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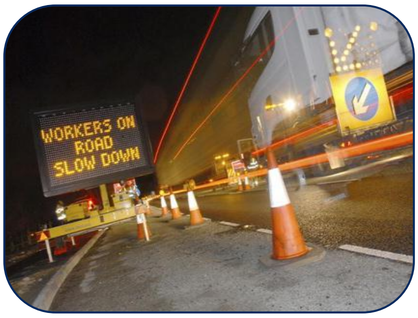


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Comparison of SCRIM and SKM sideway-force skid resistance devices

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Contents

Executive summary

The Highways Agency (HA) manages the levels of skid resistance on its network by carrying out single annual skid resistance surveys (SASS). These surveys are conducted using sideway-force skid resistance survey devices manufactured in the UK known as SCRIM. A similar device known as SKM is manufactured in Germany which uses a similar tyre manufactured using different materials, to a slightly different specification. This study was undertaken to:

1. Compare the results produced by the two tyre types to provide an initial assessment of the effect of the differences in specification.
2. Compare the two machine types to determine if a SKM type device could potentially achieve accreditation at the HA accreditation trial and be approved for use on the HA network.

After examination of the two tyre types it was found that they produced similar levels of performance (with regards to repeatability), however they produced different levels of skid resistance. The SKM tyres produced SR values 4-8% higher than the SCRIM tyres. It is suspected that the difference between the tyres could involve a temperature dependence. Other parameters such as texture of the road surface may also have an effect. Further research would be required to determine a robust correlation between the two tyre types.

A SKM device was compared to the UK SCRIM fleet and was found to be producing consistent results (when using the same tyre type). Therefore a SKM built with the test wheel on the left hand side has a reasonable chance of passing an HA accreditation trial if fitted with a tyre complying with BS 7941-1. However it would also be necessary to fit a dynamic vertical load system to the device.

Moving forward, a combined standard for these devices should allow for greater interoperability across Europe. However, particular care will need to be taken in the specification of the tyre used, potentially requiring hardness and resilience to be specified at different temperature conditions, or for a robust correlation between the two tyre types to be established. Furthermore, anecdotal evidence suggests that even with a consistent tyre specification, there can be a considerable variation between tyres produced by different manufacturers.

1 Introduction

The Highways Agency (HA) manages the levels of skid resistance on its network by carrying out single annual skid resistance surveys (SASS). These surveys are conducted using sideway-force skid resistance survey devices manufactured in the UK known as SCRIM, which comply with BS 7941-1 (British Standards, 2006). These devices use a smooth rubber test tyre mounted at 20° to the direction of travel at the midpoint of the test vehicle. The test path is wetted via a water flow system so that a theoretical water film thickness of 0.5mm in front of the test tyre is achieved when testing at 50km/h. Skid resistance is then calculated by dividing the horizontal force generated on the test wheel by the vertical load.

A similar device (using the same test configuration described above) known as SKM is manufactured in Germany. These SKM devices use tyres which are the same size as the SCRIM tyres but are produced by a different manufacturer and have slightly different material properties.

TRL was commissioned by HA to undertake comparative testing of two of the sideways-force machines (SCRIM and SKM) from a UK perspective. This study involved the following tasks:

1. Compare the results produced by the two tyre types to provide an initial assessment of the effect of the differences in specification.
2. Compare the two machine types to determine if a SKM type device could potentially achieve accreditation at the HA accreditation trial and be approved for use on the HA network.

2 Background

For historical reasons, different countries have developed and use different systems to measure skid resistance on their roads and they also have different approaches to defining the required level of skid resistance as an indicator for safety. Previous attempts to harmonise skid resistance measurements from different devices, such as the World Road Association (PIARC) experiment (Wambold, Antle, Henry, & Rado, 1995) and the European HERMES project organised by FEHRL (Descornet, et al., 2006) developed the concept of a "Common Scale" to represent the skid resistance condition of the road under defined, "reference" conditions. The concept relies on a generalised conversion formula to transform values measured by individual devices under their particular test conditions to values equivalent to the "reference" conditions on the common scale.

In practice, the main barrier to implementation of this approach has been that it has not been possible to establish an algorithm for the common scale which is sufficiently robust or has the required accuracy for it to be used for routine monitoring of skid resistance on road networks or for acceptance testing of new pavement construction. The EC funded TYROSAFE project (Roe, Do, & Vos, 2009) concluded that, with the large number of different devices operating on various principles, and with different responses to the variation in road and test conditions, it would be difficult to achieve a common scale that accommodates all devices in all conditions and still obtains a sufficient accuracy. However, an acceptable accuracy might be achievable if restrictions are placed on the range and types of devices in combination with their operating principles and conditions.

This principle has now been taken forward in the EC 7th Framework project ROSANNE which aims to group existing devices according to their main measuring principle and to define a common scale for each group. The outcomes of ROSANNE will feed into the work of CEN committee TC227 "Roads" (WG5 "Surface characteristics") which is tasked with developing a European Standard for the assessment of skid resistance.

3 Comparison of SKM and SCRIM tyres

3.1 Differences in construction

There are two main properties of rubber which define its characteristics, hardness and resilience. Hardness is a measure of the resistance of the material to indentation and resilience is the ratio between the returned and applied energy when hit (i.e. its "bounciness").

From the tyres obtained for this study an average Shore A hardness of 66 was obtained for the SCRIM tyres and 69 for the SKM tyres. It was not possible to measure resilience for the tyres, however examination of the specification for the tyres and communication with the tyre suppliers identified that SCRIM rubber for SCRIM tyres has a resilience of 40-49% and SKM tyres have a resilience of 30%. The SKM tyre does not meet the requirements of BS 7941-1 (British Standards, 2006).

Previous research (Sabey, 1961; Lupton, 1963) found that differences in hardness between 50 and 80 had little impact on the frictional properties of the rubber. Therefore the differences in hardness between the two tyre types should have little effect on the results. However, the research found that resilience does affect the frictional properties, with an increase in resilience resulting in a decrease in friction. This would suggest that the SKM tyres (with a lower level of resilience, i.e. lower proportion of energy returned following deformation) should produce higher skid resistance values in comparison to the SCRIM tyres. This work also showed that the resilience of rubber generally increases with temperature.

Following the testing described below it was found that the SKM tyres appear to wear out more quickly than the SCRIM tyres. This should therefore factor into any cost considerations between the use of the two tyre types.

3.2 Purpose of testing

The purpose of the testing described below was to investigate the differences between the two tyre types and to try an answer the following questions:

1. Do the two tyre types have similar between run variation?
2. Do the two tyre types have similar between tyre variation?
3. Do the two tyre types produce similar skid resistance values?
4. Do the two tyre types respond to changes in skid resistance in similar ways?

The first two questions are important in relation to the repeatability of the measurements produced by a tyre type. The second two questions are important for assessing the consistency in skid resistance values produced by the two tyre types.

3.3 Test programme

3.3.1 Main testing

Three SCRIM and three SKM tyres were obtained and tested using the HA's skid resistance development platform (SkReDeP). All of the tyres where fitted onto rims for use with SCRIM tyres, however there are no noticeable differences between the rims used for the different tyre types. Measurements were undertaken on the test track at

TRL and on a stretch of the A329(M) used for dynamic calibration. All of the tyres were new and were consequently "run in" for 16km before testing commenced. Measurements were conducted at 50 and 80km/h on the test track and at 80km/h on the A329(M).

To minimise track conditioning effects during the measurements on the TRL test track, two passes (one at 50km/h and one at 80km/h) were conducted with the 1st SCRIM tyre and then testing was stopped to change to the 1st SKM tyre. Then another two passes were carried out using this tyre. The tyre was then changed for the 2nd SCRIM and testing was conducted using this tyre. This pattern was continued until all of the tyres have been used and the process repeated until 5 passes at each test speed had been completed for all of the tyres. The A329(M) was open to traffic before and during testing. Therefore track conditioning effects were not a concern for these tests and as such all of the testing was conducted for each tyre before moving onto the next one.

Due to track availability and safety issues, one section of the track was tested on a separate day to the rest of the testing and only at 50km/h.

3.3.2 Additional testing at accreditation trial

A SKM machine operated by Germany's Federal Highway Research Institute, Bundesanstalt für Straßenwesen (BASt) was invited by HA to attend the 2014 skid resistance accreditation trial. This provided a further opportunity to undertake tests using the two types of tyre in addition to tests to assess the differences between the two device types when fitted with the same tyre type (discussed further in section 4.2).

These tests were conducted on the Straight Line Wet Grip area of the MIRA proving ground. The SKM machine conducted three passes of the site (at 50km/h) with a SCRIM tyre and three passes with a SKM tyre (all of these tyres were fitted to SKM rims). Due to the testing associated with the accreditation trial, it was not always possible to alternate between the tyres; the test pattern undertaken is provided in Table 3.1.

Table 3.1 Tyre rotation for Straight Line Wet Grip tests

Test	Tyre used
1	SCRIM
2	SKM
3	SKM
4	SCRIM
5	SKM
6	SCRIM

Due to the reduced number of tests, these additional tests will only provide supporting information for the last two questions identified in section 3.2 (Do the tyre types produce similar values and do they respond to changes in skid resistance in similar ways?).

3.4 Results

3.4.1 Main testing

The survey data collected from the TRL test track and A329(M) was processed to produce average values for each homogenous section (the test track sections were around 100m in length and those on the A329(M) varied between 200 and 600m). These average values were then used to produce repeatability and reproducibility values (r and R) for different subsets of the data. The average values for each section and run are given in Appendix A.

Repeatability and reproducibility were calculated using BS ISO 5725-4:1994 (British Standards, 1994) and are standard measurements for assessing the differences between laboratories. Repeatability is a measure of how consistent results should be between repeat tests using the same lab. Reproducibility is a measure of how consistent results should be between labs. These terms are formally defined as:

- Repeatability (r) = a second test for a lab should be within this value of the first test 95% of the time.
- Reproducibility (R) = a test with different lab should be within this value of the original test 95% of the time.

For the investigation of the differences between the tyre types a "lab" will be the tests from an individual tyre.

3.4.1.1 Between run variation and between tyre variation

For the first two assessments, repeatability and reproducibility were calculated for the set of SCRIM tyres and for the set of SKM tyres. Because repeatability is a measure of how consistent the results are for individual labs (i.e. tyres in this case) the repeatability values provide an indication of between run variation. Reproducibility on the other hand is a measure of how consistent the labs are with other labs. This means the reproducibility values provide an indication of between tyre variation. The repeatability and reproducibility values, in terms of SR, are shown in Table 3.2 and Table 3.3.

Table 3.2 Repeatability for SCRIM and SKM tyres

	Repeatability (SR)		
Data subset	**50km/h**	**80km/h**	**All speeds**
SCRIM tyres	4.2	3.9	4.2
SKM tyres	4.6	3.3	4.0

Table 3.3 Reproducibility for SCRIM and SKM tyres

	Reproducibility (SR)		
Data subset	**50km/h**	**80km/h**	**All speeds**
SCRIM tyres	4.4	4.1	4.4
SKM tyres	4.6	3.4	4.1

It can be seen that the repeatability values for tests with SCRIM and SKM tyres (Table 3.2) are similar. Therefore we can infer that the two tyre types have similar between run variation. It can also be seen that the reproducibility values for tests with SCRIM and SKM tyres (Table 3.3) are similar.

Therefore we can infer that the two tyre types have similar between tyre variation.

3.4.1.2 Comparison of SR measurements

In order to assess whether the two tyre types produce similar values we can repeat the analysis that was carried out in section 3.4.1.1 with the data from the two tyre types combined together. The reproducibility (the differences between tyres) for this combined group can then be compared to the reproducibility for the tyre type grouping (Table 3.3). If the tyre types do not produce similar values then there should be a significant increase in the reproducibility values. The reproducibility values for the combined data set are given in Table 3.4.

Table 3.4 Reproducibility for the combined dataset of tyres

	Reproducibility (SR)		
Data subset	**50km/h**	**80km/h**	**All speeds**
All tyres	7.4	6.7	7.0

It can be seen that the reproducibility values for the combined dataset (Table 3.4) are significantly higher than the values obtained for the tyre sets (Table 3.3).

Therefore the two tyre types do not produce the same values.

On examination of the average SR values for the survey data it can be seen that the tests carried out with the SKM tyres produced higher skid resistance values in comparison to the tests carried out with SCRIM tyres. The average SR values for the two tyre types are shown in Table 3.5.

Table 3.5 Average SR for SCRIM and SKM tyres

	Average SR		
Data subset	**50km/h**	**80km/h**	**All speeds**
SCRIM tyres	61	59	61
SKM tyres	65	62	64

To investigate this further, the average value for each 10m length (over the test lengths) for the two tyre types were calculated and plotted against each other. The plot of all of the data is given in Figure 3.1 and the plots of the 50km/h and 80km/h tests are provided in Appendix B. In all of the plots the line of best fit has been set to go through zero.

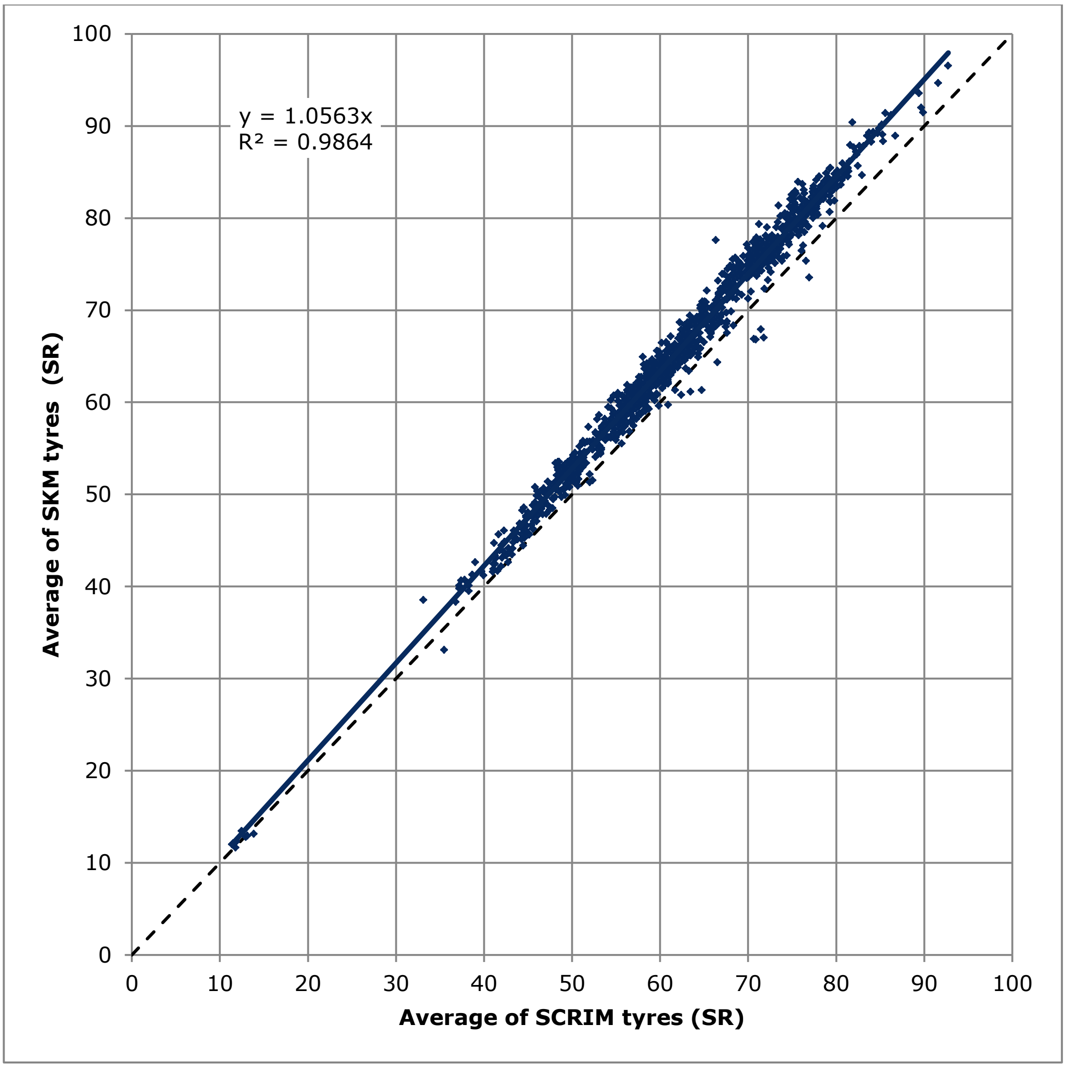

Figure 3.1 Comparison of SR values from main tyre tests

It can be seen from the plot of all of the data (Figure 3.1) that there appears to be a strong relationship between the two tyre types with the values produced when using the SKM tyres being approximately 6% higher than the values produced when using the SCRIM tyres. On examination of the data from the two speeds (Appendix B) it can be seen that this relationship is consistent between the two survey speeds, and therefore does not appear to be speed dependent.

Analysis of the 10m data plots also found that the two tyre types appear to respond to changes in skid resistance levels in similar ways.

3.4.2 Additional testing at accreditation trial

As discussed previously (section 3.3.2) the amount of data collected from the additional tyre tests conducted at the accreditation trial means that it is only possible to provide supporting data for the assessment of measured values. As with the previous analysis (section 3.4.1.2) the average values for each 10m length for the two tyres were calculated and plotted against each other. The results are shown in Figure 3.2.

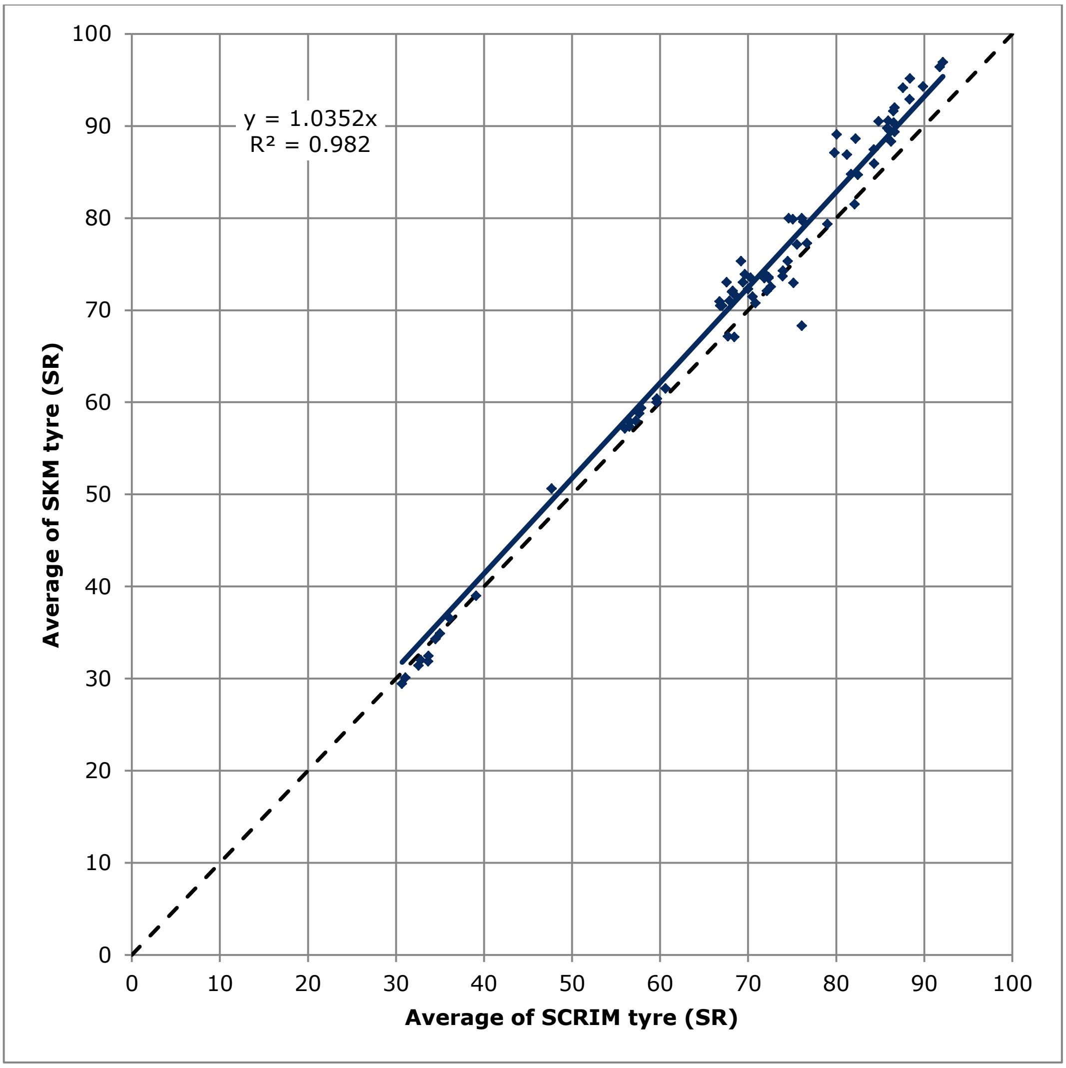

Figure 3.2 Comparison of SR values from additional tyre tests

As before, it can be seen that there is a strong relationship between the results produced by the SCRIM and SKM tyres. However, this data suggests that the results from the SKM tyres are approximately 4% higher than the values produced when using the SCRIM tyres (rather than the 6% previously seen). This suggests that there may be some additional factor(s) affecting the relationship between the two tyre types.

As with the main testing, analysis of the 10m data plots found that the two tyre types appear to respond to changes in skid resistance levels in similar ways.

3.5 Testing conducted by BASt

Comparisons of the SCRIM and SKM tyres have also been carried out by BASt on two roads in Germany; one with a concrete construction and one with an asphalt construction. This testing found the SKM tyres produced skid resistance measurements 7 to 8 % higher than the values produced by the SCRIM tyres.

4 Comparison of SKM and SCRIM

4.1 Differences in the equipment

In general SCRIMs and SKMs are very similar. They use similar test tyres (discussed in section 3) which are lowered onto the test surface at an angle of 20°. Both machines apply water in front of the test wheel so that the test wheel is pulled along a wetted surface. There are however some significant differences between the two machines.

4.1.1 Dynamic vertical load

The skid resistance value on both of these machines is determined by dividing the sideway force generated on the tyre by the vertical load applied. While both devices have a nominal vertical load equivalent to 200kg, in the case of the SCRIMs the vertical load applied is measured dynamically while for SKM it is assumed to be constant during testing. This could potentially result in a reduced consistency in the skid measurements from SKMs during acceleration/braking and bends.

4.1.2 Temperature measurement

Approximately a third of SCRIMs have air and/or surface temperature measurement fitted. These sensors are not mandatory and are generally used by contractors to determine if it is too cold to test (testing is not allowed on the HA network below 5°C on a downward trend). SKMs on the other hand have air, surface, water and tyre temperature sensors fitted. The data from the water and surface sensors are used to provide temperature corrections to the skid measurements. This means that there is potential for SCRIMs to have a reduced consistency in skid measurements between hot and cold conditions.

4.1.3 Application of water

SCRIMs are fitted with either a speed controlled or fixed flow water system. The fixed flow system is set-up so that the theoretical water film thickness (in front of the test tyre) is 0.5mm at 50km/h. The speed controlled system is set to achieve 0.5mm at all valid test speeds. In both cases the water is applied from a nozzle aimed at the road surface in front of the tyre as shown in Figure 4.1.

Figure 4.1 Water nozzle system on a SCRIM

SKMs are also fitted with a speed controlled water flow system. The system is set-up to achieve a theoretical water film thickness (in front of the test tyre) of 0.5mm. The water is applied using a guided water shoe as shown in Figure 4.2 (the water shoe is shown in its raised position). Brushes are fitted to the shoe to limit the horizontal spread of the water.

Figure 4.2 Pavement wetting system on a SKM (raised position)

4.2 Testing conducted

Every year the HA undertakes an accreditation trial for SCRIMs which might undertake surveys on the HA network. Only devices that meet the characteristics given in BS 7941-1 (British Standards, 2006) and the requirements of the trial will be accredited for use on the HA network. The HA survey contract also requires that machines are fitted with controlled water flow and GPS although these are not specified in the British standard. For the 2014 trial, BASt attended the trial with a SKM in order to allow a comparison of this machine to the UK SCRIM fleet.

The 2014 skid resistance accreditation trial took place at the MIRA proving ground near Nuneaton. The performance of skid resistance is assessed mainly from the straight line wet grip area (SWG) at MIRA with additional data supplied from a network route near to the site. During the trial the SWG is tested on two separate occasions (with the second set used for the accreditation). For the comparison of the BASt machine with the UK fleet, data collected from the network route and the 1st set of tests on the SWG were used.

Data is also collected from the twin horizontal straights at MIRA, however these sections are still experiencing “early life” skid resistance effects and are consequently not reliable for the assessment of skid resistance. Therefore the data from the twin horizontal straights has not been used in the analysis below.

On the SWG, the SKM (which tests the right-hand wheel path) conducted 3 passes with a SKM tyre and 3 passes with a SCRIM tyre. The comparison of the results from these two tyre types is discussed in section 3.4.2. For comparison to the UK fleet the tests conducted with a SCRIM tyre were used.

As part of its main testing for accreditation the SkReDeP conducted 5 passes in its normal left-hand wheel path position (along with the rest of the UK fleet). To account for differences in test line, 3 additional passes were conducted with the vehicle offset so that the test wheel matched the test position of the SKM wheel path. For all of the tests the SkReDeP used SCRIM tyres.

One of the SCRIMs owned by PMS Pavement Management Systems Ltd. (Ireland) which attended the trial (Machine trial ID 14) is configured with a test wheel on both the left and right hand sides of the vehicle. PMS agreed to make some measurements with the right-hand wheel to provide additional data for this study.

4.3 Results

4.4 Results from straight line wet grip area

On the straight line wet grip area, tests were conducted on both the right and left hand wheel paths. Tests were conducted by the SKM on the right wheel path. Two other machines (SkReDeP and Machine 14) also provided results for this wheel path. The results from these tests are given below in Table 4.1.

Table 4.1 Average SR for right wheel path

	Average SR for right wheel path				
	SWG01	SWG02	SWG03	SWG04	Avg
SKM	73	89	33	58	63
SkReDeP offset	70	92	34	66	66
14 right wheel (PMS)	74	88	31	56	62
Average	72	90	32	60	64
BESD	2.09	2.51	1.56	5.53	1.82

The acceptance criterion for skid resistance measurements is for the between equipment SD (BESD) to be ≤2.7 SR. The results show that this criterion is met for SWG01, SWG02, SWG03 and the average for the site. Note, track conditioning effects were observed on SWG04 and to a lesser extent on SWG02, and therefore additional spread of data is expected on these sections. This suggests that these three machines are acceptably consistent. However, when undertaking accreditation at least three machines are required to act as a reference. Technically, only one of the machines (SkReDeP) can be considered a reference as it took part, and met the trial criteria, in the rest of the accreditation trial. (Machine 14 also took part in and passed the rest of the trial, but was using the left hand wheel for those tests).

Therefore, to provide additional confidence that the SKM was producing results which are consistent with the UK fleet, correction factors (one for each section) were produced by dividing the results produced using SkReDeP in the left hand wheel path by the results produced by using the same machine in the right hand wheel path. These corrections were then applied to the data from the SKM and from Machine 14's OS tests. These "corrected" values are provided in Table 4.2. This table also includes the summary statistics from the UK fleet tests in the left hand wheel path and the average and BESD from different combinations of test machines.

Table 4.2 Average SR for left wheel path

	Average SR for left wheel path				
	SWG01	SWG02	SWG03	SWG04	Avg
SKM corrected	73	87	29	54	61
14 right wheel corrected	74	86	27	52	60
UK fleet Min	66	85	23	54	57
UK fleet Max	76	96	33	67	68
UK fleet Avg	70	90	27	60	62
UK fleet BESD	2.58	3.36	2.42	3.18	2.64
SKM + UK fleet Avg	70	90	28	60	62
SKM + UK fleet BESD	2.59	3.32	2.37	3.41	2.58
14 right wheel + UK fleet Avg	70	90	27	60	62
14 right wheel + UK fleet BESD	2.68	3.38	2.35	3.69	2.61
All machines Avg	70	90	28	59	62
All machines BESD	2.67	3.33	2.31	3.82	2.55

From this table we can see that (for the first set of tests on the SWG) the UK fleet met the acceptance criterion for the average of the site and for SWG01 and SWG03. These conclusions remain unchanged following the addition of the corrected data for the SKM and/or Machine's 14 right wheel. It can also be seen that the corrected data from these two machines lies within the range of values from the UK fleet (i.e. greater than the UK fleet min and lower than the UK fleet max) in all but one instance. This instance was for Machine 14's right wheel data on SWG04. As noted before, this section experienced track conditioning effects and therefore does not require further discussion.

4.5 Results from the network route

For the network route the data from SkReDeP was collected from the left hand wheel path, and the data from the SKM and Machine 14 were collected in the right hand wheel path. Plots of the results from the entire network are given in Appendix C and parts of the data are presented and discussed below.

Figure 4.3 provides a sample of the survey data where the majority of the data is the same for all three machines, but in parts the SkReDeP (measuring a different wheel path) produces different results.

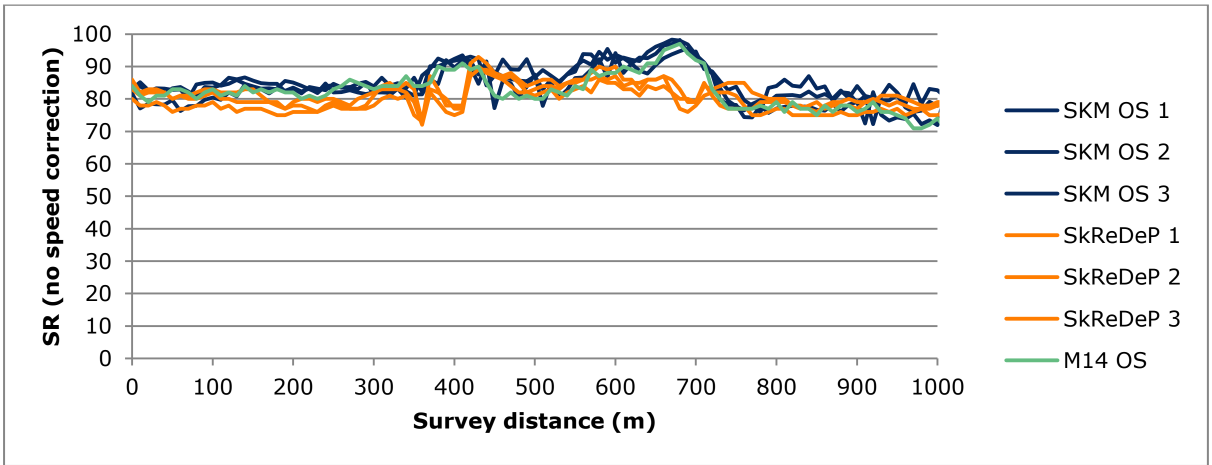

Figure 4.3 Sample of network route data showing good correlation

This is consistent with expectations as the data from the two wheel paths are expected to diverge at points. However, in another part of the dataset (between 7780m and 7950m in Figure 4.4 below) it can be seen that all three machines produced different results.

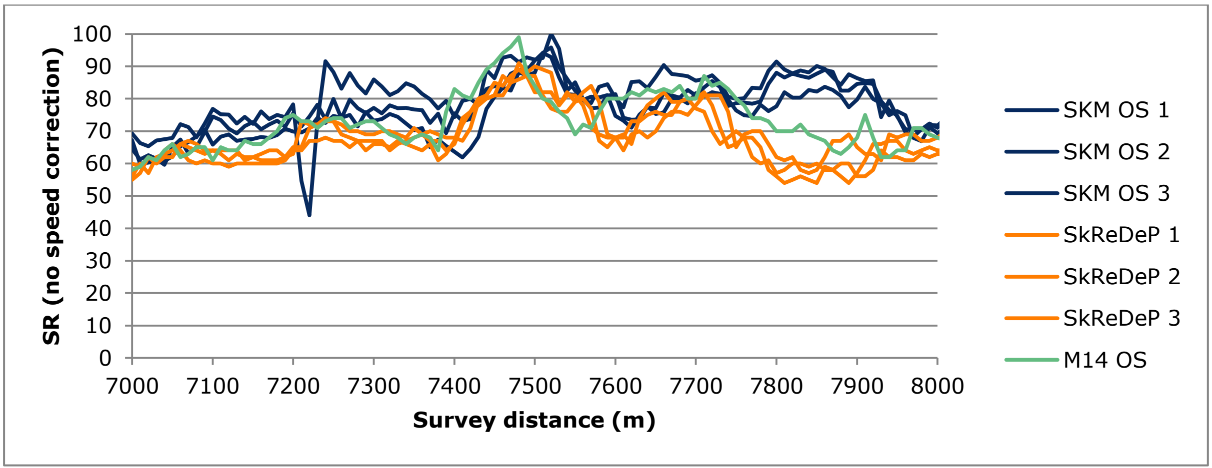

Figure 4.4 Sample of network route showing differing results

On examination of the map for the route it was determined that this part of the data (7780m to 7950m) was collected on a roundabout. This suggests one of two possibilities:

1. the SKM and Machine 14 surveyed different lines when surveying the roundabout

or

2. the lack of dynamic load measurement on the SKM resulted in an incorrect measurement on the roundabout

During the clockwise motion around the roundabout, it would be expected that the load applied to the test wheel on the SKM machine (on the right hand side) would be lowered. Therefore if dynamic vertical load was available on this machine the expected effect would be to cause the SR value to increase. This would cause the values produced by the SKM to diverge further away from the other two machines. Therefore the likely explanation for the differences is variation in test line.

5 Discussion and recommendations

5.1 Test tyres

In terms of variation between runs and variation between tyres, the two tyre types produce similar levels of performance. However, the two tyre types produce different levels of skid resistance, with the SKM tyres producing slightly higher values in comparison to the SCRIM tyres. During the main set of tests this was found to be an increase of around 6% and in the additional tests this increase was around 4%. Testing conducted by BASt in Germany found that the increase was between 7 and 8%.

It is likely that the differences in the skid resistance values produced by the two tyre types, is due to the differences in resilience of the tyres (SKM tyres have a lower resilience). Previous research (Sabey, 1961; Lupton, 1963) has found that a rubber with a lower resilience would produce a higher skid resistance value. This work also showed that the resilience of rubber generally increases with temperature. This in turn may explain some of the differences in the correlations in the tests. Other parameters such as texture of the road surface may also have an effect. Further testing to determine the factors contributing to the variation between the two tyre types would be necessary before a relation between measurements could be established. Such testing would need to cover a range of surface types, temperatures and geometries. This approach would be difficult to make robust in all circumstances and standardisation on a single tyre specification would be preferable.

However, if the SKM tyre was approved for use on the HA network, it is recommended that the survey data should have a correction (following further development) applied so that it remains consistent with survey data from previous years. Given the suspected temperature dependence on the differences between the tyre types (partly from temperature effects on the SCRIM tyres and partly from temperature effects on the SKM tyres), it is likely that temperature sensors would need to be fitted to any machine using a SKM tyre on the HA network.

It was also observed during the testing that the SKM tyres appeared to wear more quickly than the SCRIM tyres. Therefore the useful life of the tyre will need to be factored into any cost considerations of using different tyres.

A machine attending the HA's sideway-force skid resistance accreditation trial is likely to meet the measurement criteria for skid resistance if it produces results within 10% of the fleet mean. A machine testing with an SKM tyre may be able to meet this criterion (if the other machines were using SCRIM tyres), but it would not achieve accreditation as the device would not meet the requirements of BS 7941-1 (British Standards, 2006); the SKM does not have vertical load measurement and the SKM tyre does not meet the resilience specification.

5.2 Survey machines

5.2.1 Differences in construction

The two machine types (SCRIM and SKM) are very similar, with three noticeable expectations (apart from test side) which need to be considered.

The first is the measurement of dynamic vertical load, which is fitted to SCRIMs but not currently fitted to SKMs. The use of dynamic vertical load is specified in HD28/04 (Design Manual for Roads and Bridges, 2004). Therefore if an SKM (with a wheel fitted on the left hand side) was to be used in the UK then a dynamic vertical load would need to be fitted.

The second difference between the machine types is the measurement of temperatures. Temperature sensors are not generally fitted to SCRIMs and it is not a requirement in HD28/04 or the HA survey contract. However, given the use of these sensors on the SKMs in Europe, consideration should be given to introducing a requirement for them on SCRIMs to help with uniformity in standards across Europe. This will be particularly relevant if comparisons are to be made from measurements taken from different locations in Europe due to the greater range of temperature levels that could be experienced.

There is also a difference between the two machine types in the way that the water is applied to the road surface in front of the test tyre. It is unlikely that the differences in the two approaches will produce different data, as long as the same water depth is achieved in front of the test tyre.

5.2.2 Comparison of SR values

Following testing on the Straight Line Wet Grip Area at MIRA, it was found that the SKM, when fitted with a SCRIM tyre, produced results consistent with the UK SCRIM fleet. This was matched on the network route tests with some variations in the data suspected to be due to differences in test line.

Therefore a SKM built with the test wheel on the left hand side (with dynamic load taken into consideration, see section 5.2.1) has a reasonable chance of passing a HA accreditation trial if fitted with a tyre complying with BS 7941-1 (British Standards, 2006).

However any company seeking this approach should discuss their intention with HA and the QA and accreditation auditor for these survey devices.

5.3 Summary

The work undertaken under this study has broadly found that the two survey devices appear to provide consistent results when fitted with the same tyre but the two tyre types in use produce somewhat different results.

Moving forward, a combined standard for these devices should allow for greater interoperability across Europe. However, particular care will need to be taken in the specification of the tyre used, potentially requiring hardness and resilience to be specified at different temperature conditions, or for a robust correlation between the two tyre types to be established. Furthermore, anecdotal evidence suggests that even with a consistent tyre specification, there can be a considerable variation between tyres produced by different manufacturers.

References

British Standards. (1994). *BS ISO 5725. Accuracy (trueness and precision) of measurement methods and results.* London: BSi.

British Standards. (2006). *BS 7941-1 Methods for measuring the skid resistance of pavement surfaces - Part 1: Sideway-force coefficient routine investigation machine.* BSI.

Descornet, G., Schmidt, B., Boulet, M., Gothie, M., Do, M.-T., Fafie, J., et al. (2006). *FEHRL Report 2006/1 Harmonisation of European Routine and research Measuring Equipment for Skid Resistance.* FEHRL.

Design Manual for Roads and Bridges. (2004). *Volume 7 Section 3, HD28/04, Skid resistance*. London: The Stationery Office.

Lupton, G. N. (1963). *Measurement of the Resilience, Hardness and Frictional properties of eight rubber compounds.* Crowthorne: Road Research Laboratory.

Roe, P. G., Do, M.-T., & Vos, E. (2009). *Roadmaps and implementation plan for harmonised skid resistance measurement methods. TYROSAFE Deliverable D09.*

Sabey, B. E. (1961). *Measurement of resilience, hardness, and frictional properties of some samples of tread ruber vulvanizates.* Crowthorne: Road Research Laboratory.

Wambold, J. C., Antle, C. E., Henry, J. J., & Rado, Z. (1995). *International PIARC experiment to compare and harmonise texture and skid resistance measurements.* PIARC.

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Appendix A Summary of results from Tyre tests

Table A.1 Average SR from A329(M) (80km/h tests)

Tyre type	Tyre	Run	S1	S2	S3
Section length (m)			650	210	210
SCRIM	1	1	44.97	52.48	72.24
SCRIM	1	2	45.28	50.24	70.76
SCRIM	1	3	43.12	49.48	71.71
SCRIM	1	4	44.03	48.67	74.10
SCRIM	1	5	42.57	48.57	71.48
SCRIM	2	1	42.57	51.33	70.14
SCRIM	2	2	42.32	50.81	70.29
SCRIM	2	3	41.55	48.52	71.00
SCRIM	2	4	41.82	49.10	71.86
SCRIM	2	5	41.14	48.57	71.71
SCRIM	3	1	42.68	51.33	70.86
SCRIM	3	2	41.43	50.24	70.62
SCRIM	3	3	42.97	50.10	71.90
SCRIM	3	4	42.03	48.71	70.29
SCRIM	3	5	42.69	49.24	72.10
SKM	A	1	44.57	54.67	74.43
SKM	A	2	46.29	52.62	74.33
SKM	A	3	44.12	52.62	75.43
SKM	A	4	44.06	51.95	75.33
SKM	A	5	44.08	51.86	76.38
SKM	B	1	43.80	53.29	76.62
SKM	B	2	43.89	52.90	76.05
SKM	B	3	42.71	52.90	77.19
SKM	B	4	43.17	52.38	76.14
SKM	B	5	44.58	51.86	75.33
SKM	C	1	44.48	54.71	75.81
SKM	C	2	46.29	53.67	77.57
SKM	C	3	44.45	52.67	76.62
SKM	C	4	-	-	-
SKM	C	5	-	-	-

Table A.2 Average SR from 50km/h tests on test track

Tyre type	Tyre	Run	21	22	23	24	25	26	27	28	29	30
Section length (m)			100	120	80	80	120	10	70	70	80	70
SCRIM	1	1	54.30	63.17	50.88	12.88	65.08	70.30	74.43	75.43	67.25	53.86
SCRIM	1	2	58.60	61.67	51.38	13.00	72.50	78.80	72.43	79.14	69.13	54.71
SCRIM	1	3	57.80	60.67	49.75	12.25	73.33	76.20	76.86	78.71	68.38	52.57
SCRIM	1	4	57.70	61.00	49.75	11.25	71.50	68.30	73.71	79.14	68.25	52.71
SCRIM	1	5	59.70	61.08	49.50	11.88	72.83	68.40	74.43	79.14	70.13	52.71
SCRIM	2	1	58.20	60.75	50.75	13.13	69.67	72.80	72.00	75.57	67.75	54.57
SCRIM	2	2	59.30	61.08	48.88	11.75	72.50	70.20	72.00	75.29	65.63	53.43
SCRIM	2	3	58.10	60.42	49.13	10.75	71.58	66.70	75.29	78.71	69.13	52.71
SCRIM	2	4	57.50	61.33	48.63	10.63	72.92	69.30	76.43	77.86	68.38	52.43
SCRIM	2	5	58.40	61.17	47.38	10.00	71.92	66.00	75.14	79.29	69.38	53.86
SCRIM	3	1	57.50	61.92	50.25	12.63	67.58	70.50	75.14	76.29	67.63	51.86
SCRIM	3	2	58.70	61.17	49.63	11.63	71.75	69.50	74.86	78.29	68.13	53.29
SCRIM	3	3	58.60	60.75	48.75	13.13	70.17	68.60	74.86	78.57	69.50	52.71
SCRIM	3	4	58.80	60.75	49.25	16.13	71.25	66.40	73.71	78.29	68.25	54.57
SCRIM	3	5	59.40	61.33	48.25	10.88	72.25	66.70	75.43	79.29	70.13	54.29
SKM	A	1	57.90	62.25	51.50	12.38	72.83	78.40	79.14	81.71	75.38	54.86
SKM	A	2	61.10	64.08	51.50	13.25	75.33	75.40	81.43	84.71	73.38	55.57
SKM	A	3	61.50	63.58	50.88	14.63	76.92	71.20	80.29	84.00	72.50	56.43
SKM	A	4	62.50	64.17	50.88	11.63	76.42	78.70	80.29	83.71	75.13	56.57
SKM	A	5	61.90	64.33	50.50	12.75	76.67	70.10	83.57	84.29	75.63	57.57
SKM	B	1	59.10	62.42	52.00	14.00	66.92	82.40	79.57	81.57	75.25	56.00
SKM	B	2	61.90	64.00	51.75	12.38	76.58	78.30	79.86	84.57	74.13	56.14
SKM	B	3	61.00	63.75	50.63	12.25	75.58	75.60	81.43	84.43	73.63	55.43
SKM	B	4	61.20	64.08	51.63	10.75	76.83	72.70	82.43	83.86	74.63	56.29
SKM	B	5	61.60	64.42	50.63	11.63	77.00	70.00	81.43	83.86	74.50	57.14
SKM	C	1	58.10	62.75	51.75	12.75	75.17	80.10	80.14	83.71	73.75	56.43
SKM	C	2	61.60	63.75	51.13	12.00	76.08	75.20	80.71	84.57	73.50	55.29
SKM	C	3	61.50	64.08	51.13	11.50	76.08	71.00	81.43	84.14	73.38	57.86
SKM	C	4	61.80	65.83	50.00	10.63	77.17	73.80	81.43	84.71	74.63	57.14
SKM	C	5	61.90	64.92	51.88	14.38	76.92	69.40	81.29	87.00	73.63	58.71

Table A.3 Average SR from 70-80km/h tests on test track

Tyre type	Tyre	Run	21	22	23	24	25	26	27	28	29	30
Section length (m)			100	120	-	-	120	10	70	70	80	70
SCRIM	1	1	50.30	55.50	-	-	61.42	66.80	67.14	71.29	61.25	45.57
SCRIM	1	2	50.20	54.17	-	-	65.00	67.00	71.29	72.00	-	46.00
SCRIM	1	3	49.60	53.92	-	-	65.42	62.30	70.71	74.29	60.63	46.00
SCRIM	1	4	48.10	54.17	-	-	66.00	65.00	69.86	73.86	59.13	45.57
SCRIM	1	5	50.60	54.50	-	-	65.83	62.90	72.00	75.43	61.13	47.00
SCRIM	2	1	50.30	55.75	-	-	63.08	68.90	67.29	70.29	-	45.29
SCRIM	2	2	49.70	54.58	-	-	65.50	64.60	69.86	71.71	57.67	45.00
SCRIM	2	3	49.20	54.92	-	-	64.08	63.00	68.86	65.43	60.33	45.86
SCRIM	2	4	50.10	55.08	-	-	65.50	62.30	68.86	70.86	60.50	45.57
SCRIM	2	5	49.70	55.92	-	-	66.00	61.90	69.00	74.14	60.08	46.43
SCRIM	3	1	52.10	56.25	-	-	63.83	72.30	66.43	69.71	-	45.29
SCRIM	3	2	48.80	54.00	-	-	65.58	64.10	69.43	73.71	62.80	45.71
SCRIM	3	3	49.60	54.58	-	-	65.08	63.10	69.29	72.71	59.20	46.29
SCRIM	3	4	50.50	54.00	-	-	66.58	68.50	69.43	74.00	61.92	46.29
SCRIM	3	5	50.20	54.42	-	-	64.08	62.50	70.71	72.29	60.83	46.86
SKM	A	1	51.30	57.25	-	-	66.92	70.70	72.29	76.43	-	47.43
SKM	A	2	51.80	58.50	-	-	68.92	70.80	74.29	75.71	66.08	47.43
SKM	A	3	51.00	57.17	-	-	68.42	65.40	74.57	76.43	64.67	48.86
SKM	A	4	52.40	58.25	-	-	69.67	64.30	74.00	75.71	66.17	48.14
SKM	A	5	53.00	58.42	-	-	69.50	64.80	73.86	78.00	65.42	49.43
SKM	B	1	51.70	56.42	-	-	68.92	70.50	75.57	77.00	-	48.29
SKM	B	2	53.20	59.17	-	-	70.17	67.40	74.57	76.57	65.50	46.86
SKM	B	3	52.00	58.67	-	-	69.00	65.30	74.86	78.71	63.83	48.00
SKM	B	4	53.00	59.42	-	-	69.50	65.60	73.14	78.00	65.75	49.00
SKM	B	5	52.60	59.42	-	-	69.67	65.50	72.86	76.57	64.92	48.29
SKM	C	1	51.70	58.17	-	-	67.50	74.00	75.71	76.57	-	48.57
SKM	C	2	52.20	56.25	-	-	70.17	72.20	72.71	77.71	65.50	47.71
SKM	C	3	51.70	58.50	-	-	69.42	65.90	74.57	76.57	64.08	49.00
SKM	C	4	52.60	58.75	-	-	69.42	66.10	75.71	79.00	65.92	47.71
SKM	C	5	53.30	58.92	-	-	69.08	61.80	75.29	79.29	64.00	50.00

Appendix B Comparison of SCRIM and SKM tyres at 50km/h and 80km/h

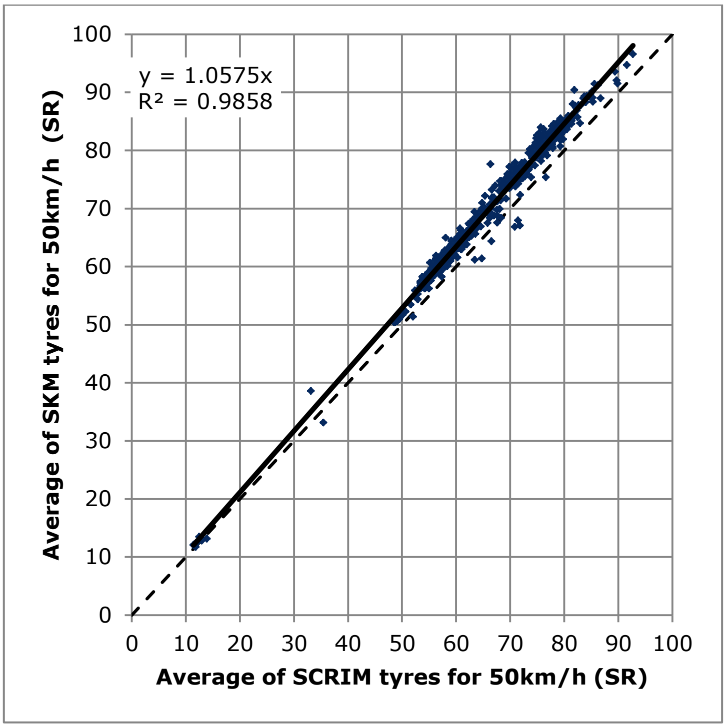


Figure B.1 Comparison of SR values from main tyre tests conducted at 50km/h

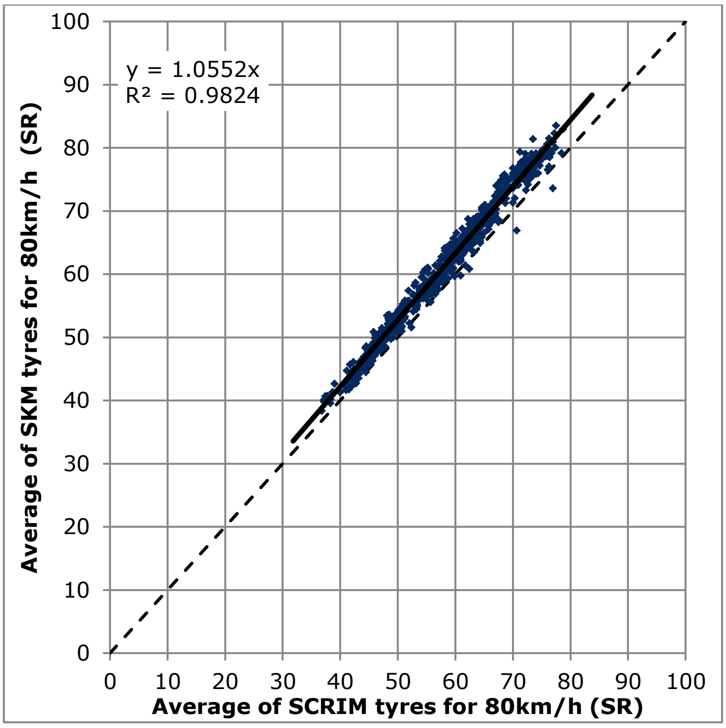
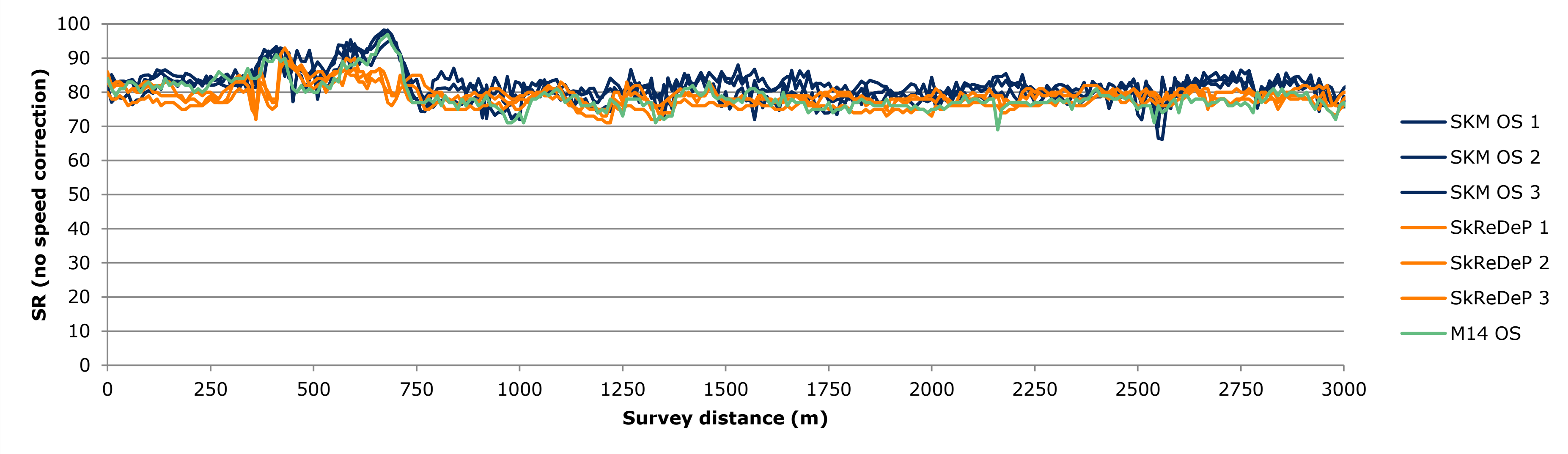
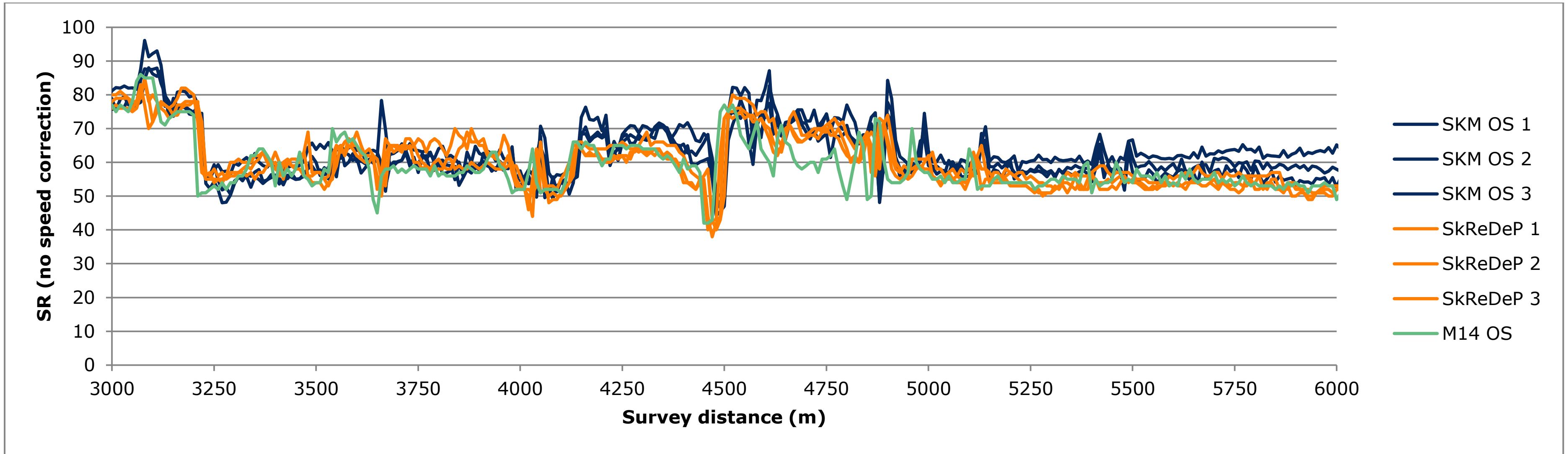
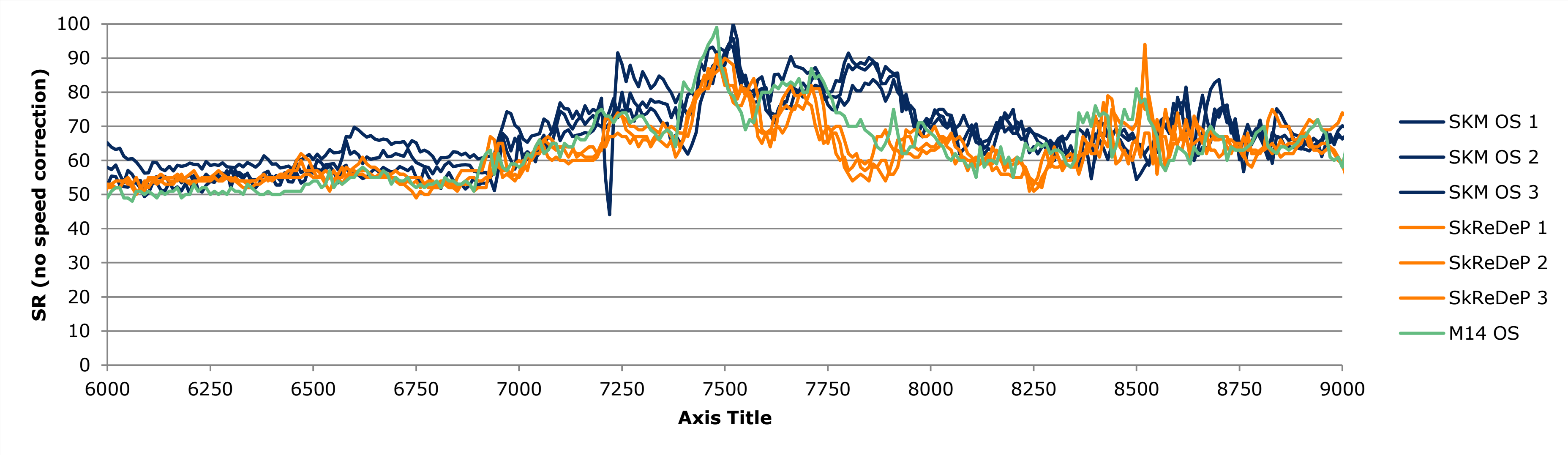


Figure B.2 Comparison of SR values from main tyre tests conducted at 80km/h

Appendix C Network route data



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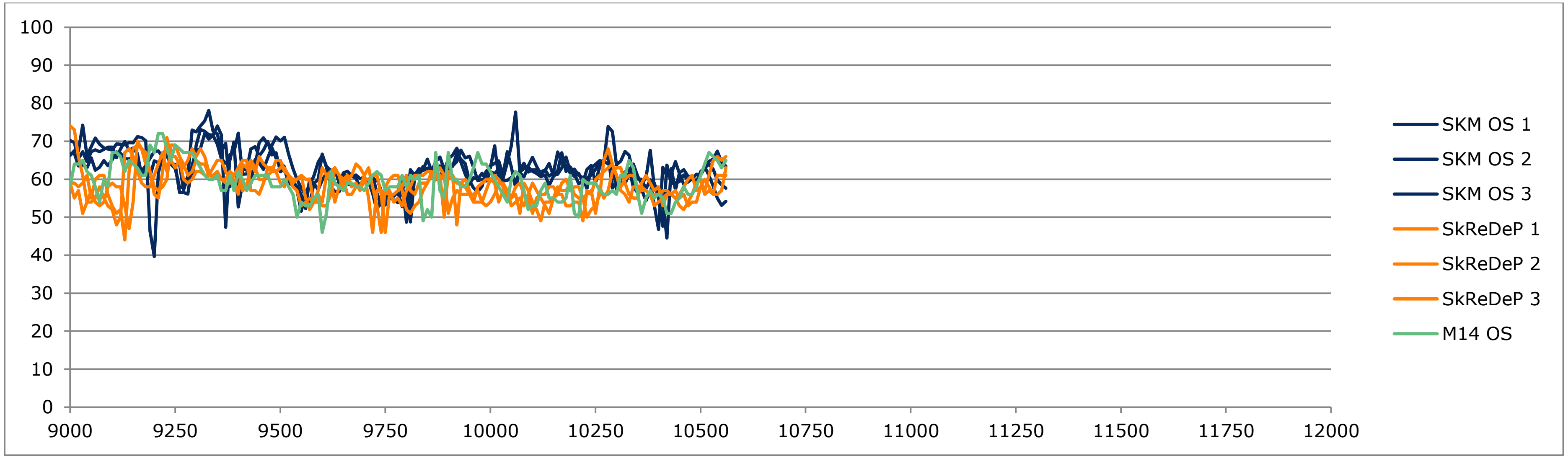
90
80
70
60
50
40
30
20
10
0
SR (no speed correction)
6000
6250
6500
6750
7000
7250
7500
7750
8000
8250
8500
8750
9000
Axis Title
SKM OS 1
SKM OS 2
SKM OS 3
SkReDeP 1
SkReDeP 2
SkReDeP 3
M14 OS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50
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30
20
10
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9000
9250
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9750
10000
10250
10500
10750
11000
11250
11500
11750
12000
SKM OS 1
SKM OS 2
SKM OS 3
SkReDeP 1
SkReDeP 2
SkReDeP 3
M14 OS