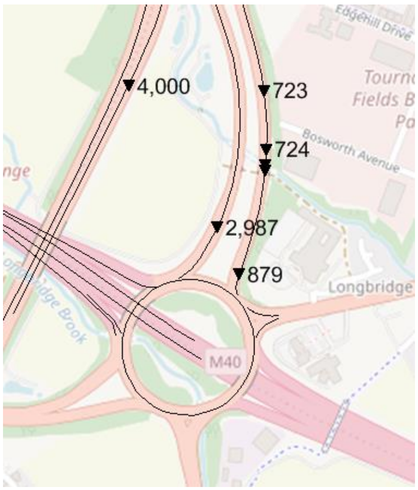
Justification: Event on slip road rather than roundabout.

Decision: Keep remaining 8 events

Justification: Remaining events are all on the same roundabout within 500m of each other

Outcome: Keep cluster with 8 events

A.1.4 Cluster 46_4



Decision: Remove event 4000

Justification: Event 4000 is on different part of the road

Decision: Remove event 2987

Justification: On wrong side of carriageway

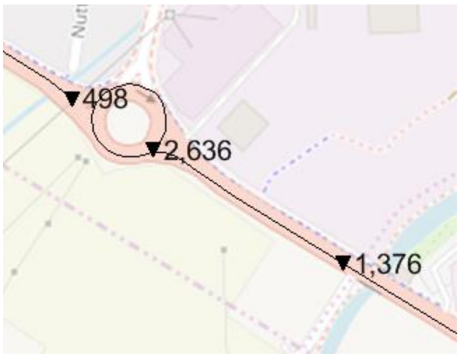
Decision: Keep remaining events

Justification: All on same side of carriageway within 500m of each other

Outcome: Keep cluster with 5 events

A.2 Clusters removed

A.2.1 Cluster A5_1

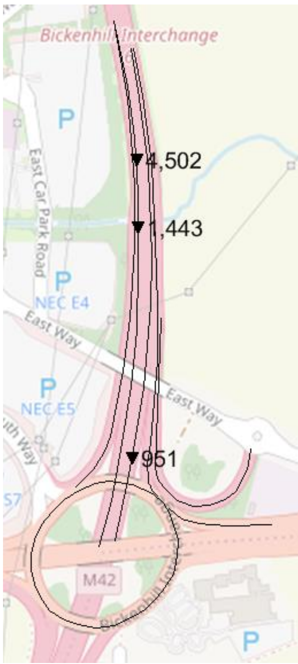


Decision: Remove event 498

Justification: Event 498 unlikely to be connected to other two events

Outcome: Lose cluster because less than 3 events

A.2.2 Cluster M42_1



Decision: Remove event 951

Justification: Event is on other side of the carriageway to the other two

Outcome: Lose cluster because less than 3 events

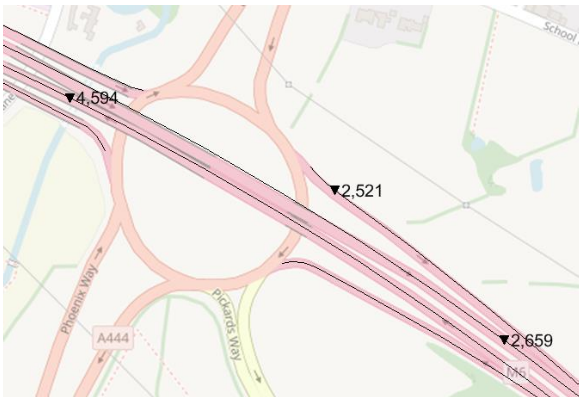
A.2.3 Cluster M6_3

Decision: Remove event 4036

Justification: Event is on other side of the carriageway to the other two

Outcome: Lose cluster because less than 3 events

A.2.4 Cluster M6_2



Notes: 3 events – 1 on slip road, other 2 each on different sides of motorway

Decision: This is not a cluster

Justification: All 3 events on different roads/carriageways

Outcome: Lose cluster

A.2.5 Cluster A46_1

Decision: Remove event 3170 due to being on a different link

Justification: Event is on a different link

Decision: This is not a cluster

Justification: Remaining three events are on different road types/carriageways

Outcome: Lose cluster

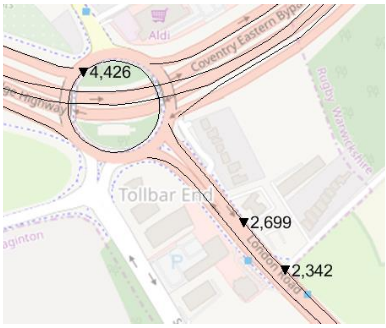
A.2.6 Cluster A46_2

Decision: Remove event 2356

Justification: Event 2356 is on main carriageway rather than roundabout

Outcome: Lose cluster because less than 3 events

A.2.7 Cluster A45_1

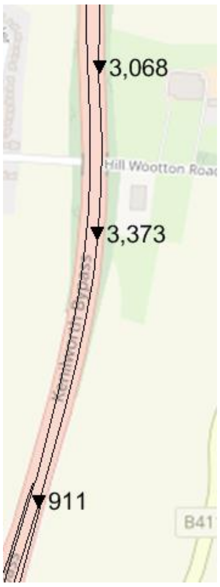


Decision: This is not a cluster

Justification: Events are on different road types

Outcome: Lose cluster

A.2.8 Cluster A46_3



Decision: This is not a cluster

Justification: Events too far apart

Outcome: Lose cluster

A.2.9 Cluster M40_1

Decision: Remove event 4804

Justification: Event is on main carriageway, the other two are on the slip road

Outcome: Lose cluster because less than 3 events

The relationship between vehicle data, collision risk and skid resistance

The current Highways England skid resistance policy uses accurate measurements of road surface properties (e.g. skid resistance and texture depth) and identifies sites where a surface treatment may reduce the risk of skidding, based on these characteristics. The aim of the current policy is to broadly equalise the risk of skidding accidents across the network, and to identify sites where maintenance to improve skid resistance would be beneficial.

The current skid resistance standard, CS228 (Highways England, Transport Scotland, Welsh Government, Department for Infrastructure, 2019), defines the approach to managing appropriate levels of skid resistance using routine (typically annual) measurements of the road network.

An alternative approach is a system whereby vehicles directly report the risks on the network. Data on the location of skidding events (e.g. anti-lock braking system (ABS) activations, and the precursors to these activations) can be used to build up a picture of areas where the friction demanded by vehicles exceeding (or nearly exceeding) the friction supplied by the road.

This report presents a study in which vehicle sensor data were used to identify areas on the road network representing a skidding risk. The effectiveness of the technique used was shown to be greater than that of the current skid resistance management policy detailed in CS228.

Other titles from this subject area

PPR806 Relationship between collisions and skid resistance on the SRN. C Wallbank, H Viner, L Smith & R Smith. 2016

PPR962 The relationship between connected and autonomous vehicles, and skidding resistance- A literature review. J Bullas, T Andriejauskas, P D Sanders & M J Greene. 2020

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