Recent Developments To The SCRIM Measurement Technique In The UK

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ABSTRACT

This paper presents recent developments to improve the performance of SCRIMs working in the UK. A concern regarding the operation of SCRIM has been the possible influence of dynamic changes in vertical load on SFC measurements, particularly when testing on bends. This paper describes the work that led to the introduction of a vertical load measuring system on the UK SCRIM fleet in 2004. This included an assessment of the operation of the new system and its use to investigate the variations in dynamic vertical load on uneven surfaces and on curves. The paper also reviews work that has investigated the possibilities of using measurements recorded over much shorter intervals than are normally used (as short as 1m), either as an investigative tool or as part of the network monitoring process. Changes in the UK approach to operational test speeds and speed correction are also discussed.

1. INTRODUCTION

The Sideway-Force Coefficient Routine Investigation Machine (SCRIM) was developed in the late 1960s as a tool for monitoring skid resistance on a network scale (Hosking and Woodford, 1976). The concept combined the well-established side-force coefficient principle for skid resistance measurement (used in Britain since the 1930s) with a large capacity on-board water supply and electronic data recording. SCRIM has been produced commercially under license by WDM Limited since 1971. Since 1988, a fleet of machines has routinely monitored the skid resistance of the UK Trunk Road Network and SCRIM is now used in many other countries.

The operation of SCRIMs in the UK is kept under continual review. Over the years, working closely with TRL, the manufacturer has made many incremental developments to the equipment in the light of operating experience and changing electronic technology but the principles have remained the same. Some developments have been to details of the mechanism, to make it more robust and reliable, while others have led to improvements in the data recording system; the latest recorder, for example, utilises an on-board PC and touch-sensitive screen.

However, as part of the review process, more significant developments to the equipment have been considered. This paper describes the evaluation of a new dynamic vertical load measuring system prior to its introduction on the whole UK fleet for the 2004 survey season. It also discusses an investigation into the potential for recording data at shorter intervals which was carried out at same time.

2. BACKGROUND

SCRIM measures SFC (side-way force coefficient) by recording the average force developed along the axle of the angled wheel and then dividing this by the vertical load acting on the wheel. Historically, the dynamic vertical load (the vertical load acting on the wheel while a test is being carried out) has always been assumed to be constant and the same as the static vertical load of 200kg.

Although the equipment is designed so that the test wheel assembly should move freely up and down during a test, there have often been suggestions that the dynamic vertical load might not actually be constant and could change during the course of a survey if the balance of the loading on the chassis shifted under different road conditions. This might occur, for example, when the machine is negotiating bends or on a gradient, with a possible unknown effect on the measured skid resistance.

At first, all UK SCRIMs were built on the same design of truck chassis with similar general equipment. It was considered that any vertical load variations would be small compared with other factors affecting the measurements and that for practical purposes they could be ignored. However, there are now more differences between the vehicles, particularly in type of chassis, chassis suspension systems and the size of water tank fitted. Consequently, there have been concerns that such differences might be influencing the system to an extent that dynamic load effects may vary from one machine to another and may no longer be negligible. Observation of unexpected variations in static loads at the Annual Correlation trials and pressure to increase operating speeds on busier parts of the UK network added to these concerns.

For these reasons, a system was needed that would enable the vertical load applied to the test wheel to be measured dynamically. Any errors in the SFC that might occur as a result of changes induced in the vertical load on uneven roads or when following bends and curves could then be automatically corrected. Highways Agency therefore commissioned TRL to investigate this and a new Dynamic Vertical Load Measuring System (DVLMS) was developed in conjunction with WDM Limited which was installed on the TRL SCRIM early in 2002. This underwent evaluation over the following eighteen months. A similar system was also fitted to one of the machines owned by WDM so that the robustness of the system could be assessed on a machine in intensive use on day-to-day routine surveys.

With the introduction of the PC-based recording system and larger-capacity storage media, there was an opportunity to make provision for recording average SFC measurements at shorter intervals than the 10m or 5m traditionally used. The potential for using short recording intervals routinely was therefore investigated at the same time as the evaluation of the new dynamic load measuring system.

3. PRINCIPLE OF THE DYNAMIC LOAD MEASURING SYSTEM

The test wheel on a SCRIM is mounted on an angled beam (known as the “swinging arm”). This is fixed at one end through a flexible bearing to a large, approximately triangular, steel plate (the back-plate) that is mounted on vertical shafts attached to the chassis through a rigid frame. Two bearing units on the forward edge of the back-plate and one on the rearward edge allow the plate to move up and down the shafts, which are protected from the elements by flexible gaiters. A spring and damper (shock-absorber) system links the swinging arm and back-plate to provide a simple suspension for the test wheel. The combined mass of the back-plate, the swinging arm, the wheel hub and the test wheel provides the 200kg static vertical load.

In order to measure the vertical load, a strain-gauge system is used, in a unit that is integral with the upper fixing point of the shock-absorber. Thus, the vertical load under the wheel is determined by measuring the reaction force between the swinging arm and the back-plate transmitted through the damper system. The various features are pointed out in Figure 1. Side force is measured with a load cell mounted behind the wheel hub.

The DVLMS is calibrated in the static condition by lowering the wheel on to a calibrated weigh pad, progressively applying and releasing the load. This is achieved by operating the lifting mechanism manually so that the load on the wheel is changed incrementally. The recording system records the signals indicated by the sensor and the actual loads recorded on the weigh pad at fixed intervals and then computes a best-fit linear “calibration line” that is used by the recorder in operation.

When skid resistance measurements are being made, the signals from both the load-cells are converted from analogue to digital form and averaged to provide dynamic values for the vertical and horizontal loads that are recorded at 0.1m intervals as the machine progresses along the road. These are then aggregated over the prescribed recording interval (normally 10m) in order to compute the SFC.

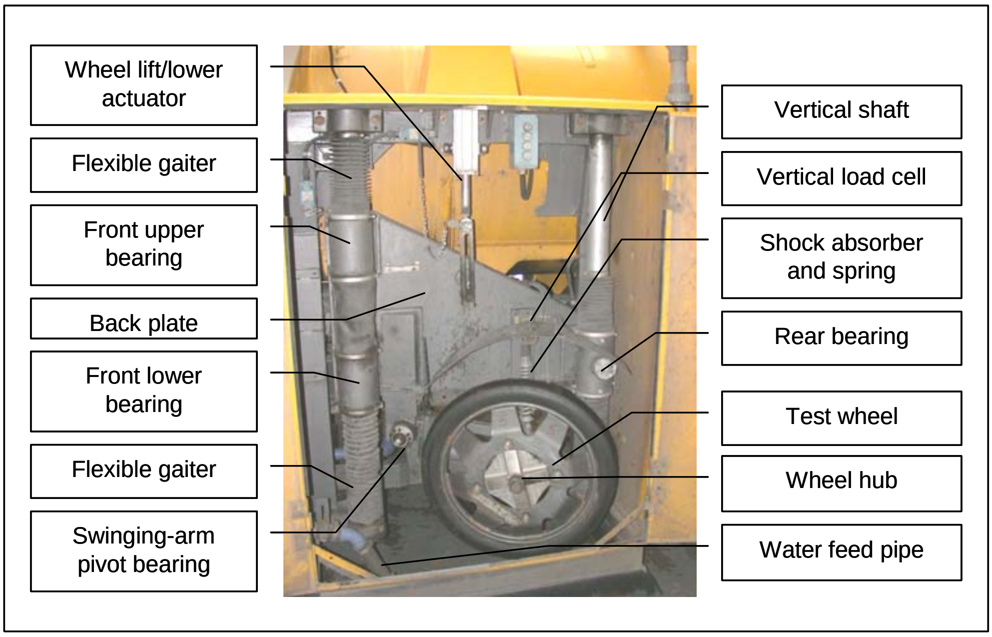

Figure 1 SCRIM test wheel assembly (wheel raised)

4. EVALUATION OF THE DVLMS

4.1 INITIAL EVALUATION

The initial evaluation of the new system was directed at assessing how effectively it operated and what it revealed about the variation in dynamic vertical load and measured SFC in practice. Three aspects were considered: variability of the load and SFC measurements; the influence of speed and surface condition; the effect of sharp curves. These were assessed using data gathered in three controlled exercises:

- Measurements of the vertical and horizontal loads at different speeds on two selected sites on in-service roads with relatively even and uneven surfaces
- Measurements of vertical and horizontal loads during repeated runs at the UK standard test speed (50km/h) on a range of surfacings on the TRL test track, using both modified machines.
- Measurements of the loads at different speeds and in opposite directions on circular tracks of different radii (60 and 100m) using the TRL machine.

In each case, the average vertical and horizontal loads were recorded at 0.1 m intervals along the road.

4.1.1 Measurements on in-service roads

The initial tests on the even and uneven surfaces clearly demonstrated the effective functioning of the vertical load system. As would be expected with measurements recorded at intervals as short as 0.1m, there was considerable “noise” in the data. Further analysis using averages over 1m and 10m intervals showed that:

- Dynamic vertical load was influenced by unevenness in the surface, with noticeably greater variations in load being observed on the very uneven section.
- The effects were greater at higher speeds.

- There was a correlation between vertical and horizontal load measurements.
- Using dynamic vertical load rather than an assumed 200kg resulted in a small improvement of the precision, particularly at higher speeds.

4.1.2 Measurements at TRL

In this work, the two machines fitted with the DVLMS made several repeat runs over a variety of surfaces on the TRL test track. Analysis of the vertical load data confirmed that the use of dynamic load measurements had a small beneficial effect in reducing the variability of the measurements. The tests also showed a marked difference between the average dynamic load and static load on each of the two machines. There were also differences in static load between the machines but it was found that using the dynamic load measurements in the calculations brought the average SFC values from the two machines much closer to one another.

The tests on the circular tracks with the TRL machine were made to assess whether there were any load transfer effects on sharp curves. It was found that there were differences in vertical load in the two directions of travel and at different speeds or radii (Table 1). More detailed tests showed that the dynamic and static vertical loads also appeared to change with different levels of water in the tank.

Table 1 Means and standard deviations of vertical load measurements during circular tests

Test lane radius (m)	Test speed (km/h)	Anticlockwise direction		Clockwise direction	
		Mean (kg)	SD* (kg)	Mean (kg)	SD* (kg)
60	20	180	9.95	200	9.49
	40	183	14.87	212	12.72
100	50	179	13.7	208	12.8
	65	173	16.6	208	15.0

* SD = Standard Deviation of vertical loads computed over three circuits of the test tracks.

Further investigations revealed that there was a mechanical link between the back-plate and the vertical shafts caused by stiffness in the lower protective gaiters when they were compressed. The influence of the gaiters was most noticeable when the water tank was almost empty; in this condition the chassis could “lift” the test wheel, an effect that was greater when the vehicle was running at higher speeds on an anti-clockwise curve. It was also observed that it was possible for the upper gaiters to partly support the load when stretched.

4.1.3 Possible irregularities in the test wheel

As well as the load transfer effects, a small-scale regular variation in vertical load was observed that had a wavelength of about 2m. This was most apparent on very even surfaces; it tended to be masked by the noise in the data on most pavements. Because the repeat distance was similar to the circumference of the test wheel, it was considered that the effect was associated with the rotation of the wheel. A number of possible sources were considered, including problems with the SCRIM wheel hub, eccentricity or distortions of the test wheel rim and irregularities in the test tyre or tyres. Further checks were made on a number of wheels and tyres. These showed that the wheels all ran true but that was a small “bump” in the tyres created by the overlap in the casing and tread when the tyre is made.

This test wheel “rotational” effect was considered not to be of practical significance in comparison with the general variation experienced in routine surveying and, since it was a result of the tyre manufacturing process there was nothing that could be done to remove it. However, its discovery did demonstrate that the new DVLMS was responding effectively to small changes in vertical load as well as to the greater variations caused by normal unevenness in the pavement.

4.2 MODIFICATIONS AND FURTHER TESTS

4.2.1 New gaiters

Having observed the apparent influence of the gaiters on both static and dynamic vertical load, WDM Ltd identified a lighter, more flexible design of gaiter. New gaiters were fitted to both the machines equipped with the DVLMS. Operation on the WDM machine allowed the durability of the new gaiters to be assessed throughout a working test season while further evaluations of the DVLMS were carried out at TRL. It was found that the new gaiters eliminated the large variations in static load previously observed on the TRL machine, particularly the influence of water load in the tank. In order to confirm that this was effectively replicated in the dynamic situation, a number of tests were made on the TRL track.

A first series of tests was made with SCRIM running in a straight line on a section of track with a surface that was homogeneous in both skid resistance and texture depth at different speeds, before and after the fitting of the new gaiters. These tests demonstrated compellingly that the new gaiters had resulted in consistent, uniform dynamic loading in straight line running and so further tests were made on the circular tracks to assess the effects of the gaiters when operating on sharp curves. The results of these circular track tests are summarised in Table 2.

Table 2 Comparison of vertical load on circular tracks with old and new gaiters

Radius (m)	Speed (km/h)	Direction	OLD GAITERS		NEW GAITERS	
			Average * Vertical Load (kg)	Standard Deviation	Average * Vertical Load (kg)	Standard Deviation
60	20	Clockwise	180	10.0	197.5	7.9
		Anticlockwise	200	9.6	198.0	7.9
	40	Clockwise	181	14.9	195.5	11.7
		Anticlockwise	212	12.7	197.2	10.5
100	50	Clockwise	179	13.7	196.3	12.0
		Anticlockwise	208	12.8	197.4	12.0
	40	Clockwise	-	-	194.0	11.0
		Anticlockwise	-	-	197.5	10.7
* Average over 3 circuits for old gaiters and 2 circuits for new gaiters						

The results in Table 2 show that the new gaiters greatly reduced the difference in vertical load between the directions of travel around the curves. With the new gaiters, the difference was less than 2kg, for any given speed or radius of circuit. In contrast, the corresponding differences with the old gaiters ranged up to 31kg. The new gaiters also reduced the variability of the vertical load measurements by about 20%.

4.2.2 Tests of load transfer on public roads

The results of the tests made on the circular tracks imply that, with the new gaiters fitted, the back-plate on SCRIM is generally able to move freely on its bearings. A theoretical review was made of the likelihood of load transfer on to the test wheel occurring which concluded that this should not occur in most practical situations if the back-plate was free to move on its vertical shafts. To assess this, measurements were made on public roads chosen to provide a range of geometrical conditions and road types with roundabouts, short lengths of hills and bends.

As well as running the TRL SCRIM, the HARRIS (Highways Agency Road Research and Investigation System) was used to measure curve radius, gradient and cross-fall along the same sections of route. Both machines recorded texture depth as SMTD (sensor-measured texture depth). The measured vertical load and recorded SFC were then compared with the topographical features of the routes.

As an illustration of the effects observed, Figure 2 shows the results obtained passing through and a little after a roundabout on one of the routes. For clarity, the graphs show data averaged at 10m intervals; the figure shows:

(a) A comparison of the texture depth as measured by SCRIM and HARRIS; these measurements were used to align the data from the two devices to allow the other results to be compared.
(b) A comparison of SCRIM vertical load with gradient
(c) Comparison of vertical load with cross-fall.
(d) Comparison of vertical load with curvature.

It was found that, as would be expected, there were substantial fluctuations in vertical load at shorter recording intervals, but it can be seen in Figure 2 that larger variations in the average dynamic vertical load were associated with sudden variations of one or more of the geometric parameters. There was also a delay between the change in geometric parameter and the associated change in vertical load, probably reflecting the time it takes for the SCRIM chassis to respond to the changes in the geometry of the road. Peaks or troughs were found in the vertical load line when rapid variations had occurred on the road. (See, for example, the change in gradient from - 5% to 5 % between 470m and 500m in Figure 2(b) or the changes in curvature entering and leaving the roundabout at 50-90m and 200m in Figure 2(c).)

These effects were typical of what was observed across the range of sites studied. Overall, load transfer effects were small and appeared as transitional responses as the vehicle encountered a marked change in gradient or curvature. It was found that by using the measured vertical load in calculating SFC, any effects due to changing vertical load were effectively removed from the average skid resistance measurements recorded.

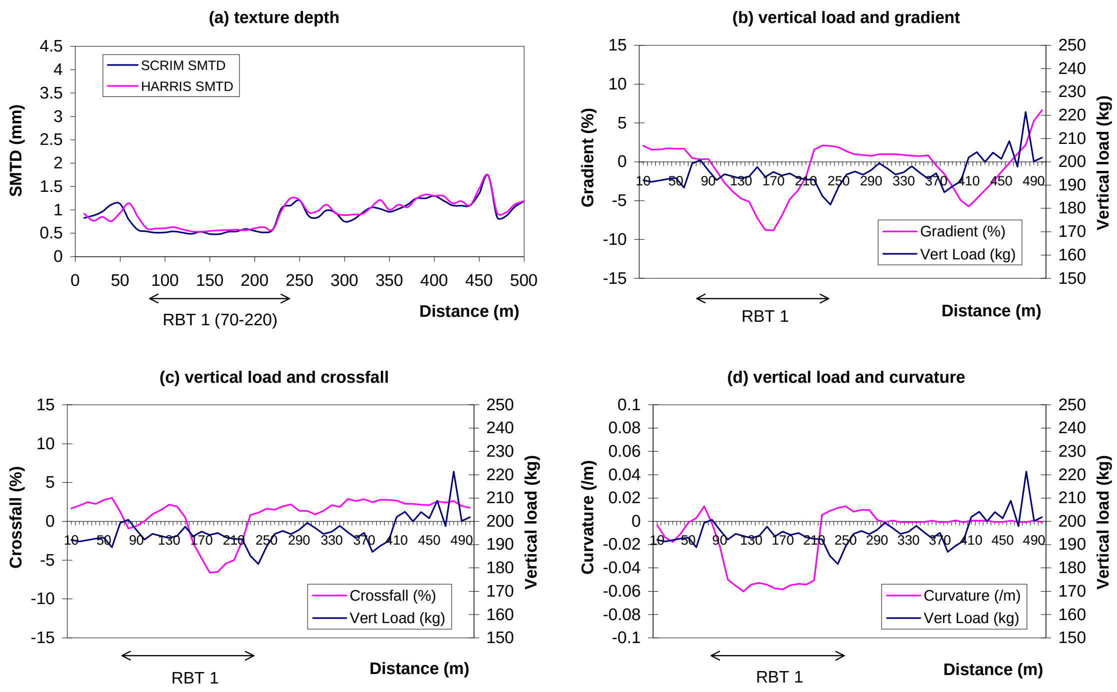

Figure 2 Comparison of geometric parameters and dynamic vertical load passing through a roundabout (10m averages)

4.3 SUMMARY OF RESULTS OF THE EVALUATION OF THE DVLMS

The results of the evaluation of the dynamic vertical load measurement system can be summarised thus:

- The new system enabled the reason for the variations in static weights that had been observed in the UK fleet in recent years to be identified. This problem was eliminated by fitting new lighter and more-flexible protective gaiters to the test wheel support shafts.

- Including the measured dynamic load reduced the variability of SFC measurements, especially on uneven road surfaces and at higher test speeds.

- With the new gaiters fitted, only small variations in dynamic load occurred during surveys on in-service roads as a result of changes in the geometry of the road such as gradients and bends. Those that did occur were associated with transitions rather than step changes and using the vertical load measurement removes the effects for practical purposes.

- A small-scale cyclic variation in dynamic vertical load was identified using the new system, demonstrating its potential sensitivity. The cause of the effect was traced to a feature of the construction of the test tyres but it is not of practical significance.

5. USE OF SHORT INTERVAL RECORDING

It has been normal practice in the UK for routine SCRIM surveys to collect data at a standard speed of 50 km/h every 10m which are usually averaged over longer lengths of 50m or 100m for comparison with the Investigatory Levels in the UK skidding standards (Design Manual for Roads and Bridges, DMRB 7.3.1). While long sections have a level of skidding resistance at or above the Investigatory Level, there might be some short lengths within the same sections that are below this and so the 10m data are also checked in case there is a possible hidden problem.

However there may also be shorter undetected lengths with markedly lower skid resistance than the rest of the road, representing a high risk to certain groups of road users (e.g. motorcyclists), and which may not be detected. A further study has considered the routine use of short-interval recording to provide data that could be used to detect short, high-risk areas in the surfacing, either routinely or in later investigations should this be necessary.

5.1 SHORT-INTERVAL MEASUREMENT PRECISION

During the evaluation of the DVLMS, it was ascertained that the use of measuring intervals as short as 1m was feasible at a test speed of 50km/h but at higher operating speeds the variability of the short-interval results might increase unacceptably. Further work studied the precision of short-interval measurements in more detail.

Existing data in which SCRIM made repeated measurements over the same length of road were used review the precision of short-interval data in comparison with the normal 10m interval. Data for this purpose were recorded during the 2003 UK SCRIM Correlation Trials and in the Netherlands while measurements were being made for a project assessing the harmonisation of measurements from different types of device.

5.1.1 Repeatability of short-interval measurements

At the 2003 Annual Correlation Trial, both SCRIMs that were fitted with the DVLMS were also set up with the short-interval recording facility and both recorded the detailed data. Each machine used four test tyres and made three runs with each tyre. The precision of the measurements was assessed by estimating repeatability.

Repeatability, r, may be defined in this context as the maximum difference expected between successive measurements by the same machine with the same driver on the same section in a short space of time, with a probability of 95% (that is, the difference between two runs will only exceed r on one in twenty occasions). Estimates of repeatability of SFC (using the dynamic vertical load measurement in the calculations) were made for each section and tyre for the two machines, together with an overall estimate over all tyres and all sections, for values recorded at 1m and 10m intervals. The results of these calculations are shown in Table 3.

This analysis demonstrated that the repeatability at 1m intervals is much poorer than over the longer 10m length. This is to be expected since over the longer distance more samples of the surface are taken, just as the repeatability of over a 100m length is expected to be better than at 10m. The correlation trials provide an estimate of the best repeatability that is practicable, i.e. when measurements are made on generally homogenous surfaces under carefully controlled conditions. Based on the pooled "all tyres" estimates for repeatability, if two measurements successive SFC measurements are made, at 10m recording intervals then, depending on the surface, they could differ by between 0.02 and almost 0.05 on one in 20 occasions. At 1m intervals, however, the difference would be in the range 0.04 - 0.1.

Table 3 Estimates of repeatability at 10m and 1m recording intervals from 2003 UK Correlation Trial data

SCRIM	Section	Pooled estimate of repeatability of SFC x 100 at given recording interval (3 replicate runs with each tyre) *Shaded values in the 10m interval data indicate unusually high between-run variation due to variation in test line or location referencing on individual runs.*									
		10m					**1m**				
		Tyre 1	**Tyre 2**	**Tyre 3**	**Tyre 4**	**all**	**Tyre 1**	**Tyre 2**	**Tyre 3**	**Tyre 4**	**all**
TRL	21 (Brushed concrete)	2.9	3.0	3.0	2.0	2.8	6.4	5.8	6.8	5.8	6.2
	22 (Grooved concrete)	1.7	2.2	1.9	2.1	2.0	6.5	6.4	7.4	6.0	6.6
	23 (Pea gravel)	2.0	3.3	3.3	3.3	3.0	3.5	4.5	4.9	4.7	4.4
	24 (smooth epoxy)	2.1	4.7	3.6	3.8	3.7	2.9	2.3	4.1	4.4	3.5
	25 (HRA)	3.2	3.7	3.1	2.5	3.2	6.2	6.8	5.3	5.7	6.0
	26 (SMA)	3.8	6.6	2.9	3.6	4.4	4.5	5.4	4.0	4.2	4.6
	27 (HRA)	3.4	2.8	4.8	6.6 *	4.6	7.6	6.9	8.7	9.4 *	8.2
	28 (HRA)	2.3	4.6	2.2	3.7 *	3.4	4.3	6.8	5.0	5.2 *	5.4
	all					**3.5**					**5.8**
WDM	21 (Brushed concrete)	1.8	3.2	3.3	2.1	2.7	8.4	9.0	8.6	8.0	8.5
	22 (Grooved concrete)	2.7	2.1	2.0	2.0	2.2	10.0	9.4	9.3	7.7	9.1
	23 (Pea gravel)	4.3	1.7	3.2	2.3	3.1	6.5	4.7	5.8	4.6	5.5
	24 (smooth epoxy)	1.9	1.8	4.2	5.7	3.8	3.0	3.1	4.8	6.3	4.5
	25 (HRA)	3.4	2.5	1.9	1.5	2.4	7.5	8.6	7.5	6.6	7.6
	26 (SMA)	6.0	3.7	3.1	4.6	4.5	6.5	5.4	5.1	5.8	5.7
	27 (HRA)	3.0	3.0	5.2	2.2	3.5	9.1	10.2	9.7	7.5	9.2
	28 (HRA)	1.7	3.6	3.2	2.9	2.9	6.3	6.8	6.9	6.1	6.5
	all					**3.2**					**7.3**

***** Only 2 runs available

The practical significance of this depends upon how the measurements are to be used. Where the difference in skid resistance between two sections being compared was large, say 0.10 SFC or more, then one could say with confidence that there was a difference based upon a single measurement at either recording interval. However, there is greater difficulty if the difference to be compared is smaller, such as in the UK when trying to decide into which of two adjacent investigatory level bands a section would fall. In such a case, repeatability would need to be less than approximately 0.03 SFC (equivalent to half the difference between the two bands). Such a comparison could be made with a single 10m measurement and 19 times out of 20 the value would be correctly assigned, but taking the average of 5 or more runs would be necessary to detect similar differences with equal confidence at 1m intervals.

However, even within the data in Table 3 there are some sections where repeatability is much higher than on others and measurements on the road are far less well controlled than is possible at the correlation trials. This is one of the main reasons why in the UK data are normally averaged over 100m.

5.1.2 Effect of speed on short-interval measurements

Figure 3 illustrates measurements from four sections of a major road in the Netherlands on which repeat runs were made at different speeds. The graphs compare the SCRIM Reading (SR, equivalent to SFC x 100) calculated using either a 1m or a 10m recording interval on four sections at two measurement speeds, 30km/h and 90km/h. Each section was 200m long and three or four repeat passes were made at each speed. With data collected on in-service roads there is often a marked difference in skid resistance between the wheel paths and the rest of the road. As a result, the repeatability can sometimes be heavily influenced by the test line followed on different runs.

The 10m data (the graphs on the right of the figure) show the effects of the differences in test line that can be blurred at the shorter intervals. The “noise” in the data at 1m intervals is very apparent, particularly in the high speed measurements. These two influences, test line and “noise” are particularly noticeable on section 3. In the 10m data at 90km/h on section 3 (Figure 3h), for example, there are two distinct test lines, each followed on two runs, a feature that is largely impossible to observe in the 1m data. The expected reduction in the level of measured skid resistance with increasing speed is also apparent in all of the graphs.

As would be expected from data gathered on in-service roads, the levels of repeatability were found to be generally rather higher than those obtained on the TRL track. Generally, repeatability for 1m was poorer than for 10m at all speeds. However, there was less of a difference between recording intervals at the lowest speed.
Also, for the 1m data, on four of the five sections where the comparison could be made, repeatability tended to worsen with increased speed. However, it also appeared on many sections that for the 10m data, repeatability *improved* as the speed increases. These observations can be explained by the fact that it is easier for the driver to hold a consistent line over 100 or 200m at higher speeds, but it is still possible to follow different lines on different passes, as seen particularly in the graphs for section 4 in Figure 3.

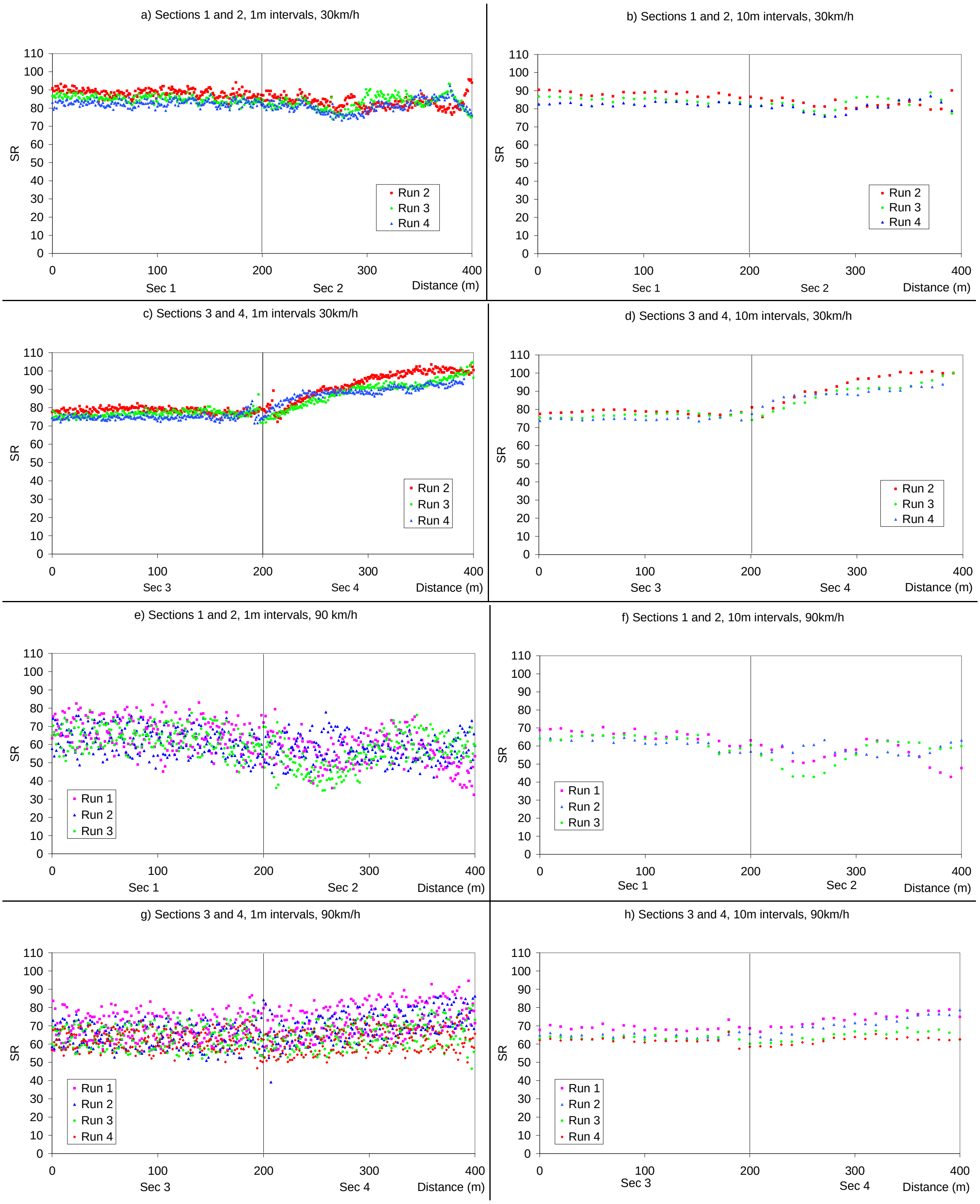

Figure 3 Comparison of SCRIM Readings on two sections of road in the Netherlands two recording intervals and two speeds

5.1.3 Inferences from this part of the study

The precision of the measurements investigated here varied widely. This was expected and is to some extent inevitable because at shorter intervals the measurements are bound to be vulnerable to variations along and across the road. The following general inferences may be drawn from this part of the study:

- Longer recording intervals are needed to smooth out the measurement uncertainty caused by variation in the surface across the test line and in the variation induced in the measurements by other factors such as unevenness in the road surface.
- Where routine measurements are made at higher speeds the noise in the data at short intervals will make interpretation difficult and is therefore not worthwhile.

If data are to be examined at short intervals and small differences between sections are to be assessed, several repeated runs will be necessary, preferably at low speed, with careful control of test line and location referencing. Although this would be impracticable for routine network surveys, shorter intervals could be useful for localised investigations, when sources of variation can be more easily controlled.

5.2 USE OF SHORT-INTERVAL DATA AT THE NETWORK LEVEL

In order to determine whether it would be worthwhile using short-interval recording in routine network surveys, a study was made that had two components:

- Data stored in the Highways Agency Pavement Management System (HAPMS) were used to investigate the risk of failing to identify short lengths that showed markedly lower SCRIM Coefficient (SC) than the rest of the road at the current 10m recording interval.
- Direct measurements to gather data at the 0.1m level were made on a small sample of trunk roads to assess on a smaller scale the occurrence of very short sections of low skid resistance.

5.2.1 The occurrence of short lengths below investigatory level

Suitable data from routine surveys were extracted for a number of maintenance areas (geographical areas into which the UK Trunk Road network is divided for management purposes). Overall, only a small proportion (generally much less than 10%) of the parts of the network analysed fell below the investigatory level (IL) as assessed by 100m averages, but the proportion varied somewhat from area to area. The areas with the greatest proportions below IL tended to be those with a relatively high proportion of rural single carriageways in the network. A likely explanation of this is that a higher proportion of the roads in these areas would have a higher investigatory level, and therefore a greater probability of sections failing, than those which are predominantly dual carriageway or motorway, which generally have the lowest IL on the network.

For individual ten-metre sections, although there was variation between areas, about 6% were below IL overall. This suggests that there are some 100m sections that include a few 10m lengths that are markedly below IL, drawing the 100m average down, rather than the whole section being below IL.

An important part of the analysis was to show how often sites that would not initially be detected as having low-skid resistance actually contained such lengths. For this purpose, the proportions of 100m sections that were above the Investigatory Level for the site but that contained 10m, 20m, 30m, 40m and/or 50m below Investigatory Level were determined and are shown in Figure 4.

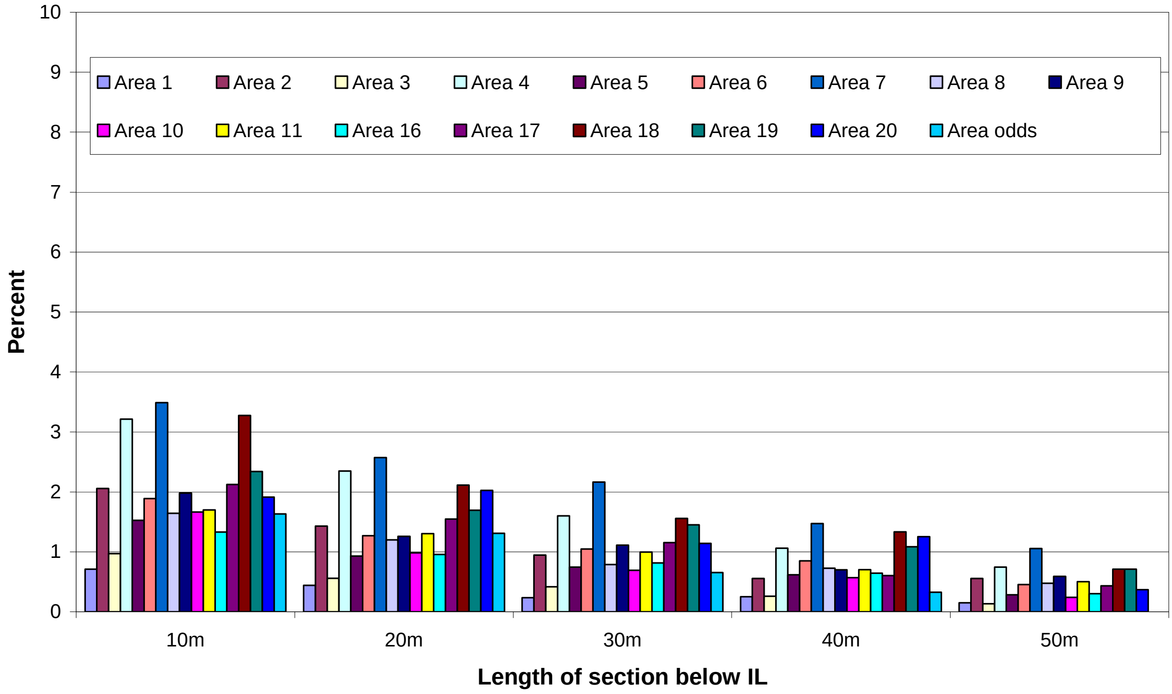

Figure 4 Proportion of 100m sections above IL that include 10, 20, 30, 40 or 50m below IL

Generally, fewer than two percent of those 100m sections that were above IL on average contained a single10m length below IL. Around three percent contained 20-40m below (not necessarily in a continuous length) and some sections also occurred that were above IL on average but had at least half of their length below this. As with the overall picture, areas with higher proportions of such sections tended to be in predominantly rural areas.

A SCRIM measurement that is below the Investigatory Level should initiate an investigation as to whether treatment to increase skid resistance is necessary. In some cases, sites that are below IL may not require treatment. However, there may be sections that on average are at investigatory level, or only just below it, but that incorporate short lengths that are markedly below. In such cases, further investigation might be appropriate.

To assess how likely this situation might be, the proportions of those 100m sections with a Mean Summer SCRIM Coefficient (MSSC) at or below Investigatory Level, but had 10, 20 or 30m that were >0.05 or >0.10 below the section mean were determined. The results for those sections with 10m over 0.05 or 0.10 below the section mean were also broken down by type of site in order to assess whether any such problem areas were more likely to occur in areas such as roundabouts and slip roads where braking could be expected to occur. It was found that, broadly, 5 to10 percent of sections below IL had 30m of their length more than 0.05 below the section mean but only 1-4 percent had 10m a similar amount below the mean. There was no clear difference between different types of site.

Generally, this study confirmed the need for the requirement in the Skidding Standard to check for short lengths below IL within sections that are apparently satisfactory and to assess whether this represents an increased risk of wet skidding.

5.2.2 Using routine short-interval data to detect areas of very low skid resistance

For this purpose, direct measurements were made on a small sample of trunk roads to gather data at the 0.1m level using the TRL SCRIM on routes for which data were available from previous surveys to compare the conventional approach of using 10m sub-sections. The choice of roads emphasised rural routes and single carriageways (particularly lengths with sequences of bends) because these roads are generally the types of site where the value of gathering this type of data is likely to be the greatest.

Measurements were made during the second half of the summer of 2003 (when skid resistance would have been at its lowest). The data from the short-interval survey measurements from 2003 were compared with the 10m interval MSSC data from 2001 on the same sections. The short-interval data consisted of a single pass over the relevant section, so it must be borne in mind that they can not strictly be compared with mean summer SCRIM Coefficient (MSSC) values that were used for comparison with Investigatory Levels at that time, although the results would have been broadly similar.

Values of SCRIM Coefficient were computed for 1m intervals, applying the standard UK speed correction where appropriate. These were compared graphically with the historic 10m data and Investigatory Levels from HAPMS. An example of the resulting graphs is shown in Figure 5. The pink line on the graphs represents the 2001 MSSC data plotted at 10m intervals and the blue lines the 2003 short-interval survey. The red lines are the investigatory levels defined in HAPMS.

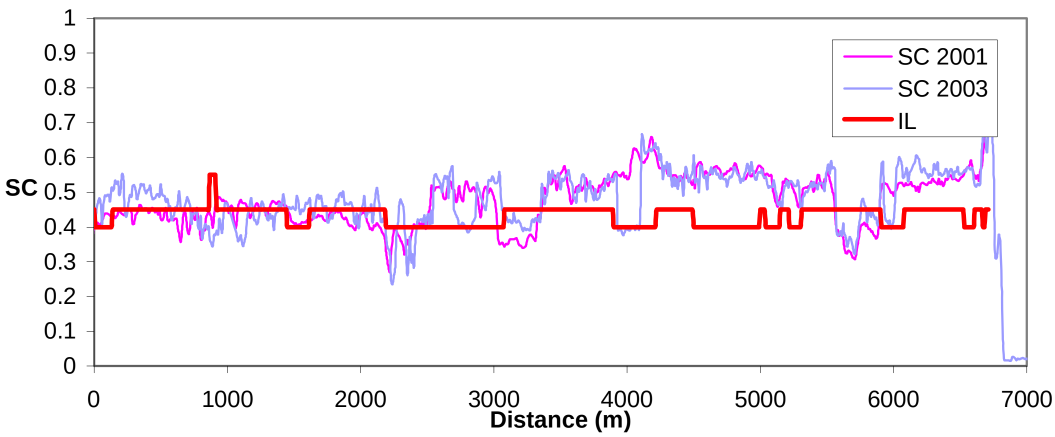

Figure 5 Comparison of SC and IL for a 7km section of trunk road (10m averages)

Overall, in spite of the differences between the two surveys (one a mean of three runs, the other a single survey two years later), there was an encouraging similarity in the patterns in the two sets of data in each case: it is clear in Figure 5, for example, that the measurements are on the same road. There were some marked differences between the two surveys where there had probably been changes to the road of some kind. There were also inevitably some areas where the road had been polished further by traffic between the two surveys.

However, disregarding these situations despite the very compressed scale representing distance along the road, in almost every instance where the short-interval data showed an area below investigatory level in 2003 (i.e. the blue line was below the red line) would have been successfully identified using the 10m interval data from 2001 (the pink line is also below the red line).

6. APPLICATION TO ROUTINE TESTING

When routine network-wide SCRIM surveys were introduced in the UK in 1987, a standard test speed of 50km/h was used on all roads except roundabouts and very sharp bends, where 20km/h was to be used. Over the years, however, traffic volumes have increased and experience has shown that greater flexibility in test speed was needed to improve safety to the machines and other road users during the surveys.

Higher test speeds were needed on high-speed roads such as motorways, particularly to reduce the differential between SCRIM and other heavy vehicles which in the UK typically run at 90km/h. Similarly, the 20km/h test speed, originally introduced to prevent SCRIMs becoming unstable when testing sharper curves, was too slow in almost all circumstances.

Exploratory surveys were made at different speeds to assess what was practical. It was decided that the standard speed of 50km/h would be retained as the reference speed to which all measurements would be corrected but different target speeds would be permitted on the network depending upon the type of road:

- 50km/h would be the target for all single-carriageway roads or roads with a speed limit less than 50 miles per hour (80km/h)
- 80km/h would be the target speed for all dual carriageways or motorways where the posted speed limit is greater than 80km/h.
- Drivers would be given the freedom to adjust their speed where circumstances dictated.

It was found that the two target speeds would cover almost all of the situations that were likely to be encountered on the network and only in exceptional circumstances would deviations from these be necessary. A revised speed correction formula was devised, with a new lower speed limit of 30km/h for all roads. It was considered that, by setting a higher target speed for high-speed roads, the variations due to correcting back to 50km/h would be less than if any speed were to be used.

With the introduction of higher-speed testing on motorways and faster tests on curves, the advantages of the DVLMS were clear. It was therefore decided that all SCRIMs in the UK fleet would be fitted with the new system ready for the 2004 test season and that the machines would be fitted with the new type of gaiters at the same time. The combination of new gaiters and dynamic vertical load measurement was expected to reduce the potential inconsistencies in measurements on bends and to reduce the variability in the SFC measurements that would result from operation at higher speeds.

The fleet of newly-equipped machines was assessed for the first time during the April 2004 Annual Correlation trials. This process itself revealed further improvements to the system electronics that were necessary for reliable operation and calibration in routine service but the system has now been operating reliably for a year. The 2005 correlation trials have recently been completed and the new system proved its worth in that exercise both by revealing a problem with one machine that was readily rectified and in a general improvement in the consistency of the UK and Ireland fleet which now includes twelve machines.

The study of short-interval recording showed that in general the current 10m approach is adequate for routine survey use. Although it was not possible in this study to investigate the data in greater detail to look for unusually low areas of skid resistance at short intervals in relation to physical features such as sharp bends, it has been observed during the course of other work that small areas of suspected markedly-low skid resistance can be identified in the data using short interval recording. However in such cases the affected areas were already known to exist from visual assessments of the road surface.

This type of measurement could clearly be of use for investigative work but the reduced precision at short intervals means that repeat passes are needed to verify the location and level of skid resistance of such areas, especially as the difference between them and the main surfacing becomes less. Therefore, although the potential for introducing short-interval recording remains, it has been decided not to gather data of this type routinely on the network.

7. CONCLUSIONS

TRL, on behalf of the Highways Agency, has worked with WDM Ltd to develop a new system for measuring the dynamic load on the SCRIM test wheel during normal surveys.

As a result of work to evaluate the new dynamic vertical load measuring system, it was concluded that the new system brought significant improvements to the operation of the SCRIM fleet, particularly:

- Variations in static weights observed in the UK fleet in recent years have been eliminated by fitting new lighter and more-flexible protective gaiters to the test wheel support shafts.

- Including the measured dynamic load reduces the variability of SFC measurements, especially on uneven road surfaces and at higher test speeds.

- With the new gaiters fitted, only small variations in dynamic load occur during surveys on in-service roads as a result of changes in the geometry of the road such as gradients and bends. Those that do occur are associated with transitions rather than step changes and using the vertical load measurement removes the effects for practical purposes.

Associated with these developments has been the introduction of new PC-based data-recorders. This has provided greater data-processing and recording capacity compared with older recorder designs, allowing the possibility of recording data over much shorter intervals than has been previous practice. A study of the use of recording intervals as short as 1m found that:

- Short interval data are not sufficiently precise to be suitable for routine use, particularly when testing at higher speeds.
- The occurrence of short sections (10m or less) of low skid resistance within the longer lengths used to compare with investigatory levels is rare, generally affecting less than two percent of 100m sections on the network.
- Short interval recording does not appear to improve the likelihood of identifying such sections compared with the current 10m data.
- Short interval data may be useful for localised investigations where a small area with low skid resistance is suspected. However, repeated runs and careful control of location referencing would be required to provide reliable comparative data, particularly where relatively small differences are being investigated.
- Overall, it is not worthwhile collecting short-interval data as part of routine monitoring surveys on the Trunk Road and motorway network and that 10m should continue to be the normal recording interval for this purpose.

The new vertical load system was introduced on the whole UK fleet in 2004, together with greater flexibility in operating speeds during routine surveys. At the recent 2005 Annual Correlation trial, the new system demonstrated improved consistency within the fleet.

8. ACKNOWLEDGEMENTS

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