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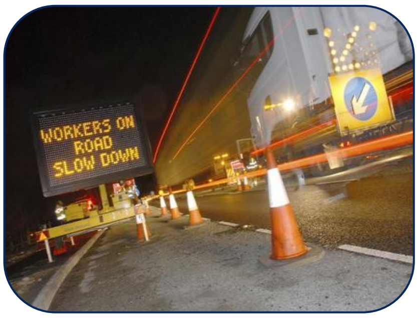

PUBLISHED PROJECT REPORT PPR587

Speed correction for SCRIM survey machines

S Brittain

Prepared for: Highways Agency, NetServ

Project Ref: 359(1308)HALC359(1308)HALC

Quality approved:

S Brittain (Project Manager)	M Greene (Technical Referee)

Disclaimer

Acknowledgements

The work described in this report was carried out in the Infrastructure Division of the Transport Research Laboratory. The author is grateful to M Greene who carried out the technical review and auditing of this report.

Contents

Executive summary

The levels of skid resistance on the Highways Agency's (HA) network are routinely monitored using SCRIMs. The survey results from these machines are speed dependent and the data collected is corrected to a standard test speed of 50km/h before use. On the Highways Agency network the target test speed for the routine surveys is 80km/h on roads with a speed limit greater that 50mph (if the SCRIM is fitted with dynamic vertical load measurement) and 50km/h on all other roads. The current speed correction formula (detailed in HD28/04) has been found to overcorrect data collected at the higher speed (80km/h), particularly for middle to low levels of skid resistance.

This report covers the work conducted to develop a new speed correction formula for SCRIM. This involved tests at a range of speeds on TRL's test track, the Twin Straights facility at MIRA and stretches of the M27 and M3 motorways. The sites were selected so that they covered the range and combinations of SR and texture found generally on the network.

Following analysis of the data collected it is recommended that a new quadratic speed correction formula should be adopted to correct SCRIM survey data as follows:

$$SR = SR(s) \times (-0.015 \times S^2 + 4.765 \times s + 799.25)/1000$$

Where:

SR = Speed corrected SCRIM reading

And

SR(s) = SCRIM reading taken at speed s

This equation should only be used to correct data collected within the speed range 30 to 85km/h. Data outside of this speed range should be disregarded.

Adopting this equation will provide a more accurate speed correction for SCRIM, but will result in a drop in the SC values reported on the network for surveys conducted at 80km/h (i.e. surveys on roads with a posted speed limit greater than 50mph). This drop is inversely proportional to skid resistance (i.e. there is a larger drop for lower skid resistance values) and is of a significant level for most sites on the network.

Three different methods are proposed for the implementation of the new speed correction formula:

1. Change the application of speed correction on all SCRIM data in the Highways Agency Pavement management System (HAPMS).
2. Change the application of speed correction on data in HAPMS from this point on (i.e. 2011 survey data onwards).
3. Change the application of speed correction on data in HAPMS from this point on and for earlier data used in the Local Equilibrium Correction factor (LECF) calculation to adjust current survey data for seasonal and between year variations in skid resistance.

1 Introduction

1.1 SCRIM and skid resistance

The Highways Agency (HA) monitors the levels of skid resistance on its network using SCRIM survey machines. These machines measure skid resistance by running a wetted test wheel at an angle to the direction of travel and recording the forces generated. The levels of friction generated decrease as speeds increase. Therefore, a method of speed correction to a standard test speed has to be applied to allow different tests to be compared on a like for like basis.

Different forms of speed correction have been applied to the SCRIM survey data over the years with each approach refining upon the previous. Recent work has found that the current speed correction equation (detailed in HD28/04) would benefit from further refinement. This report discusses the development of a new SCRIM speed correction formula.

1.2 Terminology

In order to be clear regarding the values that are being discussed, the following terminology is adopted within this report: SCRIM readings collected at speed s (in km/h) are labelled as SR(s). Data collected at 50km/h that have been converted to a SCRIM coefficient are referred to as SC. Data collected at other speeds which have been speed corrected and then converted to a SCRIM coefficient are referred to as Speed corrected SC.

2 Reason for review of speed correction formula

In addition to the routine single annual SCRIM surveys (SASS) of the HA network, the HA also undertake surveys on a number of 'benchmark sites'. These benchmark sites are spread throughout the network and each site is surveyed three times a year (once during each of the SASS survey periods). The data from the benchmark sites are used to investigate long term trends in skid resistance.

When the program for monitoring the benchmark sites was initiated it was standard practice to perform all SCRIM testing at 50km/h. However in the intervening years it has been identified that, on high speed roads, testing at 50km/h may pose a safety risk. The Highways Agency therefore decided that, for the routine SASS surveys on roads with a speed limit greater that 50mph, the test speed would be 80km/h if the SCRIM is fitted with dynamic vertical load measurement. These data are then speed corrected to the standard test speed of 50km/h to allow investigation of the skid resistance levels on the network (as detailed in HD28).

However, as stated previously, the data from the benchmark sites are used to investigate long term trends in skid resistance. It is therefore important that any differences between the measurements of skid resistance from each year are due to climatic changes rather than any changes in test conditions. To ensure that this is the case, the testing of the benchmark sites has remained at 50km/h regardless of the speed limit of the road. However the survey contractor raised safety concerns over this approach, and therefore additional tests were conducted at 80km/h on the benchmark sites to compare with the 50km/h tests. These additional tests would allow an investigation of the validity of the current speed correction formula in order to determine whether the survey speed at the benchmark sites could be increased. The data collected at 50km/h and 80km/h are plotted in Figure 2.1. The data collected at 80km/h were then speed corrected using the formula in HD28 and the speed corrected data are plotted against the 50km/h data in Figure 2.2. In both cases the line of equality is also plotted (i.e. if the datasets are comparable then the points should lie clustered around the line).

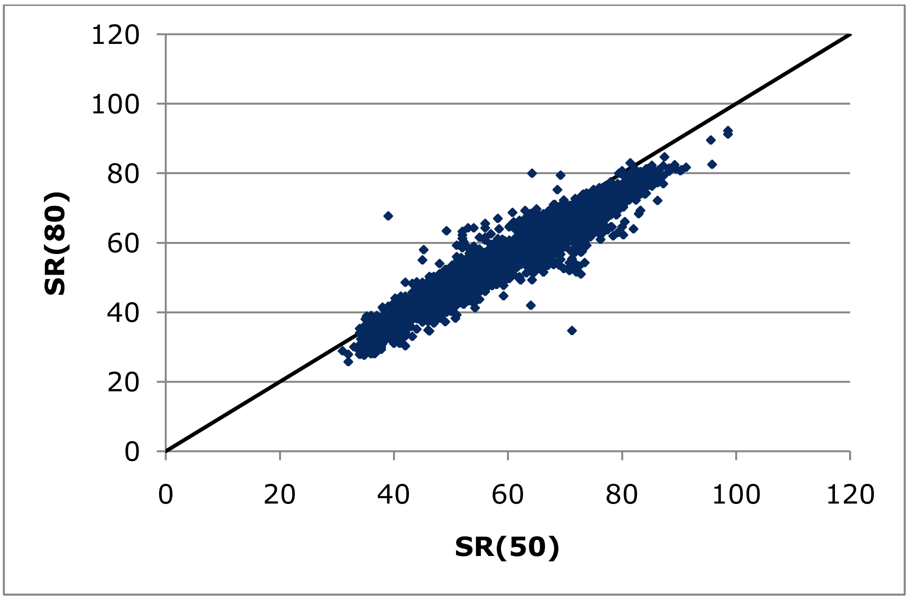

Figure 2.1 Comparing data collected at 80km/h to data collected at 50km/h on the benchmark sites (no speed correction)

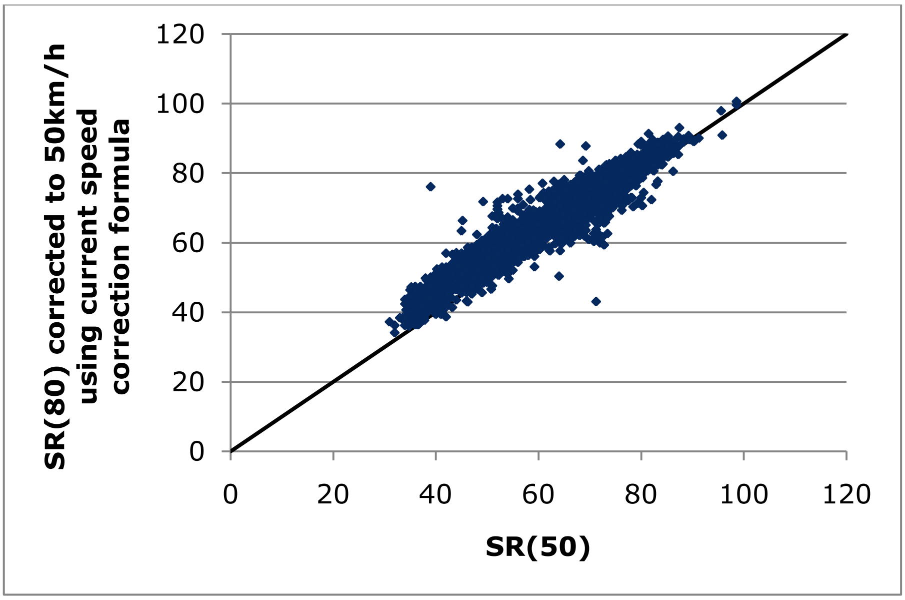

Figure 2.2 Comparing speed corrected data to data collected at 50km/h on the benchmark sites

The two graphs show that the current speed correction is "over correcting" the data for low and medium skid resistance values, i.e. the corrected values are greater than those collected at the standard 50 km/h. As a result of this finding from the benchmark sites, HA decided that further testing was required to try to develop of a more accurate speed correction formula.

This report provides details of that testing and presents a new speed correction formula. The implications of adopting the new formula on future routine survey data are also discussed.

3 Testing conducted

3.1 Test machine and limitations

The tests were conducted using HA's new skid resistance development platform. This machine has SCRIM capability and utilises a speed controlled water flow system. During testing the water depth was set to the current standard depth of 0.5mm. The specifications for the water flow system state that its operational range is 30-90km/h. The highest target speed for routine SCRIM surveys is 80km/h. Therefore, for development of a new speed correction formula, tests were conducted that covered the speed range 30 to 85km/h.

3.2 Test locations

Tests were conducted on the TRL test track, the Twin Straights test facility at MIRA and on lengths of the M27 and M3 motorways. The sites on the trunk road network were selected so that they covered the range and combinations of SR and texture generally found on the network.

3.3 Test plans

The test programme was devised to avoid any possible surface polishing or cleaning effects influencing the results. The testing was structured so that three passes would be conducted at each speed. The planned test plan for the test tracks is shown in Table 3.1.

Table 3.1 Test plan for test tracks

Speed	Run
30	1
80	1
50	1
60	1
35	1
40	1
85	1
75	1
55	1
65	1
45	1
85	2
50	2
65	2
30	2
60	2
80	2
55	2
40	2
45	2
75	2
35	2
50	3
80	3
30	3
65	3
40	3
60	3
45	3
55	3
75	3
35	3
85	3

During testing on the test tracks unforeseen circumstances impacted the time available for testing. This resulted in the test plan being modified in situ so that three passes of the test sections were conducted at 50km/h and most of the other speeds had two passes.

Due to traffic management constraints on the road sites, it would not have been possible to conduct the same test programme (even with no unforeseen circumstances) as had been completed on the test tracks. The programme was therefore amended to include three passes at 50km/h and one at each of the other test speeds. The test plan for the road sites is shown in Table 3.2.

Table 3.2 Test plan for road closures

Speed	Run
50	1
30	1
80	1
50	2
60	1
35	1
45	1
50	3
40	1
85	1
50	4
75	1
65	1
55	1
70	1

Even with this modified test plan, some of the later tests could not be completed within the available traffic management period on some of the sites.

3.4 Processing of data

When processing SCRIM survey data it is often found that there are slight differences between repeat runs. This is usually caused by natural variation of the test machine and slight differences in the test line. However, during the alignment of the test data it was found that some lengths had larger than usual variation in skid resistance between repeat runs at 50km/h. This was probably caused by the length being more variable than usual across the width of the carriageway causing the effect of slight differences in test line to be magnified. These lengths were removed from the analysis as some of the differences in the data would have been caused by changes in the test surface and not solely by changes in speed.

For the determination of the speed correction formula (see section 4) the average SR value for each speed group (if there was more than one test) was taken and compared to the average value at 50km/h. During the validation stage (see section 5) each individual test was compared to the average value at 50km/h (using the actual speed of the individual test rather than the speed group to correct the data).

4 Determination of speed correction formula

4.1 Determination of relationships at each speed

The analysis conducted on the benchmark site data suggested that the current approach for speed correction (an additive factor) is not accurate for the full range of skid resistance values. High skid resistance values appear to be modified correctly; however as the skid resistance drops the equation becomes less suitable. This suggests that a speed correction formula should have an element proportional to the SR value. The simplest formula which achieves this is a linear relationship of the form shown in equation 4.1 below.

$$SR = SR(s) \times m + c \qquad \textbf{4.1}$$

Where:

- s is the speed of the test
- m is a function involving the speed of the test
- c is the y axis intercept in the resulting graph of the equation, i.e. if SR(s)=0 then SR =c. It is expected that c will equal 0.

This type of relationship was tested for each speed (with c=0), and was found to be a good fit. There are other equations which can also achieve an effect proportional to the SR value (e.g. exponential or quadratic formulae) however for the range of SR values covered by the test programme, and typically found on the HA network, a linear relationship appeared to be the best fit.

An example of this relationship is shown in Figure 4.1 and the results from all of the speeds are shown in Appendix A and summarised in Table 4.1. In these graphs the line of equality is shown in black and the line of best fit for the data is shown in blue.

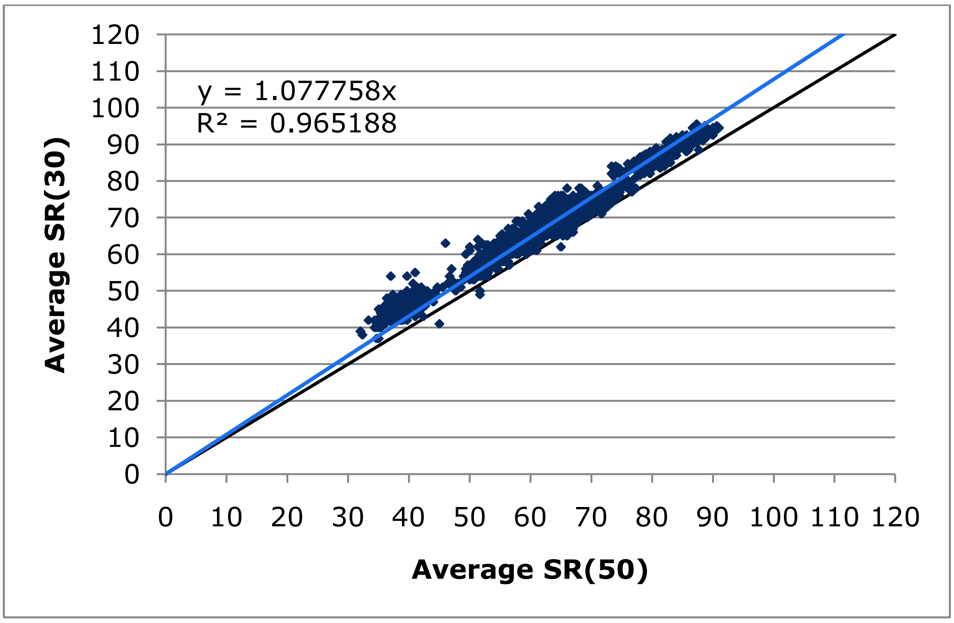

Figure 4.1 Relationship calculated between SR(30) and SR

Table 4.1 Relationships calculated for each speed in relation to the average SR at 50km/h

Speed	Gradient or "m factor"	R^2	Number of data points
30	0.927852	0.97	3734
35	0.948220	0.98	3670
40	0.969709	0.98	3797
45	0.990121	0.99	3821
50	n/a	n/a	n/a
55	1.017484	0.98	3102
60	1.034345	0.99	3771
65	1.044738	0.97	3808
70	1.092061	0.91	677
75	1.073951	0.95	3456
80	1.085465	0.97	3444
85	1.091860	0.96	3316

The gradients shown in Table 4.1 agree with expectations for the speed correction of data from SCRIMs. Low speed tests have a gradient below 1, meaning these tests produce higher values than those at 50km/h. High speed tests on the other hand have a gradient above 1 which in turn means lower values than those at 50km/h. As the test speed approaches 50km/h (from either direction) the gradient approaches 1.

Note: the tests programmed to be conducted at 70km/h were often not completed due to time constraints during testing. The m factor generated for this speed is therefore less reliable than for the other speeds and has been excluded from further analysis.

4.2 Calculation of generic relationship

The results in Table 4.1 provide values that could be used in the outline speed correction formula (equation 4.1) to correct data at those individual speeds. However, this is not ideal as it would require the replication of the above table and also speeds between these values (e.g. 32 km/h) would not be speed corrected accurately if the equation nearest to that speed was used. Therefore to determine a generic speed correction formula these m factors were plotted against speed. Review of these data suggested two possible relationships between the m factors and speed, a linear equation and a quadratic equation.

The data along with plots of the equations are shown in Figure 4.2 and Figure 4.3. Note, these are not strictly lines of best fit as they have been artificially modified to go through exactly 1 at a speed of 50km/h and produced using equations with numbers rounded to 5 decimal places.

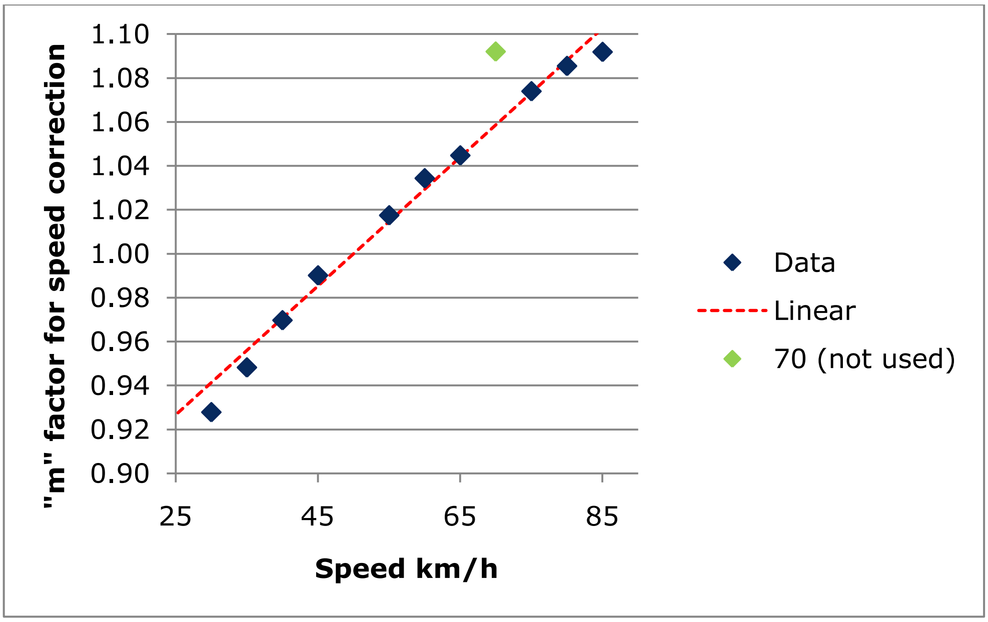

Figure 4.2 Linear fit to "m" factor values for speed correction

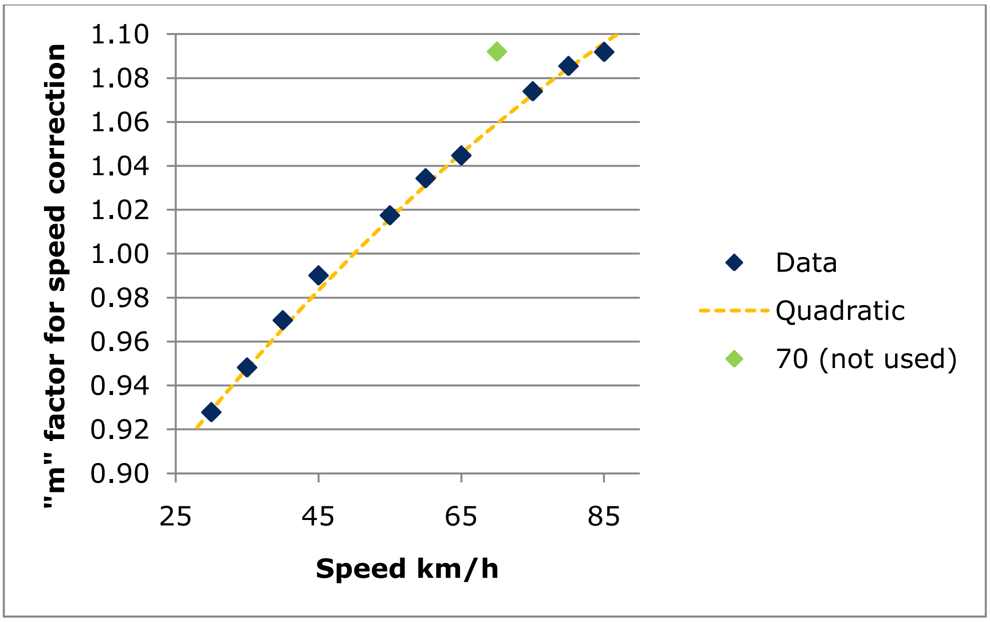

Figure 4.3 Quadratic fit to "m" factor values for speed correction

From the graphs it appears that the quadratic equation fits the data better than the linear equation. However, given the reasonably good fit for the linear equation, and the fact that the equation is simpler to use and to quote, both equations underwent further validation testing.

Substituting these two relationships into the speed correction equation template (equation 4.1) produces the following possible speed correction equations:

Linear: $SR = SR(s) \times (0.002936 \times s + 0.8532)$ **4.2**

Quadratic $SR = SR(s) \times (-0.000015 \times s^2 + 0.004765 \times s + 0.79925)$ **4.3**

5 Validation of speed correction formula

5.1 Validation of relationship using survey data

For the initial validation of the speed correction formulae the data used in their calculation was corrected using each of the three equations (the current equation and the two new ones) and the difference between these values and the associated SR(50) value was compared. These comparisons are shown below, starting with the uncorrected data (Figure 5.1) followed by the current formula (Figure 5.2) then the new linear formula (Figure 5.3) and finally the new quadratic formula (Figure 5.4). In these figures the test speeds have been grouped into bands to make the data easier to interpret. The groups are low speed (30, 35, 40km/h), medium (45, 50, 55km/h), high (60, 65, 70km/h), and very high (75, 80, 85km/h).

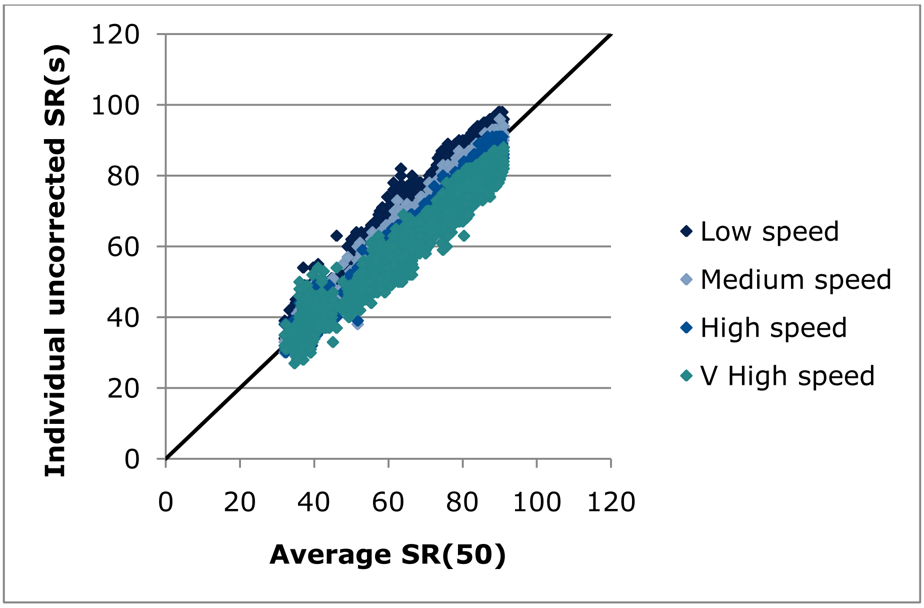

Figure 5.1 Uncorrected data compared to SR

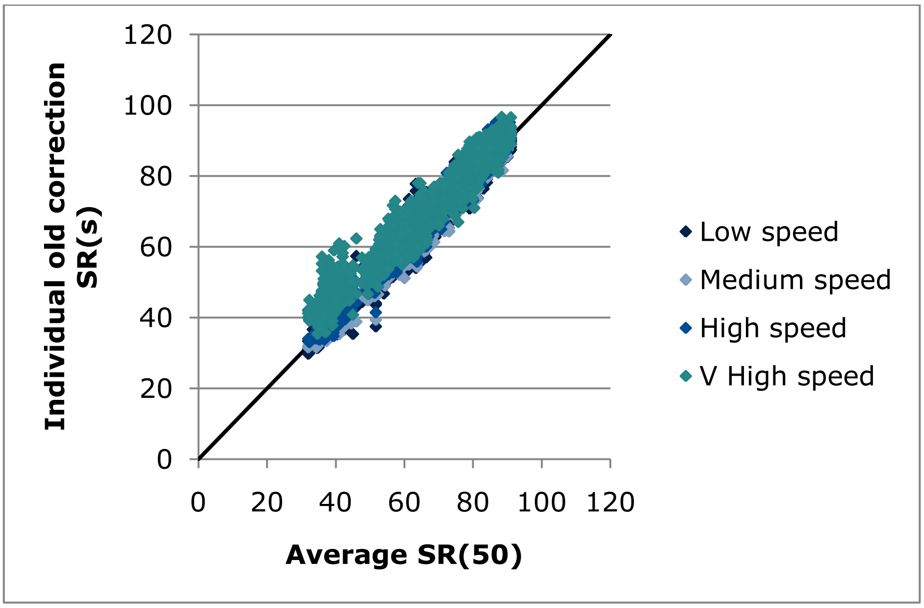

Figure 5.2 Data corrected using current correction compared to SR

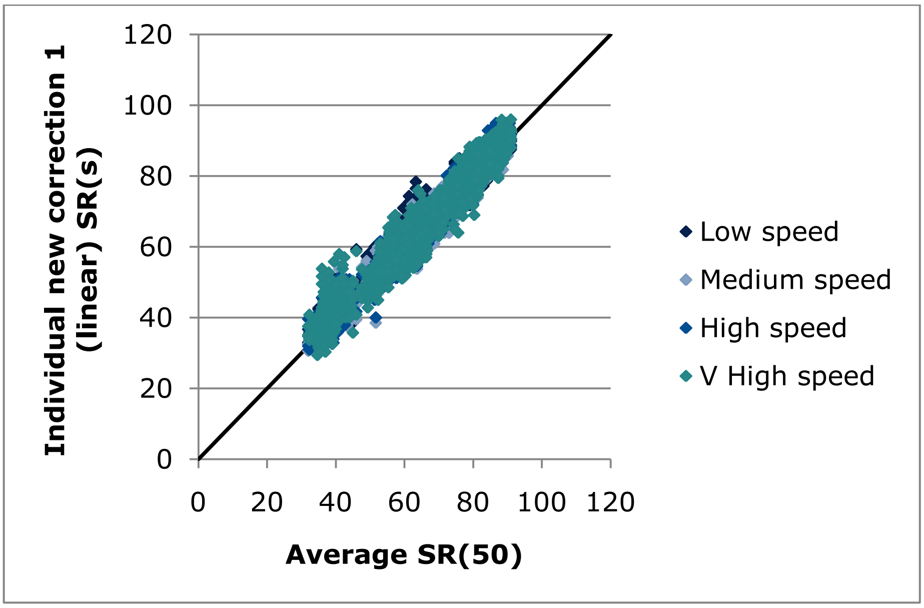

Figure 5.3 Data corrected using new linear correction compared to SR

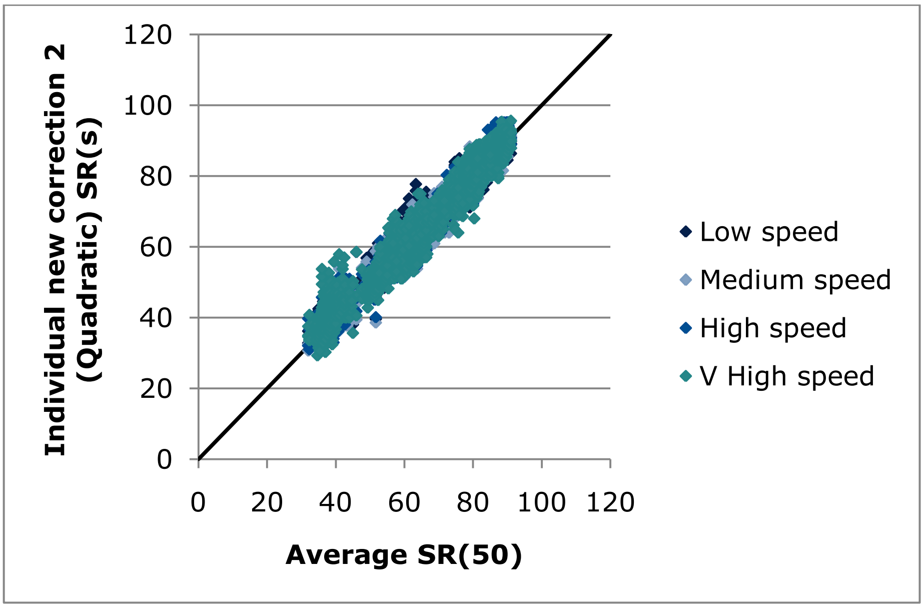

Figure 5.4 Data corrected using new quadratic correction compared to SR

On initial inspection of Figure 5.1 to Figure 5.4 it can be seen that all three speed correction formulae improve the correlation of the measurements with the reference data (the average SR(50) value). It also appears that the two new speed correction formulae provide a better correction than the current formula, with the quadratic equation giving the best results. However due to the number of overlapping data points in the graphs it is necessary to analyse these data further to confirm the initial indications and to ensure that a robust conclusion is reached.

To this end, a statistical analysis of the data was completed and a summary of that analysis is provided in Table 5.1. To help give an intuitive feeling for the impact of the differences between the results from the three equations, the data were converted to SCRIM coefficient (SC) values before calculating the statistics. This is because SC is, in general, more familiar to HA and their maintaining agents than SCRIM readings.

Table 5.1 Statistics of comparison of speed correction approaches using the survey data for development of the new corrections

	Mean difference from reference (SC)	Standard deviation of difference from reference	Number of data points	Standard error
Current correction	-0.0081	0.02440	16196	0.0002
New correction – linear	-0.0032	0.02082	16196	0.0002
New correction - quadratic	-0.0013	0.02049	16196	0.0002

The statistics in Table 5.1 confirm the conclusions drawn initially, i.e. the new correction formulae are performing better than the current one, and the quadratic correction is performing the best.

To give an indication of the strengths and weakness of the three equations, Figure 5.5 and Figure 5.6 show the mean difference between the reference value and the speed corrected value by the SCRIM coefficient band (of the reference data) and by speed group respectively. As before, the data have been presented as SCRIM coefficients rather than SCRIM readings.

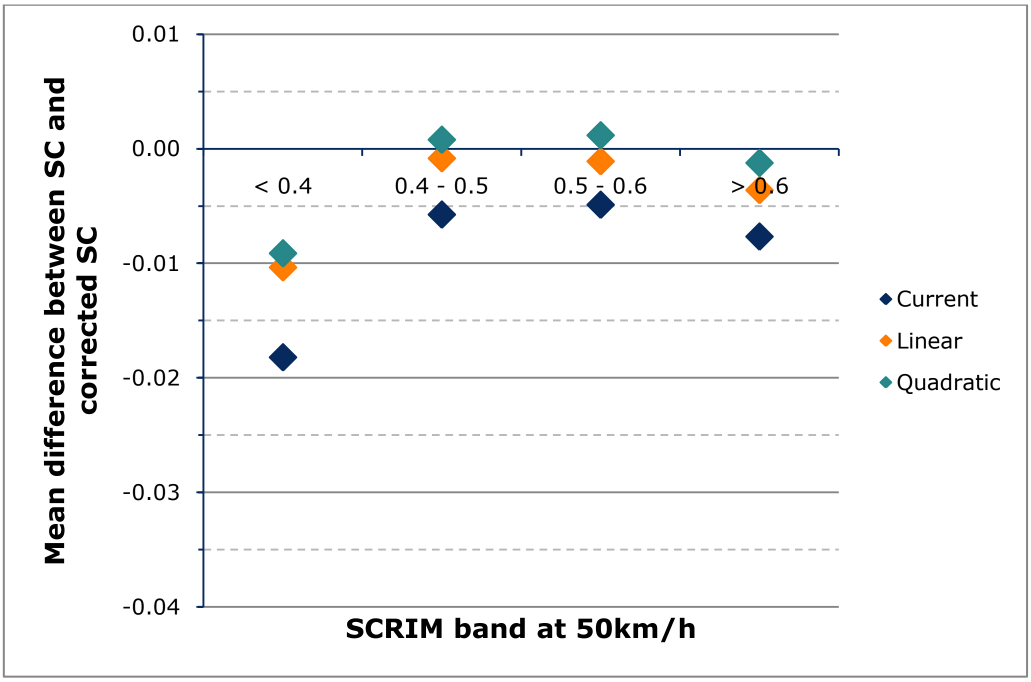

Figure 5.5 Comparison of the speed correction formulas by SCRIM coefficient band at 50km/h

Figure 5.5 indicates that, when looking at SCRIM coefficient bands, all three equations perform reasonably well with the mean difference between the reference and speed corrected data lying between 0.005 and -0.01 for the majority of the time. However, it can be seen that the new formulae outperform the current correction in each group. The two new correction formulae have a similar performance in the SC range 0.4 to 0.6, with the quadratic equation performing better outside of this range.

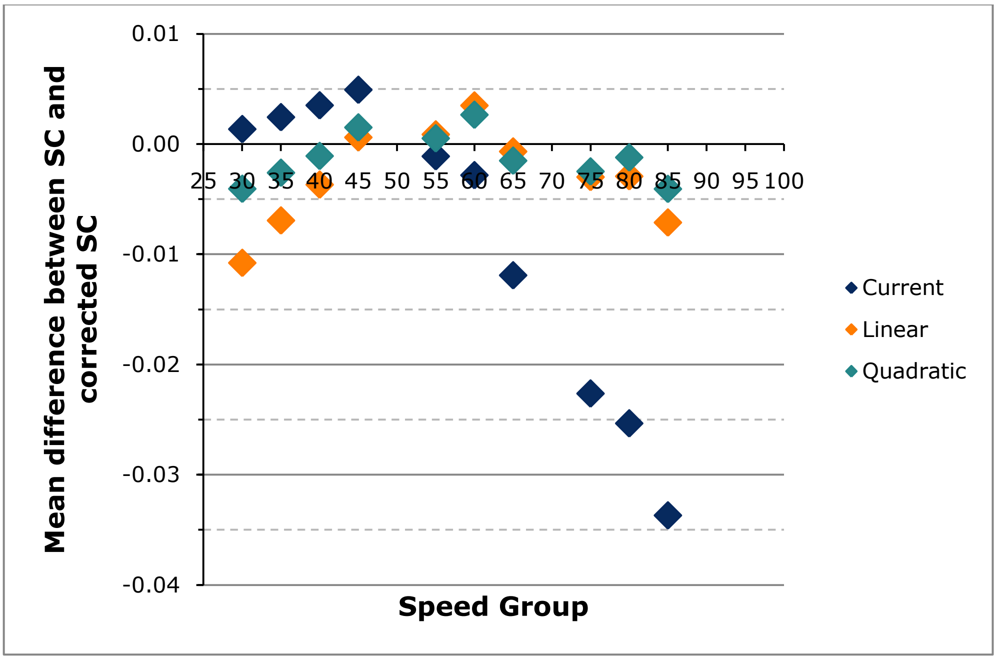

Figure 5.6 Comparison of the speed correction formulas by speed group

When performing a similar analysis but grouping the data by speed (Figure 5.6), the two new equations again perform well, with most of the mean differences lying between 0.005 and -0.01. The current correction performs well for low speeds, but provides a significantly poorer correction than the new formulae for speeds greater than 60km/h. As before the quadratic equation performs slightly better than the linear equation, with the mean differences lying between ±0.005.

It could be expected that in this analysis the new equations would perform a little better than the current equation as the data used was the same data that was used to create the formulae. However, the improvements seen in the correction of the data and the consistency of the data suggest that the new equations may provide a tangible benefit over the current speed correction formula. In order to assess if this is the case, the new and existing formulae were compared using an independent data set, namely data from the HA benchmark sites.

5.2 Independent validation of relationship using benchmark site data

In order to determine if the dataset was unfairly biasing the results in favour of the new equations, the data from the benchmark sites, which initiated this work (see section 2), were analysed using the three different equations. The data are plotted in Figure 5.7, Figure 5.8 and Figure 5.9. The statistical analysis of the data is then summarised in Table 5.2; as before these statistics are based on the SCRIM coefficient values to provide a more intuitive interpretation of the results.

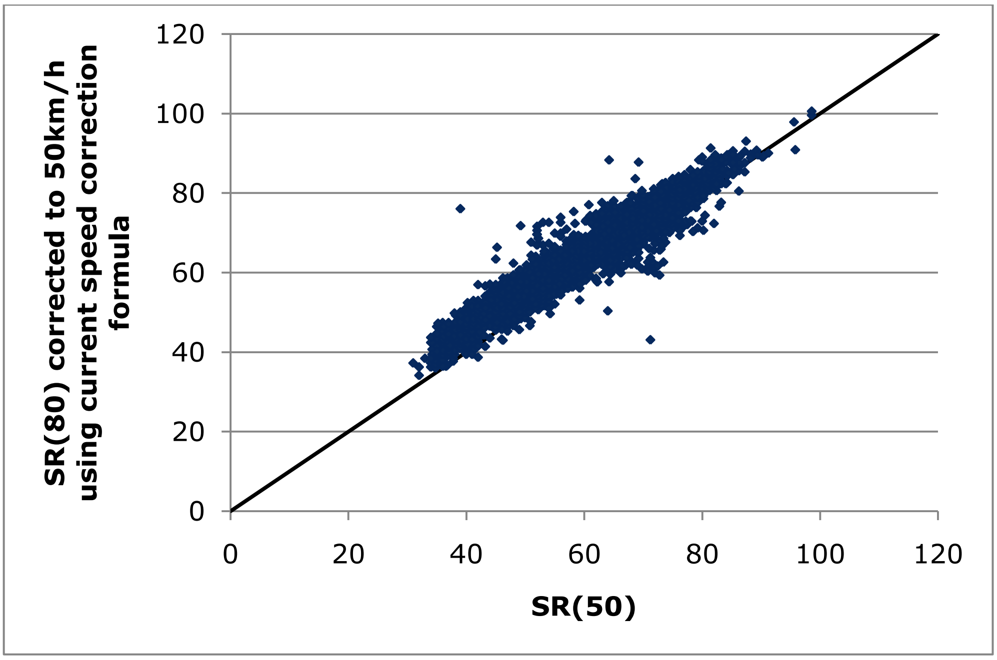

Figure 5.7 Comparing speed corrected data to data collected at 50km/h on the benchmark sites (current speed correction formula)

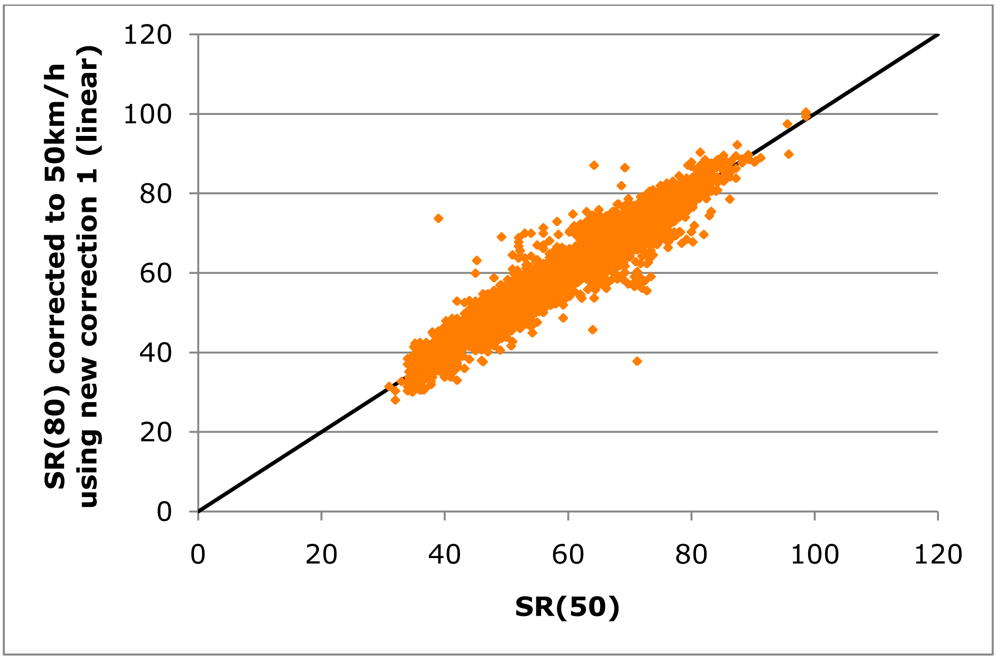

Figure 5.8 Comparing speed corrected data to data collected at 50km/h on the benchmark sites (new linear speed correction formula)

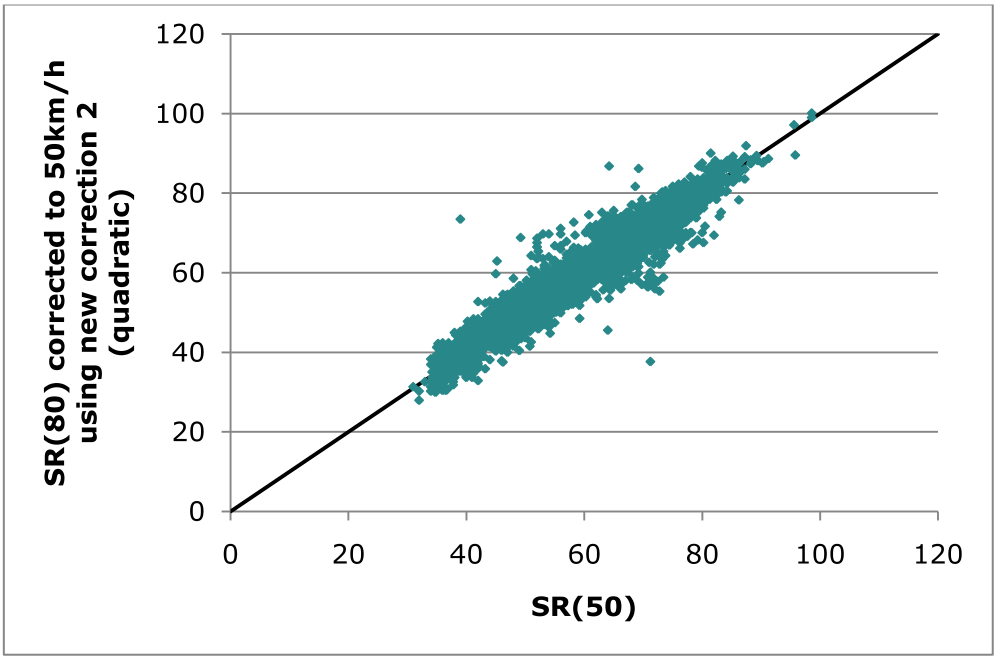

Figure 5.9 Comparing speed corrected data to data collected at 50km/h on the benchmark sites (new quadratic speed correction formula)

Table 5.2 Statistics of comparison of speed correction approaches on 80km/h data from the benchmark sites

	Mean difference from reference (SC)	Standard deviation of difference from reference	Number of data points	Standard error
Current correction	-0.0316	0.02544	6330	0.0003
New correction – linear	-0.0051	0.02542	6330	0.0003
New correction - quadratic	-0.0035	0.02539	6330	0.0003

The results from the benchmark sites appear to confirm those from the test tracks and road sections used to develop the new speed correction formulae. As before, the two new corrections perform better than the current correction, with the quadratic formula providing the best results. On initial inspection the statistics from the benchmark sites appear markedly different to those from the other sites (Table 5.1). However the benchmark sites were only tested at 50 and 80km/h whereas the other sites were tested over a range of speeds between 30 and 85km/h. The data for each speed group for the other sites can be seen in Figure 5.6. When the benchmark sites are compared to the 80km/h speed group then similar values for the mean difference were produced for both sets of data.

6 Recommendations and implications

6.1 Recommendations

Both of the new equations have been shown to be an improvement on the current speed correction on the sites tested. These sites covered the range of surface types, skid resistance and texture typically found on the HA network. Therefore it is recommended that one of the new equations should be adopted for the speed correction of SCRIM data. The two equations are shown below.

<u>Linear</u> $SR=SR(s) \times (0.002936 \times s + 0.8532)$ **6.1**

<u>Quadratic</u> $SR=SR(s) \times (-0.000015 \times s^2 + 0.004765 \times s + 0.79925)$ **6.2**

Where

SR = SCRIM Reading corrected to 50km/h

SR(s) = SCRIM Reading at speed s

S = speed of the survey

The new equations were based on a simple linear and a slightly more complex quadratic relationship between correction factor and speed. The linear equation has a slight benefit of being easier to quote and use. However, in the case of HA, the speed correction of SCRIM data happens within the Highways Agency Pavement Management System (HAPMS) and therefore the ease of use is not a crucial factor. This coupled with the improved accuracy provided by the quadratic equation, suggests that the quadratic form should be chosen for use.

It is noted, however, that the number of leading zeros in some of the constants in the equation may lead to accidental errors in calculations and so it is recommended that the equation is quoted in the following form:

$SR=SR(s) \times (-0.015 \times s^2 + 4.765 \times s +799.25)/1000$ **6.3**

This equation should only be used to correct data collected within the speed range 30 to 85km/h. Data outside of this speed range should be disregarded.

6.2 Implications

As stated earlier in this report, the current speed correction formula has been found to overcorrect data collected at 80km/h (see section 2), particularly for middle to low SC values. This means that for tests conducted at 80km/h the reported SC value (i.e. after speed correction) will be higher than the "true" SC value (i.e. the value that would be generated if the test was conducted at 50km/h).

The new quadratic speed correction equation produces SC values closer to the "true" SC value and this will result in a drop in the reported SC values for surveys conducted at 80km/h (i.e. surveys on roads with a posted speed limit greater than 50mph). The magnitude of this reduction in SC value is shown in Table 6.1.

Table 6.1 Effect of change in speed correction formula on data collected at 80km/h

SC data corrected from 80km/h		Difference
current correction	new quadratic equation	
0.30	0.25	-0.05
0.31	0.27	-0.04
0.32	0.28	-0.04
0.33	0.29	-0.04
0.34	0.30	-0.04
0.35	0.31	-0.04
0.36	0.32	-0.04
0.37	0.33	-0.04
0.38	0.34	-0.04
0.39	0.35	-0.04
0.40	0.36	-0.04
0.41	0.37	-0.04
0.42	0.38	-0.04
0.43	0.40	-0.03
0.44	0.41	-0.03
0.45	0.42	-0.03
0.46	0.43	-0.03
0.47	0.44	-0.03
0.48	0.45	-0.03
0.49	0.46	-0.03
0.50	0.47	-0.03
0.51	0.48	-0.03
0.52	0.49	-0.03
0.53	0.50	-0.03
0.54	0.51	-0.03
0.55	0.53	-0.02
0.56	0.54	-0.02
0.57	0.55	-0.02
0.58	0.56	-0.02
0.59	0.57	-0.02
0.60	0.58	-0.02

This effect is present at all speeds; however it reduces at speeds closer to 50km/h and has the opposite effect on speeds below 50km/h, i.e. the new correction formula gives higher SC values compared to the current correction. However, the effect at lower speeds is less pronounced than at 80km/h and these low speeds tend to only occur occasionally at approaches to traffic lights and roundabouts. The magnitude of the increase in SC for tests at 30km/h is shown in Table 6.2.

Table 6.2 Effect of change in speed correction formula on data collected at 30km/h

SC data corrected from 30km/h		Difference
current correction	new quadratic equation	
0.30	0.32	0.02
0.31	0.33	0.02
0.32	0.34	0.02
0.33	0.35	0.02
0.34	0.36	0.02
0.35	0.37	0.02
0.36	0.37	0.01
0.37	0.38	0.01
0.38	0.39	0.01
0.39	0.40	0.01
0.40	0.41	0.01
0.41	0.42	0.01
0.42	0.43	0.01
0.43	0.44	0.01
0.44	0.45	0.01
0.45	0.46	0.01
0.46	0.47	0.01
0.47	0.48	0.01
0.48	0.49	0.01
0.49	0.50	0.01
0.50	0.50	0.00
0.51	0.51	0.00
0.52	0.52	0.00
0.53	0.53	0.00
0.54	0.54	0.00
0.55	0.55	0.00
0.56	0.56	0.00
0.57	0.57	0.00
0.58	0.58	0.00
0.59	0.59	0.00
0.60	0.60	0.00

It is expected that the combination of these two effects will reduce the average speed corrected SCRIM reading on the network. This would cause a drop in the seasonally corrected SCRIM values (Characteristic SCRIM Coefficient (CSC)) which could lead to an increase in the number of sites falling below Investigatory Level. This could therefore result in more sites being identified as requiring treatment. To investigate the magnitude of this effect, the new (quadratic) speed correction formula was applied to the 2010 SCRIM survey data (without seasonal correction). The results are shown below in Figure 6.1 and Figure 6.2.

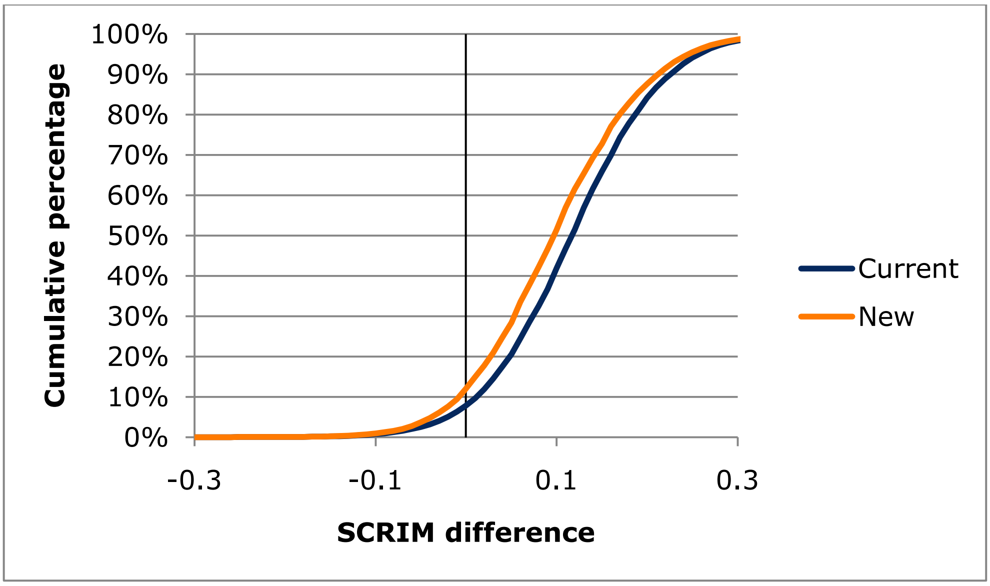

Figure 6.1 Distribution of SCRIM difference levels

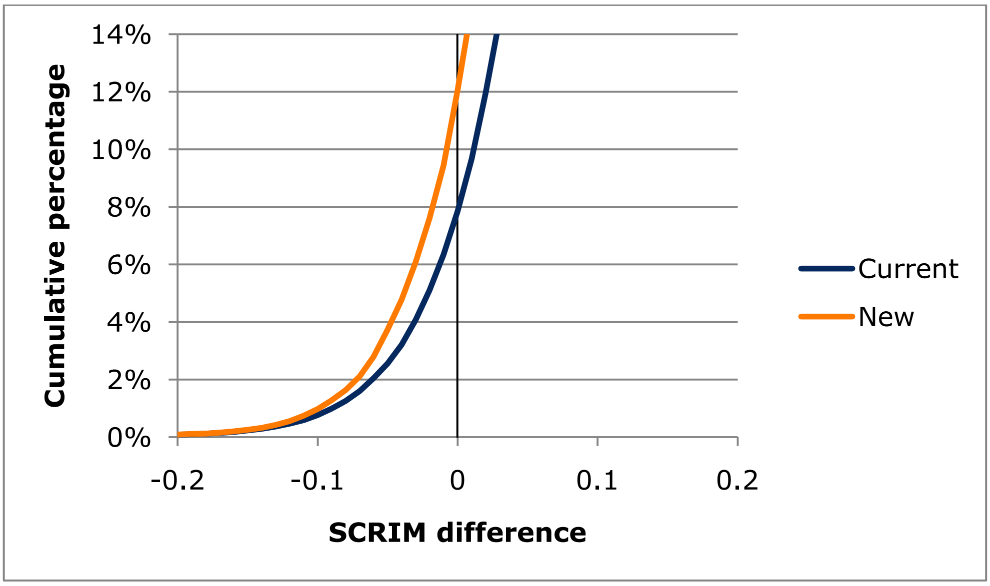

Figure 6.2 Distribution of SCRIM difference levels (focusing on 0 SD)

The data suggests that an additional 4% (approx 660km) of the network would be at or below Investigatory Level following the implementation of the new speed correction.

This change could be implemented in a sharp or gradual manner using one of the three methods:

1. Change the application of speed correction on all SCRIM data in HAPMS. This means that any SCRIM query performed on HAPMS would produce the new corrected results (no matter how old the data). This would result in a sharp change between queries done in the past, but no change between any queries run from this point on (on old or new SCRIM data).

2. Change the application of speed correction on data in HAPMS from this point on. This means that only queries on new SCRIM survey data would use the new speed correction. This would result in a difference between speed corrected data from surveys undertaken before and after the implementation of the new speed correction. However, this difference would be implemented gradually as a result of how seasonal correction is applied. The method used for seasonal correction is, in effect, to adjust the average SCRIM value for a locality (typically a road and area combination) to the average of the previous three years. This means the full impact of the change in speed correction would not be experienced until three years after the implementation of the new equation.

3. Change the application of speed correction on data in HAPMS from this point on, and for data used in the calculation of the seasonal correction factors. This would again result in a difference between speed corrected data from surveys completed before and after the implementation of the new speed correction. In this case, however, the change would occur fully in the first year of implementation rather than gradually over three years.

The option taken will depend initially on the feasibility of implementing the option (i.e. will it be possible to modify the correction applied to old data in HAPMS). The speed of the SCRIM surveys is stored in HAPMS so it would therefore be theoretically possible to adopt any of the three options above. It may however not be a simple process and the viability of the options should be discussed with the HAPMS support team. The other aspect to consider is whether it is preferable to have new queries of old data producing the same results as before or if new queries should produce results based on the new speed correction.

Appendix A Graphs of relationship between SR(s) and SR(50)

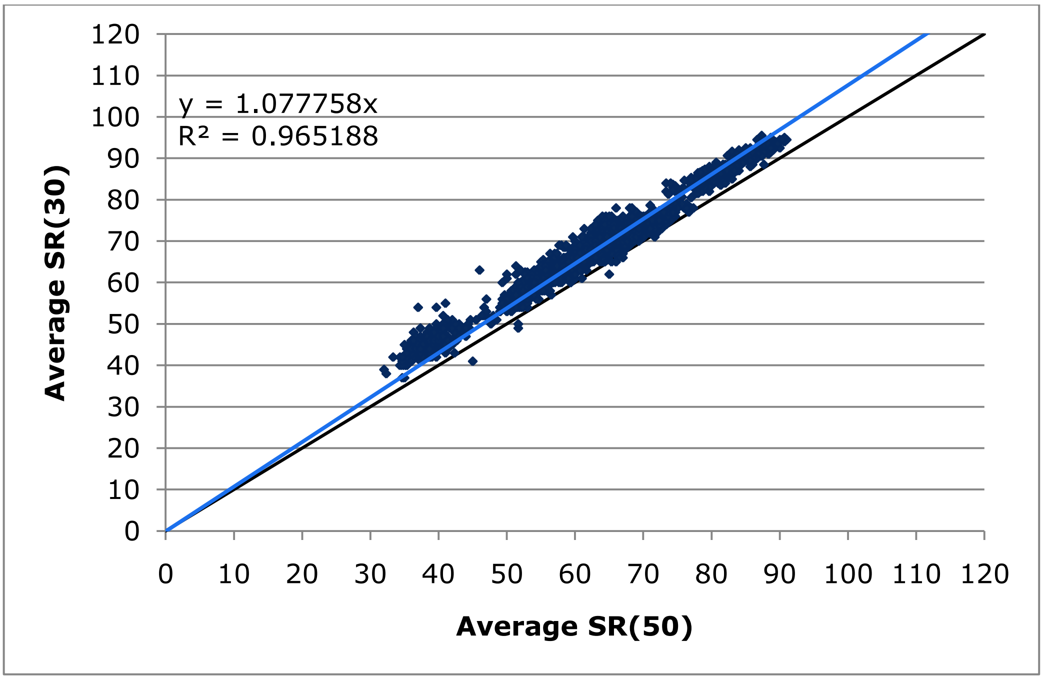

Figure A.1 Relationship calculated between SR(30) and SR(50)

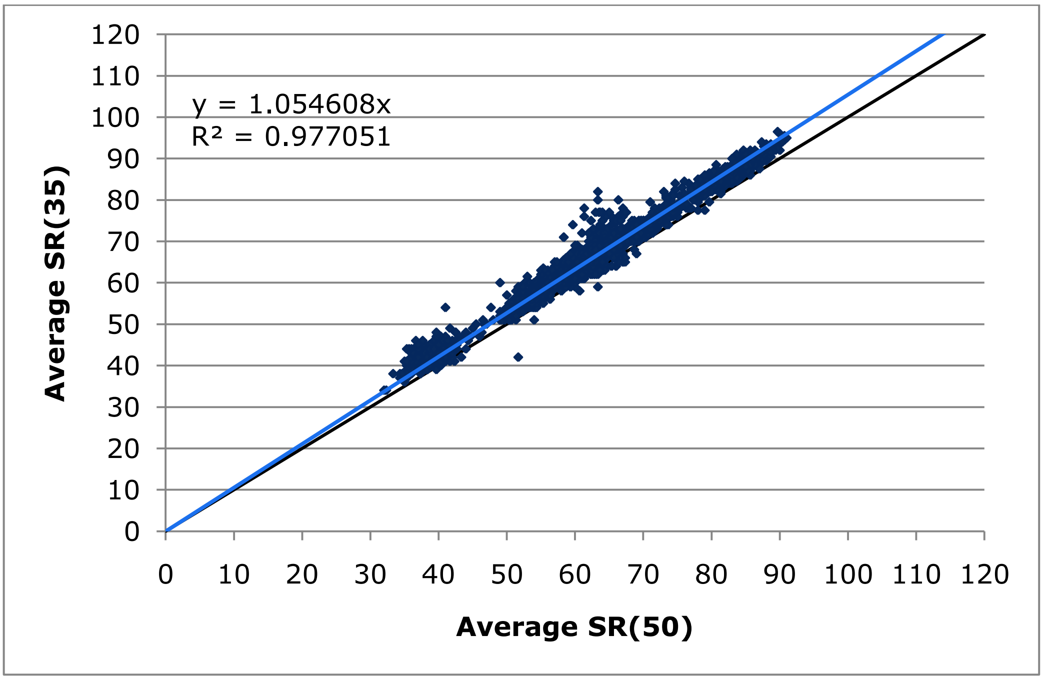

Figure A.2 Relationship calculated between SR(35) and SR(50)

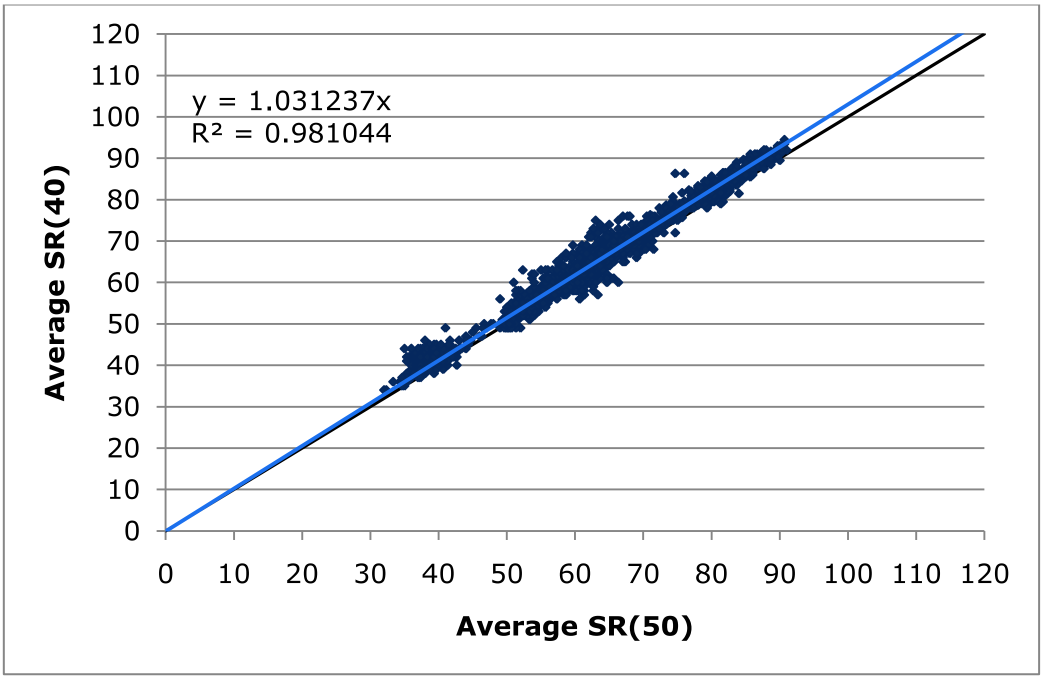

Figure A.3 Relationship calculated between SR(40) and SR(50)

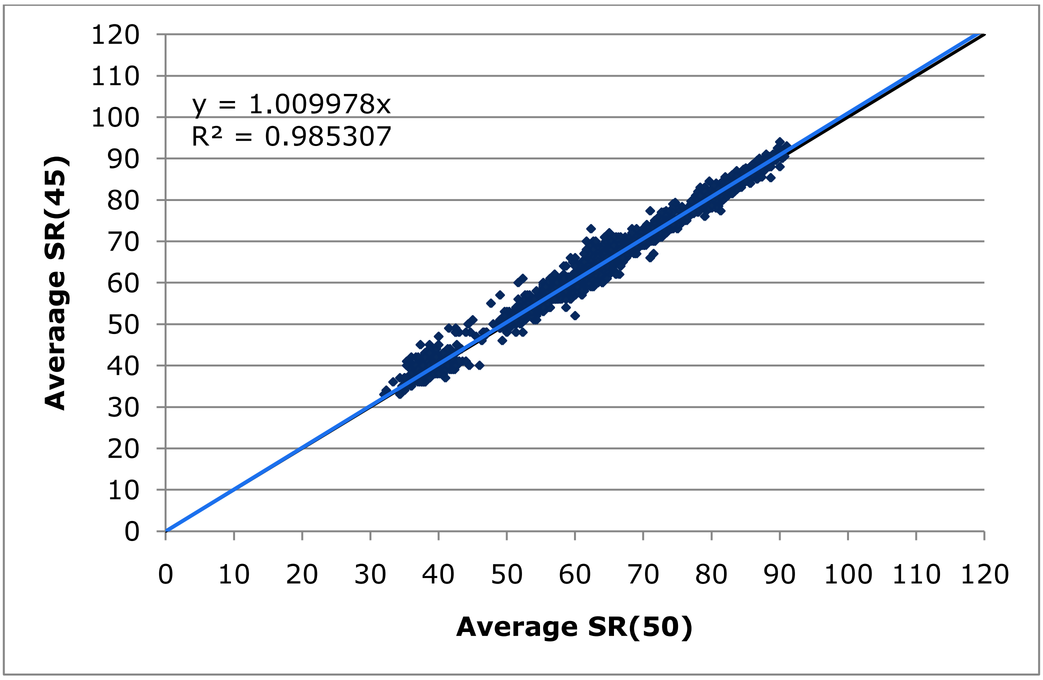

Figure A.4 Relationship calculated between SR(45) and SR(50)

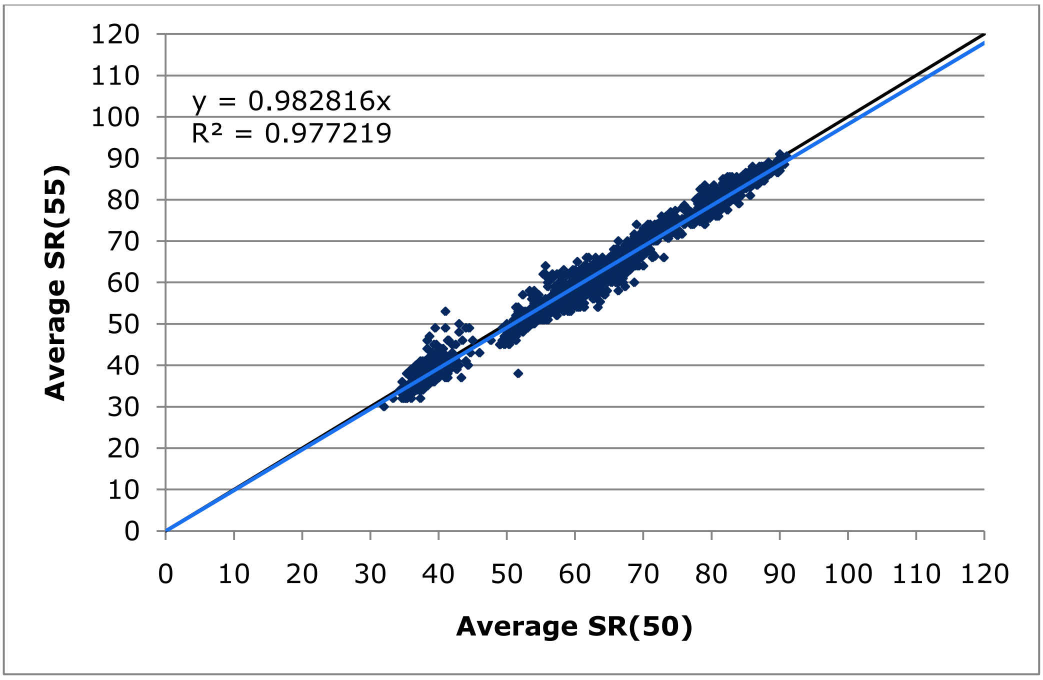

Figure A.5 Relationship calculated between SR(55) and SR(50)

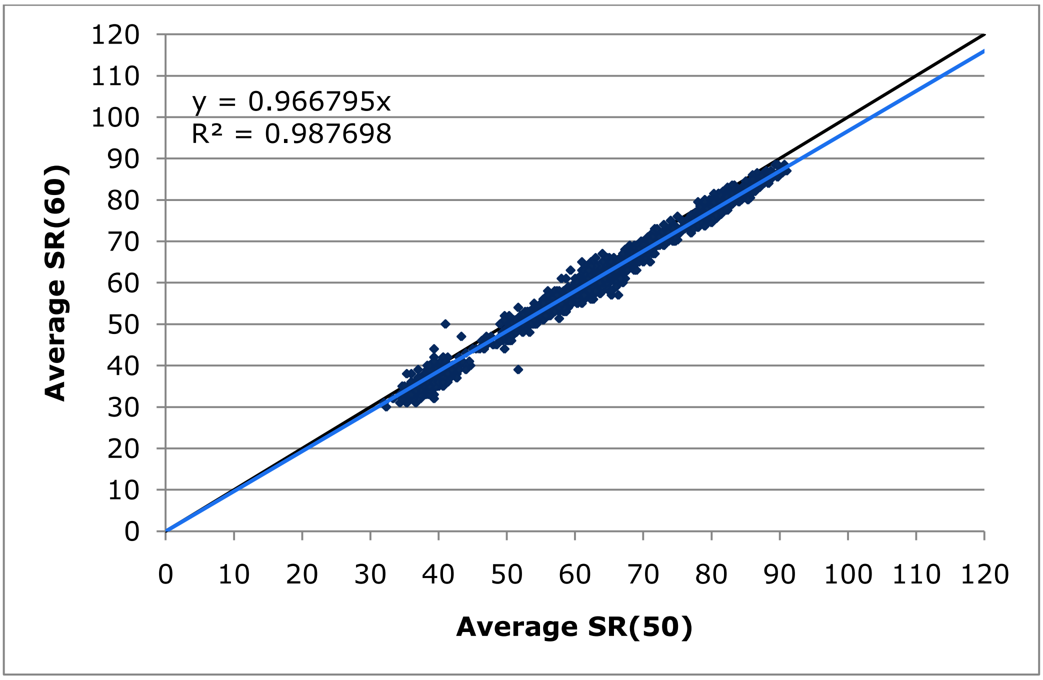

Figure A.6 Relationship calculated between SR(60) and SR(50)

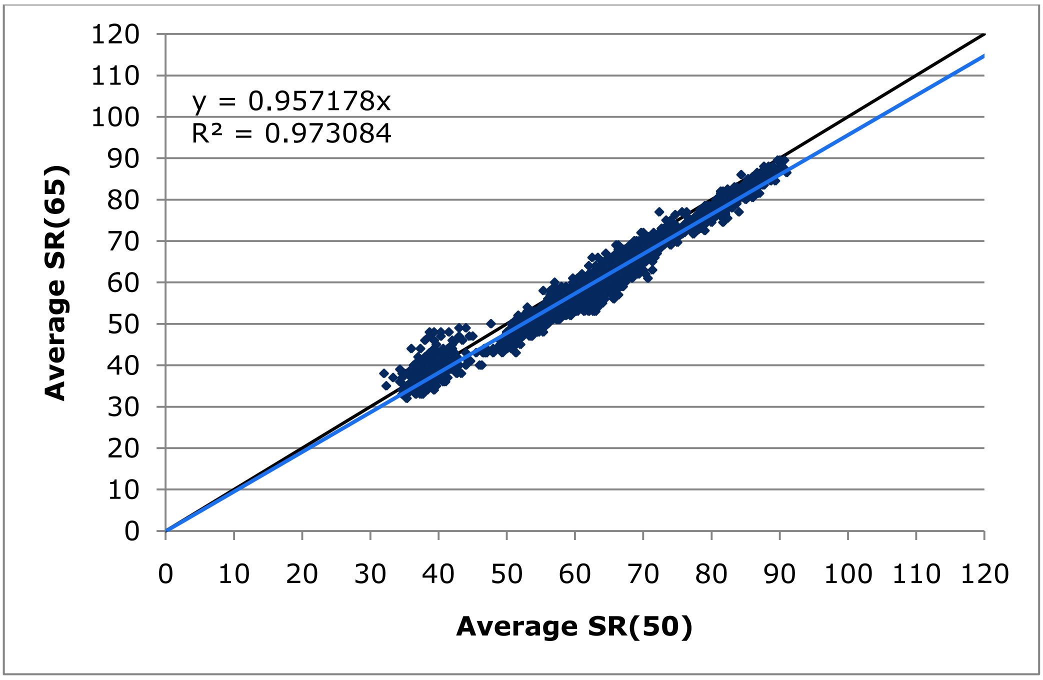

Figure A.7 Relationship calculated between SR(65) and SR(50)

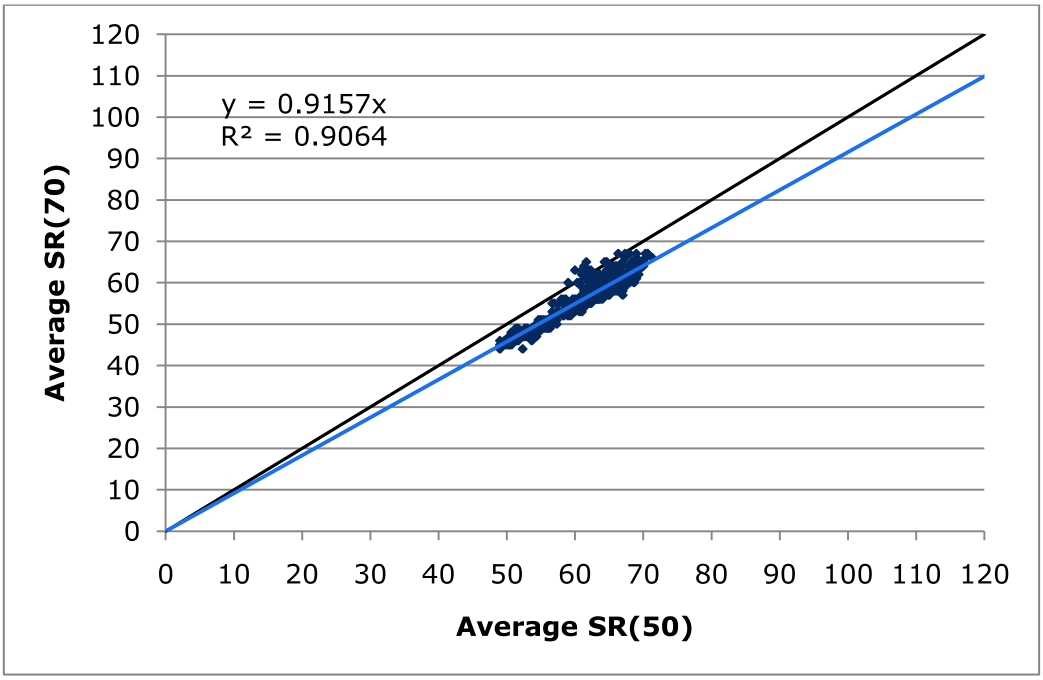

Figure A.8 Relationship calculated between SR(70) and SR(50)

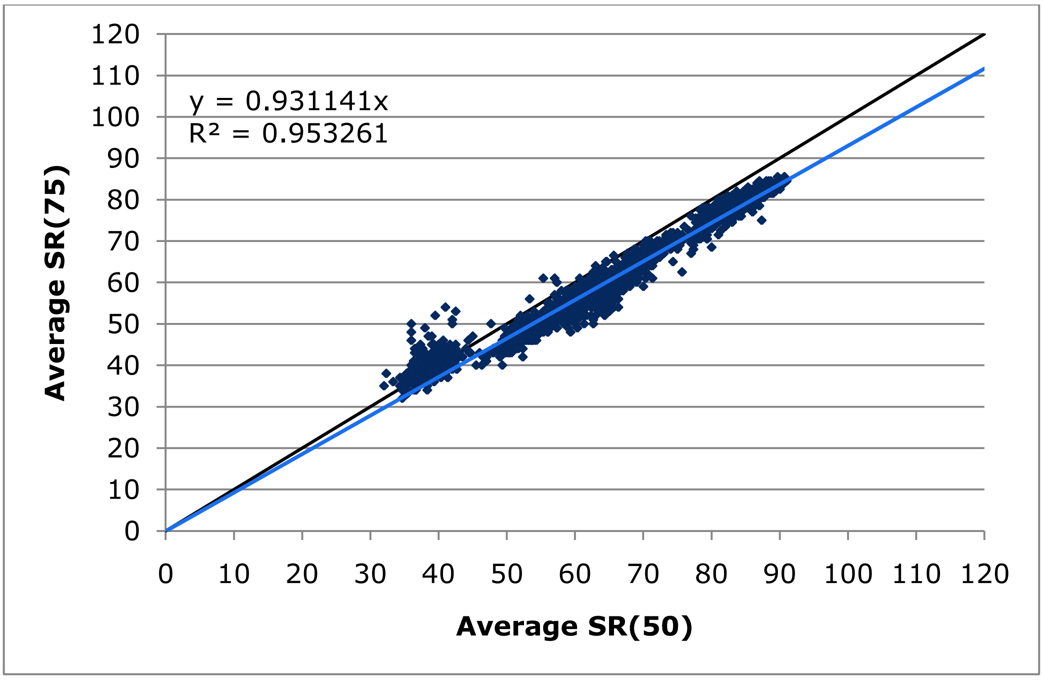

Figure A.9 Relationship calculated between SR(75) and SR(50)

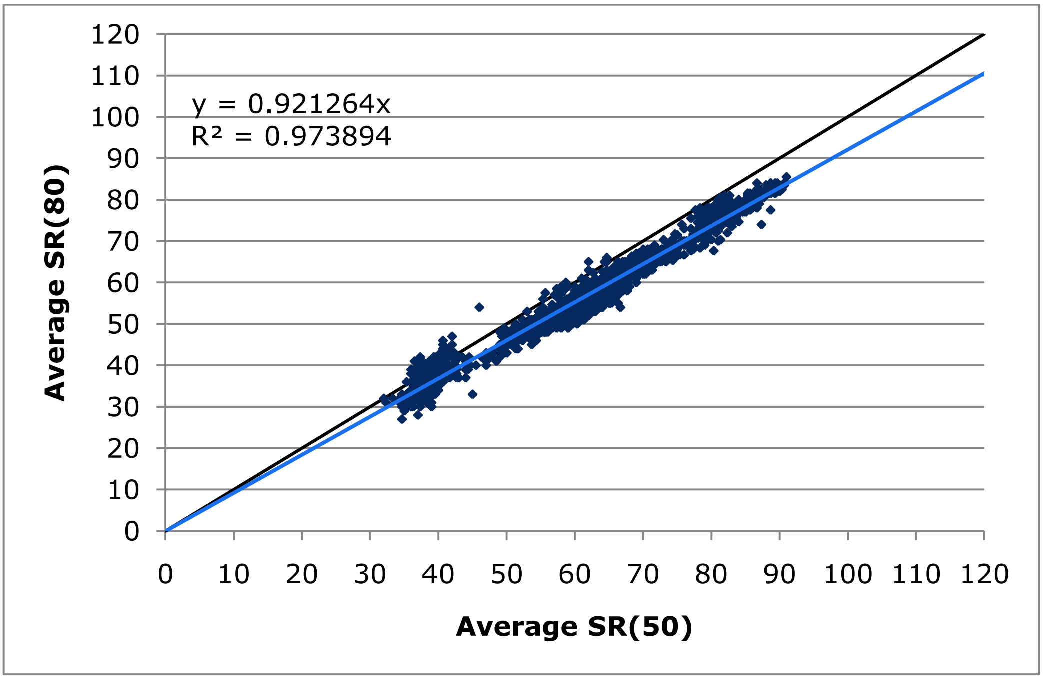

Figure A.10 Relationship calculated between SR(80) and SR(50)

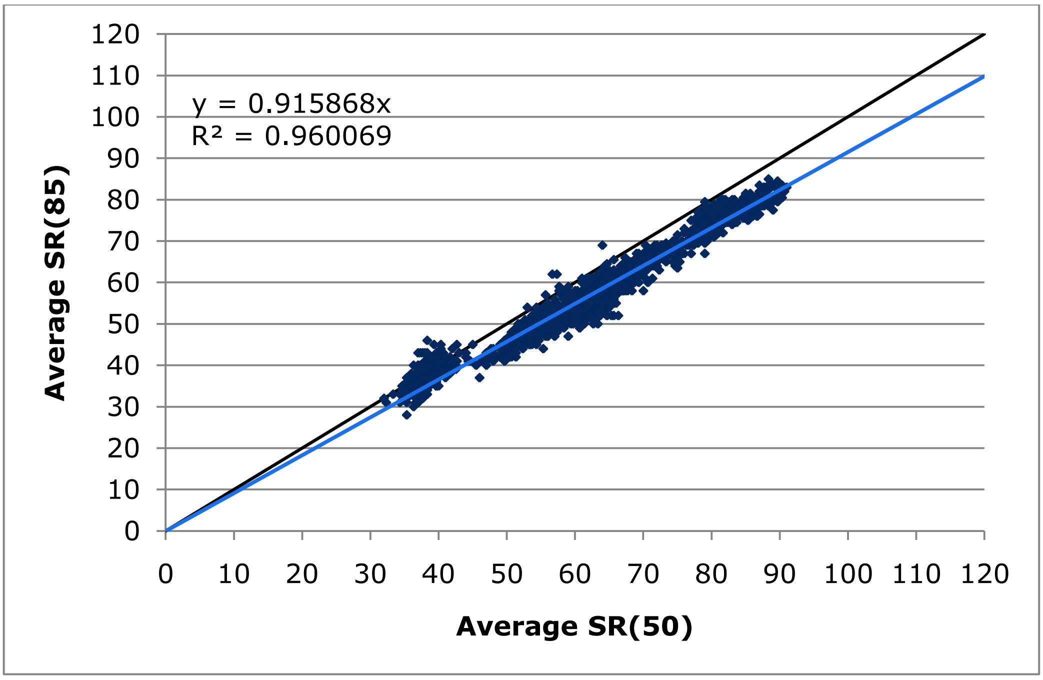

Figure A.11 Relationship calculated between SR(85) and SR(50)