LONG TERM STUDY OF SKID RESISTANCE ON IN-SERVICE ROADS IN ENGLAND.

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ABSTRACT

The Highways Agency has established a number of benchmark sites for long term study of the in service performance of surfacing materials. These benchmark sites have provided a cost effective source of historical measurements of skid resistance across the network from which trends have been established to provide early warning of changes that may be required in policy. This paper presents the results and explains the effect they have on changing policy in the UK over the 9 year study period.

The results have:

- indicated that the summer season has extended into the autumn over the study period, which has led to the survey period being extended;
- confirmed that SCRIM survey's should not be carried out in heavy rain
- confirmed the link between the extent of polishing each year and the amount of rainfall;
- identified that the skid resistance appears not to plateau.
- indicated that different corrections factors are required for bituminous and concrete surfaces.

INTRODUCTION

The Highways Agency in the UK has established a network of 43 skid resistance benchmark sites in England. The 43 sites are distributed across the motorway and all purpose trunk road network and are typically 1 to 2 kilometres in length. Thirty nine of the sites were established in 2002 and have bituminous surfacing. In 2008, two additional sites were added that had predominantly concrete surfacing. In 2009 another 2 sites were added also with concrete surfacing. These additional 4 sites were added so the seasonal characteristics of concrete could be evaluated.

In this paper, the results for long term testing on the 39 sites will be discussed separately to the four newly added concrete sites.

Original 39 Benchmark sites

The principal reason the original 39 benchmark sites with bituminous surfacing were established was to provide a cost effective source of historical measurements of skid resistance across the network from which trends can be established to provide early warning of changes that may be required in policy.

Surveys on these sites have been undertaken by Jacobs UK Ltd each year since 2002 and WDM® has been responsible for the management and the analysis of the data from the sites.

There have been 3 SCRIM surveys carried out for each site in each survey period early 1st May to 20th June; Mid 21st June to 10th August and Late 11th August to 30th September for each year up until 2005.

In the beginning of summer the skid resistance is relatively high, then drops for the mid-summer, and recovers again toward the end of the summer period. This is illustrated in Figure 1.

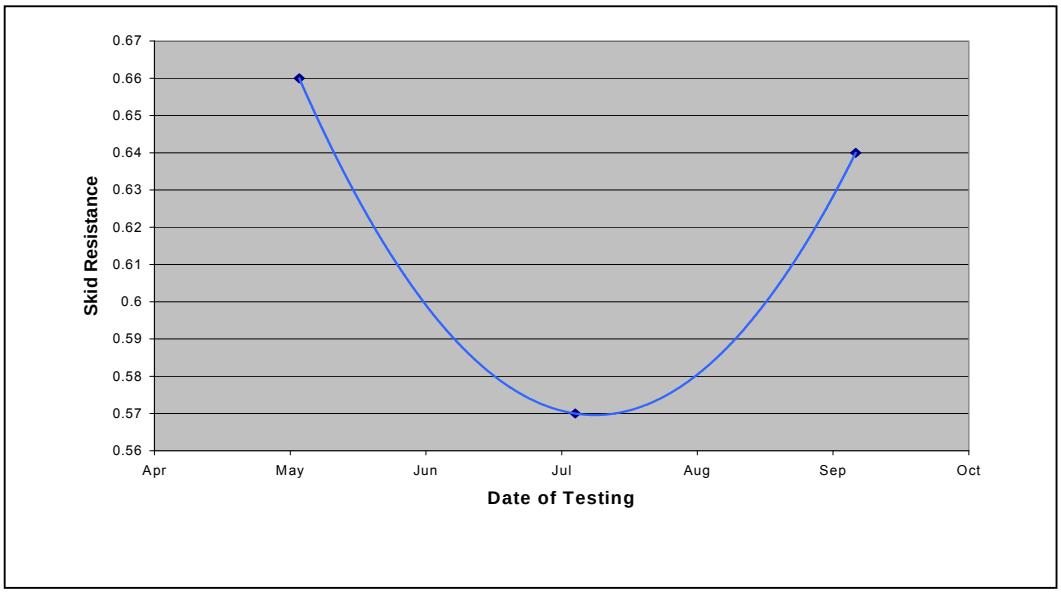


Figure 1: Expected Pattern of Skid Resistance over the Summer Period

It was found however, in 2005 that the recovery of the skid resistance towards the end of the test season had not occurred for 3 consecutive years and the late runs were equal to, or often, lower than the mid runs. In 2006, an additional survey for each of the benchmark sites was undertaken outside the SCRIM test season, at the end of October, to determine if the SCRIM readings of the benchmark sites would return to those of the early run. It was found that the skid resistance did recover in the 4th run so this was continued up until 2009.

SITE SELECTION

The location of each of the original 39 benchmark sites are shown on the Benchmark Location Map (Appendix 1).

The main site selection criteria were:

- the site should be well defined (i.e. easily locatable)
- safe to test at 50 km/h
- unlikely to have traffic delays or parked vehicles
- straight and level
- typical trunk road surfacing type (but not concrete)
- surfacing in good condition

DATA SUPPLIED FROM THE BENCHMARK SURVEYS

After each SCRIM run, the survey contractor supplies the survey measurements and an operators report with dates and details of the vehicle test tyre, a note of any unusual conditions that could influence the test results, photographs of each site at the time of each survey and calibration records.

Data from the Sites

Each year the mean SCRIM reading for each run, the average SCRIM reading for all runs and the range is collated to provide information on the within year variation. The data for 2009 is shown in Table 1.

Table 1: SCRIM Readings and Range from the 2009 Benchmark survey

Site Number	Area	Mean SR (Corrected for Speed)					
		Run 1 2009	Run 2 2009	Run 32 009	Run 4 2009	Mean 2009	Range
1	1	71.6	73.2	73.3	69.4	71.9	3.9
2*	1	68.5	75.8	70.2	64.6	69.8	11.2
3	2	63.8	68.7	70.2	60.1	65.7	10.1
4*	2	72.2	81	65.3	67.1	71.4	15.7
5	3	62.8	62.5	61.5	65.7	63.1	4.2
6	3	68.8	69.5	66.5	66.2	67.8	3.3
7	3	66.3	66.8	67.2	69.8	67.5	3.5
8	4	66.1	63.5	67.5	63.4	65.1	4.1
9	4	52.8	52.4	51.8	49.8	51.7	3.0
10	5	72.5	67.2	70.3	69.8	70.0	5.3
11	5	70.2	71.8	67.9	66.3	69.1	5.5
12	6	64.9	55	58.9	62.3	60.3	9.9
13	6	60.7	49.3	51.8	48.7	52.6	12.0
14	7	68.5	68.1	68.3	67.6	68.1	0.9
15	7	56	57.3	54.2	56.8	56.1	3.1
16	8	64.1	59	64.2	61	57.1	5.2
17	8	50	46.8	44.2	40.9	50.5	9.1
18	9	66.7	55.8	61.4	60.1	61.0	10.9
19	9	61.4	56.3	58.5	53	57.3	8.4
20	9	54.8	54	54.6	55.1	54.6	1.1
21*	10	60.7	49.4	52.7	63	56.5	13.6
22	11	72.2	63.5	66.1	64.2	66.5	8.7
23	11	67.8	57.7	62.5	58.6	61.7	10.1
24	11	64.4	No survey	61.2	56.6	60.7	7.8
25	9	70.5	69.2	68.8	64.9	68.4	5.6
26	7	61.5	53.8	54.2	52.8	55.6	8.7
27	12	64.7	65.9	60.3	61.3	63.1	5.6
28	10	55.8	50.8	49.9	45.2	50.4	10.6
29	12	58.4	54	54.5	53.5	55.1	4.9
30*	12	67.8	59.6	59.8	59.9	61.8	8.2
31	13	70	63.6	64.3	60.5	64.6	9.5
32	10	59.5	51.7	51.9	48	52.8	11.5
33	12	65.6	63.9	61.9	63.1	63.6	3.7
34	14	56	53.8	50	51	52.7	6.0
35	13	62.4	57.5	55	54.8	57.4	7.6
36	13	66.5	57.5	57.8	55.2	59.3	11.3
37*	13	68	64.9	62.9	61.3	64.3	6.7
38	14	62.9	63.7	58.6	59.2	61.1	5.1
39	14	50.6	51.5	46.1	48	49.1	5.4

**sites where resurfacing has been confirmed*

All the data is in SCRIM readings that have been corrected for speed. The sites where the range is ≥ 12 have been heighted in red, there are 3 sites and 2 of these have been resurfaced.

However, quite large changes between the runs can occur due to natural variations in the skid resistance over the summer period, where it is expected that the readings taken early and late in the summer would be higher than reading taken in the middle of the summer, as illustrated in Figure 1.

The average SCRIM readings for each run in 2009 are plotted and are shown in Figure 2. As discussed previously there has been an additional very late survey runs for 2006, 07, 08 and 09, this was justified because the 3rd run which represents the late run, shown by the green line on the chart, at the end of season has not recovered. Interestingly the very late 4th run is relatively low for the 2009 year, this is discussed Section 4.2.2.

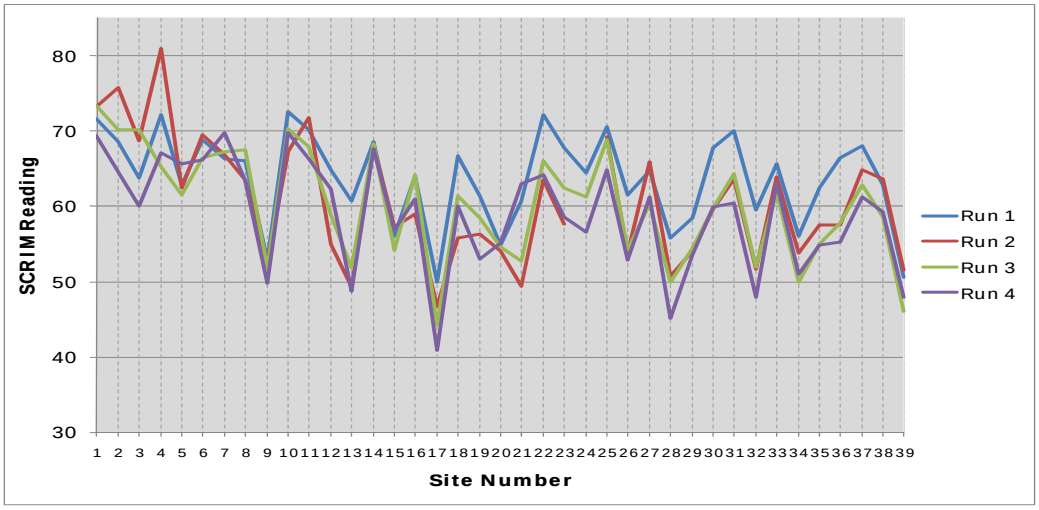


Figure 2: Average SCRIM Readings for Each Survey run

Detailed Review of the Sites

A number of sites have been examined in detail particularly those where the operator has suggested resurfacing or surface effects may have affected the readings. An example of these sites is shown in the figures below.

Figure 3 shows the Line plot for Site 4. The five lines represent the 4 runs for 2009 and the 4th run from 2008 (VL08) to provide information from the previous year to identify any changes particularly between 2008 and the early run in 2009. As can be seen the SCRIM readings for the mid period (coloured red) are higher than all the other runs for 2009.

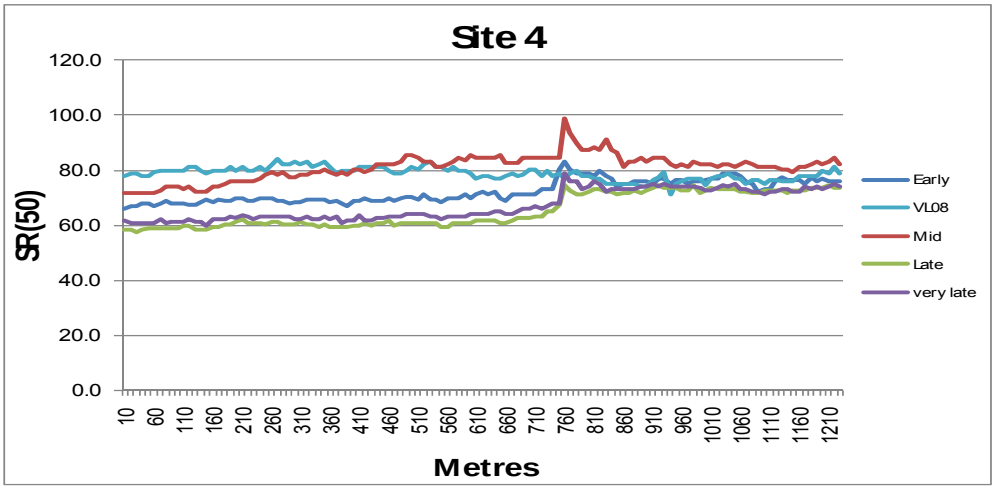


Figure 3: 2009 SCRIM Readings Plus 4th Run for 2008(VL 08) for Site 4

The skid resistance for the mid period is generally lower than the other periods so the data for site 4 would be regarded as atypical. The Operator stated that there was a surface change between 0 and 740 but this was reported in the late period. However, from a photo of site 4 in the early period, see Figure 4, it can be seen that the site was actually resurfaced prior to the 2009 early run, which is interesting since the skid resistance for the first 740m is significantly lower than the very late run for 2008. This could be seasonal variation but could also be that the skid resistance of the new surface is reduced due to binder on the surface. The skid resistance of the surface has increased for the mid run possibly indicating that the traffic has removed the binder rich surface and the aggregate is exposed. However, from the photo taken during the mid run, shown in Figure 5, there are other considerations.

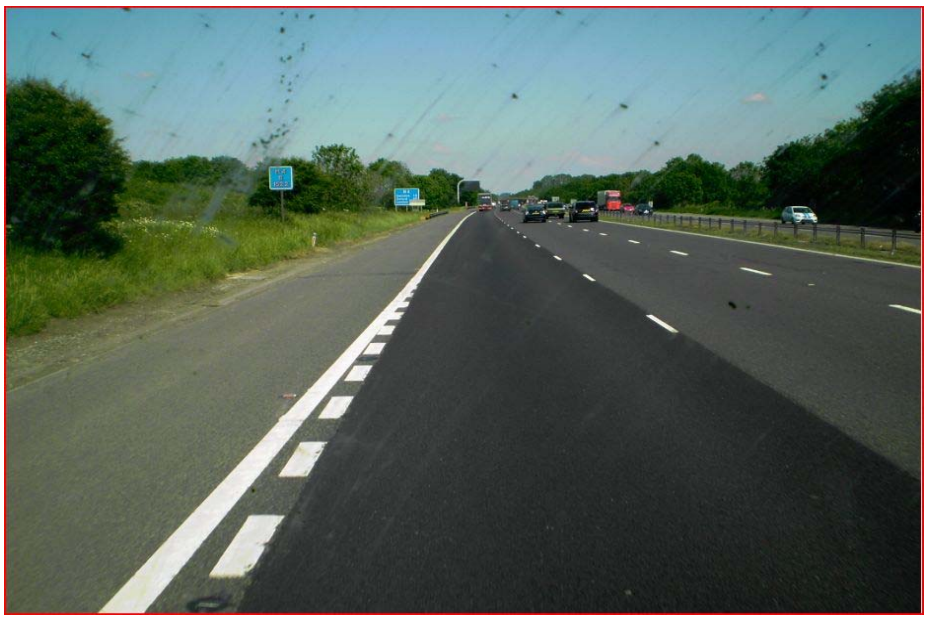


Figure 4: Photo of Site 4 during the Early Period Run

Figure 5: Photo of Site 4 during the Mid Period Run

Figure 5 shows that the road was surveyed during very wet conditions. It is still possible that the skid resistance of the site has increased because a binder film has been worn off the surface. However, taking into account the fact that the skid resistance for the mid period for the whole site is higher than for other runs the main cause of the increase in the skid resistance is either

seasonal (rain prior to the SCRIM mid survey leaching the fine aggregate powder away leaving the course grit to rejuvenate the microtexture under the action of traffic), or the effect of standing water providing additional resistance to the SCRIM test wheel which would translate into a higher SCRIM reading. Note that the late and very late runs have actually fallen below the early run for the first 740m. The survey company has since been given strict instruction not to survey when there is standing water.

This illustrates that the Operators comments can be very useful but confirmation should be obtained using other data whenever possible.

Another example is site 21. The Operator's report stated that for the very late run for site 21 there are patches between 240m and 550m and between 790m to 1100m. The line plot is shown in Figure 6.

As seen, the SCRIM readings in the areas where the operator states there are patches, are significantly higher than the other runs, this confirms that these sites have been resurfaced.

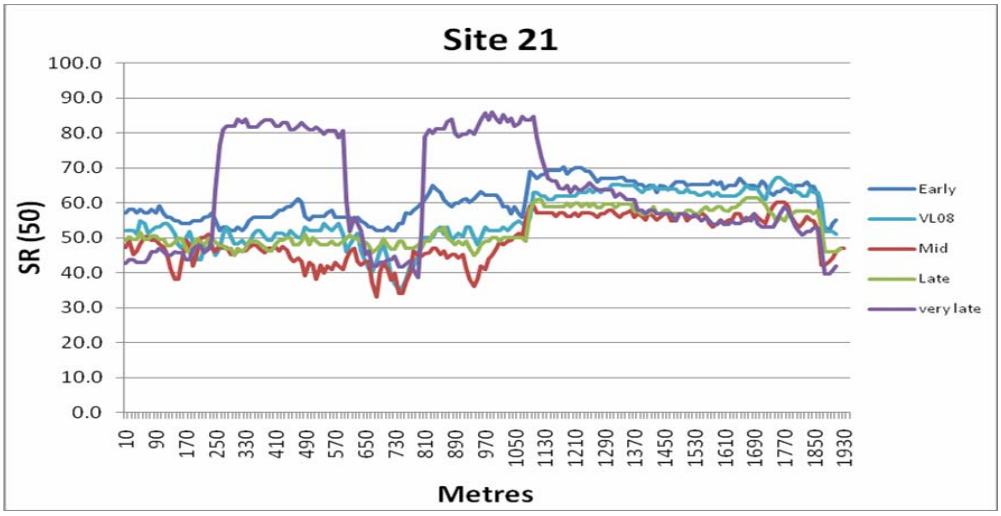


Figure 6: 2009 SCRIM Readings Plus 4th Run for 2008 for Site 21

In addition to the sites that were reported as resurfaced, sites that had a large range in SCRIM readings were also examined in detail. Site 13 had a range of 12. The line plot for site 13 is shown in Figure 7.

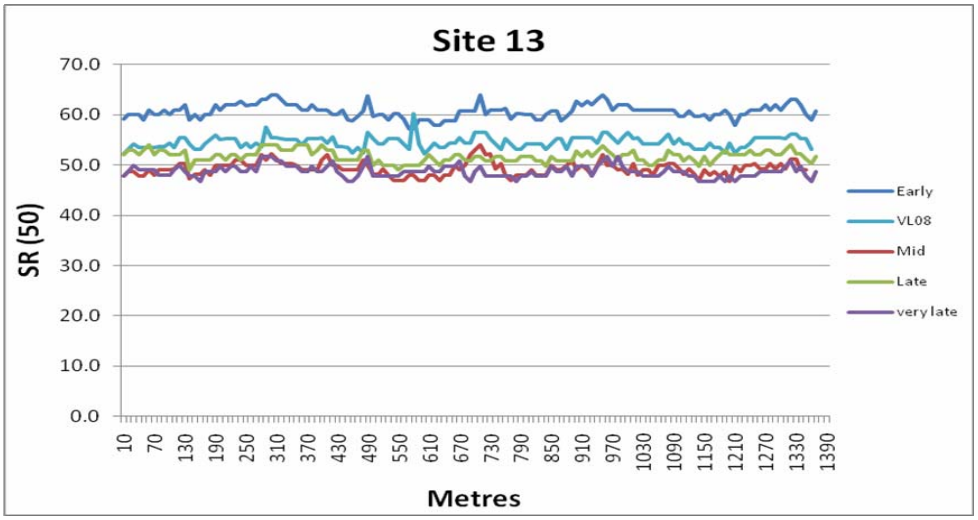


Figure 7: 2009 SCRIM Readings Plus 4th Run for 2008 for Site 13

As seen, there is a reasonably large difference between the readings in the early period and the very late period but there is nothing to suggest that this is caused by anything but seasonal variation.

RESULTS FROM 2002 TO 2009

Ranges for the SCRIM Readings for all Sites Since 2002

In Table 2, the ranges, the difference between the minimum and maximum SR for each of the 8 years have been compared.

There were 4 survey runs in 2006, 2007, 2008 and 2009 but there were only 3 survey runs prior to this. Therefore, all ranges shown in Table 3 are from the first 3 runs so they are comparable.

The figures in red font show sites that have been resurfaced during that year. In some of the cases, the range over the 3 survey runs has not been affected by the resurfacing because the resurface was constructed between the late and very late survey.

Table 2: The Range in SCRIM Readings for each Year from 2002 to 2009

Site Number	2002	2003	2004	2005	2006 3 runs	2007 3 runs	2008 3 runs	2009 3 runs
1	8.0	3.3	4.2	0.4	9.7	6.4	7.1	1.7
2	2.3	3.9	5.3	6.5	13.1	3.5	6.8	7.3
3	4.5	2.1	1.9	3.9	9.2	11.4	2.9	6.4
4	10.8	2.5	5.7	2.9	6.2	12.4	4.9	15.7
5	3.6	5.6	3.1	7.7	11.1	6.7	6.9	1.3
6	7.0	4.0	4.5	3.9	11.3	10.1	2.3	3.0
7	8.5	7.3	1.2	3.8	6.9	6.3	4.7	0.9
8	8.7	1.3	1.6	3.9	7.4	4.1	6.8	4.0
9	3.8	1.8	0.7	2.4	9.6	7.4	7.1	1.0
10	3.5	2.8	4.1	2.6	7.3	3.1	21.2	5.3
11	1.6	3.9	1.9	2.5	10.1	6.1	6.1	3.9
12	7.0	7.4	18.2	2.3	5.9	5.0	6.4	9.9
13	2.9	3.8	7.9	5.4	5.3	8.4	8.6	11.4
14	2.0	2.7	4.3	5.5	9.1	5.5	6.2	0.4
15	3.3	4.9	1.2	7.3	7.8	3.6	7.6	3.1
16	4.4	9.5	4.6	10.9	11.6	6.8	12.5	5.2
17	2.7	3.1	3.7	5.5	9.6	6.1	10.0	5.8
18	1.5	5.5	5.8	4.2	11.5	10.4	2.5	10.9
19	1.5	2.5	2.7	5.8	8	9.7	3.7	5.1
20	3.2	4.5	0.9	0.6	10.5	10.5	13.2	0.8
21	4.9	4.5	6.8	4.7	7.3	8.6	2.0	11.3
22	2.1	6.4	4.1	6.8	10.2	5.7	4.0	8.7
23	3.2	1.3	11.2	6.5	11.1	11.9	6.7	10.1
24	1.6	3.4	2.9	4.7	9.1	5.3	5.5	3.2
25	3.7	4.0	5.6	4.4	9.3	5.6	4.9	1.7
26	4.7	6.8	3.4	5.5	8.1	9.1	3.8	7.7

Site Number	2002	2003	2004	2005	2006 3 runs	2007 3 runs	2008 3 runs	2009 3 runs
27	2.6	9.2	4.1	3.1	6.9	8.9	5.2	5.6
28	1.5	3.3	5.8	4.7	8.3	8.1	1.4	5.9
29	2.4	2.6	2.1	1.9	10.4	10.2	2.9	4.4
30	1.2	1.8	4.6	4.0	9.4	12.5	8.8	8.2
31	1.4	7.3	5.6	3.7	4.2	8.3	0.8	6.4
32	2.9	5.9	5.8	3.3	5.3	8.4	2.1	7.8
33	1.3	4.6	5.0	8.0	12.9	26.6	2.8	3.7
34	2.4	2.4	4.4	6.3	11.3	10.1	2.6	6.0
35	4.6	2.5	1.3	4.2	6.5	14.3	2.1	7.4
36	2.1	8.0	4.2	4.3	6.6	10.6	2.7	9.0
37	2.3	3.8	2.2	4.4	7	8.6	2.9	5.1
38	4.6	3.4	4.7	4.7	5.4	9.0	3.0	5.1
39	6.2	3.0	6.6	8.6	6.1	7.7	2.6	5.4
Overall Mean	**3.8**	**4.3**	**4.5**	**4.7**	**8.6**	**8.5**	**5.5**	**5.8**
Overall Mean with resurfaced Sites removed	**3.6**	**4.0**	**4.1**	**4.6**	**8.6**	**8.3**	**4.6**	**5.2**

It can be seen from Table 3 that there is a trend for the average range to increase from 2002 to 2005, and then a very large increase in the range in 2006 and this has been maintained in 2007. For 2008 and 2009, the range has dropped back in line with the pre 2006 values especially when the resurfaced sites have been removed.

National Trends in Skid Resistance

In order to assess the average skid resistance on the benchmark sites over time the average SCRIM readings for 2002 to 2009 have been calculated and are shown in Table 3. The mean for 2002 to 2005 are calculated from 3 readings and the mean for 2006, 2007, 2008 and 2009 are from 4 readings.

Table 3: Average SCRIM Readings for 2002 to 2008

Site Number	Mean SCRIM Reading Runs for 2002 to 2009								
	2002	2003	2004	2005	2006	2007	2008	2009	Mean
1	76.6	73.5	75.3	74.7	73.4	72.0	70.7	71.9	73.5
2	71.9	68.8	71	69.1	71.1	69.3	68.4	69.8	69.9
3	70	66.5	67.5	66.8	65.2	62.8	61.7	65.7	65.8
4	78.7	76.8	77.1	75.4	74.5	74.7	73.9	71.4	75.3
5	71.1	70	74	69.7	69	69.7	68.8	63.1	69.4
6	68.8	66.5	67.3	67.7	65.5	66.8	66.2	67.8	67.1
7	69.1	66.4	64.9	66.7	65.2	66.9	65.4	67.5	66.5
8	70.2	67.9	67.7	65.1	64.9	65.0	66.2	65.1	66.5
9	59.6	55.8	56.3	55.9	52.7	52.0	51.1	51.7	54.4
10	71.1	69.6	73.6	70.4	69.8	70.5	75.0	70.0	71.2
11	71.1	69.6	72.5	72	66.3	66.9	66.4	69.1	69.2
12	53.5	53.6	76.2	64.4	59.4	59.3	63.7	60.3	61.3

Site Number	Mean SCRIM Reading Runs for 2002 to 2009								
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Mean**
13	58.3	57.4	60.1	58	52.9	52.9	54.6	52.6	55.9
14	73.6	70.4	73.5	71	69	67.2	66.0	68.1	69.8
15	63.2	61	61.7	60.8	58.8	60.8	56.3	56.1	59.8
16	68.9	71.5	71.7	65.4	67	66.5	63.2	57.1	66.4
17	50.1	49.3	50.1	46.9	44.9	46.4	47.0	50.5	48.1
18	69	62.7	60.9	58.3	55.6	58.5	57.7	61.0	60.5
19	63.5	59.7	60	58.5	56.9	56.6	56.0	57.3	58.6
20	48.9	45.1	43.3	43.9	41.8	44.0	57.3	54.6	47.4
21	56.8	53.9	55	53.7	50.5	50.1	51.3	56.5	53.5
22	62.9	64.2	61.6	59.6	60.2	59.0	67.8	66.5	62.7
23	57.8	56.2	59.7	57.3	54.5	63.2	64.7	61.7	59.4
24	62.4	62.5	65.4	62.9	62.3	63.9	60.2	60.7	62.5
25	70	67.7	69.1	67.7	66.1	68.9	64.9	68.4	67.8
26	61.4	57.5	60.6	57.7	56.3	56.3	52.9	55.6	57.3
27	59.1	72.3	67.3	66.9	63.1	64.9	63.9	63.1	65.1
28	54.9	53.6	49.6	52.2	48.4	46.7	51.1	50.4	50.9
29	62.8	59.5	60.4	59.9	55.3	56.3	56.2	55.1	58.2
30	63.6	58.5	61.7	59.2	58.1	57.2	62.2	61.8	60.3
31	74.5	69.9	69.3	69.8	63.6	66.2	62.4	64.6	67.5
32	60.1	56.1	55.4	54.2	49.9	49.8	51.1	52.8	53.7
33	71.6	66.7	69.1	65.7	64.9	69.8	62.1	63.6	66.7
34	55.8	50.2	56.3	52.1	51.3	50.1	49.0	52.7	52.2
35	64.8	63.3	62.9	59.9	56.6	59.8	57.8	57.4	60.3
36	62.8	60.6	63.4	60.6	56.5	58.7	60.1	59.3	60.2
37	67.4	63.5	67.2	64.1	61.5	61.7	58.5	64.3	63.5
38	66.9	63.4	65.3	61.6	57.7	59.6	58.8	61.1	61.8
39	55.8	51.8	53.7	51.2	47.2	48.7	45.8	49.1	50.4
mean	**64.6**	**62.4**	**64.0**	**62.0**	**59.7**	**60.5**	**60.4**	**60.9**	**61.8**
Mean with Resurfaced sites removed	**64.6**	**62.4**	**63.3**	**61.4**	**59.2**	**59.5**	**59.6**	**60.3**	**61.3**

The average for all 39 sites in 2009 is slightly higher than the previous 3 years. In spite of including the 4th (very late) run in the calculation of the mean for 2006-2009, which will tend to increase the mean value, these results are low compared to the results from 2002 to 2005. However, the values from 2006 to 2009 are now forming a trend, which has lowered the overall mean for all sites to 61.3.

The average SCRIM Readings for 2009 are shown in Figure 8 in the brick red line with a slightly enhanced line thickness the skid resistance in 2009 is generally comparable in shape to other years, exceptions to this are sites 4, 5, 16, 20 and 23 where resurfacing has been confirmed in either 2008 or 2009.

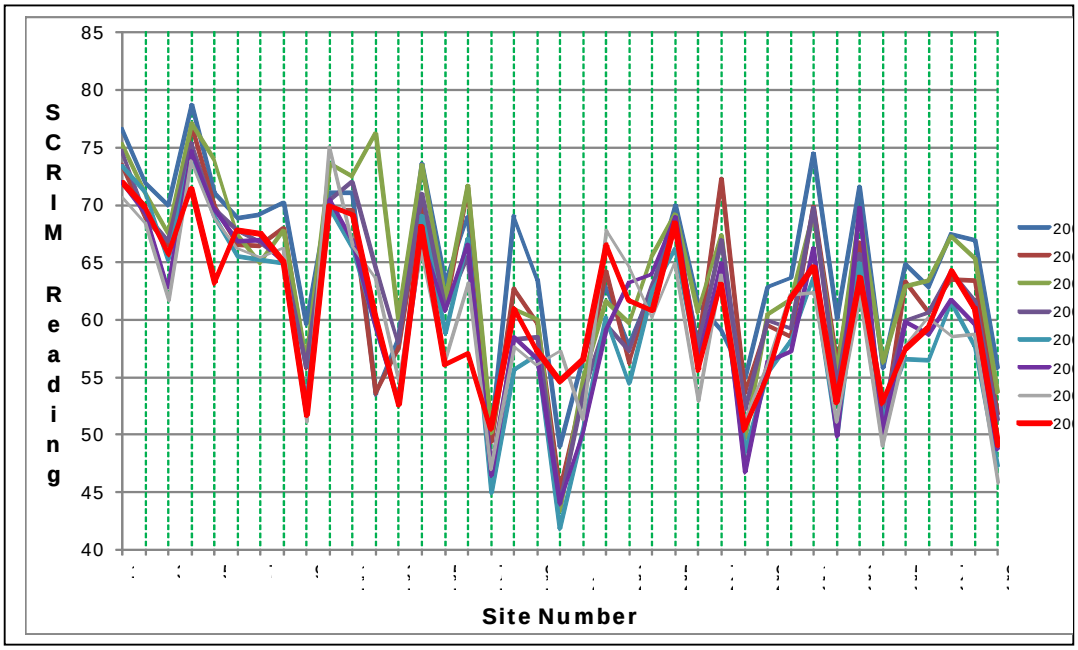


Figure 8: Average SCRIM Readings for all Runs for Each Site

Average SCRIM Values for Each Period for All Years

To examine the trends in more detail, the overall means for each run over all sites for each of the survey years were calculated and are shown in Table 4.

Table 4: Comparison of the overall Mean SR for 2002 to 2009

Date	Mean SCRIM Readings for Each Run 2002 to 2009					
	Run 1	Run 2	Run 3	Run 4	Average Over 3 Runs	Average Over 4 Runs
2002	65.0	63.4	65.2		64.5	64.5
2003	63.4	62.1	61.2		62.2	62.2
2004	65.8	64.5	61.8		64.0	64.0
2005	63.7	62.5	59.8		62.0	62.0
2006	63.4	57.0	55.8	62.6	58.7	59.7
2007	63.4	59.8	55.3	63.4	59.5	60.5
2008	58.9	58.1	60.7	64.0	59.2	60.4
2009	63.3	59.9	59.9	58.3	61.0	60.3

The readings for run 1 show some change between years, as would be expected, with 2002 and 2004 having higher averages than the other years, but all of the mean levels are comparable except for 2008, which is considerably lower than the other years. The averages for run 2 form into two comparable groups the first from 2002 to 2005 and the second from 2006 to 2009. The second group (2006 to 2009) is significantly lower than the first. The readings from run 3 show that the 2002 reading is relatively high. The readings for 2003 and 2004 are very similar and quite close to the 2005 readings. The readings in 2006 and 2007 for run 3 are much lower than the other years but the 2008 and 2009 average readings have increased back to the pre-2006 values. The readings for the fourth run are reasonably close for 2006, 2007 and 2008 with the highest values coming from 2008. The 2009 reading however dropped significantly this is discussed in Section 4.2.2.

Comparison with Rainfall Data

If the changes discussed in 4.2.1 are due to seasonal variation, the high and low readings should coincide with wet and dry periods. The rainfall data for the last 30 years has been obtained from the Met Office statistics and are shown in Table 5.

The individual monthly rainfall values from January to December are shown for England for each year. The average for each month over the 30 years is shown in the row termed "30 year average". The average for the period that the benchmarks have been in place is shown in the row "Average 02-09". The months where the surveys took place have been highlighted in yellow. Generally, the surveys were carried out in May, July and September and October for the fourth run. However, there have been some variations to this, in 2002 the surveys were carried out in June, August and September and in 2005 they were May and June for the first and second runs and the third run was carried out in August and September.

There is some uncertainty as to what surfacing took place between 2002 and 2005 therefore the rainfall data is only considered for 2006, 2007 2008 and 2009.

From Table 5 it can be seen that in May the 2006 and 2007 rainfall figures exceeded the average whereas the 2008 rainfall was comparable with the average and that this coincides with the 2008 SCRIM readings for run 1 being lower than 2006 and 2007.

The 2009 early survey was at the beginning of June, the rainfall in this month was 55.1mm, which is lower than the previous 3 years but the average SCRIM reading is about the same as the 2006 and 2007 readings.

Table 5: Average Monthly Rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	74.3	57.6	115.3	61.2	108.2	36.7	32.3	84.2	35.9	67.4	77.7	142.4
1980	69.8	80.9	91	16.7	27.2	115.2	62.9	83.3	60	118.9	78.6	68.9
1981	53.8	48.2	136.7	57.4	83.3	43.7	51.9	41.8	126.7	108	62.3	85.3
1982	66.1	40.9	90.5	20.3	41.9	115.6	33.2	77.6	67.6	109.8	110.9	91.6
1983	87.1	36.5	59.1	100.2	105.9	32.2	35.4	26.3	86.9	72.5	46.3	101.1
1984	130.6	50.8	60	10.2	59.5	42.4	25.1	54	105.4	85.4	131.1	68.9
1985	68.3	24.7	60.3	61.8	63.3	86.7	66.6	101.7	41.5	39.6	69.4	113.3
1986	108.7	17.9	70.3	78.8	79.9	39.6	48.7	109.8	25	86.4	104.3	122.4
1987	28.1	51	80.5	59.6	44.9	101.1	71.6	66.3	57.6	150.9	71.2	51.6
1988	139	57.6	90.4	37.6	52.6	37.4	120.3	73.6	53.9	82.6	44	39.9
1989	38.7	76.3	77.6	79.3	19.3	52.6	35.8	51.4	37.3	83.1	52.1	122.5
1990	112.9	127.9	20.1	36.2	22.4	65.9	30.8	42.6	46.6	91.8	57.9	88.5
1991	81.5	58.1	65.6	59.8	13.6	89.4	62.8	25.9	58.1	63.2	84.4	44.9
1992	43.6	40.3	75.1	68.2	44.3	35.2	79.7	112.4	86.7	79.4	123.3	71.8
1993	96.5	13.7	23.5	88.1	78.7	58.6	75.1	49.2	109.2	88.9	65.4	142.8
1994	109	71.8	77.4	64.4	59.2	31.6	41.9	66.1	98	87.7	75.7	118.6
1995	142.7	99	61.5	24.5	43.2	21.5	33.6	9.6	108	46.6	72.8	78.7
1996	56.3	74.1	37.6	43.4	47.7	26.4	39.4	74.8	29.4	72.9	116.8	51.4
1997	14.2	100.2	27.3	22.2	66.9	121.2	46	85.2	29	62.3	101.4	97.3
1998	102.5	19.2	82.9	116.5	32.8	114.9	54	45.4	85.7	143.7	75.4	81.5
1999	116.5	43.3	66.6	68	54	82.1	23.7	98.3	106.5	73.6	54.9	135.4
2000	45.7	83.7	33.7	130.2	82.3	41.5	58.8	60.5	114.9	164.8	157.8	119.5

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	70.1	90.8	87.5	91.3	39.8	41.1	67.9	78.8	78.8	119.6	57.7	39.4
2002	81.6	120.6	46.6	46.4	84.9	54.4	84.8	66.1	34.7	122.9	142.2	121.6
2003	81.6	34.8	32.7	40.1	66.1	66.6	67.8	16.5	33.1	52	93.9	90.7
2004	113.1	49	48.1	78	42.6	56	66.8	147.7	53.2	131.3	46.5	59.1
2005	58.6	45.9	48.4	68.1	45.2	53.7	63.2	58	63.1	106.4	74.9	61.6
2006	30	52.6	81	42.5	100.9	24.1	41.8	88.4	73.6	106.5	96.1	109.4
2007	95.8	93.8	56.1	10.7	107.1	146	125.1	54.3	44.1	45	70	86.4
2008	129.1	37.7	91.8	64.4	62.1	59.1	100.5	106	96.3	94.9	81.8	58.4
2009	82.3	52.7	41	39.7	54.2	55.1	128.6	58.5	32.5	67	175.5	92.1
30 year Average	81.55	59.73	65.68	57.61	59.16	62.83	60.52	68.2	67.07	91.13	86.2	88.94
Average 02-09	84.01	60.89	55.71	48.74	70.39	64.38	84.83	74.44	53.83	90.75	97.61	84.91

For July (run 2), the 2006 rainfall is the lowest of the 3 years and is below the average. The highest rainfall is in 2007 followed by 2008, this coincides with the 2006 average SCRIM reading for run 2 being the lowest followed by the 2008 reading with the 2007 SCRIM reading being the highest. It would be expected that the rainfall prior to the 2009 mid survey would be relatively high since the SCRIM reading is the highest for all 4 years and this is indeed the case. The mid survey for 2009 was carried out mostly in early August and rainfall for August was generally below the average however, there was a reasonable amount of rain on the first 6 days of August see quote from the Met Office.

"1st to 6th August. Generally unsettled for the first few days of the month, although one or two dry days occurred across the Southeast. Some heavy rain on the 1st with some hourly rainfall totals of 10 to 15mm being recorded across the Midlands and Lincolnshire, but the wettest day was the 6th with 60.4 mm at Holbeach (Lincolnshire) and 47.8 mm at Boscombe Down (Wiltshire)"

All the mid surveys were carried out between the 31st July and 5th August, therefore it is likely that a good deal of precipitation had taken place, prior to, and during the surveys.

The highest rainfall for September (run 3) fell in 2008 and this has the highest average SCRIM readings.

The rainfall readings for the fourth run coincide for 2008 i.e. very high rainfall over 3 month and very high SCRIM readings. For 2009 there was very low rainfall for over 3 months and very low SCRIM readings as illustrated in Figure 9 which shows a line plot of the SR for each site for 2006, 2007, 2008 and 2009.

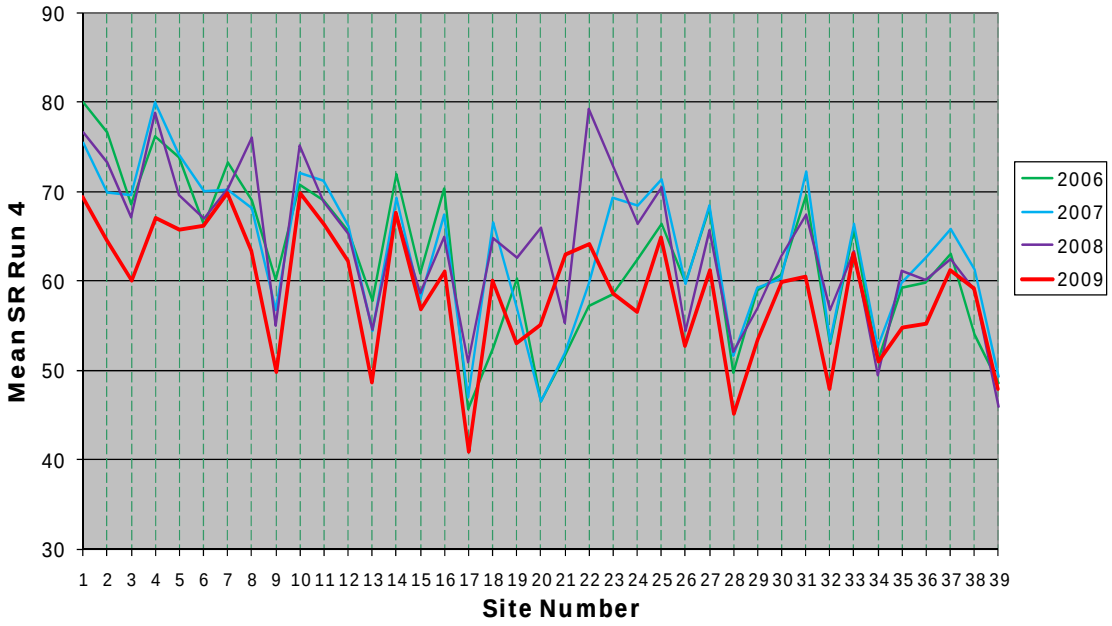


Figure 9: Mean SR for Run 4 for Each Site

It can be seen that the shape for the 2006, 2007, 2008 and 2009 data is very similar however, the SCRIM readings for 2009 are lower in almost all cases than for the 3 previous years. As stated the rainfall data shows that the rainfall was below average for August, significantly below average for September and below average for October providing a dryer than average 3 month period prior to and including the survey month. Therefore, it would be expected that the SCRIM readings for the very late period in 2009 would be low relative to the other years.

In 2006 however, rainfall is higher than 2007 but the SCRIM reading for 2006 are lower than for 2007. It should be noted that the rainfall is averaged over the country and over the month, therefore the relationship between the average SCRIM readings and the average monthly rainfall will not be completely robust. This has been found in previous studies and since rainfall can be very localised, meteorological data is useful in explaining general trends but may not be capable of providing correction factors for SCRIM measurements unless very detailed data is available.

Plateau Skid Resistance

It is generally accepted that the skid resistance of a new surface will reduce initially and then plateau after a period of time depending on the traffic volumes. The results from the Table 3 indicate that the skid resistance changes continually rather than plateaus. To examine this in more detail the sites that have not been resurfaced have been collated in Table 6.

Table 6: Annual SR for Sites that Have Not Been Resurfaced

Site Number	Year of Survey								Change in SR 02 to 09
	2002	2003	2004	2005	2006	2007	2008	2009	
1	76.6	73.5	75.3	74.7	73.4	72	70.65	71.88	-4.72
3	70	66.5	67.5	66.8	65.2	62.8	61.7	65.7	-4.3
6	68.8	66.5	67.3	67.7	65.5	66.8	66.23	67.75	-1.05
8	70.2	67.9	67.7	65.1	64.9	65	66.18	65.13	-5.08
9	59.6	55.8	56.3	55.9	52.7	52	51.13	51.7	-7.9

11	71.1	69.6	72.5	72	66.3	66.9	66.35	69.05	-2.05
13	58.3	57.4	60.1	58	52.9	52.9	54.6	52.63	-5.68
14	73.6	70.4	73.5	71	69	67.2	65.95	68.13	-5.47
17	50.1	49.3	50.1	46.9	44.9	46.4	46.98	45.48	-4.63
18	69	62.7	60.9	58.3	55.6	58.5	57.68	61	-8
19	63.5	59.7	60	58.5	56.9	56.6	55.98	57.3	-6.2
24	62.4	62.5	65.4	62.9	62.3	63.9	60.18	60.73	-1.67
25	70	67.7	69.1	67.7	66.1	68.9	64.93	68.35	-1.65
26	61.4	57.5	60.6	57.7	56.3	56.3	52.88	55.58	-5.83
27	59.1	72.3	67.3	66.9	63.1	64.9	63.9	63.05	3.95
28	54.9	53.6	49.6	52.2	48.4	46.7	51.05	50.43	-4.48
29	62.8	59.5	60.4	59.9	55.3	56.3	56.18	55.1	-7.7
31	74.5	69.9	69.3	69.8	63.6	66.2	62.4	64.6	-9.9
32	60.1	56.1	55.4	54.2	49.9	49.8	51.1	52.78	-7.33
34	55.8	50.2	56.3	52.1	51.3	50.1	48.98	52.7	-3.1
35	64.8	63.3	62.9	59.9	56.6	59.8	57.78	57.43	-7.38
36	62.8	60.6	63.4	60.6	56.5	58.7	60.13	59.25	-3.55
37	67.4	63.5	67.2	64.1	61.5	61.7	58.53	64.28	-3.13
38	66.9	63.4	65.3	61.6	57.7	59.6	58.75	61.1	-5.8
39	55.8	51.8	53.7	51.2	47.2	48.7	45.75	49.05	-6.75

The final column of Table 5 shows the reduction in the SCRIM reading from 2002 to 2009. A negative value indicates that there has been a reduction. None of the readings have been corrected for seasonal variation. To test if the level of skid resistance has an effect on the potential for change the sites were split into the following bands of SR, 70+, ≥60<70, and <60. The average SR for each year in each band was calculated and is shown in Table7.

Table 7: Average SCRIM Reading for Each Band

SR Band	2002	2003	2004	2005	2006	2007	2008	2009	Change in SR
70+	72.29	69.36	70.70	69.56	66.91	66.99	65.45	67.55	-4.74
60 - 70	64.54	61.39	62.62	60.49	57.64	58.89	57.76	59.30	-5.24
<60	56.23	55.77	56.19	54.73	51.49	51.64	51.77	52.15	-4.08

As seen from Table 7 there is a reduction in the average SR for each band. Also, the reduction is substantially the same with possibly the sites with the lower SR changing slightly less than the higher SR bands. The SR results from Table 7 have been plotted on a line chart, see Figure 10.

In addition to the average results a trend line and the equation of the line has been added. It can be seen in Figure 10 that there is between year variation which is likely caused by seasonal effects. However, the trend lines quite clearly show that regardless of between year variation there is a downward trend in the SCRIM readings.

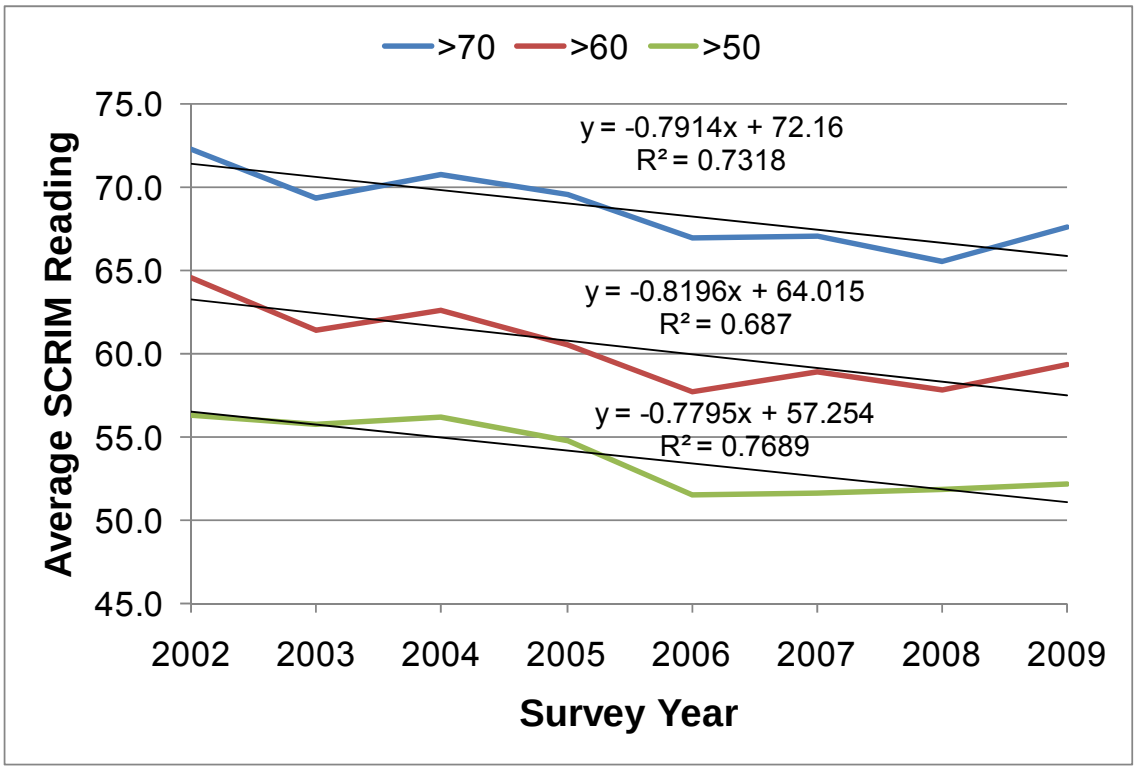


Figure 10: Average SR for Each Year in Each Band

If the equations of the trend lines are considered the annual reduction in the SR is between 0.81 and 0.77 depending on the SR level. This translates to a reduction of about 0.006 per year to the SCRIM coefficient. Consequently, this downward trend could reduce the skid resistance by an Investigatory Level band (0.05) over an 8 year period.

NEW SITES

Two new sites numbered 40 and 41 were added in 2008 and 2 additional sites were added in 2009 numbered 42 and 43. These sites have significant amounts of concrete as a surfacing and were specifically included to review how the skid resistance of concrete reacts to climatic effects.

The skid resistance data for site 40 is shown in a line plot in Figure 11.

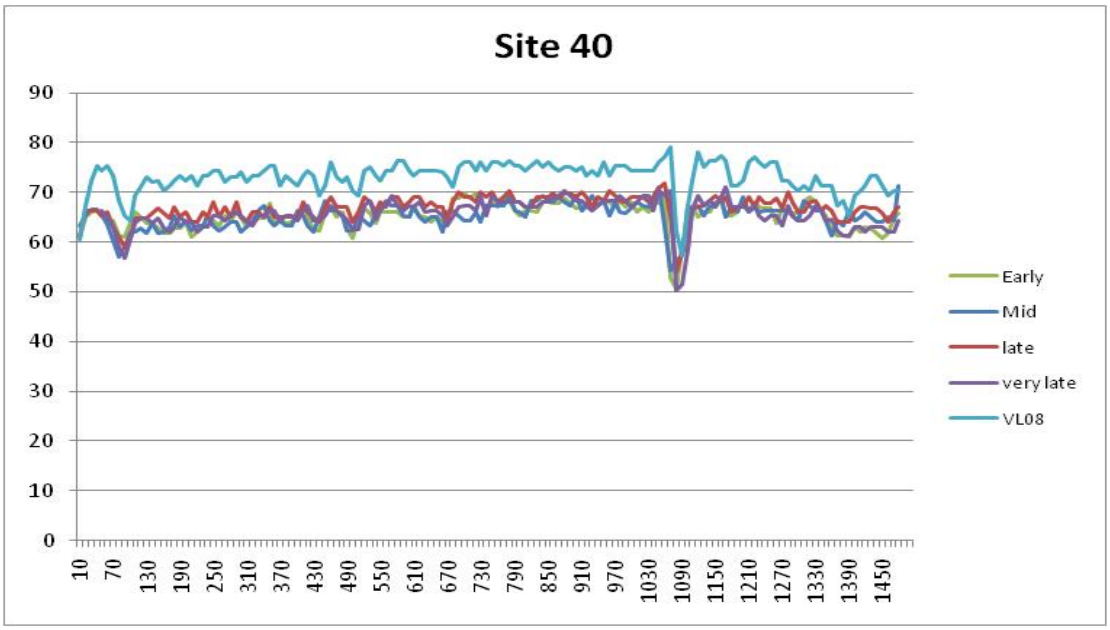


Figure 11: 2009 and Very late 2008 SCRIM Readings for Site 40

All the 2009 readings are very similar for each period, but although the shape of the 2008 very late readings (VL08) is similar, the readings are significantly higher. In the Operators report, it states that it had been snowing. The line plot of the 2008 data for site 40 is shown in Figure 12 and it can be seen that the very late run is higher than the SCRIM readings for all the other runs. Therefore, it appears the very late 2008 readings are not representative of the surface of the road and should be discarded. The remaining 3 runs for 2008 and the 4 runs for 2009 are very similar indicating that site 40 has not experience any seasonal variation over the 2 years of surveys.

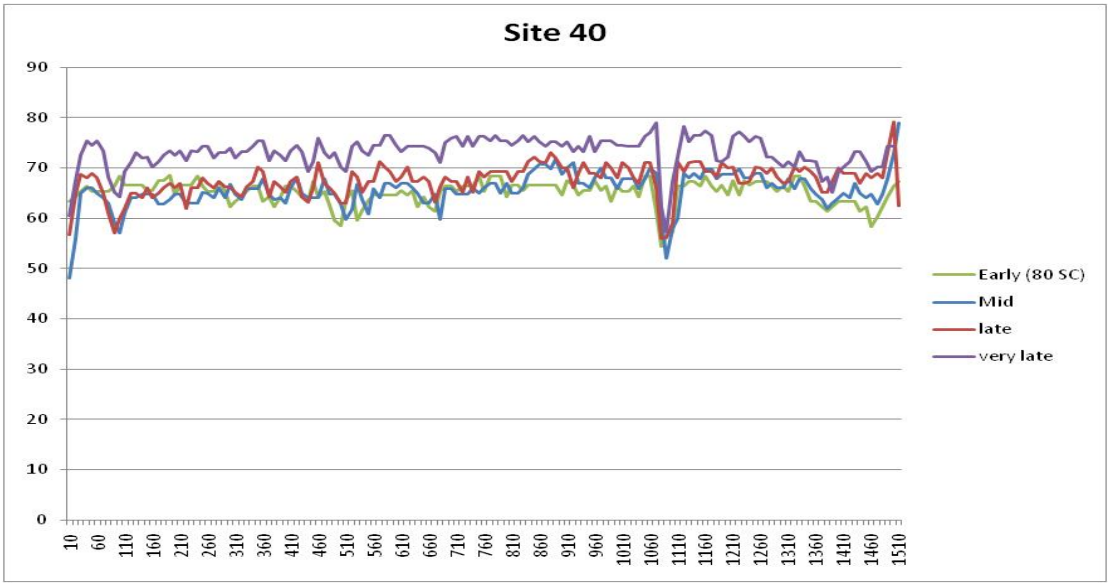


Figure 12: 2008 SCRIM Readings for Site 40.

The line plot for the SCRIM readings for site 13 is shown in Figure 13. In this case the concrete is either side of a bituminous surfacing this provides an ideal situation to determine the difference between the seasonal effects on the concrete and bituminous surfacing. Looking at the bituminous surface, between the 2 vertical lines, it can be seen that there is a significant difference between the runs for 2009 and since there are no changes stated in the Operator's reports it is assumed that these are due to seasonal effects. The SCRIM readings for the

concrete surface are much lower and appear very similar for each run except for the mid run which is shown by the light blue line. There is no obvious reason why the mid run should be so different to the other SCRIM readings.

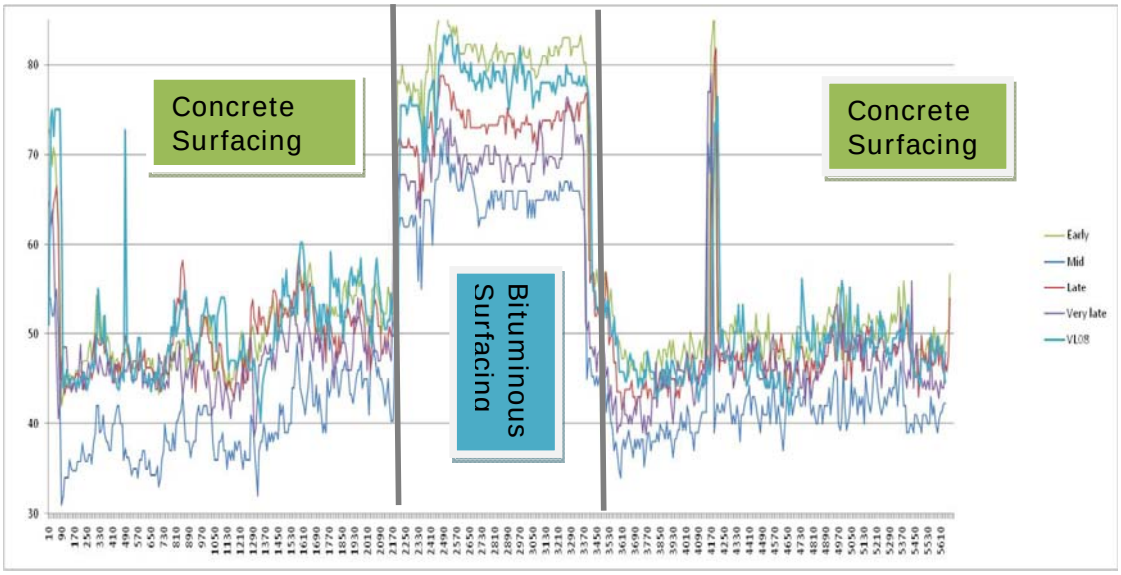


Figure 13: 2008 SCRIM Readings for Site 41.

The line plot for SCRIM readings for site 42 is shown in Figure 14. In this case, there does appear to be some seasonal variation with the mid reading being lower and the early and very late having higher SCRIM readings. Note that 2009 was the first year site 42 and 43 were surveyed so these 2 sites do not have a VL08 reading included.

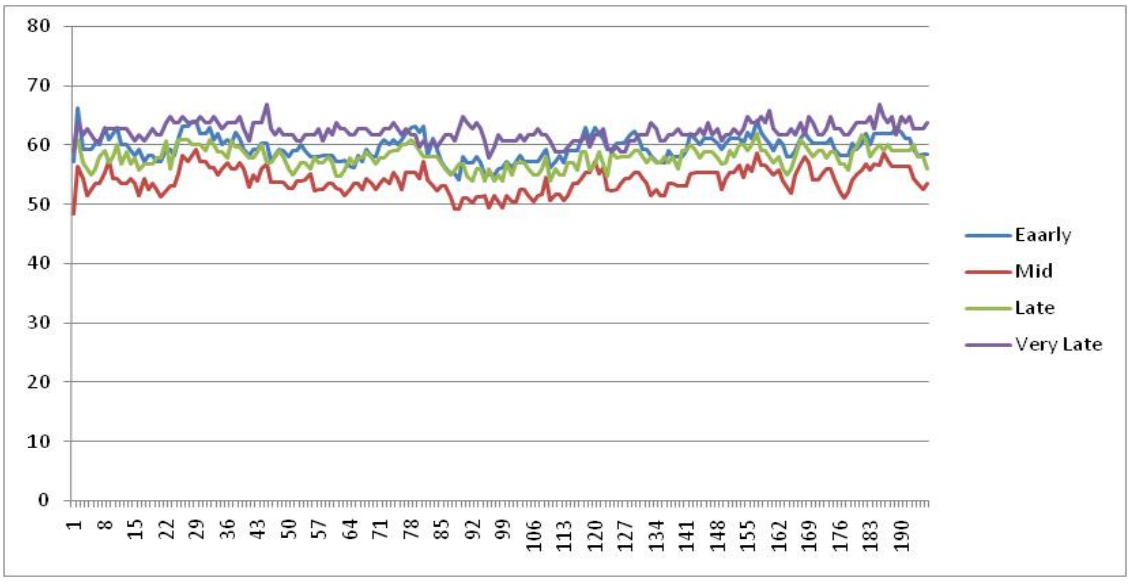


Figure 14: 2008 SCRIM Readings for Site 42.

Figure 15 shows the SCRIM readings for site 43. In this case, the readings for each run are quite similar although the mid SCRIM readings are slightly higher than those from the other runs. The area between 176 and 183 with the increased SR is surfaced in calcined bauxite.

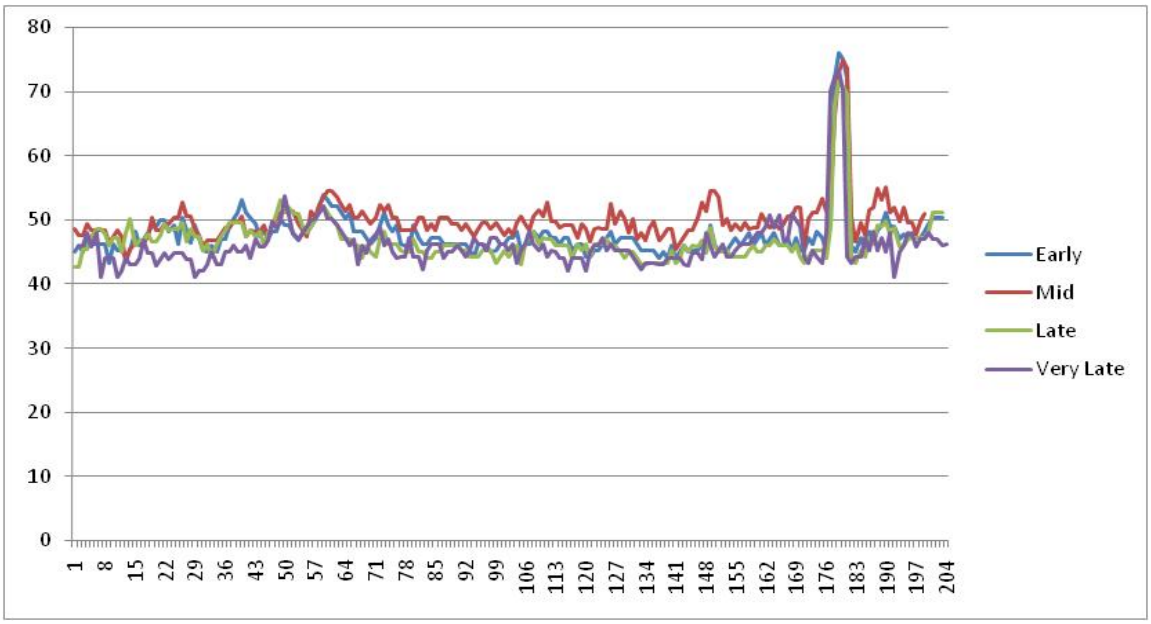


Figure 15: 2008 SCRIM Readings for Site 43.

The changes in the SCRIM readings for the concrete section may be related to seasonal effects although apart from site 42 the SCRIM readings did not appear to follow the expected trend where different runs would be higher or lower depending on climate. Site 40 for example has very similar readings for all the valid reading. Site 41 shows that SCRIM readings for the bituminous section all differ from each other whereas only the mid value differ for the concrete section. The slight differences site 43 could be explained as changes in the driveline.

From the results on the concrete sites thus far there it appears that the Highway Agency approach to not seasonally correct concrete surfaces is correct.

CONCLUSIONS

There has been eight years of skid resistance surveys over the benchmark sites in England, between 2002 and 2009

There have been four runs since 2006 with the fourth run being towards the end of October because the skid resistance of the third run in September was found not to be rejuvenating. These findings have led to a change in policy on the SCRIM survey periods. Interestingly the SR's from 2009 indicate that the 4th run was lower than expected but this coincided with 3 months of atypically dry weather

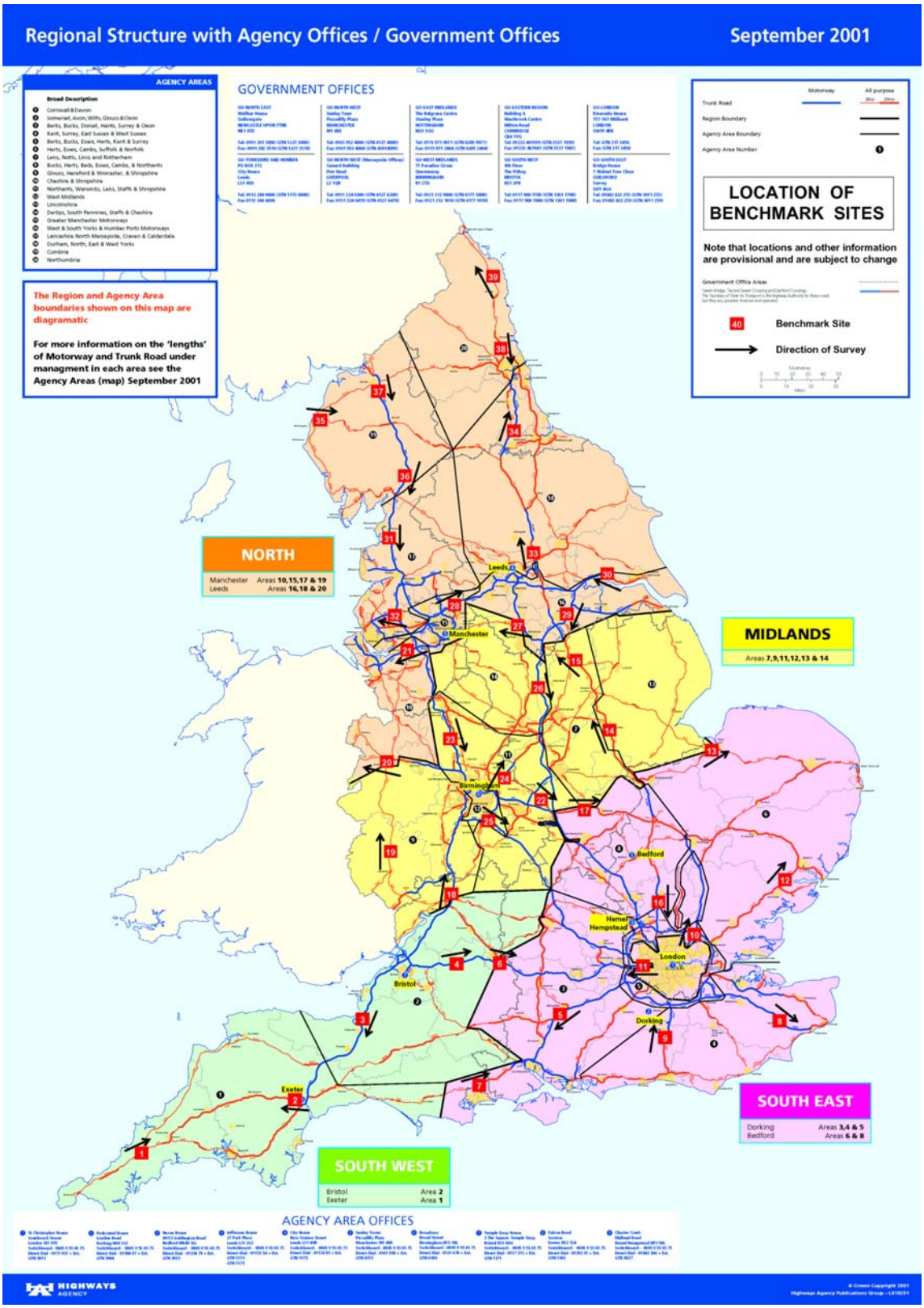
It was found that surveying on sites that had standing water is likely to give erroneously high results due to the additional drag on the test wheel.

It was found that the broad features of the trends in skid resistance between periods and years coincide with national rainfall patterns, which support the general view that seasonal variation of skid resistance is strongly affected by rainfall.

Although the skid resistance on the sites increased and decreased from year to year as a result of seasonal variation there was a definite overall trend for the skid resistance to decrease continually over the 8 year study rather than plateau. The average decrease was about 0.006 SC per annum.

There was much less variation in SR between periods for the concrete surfaces than on the bituminous surfaces indicating that the skid resistance of the concrete reacts differently to that of bituminous surfaces.

APPENDIX 1: MAP SHOWING THE BENCHMARK SITES



AUTHOR BIOGRAPHIES

Ramesh Sinhal
Ramesh Sinhal currently works for the Highways Agencies and has held the position as Head of Pavements for the last 14 years. He is responsible for policies and standards for the strategic road network of England and indirectly supports the policies for the Scottish, Welsh and Northern Ireland road networks. Ramesh sits on the UK Department of Transport Roads Board as an advisor on policies for local roads. Ramesh has had many experiences on national and international transport related assignments throughout his career, which spans almost 40 years.

John Donbavand
John began work in NZ after completing his PhD in the UK in 1983. John worked in NZ for 18 years and has held a number of positions including research scientist studying bitumen for the New Zealand Ministry of Works, Surfacing Scientist for the National Roads Board and Transit New Zealand and Engineering Policy Manager for Transit New Zealand. John returned to the UK in 2001 to take up the position as Project Development Manager at WDM Limited in 2001. In this position, John has been involved with a wide range of projects, including: developing procedures to estimate the national maintenance budgets for Highway Agencies, asset valuation for local roads, providing scheme prioritisation techniques for Highway Authorities, providing skid policies and training for site investigation. John was also a member of the TRL group that assisted the Highway Agency to develop the latest HD28, to be published in 2011.

Chris Kennedy
Chris Kennedy is a Chartered Civil Engineer and a Director of W.D.M. Limited a post he has held since 1985. He is responsible for Survey and Consultancy surveys. This has involved the introduction and development of highway condition surveys which are now operated on a world-wide basis, together with the development of computerised management systems to achieve cost-effective maintenance programmes. His current areas of interest include surface characteristics of roads, particularly skid resistance, and the development of Safety Policies and tools to enhance Asset Management of highway networks as well as developing budget prediction models to define service levels outcomes.

After gaining his Doctorate at Birmingham University he worked for four years at the Transport Research Laboratory where he took a leading role in development the UK Structural Maintenance Evaluation and Overlay Design Method. He then moved to the University of Plymouth, England as Head of Department of Civil Engineering before joining W.D.M. Limited.